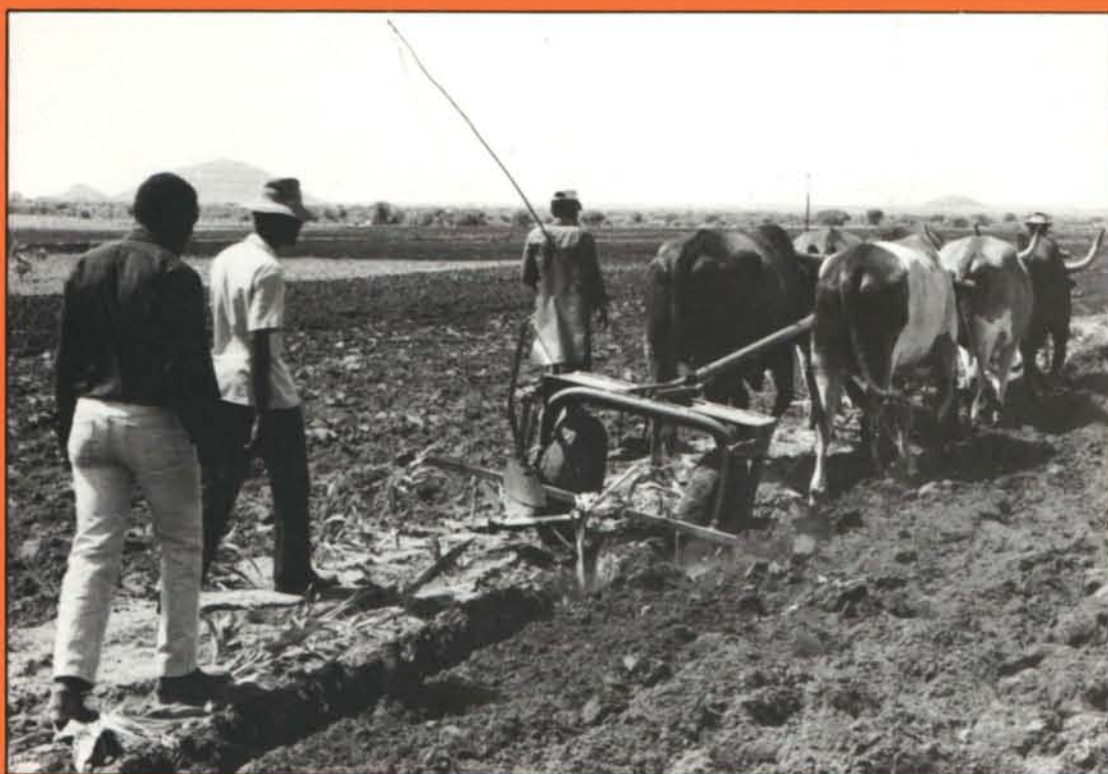


Agricultural Mechanization Policies and Strategies in Africa

Case Studies from Commonwealth African Countries



Commonwealth Secretariat

AGRICULTURAL MECHANIZATION POLICIES & STRATEGIES IN AFRICA

Case Studies from Commonwealth African Countries

edited by

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CONTENTS

	<i>List of Tables</i>	v
	<i>Foreword</i>	ix
Chapter 1	An Overview of Agricultural Mechanization in the World	
	<i>by G.C. Mrema</i>	1
Chapter 2	Agricultural Mechanization Strategy Formulation: Procedures and Issues	
	<i>by R.C. Gifford</i>	15
Chapter 3	Agricultural Mechanization in Africa: An Overview of Main Issues	
	<i>by R.N. Kaul</i>	29
Chapter 4	A Review of Developments in Agricultural Mechanization in Botswana	
	<i>by G.C. Mrema & C. Patrick</i>	43
Chapter 5	Agricultural Mechanization in Ghana: An Overview	
	<i>by A. Twum and O.K. Gyarteng</i>	59
Chapter 6	Agricultural Mechanization Policies and Strategies in Kenya	
	<i>by G. Muchiri, C.J. Mbara, & C.O. Mwanda</i>	77
Chapter 7	Agricultural Mechanization Policies and Strategies in Nigeria	
	<i>by G.A. Makanjuola, T.O. Abimbola & U.G.N. Anazodo</i>	99
Chapter 8	A Review of Agricultural Mechanization Strategies for Small Scale Farmers in Swaziland	
	<i>by D. Agrippa & P.K. Lukhele</i>	121

Chapter 9	Agricultural Mechanization Policies and Strategies in Tanzania	
	<i>by G.C. Mrema</i>	132
Chapter 10	An Overview of Agricultural Mechanization Strategies in Zambia	
	<i>by G.M. Silumesii & N.G. Musonda</i>	160
Chapter 11	Adoption of Research Findings in Africa: The Nigerian Experience	
	<i>by J.Y. Yayock & S.M. Misari</i>	177
Chapter 12	Formulation and Implementation of Agricultural Mechanization Policies in India	
	<i>by S.M. Misra</i>	189
Chapter 13	Small Four-Wheel Tractors for the Tropics and Subtropics: Their Role in Agricultural and Industrial Development	
	<i>by R.G. Holtkamp</i>	217
Chapter 14	Synthesis of the African Experience in Agricultural Mechanization	
	<i>by G.C. Mrema</i>	250
	<i>References</i>	288
	<i>Abbreviations</i>	310
	<i>About the Contributors</i>	312

LIST OF TABLES

<u>Table 1</u>	Growth of tractor use in selected developed countries	6
<u>Table 2</u>	Growth of tractor stocks in selected developing countries	10
<u>Table 3</u>	Agricultural statistics for Botswana	44
<u>Table 4</u>	Population of Botswana 1960-2010	46
<u>Table 5</u>	Tractors in use in Botswana	50
<u>Table 6</u>	Tractors in use in Ghana 1950-1969	60
<u>Table 7</u>	Inventory of agric. machinery held by Ministry of Agriculture - Ghana January 1971	61
<u>Table 8</u>	Annual importation of wheeled agricultural tractors - Ghana - 1973-1988	62
<u>Table 9</u>	Institutions in Ghana offering formal training in agric. mechanization	68
<u>Table 10</u>	Effects and profitability of agric. mechanization and improved technology on yields of selected crops in Ghana	70
<u>Table 11</u>	Total demand of grains for food, feed, and industrial use in Ghana	73
<u>Table 12</u>	Production of important crops Ghana 1982-89	75
<u>Table 13</u>	Tractor hire service operation - Kenya	83
<u>Table 14</u>	Handtools and animal drawn implements in use in Kenya in 1990	86
<u>Table 15</u>	Performance of govt. plant hire services - Kenya (1968-1988)	87
<u>Table 16</u>	Performance of the govt. tractor hire services Kenya 1975-1988	89
<u>Table 17</u>	Mechanical equipment on large farms Kenya 1980-88	91

<u>Table 18</u>	Tractor sales Kenya 1970-89	92
<u>Table 19</u>	Estimates of areas under different cultivation systems - Northern States of Nigeria	109
<u>Table 20</u>	Breakdown of tractors sold in Nigeria 1979-83	110
<u>Table 21</u>	Estimated agricultural machinery in use in Nigeria 1988	111
<u>Table 22</u>	Land ownership in Swaziland	122
<u>Table 23</u>	Production of various crops by ITF & SNL - Swaziland 1981/82	123
<u>Table 24</u>	Livestock population on the SNL - Swaziland	124
<u>Table 25</u>	Levels of mechanization in Swaziland - 1988	125
<u>Table 26</u>	Tractor numbers in Swaziland	127
<u>Table 27</u>	Method of ploughing - Swaziland	127
<u>Table 28</u>	Agricultural statistics Tanzania	135
<u>Table 29</u>	Rural/urban population Tanzania	136
<u>Table 30</u>	Tractors in use Tanzania 1950-85	143
<u>Table 31</u>	Trained oxen and ox-implements Tanzania	156
<u>Table 32</u>	Sex ratio - Zambia 1980	162
<u>Table 33</u>	Maize production - by Province - Zambia	163
<u>Table 34</u>	Schedule of farm tools and equipment imported into Zambia 1970-79	165
<u>Table 35</u>	Tractor vs oxen for land preparation costs - Zambia 1980	167
<u>Table 36</u>	Estimated levels of implements - Zambia - 1985	168
<u>Table 37</u>	Projected annual market for implements Zambia - 1986-90	168

<u>Table 38</u>	Summary of area, production & sale of maize by commercial farmers 1940-88 - Zambia	169
<u>Table 39</u>	Fertilizer consumption Zambia 1978-87	171
<u>Table 40</u>	Target numbers of trained pairs of oxen - Zambia 1985-90	172
<u>Table 41</u>	Yield performance of major food crops at three levels of technology Nigeria	182
<u>Table 42</u>	Some prototype equipment designed and fabricated at IAR - Samaru Nigeria	186
<u>Table 43</u>	Distribution of land holdings - India	191
<u>Table 44</u>	Cropping pattern - India	192
<u>Table 45</u>	Area under high yielding varieties India	192
<u>Table 46</u>	Consumption of chemical fertilizers India	193
<u>Table 47</u>	Consumption of technical grade pesticides - India	193
<u>Table 48</u>	Area irrigated by different systems - India	194
<u>Table 49</u>	Electrical power consumption India	194
<u>Table 50</u>	Average yields of principal crops - India	195
<u>Table 51</u>	Selected agric. mechanization inputs in use in India 1945-85	208
<u>Table 52</u>	List of major tractor manufacturers - India	209
<u>Table 53</u>	Licensed/installed manufacturing capacity of power tillers - India	210
<u>Table 54</u>	Global production of farm wheel tractors with engine power ratings of up to 26 kW (1985)	221
<u>Table 55</u>	Production of single axle and four wheel tractors in PR of China	223
<u>Table 56</u>	Small tractors as a % share of total exports and first registrations in UK	230

<u>Table 57</u>	Survey of type-specific case studies	232
<u>Table 58</u>	Technical data for a selection of four-wheel tractors up to 26 kW	246
<u>Table 59</u>	Potential means of cutting production costs	248
<u>Table 60</u>	Tractors prices in selected countries	249
<u>Table 61</u>	Tractor numbers in selected areas	279

FOREWORD

The Workshop on Agricultural Mechanization in Commonwealth Africa held from 13-17 August, 1990 was organized by the Food Production & Rural Development Division of the Commonwealth Secretariat, in collaboration with the Federal Government of Nigeria through Federal Ministry of Agriculture and Natural Resources, Abuja; Federal Ministry of Science & Technology, Lagos; and the Institute for Agricultural Research, Ahmadu Bello University, Zaria.

The Workshop brought together, perhaps for the first time, the first generation of African Agricultural Engineers and Mechanization Experts to discuss the policy and strategy formulation aspects of the agricultural mechanization in Commonwealth Africa.

The main report and recommendation of the workshop have been published - under the title: *"Report of a Workshop on Agricultural Mechanization in Commonwealth Africa, Zaria, Nigeria 13-17 August 1990"*, Published by Commonwealth Secretariat in January 1991, 80 pgs.

This volume "Agricultural Mechanization Policies & Strategies in Africa: Case Studies from Commonwealth African Countries" consists of selected country case studies and technical papers prepared by experts and resource persons. It will, therefore, be of interest, not only to policy makers, researchers and development agencies, but also to students of agriculture, agricultural mechanization and agricultural economics.

The Commonwealth Secretariat is most grateful to all contributors to this publication, and particularly to Professor G.C. Mrema for his editorial assistance.

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CHAPTER 1

AN OVERVIEW OF AGRICULTURAL MECHANIZATION IN THE WORLD

by

G.C. Mrema

INTRODUCTION

None of the modern technologies required for increasing agricultural production and productivity in Sub Saharan Africa has invoked so much controversy as agricultural mechanization technologies. Indeed the controversy, is such that it is difficult, in certain instances, to agree on how agricultural mechanization should be defined. It is however clear that agricultural mechanization, however one defines it, has wide support throughout Sub Saharan Africa and is a dream of many politicians and experts both indigenous and foreign who have been involved with the rural development efforts in this continent over the past eight decades. However unlike the biochemical technologies (e.g. improved seed varieties, fertilizers, crop protection chemicals and better crop and livestock husbandry techniques); the use of which most experts agree should increase on the African continent, there is still a lot of controversy on what type and levels of the physical technologies (e.g. agricultural machinery and implements as well as irrigation) should be used in this part of the world. The debate on what type of mechanization inputs should be used in agriculture in Africa, in particular for the small holder farmers has been going on over the past 5-6 decades and has intensified over the last 30 years when most countries in Africa attained their independence status. Yet despite such a long term debate by, among others, engineers, economists, sociologists, agriculturists and politicians, most African countries are still far from formulating agricultural mechanization policies and their implementation strategies.

It is perhaps the indivisible nature of the agricultural mechanization technologies, as compared to the biochemical ones, which has made this technological input in African agriculture so controversial. A small scale farmer can afford to purchase 0.5kg of a high yielding seed variety but he cannot buy a quarter or half of an ox-drawn plough or tractor. The indivisibility of the physical technologies inevitably makes them much more expensive with a resulting host of social, technical and economical problems both to the farmers (be they small or large scale) and the policy makers. In most instances, in the developing world, only the richer and more progressive farmers have been able to acquire and use them. In areas where there is a serious shortage of land and

a substantial proportion of the rural population earn their living through employment as farm workers it has often been claimed that agricultural mechanization leads to serious equity and unemployment problems. Even in countries where there is still plenty of uncultivated land, which could be opened up by increased utilization of mechanization inputs, the choice of right type of mechanization technologies as well as the high cost of acquiring them (often through importation) has often been difficult to most policy makers in the developing countries. This is particularly the case, in Africa where past experience with many types of mechanization technologies has been rather disappointing.

As Gemill and Eicher (1973) have noted, a review of the literature on agricultural mechanization reveals sharply divergent policy prescriptions among agricultural engineers and social scientists. Agricultural engineers and economists have been 'talking past each other' and policy makers in most African countries have been confused by the advice emanating from these two disciplines. In order to bridge the gap between these two disciplines, FAO and OECD convened an expert consultation on agricultural mechanization and its effect on employment in 1975 in Rome, Italy. Further a number of international agencies have commissioned studies on various aspects of mechanization over the past two decades (Kline *et.al.* (1969); Yudelman *et.al.* (1971); ILO (1973); FAO (1975); Gifford (1981); Bartsch (1977); Binswanger (1984); Moens and Siepmann (1984); Pingali *et.al.* (1987)). Whereas the policy issues on agricultural mechanization, as we shall see later, appear to have, by and large, been resolved on the Asian continent, and to a lesser extent in Latin America, it would seem however for Sub Saharan Africa there is still a lot of confusion on what type of agricultural mechanization policies as well as implementing strategies should be followed.

In an attempt to clear the confusion, the Commonwealth Secretariat - Food Production and Rural Development Division convened a consultation of experts from among other areas, African Commonwealth countries in London in April 1990 (COMSEC-1990). This expert consultation was followed by a workshop on agricultural mechanization in Commonwealth Africa held at the Institute of Agricultural Research (IAR) of Ahmadu Bello University in Zaria, Nigeria. In this workshop the Commonwealth Secretariat had requested a number of African experts to prepare detailed reports on the evolution of agricultural mechanization policies and strategies in their respective countries over the past 3 decades for discussion. The workshop was attended by about 60 agricultural engineers and economists from Commonwealth African countries as well as representatives of donor and other agencies such as FAO; ECA; GTZ and AFRC-Engineering of Silsoe, UK. Majority of participants were drawn from agricultural engineering/mechanization departments in the faculties of agriculture/engineering of the various universities in the Commonwealth Africa region as well as the National Agricultural Research Systems (NARS) and the extension services. Almost 90% of the participants were nationals of the Commonwealth countries in Africa and they perhaps

represented the first generation of African experts in the field of agricultural mechanization/engineering. Unlike past workshops/expert consultations on agricultural mechanization in Africa, where majority of the participants have often been foreign experts with some experience of Africa, the Zaria workshop was dominated by African experts with some of them having been continuously working on agricultural engineering/mechanization problems in Africa over the past quarter of a century.

Participants of the Zaria Workshop made a number of observations and recommendations. These have been published as volume I (COMSEC 1991) of these proceedings and we do not intend to repeat them here. In this volume of the proceedings we present a majority of the papers presented at the Zaria workshop. These have been edited, and in some cases two papers from one country have been merged to avoid repetition of the same information. Thus the two papers presented from Botswana, Kenya and Nigeria have been combined into one paper for each country. In some cases papers have been condensed and an effort has been made to the extent possible to standardize the format of presentation, references and spellings throughout the text. In order however to make the proceedings as comprehensive as possible on the whole question of agricultural mechanization policies and strategies in Africa, two chapters have been added, this chapter which gives an overview of agricultural mechanization in the World and the last chapter which synthesizes experiences of the Commonwealth African countries as presented in the intermediate chapters. Thus in chapter 2 Mr. Gifford presents FAO's experience on the question of agricultural mechanization policy formulation with particular reference to Africa while in chapter 3 Prof. Kaul presents an overview of agricultural mechanization in Africa. This is followed by case studies from the individual countries (Botswana - by Mr. C. Patrick and myself; Ghana by Messrs Twum & Gyarteng; Nigeria by Professors Mekanjuola, Anazodo and Abimbola; Kenya by Messrs Muchiri, Mbara and Mwanda, Tanzania by myself; Swaziland by Messrs Agrippa & Lukhele, and finally Zambia by Dr. Musonda and the late Mr. Silumesii. Professors Misari & Yayock give a paper on experiences of extension of mechanization technologies in Africa in Chapter 11, and Dr. Misra gives India's experience on agricultural mechanization in Chapter 12. Due to the thinking in some quarters that small tractors can solve the mechanization problems in developing countries, a paper on small tractors is given as Chapter 13 by Dr. Holtkamp. We then conclude with a discussion and synthesis chapter at the end.

We should add that in all the papers presented, as well as in the discussions, we are neutral to any particular type of technology. We have avoided being biased towards any particular technology - be it handtool, draught animal, or mechanically powered and have attempted to provide the facts as objectively as it is seemingly possible. As was noted in the conclusions of the Zaria workshop, among the major weaknesses of many of the previous studies on agricultural mechanization has been their bias towards one type of technology or their concentration on the failure cases (Pingali *et.al.* (1987),

Ahmed and Kinsey (1984), Binswanger (1984); (COMSEC (1991)). Further we have tried in as much as it is seemingly possible to include data from the medium and large scale farming enterprises which are quite important in many of the Commonwealth African countries. In the view of many African experts in agricultural engineering, there has been too much attention paid to the peasant and subsistence sector, which although quite important, does however contribute only a small percentage of the marketed agricultural output. Therefore equal attention has been paid to the major contributors of the marketed agricultural output although due to inadequate research attention paid to this sub-sector, the available data is rather limited. Further in quite a number of Commonwealth African countries there are quite a number of 'emergent' medium and large scale farmers. These are becoming quite important especially in producing the surplus which reaches the market in these countries. Such farmers use an increasing amount not only of the agricultural mechanization inputs available in these countries but also the biochemical inputs and it is likely that in the next 2-3 decades they will play a leading role in meeting the food requirements of many of these countries. Again we have to confess that due to inadequate research attention paid to these farmers, there is paucity of data in particular on how efficiently they are able to utilize the agricultural mechanization inputs.

The main objective of this chapter is to give a brief overview of developments in agricultural mechanization elsewhere in the World so as to put the African case studies and experiences in a proper perspective. It is of course difficult in such a short chapter to exhaustively cover all the developments in a subject as complex as agricultural mechanization. However an attempt will be made to highlight the main developments in agricultural mechanization concentrating in the last 100 years as it is during this period that there has been remarkable progress in this field.

THE EVOLUTION OF AGRICULTURAL MECHANIZATION

The evolution of agricultural mechanization in the World can be divided into 3 distinct periods. The period before 1920, the period between 1920-1945 and the post second world war period (i.e. 1945-todate). The major innovations and developments in agricultural mechanization in the World occurred in these three periods. The developments were however not evenly spread all over the World, and in some continents technologies which had been abandoned in other continents well before the 19th century are still being used in others today as we approach the 21st century. Development of new technologies for agriculture in the biological and chemical fields (e.g. new seed varieties, fertilizers and crop protection technologies) have also induced the development of new technologies in agricultural mechanization. In a few instances development of agricultural mechanization technologies has led to the development of related technologies in the biological and chemical fields. Gifford (1981) and Binswanger (1984) have reviewed the evolution of

agricultural mechanization technologies in the World whilst Gibb (1988) has reviewed its evolution in UK, and Le Moigne (1975) gives a treatise of agricultural mechanization developments in France over the past 2 centuries.

Most of the studies on agricultural mechanization concentrate on the power sources required to perform the different field operations. Initially all over the World, the agricultural tasks were performed with entire reliance on human muscle power. Simple tools which made the execution of these agricultural tasks more efficient had been discovered as long ago as 7000 BC. Thus the handtool technology - with the use of the hand hoe, cutlass, sickle, etc. is as old as documented history of the human race. The shift from entire reliance on the handtool technology to animal draught technology occurred at about 3000 BC (Gifford 1981). Man then learned how to harness animals and use them for performing some of the more power intensive agricultural operations like ploughing. The invention of the wheel at the same time, extended the use of draught animals in transport with the development of the more efficient 2 wheel carts pulled by humans or animals. Initially wooden implements and tools were used until the development of iron during the iron age, when metal implements, though of basically the same design as the wooden ones were then introduced. The use of human and animal power in agricultural mechanization continued until early on in the 19th century when some forms of mechanical power begun to be used. The shift from animal power to mechanical sources started with a shift to water power - water hammer, windmills for pumping water, milling of grains, etc. and through to the external combustion engines in the late 18th and throughout the 19th century. The external combustion engines in the form of steam engines were initially used to power the more difficult and arduous operations like processing of grains and other agricultural products and it is only in the late 19th century when steam powered tractors begun to be used.

Developments in agricultural mechanization were very much influenced by the industrial revolution which occurred in much of Europe and North America in the 18th and 19th century, which resulted in a drastic reduction in labour available for agricultural production. The output from agriculture had to be increased to feed not only the increasing total population, but also an even larger urban population and which was also increasing at a much faster rate. As a consequence of the need to produce more food, there were scientific advances in soil management and plant sciences. In this regard, the work of Liebig, Mendel and others in soil science and plant breeding were notable. The period between 1830 and 1850 was also significant in so far as agricultural mechanization was concerned. Many important machines such as the horse drawn revolving hay rake, the reaper, the thresher, the combine, the steel plough, the grain drill, the disk plough and portable steam engines were developed and used in agriculture. Important names in this process of design and invention of new agricultural machines at this time included John Deere, Cyrus McCormick, Jethro Wood and John Nuebold (Promsberger 1976). Most of these pioneering inventors lived and worked in the United States of

America. These developments in USA were, by and large, quickly adopted in Europe but they by passed most of Africa, Asia and Latin America as there was not that much pressure for producing more food in these parts of the World. Majority of the inhabitants in these areas lived in rural areas essentially as subsistence farmers.

TABLE 1: Growth of tractor use in selected developed countries

<u>(no. in thousands)</u>						
Year	USA	UK	Germany	France	Denmark	Yugoslavia
1920	246	10	-	-	-	-
1930	920	30	-	27	-	-
1940	1545	55	30	36	4	-
1950	3394	325	140	137	17	6
1960	4688	456	857	680	111	36
1970	4619	514	1371	1230	175	91
1980	4768	512	1467	1484	211	440
1987	4676	520	1470	1520	240	1017

SOURCE: FAO Production Year Books various issues & Binswanger (1984)

By the later part of the 19th century, the need for a higher level of mechanization became a necessity in most of Europe and North America. The need was particularly for a new source of power on the farm. The steam engines furnished belt power but had to be moved from place to place by oxen and horses, and the self propelled steam tractors were huge and cumbersome - weighing as much as 36 tonnes (Liljedahl *et.al.* (1989)). A power source for farm operations and transportation that was more powerful and faster than animals and lighter and more adaptable than steam engines was required. This problem was tackled through the work of two German scientists - Dr. N.A. Otto and Dr. Rudolph Diesel. Dr. Otto had patented in 1876 the first spark ignited (petrol) internal combustion engine while Dr. Diesel had in 1892 patented the first compression ignited internal combustion engine and hence the name diesel engine (Jones & Aldred (1980)). These developments although initially used for road transport were later on in 1900 adopted for tractors and it is reported that the first tractor with an internal combustion engine was built in 1889 in USA (Liljedahl 1989).

The design and development of the tractor was perfected in North America during the period 1900-1921 by introduction of the power take off in 1919; promulgation of the Nebraska tractor test law in 1916; and after the First World War tractor use increased significantly in the USA from 250 000 units in 1920 to 500 000 units by 1925. Further refinements were incorporated in the tractor in the period 1930-1941 - e.g. three point implement hitch and linkage, automatic hydraulic draught control; pneumatic tyres in 1931;

hydraulic controls for drawn implements, etc. The fundamental design of the tractor has remained basically the same since 1945 with improvements and refinements such as power steering, automatic transmission, improvements in operator comfort and safety, higher number of speed selections, use of radial ply tyres, etc. The tractor has revolutionized agriculture in most of the developed world over the past 50 years and its adoption in agriculture has become synonymous to advanced agriculture. It should however be realized that in most of the developed world, the widespread use of tractors started just after the second world war with the exception of North America where utilization of tractors was already ubiquitous during the mid 1930's (Gray (1956)).

DEVELOPMENT OF AGRICULTURAL MECHANIZATION SINCE 1945

The design, development and perfection of the tractor using an internal combustion engine in 1930's and 1940's was a major breakthrough in so far as agricultural mechanization technologies are concerned. It is no wonder therefore that agricultural mechanization has often been equated with tractorization. Secondly within a span of about 20 years, the manufacture, and distribution of tractors in the so called western world and a large part of the developing world came to be dominated by about 5 multinational companies (Kurdle 1975). The tractor has had profound effect on labour productivity as well as farming systems in most countries in the World. Unlike the biological and chemical technologies developed for agriculture, agricultural mechanization inputs are not infinitely divisible and are often characterized by considerable economies of scale, and therefore they tend to favour larger farmers. It, therefore, in certain cases encouraged larger farmers to take over more farming operations and at times evicting tenant farmers, or buying out smaller farmers. The agricultural mechanization process has tended to follow certain patterns in its development over the past 50 years in both the developed and developing countries.

Developed countries

In most of the developed countries the first stage of agricultural mechanization following the perfection of the tractor, was the substitution of draught animal power for mechanical power. Thus horses were replaced by tractors for tillage, transport, and other field operations. Initially due to lack of pneumatic tyres only the on farm operations were done using tractors but with the development of tractors with pneumatic tyres in the 1930's the horses and oxen were completely replaced on the farm in most of the developed countries of Europe and North America. Initially the tractors used were of low horse power (25-45 hp) but eventually higher horse power tractors (70-140 hp) became more common in the 1970's and 80's. The data in Table 1 for a selected number of developed countries clearly shows that the replacement of animals by tractors occurred in many of them in the last 50 or so years. For example in 1939/40 about 90% of the cultivated land in France was ploughed by horses but by 1970

almost 95% of the cultivated land was ploughed by means of tractors (Le Moigne 1975). Similar figures are also pertinent to United Kingdom and other countries of Europe (Gibb (1988)). The replacement of horses by tractors occurred earlier in the USA compared to European countries. (e.g. tractor number in USA reached their peak at 4.5 million in the 1950's compared to 1960's in UK, Germany and France, and in some European countries this occurred in the 1970's and 1980's - e.g. Yugoslavia, Ireland, Spain, Greece, Portugal, etc. (see Table 1).

In addition whereas in Europe and North America the type of tractor used is the high horsepower conventional tractor, in Japan and indeed other South Asian countries, due to the small size of the farms, and the type of farming system (wetland cultivation) they developed the low horse power single axle and 2 wheeled tractors (power tillers). Nevertheless the number of these in use in Japanese agriculture recorded a dramatic increase over the same period (e.g. increasing from about 500 000 by 1945 to over 3 million by 1965 while the number of draught oxen and horses in use decreased from 2.8 million to less than 400 000 in the corresponding period). Secondly in North America there was little subsidy provided by the states for mechanization (other than in extension and to a limited extent research and development), and the pace of mechanization proceeded, by and large, through market forces, with the rate and pattern of invention, as well as adoption being dictated more by the economy's resource endowments (labour and land) and demand for the final product. In Europe and Japan the pace and pattern of mechanization was very much influenced by state subsidies. These included direct assistance to foreign companies to set up tractor manufacturing enterprises in Europe, or fiscal measures such as income tax rebates and other assistance or assured produce prices usually at a much higher level than prevailing world market prices through such price manipulations as is now common with the Common Agricultural Policy of the European Economic Community (Gibb (1988); Burch (1987)).

Once the first stage of substitution of the power source from animate to mechanical was accomplished then the subsequent stages were relatively easier to be adopted. These included the mechanization of the control-intensive operations i.e. the substitution of human control functions which require more sophisticated implements and machinery e.g. planting, weeding, fertilizer placement, etc. This has usually been followed by the adaptation of the cropping systems to the machine - change from broadcasting of seeds to row seeding, adjustment of row width to facilitate interrow weeding/cultivation by machines, etc. This stage has in some cases led to the change of the entire farming system to accommodate mechanization (e.g. intensive livestock systems, disappearance of crops which are difficult to mechanize etc.). In the developed countries and some of the developing countries, a stage has been reached where plant scientists through plant breeding are adapting plants to mechanization e.g. reduction in lodging, ease of post harvest processing, uniformity of size of final produce, etc. Most of the developed countries have

passed the first stage of mechanization (power substitution) and second stage (i.e. mechanizing control intensive operations) and are now in the stage three or four - adaptation of the cropping systems and crops to mechanization as well as automation of the agricultural production system for more efficient production and higher productivity of labour and land. It should be emphasized that they have gone through all these stages in the last 30-40 years.

It should also be appreciated that significant developments in the knowledge base for agricultural mechanization have occurred over the past 50 years. In the last century and early years of this century the inventions and innovations in agricultural machinery engineering were mostly the work of individual entrepreneurs both farmers and manufacturers, who were basically responding to a felt need for a particular implement or machine. However a recognition of the need to have a more formal method of coordinating research and developments in agricultural engineering was appreciated first in the USA where the land grant universities established, in the second half of 19th century, agricultural engineering departments initially for training but later on they assumed a more important role in extension and research. This subsequently led to the formation of the American Society for Agricultural Engineers in 1907 which brought together trainers, extension agents, researchers, manufacturers and progressive farmers. On continental Europe however the agricultural engineering profession developed much later. In many countries it is still an appendage of the traditional engineering disciplines (civil and mechanical engineering). In UK for example the Institution of Agricultural Engineers was established in 1938 through the primary efforts of a group of farmers, manufacturers of agricultural implements and army officers who were more interested in terrain mechanics. It had quite a difficult task in establishing itself and making the agricultural engineering profession well known in UK and in the British dependencies and colonies. One of its first tasks after consolidation in the period 1938-45, was to campaign for training and education programmes in agricultural engineering as well as strengthening the research institute for agricultural engineering (Gibb 1988). It is perhaps this late start in agricultural engineering research and training in the UK in comparison to USA that has influenced the development of agricultural engineering education in Commonwealth Africa.

In conclusion, therefore, for the developed countries of Europe, North America and Japan, the development and adoption of agricultural mechanization technologies as is commonly perceived by most people (i.e. use of internal combustion engines - tractorization) is a fairly recent development and has occurred in most countries over the last 40 years. Most of the European countries subsidized the introduction of agricultural mechanization - either through attracting the agricultural machinery manufacturing companies to set up manufacturing entities in their countries through outright grants/concessional loans and other subsidies, or through such assistance programmes as the Marshall Plan (Burch (1987), Kurdle (1975)). Many countries also, through agricultural marketing fiscal measures (e.g. setting prices of

agricultural produce at a much higher level than World market levels) ensured that farmers who mechanized had reasonable returns from their investments. Other measures which have encouraged the adoption of mechanization inputs, have included concessional loans, and favourable income tax measures which have allowed farmers to claim tax rebates against depreciation and investments in machinery (Gibb 1988). Further services such as extension and training have been provided at virtually zero cost to the farmers in most of the European countries and Japan. All these coupled with the higher level of technological and industrial development of these countries has enabled them to shift from an agriculture dominated by draught animals 40-50 years ago to one in which the tractor is the basic farming machine within a period of less than four decades.

TABLE 2: Growth of tractor stocks in selected developing countries ($\times 10^3$)

(no in thousands)							
Year	India	Pakistan	Brazil	Zimbabwe	Kenya	Tanzania	Srilanka
1940	2	-	-	-	-	-	-
1950	9	0.8*	23	5.1	3.7	2.1	-
1960	31	1.4*	-	12.5	6.1	2.7	6.2
1970	148	15.5*	-	-	6.5	5.2	9.2
1980	393	99	543	20.1	6.4	18	24
1987	698	175	780	20.4	8.6	19	29

SOURCE: FAO Production Year Books various issues

* including Bangladesh

- not available

Developing Countries

Most of the developing countries in Africa and Asia attained their independence within the last fifty years. Latin American countries although most of them had attained independence much earlier, were, by and large, at the same level of development 40-50 years ago as the African and Asian countries which were gaining their political independence then. At independence most of these countries inherited economies which were largely dependent on agriculture, with a larger part of their merchandise exports being primary agricultural commodities and an insignificant or small industrial sector. In most countries a majority of the population lived in rural areas, practising subsistence agriculture, and in a few countries employed as agricultural labourers on farms owned by indigenous or foreign large scale farmers. At independence most of these countries drew up economic development plans with the objective of rapid development and modernization of their economies - agricultural, social, and industrial development. In many of these countries urban populations were quite low, (in most cases less than

10% of the total population) and majority of the rural population subsisted on the food they produced, rarely requiring any food from outside. In most cases through the efforts of the small scale farmers and/or large scale farmers, surplus food was produced from the rural areas, which was enough to feed the urban population as well as realizing in a few countries a surplus which was exported.

There was considerable debate in the 1950's and 1960's on the role and contribution of agriculture to overall economic development. This debate was often centred on how much investment should be directed to the agricultural sector, and the resulting effect of this investment in solving the other perceived problems like unemployment, rural-urban migration, overall economic development, etc. The question then was whether the subsistence agriculture should be 'transformed' or 'improved' (Hayami and Ruttan (1971); Johnston (1970); Johnston and Clark (1982); Eicher and Staats (1984)). The attainment of independence by most of the developing countries in Africa and Asia was also followed by important technological developments in the biochemical field which resulted in the green revolution with its high yielding varieties of important food grains, fertilizer and irrigation technology. It also coincided with the period when most of the countries in Europe were shifting from an agriculture dominated by draught animals, as the main source of power on the farm, to one in which the internal combustion engine, in the form of a tractor, was becoming the dominant power source. This shift in power source on the farm in Europe and North America led to a drastic reduction of agricultural labour force and in many countries declining to less than 10% of the total labour force within a period of one or two decades. However in Europe, North America and Japan the displaced agricultural labour force was easily absorbed by the expanding industrial and service sectors in the urban areas. For the developing countries however the urban industrial sector was not that large and it was not expanding that fast. Already in the 1950's the rural-urban migration was viewed with alarm. Any agricultural development policy which would have led to increased rural unemployment was considered with apprehension by many development economists.

As a consequence of this concern on the effect of agricultural mechanization on employment and equitable development in the so called 'labour surplus' developing countries there have been a number of policy prescriptions advocated by different researchers/development planners over the past 50 or so years on this question. In prescribing agricultural mechanization policies and strategies for developing countries it would seem there are four groups among experts:-

- (a) The first group are those who oppose the widespread adoption of advanced technologies (mostly internal combustion engines and tractors) in agricultural mechanization as entirely inappropriate in most situations in the developing countries. This group argues that mechanically powered agricultural

mechanization, often leads to displacement of labour and hence increased unemployment, and this results in a host of other socio-economic problems, among others, rural-urban migration, inequitable distribution of wealth and in many cases an increase in absolute poverty; balance of payments due to the need to import the machinery, fuel and sometimes technical assistance to manage them. They further argue that adoption of mechanical technologies does not necessarily lead to increased yields and land productivity and equal or even higher increments could be achieved by use of the biochemical inputs alone. This group often advocates the use of improved handtools, and/or draught animal technologies coupled with the biochemical inputs (hyv, fertilizers, etc.). Essentially they see the handtool and animal powered technologies as an alternative to mechanical technologies in the agriculture of the developing countries especially the small holder sector.

- (b) The second group comprises those who view the use of the improved handtools and animal powered technology as a transitional step between the most rudimentary step in technological development (characterized by entire reliance on human muscle power) and the advanced technologies (characterized by reliance on tractors and other machinery). This group argues that the course of technological development is evolutionary and it is each country's prerogative to aspire to a higher technological plateau. It is argued, modernity is a legitimate goal, but care should be taken to ensure that technological, cultural, economical and social development all work in tandem to ensure a well balanced society. This group opposes any rapid mechanization policies in particular those which aim at widescale adoption of mechanical technologies among small and medium scale farmers. In many cases this group has attempted, at times convincingly and at other times unconvincingly, to show that these improved handtools and draught animal power are just as 'good' and 'economical' as the mechanical technologies.
- (c) The third group comprises those who regard these intermediate technologies (i.e. improved handtools and draught animal technology in agriculture) as a 'delaying' tactic and they advocate the use of mechanical technologies as the most appropriate. This group argues that alternatives to the mechanical technologies do not just exist as a practical matter or if they are available they are inefficient and they cannot be compared to the mechanical technologies in terms of economics and productivity. They further argue that, where these mechanical technologies have failed in developing countries this

has in most cases been as a consequence of poor planning, management and supervision. They view the agricultural production process as a thermodynamic process (advocating a minimum level of hp per hectare) and argue that food and crop production has to be achieved in the most efficient way, maximizing the productivity of land and labour, and it is only by doing this that a surplus can be realized which can then be marketed at a lower price. They scorn at those who oppose agricultural mechanization for fear of creating unemployment and compare them to the Luddites in England in 19th century, who smashed textile machinery because they feared it would create unemployment. This group argues that as long as agriculture in developing countries is perceived as a "gigantic programme" of relieving unemployment, then these countries will continuously face hunger and massive starvation. On the question of energy problems required for running these tractors, it is argued that the fossil fuels spent in running them even in the most advanced countries is less than 5% of the total commercial energy used, and in any case the other biochemical inputs which do not seem to be questioned in so far as energy is concerned, are even much more energy intensive than the fuel required to run the machinery and implements. (Stout (1979); Fluck and Baird (1979); Gohlich (1984)).

- (d) The fourth group advocates a compromise between groups 2 and 3 above. This group views the improved handtools and draught animal technology as more of a 18th century technology and the modern tractor and combine as more of a 21st century technology for most of the developing countries. This group argues that more appropriate form of mechanical technologies can be developed for the farming systems in the third world. Thus over the past 30 or so years this group has been busy designing an 'intermediate', 'appropriate', 'mini', 'micro' tractor for use by farmers in the developing countries. The idea here has been to develop a technology which can be afforded by the small and medium scale farmer and which is also multi purpose. Development of such technologies has been particularly done on the Asian subcontinent (Phillipines, Thailand, etc.) as well as some of the more advanced countries in Europe and in Africa e.g. *Tinkabi* and *Kabanyolo* tractors.

There have been quite a number of research papers published over the past 40 years concluding with one or a combination of the above views. By and large there has been more work done on the Asian continent in this regard than in either Africa or Latin America (de Wilde (1967a,b); Hall (1968); Kline (1969); Chancellor (1971); Southworth (1972); Abercombie (1973); Clayton (1973); Barker et.al. (1973); Gotsch (1973); Binswanger (1974, 1978, 1984);

Oluwasami (1975); McInerney and Donaldson (1975); Bartsch (1977); Pollard et.al. (1979); Mrema (1981, 1983); Clayton (1983); Farrington et.al. (1984a,b); Duff and Kaiser (1984); Pathak (1984); Sukharomana (1984); Ahmed and Kinsey (1984); Booth and Sundrum (1985); Tam (1985); Westley (1986); Commander (1987); Pingali et.al. (1987)). These research papers have often been used as a basis for giving blanket policy prescriptions on the whole question of agricultural mechanization in particular in Africa. As an introductory data Table 2 gives the number of tractors in a selected number of developing countries over the period 1940-1987 which is self explanatory showing similar percentage increments as in Europe (cf. Table 1) although from a lower numerical base. We do not intend at this stage to comment on the conflicting views presented above on the policies on agricultural mechanization advocated by different experts. We shall do this in the concluding chapter after going through the experiences of a selected number of African countries as well as that of India as given in the intermediate chapters of this volume. We believe we shall then be in a better position to analyze the African experience in agricultural mechanization and relate it to the above theoretical views.

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CHAPTER 2

AGRICULTURAL MECHANIZATION STRATEGY FORMULATION: PROCEDURES AND ISSUES

by

R.C. Gifford

INTRODUCTION

For over fifteen years, FAO has been working to develop an approach to planning for the rational introduction and use of agricultural mechanization which would be applicable to all developing countries. For over ten years, FAO has provided encouragement and assistance to some sixteen member nations in the formulation of national agricultural mechanization strategies or action plans to help ensure a positive role for mechanization in the rural development process. In spite of these efforts, and the positive developments in some countries in Asia, there are at least one hundred developing countries which do not have a formal plan to guide the introduction and application of mechanization for development. These countries are likely to have a total investment in agricultural hand tools, draught animals and equipment, stationary machines, mechanical power and equipment, and in facilities for mechanization of about US\$ 30,000 million by the year 2000. In light of this investment, it is inconceivable that so many governments would neglect or avoid planning for mechanization's efficient and effective use in efforts to achieve food self-sufficiency and a better way of life for rural people.

It is a pleasure to report, however, that the governments of two African nations - Malawi and Zimbabwe - have taken steps in the past six months to redress this situation and by the year 1992 will have national agricultural mechanization strategies to guide the public and private sectors alike in introducing and applying appropriate mechanization inputs in the development process. This paper repeats the message on agricultural mechanization strategy formulation which has been delivered over and over again by various officers of FAO to countless governments, national seminars and workshops, and international conferences during the last decade (Gifford (1981)). It defines and describes what is meant by "agricultural mechanization strategy". The procedures to be followed in formulating a strategy are outlined. And finally, the issues constraining the widespread formulation of strategies and the introduction and use of appropriate mechanization are reviewed.

DESCRIPTION OF MECHANIZATION STRATEGIES

Agricultural mechanization in most of the industrialized countries has developed mainly through the initiative and efforts of the private sector. Private individuals and groups of farmers and manufacturers have formulated

and implemented their own plans. Government have had little need, therefore, to take the lead in developing strategies to ensure an appropriate role and place for agricultural mechanization in the rural development process. Many developing countries have attempted to follow this same pattern and let mechanization find its own course and pace in development. In general, this approach has failed because circumstances are radically different. Developing countries, for a variety of reasons, are under pressure today to develop agriculture in less than 20 years instead of the 200 years taken by the industrialized countries to achieve their advanced level of agricultural production and operational efficiency. The internal capacity of most developing countries to manufacture the inputs required for agricultural development has not evolved at the same pace as the need for the inputs. The chronic shortage of foreign exchange has been a major constraint on importation of the inputs needed for rapid development. And finally, contrary to the historic situation in the industrialized countries, most developing countries do not yet have a dynamic private sector which is capable or interested in assuming the lead in organizing, introducing and supporting mechanization systems for rural development.

Consequently therefore, governments in developing countries must take the initiative to influence, guide and support the introduction and use of mechanization inputs for development. These inputs require a strategy for their identification, mobilization, distribution and support which should be an element in the government's national development plan. Without a strategy, the type and pace of introduction will certainly have unconsidered, and often undesirable effects on overall development objectives, goals and targets. This is not to say that the governments in most developing countries should implement and control mechanization programmes and systems. In FAO's experience, the private sector is more capable and efficient in respect of agricultural mechanization than the public sector. It is generally accepted that the government's role should be restricted to establishing an economic and physical environment in which private individuals or organizations can move ahead with the tasks of introducing and supporting agricultural mechanization systems.

In agricultural development, the inputs critical to development beyond the subsistence farming level are usually improved seed, fertilizers, pesticides, increased farm power, improved credit and marketing systems and improved management capability. These inputs are resources which contribute to development. The plan for their selection, introduction, use and support is, according to internationally accepted definitions, called a strategy. The word strategy has been adopted from the military vocabulary where it means the manner in which a military leader mobilizes and deploys available resources (e.g. troops, artillery, ammunition, support staff, etc.) for fighting a battle or a war. Whether the battle or the war should be fought is a matter of policy; as determined by overall government objectives; and is the prerogative of politicians, not military commanders. This distinction between strategy and

policy is important but has often been lost by people in many countries when they embark on formulating plans for introduction and use of agricultural mechanization technologies. When people say they want to formulate a mechanization policy, there is a great risk that politicians will see the exercise as an infringement on their prerogative and balk at giving their active support. If, on the other hand, people say they want to formulate a mechanization strategy and take time to explain that the strategy will be formulated within the existing national policy framework, politicians are much more likely to accept and support the idea. In the above context, a national agricultural mechanization strategy becomes an integral element in the overall national development plan. It is, therefore, important to have an understanding of the elements and sequence of actions relative to national development planning. This paper does not presume to discourse on development planning in detail; the only intention is to put mechanization strategy in perspective.

NATIONAL DEVELOPMENT PLANNING: THE STRATEGY ELEMENT

There are many ways to approach national development planning. The components of the national plan are reasonably specific but the order in which they are considered during the planning process may vary amongst planners and according to circumstances. Nonetheless, it is useful to look at planning as a rigid sequence of actions in order to clarify what needs to be done and to decide where the action will take place and by whom. The following definitions were developed by FAO and have been in use for some ten years. They are presented below in the order in which action is normally taken:

Development Objectives: Statements of purpose which, in the development plan, define what the government wishes to accomplish.

Development Goals: Statements in the development plan which quantify expected development achievements.

Development Targets: Statements in the development plan which establish the time-frame for achieving goals.

Development Policies: The laws, rules, regulations, etc. which establish the parameters within which actions for development will be carried out.

Development Strategy: A comprehensive description of how, when and by whom resources will be mobilized, deployed and used, within the framework of policies, to achieve development targets, goals and objectives.

Development Programme: A detailed design for the implementation of projects and activities to achieve development objectives.

Development Project: A detailed description of actions that are to be taken to carry out a specific portion or element of a programme.

The national development plans in most developing countries usually contain details on development objectives, goals, targets and policies. Strategies, programmes and projects are seldom contained in the national plan document. Some, however, are included in sectoral working documents and annual plans. It is common, for example, for the Ministry of Agriculture to have detailed working plans for the mobilization and distribution of seeds, fertilizers and pesticides. Unfortunately, similar detailed plans for agricultural mechanization inputs are usually missing, though many isolated projects are likely to be described.

The use of agricultural mechanization inputs for development (e.g. hand tools, draught animals and implements, tractors and implements, combines, threshers, sprayers, pumps, etc.) must be planned if technical progress is to be cost effective and compatible with overall development objectives. A strategy needs to be formulated at the national level which ensures that mechanization inputs are selected, introduced, used and supported effectively and efficiently; and which also ensures that agricultural mechanization is in harmony with the national technical, economic, social and political development environment.

PROCEDURES AND RESPONSIBILITIES FOR STRATEGY FORMULATION

Information base

The primary and most often neglected requirement for the formulation of a national strategy for agricultural mechanization is a background of usable information. In most developing countries, this information may exist but it is not generally available in a form suitable for mechanization planning. Much of the required information can be collected from various public or private organizations or individuals, and processed to make it usable - at least as a starting point for mechanization planning. Additional information, however, will need to be obtained from the results of studies, surveys, inventories, etc. This latter action is expensive and time consuming and must, therefore, be well planned and efficiently carried out. Collecting and analyzing the needed information should usually be under the leadership of the planning unit in the Ministry of Agriculture. It will require, however, coordinated cooperation of many ministries, organizations and individuals in both the public and private sectors.

The development of an information base will include but not necessarily be limited to the following actions:

- (a) An indepth assessment of national development plans to see how existing plans affect or will be affected by agricultural mechanization.

- (b) The identification and categorization of all existing farming systems in the country to provide the basis for identification of appropriate mechanization inputs according to technical, economic, social and political factors.
- (c) An inventory of the current national mechanization park which includes a quantitative and qualitative assessment of the composition of the national park (i.e. type, size, age of machinery); of the ownership pattern; and of the main use of each type of machinery or power unit.
- (d) A description and assessment of institutional arrangements and infrastructural facilities to support mechanization; with particular attention to credit, research, extension, education and training, input supply and distribution, and machinery operation, maintenance and repair.

Input identification

Using the information generated by the above activities, it will be possible to describe the mechanization systems and specific inputs which are appropriate for each agricultural development and operational situation in the country. Included will be mechanization systems and inputs for land development and soil and water conservation; for crop and animal production enterprises; and for produce processing, handling, storage and transportation. In order to ensure overall appropriateness, the identification of mechanization inputs must be undertaken with the full collaboration of many individuals, organizations and technical disciplines. These include among others the following:

- i) Most important, but usually neglected, is the need to have farmers actively involved. After all, they are the end-users of the system and if they are not totally satisfied, the system will not be adopted and the potential impact of mechanization on development will be minimal or completely lost.
- ii) Agricultural engineers and other specialists must assess the technical requirements for each development situation and look carefully at the comprehensive list of mechanization inputs which are on the world market and could be selected to meet those requirements.
- iii) Farm management specialists and economists must assess all input cost/output value relationships at the farm level, and the economic implications of mechanization alternatives with regard to the national development situation. Any mechanization

system must be financially profitable for the farmer and economically justified for the country in order for its use to be sustained.

- iv) Specialists in rural, cultural and social systems must be brought in - to determine the appropriateness of mechanization at an early stage. There are many examples where the introduction of mechanization systems which were technically, financially and economically appropriate but which were not adopted by farmers for social or cultural reasons.
- v) National development planners have an important role to play in the selection of mechanization systems. They are well placed to be aware of and to understand the political implications of mechanization system alternatives which might be proposed by technical specialists.

Input acquisition or mobilization

Once the appropriate mechanization system and inputs have been identified, a comprehensive programme to ensure the availability of machinery, parts and supplies in the country must be carefully formulated. Basically, there are two alternatives; importation or local manufacture. Within these broad alternatives, however, there are many choices and combinations and each will need to be considered in the light of all development plans and situations in the country and in light of the critical requirements for technical and managerial capability.

For the importation of machinery, parts and supplies it is usually a government function to make some or all of the following key decisions and establish appropriate laws, policies, regulations or systems whereby these decisions can be implemented:

- i) What inputs will be allowed into the country?
- ii) Who will be licensed or responsible for importation and under what conditions?
- iii) How much foreign exchange will be allocated for importation of machinery and for subsequent importation of parts, etc. to sustain its use?
- iv) From which countries will inputs be obtained?

Many developing countries have opted for the local manufacture or assembly of all or part of the required mechanization inputs. When considering this alternative, the following points should be borne in mind:

- a) Local manufacturing should be based primarily on real local market demand and not on perceived export market potentials.
- b) Technical capability and business management skills are critical prerequisites for successful local manufacturing or assembly.
- c) Some protectionist measures may be required during the initial growth of machinery manufacturing, but if applied over the long term, adverse effects are likely to result.
- d) Quality control must be rigidly applied if the mechanization product is to be acceptable to the farmer and economically viable for the country.
- e) The design of mechanization inputs produced locally must keep pace with design improvements in other parts of the world.

The national agricultural mechanization strategy must describe the measures for implementation of the system chosen for machinery mobilization or acquisition. Many government ministries and agencies will need to cooperate in formulating this section of the strategy and the difficulties are likely to be enormous. The voices of vested interest groups inside and outside the government will be loud and persistent on every issue under consideration. In spite of these expected difficulties, the task must be carried out or the farmer or other end-users of mechanization inputs will not have access to what is needed at the time it is needed.

Input allocation or distribution

The national mechanization strategy must address the issues of who should be encouraged to own and operate mechanization inputs and who should be responsible for their introduction, distribution and promotion. The alternatives for machinery and equipment ownership and operation are so many and so varied that details are beyond the scope of this paper. In general, however, the choice of alternatives should reflect the needs and conditions of the small-farm sector as a priority in most developing countries. Also, the concept of multi-farm use of machinery and power should be encouraged and supported in order to increase economic efficiency of mechanization systems and to bring mechanization services within reach of small- and large-scale farmers alike. Some alternatives for the multi-farm use of machinery and power are:

- i) Ownership/operation by individual farmers who use machinery on their own land and use surplus capacity to provide services to others in a relatively small area on a casual or informal hire basis.
- ii) Ownership/operation by individuals in rural areas who carry

out a machinery hire service as a business which provides a major source of their income.

- iii) Ownership/operation by informal but legally constituted farmer groups.
- iv) Ownership/operation by formal rural cooperatives.

The omission of government tractor hire schemes or machinery pools from the above list of alternatives is deliberate. Years of experience of these schemes clearly shows that they have failed to be effective or economically viable over the long term.

The introduction and distribution of appropriate mechanization inputs in most developing countries should be a joint and coordinated effort of government institutions and private machinery manufacturers or distributors. Government institutions, usually the engineering and extension units in the Ministry of Agriculture, should assume the basic responsibility for ensuring that farmers are aware of appropriate mechanization alternatives. These units, however, must work closely with machinery manufacturers and distributors to learn of innovations in the international or national market which would be useful in the farming systems of the country. In the ability to respond to farmer demand, manufacturers or distributors are usually more efficient and effective than government agencies in promoting, demonstrating, selling and delivering mechanization inputs. These actions follow naturally if government engineers and extensionists do an effective job of making farmers aware of mechanization alternatives.

Institutional and infrastructural support arrangements

The quality and comprehensiveness of arrangements to support agricultural mechanization will largely determine its impact and sustainability in the development process. The role of government in providing support is critical but not exclusive. This is equally true for the private sector. In most countries, therefore, the best arrangements will consist of a combination of responsibility between the public and the private sectors which reflects the ability of each to perform under the specific conditions of the country.

Research and development (R & D)

Mechanization is a dynamic input into agriculture and farmers obviously have a vested interest to employ the most appropriate inputs they can afford to improve farm performance. The role of farmers in R & D is, therefore, critical; particularly in light of the fact that historically, more machinery innovations have been developed by farmers than by public sector institutions.

Furthermore, there is little evidence that the agricultural mechanization development carried out in public sector institutions in Africa has been taken up and used by farmers. In most industrialized countries, mechanization is the result of the combined efforts and inputs of farmers and machinery manufacturers. In the developing countries, however, circumstances are different and the role of the public sector will need to be greater. This suggests that public sector R & D will need to be very carefully planned and carried out; and indeed, will need to emulate the historical pattern of successful R & D by farmers and machinery manufacturers in selected industrialized countries. In general, mechanization R & D in most developing countries should have the following features:

- a) Applied research should be emphasized; basic research is best left to those countries and organizations with resources to meet the high financial and manpower costs involved.
- b) R & D should always be in a problem-solving context and the problems should always be defined in close collaboration with farmers.
- c) There should be only one national focal point for mechanization R & D in most developing countries, and the focal point institution should have a sound working mandate to coordinate inputs from all concerned-public and private sector organizations.
- d) Mechanization R & D should not be carried out in isolation; it can be successful only when it is an integral part of other agricultural and industrial research activities.

Extension

In general, extension and research in agriculture should be considered as a single action programme; one without the other will have little impact at the farm level. Just as mechanization R & D should be an integral part of other agricultural research activities, it should also be an integral part of the overall agricultural extension programme. Extension agents, who have the first and most direct contact with farmers, should be as well grounded in the basics of mechanization as they are in agronomy or plant protection or animal husbandry. If this principle is followed, major changes in the programme for training extension agents and in the extension programmes themselves will be required in most developing countries. A national mechanization strategy must reflect this situation and ensure that measures are included to establish links from R & D to the farmer. Traditionally, this link has been through established extension agents and has been a function of the Ministry of Agriculture in most developing countries. Many experts are questioning this arrangement, which has been adopted almost in total from the industrialized countries, and there

is considerable agitation for an approach which is more suited to the needs and conditions of developing countries.

Education and training

It is convenient in formulating mechanization strategies to define education as a formal activity to develop a broad base of knowledge. Training can be defined as a formal or informal activity to develop specific skills to meet the requirements of specific jobs or tasks. In this context, some developing countries have education programmes for agricultural engineers which are adequate from the standpoint of developing a broad technical knowledge base. Many of these programmes, however, are not adequately orientated towards farm mechanization and engineering students are too often weak in their basic knowledge of agriculture. A national mechanization strategy should reflect this situation and measures will usually be required to improve or re-orientate the agricultural engineering education programme.

Agricultural mechanization, at the level of animal draught and mechanical power technology, calls for skilled or semi-skilled rural labour. In most developing countries, training programmes to develop the skills required for management, operation and maintenance of mechanization inputs are insufficient or inappropriate. The training of managers for hire-service operations is virtually non-existent in the developing world. Operator training, including animal draught operation, has received too little attention and usually is given in an institutional setting instead of at the on-the-job field level where people can learn the needed skills for machinery operation rather than simply being drivers or animal handlers.

The need for trained mechanics to maintain a tractor fleet is well recognized in some countries and there are usually adequate arrangements for training. However, many countries do not recognize that skills to repair trucks and automobiles are not necessarily appropriate for the repair of agricultural tractors and equipment. Adjustments are needed, therefore, in many country programmes to ensure that mechanics have the skills to meet the specific requirements of agricultural machinery.

The need to have trained blacksmiths/artisans at the village level is only now receiving the needed attention in some developing countries of Africa. With 80-90 per cent of the farmers relying solely on hand tools and draught animal implements, measures to establish a network of facilities at the village level to fabricate and repair these tools and implements should be given priority in most national mechanization strategies.

An often neglected area in developing countries is media education for mechanization. Radio, television and newspapers are all potential education media for such things as animal health, machinery safety, machinery efficiency and energy saving. Strategies should reflect this potential.

Credit

Mechanization strategy measures related to credit for input purchase and operation have many implications outside the agricultural sector. Decisions on whether credit for mechanization should be made available through public institutions or commercial banking channels can be politically sensitive. Often they need only small amounts of credit which is costly to administer; they seldom have collateral required by many institutions; they tend to be isolated with limited access to regular credit facilities and, they are often classified as poor credit risks in the criteria of many credit institutions.

As a mechanization strategy element, credit should be considered in light of the following fundamental principles:

- a) Credit for mechanization should facilitate improvement in land or labour productivity - it should not be used solely as a subsidy to promote mechanization as a means to achieve "modernization" of agriculture.
- b) Credit should be extended only on a sound business basis - farmers should not be led to expect relief from repayment in full and on time, and the payment should be feasible from increased farm income resulting directly from the use of additional or improved mechanization inputs.
- c) Credit should be available to all sizes of farm holdings regardless of the level of mechanization technology being used (i.e. hand tools, animal draught or mechanical power).
- d) Credit terms should reflect a time frame which is compatible with the users access to income and, therefore, ability to repay loans on time.

Supply, maintenance and repair services

Countless idle tractors and graveyards of mechanical and animal drawn implements in developing countries attest to the inadequacy of arrangements that will keep mechanization hardware operational. Supply networks to ensure the timely availability of fuel, lubricants and parts do not simply "happen". Blacksmiths to fabricate and repair hand tools and animal implements require training and measures to help establish their businesses on a sustainable basis. Mechanics, replacement parts and repair shops to repair and maintain advanced mechanical-power technology cannot be established to properly serve farmers on a sustained basis in a few short weeks. Draught animals are ineffective as farm power unless measures are taken to ensure a regular supply of feed and health care.

A national mechanization strategy will define what measures are required to ensure the support for mechanization as described above. It will also identify who should provide the support. Experience shows that public sector attempts to organize and operate supply networks or maintenance and repair facilities have not generally been effective or efficient. Government organizations simply have not been able to overcome the constraints on performance caused by unwieldy government financial procedures and inadequately motivated government civil servants.

MAJOR PROBLEMS TO BE SOLVED

Basic to this paper is the strong belief that national agricultural mechanization strategies are essential to the introduction and use of appropriate mechanization in the developing countries. As stated earlier, most developing countries have not yet formulated such a strategy and this maybe the root of the problem. The lack of understanding of what a strategy is and why it is needed; the shortage of trained manpower to formulate and implement strategies; and the shortage of funds to prepare a strategy and supervise its implementation have all contributed to this unfortunate situation.

In addition, the following are specific problems that are major constraints on programmes to introduce and sustain mechanization, which are common to most developing countries:

- (a) Neither recipients nor donors have effectively planned and executed international aid programmes in respect of agricultural mechanization. Bulk delivery of inappropriate mechanization inputs is common and often occurs without adequate measures to support and guide input distribution, use and maintenance at the farm level. The results have been disillusioned farmers, graveyards of machinery, discouraged government officials and an unnecessary drain on scarce foreign exchange.
- (b) International and bilateral aid agencies have too often made "desk" decisions on the type of mechanization they will support. It is rare for studies to be made of the real farming situation and the realistic requirement for inputs. Such studies would clearly show that combinations of mechanization technology (i.e. hand-tool, animal-draught and mechanical-power technology) are the only way appropriate mechanization can be made available to all sizes and types of farming systems.
- (c) Developing countries have often dispersed the authority and responsibility for mechanization so widely amongst ministries, agencies, institutions or organizations that it is impossible to achieve a coordinated effort to provide farmers with the mechanization inputs and systems requirements.

- (d) The role of village blacksmiths and repair shops in supporting mechanization for 80 per cent of the world's farmers has been seriously neglected by developing countries and aid agencies alike. Simply training blacksmiths and mechanics is not enough - they must be assisted to establish their businesses at the village level and then supported over time with training opportunities, credit, markets and access to a supply of raw materials.
- (e) Some developing countries are still trying to establish and operate government machinery-hire service schemes which, according to 35 years of experience would seem to be, are doomed to financial failure.
- (f) Many agricultural machinery manufacturers persist in using the developing countries as a dumping ground for their surplus production. Sales efforts in developing countries usually do not include efforts to develop a sustainable network of distribution and service facilities throughout rural areas.
- (g) Bilateral aid agencies in particular have mostly failed to design their loan or grant programmes for mechanization to take advantage of the large store of expertise available from machinery manufacturers in their own countries. This has deprived the recipient countries of valuable and much needed technical assistance which could be made available at a very modest cost.
- (h) Training for agricultural mechanization in most developing countries has neither been adequate in scope nor appropriate in form. Often, training needs are ill-defined and training methods are not up-to-date. The result is a labour force which lacks the skills to use mechanization effectively and efficiently. On the education side, it is common knowledge that many programmes to develop agricultural engineers fail to reflect the real needs for skills in the home country.

CONCLUSION

This paper has presented the same message on agricultural mechanization strategy formulation that FAO has been delivering for over ten years. The hope is that if enough different people listen to the message, action will eventually be taken to rationalize the role of mechanization in the development process. This hope is being realized with the progressive attitude of Malawi and Zimbabwe. The experience gained by their action will benefit not only themselves, but all of Africa.

The holding of this workshop represents an important step in the evolution of mechanization strategy formulation. It reflects a recognition that the role of mechanization in the development of African agriculture can be

improved or expanded. Some thirteen nations are represented here by senior decision makers and, if among others the FAO message has been understood and believed, they will go back home and initiate actions that will eliminate the graveyards of equipment, reduce the unjustified drain on foreign exchange, and avoid unpleasant surprises and delays in bringing relief to the millions of farmers in Africa whose physical and financial burdens can be at least partially relieved through the introduction and use of appropriate agricultural mechanization.

CHAPTER 3

AGRICULTURAL MECHANIZATION IN AFRICA - AN OVERVIEW OF MAIN ISSUES

by

R.N. Kaul

INTRODUCTION:

It is recognized that the major area of agricultural potential in Africa is the Sub-Saharan Africa region. However, during the past 30 years agricultural production in the region has increased by only 2% a year, whilst agricultural exports have declined, and food imports are increasing at about 7% a year. Only 30% of Africa's land area is capable of sustained production of rainfed crops with about one-quarter of this currently being used. It is reported that acreage expanded by only 0.7% per annum during the past 20 years. At this expansion rate productivity must rise by more than 3% a year - three times faster than in the past (IBRD, 1989). This is indeed a gloomy scenario. However, Swaminathan (1986) has compared the current spotlight on Sub-Saharan Africa for struggle against hunger to what several food experts predicted for many countries of Asia and Africa over 25 year ago. For example, India was singled out as a hopeless case that could not be saved from hunger and famine. Today India, has over 30 million tonnes of grain stock as a food security reserve. In this regard, Swaminathan (1986) and many others are optimistic of similar strides being possible for Sub-Saharan Africa if an appropriate action plan, involving appropriate technological change, is formulated and implemented.

Agricultural mechanization is one of the inputs in the farming production cycle. In a way it even signifies the technological status of agriculture in a country as, for instance, the African farmer is generally referred to as a "Hoe Farmer". Unfortunately mechanization is the most neglected production component (in comparison to the biochemical inputs e.g. seeds, fertilizer, etc.) and to a large extent, a controversial one too. Application efficiency in terms of placement, precision and timeliness etc. of other inputs like seeds, fertilizers, pesticides, is considerably influenced by the equipment being used in addition to it affecting other factors like labour needs, optimal crop combinations and production costs as well as timeliness of field operations. Agricultural mechanization thus plays a vital role in the overall production cycle and socio-economic development of a country.

Many workshops/symposia/seminars have been held over the past 3 decades, and at different locations to deliberate on the mechanization issue in Africa and examine the constraints that impede its adoption. Several

commissioned studies have also been undertaken on specific topics pertaining to agricultural mechanization. Commonwealth countries like Botswana, Gambia, Ghana, Kenya, Malawi, Nigeria, Tanzania, Uganda, Zambia, Zimbabwe have received reasonable coverage in identifying critical issues on mechanization through studies by Commonwealth Secretariat, UNIDO, FAO, ILO, PUDOC, World Bank, MSU and others. Among non-Commonwealth African countries, Algeria, Sudan, Ethiopia and Senegal have attracted good attention. The highlights of recommendations emerging out of such workshops/commissioned studies, over last several years, have been compiled to identify issues which are common. This paper gives the summary of these issues. Hopefully by bringing the international agencies and national experts together, as in this workshop, a common approach can be discerned which recognizes the problems involved and develops into an implementation strategy, so that the repetitive nature of "problem identification" can be halted and efforts diverted towards finding actual solutions.

MAJOR HIGHLIGHTS OF PAST WORK

The review of past work on agricultural mechanization problems in Commonwealth Africa, indicates that the following issues as being of major significance:-

- (i) Proper place of agricultural mechanization in the production cycle.
- (ii) Need for a national policy and strategy on agricultural mechanization.
- (iii) Issues related to labour in the context of agricultural mechanization.
- (iv) Lack of focus on small scale farmers.
- (v) Neglect of local manufacturing.
- (vi) Power sources on the farm.
- (vii) Research and extension on agricultural mechanization.
- (viii) Lack of continuity.
- (ix) Networking and communications.
- (x) Gender issue in mechanization.

These will be discussed in greater detail in the subsequent sections of this paper.

Proper place of agricultural mechanization in the production cycle

While it is recognized that lack of appropriate agricultural equipment/implements and power is one of the critical limiting constraints in increasing agricultural production, there has, however, not been a coordinated effort to focus attention towards removing this constraint. Often through a wrong approach, like indiscriminate importation, more damage has been done to the existing system than any help. Kline et.al. (1969) during an extensive review of agricultural mechanization status in Africa over two decades ago observed that:

"Role of mechanization must be seen in relation to the roles of other factors in the production function. In this context, mechanization is entitled to a special place in the order of priorities for developing systems of agriculture; the order of priorities for mechanization is frequently not the first".

This observation is as valid today as it was in 1969, and is further stressed by Dr. Julius K. Nyerere when he addressed, as the host country President, the opening session of an International Conference convened by the Commonwealth Agricultural Bureau on "Advancement of Agricultural Production in Africa". We quote,

"In Africa now, mechanized equipment, chemicals and technical or scientific knowledge are not readily available to the farmers. Nor are they likely to be in the near future. Those facts have to be taken as a starting point for any consideration about how to advance agricultural production in this continent. For Third World countries are - almost by definition - short of capital, of economic infrastructure, and of technical and scientific knowledge in the rural areas. Thus, for example, even when tractors or combine harvesters have been acquired, they sometimes have to be sent hundreds of miles for servicing, and minor breakdowns can result in their being out of action for months at a time. Basing African agricultural advance exclusively, or even mainly, on industrial and capital intensive techniques of production is thus a contradiction in terms. A tractor can plough hundreds of acres; waiting for one which does not exist, or is not working, means that you get less output than if you had cultivated with a hand-hoe, and much less than if you had based your production plans on the use of animal-drawn implements" (CAB, 1984)

Ironically not a single paper was devoted exclusively to problems of mechanization at that global conference, even though the proceedings covered 85 chapters and the Conference was attended by 360 delegates representing 36 countries as well as leading agricultural scientists from all over the World and the Conference was to give a "Comprehensive survey of the current status and constraints to advancing agricultural production in Africa" (CAB 1984). This

thus stresses the neglect of agricultural mechanization, in the production cycle and figures as a basic policy issue. The conference organizers did not see the role and importance of agricultural mechanization in advancing agricultural production and productivity in Africa.

Need for a national policy and strategy on agricultural mechanization

Practically all the reports have pointed to the need for a national policy and strategy on agricultural mechanization for each country. Despite having existed for over 35 years by then, and seeing so many developing countries committing serious mistakes in their endeavours to mechanize their agriculture, it is only in 1981 that FAO, belatedly decided to commission a study which resulted in a very detailed treatise as a guideline on agricultural mechanization policy and strategy formulation in developing countries (Gifford, 1981). At a recent expert consultation (COMSEC, 1990) convened by the Commonwealth Secretariat the following additional points were recommended to be incorporated in the guidelines in the light of additional experience gained:

- (i) The concept of a national mechanization strategy and its importance in promoting agricultural mechanization is not fully appreciated. The purpose, justification and content of such a strategy need to be further clarified.
- (ii) There is a need for practical guidelines on the methodology for strategy formulation especially regarding the organization and management of the process of achieving this.
- (iii) There is a need for adoption of a flexible approach in the implementation of agricultural mechanization strategies in accordance with the country's circumstances.
- (iv) Agricultural mechanization strategy should pay particular attention to meeting the needs of small farmers and women.
- (v) The agricultural mechanization strategy should provide a focus and channel for technical assistance and investment funding by donor agencies and private sector organizations.

The above issues, among others, need to be considered in strategy formulation. So far however, few countries in Africa have even initiated the process of policy and strategy formulation for agricultural mechanization.

Issues related to labour in the context of mechanization

Labour has been recognized as the key to the understanding and improving of agriculture in Africa. Seasonal shortage of labour in Africa is a far more limiting factor in increasing productivity than in Asia. The major concern

voiced is the 'displacement of labour' by mechanization but that sounds more academic, in the African context, if taken in isolation as the labour problem appears to manifest itself in different forms. Few aspects are given below:

- (i) There isn't that much surplus labour, in the African agriculture scene, if 'invisible' labour inputs are considered. The 'invisible' labour inputs include; walking to and from the fields (which can take up to 25% of hours spent per day); and other non-farm activities such as collection of firewood and water and other life support activities.
- (ii) Increased utilization of biochemical technologies - e.g. fertilizers, hyv, etc. and sometimes even physical technologies - animal traction, can lead to increased labour demand in other parts of the agricultural production system which may greatly influence the adoption or non-adoption of these technologies.
- (iii) Many of the recommendations on increased plant population and crop mixtures have not been fully accepted by farmers due to higher demand on labour for implementing them.
- (iv) From a farmers' view point the returns to labour and risk management, the traditional cultivation practices appear still better adapted to the physical and economic environment of West Africa.
- (v) Studies also do show that at the busiest period soon after the onset of the rains, farming efficiency using the handtool technology, with entire reliance on human energy can only be increased through using better mechanical aids.
- (vi) Research by among others, Malton et.al. (1984), and Kaul (1989), has shown that any excess demand of labour negates farmer response to adoption, e.g. even though in cowpea - sorghum intercropping 15,000 plant/ha. (against farmer practice of 1,000 to 8,000 plant/ha.) gave higher yields, farmers rejected it due to excessive labour demand. On-farm trials confirmed that with higher plant population for planting and weeding, labour demand increased by 50 and 25 percent respectively. Similar experiences have also been reported in studies by the Agricultural Development Projects (ADP's) in Nigeria.

Labour related issues in the agricultural mechanization debate, are thus quite vital from several aspects and need not be seen only in context of 'displacement of labour' which is actually in many cases misleading.

Lack of focus on small scale farmer

In general though most rural development projects emphasize the role of small farmers, their beneficial effects can be offset as a consequence of distorted mechanization policies which usually benefit the capital intensive large scale farmers. About 80% of agricultural engineering imports are intended for modern farming (state farms, plantations, agro-food complexes) leading to only 10% of people benefitting from 80% of foreign exchange allocations for agricultural mechanization. This has been consistently perpetuating and continues to figure as an 'issue' in mechanization. The low purchasing power and generally poor economic status of small scale farmers have been seen as serious constraints to their adoption of improved technologies. Similarly there is need to identify the farmer's needs and wishes which may not always be the same. Equipment for small scale farming appears to exist in other regions of the world which could meet some of the requirements of small farmers in Africa. The small scale farmers face a lot of problems in so far as agricultural mechanization is concerned.

Neglect of local manufacturing

In Sub-Saharan Africa investment in agricultural equipment is about 1% of the agricultural production. Outlays on fertilizer and pesticides consumed in one growing season is far greater than that for equipment which has a working life of 15 to 20 years. Eighty percent of the agricultural equipment imported is used in the modern farming sector (state farms, plantations and agro-food complexes). It is appreciated also that the modern sector produces some key crops which are vital to the economies of many of the African countries especially for foreign currency earnings. The agricultural machinery industry provides an important linkage between industry and agriculture. Our review reveals an apparent neglect of the local manufacturing sector in most of the African countries. Among the major points which are significant from the many reports include:

- (i) There are many small scale manufacturers and fabricators found all over Africa. These should not be ignored and regarded as a 'stigma' for even in the developed countries such manufacturers dominate the industry e.g. in Italy there are over 2000 small scale manufacturing firms, whilst in UK about 70% of the manufacturers employ less than 10 people. It is also possible to integrate the small scale artisan sector with the industrial sector by subcontracting fabrication and manufacturing of parts to them. Grouping of artisans together such as COBEMAG in Benin has helped to keep them engaged.
- (ii) About 90% of the demand is met through importation in particular for motorized equipment, and only 10% is met through local production. It is estimated that the local market

for agricultural mechanization inputs in SSA is worth about US\$3.0 - 3.8 billion in 1990 and is expected to increase to US\$4.7 - 7.00 billion by 2000 (UNIDO (1983)). The agricultural machinery manufacturing industry in Africa employs less than 1% of the total industrial labour with only one third of the companies producing exclusively agricultural implements and equipment.

- (iii) The predominant equipment in most countries are handtools being used in 60-95% of cultivated land with the exception of Botswana and Zimbabwe where in the former there is a widespread tradition of using draught oxen, and in the latter there is a large commercial farmers sector. There is also a supply-demand gap in most countries for handtools ranging from a few thousand pieces to hundreds of thousands.
- (iv) The local manufacturer is also dependent on imported raw materials. The local value added ranges from about 30% for handtools to about 30-50% for animal drawn implements (UNIDO, 1983). Most local manufacturing companies operate at 30-60% of their installed capacity due to lack of raw materials; lack of skilled labour; or disorganized internal market, and high cost of imported raw materials (with freight costs being 30% of total cost).
- (v) Multinational corporations have concentrated their efforts on assembly of tractors from CKD or SKD components, or they hold the local franchise for certain machinery brands. In many cases they concentrate on supplying the machinery and do not provide adequate spare part and maintenance support services. In addition due to their international connections they are able to win tenders for most tied aid which in many cases disrupts local manufacture and threatens existing production facilities.
- (vi) Few of the local manufacturing companies have an internal R&D capacity. This has led to many of them copying foreign machinery and implements or manufacturing them under licence.

Issues on commercialization of prototypes

The problems of commercialization of prototypes vary between countries but some aspects which tend to appear repeatedly include:

- (i) Prototypes being introduced may not be quite relevant to the farmer's needs. As for example, in a review panel observation, the following comment was made which is generally relevant

even today in relation to the prototypes being developed:-

"The ultimate goods are still far away. What we have seen are ideas yet to be fully developed. The real needs still remain to be properly diagnosed and then multi-disciplinary research and development has to take place at all levels" (COMSEC 1977)

(ii) Even in prototypes which look commercially promising, the problems of commercialization are affected by the following factors:

(a) Pre-commercializing factors like:

- poor design
- wrong feasibility
- lack of extension services
- lack of entrepreneurs willing to take risk
- lack of raw materials

(b) Post commercializing factors like:

- Lack of unified policies (government) to protect local industry especially in relation to tied external aid.
- lack of manufacturer's initiative.
- unstable raw material source - both in quality and pricing.
- lack of prime mover and relative cost factor in relation to machine.

These have made many prototypes developed in Africa remain laboratory/workshop show pieces.

Power sources on the farm

Our review has established that most people take animal and tractor power as the only sources of farm power. Ironically the human manual power is not seen as a 'power source' but as a 'labour' matter. Few specifics on the animal and mechanical power sources, which cut across most reports are as follows:

(i) **Animal power**

There appears to have been 'waves' of animal traction efforts

over the past 50 years which have receded or disappeared during periods of drought, change of government policy etc. Government policies tend to vacillate over emphasis on oxen and tractor system over time. There have been mixed reactions to its success and failures. For instance:

- (a) In a review of 27 animal traction projects in Francophone countries it was found that most of them had not lived up to expectations because of high cost of animals and equipment, low acreage and yield effects, and the lack of reliable institutional support.
- (b) The results of research in the Gambia revealed that the impact of oxenization has been largely confined to the groundnut crop with a small increase in area cultivated but no increase in yields. While in a study of 40 farmers in south-eastern Mali, it was found that animal traction farmers increased their acreage by 39 percent over hoe farmers but there was no change in yields.
- (c) The profitability of animal drawn equipment is constrained by the length of the growing season. Horse drawn seeders were readily adopted in Senegal in 1930 as the speedy completion of seeding is essential in order to ensure germination. Similarly the ridger was accepted in Northern Nigeria as the soils were susceptible to high level of erosion (which can be controlled by ridging). Animal traction is risky in semi-arid environment with irregular rainfall. Tied ridging, especially in combination with fertilizer and animal traction, has been shown to alleviate, soil, water and labour constraint.
- (d) One of the constraints identified on animal power utilization is that its application remains concentrated in a limited number of tasks typically transport or land preparation. Multi-purpose implement or 'tool carriers' have not proved successful at farmer level despite about 10,000 such carriers of 45 different designs having been fabricated. Information dissemination about the results on farmer's fields was not adequate which led to duplication and subsequent mistakes and failures.
- (e) Substantial capital requirement for animal traction in West Africa has led to major cash flow problems in the early years following adoption. This initial cash flow problem poses an obstacle to adoption and reduces

acceptability. Introduction of a cash crop reportedly eases the situation.

- (f) Other problems plaguing animal traction programmes include: poor nutrition; lack of dry season fodder; disease; high mortality rates; uncertain supply of tools; problems in destumping and consolidating of fields; lack of reliable markets, and failure to establish training programmes for potential animal owners.

Thus a multiplicity of factors have influenced the adoption rates of animal traction technology in Africa and no single factor can solely be blamed for its non-adoption.

(ii) **Tractor power**

The following are some of the common points noted from many studies on the issue of tractors in African agriculture:

- (a) Since there is no domestic manufacturing industry, most tractors are imported. There is no control on the types and makes which can be imported. This has therefore generated a proliferation of types and makes of tractors e.g. a country which has a fleet of 3000 tractors and can import only 200-300 tractors per annum, has often got 12-15 makes. The consequence of this is large overhead costs in maintenance infrastructure (each make with its own dealer) and large inventories of spare parts which require foreign currency to maintain.
- (b) Sub-Saharan Africa has fewer tractors per thousand inhabitants than either Asia or Latin America. This is the case even in countries where tractors were introduced first, with the number of tractors per thousand inhabitants actually declining, e.g. Nigeria: 1947 - 0.23; 1954 - 1.14; 1958 - 1.38; 1968 - 1.11; 1970 - 1.08; 1975 - 1.01; 1981 - 0.88. The use of tractors is by and large restricted to the large scale commercial 'agriculture in' many of the countries. Tractor use for small holder agriculture has usually come in 'waves' often dependent on donor's interest, and/or economic 'booms'.
- (c) Studies on tractor hire projects have in most cases concentrated on the few failed Government owned and managed tractor hire schemes. These have shown a dismal picture in relation to their costs, economics and sustainability. Few studies have been undertaken on the

successful tractor hire schemes - e.g. contract farmers in Eastern Africa, etc. In many cases researchers who have studied these tractor hire schemes have often done a rushed job or have studied only a limited number of projects often those in the public sector. They have also been quite ready to give blanket prescriptions based on the conclusions of their limited studies. For example, Pingali *et.al.* (1987) in a study of 30 tractor projects in Sub-Saharan Africa from 1945-1980 (7 small holder; 13 Government tractor hire schemes, and 10 block cultivation schemes) concluded:

"In many tractor project areas no tractors can be found today. Where any tractors are still being used, their use is inevitably associated with rice cultivation. But even these surviving tractors today are privately owned. The transition from the hand hoe to animal-draft power, where its use is appropriate, continued to be made despite the emphasis on tractors. Of the seventeen attempts to bypass animal traction for tractorization only three succeeded, all of them associated with low-land rice cultivation schemes"
Pingali et al 1987.

Thirty tractor schemes (with less than 3000 tractors total), spanning over a period of 35 years (1945-1980) and covering the entire SSA region is just a very small and unrepresentative sample for one to conclude with such a blanket prescription. In addition animal traction has been even less successful despite over 80 years of extension effort.

Research and extension for agricultural mechanization

There has not been, by and large, any long term research undertaken on agricultural mechanization in Africa. Major emphasis within agricultural research systems has been on aspects that increase output directly (biochemical inputs) and relatively less has been placed on indirect contribution as can happen through mechanization. The research efforts of the international agricultural system (CGIAR) on agricultural mechanization has been insignificant. Similar situation exists also in the national research systems. Whenever economies have to be made on the research budget, the agricultural mechanization research programmes have been the first to suffer because these are relatively under-budgeted and in some situation may mean even complete elimination. In addition the following factors are pertinent in so far as R&D efforts on agricultural mechanization are concerned:-

- (i) Farm mechanization R and D is generally undertaken in isolation from the work undertaken by the biological, (e.g. crop) chemical and social scientists.
- (ii) There is little or no coordination between R and D efforts; local manufacture, marketing, distribution and farmers on agricultural mechanization research.
- (iii) The beneficial effect of any rural development programme emphasizing small farmers can easily be offset if distorted mechanization policies encourage capital intensive large scale farmers elsewhere in the country.
- (iv) Testing and evaluation have confirmed the difficulties of 'transplanting' machinery from other countries because of mis-matching of desirable specifications; over claims of operational performance, and high prices; among other difficulties.
- (v) Farming System Research (FSR) has by and large, played a low key in trying to integrate agricultural mechanization aspects in the overall farming systems concept - which ironically is not in line with the 'holistic system' approach philosophy of FSR.

Lack of continuity

Some notable achievements have been recorded in various spheres of agricultural mechanization at different points in time and locations in the world. Ironically one of the major reason for failure of such achievements to spread in SSA has been the apparent lack of continuity. There have been substantial research and development contributions in areas of equipment development - manual/oxen drawn/motorized, throughout the continent, but most promising ones appear to suffer from lack of continuity. New concepts like multi-farm use of equipment and block farming have met with marginal success.

In commenting on success of research efforts, there are very few cases which can be considered as having been widely adopted though the innovations may have been very promising. A long time period is needed even to carry a prototype to a limited adoption scale. For example:

- (i) In Botswana the Mochudi Toolbar (called the *Makgonatsotlhe*) took over 5-years under research and design before reaching limited trials stage.
- (ii) the 'Snail' winch developed at Silsoe for ploughing/transportation took 6 years before the first prototypes were field tested.
- (iii) The 'Tinkabi' tractor of Swaziland took nearly ten years to reach limited adoption stage.

At IRRI, in South East Asia however, within ten years, several of their prototypes (threshers, etc.) reached wide-spread adoption due possibly to the massive support and clarity of approach and the fact that fabricators were initially given firm orders to cover risk of capital involved. In general, however, on mechanization research in Africa there is too much expectation to have immediate results. The projects are conceived, and executed for some time, and then dumped either after or even before completion, if the researcher leaves the station or there is a priority of allocating research funds elsewhere. A new researcher comes, has different priorities and starts afresh, either on the same equipment (but has to be modified!) or a new one. This has thus generated a 'grave yard' of such experimental outfits, and mechanization dubbed as a failure, by those very planners who did not provide support to logical conclusion.

There have been undoubtedly failures on mechanization attempts all along but these have to be taken in their right perspective especially when compared with the Biological research thrusts such as:

- (a) It is estimated that despite years of research on sorghum and millet, less than 5% of their combined cultivated area in West African semi-arid areas is sown to varieties developed through modern genetic research.
- (b) Among some 7,000 sorghum introductions screened by ICRISAT in Burkina Faso only two cultivars have been found to be superior and well adapted under farmers' conditions.
- (c) Among 300 millet entries screened, no superior cultivars have yet been identified.
- (d) From the farmers' view point, in terms of return to labour and risk management, traditional cultivation practices still appear to be the best. (Schuh, 1986).

The idea is not to justify mechanization failures by citing Biological research failures, as above, but to emphasize that comparatively all is not bad in agricultural mechanization at least in relative terms to Biological research. If there was more continuity in agricultural mechanization projects the results could be more encouraging.

Net-working and communication

A common view which is quite ambiguous, in the reports reviewed relates to the problem of lack of exchange of information between countries and within a country. Each country has a capability to make a significant contribution to networking and for lack of regional cooperation, there are duplication in the R & D efforts. Thrust on networking can build on innovation already

developed. By having a regional project, efforts can be directed towards transfer/adoption of innovation from one country to another e.g. animal drawn planter from Botswana can be transferred to Zambia, helping their developmental work in the same area.

There have been a few attempts that have been initiated in this direction, among them:

(a) **Networking committees**

- (i) ANSTI is the African Network of Scientific and Technological Institutions and operates through disciplinary based sub-networks, among which Agricultural Engineering is one. It has a wide range of activities including one covering agricultural engineering in general. Main focus is however on training at post graduate level.
- (ii) Commonwealth Secretariat followed up a recommendation emanating from the Arusha meeting of 1977 by convening a meeting of the National Appropriate Technology Coordinators (NATC) in 1981 and came out with suggestions for setting up a coordinating mechanism at regional level in Africa on appropriate technology in areas like: research and development - approaches and institutions; linkages with industry; external assistance; local manufacture; promotion, adoption of appropriate technologies; coordinating institutions; secretariat for NATC; follow-up to a RATC (Regional Appropriate Technology Committee)
- (iii) ILO/FAO planned a series of national workshops in several countries (Zambia, Sudan, Tanzania, Ethiopia and Kenya) to give an input to the work of an interagency joint activities project (ILO/FAO/UNIDO/UNECA) for an African Regional Network for Agricultural Tools and Equipment (ARNATE). As a follow up, preparatory and implementation strategies were agreed. The preparatory phase involved, regional consultation, preparatory technical mission, national workshop and follow up preparation for the network.

Most of these networks face serious financial problems, do not hold their meetings/workshops regularly, there is no continuity in their core activities and this often changes with changing

fashions in the international donor system, loss of interest by the main steering agency (FAO, ILO, UNIDO, etc.) due to changes in emphasis, etc. There has thus been little effort in creating a functioning network in Africa at regional or continental level.

(b) **Networking literature**

Few attempts are also reported towards communicating through Newsletters, Directories, etc. For instance:

- (i) Commonwealth Secretariat compiled a *Guide to Technology Transfer in East, Central and Southern Africa* (1981). It gives an overview of agricultural implements situation and also gives an overview of agriculture, the technology available, existing trade and tariffs, etc. for the countries surveyed.
- (ii) The Commonwealth Secretariat produced a booklet called "*Rural Technology in the Commonwealth - A Directory of Organizations*". It lists 122 organizations from many African countries involved with agricultural development and training.
- (iii) UNIDO (1982) published a booklet on *Information Sources on the Agricultural Implements and Machinery Industry*. It has 941 entries.
- (iv) UNIDO had planned to start an *Industrial and Technological Information Bank* (NTIB), as a depository of major items related to equipment, however it is difficult to determine progress to date.
- (v) ILO made a country profile study on farm tools and equipment in 5 countries and it generated a *Manual on Tools and Equipment for Labour Intensive Farming*.
- (vi) Others are from Intermediate Technology Group in U.K. and similar organizations elsewhere.

Again the problems of continuity, lack of funds, high turnover of key individuals etc plague these efforts at communicating.

The gender issue in mechanization

The role of women, though mentioned in several reports has not been properly focussed on agricultural mechanization issues. The so-called gender issue is not

really only the sex related differentiation. What is actually involved is to look at a typical system where men, women and children are traditionally integrated into a working unit with an unwritten understanding of the division of labour. The system though skewed in favour of total work hours put up by women, is operational though not with desired efficiency. Most attempts to introduce better farming tools further complicate the issue in that the tasks that were traditionally done by women, get unconsciously passed on to men who, with the new equipment, find the task easy and remunerative and leave only the difficult ones like pounding of grains and internal transportation for women to perform. Thus a new dimension gets introduced in this system, creating displacement of women from their traditional tasks and subsequent loss of income. In the African context, this involves extra difficult position for the family for, despite their hardship, women contribute a lot to the family income. Basically therefore the issue boils to finding appropriate technology for women so that within the existing farming system they can still perform tasks which are traditionally theirs.

DISCUSSION AND CONCLUSION

This review has clearly shown that the issue of agricultural mechanization is not 'unknown', but what is lacking is continuity and coordination on decisions on mechanization made by various agencies both on the national side and the international donor side. This may well be the main issue in so far as agricultural mechanization is concerned. Even a casual examination of the proceedings of various symposia / workshops and commissioned studies reveals that issues which were voiced two decades ago (Kline *et.al.* 1969) are being voiced again in almost the same language (Gifford (1990)). Among the areas where action has been on a discontinuous and often ad hoc basis, has been in the formulation of agricultural mechanization policies and planning for strategies at national level. Whereas national priorities do often change depending on the political climate within a country, and often beyond the scope of technicians, a start on agricultural mechanization policy and strategy formulation can be made through the National Appropriate Technology Committees. This approach was advocated by the workshop held in Arusha in 1977 and sponsored by Commonwealth Secretariat. Some progress was made between 1977-80 and a regional workshop of national coordinators was held in 1980. There was however no further action after this workshop both at regional and in many cases at national level.

It was hoped then in 1977 that a network on agricultural mechanization and appropriate technology would have evolved out of the meetings of national coordinators. Such a network would have facilitated communication not only within a country but also on regional basis and lead to the establishment of formal mechanism of communication such as newsletters, seminars, regional training courses on appropriate agricultural mechanization technologies. However progress on this front appears to have floundered right

from the first workshop of national coordinators held in 1980. It should be appreciated that agricultural mechanization's role in development is still shrouded by controversies and there are number of myths. These include fears that agricultural mechanization displaces labour and hence leads to unemployment problems - which is a potentially sensitive issue to many policy makers. It can however be shown that such fears are usually unfounded, if agricultural mechanization is well planned. There are also fears about the expensive nature of agricultural mechanization inputs but it can be shown that the apprehension on high cost of equipment is not that serious if it is considered in relation to annual inputs like fertilizers and pesticides (c.f. machine costs which can be spread over a 5-10 years period).

There is also need to initiate research in all areas identified in this review and on a more continuous basis rather than the ad hoc way it has occurred in the past. There is need for example, to synthesize all experiences on efforts so far made to develop equipment for small farmers - success and failure cases and reasons for the same. This could be done by a panel of experts and their report could be reviewed periodically. There is also a need to initiate research on the more difficult tasks currently done entirely by handtool/human energy - food processing innovations; small scale cotton pickers; mechanization of mixed cropping systems; harvesting aids for fruits and vegetables; small scale rural transport equipment and mechanical means of scaring birds and other predators. Action will also be required in the research front on better/improved techniques of extending mechanization technologies through both the public and commercial systems; as well as studying effective ways and means of integrating the small scale blacksmiths and manufacturers with the medium and large scale production systems. Above all, there are also the management challenges of agricultural mechanization systems which require research attention at all levels - planning and policy leaders; research management, farm manager level in both large scale and small scale agriculture. There will also be a need to develop better communication between agencies involved in development efforts, official government and non governmental agencies as well as the donor agencies. Hopefully all this should result in an end to the current practice whereby every 5 or so years we meet to redefine and identify the mechanization problem and we should instead focus our attention on a continuous and progressive basis on the this problem. The need for an annual workshop to monitor progress and sustain interest is singled out as one of the most appropriate action to ensure continuity.

CHAPTER 4

A REVIEW OF DEVELOPMENTS IN AGRICULTURAL MECHANIZATION IN BOTSWANA

by

G.C. Mrema and C. Patrick

INTRODUCTION

Botswana is in the Southern half of Africa with the Tropic of Capricorn dividing the country into about two equal halves. Total land area is about 60 million hectares with only about 5.3 million hectares being suitable for agriculture (Table 3). The larger part of the country is a semi desert with annual rainfall of less than 300mm. The total population is estimated at 1.3 million in 1990 and growing at about 3.7% per annum. Rainfall is unimodal falling between October-March. Over 90% of the country receives less than 600 mm rainfall, and chances of crop failure due to drought are quite high. Up to 1976 the economy was dominated by beef exports to the EEC, but after this year, diamonds and other minerals have dominated the economy. Botswana has registered a real GDP growth of over 10% per annum over the past 10 years and has built up impressive foreign currency reserves (over US\$2.0 billion by 1988). The livestock population is estimated at 2.8 million cattle and 1.5 million sheep and goats. Over 80% of the population live in the south and eastern parts of the country which have better rainfall. The country borders South Africa and Zimbabwe and a significant proportion of its trade is with these two countries. About 70% of the population derive their livelihood from agriculture (livestock and subsistence crop production) (GOB - 1989) (Table 3).

The demographic pattern shows disturbing trends. Close to 50% of the population in Botswana is in the dependent age group (i.e. children under 15 years and aged people over 65 years old). In addition a significant proportion of rural households are headed by women. The urban population is expected to increase to about 70% of the total population of Botswana by the year 2010 AD (Table 4). The implication of this trend is that there will be more urban dwellers in 2010 AD than Botswana's total population in the 1990. This means therefore that the rural population with only about 54% of them being economically active will be required to produce enough food to feed not only the numerically increased rural population but also the urban population which is increasing at an even faster rate. Even more serious is the fact that those who migrate to urban areas are the younger members of the population (less than 30 years) and in most cases the educated, thus depleting the agricultural and/or rural sector of its most economically active population group. Indeed the average age of the rural population has been progressively

increasing (ATIP (1988)) and this trend will undoubtedly have serious implications on the food and overall agricultural production and productivity if current levels of mechanization are maintained.

TABLE 3: Agricultural Statistics for Botswana

1. Total Area x 10 ³ ha.	60,037
2. Total Land Area x 10 ³ ha.	58,537
3. Potential Agricultural Area x 10 ³ ha.	5,330
4. Cultivated Area x 10 ³ ha. (including ranches)	1,330
5. Forests, Deserts and others x 10 ³ ha.	53,207
6. Cultivated Land under	
(a) Large Scale farms x 10 ³ ha. (% of cultivated area)	330(25%)
(b) Small scale/peasant farms x 10 ³ ha. (% of cult.area)	1,000(75%)
7. Irrigated Land Area x 10 ³ ha.	3
8. % of Total Agric. Area Cultivated	25%
9. % of Cultivated Area Irrigated	=0%
10. Methods of Land Preparation	
(a) Handtool Technology % Cultivated Area	20%
(b) Animal Draft Power % Cultivated Area	40%
(c) Mechanical Power (tractor)	
Cultivated Area	40%
11. % Agriculture to GDP	6%
12. % Agriculture to Exports	5%
13. Per Capita GDP (1987) US\$2,000	2,000
14. % Food Imports to total consumed	80%
15. Principal Export Crops	Diamonds, Copper, Nickel, Beef

SOURCE: World Bank (1987), Economic Statistics (SADCC) 1988, FAO (1986), GoB (1989),

STRUCTURE OF THE AGRICULTURAL SECTOR

As in many countries in Eastern and Southern Africa, the agricultural sector in Botswana is characterized by the diversity of farm sizes and farming enterprises. The sector can be broadly divided into four groups of farmers. The

first group are the Peasant Subsistence Farmers (PSF) who practise subsistence agriculture - growing mostly sorghum, millet and pulses. They do not own cattle and in many cases do hire draught power from their neighbours if it is available. Their agricultural practices are usually very traditional - broadcasting of seeds; little or no weeding and the yields are quite low usually in the region of 10 or 20 kg per hectare. This group cultivates about 20% of the cultivated land in Botswana and constitute about 49% of the farm holdings. The average farm size is in the region of 1-2 hectares. Next to the PSF's are the Small Scale Farmers (SSF) who produce food crops for subsistence and cash (or food) crops for the market. In Botswana such farmers would have livestock as their main cash crop (usually less than 40 animals) and for agricultural field operations they have their own draught oxen. The offtake levels from their livestock enterprise is low (usually less than 10%) and they grow sorghum and other drought resistant cereals. A few may venture into horticultural production. Their agricultural practices are at a higher level than those of the PSF's, although by modern scientific standards they are still low, e.g. yields are still in the region 200-300 kg/ha. The SSF cultivate about 48% of the cultivated land (average land holdings 5-15 ha) in Botswana and constitute about 41% of the farming families. The third group are the Middle Scale Farmers (MSF) who produce both cash and food crops for the export and internal market. In the Botswana case these tend to be local merchants, retired civil servants, or Government officials who decide to invest their savings in agriculture. This group can normally obtain credit from the credit institutions, and use both divisible and indivisible inputs. Many of them own several pairs of draught oxen, and a few own tractors. They cultivate about 20% of the cultivated land and in many cases they employ extra labour from neighbourhood villages. The fourth group are the Large Scale Farmers (LSF). Their land holdings are usually quite large (sometimes over 1000 ha.). A number of the large scale farms in Botswana are owned by the state (BDC farms) although there are quite a number of private large scale farmers (e.g. Barolong farms, Pandamatenga farms, etc.). The Government has in recent years allocated land on 99 years lease in blocks of 500ha. in the Pandamatenga area. They grow cereal grains (sorghum, millet, maize), and a few have invested in irrigation. Most of their field operations are mechanized. They cultivate about 20% of the cultivated land in Botswana. There are also quite a large number of livestock farmers who do not grow any crops and concentrate only on livestock ranching for beef production.

The above structure of the agricultural sector in Botswana has, by and large, remained the same over the past 3 decades, with some of the farmers moving from PSF to SSF, SSF to MSF and MSF to LSF. Due to the semi arid nature of the climate (rainfall in the region of 250-600 mm) the country has been unable in quite a number of years to produce enough food to feed her growing population (in extreme dry years upto 80% of the cereal grains consumed is imported while in good years 20% is imported). However with expansion of the area under cultivation she could produce internally a higher percentage of her food requirements even in the extreme dry years. Given her

low population and the large areas which have to be cultivated to meet her food needs, to increase food production then an extensive type of agriculture has to be practised. The semi arid nature of the climate limits any intensive type of agriculture to a few areas in the country, and to areas which can be irrigated. To cultivate large areas Botswana will have to mechanize her agriculture. Agricultural mechanization will therefore play a crucial role in enabling the country to meet her food and agricultural production challenges over the next 2 decades. In the subsequent sections we shall review the agricultural mechanization policies and strategies in Botswana over the past 3 decades.

TABLE 4: **Population: (in thousands)**

Year	Total Population	Rural Population	% of Total	Urban Population	% Total
1960	507	498	98%	9	2%
1970	622	570	92%	52	8%
1980	807	569	71%	238	29%
1990	1300	614	49%	686	51%
2000 (projected)	1634	650	40%	984	60%
2010	2378	720	30%	1658	70%

AGRIC. MECHANIZATION POLICIES AND STRATEGIES

Three factors have significantly influenced the pace of agricultural mechanization in Botswana. These are first her livestock industry and tradition of keeping livestock by most Batswana; second her proximity to South Africa which has led to her, together with South Africa, Lesotho, Namibia and Swaziland being members of the Southern Africa Customs Union (SACU) and third the semi arid nature of the climate. These three factors have influenced the pace and rate of adoption of some mechanization technologies especially draught animal cultivation. Compared to other African countries, Botswana has a large percentage of her cultivated land ploughed by draught animals and tractors (40% for each category). The Batswana traditionally maintain three homes - a permanent home in the village (some villages have populations of over 40,000); a hut in the lands (where most of the crop production is undertaken) and this may be up to 10kms from the village home; and a cattle post - where the livestock are kept and graze in the communal grazing lands. During the crop growing season, nearly the whole family moves to the lands

and stays there until when planting is completed and they return again during bird scaring and harvesting period.

During the colonial period, Botswana - then known as Bechuanaland Protectorate had her capital in Mafeking - in South Africa and British Resident Commissioner had his offices there. A lot of economic activities in the territory therefore were linked to South Africa. A large number of Batswana worked in the mines in South Africa and indeed their repatriations formed a major part of the national income in the early days after independence. There was free flow of people and goods between South Africa and the Bechuanaland Protectorate. A number of South African and other white farmers settled in Botswana. These farmers, together with the Batswana migrant workers when they returned home brought with them into the country the technology of draught animal ploughing and transport. Given that the Batswana were already livestock keepers, and the arid nature of the climate which necessitated that each family had to plough relatively large areas in order to obtain enough sorghum and millet for subsistence, this made the adoption of the draught animal technology quite easy by most Batswana. Thus the animals were used for ploughing, transport - to collect water and movement of the family to and from the cattle posts and the lands. A few large scale farms were opened up in the Tuli Block, Pandamatenga and Barolong, but these concentrated mostly on ranching. Arable agriculture remained mostly for subsistence, and during drought years, grain could always be imported from South Africa and the then Rhodesia.

TABLE 5: **Tractors in use in Botswana**

<u>Year</u>	<u>No. of Tractors</u>
1950	45
1955	74
1960	107
1965	200
1970	790
1975	1859
1980	2123
1985	2155

FAO Production Yearbooks: Vol. 13, 24, 29, 36, 42;

* Tractors - include both crawler & four wheel tractors but excludes 2 wheel tractors.

The total number of tractors in the country was quite low and upto 1965 (on advent of independence) there were only 200 tractors (both crawler and four wheeled) and most of these were used in the large farms and for public works. A review of agricultural research on cultivation techniques (1947-59), shows that the Agricultural Research Station did not use any mechanical implements in its experiments, and relied on mules/horses/donkeys/oxen and handtool technology (ARS-1978). After independence in 1965, the Government encouraged investment in agriculture

(both livestock and arable). The arable agriculture was mostly for internal food self sufficiency and a number of large scale commercial farms were started in the areas where it was feasible to grow crops. In particular in this regard, a number of freehold large farms were started through private investment, and some of these specialized in cattle while others raised both cattle and food crops. Most of the agricultural machinery in the country then was owned by these freehold farmers (Table 5). Thus the number of tractors in the country gradually increased to about 790 and 1850 by 1970 and 1975 respectively. Most of these were on the 360 large scale commercial farms. The peasant subsistence farmers, small scale farmers (SSF) and medium scale farmers (MSF) relied on draft oxen for their field operations. (ARS (1978); IBRD (1986), GoB (1985, 86).

The opening up of the mining industry from the mid 1970s and the resulting substantial increment in Government and the country's revenue, through royalties, taxes, and foreign exchange earnings, enabled the country to provide more assistance to the arable crop production sector and as a consequence led to higher levels of mechanization (NDPIV, NDPV, NDPVI - (GoB; 1974, 1979, 1985). Initially Government efforts were directed at assisting those farmers who could start arable crop production by provision of inputs - draught implements, seeds and fertilizers and low interest loans through the National Development Bank. For the traditional farmers, Government efforts were directed at provision of assistance through various drought relief programmes. It was realized by the Government that given Botswana's climate and soils the potential for dryland farming was limited (IBRD 1986, ARS 1978) given the technology available then. The Government, through its own funds and donor assistance invested a lot of money in research and development with the objective of developing a technology which could increase arable crop production given the limitations of climate and soils (Gibbon *et.al.* (1974); EFSAIP (1984); DLFRS (1985, a,b)). It was then felt, in Government and research circles, that a tillage technology could be developed which reduced draught power requirements (Batswana farmers use 3-4 pairs of draught oxen for ploughing); ensure timeliness of ploughing and planting (the short rainy season is a major problem in crop production) and conserve soil and water for crop growth and production. Researchers were therefore imported to develop this tillage technology.

The first attempts at developing this tillage technology were simultaneously initiated in 1971 by an NGO in Mochudi district - Mochudi Farmers Brigade and Department of Agricultural Research in Sebele. The former developed a tool carrier which they called "*Makgonatsotlhe*" - and popularly known in the profession as Mochudi tool carrier which was launched in 1973. It was made from imported components and fabricated steel and by 1975 production started in a workshop in Mochudi. The Agricultural Research Station through an ODA-UK funded project - called the Dryland Farming Research System Project (DLFRS) designed and developed their own tool carrier - at Sebele which they called *Versatool*. Essentially it had more or less the same features as the Mochudi tool carrier only that it was more

sophisticated (Gibbon *et.al.* 1974; DLFRS (1985) EFSAIP (1977; 1978; 1979; 1980). This was tested mostly on station and there was no attempt at starting manufacturing. A lot of things were claimed of these two tool carriers, and some prototypes were shipped as far north as Tanzania and Kenya for testing. About 150 Mochudi tool carriers were manufactured between 1973-1980 and several were bought by Government departments and loaned to farmers for testing. There was however little coordination of the research and development efforts between the Mochudi and Versatool developers despite being 30kms from each other.

It is perhaps because of the enthusiasm shown by the two groups, and what appeared to be promising developments, that the Government signed a memorandum with ODA, starting up another project, known as Evaluation of Farming Systems and Agricultural Implements Project (EFSAIP). The principle objective of this project was to, among other things, evaluate the whole animal draught minimum tillage system, following on the earlier results obtained from tests on the Versatool. This project started in 1976, and a number of scientists and research students from UK were seconded to the Agricultural Research Station. It would seem that the EFSAIP team had better agricultural engineers, (at least one Ph.D was completed in the field of Agricultural Engineering) and it became quite apparent to the team that the tine cultivation system used on the Versatool and Mochudi tool carrier had a number of teething problems, especially when used on farmer's fields. They therefore concentrated on the Mochudi tool carrier, fitted with a standard mouldboard plough for primary tillage and they also developed a planter and plow-planter to go with it. However when an economic analysis was undertaken it became apparent that this was going to be too costly and the trials were abandoned in 1984 and the project terminated (Horspool 1988). The Agricultural Research Station however decided to establish a Farm Machinery Development Unit (FMDU) to continue with limited research on the other implements. This was however very understaffed (only 1 agricultural engineer) and the unit has, by and large, done limited development work since then.

Following the termination of the ODA funded EFSAIP Project in 1984, the Ministry of Agriculture appears to have adopted a two pronged approach in so far as mechanization was concerned. It was decided then to continue with the research work and a new project, this time funded by USAID was started - ATIP - Agricultural Technology Improvement Project. This project which was implemented under contract by a consortium of USA Land Grant Universities (MIAC - Midwest International Agriculture Consortium) was supposed to come up with, among other things, new and better tillage technologies. The basic approach was the Farming Systems approach. ATIP has generated a lot of socio-economic data so far, through its numerous Working Papers (ATIP-WP-1-20). There has not however, been any major breakthrough in so far as either tillage methods are concerned or new implements for tillage. It would seem ATIP has concentrated on evaluating current tillage practices and trying to identify the farmers constraints in this

regard (Baker, 1988). The project is currently in the process of being wound up and is expected to end by 1991. Two things may have affected ATIP's ability in developing new technologies for tillage. First the country was hit by a severe drought lasting for seven years from 1981/1987, and the severity of the drought was such that any new tillage technology which ATIP would have developed during this period would have had marginal effect on productivity and production. Secondly, Government assistance programmes, which provided farmers with assistance in tillage, during a larger part of ATIP's existence would have, in our opinion, made it uneconomical for ATIP to try to develop any new implements.

The second prong of the Ministry's approach was to initiate programmes which assist farmers (in particular the poorer ones) to get, among other things, mechanization inputs at highly subsidized rates or even free. Among the programmes introduced then is ALDEP - Arable Lands Development Programme, which was introduced in 1982 through a loan from the African Development Bank and IFAD and FAO providing technical assistance and through which the Government is removing some of the constraints facing the poorer traditional farmers. These farmers are defined as those with less than 10ha. of land and owning less than 40 herd of cattle and the potential maximum assistance one could get through ALDEP initially was P2,000.00 (then equivalent to US\$2,000.00). This figure has been progressively reviewed upwards in Pula terms although in US dollar terms it has remained at around US\$2,000.00. The package provided up to now includes - agricultural implements up to 15% of maximum grant, fencing materials 25%, animal draught power (oxen & donkeys) 45%, water tanks 15%. From this it is apparent that animal draught power and implements account for about 60% of the maximum assistance. To be able to qualify however the farmer has to put up about 15% of the amount he is requesting. The programme is administered by the extension services of the Ministry of Agriculture. Over US\$30 million has been given in the last 6 years (Mokoene & Sebolai (1989)). This programme which is still being implemented was directed mostly at the small farmers and has focused principally at provision of draught animal power and implements. These farmers would not have been able to undertake such on farm investments without this programme. It was however launched in the middle of a prolonged drought cycle, and it is difficult to isolate its impact on productivity and overall production in view of other programmes which started at the same time.

A second programme - which has had a profound impact on mechanization was the Accelerated Rainfed Arable Programme (ARAP) which was started in 1985/86 as a five years project, with an estimated total operational budget of P29 million (then about US\$22 million). The programme was launched to assist all farmers (irrespective of size of land holding) and included the following components: ploughing P70.00 (US\$36.00) per hectare up to a maximum 10 hectares; P20.00 per ha for planting up to a maximum of 10ha.; free seeds to plant 10 hectares (equivalent to 8kg/ha); land clearing

through destumping grants, fencing grants, water development in the lands area (upto a maximum of P20,000 (US\$10,500.00)). The programme was administered by the extension services of the Ministry of Agriculture. Over US\$30 million has been spent in this programme over the past five years and the programme is being phased out w.e.f. 1990/91 financial year. This programme has had a significant impact on the level of tractor mechanization as quite a number of farmers, merchants, and civil servants, borrowed money from the National Development Bank (at low interest rates) to purchase tractors which they hired out to plough land for the small farmers as they were assured of payment. (The commercial cost of ploughing one hectare is about P70.00). Whether these small scale farmers will be able to continue to afford hiring such tractors, without the Government grant remains to be seen. There are also a number of other programmes which assist farmers - in particular women farmers (AE10 - for horticultural projects, etc.); Financial Assistance Policy - for commercial farming enterprises, etc.

A recent study by two consultants, on the relative economics of different draught power sources in Botswana has advised against Government subsidy on tractors (MoA-GoB 1989). In its recent review of agricultural policy, the Ministry of Agriculture has recommended that Government assistance should continue to be provided to procure draught animal power for both efficiency and equity considerations (MoA-GoB-1989,1990) and farmers who wish to get tractors should apply for loans from the commercial banks at full market prices. Also in the last 3 years, a small engineering firm in Gaborone, has started to assemble Yugoslavian manufactured tractors under licence from the main Yugoslavian company IMT. Although the tractors carry local names like Tshukudu, they are essentially a copy of the Yugoslavian tractors as they are assembled from SKD parts with no modification to suit local conditions. About 250 of these tractors have been assembled locally over the past 3 years and it is claimed a few have been exported to other SADCC countries. Also in 1990, a high powered study team, has been sent to some Asian countries (Japan, South Korea, etc.), to study the mechanization programmes of these countries. However recommendations emanating from this mission have yet to be considered by the Government. The major makes of tractors in the market are Ford, Massey Ferguson, Deutz, and the locally assembled Tshukudu, (which is essentially a variant of MF 300 series). Spare parts are not difficult to get as Botswana is linked with South Africa through the customs union, and all the major manufacturers have assembly factories in South Africa manufacturing from CKD components with 30-40% local content.

A key feature of Botswana's agricultural mechanization policies and programmes, has been Government assistance for performing certain tasks (e.g. ploughing). The Government however has avoided getting involved directly in provision of these mechanization services, and has allowed the farmer to get them from whatever source and subsidized him for the work accomplished. The opening up of new lands in Pandamatenga and Barolong areas for large scale commercial crop production, and the Government assistance programme

led to a significant increment in the number of tractors in the country from under 1000 in 1970 to over 2000 by 1985 (Table 5). Further although the Government and donors have invested a lot of money in research and development efforts over the past 3 decades for appropriate mechanization implements, (over US\$50 million) these efforts would seem have not yet yielded any readily adoptable technology which meets the key criteria for tillage in such a dry country - water retention technology. On the post harvest front however, local efforts appear to have yielded a successful technology in the form of a sorghum dehuller. This dehuller, developed by a local appropriate technology group - Rural Industries Innovation Centre, (RIIC) initially with IDRC assistance, appears to be quite successful and is now widely used and a few of them have been exported to other SADCC countries (Schmidt & Bassie 1988, RIIC 1988-89). RIIC is also involved in development of other technologies in particular water lifting devices and rural transport. These are however still at developmental stage, although a few of them have reached large scale testing by farmers. Another key problem of agricultural mechanization in Botswana is the lack of manpower required at all levels - artisan, technician, managerial and professional. An important factor in Botswana, which contributes significantly to making mechanized agriculture profitable has been the price subsidy provided by the Government on important cereal crops e.g. sorghum and maize. Prices paid to farmers for their produce sold to the Botswana Agricultural Marketing Board, has been about 2-3 times the world market prices. This has made it profitable for medium and large scale farmers to embark on mechanized cereal production. The objective of the Government then in providing such a high subsidy was to attain food self sufficiency. However, the Government is currently (1990) reviewing its policy in this regard, and indications are that there will be a shift from food self sufficiency to food security. It is likely therefore, due to this shift in policy, that the subsidies will be phased out and farmers will be encouraged to grow crops which are more profitable and which do not require subsidization from the Government. What impact this will have on agricultural mechanization is difficult to predict - precisely. It is likely however that the profitability of cereal production by large scale mechanized farmers will be greatly reduced.

INSTITUTIONAL FRAMEWORK

In Botswana few institutions/Government departments have been involved with mechanization policy compared to other African countries. Policy formulation has been initiated by the Department of Planning and Statistics in the Ministry of Agriculture (e.g. programmes such as ARAP, ALDEP have been initiated in this department). For programmes which involved crop production this department normally works closely with the Department of Field Services which controls most of the extension services and is responsible for arable crop production. The draft policy paper so prepared then is considered by the policy formulation committee of the Ministry of Agriculture, which comprises of all Heads of Departments in the Ministry and is chaired by the Permanent

Secretary of the Ministry. Once a policy paper has been approved at this stage it is then sent to the Rural Development Council - which is a high level council - chaired by the Minister of Finance and Development Planning and its membership comprises of all Permanent Secretaries. If the policy document is approved at this stage, it is then sent by the ministry concerned for consideration and approval at the highest Government levels and after this the usual process of preparing budgetary estimates and getting them approved by the legislature follows.

Implementation of most programmes/projects involving mechanization has been done by two departments in Botswana - Agricultural Research Station and the department of Field Services. The department of Field Services has been involved with the implementation of such programmes as ARAP and ALDEP through its extensive network of front line extension workers - supervised at district level by District Agricultural Officers and at regional level by Regional Agricultural Officers. The front line extension workers, who work in the villages, are the ones who assist the farmers in filling the various forms required for obtaining Government assistance and pass them to the supervisors who forward them to the District Agricultural Officers for approval and payment in the case of ARAP payments and ALDEP assistance. Even in other schemes such as the Agricultural Credit Guarantee Scheme, whereby farmers can secure loans from the National Development Bank for purchasing inputs - including farm implements and machinery, the District Agricultural Officers and Regional Agricultural Officers have to be involved before the Bank can provide the assistance. Compared to other countries, the procedures for getting Government assistance under the various programmes has been quite straight forward and quite efficient. It would seem abuse of the scheme has also been minimal. The low population may well have contributed to this higher level of efficiency (Mokone & Sebolai (1989)).

On the research side the agric. mechanization work has been undertaken mostly through donor funded projects (DRFSP, EFSAIP and ATIP). All of these projects operated as semi autonomous projects/sections within the Agricultural Research Department, with their own funding, staff and equipment. Nearly all the senior staff in these projects were/are expatriates. It is perhaps because of this type of arrangement that these projects have had little impact on the agricultural situation in Botswana as the projects were, by and large, terminated when the expatriate staff left and donor funding stopped. Further, with the exception of ATIP, these projects did little in training of national staff in the critical areas. Thus despite 15 years of project funding for tillage only 2 agric. engineers have been trained and one of them is no longer working for the Agricultural Research Station. Other institutions which have been involved in one way or another in agricultural mechanization are the NGO - Mochudi Farmers Brigade, which developed the Mochudi Tool Carrier and RIIC - Rural Industries Innovation Centre. The latter has been involved in the development of the sorghum dehuller which, as we mentioned earlier has been more widely adopted than any other mechanization technology

developed in Botswana. The Botswana Agricultural College has been indirectly involved in agric. mechanization efforts as it trains all the front line extension workers who have been involved in implementing Government assistance programmes such as ALDEP and ARAP while the Ministry of Industries has been involved in assisting in establishment of manufacturing utilities such as the Montenegeiro Engineering which is assembling tractors. Other than coordination through the Rural Development Council and its committees which coordinates activities more at policy level, there is little, it would seem, coordination at professional level.

DISCUSSION AND CONCLUSION

We have in the preceding paragraphs reviewed mechanization policies and strategies in Botswana over the past few decades. For Botswana three distinct periods can be discerned. These are the period before 1970 - when *laissez faire* - existed - oxen powered cultivation had been adopted by the Batswana farmers and the standard ox-drawn mouldboard plough was being used and there was little effort to change this type of mechanization technology. This was followed by the period between 1970-84 which may be called the period of experimentation - when there was a lot of activity on the research and development front aimed at developing better animal drawn implements which in addition to reducing the draught power requirements, would also be able to retain as much moisture as possible in the soil. Both the Botswana Government, Non Governmental Organizations and donor agencies were very active in these efforts. However despite a lot of money and manpower being devoted to these efforts, we can conclude that no such technology was developed. The period of experimentation was followed by the period of subsidization from 1984 to todote. During this period the Government has instituted a number of assistance programmes most of them with a mechanization subsidy component. The government has however, unlike in other countries avoided setting up projects/institutions to offer these services and has been content to pay for the services provided in ploughing by whatever means - tractors, animals, or human power! Given her favourable economic conditions, Botswana has been able to subsidize her agricultural production in various ways. There is however an increasing concern that the subsidization has been to much and there have been calls to reduce it. A significant proportion of the subsidy has been provided for mechanization inputs. As a large proportion of the population live in rural areas it will be difficult to phase out all the subsidies provided to crop production. Further as a % of Government expenditure, the subsidy provided to farmers is still a small amount. In addition the Government is keen to reduce rural-urban migration as its capacity to provide productive jobs in the urban areas is also limited. Consequently therefore an agricultural mechanization policy and strategy will have to be formulated which reduces the drudgery of agricultural field operations, while at the same time increases agricultural production and productivity. Given the climatic constraints, this will be difficult to achieve without some form of assistance to farmers. Perhaps what is important is to

ensure that whatever subsidy is given to farmers enables them to establish a sustainable and profitable farming enterprise which will not require continued government assistance after a few years. This will require careful selection of crops to be grown as well as judicious use of all inputs required including agricultural mechanization inputs.

CHAPTER 5

AGRICULTURAL MECHANIZATION IN GHANA **- AN OVERVIEW**

by

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INTRODUCTION

The Ghanaian economy, like that of most other African countries, is primarily agricultural. Agriculture continues to account for roughly 50% of Ghana's Gross Domestic Product (GDP), and provides close to 70% of all merchandize exports. Over 66% of the population earn their livelihood from agriculture. A recent World Bank study on Sub-Saharan Africa concluded that "If Africa is to avert hunger and provide its growing population with productive jobs and rising incomes, its economies need to grow by at least 4 to 5 per cent a year The primary source of this growth can only be agricultural production " (IBRD (1989)) This primacy of agriculture in the economy is true for Ghana as it is for most of Sub-Saharan Africa. It is thus believed that the key to sustained economic development for Ghana lies in raising the productivity of the agricultural population.

Agricultural production may be increased by either cultivating more land, or by increasing the productivity of land under cultivation, or both. Whichever strategy is chosen, mechanization plays a vital role as a necessary component for supplying the needed impetus and input towards agricultural development and modernization. Ghana recognized this crucial role of mechanization early in her nationhood when she embarked upon large and rather costly mechanization schemes, and imported quite an array of agricultural machines in the 1962-1964 period. However, success has eluded the country in her mechanization attempts, and the problem now is "which way agricultural mechanization?".

HISTORICAL PERSPECTIVE

First attempts at mechanizing Ghana's agriculture were made in 1938 when the use of animal draught power was introduced in the Northern Territories of the then Gold Coast for the cultivation of groundnuts and cereals. However, interest in the scheme fizzled out soon thereafter, and the country had to wait till ten years later when in 1948/49 tractors were introduced in Damongo, also located in the Northern Territories, in a package under a Gonja Development Company. In 1950, the Ministry of Agriculture introduced tractors at some of its agricultural stations at Pokuase near Accra and Kwadaso near Kumasi in the Ashanti Region (Wadhwa, (1964); Gyarteng (1983)). Other agricultural

machinery were later introduced between 1952/54, and these included rice threshers, coffer hullers, and crop driers. A census of agricultural tractors taken in 1952 showed that there were 64 wheeled tractors and 6 crawler tractors in the country (Wadhwa (1964)). The 1952/54 attempt also fizzled out, until after Ghana's political independence when in 1962/63 the then Government in a bid to produce food and fibre for the increasing population and the nation's infant industries, embarked upon a bold scheme and imported into the country a large number of agricultural tractors and related implements.

The Government's policy on agricultural mechanization then as set out in Ghana's first seven-year development plan (1963-1969) (GoG (1962)) was to bring about a revolutionary change which would increase the cash incomes of farmers, and would meet the high demand for food and fibre in the economy, by getting away from the traditional cutlass and hoe shifting cultivation method of farming towards intensification and diversification of farm resources. The number of farming families was to be quickly reduced to one-quarter of its population within the plan period through the creation of large agricultural production units based on mechanization. Table 6 gives an inventory of farm machinery in the country during this period, and does indicate the level of mechanization introduced.

TABLE 6: ANNUAL TRACTOR POPULATION IN GHANA 1952-1969

Year	Wheeled Tractor	Crawler Tractors	Total
1952-1956	93	8	101
1961	115	9	124
1962	315	9	324
1963	1115	141	1256
1964	1865	351	2216
1965	2265	586	2851
1966	2965	736	3701
1967	3221	820	4041
1968-1969	3602	800	4402

SOURCE: MoA-GoG (1989)

Due to poor management resulting from inexperience and the rather high level of operations, coupled with lack of trained personnel, this attempt did not yield the anticipated results compared with the massive capital outlay. The programme resulted in an economic disaster with most of the imported machines soon ending up in agricultural machinery graveyards scattered all over the country as a result of breakdowns beyond repair (see Table 7). It is however noted that irrespective of its economic disaster, this 1962/63 attempt at mechanization succeeded in introducing a fairly high proportion of Ghanaian farmers to the potentials of mechanization in farming to the extent

that by the early 1970s some farmers, notably those in the savanna areas relied on tractors for the cultivation of rice, maize, sugar cane, tobacco and kenaf. To meet their machinery requirements, the Ministry of Agriculture's Mechanization and Transport Department used the remnants of equipment imported during the 1962/63 period to operate a Tractor Hire Service Scheme.

TABLE 7: INVENTORY OF AGRICULTURAL MACHINERY HELD BY MINISTRY OF AGRICULTURE - GHANA AS AT JANUARY 1971: NATIONAL SUMMARY

TYPE OF EQUIPMENT	SERVICEABLE	UNSERVICE- ABLE	SCRAP	TOTAL
Crawler Tractors	200	494	114	808
Wheel Tractors	385	988	866	2239
Ploughs	421	494	882	1787
Harrows	2552	297	236	3085
Ridgers	250	108	87	445
Cultivators	494	95	23	612
Planters	119	95	23	237
Seed Drills	108	141	40	289
Rice Combines	28	52	18	98
Corn Pickers	8	3	-	11
Rice Threshers	39	14	-	53
Rice Hullers	6	4	-	10
Maize Sheller	42	34	20	97
Grain Driers	17	10	1	28
Trailers	232	94	138	464
Miscellaneous	500	234	83	817

SOURCE: MoA - GoG (1971)

CURRENT TRENDS IN MECHANIZATION

Since the mid-1970's there has been a general desire by the Government to pull out of the tractor hiring service, with the hope of passing this job on to private entrepreneurs. It is clear that the Government Tractor Hire Service Scheme helped in developing farmers' interest in mechanization, as well as building up a nucleus of operators and maintenance staff. The advisory and administrative staff learnt what mechanization can do, what it costs and generally gained some experience necessary for the future. The Agricultural Mechanization and Transport Department of the Ministry of Agriculture has now been re-organized and renamed Agricultural Engineering Services Department, and has moved away from tractor hiring service. It now plays the role of an advisory and training entity. Through a recent proposal, it intends setting up a soil and water conservation unit within the department, which will be responsible for providing direct mechanical services to soil and water conservation ventures, and the construction of fish ponds and watering points for livestock and dry season gardening in the drier areas of the country.

TABLE 8: ANNUAL IMPORTATION OF WHEELED AGRICULTURAL TRACTORS AND COMBINE HARVESTERS 1973-1985

YEAR	WHEELED TRACTORS IMPROTED	COMBINE HARVESTER IMPORTED
1973	333	102
1974	760	66
1975	77	7
1976	137	-
1977	735	-
1978	873	-
1979	531	-
1980	371	-
1981	965	36
1982	716	30
1983	637	16
1984	353	N/A
1985	28	N/A

SOURCE: For 1973-1982 Figures by Gyarteng (1983). For 1984-1985 Figures: Provisional Figures supplied by Statistical Service, Accra.

To fill the vacuum created by the departure of the Agricultural Mechanization and Transport Department from tractor hiring, a number of fiscal policies and institutional arrangements have been formulated. These have come in the form of agricultural production packages which supply small-scale farmers with extension services, seeds and fertilizers, with mechanization as a component of the packages. Among such projects is Block Farms Limited, a subsidiary of Ghana's Agricultural Development Bank, the Upper Regional Agricultural Development Project (URADEP) in the Upper Region, the Volta Regional Agricultural Development Project (VORADEP) at Ho in the Volta Region, and more recently the Ghana/FAO/Italy Afram Plains Mechanization Programme located at Donkorkrom in the Eastern Region, and the Global 2000 Project which is nationwide. All these projects are run with foreign loans or grants and have agricultural mechanization components. Additional to these regional projects, joint-venture projects involved in large-scale production of cereals have been established in certain localities. These engage in large-scale fully-mechanized farming. Some have been very successful, others have not survived. Among these ventures may be mentioned the Ejura Farm Ltd., at Ejura, and the Kumawu Industrial Farm Complex (KIFCOM) Kumawu, all in the Ashanti region.

Other users of agricultural machinery are the farmers located at the various state-owned irrigation project sites. These farmers produce rice and vegetables on a hectare piece of irrigated land. The package here includes the provision of tractors and other farm machinery, mostly for primary tillage. Table 8 shows imports of tractors into the country for the 1973 - 1985 period. It is noted that whilst figures of tractor imports fluctuate, there has been

generally persistent increase in the importation of tractors into the country over the years, especially during the late 1970's and early 1980's. The average annual number of tractors imported is around 700 units, with the exception of 1975-76 when economical and political problems affected the level of importation.

LEVEL OF AGRICULTURAL MECHANIZATION

The greatest demand for mechanization among the small-scale Ghanaian farmers is for land preparation, especially ploughing. This is attributed to the seasonal shortages of labour, and the need for timeliness of operation. Labour is also expensive. Availability of tractors for hire is limited, and this limits the area which can be prepared at the appropriate time. The common choice of equipment is a standard 30-50kw four-wheeled farm tractor, complete with 3-furrow disc plough, a disc harrow (off-set or tandem) and a 3-5 tonne trailer. Some farmers just double plough and plant without harrowing. This is common among farmers who grow maize. The use of single-axle pedestrian tractor (or the power tiller), complete with a rotovator is popular among the rice growing farmers on the irrigation sites in the Southern part of the country. Mechanical seed planting is practised mainly by the large-scale farmers, and hardly by the small-scale farmers. Very few farmers do row-cropping, and consequently cultivators are rarely used for weed control. The use of sprayers, especially the knapsack sprayers, has been popular, especially among the country's cocoa farmers. These cocoa farmers use the knapsack mist blowers for the control of capsid disease and mealybug attack. This has been specially promoted and subsidised by the Ghana Cocoa Marketing Board over the past three decades, mainly because of desire to maintain increased production of cocoa, the country's number one foreign currency earner. The use of crop sprayers among farmers who grow food crops is limited to a few vegetable growers, but again the popular models are the knapsack sprayers rather than the tractor-operated boom sprayer. Fertilizer application is generally done by manual broadcasting and drilling is hardly practised.

The use of combine harvesters is also limited to the large-scale farms producing maize and rice as monocrops, and combines are rarely used by the small-scale farmers who mostly practise mixed cropping. The low use of combines by the small-scale farmers is also explained by the limitations imposed by small size of their farms, and by the fact that most of the common staples like plantains, yams and cassava which are usually cultivated do not easily lend themselves to mechanical harvesting. Tractors play a vital role in rural transportation. Most of the access roads to the food producing areas are in poor condition during the rainy seasons and tractors are the only means of transport to ferry the farm produce to the marketing centres. This is one area where tractors are intensively used during off season and is rarely considered in many economic studies but is crucial to the profitability of the entire agricultural system as well as a means of earning extra revenue by tractor owners.

Use of draught animals

Many farmers in the Upper and Northern regions of the country have traditionally been using bullocks for farming. In recent years the limited availability of tractors for hire, coupled with rising costs, has led to an increase in the number of bullocks used in mechanized farming. Unfortunately, there are no data on the number of oxen currently being used for draught purposes and evidence of the spread of the use of draught animals in agriculture has only come from subjective observations by extension officers and the demand for ox-ploughing training centres (NORRIP (1982)). The main reason for using bullock traction technology has been the need to overcome seasonal labour shortages for land preparation rather than a desire to increase land under cultivation. This is substantiated by data which shows that the average area cultivated per one adult is not greater in households using bullocks than in households using the traditional hoe and cutlass. The explanation for this situation appears to come from the fact that the weeding and crop harvesting aspects in the crop production process have still not been mechanized and these operations become serious bottlenecks when cropped lands are expanded using bullock ploughing. It is unlikely that the numbers of farmers in Ghana using draught power is that significant. Panin (1990), for example casually estimates that about 20% of the farmers in North Eastern Ghana use draught oxen for ridging. It is significant also that Ghana is not a member of the West African Animal Traction Network (Starkey and Ndiame (1988); Starkey and Faye (1990)).

Crop processing

One area of success in the food production chain in so far as mechanization is concerned is that of primary processing of staple foods and oils. The use of locally fabricated grain threshers for rice, cassava graters, palm fruit digesters, palm kernel crackers, poultry feed mixers and a few other mechanical equipment is now fairly common and this is assisting in mechanizing food preparations, and helping rural women in their daily chores. Most of these equipment have been locally designed and fabricated. The exact production figures are difficult to determine, what is clear is that it is rare to see farmers and women in households using the traditional handtool methods in performing these tasks. This is perhaps one example of successful mechanization which has not been documented and useful lessons may be learned if research is undertaken to determine why these devices have spread so fast in Ghana.

CONSTRAINTS TO AGRICULTURAL MECHANIZATION

The whole process of agricultural mechanization is influenced by both the economic and social systems in Ghana, and is affected by both push and pull factors within and outside the agricultural sector. The core push factor is the supply of good quality machines at reasonable prices, and Government's

assistance through financial and institutional arrangements which help to accelerate the adoption of machines by farmers. The pull factor or demand for agricultural machinery may be considered as a function of time saving; yield increase; ratio of machinery cost to farm produce price; the ratio of machinery costs to costs of substitutable inputs; reduction in drudgery of farm work with machinery; and expected psychological income from owning machinery. The relative importance of each of these variables differs with time and among farmers, but generally national policies should be seen to positively favour these factors. In Ghana the promotion of agricultural mechanization goes beyond the Ministry of Agriculture, and involves the Ministries of Finance and Economic Planning, the Ministry of Industries, the Ministry of Fuel and Power and the Labour Ministry. These sectoral ministries should necessarily work together to ensure the creation of the right atmosphere for mechanization.

The major constraints to agricultural mechanization which can be cited include, inter alia

(i) ***Problems of Provision of Basic Equipment and Services***

The Government has since the 1970's gradually been decreasing its involvement in the tractor hiring service with the hope that the private sector will take up the provision of such services. Unfortunately the private sector has not been able to provide the needed machinery in adequate numbers. To activate and ensure progress in this direction, the private sector would have to be expanded to identify entrepreneurs or farmers' groups who will operate successful commercial machinery hire service. Such entrepreneurs will require technical assistance in managing their tractor fleets.

(ii) ***High Cost of Agricultural Machinery***

The cost of machinery is unreasonably high to the extent that very few farmers can afford to own any farm machinery. In addition current bank lending rates at between 25-33% are high and scare away prospective entrepreneurs and farmers from seeking financial help from the banks.

(iii) ***Lack of Mechanization Extension Services***

The majority of the extension officers in the country concentrate more on the agronomy aspects of crop production and hardly on issues relating to mechanization. Their knowledge of agricultural mechanization technologies is also limited. This leaves the farmer totally ignorant as to what should be done when it comes to mechanization issues.

(iv) *Problems of Mechanization of the Basic Staples*

Whilst the production of most of the cereal crops such as rice, maize and sorghum, and some legumes can be easily mechanized, there is still the problem of mechanizing most of the local staples including cassava, yams and plantains. Solution here calls for sustained research on mechanizing production of these crops. Meanwhile, an attempt should be made at mechanizing certain tasks connected with the production of these staples through selective mechanization or task mechanization.

(v) *Lack of Long-term Mechanization Programmes and Strategies*

Following the low economic returns which characterised Ghana's first mechanization attempts in the 1960's, succeeding Governments have become reluctant to get directly involved with agricultural mechanization, or even to pursue policies which would accelerate the adoption of more agricultural field machines by farmers. It seems the country has opted for the 'no strategy' approach for mechanization, with the hope that mechanization will automatically come when conditions are ripe for it. The few major production ventures which were using agricultural machinery for the production of such crops as sugar cane for the country's sugar factories and the large-scale rice farmers at Tamale which characterized the Operation Feed Yourself Campaign are all operating on limited capacity now. Consequently, except for the special projects mentioned earlier, the use of farm machinery by individual farmers is rather limited.

TRAINING AND EDUCATION

Provision of adequate educational and training facilities, including qualified instructors, is an important pre-requisite for mechanized agriculture. Education, training, research and extension activities become essential when mechanization is introduced into a predominantly traditional peasant agriculture. The shortage of skilled personell in Ghana coinciding with the sudden introduction of tractorization in the early 1960's was serious. Unlike the situation in most European and other countries in the world, agricultural mechanization in Ghana was introduced in a revolutionary way rather than by evolution. There was therefore the need to train "everybody", and, consequently to provide for education at all levels on the operation, maintenance and repair of tractors and field equipment, otherwise the heavy investment in equipment would have gone to waste. Education was to include orientation of the farmer to the use of improved farming practices in conjunction with tractor use, and this was to cover fertilizer application,

irrigation farming and changing of certain cultural practices. Machinery operators, mechanics, technical staff and administrative personnel also had to be trained to properly handle and manage the imported equipment and it was hoped this would lead to profitable farm mechanization.

The initial strategy adopted in Ghana was therefore aimed at building a corps of trained personnel capable of running and maintaining imported equipment through accelerated training programmes which were practical in scope and sacrificing much theory, but providing experience through field practice in the proper use and operation, maintenance and repair, including the use of manuals. This was to be followed by plans for more intensive formal training to provide theory and knowledge in agricultural mechanization, resulting in the production of supervisory grade personnel and professional agricultural engineers, well-versed in the theory and knowledge of mechanization. Like in other developing countries, Government educational and farming programmes to accomplish the above goals have been the most prevalent.

The various Government agencies charged with the operation and maintenance of the imported equipment, (e.g. the United Ghana Farmers Cooperatives Council, the Volta River Resettlement Unit, the Division of Irrigation, Reclamation and Drainage, etc.) all initiated training programmes which recruited and converted truck drivers to tractor operators, and vehicle mechanics to farm machinery mechanics. By 1966 the engineering wing of the Ministry of Agriculture, the Agricultural Mechanization and Transport Department which had taken over the activities of the United Ghana Farmers Cooperative Council (UGFCC) had 1,500 tractor operators and 600 tractor mechanics on its pay roll.

Farm mechanization schools were later established at vantage points in the country at Navrongo in the Upper East Region, Nyankpala in the Northern Region, Ejura in the Ashanti Region and at Ohawu in the Volta Region, with technical assistance from the USAID. The USAID supplied inputs, together with experts, whilst the Government of Ghana contributed buildings and other physical infrastructure and counterpart staff. In 1970 USAID withdrew from this training project, and due to lack of support, these well-equipped and organized establishments deteriorated quite fast. Equipment were abandoned because of lack of spare parts and the local staff were absorbed by other organizations. (Ewusi *et al.* 1974) Now farm mechanization has become part of the syllabus of all Agricultural Colleges in the country.

However, to maintain the momentum in training, started in the early 1960's, the Government of Ghana, in 1968, received technical assistance from the FAO and agricultural engineers were posted to the Ministry of Agriculture, with duties which included on the spot advice and training of personnel, programming of work selection and correct utilization of farm machinery and general advice on farm mechanization. These engineers helped to re-train

mechanics, operators and farmers through in-service training programmes between 1968-1975. Technical personnel and managers, including professional agricultural engineers and supervisors, were in the meantime, trained in overseas institutions as there were no training facilities then in Ghana. Institutions for training this upper grade personnel for mechanization have been established in the country and since the early 1970, most of the needed personnel are currently locally trained. Table 9 shows a list of training programmes in agricultural mechanization offered in Ghana.

TABLE 9: INSTITUTIONS IN GHANA OFFERING FORMAL TRAINING PROGRAMMES IN AGRICULTURAL MECHANIZATION

NAME OF INSTITUTION	TYPE OF TRAINING	PRODUCTS
Asuansi Technical Institute	Agric. Mechanization Mechanic Course	Mechanization Mechanic
Tamale Polytechnic	Agric. Mechanization Technician Course	Mechanization Technician
Ho Polytechnic	Agric. Mechanization Technician Course	Mechanization Technician
Chawu Agric. College	Post-Secondary Agric. Mechanization Technical Officers Course	Technical Officer (Extensionist)
University of Ghana, Faculty of Agric., Agric. Engineering Section	National Dip. in Agric. Mechanization	Senior Technical Officer
*University of Science and Technology, Kumasi, Mechanical Engineering Department	Higher National Dip. in Mech. Engineering with Specialization in Agric. Mechanization	Engineering Technician
University of Science and Technology, Kumasi. Agric. Engineering Dept.	4-year BSc programme in Agricultural Engineering	Professional Agricultural Engineer

Beside the above, the three University Faculties of Agriculture at Legon, Cape Coast and Kumasi offer specializations in agricultural mechanization in their undergraduate agriculture programmes. These agricultural mechanization majors, though not educated as engineers, are however in a position to render competent and substantial services in agricultural engineering, because of the course-work that they complete in order to obtain the BSc. degree in Agriculture. Post-graduate programmes in Agricultural Engineering, preferably after two to four years employment, does convert them to the professional agricultural engineers status.

The training of farmers is now done at the Farm Institutes run by the Ministry of Agriculture at Wenchi, Asuansi, Damongo, Navrongo and Ejura. Formal training and re-training of tractor operators and mechanics takes place at Ejura Agricultural College and as components of some foreign-assisted agricultural projects initiated by the Ministry of Agriculture. Examples of such projects are those at Atebubu Agricultural Station, Somanya Agricultural Machinery Centre, and the Ghana/FAO/Italy Agricultural Mechanization Project based at Donkorkrom and Tamale. The various agricultural machinery dealers also train operators and mechanics and render after-sales services to machinery owners. It is believed that the annual output from these various training institutions is enough to satisfy current demands of personell for agricultural mechanization in the country.

AGRICULTURAL MECHANIZATION RESEARCH AND EXTENSION ACTIVITIES

Research and Development activities are important requirements in the build-up of local technological capabilities not only in the production of machinery needed to promote and sustain agricultural mechanization, but more so to understand local environment in the natural, technical, economic and social context. A continuous R and D effort and efficient use of human resources and technical inputs are essential pre-requisite for sustainable development of mechanization. There is ample demonstration in the developed nations, and even in Ghana (see Table 10) to show that machine use increases production and decreases labour requirements. Nonetheless, the scope of machine use in Ghanaian agriculture still remains an unanalysed and controversial issue owing to the absence of specific knowledge of agricultural mechanization factors resulting from the low priority given to agricultural mechanization research at the national level. Most of the research efforts undertaken to increase agricultural production in Ghana have been concentrated on the inputs of high yielding crop varieties, fertilizer use and pest control, with very little attention given to farm power and implement innovations and their effects on production. Research, if any at all, in the field of mechanization is scattered and cannot form any basis for major policy decisions on mechanization. The possible role of mechanization in Ghana is yet to be evaluated in a comprehensive manner.

This does not however mean that agricultural mechanization practitioners in Ghana do not know what needs to be done. It is rather to be contrary. For as far back as 1964 (Ewusi *et.al.* 1974), there have been repeated calls for systematic research into such important mechanization areas as:

- (a) research to determine what factors favour adoption of mechanization technologies by the small farmer and what are the constraints which prevent him from moving faster toward higher levels of mechanized agriculture.

- (b) testing, selection and modification of machinery to suit different jobs and purposes, from both technological and economical points of view;

TABLE 10: EFFECTS AND PROFITABILITY OF MECHANIZATION AND IMPROVED TECHNOLOGY ON YIELDS OF SELECTED ANNUAL CROPS IN GHANA

COMMODITY & PRODUCTION SYSTEM	YIELD KG/HA
<u>Rice</u>	
Traditional	1000
Improved Technology (seed & fertilizer)	1400
Modern (fully mechanized with seed & fertilizer)	1800
Small-Scale Irrigation and Mechanized	4500
<u>Maize</u>	
Traditional	1000
Improved Draught	2500
Modern (Mechanized, Seed & Fertilizer)	3000
<u>Sorghum</u>	
Traditional	700
Improved Technology	1800
<u>Cotton</u>	
Semi-Traditional	550
Improved Draught	1200
<u>Cassava</u>	
Traditional	3000
Improved Draught	5000
Modern (Mechanized, Seed & Fertilizer)	10000

SOURCE: Adapted from Ghana Medium-Term Agricultural Development Programme Table 4.1 by World Bank, Agricultural Operations Division, Western Africa Department, Africa Region December 15, 1989;

- (c) research aimed at improving existing production methods and developing new techniques of mechanizing the various production processes, including modifications in farming practices to enhance the utility of machines and implements;
- (d) research into selecting and breeding of crops suitable for mechanization, e.g. with regards to uniformity of height of plants and ripening to make use of mechanical harvesters, etc.

- (e) research to find answers to the serious technical problem of maintenance of soil fertility and conservation of soil and water in the tropical rain-forest belt with its high rainfall, high temperatures and generally thin topsoil.

Thus, there are a lot of areas in which research could be undertaken on agricultural mechanization in Ghana.

One successful research output, however, stands out. This involved the system of land capability classification based on the degree of limitation of the soils of Ghana to mechanized farming and management which had been worked out by the Soil Research Institute, of the Council for Scientific and Industrial Research (CSIR) (Obeng and Smith (1964)). It is unfortunate that this valuable research output has generally been ignored, and mechanization schemes continue to be located in particular areas on the basis of political motives. The Agricultural Engineering Services Department of the Ministry of Agriculture has occasionally conducted field trials and adaptability of agricultural machines being introduced in Ghana. This formed part of the research and extension activities of the department, especially in the 1970's but activities in this area have now declined due to financial problems and more so due to the absence of a centre with basic facilities to undertake the trials.

The few R and D activities currently going on are found mainly in the universities where research efforts are directed at machinery development for crop storage and processing, and to tillage and other general mechanization topics to a limited extent. Output from these research efforts has been rather low and their impact not much felt. Thus one sees a general lack of sustained research effort in the field of agricultural mechanization in Ghana, and this calls for an urgent need to address the issue seriously. The main constraint has been the lack of purpose and direction, with each small unit doing its own thing. In this regard one cannot but add one's voice to the call for the establishment of a National Institute of Agricultural Engineering which will be the focal institution for a systematic and concentrated research in all aspects of agricultural engineering, including mechanization.

Mechanization Extension Activities

Upto 1988, the main Government institution which was charged with agricultural mechanization extension activities was the Agricultural Mechanization and Transport Department of the Ministry of Agriculture. This had a core of technical officers who provided extension services to farmers on agricultural mechanization issues. Efforts of these specialist personnel were supplemented by other public organizations such as the Grains and Legumes Development Board, the Cotton Development Board and other Non-Governmental Organizations such as the Christian Service Committee who were training farmers on the use draught animals. Following the re-organization of the Ministry of Agriculture, a Department of Agricultural

Extension Services has been created, and charged with the responsibility of handling all the agricultural extension activities of the Ministry. The Agricultural Extension Services Department is thus the front line contact between the farmer and the various specialist departments of the Ministry of Agriculture, including the Agricultural Engineering Services Department as well as being the liaison between the farmer and research institutions. The NGO's and the quasi-government institutions however still operate independently of the Government system.

ROLE OF EXTERNAL DONOR AND DEVELOPMENT AGENCIES

Ghana has received considerable support from external donor and development agencies in her quest to mechanize her agriculture. Foreign assistance has come from individual countries and international development agencies like the FAO, UNIDO, USAID, CIDA and GTZ to name a few. This has come in the form of direct donations of machinery and equipment, participation in mechanization projects, supply of experts for training and advice in mechanization. A few countries have been involved in providing technical assistance for the education of national mechanization experts and in the establishment of training facilities for professionals; and in the local production of farm implements, especially for bullock farming. Continuing-education opportunities have been provided by some of these external donor and development agencies for Ghanaian experts and professionals through sponsorship to international workshops, seminars and symposia.

DEMAND AND SUPPLY OF AGRICULTURAL MECHANIZATION INPUTS

Shortage and high cost of labour have been identified as two of the major constraints limiting increased agricultural output in Ghana. Current national policies relating to agricultural development in Ghana emphasize the need for significant increment in agricultural production. The production activities contained in all the agricultural programmes for the 1990's through to 2000 as set out in the Medium Term Agricultural Development Programme (MTADP) (MoA-GoG (1989)) and the draft proposals of the National Science and Technology Plan (1990-1995) (CSIR (1990)) all show changes in the total requirement and in the sources of power which will result from:

- expected expansion of total cropped area
- utilization of water resources for agricultural purposes
- changed cropping pattern, and
- expected change in the technology level.

Table 11 shows the total demand in Ghana for food, feed and industrial raw materials of the major agricultural products, for the years 1987, 1995 and 2000, whilst Table 12 gives current levels of production of cereals and some of the important crops. Whilst a proportion of the total demand will be met by

imports, the various programmes mentioned above call for growth rates of about 4% per year in local production to be achieved over the plan period, and this necessarily requires expansion of cropped area over and above current levels.

It is envisaged that area expansion for vegetables, rice, tobacco, cotton and some tree crops, estimated to be of the order of 2.5 per cent per annum, will play a crucial role and is considered as the main prospect for improving rural incomes.

TABLE 11: TOTAL DEMAND FOR FOOD FEED, AND INDUSTRIAL USE IN GRAIN EQUIVALENTS (METRIC TONS)

	<u>1987</u>	<u>1995</u>	<u>2000</u>
CEREALS, Total	822288	1210619	1546585
Wheat	75696	116809	153189
Rice	88976	232253	169430
Maize	406136	611089	793392
Millet	109272	152393	187608
Sorghum	142208	198530	244564
NON-CEREALS, Total	1510016	2245859	2881918
Cassava	599008	894700	1153333
Yam	173968	258231	330537
Cocoyam	355904	527710	675009
Plantain	312080	468856	604675
Groundnut	69056	96563	119073
TOTAL FOOD CROPS	2332304	3456478	4428503
LIVESTOCK			
Meat:	47808	72488	94039
Cattle	17264	26154	33907
Poultry	9296	14552	19255
Others	21248	31783	40877
Eggs	6640	10083	13090
Milk	13280	21954	30057
SUGAR	34528	53151	69597
VEGETABLE OILS	92960	137627	175877
FISH	171312	252724	322243
COTTON	31872	48397	62834
TOBACCO	1414	2146	2787

SOURCE: World Bank Mission to Ghana; December 1989 "Ghana Medium Term Agricultural Development Programme", Table 4.12. Accra, Ghana December, 1989.

About 1% of this expansion in cropped area is expected to be induced as a result of growth in rural population, whilst the remaining 1.5% is to be met through programmes like the introduction of animal draught power, power

tillers and tractors, and exploitation of small-scale irrigation schemes. Utilization of fertilizers is also estimated to grow at 10% per annum, as a productivity enhancement strategy. To derive maximum benefit from this increased use of fertilizers, agricultural mechanization will have to be developed to ensure proper placement of fertilizers and ensure optimum utilization of these fertilizers by the crops.

Based on the above policy measures, it can be concluded that there is a very high possibility for increased use of agricultural mechanization inputs in Ghana in the 1990's. The actual supply of agricultural mechanization inputs to meet the anticipated demand will however be greatly influenced by such forces as the country's economic growth, population pressures, farming systems which will emerge, and finally but perhaps the most important, Government policies relating to mechanization.

CONCLUSION

In spite of the irrefutable evidence regarding the desire among farmers and mechanization professionals to mechanize, the mere will to mechanize is not sufficient - there must be a complete, widespread and profound understanding of the true dimensions of mechanized agriculture, including the benefits, pitfalls and other implications. As a nation and a continent, we cannot mechanize our agriculture unless there is a widespread desire to do so. This should include the individual farmers, community leaders, government officials and Governments themselves. Mechanization cannot be effectively promoted and sustained through sporadic effects or short-term programmes, what is needed is a long term programme backed by sound policies and strategies to catalyse its development.

Ghana presents an interesting case in the agricultural mechanization saga in Africa. At independence, the Government introduced agricultural mechanization in a revolutionary manner. Within a period of a few years the number of tractors in Ghana increased from a few hundred to several thousands. Tractors were imported or provided through aid programmes from all countries. Russian, Yugoslavia, Czech, British, German, Canadian and American wheeled and crawler tractors were all imported. As Gordon (1970) noted ... "Perhaps nowhere else in the tropics can so many tractors be seen lying in yards or abandoned in the bush". It is also important to realize that lack of records hindered all attempts to assess the economics of mechanization in the Ghanaian agriculture in the period 1960-66.

From this exercise two things emerged, first the farmers appetite for mechanically powered mechanization was increased significantly and secondly the Governments which followed the Nkrumah's government were all too cautious with mechanization. The unfortunate thing about this whole exercise is that there followed a period when the whole programme was blamed on Marxism and socialist policies rather than being technically analysed without

any political biases (Gordon 1970). Draught animal power, which has been promoted through various aid programmes currently plays an insignificant role in Ghana's agricultural production system and is unlikely to become a major source of farm power given the other problems like tsetse flies, etc. It appears therefore, policy makers in Ghana have to find better and more efficient ways of introducing mechanical technologies in mechanizing Ghana's agriculture. To do this however we need to study thoroughly the past projects and determine the main reasons for their failure. It is only by learning from our past mistakes that we can succeed.

TABLE 12: PRODUCTION OF IMPORTANT CROPS: 1989-1989

	1982	1983	1984	1985	1986	1987	1988
1. CEREALS	544	308	1,066	909	867	905	995
Maize	346	172	696	584	559	553	600
Rice	36	40	65	68	70	81	95
Millet	76	40	133	112	110	271	300
Guinea Corn	86	56	172	145	128	..	-
2. STARCHY							
STAPLES	4,431	3,656	11,173	9,378	6,016	5,949	6,815
Cassava	2,470	1,728	6,186	5,193	2,876	2,943	3,300
Cocoyam	628	720	1,866	1,569	1,005	1,000	1,116
Yam	588	866	1,178	987	1,048	1,001	1,200
Plantain	745	342	1,943	1,629	1,087	1,005	1,200
3. PULSES & NUTS	1,342	1,331	1,214	1,013			
Groundnuts	111.1	91.1	167	140	190	..	..
Coconuts	337.0	338.8	265	219	..	..	..
Oil palm	889.4	889.4	768	643	..	..	..
Beans & Peas (dry)	14.1	11.7	14	11	20	..	..
4. VEGETABLES	186	202	674	566	670	..	..
Tomatoes		52.3	57.2	456	384	380	..
Pepper	62.6	62.6	74	62	137	..	..
Ocra	46.4	62.0	121	102	146	..	..
Garden Eggs	24.2	20.2	23	18	7	..	..
5. COCOA	202.5	168.1	166.7	194.4	226.4	233.6	288.8
6. OTHERS	178	224					
Sugar Cane	58.5	85.9	..	..	..	..	..
Orange	107.9	129.3	..	..	..	..	..
Pineapple	6.9	5.5	..	..	..	..	..
Banana	4.7	3.0	..	..	..	..	..

Source: Statistical Service Accra, Quarterly Digest of Statistics, Various Issues

As we noted earlier, research on agricultural mechanization problems of Ghanaian agriculture has been undertaken in an adhoc manner, with each small unit working in isolation. In many cases these small units have been starved of funds and other resources. Further they have concentrated on development of the hardware and little has been done researchwise, to develop better and more efficient management systems for agricultural machinery and equipment. The research effort has not been a waste, significant and notable achievements have been made in the post harvest field as was noted earlier. However we do not yet know why these post harvest technologies (cassava graters, palm oil processing devices) have been so readily adopted by farmers. Some of them are technically more complex than the mechanization technologies required for tillage. It is in the field operations that mechanization has yet to make a pronounced effect in Ghanaian agriculture. It is these field operations which make agriculture so unpopular among our young population and lead to rural urban migration. Perhaps our efforts in the last decade of the 20th century should aim at finding better and improved ways of introducing and managing the agricultural mechanization inputs required to reduce the drudgery of field operations. This is a challenge to all agricultural engineers as we approach the 21st century.

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CHAPTER 6

AGRICULTURAL MECHANIZATION POLICIES & STRATEGIES IN KENYA

by

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INTRODUCTION

The agricultural sector is the most important in Kenya's economy, as it employs about 70% of the country's population, produces about 30% of the GDP, and 60% of the foreign exchange earnings are obtained by export of agricultural commodities. Further, a large proportion of the manufacturing industry relies on raw materials from the agricultural sector. The current population is estimated at about 22 million increasing at quite a high rate of about 4% per annum and is expected to be about 35 million by the year 2000 AD. The urban population which was only 9% of the total population in 1965, is now about 25% of the total population and is growing at an even faster rate of about 7% per annum. At this rate, it is expected that by the year 2000, there will be about 10 million people living in urban areas, (almost the same as total population in 1965) who will need to be fed from food produced in the rural areas. At independence in 1963, Kenya inherited a dual size structure agricultural sector, which had quite a sophisticated large scale commercial sector, dominated by the white settlers, and a small scale sector dominated by African farmers, who were largely subsistence farmers, but also there was an emerging small scale commercial farming sector which was becoming increasingly important in the economy of the country. In order to appreciate the framework under which agricultural mechanization policies have been formulated in Kenya over the past 30 years, and the implementation strategies adopted, it is necessary to give a brief background on the changes which have occurred in the agricultural sector over the past 3 decades. This paper begins therefore by giving a brief historical overview of the structure of the agricultural sector at independence, policies which were adopted by the Government of Kenya then with the objective of incorporating more African farmers in the commercial agriculture sector, and the impact of these policies on the agricultural mechanization scenario in Kenya. Next the current status of agricultural mechanization will be presented, together with the problems which have constrained increased utilization of mechanical and draught animal technologies. This analysis will also include, an examination of the agricultural machinery industry in Kenya, as well as, the institutional framework within which agricultural mechanization technologies are provided to farmers and finally we shall attempt to project the likely scenario for the future in so far as agricultural mechanization is concerned. Compared to other African countries,

in so far as agricultural mechanization is concerned, Kenya presents an interesting case; for the use of mechanical technologies in agriculture is as old in Kenya as perhaps in some of the European advanced countries. There are however other physical, technical and economical factors which have greatly influenced the pace of agricultural mechanization in particular that of small holder farmers and this has made the level of agricultural mechanization in Kenya to be similar to the situation pertaining in other African countries.

AGRICULTURE IN KENYA DURING COLONIAL PERIOD

During the colonial period, agriculture in Kenya was carried on, under two separate systems. On one hand, there were about 3000 white farmers who had been allocated large tracts of land in the high and (the so called "scheduled" lands) and medium potential areas of Kenya and who grew cash crops for export or food crops for feeding the emerging and increasing urban population. Many of these farmers had been officers in the British Army who had been demobilized and given the land by the Colonial Government. The "scheduled" lands were reserved for European farmers and covered about 2.9 million hectares. On the other hand, the African native farmers, were engaged in subsistence agriculture in the "unscheduled" areas, which were mostly in the low and medium potential areas. These unscheduled lands comprised of about 13 million hectares of land. The main crops grown on the white highlands included coffee, tea, pyrethrum, wheat, maize as well as dairy and beef production. The African farmers on the unscheduled lands grew mainly maize, sorghum, pulses and were also engaged in livestock production mostly for subsistence and for meeting of social obligations. African farmers were not allowed to grow cash crops such as coffee, tea, wheat, etc. for fear of introducing plant diseases which could have affected the white farms. The holdings on the unscheduled areas were often fragmented and the land was basically communally owned. Many of the African farmers on these unscheduled lands or "reserves", were employed as labourers on the European farms. The European farms were capital intensive and from 1945, most of them were highly mechanized. The tractor population in the country increased from less than 1000 tractors by 1940 to over 6000 tractors by 1960. Prior to the introduction of tractors, draught animals were used (this technology was imported from South Africa) and the 'victory' plough was the common tillage implement.

Due to, among other things, the pressure for land, in particular in the Central Province, where a significant proportion of the scheduled lands were located, the "*Maumau*" war broke out in the early 1950s, and the Kikuyu tribe was the main one involved in this struggle. At this time also the Colonial Government had formed a commission, to study ways and means of improving agriculture in the unscheduled areas. This commission came up with the so called Swynnerton Plan (Swynnerton (1954)). This plan called for intensification of agriculture through cultivation of cash crops such as coffee and tea previously cultivated primarily by Europeans, and livestock production

through improved cattle for dairying. The plan also emphasized the need for the African farmers, in addition to cultivating commercial crops, to grow their own food. In addition the plan recommended a campaign to promote land consolidation and enclosure, in the unscheduled areas, issuance of land titles, with the broad objective of enabling farmers to use these titles for obtaining credit, and enabling the more progressive farmers to buy out those farmers who were incapable of developing their own holdings. In the lower potential areas the Swynnerton plan called for improvements in livestock production through better marketing channels to increase offtake levels; controlled rotational grazing, development of rangelands through provision of watering points and eradication of the tsetse fly as well as controlling the stocking levels. The period between 1954-1962 was therefore used to implement this plan, and land consolidation and registration was undertaken throughout the unscheduled areas. Further African farmers started growing cash crops - coffee, tea, pyrethrum, in addition to growing their own food. There was also intensification of livestock production through dairying, and some horticultural production.

The consolidation of the fragmented land holdings into plots varying in size from 1.5 ha to 10 ha, and the adopted farm layout and plans for each individual holding (there were two standard farm layouts) as well as the fact that perennial cash crops such as coffee and tea were introduced, and grown by the farmers, has severely restricted the mechanization options in these unscheduled areas to either handtool or animal powered technologies in exceptional areas. This is particularly the case in the high potential areas where a significant proportion of the population lives. The process of consolidation and layout of farms was however constrained by lack of adequately trained manpower and other logistical problems. Therefore although many farms had been registered and title deeds issued, the actual surveying and laying out of the farms took a long time to complete. By the end of 1965 a total of 1.631 million acres had been consolidated and registered (GoK (1967)).

AGRICULTURE IN KENYA AFTER INDEPENDENCE

With attainment of independence in 1963, the whole question of land took a different turn. The British Government had provided a loan to the independent Kenya Government for purchasing some of the land owned by the European settlers in the so called "white" highlands (the scheduled areas). This land was intended to be taken over by African farmers and by 1969 about 800,000 hectares had been taken over in this way. This land which was taken over by African farmers was farmed at four different levels. The high density settlements which were primarily designed to accommodate the landless and unemployed and the size of the individual holdings here was in the region of about 12 ha, and about 300,000 ha were settled under this category (Maina & MacArthur 1970). The second category was the low density settlements which were intended for farmers with some advanced agriculture and who could provide some working capital. The average size of the holdings here was about

20 ha. By 1970 about 100,000 ha. of previously owned white highlands had been settled in this way. The third way was through the 'Yoeman' farms scheme where experienced African farmers with substantial amount of capital were assisted to acquire some European farms and run them as medium scale farms (50 ha - 100 ha). They were provided with loans from the Government. The fourth way was by individual African farmers, or syndicates of Africans, grouped in cooperatives or companies, purchasing land from Europeans through their own capital funds and loans secured from Agricultural Credit Banks and Commercial Banks.

The acquisition of large individual farms for settlement of either smallholders, or medium scale African farmers, often led to a marked drop in output and income due to the time required for new farmers to adjust to the new farming system. In addition acquiring these farms was rather an expensive undertaking and led to a review of this policy in the late 1960s. It was felt then that the settlement schemes were benefiting only a few farmers in relation to the whole population still remaining in the unscheduled areas, and it would have been better to spend more money to improve the agriculture in these unscheduled areas where a majority of the African farmers lived. In addition in view of the importance of the large scale farms in producing the required cash crops for export, as well as the marketed food crops, it was felt that it would have been better to avoid subdividing these farms to small holders as this was likely to have a serious impact on commercial agriculture. From the late 1960s therefore, a policy whereby Africans were encouraged to form syndicates or cooperatives to purchase the large farms and run them as commercial entities was encouraged. (de Wilde (1967), Maina & MacArthur (1970), Mercer (1970), Clayton (1973)). A number of medium scale and large scale farming ventures run by African farmers were therefore established in the late 1960s and early 1970s and these have significantly influenced the pace and form of agricultural mechanization policies in Kenya (Mercer 1970, Mettrick 1970).

AGRICULTURAL MECHANIZATION POLICIES IN KENYA

As noted above, Kenya has had a dual size agriculture, with a large scale farm sector, originally dominated by European settlers and a small farm sector dominated throughout by African subsistence farmers and who also grow some cash crops. The large farm sector was after independence in 1963 taken up by African farmers, or was used for small holder settlement schemes. The commercial large scale farmers grow cash and food crops for the market and their farms are located in the high potential areas of Kenya. The major steps towards the mechanization of Kenyan agriculture followed the arrival of European settlers. Indigenous and improved varieties of oxen were trained for transport and other farm tasks including ploughing, harrowing and ridging. They became the main source of draught power on large farms, though still heavily supported by hand labour for many operations. The first tractors were introduced on a few large farms in the 1920s but they were widely adopted

only from the time of World War II when great efforts were made to raise agricultural output. In 1945 the number of tractors and combines in use in Kenya was still small, but by 1960 they had risen to 6400 and 1000 respectively. They were owned almost entirely by large farmers or contractors working in the large farm sector.

Tractors were first used by the small farmers in the 1950s in Kericho district. This was a consequence of the consolidation of the small holdings and this led to some of the more progressive farmers being able to acquire tractors for their own use and for hiring to their neighbours. Some small and medium scale farmers in the Central Province also acquired tractors following the consolidation of land as a result of the Swynnerton plan. The Government also assisted by establishing a tractor hire unit which had a few tractors. Through its soil conservation unit the Government set up a soil conservation service machinery unit with the following objectives:

- (a) To ensure that every acre of cultivated agricultural land is maintained at its maximum level of production, consistent with the use of appropriate soil and water conservation measures.
- (b) To bring more land into agricultural production by:
 - applying appropriate conservation treatments;
 - implementing drainage measures;
 - providing dams and water holes in marginal areas;
 - planning minor irrigation projects in areas with irrigation potential.
- (c) To be responsible for informing farmers and agriculturalists on the appropriate conservation techniques and requirements and to carry out services in accordance with approved plans and conservation principles.

This was part of the overall Swynnerton plan. After independence in 1963 and the initiation of the programme of settling smallholder farmers on formerly European owned land (the million acre settlement scheme), this increased the demand for tractor hire services for primary cultivation (Mettrick 1970). During the first year of settlement and to ensure timely land preparation, virtually all the settlers had several acres of their newly acquired land plowed for them by tractors provided by the settlement department or hired by this department from private contractors. The cost of this operation was defrayed out of the portion of the loan earmarked for crop establishment. In subsequent years, a large number of these settlers, who had previously in their reserve farms relied on hand hoe and animals for primary cultivation, once they had experienced the convenience of mechanization continued to rely on tractors for seedbed preparation (de Wilde 1967, Mettrick 1970, Clayton 1973). Thus the demand for tractor hire services increased quite significantly

during the period 1963-69. The Government therefore, decided to launch a programme whereby small farmers could be assisted to acquire tractors through provision of credit. Through a loan provided by the World Bank through IDA; 210 tractors and auxiliary equipment were purchased by farmers (mostly small scale) between 1967 and 1968. There was little training of the farmers on the technical maintenance of these tractors as well as economical use of the same. The Government was keen to provide the loans and farmers were eager for one reason or another to acquire the tractors.

In an evaluation of this project, White and Downing (1968) who were working in Ministry of Agriculture headquarters, were quick in condemning the project as a costly failure which did not result in any increment in production and employment. We should add here however, record keeping by these small scale farmers, as is common elsewhere in the developing countries, was quite poor and how they came to this conclusion is difficult to say. Their report was quite critical of the project - and they made some rather strong claims like:

"... farmers in numerous cases, seem to have purchased tractors for prestige purposes and have made little effort to increase the cultivated area on their farms ..."

The main reasons for the failure of the scheme is attributed by Clayton (1973) to the Kenyan farmers inadequate knowledge of the nature of capital investment; his unawareness of the need to provide for repair and replacement and of the technical requirements for the maintenance and efficient operation of machinery and his inability to plan for efficient use of tractors on his own farm and on those of his customers. A number of these small scale farmer however expanded their scale of operation and continue to provide tractor hire services, as private contractors up to today.

GOVERNMENT TRACTOR HIRE SERVICES

Concurrently with assisting small holder farmers to acquire their own tractors, the Government started its own tractor hire service in 1966. This was also started with assistance of the International Development Association of the World Bank. Initially this tractor hire service was intended for primary land preparation and planting for the Masai Wheat Scheme, through which wheat was produced in large land blocks so that the advantages of large scale operation could be attained through use of machinery. Payment for the tractor hire services was assured through the Wheat Development Authority which was responsible for marketing the farmer's wheat. The tractors were also intended for land preparation for cotton production which took place at a different time from that of wheat, and thus helped to utilize excess and off season tractor capacity. The main objectives of the tractor hire services as established in 1966 included among others:

Table 13: Tractor Hire Service Operation

Performance, costs and income	1966-67	1967-68
Tractor months	300	600
Total hours	35 317	50 849
Productive hours	27 175	38 621
Hours per tractor month	118	85
Productive hours per tractor month	91	64
Productive hours as percentage of total	77.0	75.0
Operating cost per productive hour (shs.)	38.70	36.76
Total expenditure (shs.)	1 055 255	1 419 546
Earned revenue (shs.)	1 068 912	1 544 872

Source: Downing and Goldsack (1968)

- (i) To open new areas for agricultural production.
- (ii) To introduce modern agricultural techniques to farmers and to stimulate private ownership of farm machinery.
- (iii) To supplement land preparation (especially in family farm areas) where private contractors are not sufficiently operative.
- (iv) To increase agricultural productivity, especially cash crops such as cotton which are important to the Kenyan economy.

The THS started with 50 tractors which were primarily intended for the Masai Wheat Scheme. The Government realized that the tractor hire service was merely a means of stimulating development and it was felt that ultimately a private hire service would have a better chance of lasting success. Initially the THS operated quite successfully and was able to meet all its operating costs as well as generating a small surplus between 1966-68 (Downing & Goldsacks (1968), Clayton (1973)). The tractor service operated in mobile units, with no permanent base, and virtually year round utilization of machinery was possible as the tractors could be moved from area to area to follow work given Kenya's diverse ecology and agriculture. In the first few years the THS was managed by experts provided through various donor agencies and their reports do indicate that they were operating at a surplus (see Table 13)

It is difficult however from the figures shown in Table 13 to categorically state that the undertaking was really profitable at this stage, and had a firm business foundation. The record keeping was rather sketchy and

only overall records are available. It is thus difficult to determine how many tractors were really operational in any one month, how the tractor hours were achieved, and the cost analysis would in our opinion be doubtful as the salaries of the experts have been excluded. The project however appears to have faced a number of problems from 1969-onwards and became rather unreliable and farmers relied to a greater extent on private tractor hire services provided by farmers who owned tractors with some of the tractors coming as far away as from Tanzania.

From 1974/75 onwards the THS was re-equipped and expanded, and its fleet became increasingly mixed. The proportion of work carried out for small farmers rose, and the geographical spread of operations widened. Originally all major repair work was carried out at a central workshop in Nakuru, but three new regional workshops were constructed in 1979-1981 at Machanga, Mariakani and Migori under a Netherlands technical assistance programme. Since the creation of AMSB (Agricultural Mechanization Service Bureau) the tractors and their implements have been assigned to 17 of the 21 stations which fall under the new organization, and their mobility has thus been greatly reduced. The rapid expansion of the organization (to 197 tractors by 1981), the increased emphasis on small farm cultivation, and the geographical dispersion of the machines, has led to a fall in efficiency resulting in official criticism of THS. Of the 197 tractors currently (1990) in the fleet, 73 are in good condition and operational, 61 require repairs and can be put into service if the required spare parts are procured, and 62 are unserviceable and are being boarded off.

In addition AMSB operates the heavy crawler tractors under the Plant Hire Service programme. The Plant Hire Service (PHS) of AMSB has its origins in the Soil Conservation Service (SCS) machinery unit of pre-independence days. Its main objectives have been given earlier in this paper. In addition to its soil and water conservation operations, PHS has undertaken other activities which contribute directly or indirectly to increasing agricultural output, e.g. bush-clearing and farm road construction. This is partly due to a change in role since 1980. Prior to then, PHS concentrated mainly on the implementation of Government programmes which were considered to be of national or provincial priorities. The service has subsequently become essentially revenue earning, providing construction services almost exclusively to private farmers. Until 1978 the plant operated from seven stations: Kitale, Eldoret, Kipkelion, Nakuru, Nyahururu, Ruiru and Mariakani. Additional stations were established as "Pilot Soil Conservation Stations" in the period 1978-81 so that at amalgamation into AMSB there were 19 stations in all, although some of them had virtually no facilities. As the new stations were opened plant was transferred to them from the older stations. The PHS fleet increased from 54 in 1974 to 113 in 1982, largely due to a re-equipping and expansion programme for crawler tractors during 1978-79 which resulted in a fleet of many different makes. The Plant Hire Service operates mostly crawler equipment with angle dozer blades and many also with rippers. These are backed up by motor

graders, self-propelled scrapers, and some small plant including towed scrapers, terraces, rollers and front loaders. There are machines from 9 different manufacturers in all creating many problems of spares, supplies and dealer service. The total recorded fleet size in 1990 is 107, including 39 which are operational, 41 serviceable (if spares can be provided) and 27 unserviceable which are due for boarding.

Generally the plant operated by PHS is unnecessarily large for the bulk of the work carried out. The larger crawler tractors (>140 hp) are essential only for the heavier bush clearing operations and for ripping of rock during dam construction, and while they carry out the lighter work more quickly and generally more efficiently than small machines, the jobs are often so small that disproportionate time and effort are involved in organizing and transporting the equipment. The large, self-propelled scrapers are of use only on large dams, where there is room to manoeuvre and the rate of earth moving can be critical: they are of no use on the small water holes which form by far the greater proportion of the water conservation activities of AMSB. In summary the current agricultural mechanization situation under the Government is that, there are 21 agricultural mechanization stations offering both plant and tractor hire services. They are supported by the Central Workshop based at Nakuru for repairs. The farm tractors stock now stand at 73 operational, 61 serviceable and 62 which have been recommended for boarding. The industrial tractors stock of the plant hire services now stands at 39 operational, 41 serviceable and 27 recommended for boarding.

In addition to the above two services THS and PHS under AMSB, there are also small units responsible for Small Farm Mechanization Programme and post harvest processing and storage. The main objective of the Small Farm Mechanization Programme (SFMP) is to extend the range of handtools and ox-drawn implements to small farmers, in particular to cater for more than one operation and include other operations such as planting and weeding. Under a UNDP/FAO assisted project - Agricultural Equipment Improvement Project the following prototypes have been developed and a limited number distributed to farmers since 1977 - multipurpose tool carrier; mouldboard plough attachments, wheel hoe for weeding which is hand pushed, punch planter, maize sheller, chaff cutters, squirrel traps. The number of these prototypes under this programme so far distributed to farmers is however quite small:

Punch Planters	- 50
Maize shellers	- 100
Multipurpose tool bar	- 600 (with plough)
Multipurpose tool bar	- 100 (with ridger)
Light weight plough	- 300

Given the numbers of traditional handtools and animal drawn implements in use and annual demand, as shown in Table 14, it is obvious that

this UNDP/FAO project has so far had very limited success in popularizing its 'improved' handtools and animal drawn implements to the small holder farmer. Thus the programme despite over 10 years in existence has not even approached 0.001% of the handtools and ox-drawn implements in use.

Table 14: Handtools and Animal Drawn Implements in Use in Kenya 1990

Estimated no. of handtools in use	1 039 000
Estimated no. of ox-ploughs in use	150 000
Estimated annual demand for handtools	60 000
Estimated annual demand for ox-ploughs	14 000

The post harvest processing and storage programme of AMSB has the main objective of reducing on-farm food storage losses currently estimated at 16-30%. This is mainly aimed at the grain stored by small scale subsistence farmers for their own consumption as the marketed grain is catered for by the National Cereals and Produce Board. The programme is supported in Western & Nyanza Province by the USAID supported On-Farm Grain Storage Programme and in other districts, some 2000 demonstration improved on-farm grain storage structures (storing up 2 tonnes of grain) have been constructed under the Rural Structures Programme. There are also programmes for oil seed processing supported by the East African Industries.

Performance of Government Agricultural Machinery Service

The cumulative total of work executed by the Plant Hire Service is shown in Table 15. Overall, given that PHS has had to operate under the civil service system its achievements are, by and large, quite reasonable. Generally most of the work undertaken were for government sponsored projects and there has been a decline in output since 1981 due to a decrease in Government sponsored projects as a consequence of the financial austerity measures. The PHS has therefore since 1981 been more involved, on hire basis, in work on private large and medium scale farms where the scale of operation is often not that big hence the 'decline' in output. The performance of the tractor hire service is given in Table 16. It is evident from this table that the output of THS is dismally low. The number of tractor hours per year averages 154 hours which is quite low compared to private contractors. Even by standard of tractor hire services run by Governments in other parts of the World, this is comparatively low.

A number of factors have influenced the performance of the tractor hire service run by AMSB. Compared to 1968, as shown in Table 13, the performance has declined significantly. The reasons for this include:

- (i) Operational autonomy: In 1967-69, when the THS was started with donor funds, it was run as a project and not subjected to

Government financial regulations. Hence the project managers had autonomy in running the service as a commercial project, whilst now it is run under Government financial regulations which at best are quite cumbersome.

Table 15: Performance of Government Plant Hire Services (1963-1988)

Activity (Unit)	Target*	Achievement*	% Performance
Bush clearing of Ripping (ha)	31,100	18,125	58
Dams (No.)	708	649	91.6
Water holes (No.)	5,080	1,108	22
Farm roads (km)	12,000	6,900	58
Terraces (km)	21,200	9,500	45
Cut-off drains (km)	7,100	4,845	68
(Cumulative total 1963-1988)			

- (ii) Fragmentation of land holdings: The period 1967-69 was the peak one for the resettlement programme and a lot of the farms were still new. Since then however, the land on these settled areas has been fragmented through inheritance etc. and perennial cash crops such as coffee, tea, etc. have been established on part of the land thus leaving only small areas for the annual arable crops which require tractor ploughing.
- (iii) Lack of fuel: Fuel shortages in many of the sub-stations of AMSB has been a main cause of down time. This is in part caused by the bureaucratic procurement system followed under the civil service system.
- (iv) Machine breakdown: This is responsible for a high proportion of down time. The frequency of breakdown may result from inadequate routine servicing and from improper use by unskilled operators. Breakdowns are however inevitable if machines work in difficult conditions and where a high proportion of work is on uncultivated land. Long delays in repairing machines occur because of lack of spares, either because spares are not available in Kenya and have to be imported from Europe or because there are no funds at AMS-stations to buy the spares.

- (v) Seasonality and lack of incentives: The seasonality of demand, and inflexibility in deployment of THS tractors is responsible for many idle months in many stations. It should be remembered that when the THS started in 1967 the tractors could be moved from one part of the country to another in pursuit of ploughing work. However since the establishment of 21 stations this has created inflexibility in movement of these tractors. Secondly the tractors should be operated as long as possible when the work is available. Under the civil service system however there is no incentive for the tractor operators and their managers to work late as they are not remunerated for such late work. This is in part due to the financial regulations they have to operate within and the fact that hire rates are fixed centrally.

PRIVATE HIRE SERVICES

Crawler Tractors

The private sector is operating mainly in road construction and repairs, on buildings sites, and on dam construction. To a limited extent the plant is also used for bush clearing, e.g. by large estates such as those owned by sugar companies. Private forestry operations also absorb a significant number of old crawler tractors. Most major makes of plant are in use, including *inter alia*, Caterpillar, Aveling Barford, Champion, Komatsu, Fiat, MAN, JCB Hymac and Terex Poclain. The number of items is difficult to estimate, but from indication given by plant agents and contractors, there is approximately a total of up to 2000 units, although a large proportion are inappropriate for agricultural activities because of their type or size (for example, large scrapers, or dump-trucks and excavators). Although the agents have recently been having great difficulties in importing spares, the contractors have had few difficulties in obtaining their requirements up to now. The private sector has therefore not been greatly restricted by lack of spare parts, and a down time of 2 to 3 weeks for even a major repair appears typical. Although this will probably change in the near future as import restrictions affect spare stocks even more, this downtime is in great contrast to the PHS situation, when repair times have often been in terms of months or even years.

Consultation with local contractors, indicates that there is spare plant capacity which could be utilized on works in the same way as Plant Hire Services. However, there are three main factors preventing the private sector from getting more actively engaged in agricultural activities as the Government PHS. These include:

- Geographical distribution of plant is unsuitable, being concentrated around Nairobi, and to a lesser extent near Nakuru and Mombasa. A job would need to be large (e.g. dam or large scale bush clearing) to attract a contractor to areas away from these centres;

- Minimum costs for a contractor are approximately double the present level of PHS charges, and effectively no private farmers are interested in approaching contractors even now when the Government PHS operations are quite limited.
- Difficulties in obtaining payment for small, casual jobs is a strong deterrent for a contractor. This reluctance by farmers to pay has also affected the Government operated Plant Hire Services.

A prospective area for private contractors to get involved in place of PHS is in the construction of dams in high potential areas, where the economics of irrigation of large farms are able to bear the higher cost of using the private sector. Indeed, some dams which were designed by the old Soil Conservation Service were subsequently constructed by private contractors.

TABLE 16: Performance of the Government Tractor Hire Service

YEAR	TOTAL NO. OF TRACTORS AVAILABLE	AVERAGE NO. OF TRACTORS ON ACTIVE DUTY	ACTUAL NO. OF PRODUC- TIVE HOURS	ACTUAL NO. OF HA. PLOUGHED	NO. OF HA. PLOUGH PER TRACTOR
1975/76	54	-	15442	3861	-
1977/78	57/104	-	15302	4694	-
1978/79	104	75	14221	4132	55
1989/80	102	67	19485	5056	75
1980	159	61	26656	6664	109
1981	185	80	33112	8647	108
1982	191	90	22300	5600	62
1983	197	85	16928	4232	50
1984	197	85	11084	2771	33
1985	197	85	11676	2919	34
1986	203	90	14180	3545	39

SOURCE OF DATA - MINISTRY OF AGRICULTURE RECORDS

Tractor Hire Services by Private Sector

The private tractor hire service provides crucial service to small scale farmers. It is by far larger than the Government Tractor Hire Service although the exact number of tractors in use is difficult to estimate. Tractor contractors vary in

scale and type of operation. At one extreme there are large specialist operators with as many as ten or more tractors who undertake mainly large-scale jobs for organizations such as Kenya Breweries Sugar Estates, etc. and who obtain very high rates of machine utilization by travelling over a wide area to find work. They employ high horsepower tractors, in many cases with 4-wheel drive, and hence can achieve fast work rates on large and well-cleared fields. In the longer term, it seems inevitable that as farms and estates are subdivided the demand for large-scale contracting will decline. At the other extreme is the operator with just one tractor who cultivates his own farm first and then looks for additional work either in his immediate neighbourhood or further afield. This is the most common type of contractor in Kenya today, and the majority of tractor cultivation in the small family farm sector is performed by such operators. It is not unusual for a tractor to be owned by a group or partnership of 2, 3 or 4 farmers and Agricultural Finance Corporation loans are available for such group purchases. Small contractors usually go for the lower hp tractors (e.g. the 40-60 hp MF 265, IH 384). There has been very little uptake of 4-wheel tractors of less than 40 hp. An increasing proportion of total tractor sales are to such operators with only one machine undertaking a mixture of their own work and contracting to other small scale farmers.

Estimates of total number of tractors involved vary widely and in particular determining the numbers which are operational and those which have broken down beyond repair in any one year is quite difficult. Although import figures show that Kenya has been importing on the average about 1095 wheeled tractors per year, it is difficult to estimate how many of the old tractors are boarded off each year. The total number of tractors on large farms are shown in Table 17. These large farmers are defined as those with cultivated area of 8 hectares and above.

In addition there are quite a number of farmers with less than 8 ha of cultivated land who own their own tractors and who do contract ploughing for other farmers for a larger part of the year to maintain their equipment. Such farmers and a number of the larger farmers who cultivate land near the region of 8-20 ha provide contract hire service to the small farmers. It is estimated that there are about 3400 tractors which are engaged wholly or principally in contracting work (AMSB (1990)). Some of the large farms do provide contract hire services especially to small-scale growers of sugar cane, rice and other crops in irrigated schemes. A survey undertaken in 1978 for AMSB shows that the large farm sector (over 8 ha.) owned about 80% of the tractors in the country and the remaining 20% were owned by farmers with less than 8 ha. Precise figures however will require more detailed survey and consistent record keeping a tradition which has not been developed in many developing countries. It is however clear that the Government and other public tractor hire services with a total of about 300 operational tractors, has less than 10% of the tractors owned by the private sector engaged wholly or principally in hire services. Efforts should therefore be directed at assisting this private sector to provide this service more efficiently.

TABLE 17: Mechanical Equipment on Large Farms (cultivated area 8 ha and above) 1980-1988

YEAR	TRACTORS		COMBINE HARVESTERS	
	Wheel	Crawler	Self-Propelled	Tractor Drawn
1980	6180	366	302	111
1981	6075	324	205	100
1982	6322	322	193	106
1983	8200	368	238	315
1984	8077	317	250	195
1985	6330	338	347	93
1986	8760	464	416	173
1987	9050	362	522	169
1988	9050	362	522	169

SOURCE: (AMSB; 1990)

Standardization of the Tractor Fleet

Table 18 gives the figures for the various makes of tractors sold in Kenya between 1970-1989. Thus a total of 21900 tractors were imported between 1970-89 with the average annual importation figure being about 1095. These figures are from the major distributor (Farm Machinery Distributors) and others who keep records of their sales. It should be added that there are other tractors either imported directly through donor projects, and NGO projects which are not included in this number. This also excludes individual farmers/or other nationals who have access to foreign currency who import directly and thus their tractors are not recorded by the local franchise holders. In particular of late there has been an increase in importation of second hand tractors from Europe and North America. Table 18 shows that Massey Ferguson has dominated the local market with about 31% of the sales, followed by Ford with 24%, and Same and International Harvester/Case with 19 and 14% respectively. There are some suppliers who come on and off such as FIAT, Deutz, John Deere.

TABLE 18: Tractor Sales (Private and Government) 1970-1988

Year	Deutz Others	Deutz Total	Fiat	Ford	Case IH	John Deere	Lambor- ghini	MF	Same	
1970		7	-	305	64	-	-	328	-	704
1971		6	-	213	70	33	-	321	-	643
1972		-	-	194	69	112	-	483	62	987
1973		1	-	325	74	19	-	376	71	917
1974		1	-	240	81	30	-	306	76	756
1975		-	-	213	21	113	-	387	142	896
1976		-	29	242	137	109	66	266	174	1 944
1977		-	109	335	417	-	170	417	283	1 788
1978		-	112	419	332	-	159	481	291	1 932
1979		-	94	236	338	-	109	311	184	1 365
1980		-	81	239	124	-	125	302	216	1 178
1981		26	117	213	174	-	110	254	207	1 192
1982		8	118	186	109	-	68	136	169	834
1983		-	57	150	68	-	61	127	126	614
1984		-	44	222	46	-	6	202	163	727
1985		-	62	285	74	-	-	277	259	1 013
1986		117	80	300	39	8	-	420	221	1 299
1987		154	72	241	60	8	-	500	174	1 295
1988		147	12	371	210	19	-	445	188	1 462
1989		-	55	257	185	-	-	478	220	1 257
TOTAL	467	1 042	5 186	2 692	451	874	6 817	3 226	1 148	21 903

DRAUGHT ANIMAL POWER

There is a wide disparity in the estimates of draught oxen numbers in use in Kenya partly because of differences of definition between the studies. In some

cases untrained animals are included, whilst in others donkeys which are used primarily for transport especially among the pastoral tribes have been counted as draught oxen. In a survey undertaken by a Dutch consulting firm in 1979/80, it was estimated that there were 90-100,000 working oxen in Kenya, while a study by the World Bank put the number at 100,000 to 200,000 and Pollard (1982) estimated the number of working oxen as 700,000 which would seem to be quite on high side in view of his enthusiasm for this technology. The annual demand for ox-drawn ploughs is estimated at 12,000-14,000. Thus we are not even sure of how many draught oxen are in use, given the above figures which vary by over 800%.

There is a marked regional concentration of oxen use, resulting from historical differences, tribal attitudes, and the spread of livestock diseases. The National Sample Survey found that the percentage of rural households owning oxen is highest in the south west of Kenya (34% in Bungoma and South Nyanza Districts, 26% in Nandi, and 22% in Kisii). The other main band of concentration is from Kajiado District (20%) and Machakos (30%), through Kitui (14%) and Embu (18%), to Kirinyaga District (17%) (Pollard 1982). The proportion of households owning ox ploughs was higher in many districts than the number owning oxen, which might indicate that when farmers hire oxen they use their own plough, or that some households have given up ox cultivation. Most ox owners provide a hire service to neighbouring farmers after completing their own cultivation. The per acre charges for ox cultivation appear to be equal to those for tractor hire, despite the reportedly cheaper cost of maintaining oxen.

Oxen have a limited work output per day and cannot plough heavy soils until they have been softened by the rains, so their seasonal work capacity is low. At a rate of work of 20 hours per ha. and a daily achievement of 5 hours work, it would take an ox-pair 4 days to cultivate a hectare. With the period available for ploughing after the onset of the rains seasonal output of an ox-pair would be only about 5 ha. In contrast, the grazing required per animal would be 0.5 to 1 ha. A large team of 4 or even 6 oxen (as sometimes used in Kenya) would achieve a faster work rate but have a higher grazing requirement.

The direct costs of keeping oxen are low when adequate grazing is available. Costs of veterinary inputs, harnessing, housing, and labour for herding are all modest. The major cost of keeping cattle is the opportunity cost of land used for grazing and this will vary very much from area to area. Some observers have argued that in Agricultural Ecological Zones (AEZ) II, III, and to some power extent IV, the opportunity cost of land is too high to make animal draught economically attractive, and that only in the lower potential areas can the allocation of land for grazing of draught animals be justified (Aldehem & Schmidt 1975). Even there, the opportunity cost of the alternative use of the land for dairy farming must be taken into account. Pollard (1982) considers that even allowing for the opportunity cost of land, animal draught

is cheaper both in financial and economic terms than tractor cultivation, at least in three areas which he studied. He also points out that costs of ox cultivation could be reduced, e.g. by increasing utilization of animals for operations other than ploughing; improved methods of feeding (e.g. growing of fodder crops and raising the quality of implements and standard of operations).

It suffices to say that a number of factors have inhibited widescale adoption of draught animal cultivation and despite over 90 years of use in Kenya the number of draught oxen in use is still very small (less than 200 000 animals) and it is unlikely that they cultivate more than 200 000 ha. of land (because of rainfall limitations a pair cannot do more than 5 ha. per season). Other economic factors such as shortage of grazing land in most parts of Kenya are likely to limit the future potential of this type of technology in many parts of Kenya.

RESEARCH AND TRAINING FOR AGRIC. MECHANIZATION

Research on agricultural mechanization problems has been, by and large limited. There was no particular institution established to handle research in this area. The Agricultural Machinery Testing Unit (AMTU) in Nakuru was established specifically to test agricultural machinery and implements imported or locally manufactured. It has however undertaken limited research on agricultural mechanization problems. This has been mostly in the form of projects sponsored by donor agencies to deal with specific problems and the research project is usually terminated once the donor funding stops and the foreign experts leave. The Agricultural Engineering departments at Nairobi and Egerton Universities also undertake limited research mostly in the form of undergraduate and postgraduate student dissertation research. A number of agricultural engineering projects/programmes have also been undertaken in various other departments at the Nairobi University, Jomo Kenyatta University, Ministry of Research and Technology, Kenya Agricultural Research Institute, and Kenya Bureau of Standards. There is also a strong professional society for agricultural engineers (Kenya Agricultural Society of Engineers) which organizes regular meetings/symposia/workshops for professional agricultural engineers.

Kenya has, in comparison to other African countries, had a relatively strong training programme for agricultural mechanization. The Egerton College, established in the 1940s through an endowment from Lord Egerton, was meant to train 'sons and daughters' of farmers the 'science and practice' of agriculture. Initially it confined its intake to 'sons and daughters' of the white settler farmers and it had a strong programme in agricultural engineering. In the 1950's however it began to admit African students into its various diploma programmes. Many of the early agricultural engineering technicians in Eastern & Central Africa were trained at this college. The department of agricultural engineering at Nairobi University was established in 1976 to offer BSc. degree in agricultural engineering and it was the first

department in the Eastern & Central Africa region to offer such a programme. The annual intake is about 20 students. At the front-line level, the Ministry of Agriculture realized that there was something missing in training of manpower for agricultural mechanization and as a consequence started two institutions - the large scale training centre at Eldoret which trains secondary school leavers at certificate level. These certificate in agricultural engineering trainees are employed as technical assistants in farm power and machinery and form the front-line extension workers of the ministry in this field. They are also employed by the large scale farmers as machinery management operators/specialists as their training is quite practical and vocational. The second institution established is the Narosura Training Centre which trains plant (mostly crawler & heavy tractors) operators for agricultural mechanization service. These plant operators are in high demand as many of them have been employed by the private plant hire operators.

Therefore on the research and training front, there have been significant developments over the past 15 or so years. It is however too soon to say that these efforts have led to significant improvements in agricultural mechanization. Both training and research are long term investments and the fruits of current investments in this area are yet to be fully realized. Some of the institutions recently established should have been established in the 1950's and 1960's rather than now. There is also a need to coordinate the efforts of all these institutions involved in agricultural engineering research and training and develop a more focused and long term research strategy.

MANUFACTURING OF AGRICULTURAL MACHINERY

Although Kenya has by African standards, a comparatively large industrial sector, the manufacturing of agricultural machinery and implements is relatively limited. There are quite a number of small and medium sized firms producing handtools (hoes, fork hoes, wheelbarrows, machetes, etc.) and animal drawn implements (mostly the victory plough). There are also some firms which fabricate specialized equipment for the large scale estate farms - coffee pulperies, tea processing equipment, sisal processing equipment, etc. and the large scale millers. These are found mostly in Nairobi, Nakuru, Eldoret, Kisumu, which are the major towns for the high & medium potential agricultural areas. Some of these firms also produce, on a comparatively large scale such agricultural equipment and implements as hammer mills, disc and chisel ploughs, trailers, etc. Recently however the Government has been encouraging small scale fabricators and manufacturers under the *Jua Kali* (under the hot sun) programme to venture into manufacture of agricultural tools, and implements. Such *Jua Kali* enterprises are found all over the country and are equipped with basic metal working equipment and welding sets and they can make quite a range of handtools and domestic appliances. The major constraint of the manufacturing sector is lack of raw materials and marketing problems.

ROLE OF DONOR AGENCIES

Several donor agencies have been associated with Kenya's agricultural mechanization efforts. The British Overseas Development Administration (ODA) played a key role in the earlier settlement schemes programme in the 1960's and 1970's including provision of commodity assistance for tractors and implements as well as technical advisors for agricultural mechanization. In 1978 ODA provided technical assistance to rehabilitate Averell Marshall tractors which had been provided in the 1960's as a commodity aid. The World Bank, as we described earlier, has also provided loans through its IDA affiliate for purchase of tractors which were sold to small holder farmers. In 1980's the Federal Republic of Germany provided a commodity aid programme in the form of Deutz tractors, spares and workshop tools. Indeed a majority of the Deutz tractors currently in the country were provided under this programme. The Dutch Government provided technical assistance to the Ministry of Agriculture to conduct a review on the status of agricultural mechanization in Kenya in the 1970's. This study conducted by the Dutch firm CEBECO was followed up by provision of some equipment to the ministry for construction of agricultural machinery workshops.

Other donors who have been involved in agricultural mechanization in Kenya include FAO/UNDP/UNIDO/ILO who have provided, as we noted earlier, some technical, and operational assistance to several projects involved in research, development and extension of agricultural mechanization technologies like: Agricultural Equipment Improvement Project, Regional Rural Structures Programme, Rural Oil Processing and Production Project, Farm Equipment Use in Small Holder Agriculture, and upgrading skills and facilities of *Jua Kali* artisans producing agricultural tools. Others like British Council, USAID and SIDA have been involved in technical training whereby Kenyans were availed training opportunities overseas in the field of agricultural engineering as well as provision of lecturers to the training institutions. In addition there have been quite a number of Non Governmental Organizations (NGO) involved in different aspects of agricultural mechanization - biogas plants, food processing, etc. All in all the donors have been relatively active in the field of agricultural mechanization in Kenya and some of their programmes have had very positive effects while others were only partially successful.

CONCLUSION

We have in the preceding sections reviewed the agricultural and agricultural mechanization developments in Kenya over the past four decades. Kenya's agriculture has since colonial times been characterized by a dual size structure. On one hand are the large commercial farms, which during colonial times were exclusively owned by European settlers producing high value cash crops such as coffee, tea, pyrethrum, wheat, and dairy products for the export and the internal urban market. These were and have remained highly mechanized enterprises and are quite important to the Kenya's economy. At independence

the area covered by these large farms was 3 million ha. and since then about 1 million hectares have been taken over under the various government schemes and subdivided for settlement of African farmers as small (less 5 ha.) and medium scale (5-25 ha.) farms. Most of these farms are in the high potential areas, where both the rainfall is adequate and soils are of high fertility. On the other hand are the small scale farmers found all over the country. A significant proportion of these farmers lived in the African reserve lands during the colonial period and owned fragmented parcels of land, from which they practised predominantly subsistence agriculture. As a consequence of the *Maumau* wars, in the early 1950s, the Swynnerton Plan was adopted in 1954 through which a land consolidation programme was instituted on these African farms and the small farmers were encouraged to grow high valued cash crops such as coffee, tea, and pyrethrum. At independence some of the landless people from these African reserves as well as the small scale farmers were settled in some of the land acquired by the Government from the European settlers. A number of mechanization schemes were started in 1960s to help these settlers in opening up their new lands as well as construct soil conservation structures. These were both Government as well as privately owned and operated.

Initially these tractor hire schemes (both Government and private) were quite successful as there was a high demand for their services as most farmers grew annual crops - wheat, maize, beans, etc. This also coincided with the time when hybrid maize was being introduced in Kenya with the resulting higher yields (Gerhardt 1975). Due to the high yields, and hence increased production, many farmers in the newly settled lands in the high potential areas shifted from cultivating annual crops such as maize into higher valued cash crops such as coffee, tea, pyrethrum as well as dairy cattle. These being perennial crops did not require that much of tractor tillage and hence this affected the tractor hire services which then moved to the dominantly cereal producing areas. With the fragmentation of the land due to population pressure, this has led to the handtool technology being the predominant type of technology in the small holder sector in the high potential areas. Agriculture however is quite intensive due to the favourable climate and the range of cash and food crops which can be produced. Draught Animal Technology is unlikely to be adopted in these areas as grazing is not available and the opportunity cost of land is too high to make draught animals economical. In the main cereal producing areas, the farms are cultivated by tractors and some of the medium and small farmers hire tractors for cultivation. It is estimated, in addition to the 300 public owned tractors available for hire, there are over 3400 tractors owned by small and medium farmers which are engaged wholly or principally in contracting work.

Even though yields can still be increased in the high potential areas (both on large and small scale farms) it would appear however if Kenya is to be able to feed her ever increasing population then significant increment in yields and overall production will have to be obtained from the medium and

low potential areas. At present time, less than half of the bio-chemical agricultural potential of these areas is being realized while the country is importing wheat, rice, vegetable oils and cotton all of which can be produced in these areas if mechanization and other inputs can be provided to farmers at affordable prices. It should be realized that agriculture in these areas is rainfed and timeliness of field operations is critical if reasonable yields are to be achieved. Draught animal technology can play a role in enhancing the production potential of these areas. However as Johnston (1975) has noted prior to 1975 very little has been done in Kenya by the Government to promote ox-cultivation and many policy makers and agricultural specialists in Government are of the view that the country's farmers should shift directly from hoe cultivation to tractors. A number of programmes to develop and popularize ox-drawn implements have been initiated but so far success has been elusive (Muchiri and Johnston (1975); Pollard (1982); Muchiri (1984)). Experience with Government tractor hire schemes also indicates that there are serious problems in taking this route. Private tractor hire services appear to be a viable option if however, these contractors are assisted to remove some of the constraints they face. There is need therefore to develop an agricultural mechanization strategy for Kenya which will have both short and long term objectives. Such a strategy needs to be developed by multi disciplinary teams of agricultural engineers, economists and agronomists. It should involve all the aspects of agricultural mechanization - both requirements on the farm as well as manufacturing and servicing of agricultural mechanization inputs. This is the challenge to Kenya's agriculture over the next two decades.

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CHAPTER 7

AGRICULTURAL MECHANIZATION POLICIES & STRATEGIES IN NIGERIA

by

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INTRODUCTION

Nigeria is the most populous country in Africa with a population estimated at 107 million in 1987 and growing at a rate of about 3.0% per annum. About 30% of the population (about 35 million) live in urban areas and are dependent on the rural population for their food requirements. The formulation of policies and implementation of strategies for mechanizing Nigeria's agriculture have not been accorded the necessary attention and both have not been systematically pursued. Although Nigeria is blessed with abundant land with an area of 98.3 million hectares out of which 72% is considered as suitable for agriculture, only about 28.31 million hectares are currently under cultivation. Several efforts by the various governments (Federal and State) over the last three decades to formulate policies and implementation strategies for agricultural mechanization have not been significantly effective due to the ad hoc approach and poor funding and non-integration of engineering technology research and development as well as training and extension within the entire agricultural development system. The current state of agricultural mechanization technology systems management is inadequate in assisting the Nigerian farmer to increase the productivity and overall production of the agricultural sector. Thus essential farm mechanization inputs, including equipment and spare parts are very scarce and their prices are exorbitant and hence not within the reach of majority of the farmers. Consequently, over 90% of farm operations in Nigeria (ranging from bush clearing to land preparation, planting, weeding, pest control, harvesting and primary processing) are still being carried out using handtools which depend entirely on human muscle as the major or only source of farm power. The application of animal power technology is still limited and restricted. In this paper a review of Nigeria's agricultural development efforts with specific reference to agricultural mechanization is presented. The aim is to identify the constraints, review possible options and draw up recommendations for a more realistic approach in the application of agricultural mechanization technologies for an enhanced agricultural development.

PERFORMANCE OF THE AGRICULTURAL SECTOR SINCE INDEPENDENCE

Agriculture is an important occupation in Nigeria. About 70% of the population is dependent on it directly or indirectly for its livelihood. It provides the bulk of the employment, income and food for the nation's rapidly growing population as well as supplying raw materials for agro based industries. Majority of Nigerian farmers are subsistence small holder farmers. They farm about 1 to 2 hectares of land which is usually scattered over a wide area. The farming system is mainly rotational fallow agriculture involving alternating a period of cropping with a period of bush fallow. Some farmers engage in semi-permanent or permanent agriculture and mixed agriculture. Farmers employ family labour and utilize low level mechanization inputs. With the exception of the Northern States where animal power is used, the only tools used by the majority of Nigerian farmers are the hoe, cutlass and harvesting knives. At independence in 1960, Nigeria was by and large, self sufficient in food production, and the bulk of her merchandize exports were agricultural products. Cocoa, palm kernels, rubber, groundnuts, and cotton were the major agricultural exports and Nigeria was a leading world exporter. Since independence however, agricultural policies, strategies, and programmes have undergone many significant changes. These changes were a consequence of changes in governments (from civilian to military - and military to civilian, etc.). In general government philosophy on agricultural development has gone through three major phases from 1960-1970; 1970-1985, and from 1985 to todate.

The period from 1960 to 1970 was characterized by a decentralized approach to agricultural development in Nigeria. The centres of agricultural development activity were the regions or states with the Federal Government playing only a supporting role. As such, approaches to agricultural development were not uniform. But generally, the approaches adopted involved a combination of private sector/small farmer and government direct production approaches. The period from 1970 to 1985 was characterized by a much greater involvement of government, especially the Federal Government, in agricultural development efforts. New policies, programmes and projects were launched at rates that were hitherto unknown in Nigeria. This was, in a way, a reaction to the rapid deterioration in the state of the country's agricultural economy towards the end of the 1960's and the beginning of the 1970's. It was also in response to the devastating effects of the Nigerian civil war on the agricultural economy in particular. More agricultural development institutions were created and more special programmes and projects were launched in the 1970-1985 period than at any other corresponding period in the history of Nigeria. These included the establishment of the Nigerian Agricultural and Cooperative Bank (NACB) and the launching of special agricultural credit schemes; the National Accelerated Food Production Programme (NAFPP); the integrated Agricultural Development Projects (ADPs); the reorganized commodity marketing boards and new food crop

commodity marketing boards as epitomized by the Nigerian Grains Board. The Federal Government took over the procurement and distribution of fertilizers, launched ambitious input subsidy schemes and a guaranteed minimum price scheme for grains. Most of these programmes and projects were instituted and implemented under the ambit of two umbrella "programmes". The first was the Operation Feed the Nation (OFN) from 1976 to 1979 and the second was the Green Revolution Programme from 1979 to 1983. Some of them also found expression in government investment in direct large-scale agricultural production. An important indicator of the degree of government involvement in agricultural development efforts in Nigeria during this period is the amount as well as the relative share of government budget going to agriculture which increased significantly.

The period between 1985 - todate may be characterized as the period of Structural Adjustment Policy where there has been massive devaluation of the naira and reduction in Government expenditure. All these have affected the agricultural sector quite significantly especially investment on agricultural mechanization inputs. Despite huge investments in agriculture, during the period from 1970 to 1985, the performance of the sector has been disappointing. This is evidenced by:

- (a) a decline in the agricultural sector's share of the Gross Domestic Product from an average of about 56 percent in the 1960-69 period to about 20 percent in the 1981-85 period;
- (b) a systematic decline in the share of the country's total labour force in agriculture at an average annual rate of 1.3 percent since 1960 without a corresponding increase in production;
- (c) increasing shortage of food to Nigerians as evidenced by increased food imports and high rates of increase in food prices, particularly since 1975;
- (d) the virtual disappearance of agricultural commodities from the country's export trade; and
- (e) increasing shortage of agricultural raw materials required by industries.

This decline in the agricultural sector has inevitably affected the pace and progress of agricultural mechanization.

AGRICULTURAL MECHANIZATION POLICIES AND STRATEGIES

During the colonial period, attempts were made to improve agricultural mechanization in Nigeria from the handtool technology by introduction of draught oxen technology at Daura in 1922 (Musa 1988). The northern part of

the country (from latitude 12°N) which is tsetse free, and where farmers have the tradition of keeping livestock was a suitable area for such an attempt. Farmers in the southern part of the country, due to the tsetse fly problem had no tradition of keeping draught animals and relied entirely on the handtool technology for their farming operations. In addition the cash crops grown in the south were perennial - cocoa, palm kernels, rubber, as opposed to the north where the cash crops were annuals groundnuts and cotton. Due to the higher rainfall common in the south, the southern farmers have different subsistence food crops - cassava, yams, and plantains which required less primary tillage compared to the subsistence crops of the mid-belt and northern parts of the country - where maize, sorghum, millet are the common subsistence crops. Animal traction was therefore much readily adopted in the north and has remained an important source of draught power up to today. In the early 1950s a few tractors were introduced both in the south and north of the country (Aboaba 1988). By 1956 a Tractor Hiring Unit (THU) was established in the then Northern Nigeria by the State Government, and ploughing was done for farmers at a nominal charge. This became quite popular and demand increased significantly over the next decade. Similar Tractor Hire Units were started in the Western and Eastern states. Due to the nature of the farming systems in the south, and perhaps less demand on an annual basis on tractor power these did not develop initially that well. The Tractor Hiring Unit in Western Nigeria did not get a firm footing until 1958 when tractors were hired out to farmers cultivating paddy in Oyo and Ibadan.

Following the nation's independence in 1960, intensified efforts were made to improve agricultural production through improved mechanization technology by introducing different programmes and schemes. In the late 1960s, Farm Training Institutions (FTI) were established in eight different locations in the Northern Nigeria, namely; Gongola, Borno, Kaduna, Sokoto, Kano, Katsina, Niger and Plateau states to train farmers on mixed farming technologies and the use of oxen for farm work. It was hoped once these farmers returned to their villages, they would pass on the technology to others. The civil war of 1967-70 did interrupt agricultural mechanization efforts in the south of the country. Policy makers however were beginning to get concerned on the pace and scope of agricultural mechanization. Concern was particularly raised on the handtool technology being used in the humid areas of the country. The second national development plan had the following on agricultural mechanization:

"No realistic change can be expected from the present nature of Nigerian agriculture from the drudgery attached to it until the farmer finds an alternative to the hoe and cutlass technique of production. The clearing of bush, the preparation of land, the sowing of seeds, the various post planting operations are all processes in which the farmer's present tools can do little for high productivity per man day or per acre. Removing the physical drudgery and the cause of low output need not, however, involve the use of sophisticated farm machinery

and equipment. Cheap simple implements can replace the hoe and other traditional implements which make farming a tedious and unattractive occupation. The use of small motor powered implements and animal drawn implements and carts will be encouraged. To achieve this, research programme on these problems will be intensified during the plan period" (FMI 1970)

Nigeria was then considering introducing power tillers and small tractors as an answer to the mechanization problems in the south of the country where draught animals cannot be used due to the tsetse fly problem. Other advisors were also advocating trying these power tillers even in the north of the country as it was felt that in the long term draught animal technology will not be adequate to meet the power requirements there (Rana 1971, Gemill and Eicher 1973). The feeling was then that since these power tillers had been so successful in Japan they could also, with some modification, be used in the humid zone of Nigeria where the rainfall was plentiful and the situation there was nearer to the wetland farming system found in Japan which had been successfully mechanized by these power tillers in the 1950s. This trend was however contrary to what the FAO team which had been called in before the civil war to advise on long term agricultural development in Nigeria (1960-1980) had recommended. The FAO team had cautioned against these power tillers. A few of these power tillers had been tried in the Western State and the results were rather varied (Oluwasami 1975, FDA 1971).

The FAO team had cautioned that although small, single axle tractors were superficially attractive they had however never proved successful in any country with conditions similar to those of Nigeria. FAO team alleged that it was common experience that these garden tractors were extremely tiring to operate (especially in tall crops where the exhaust fumes do not disperse) and that there was seldom any marked increase in the acreage that a man could cultivate. Few crops could be harvested by these machines, although auxiliary equipment such as water pumps and sprayers could be very useful in intensive farms such as vegetable gardens. The tractors and implements themselves were expensive because of the low volume of production. Also the selling price was extremely high because the cost of financing, and after sales service is much the same for one garden tractor as for one conventional farm tractor. Operating costs were high in relation to output because of high fuel and repair bills. Many makes were available with a wide range of accessories and implements, but most required careful setting and constant adjustment if they were to perform any useful work. Some were provided with a high speed gear for road work, but the capacity of the trailers was very low and the cost per ton-mile was considerable (FAO (1966)). This advice was however fairly subjective and no figures were given to support the FAO arguments. In addition this type of technology had just then been developed and adopted in Japan and had, in reality never been tried in any Tropical African country by then. A National Study Group on Agricultural Mechanization was therefore in a predicament on what policy to advise to be followed as regards the

mechanization of the handtool technology agriculture in the Southern part of the country.

In their report, the Study Group on agricultural mechanization observed that the engagement of handtools in the country's agriculture "had become a forceful repellent to farmers and it will be progressively more repulsive with time". The study group felt that the priority in research and development of handtools will be futile because of among other reasons: failure of attempts to introduce exotic hand-tools in the past; dearth of experts on handtools; and social attitudes of the farmers towards the use of handtools (FDA 1971). It was felt that the young generation of farmers who would be school leavers were likely to detest the use of any implements that will make farming a more difficult manual work than other jobs (like motor driving, motor vehicle mechanic's work, tailoring, hair cutting, etc.) which people of their own comparable education do. The committee concluded by observing that the effects of any improvements of handtools which may result out of research and development efforts, on agricultural production are unlikely to be spectacular, and thus Government efforts should not be wasted on this technology.

Likewise draught animals were ruled out in so far as the south was concerned, as it was concluded that introducing them would involve not only teaching the farmers the techniques of handling draught animals, but also the techniques of animal husbandry. Doubts were also expressed about the long term utility of draught animals in the tsetse free northern states. Among the reasons advanced for this pessimism was that the northern states had a long dry season and the peak of work demand, came at the end of the dry season when the animals are in poor condition and food for draught animals and people is in short supply. It was also argued that even though the number of draught oxen had increased quite significantly up to 1965, the power provided by the total stock of these draught animals in the entire northern states was by then merely equivalent to 450 medium powered tractors (Rana 1971). It was further argued that even if this high increment rate (of use of draught animals) could be maintained and the limitations of Biological reproduction, the necessity of replacements and such other factors like the recent drought are ignored, it would be more than 40 years before each farmer in the tsetse free areas of the northern states can own a pair of draught animals" (Rana 1971). The technical advice to policy makers on draught animals as a source of power was therefore pessimistic.

Since independence, all the state Governments had introduced Tractor Hire Units (THU). These THU's were owned by Government - Ministry of Agriculture and Natural Resources, or by cooperatives or individual entrepreneurs. They provided tractor hire services to farmers for land preparation (primary ploughing and harrowing) and in some cases even planting and were used for transport during the off season. The agricultural mechanization study group observed that "More operations are now done by tractors, after-sales service has slightly improved and the operator's and the

mechanic's competence has improved with time. Thus the annual output of the tractor has increase considerably. The average yearly hour-output per tractor in the Western State has attained 600 - and 800 - levels for the Government and the private hire services respectively. During the current active season of March-June 1971 the average output per tractor reached 90 and 130 acres (of full complement of regular operations ploughing, discing and ridging or mechanical planting) respectively for the Government and private hire services" (FDA (1971)). Even though an optimistic picture of THU was being reported by the agricultural mechanization study group, a more cautious approach was being advocated by other research workers (Kolawole (1971, 1974); Gemill and Eicher (1973)).

This debate coincided with the first oil boom in Nigeria of 1973/74. Government revenues increased significantly and there was optimism throughout the country. Money was no longer a problem and hence the tractor hire units were significantly expanded. During the period of the Third National Development Plan 1975-80, Federal Government as well as the State Governments expanded their activities in direct production of essential agricultural products by establishing food production companies. The National Accelerated Food Production Programme (NAFPP) was established to use individual farmers to produce and multiply improved seeds of rice, maize, sorghum,, wheat and cassava for wider distribution to farmers for planting. In addition the Nigeria Agricultural and Co-operative Bank and the Agricultural Credit Guarantee Scheme were established for provision of credit for agricultural production. The Governments also expanded their irrigation schemes and rural electrification programmes. In order to facilitate these expanded activities of Federal and State governments in the promotion of the production of some crops and to improve access of small farmers to the services of farm machinery, State and Federal Governments imported a lot of crawler tractors, agricultural tractors and complementing agricultural machinery for establishment of land clearing units; establishment of tractor hiring units; establishment of central, field and mobile workshops to provide repair and maintenance of farm machinery. The extent of subsidies by governments on land clearing and tractor hiring services ranged from 30 percent in some states to 75 percent in other states. Some state governments also undertook the purchase of Agricultural equipment and spare parts for resale to farmers at subsidized prices.

During the Third National Plan period, seven states namely Kaduna, Sokoto, Bauchi, Benue, Plateau, Kwara and Niger with the assistance of the Federal Government and the World Bank established the Agricultural Development Programmes in Funtua, Gusau, Gombe, Ayangba, Lafia, Ilorin and Bida to improve socio-economic activities such as agriculture, rural road construction, dam construction, water supply, livestock production etc. A component of the programmes is the establishment of Farm Service Centres (FSC) from which small-holder farmers could obtain items of farm inputs including farm machinery. As a result of all the activities described above,

massive importation of land clearing equipment, road making equipment, agricultural tractors and machines took place during this period.

In addition the National Centre for Agricultural Mechanization was established as part of the Federal Department of Agriculture. The Centre was sited at Ilorin, Kwara State with the following objective, among others:

- provision of guidelines with respect to importation of agricultural machinery.
- encouragement and motivation of local design and manufacture of equipment and machinery for agricultural production for the various local conditions.
- aiding and promoting effective cooperation among various institutions by encouraging multi-disciplinary approach in the improvement of mechanization of the agricultural production processes.
- provision of supplementary facilities for manpower training and development in the different fields of agricultural engineering.

During the Fourth National Development Plan 1981-85 Government policy of direct agricultural production was modified and changed to equity holding in commercial ventures with the private sector. Emphasis was therefore placed on encouragement of private entrepreneurs to establish large scale farms. Agricultural production and processing was transferred from Schedule II to III of the Nigeria Enterprises Promotion Act to allow foreigners to own up to 60% of the equity of an agricultural enterprise. Commodity Boards, Grain Production Company and State Agricultural Development Corporations were encouraged to go into partnership with private indigenous or foreign investors in establishing large scale farms. The main highlights of the policies and programmes for agricultural mechanization during the Plan period were:

- (a) making agricultural machines available to the farmers through the Federal and State programmes of provision of mechanical services under the agro-service system (FSC) and through subsidizing the purchase of mechanical equipment by individual farmers.
- (b) establishment of about 285 agro service centres and mechanical workshops for facilitating access by farmers to farm inputs as well as agricultural machines.
- (c) provision of subsidy to encourage farmers to mechanically clear land and to bring under cultivation a total of 250,000 hectares

between 1981 and 1985.

The latest policy document, the Agricultural Policy for Nigeria reprinted in April 1989, still emphasises the following as the objectives of mechanization policy in the country:

- (i) Reduction of the drudgery of agriculture by providing mechanical power to replace some of the labour required in agricultural business.
- (ii) Reduction of high cost of agricultural production which arises from high labour wage rates and the high share of labour cost in the total cost of agricultural production.

A number of strategies mapped out in the Agricultural Policy for achieving the objectives stated above summarized the thrust of post independence efforts in promoting access of farmers to agricultural mechanization. These strategies are reproduced below for ease of reference:

- "(i) The responsibility for land clearing for agricultural purposes will essentially be that of agencies of the state governments. In this regard, government will provide advice on proper agricultural land clearing methods as well as regulate the activities of all land clearing and development agencies.*
- (ii) Government will, in appropriate cases, subsidize agricultural land clearing.*
- (iii) To promote privatization of tractor hiring units, state governments will be encouraged to support a programme of assistance to entrepreneurs to enable them to get bank loans to set up private agricultural mechanization enterprises and/or tractor hiring units (THUs) and repair workshops.*
- (iv) Training will be provided to tractor and land clearing operators in the proper use of these equipment to prevent soil loss and reduce soil erosion.*
- (v) The use of small motorized farm machines, ox-drawn equipment (animal traction) and processing equipment will receive greater attention than ever before. The identification of such machines and their local development and fabrication by the use of small-scale farmers will be promoted on a continuous basis. Government will also promote the local manufacture of medium and large size farm machinery for land preparation, crop cultivation, harvesting, processing and storage on large-scale farms.*

- (vi) *The development of the National Centre for Agricultural Mechanization will be accelerated to enable it to perform its function of standardization of farm machinery and equipment and the promotion of the production of locally designed prototypes.*
- (vii) *Active encouragement will continue to be given to Universities, Polytechnics and Research Institutes on accelerating the development and local fabrication of suitable equipment for use by intermediate and small farmers. The participation of the private sector in the commercialization of prototypes will continue to be promoted."*

Thus the agricultural mechanization policies and strategies in 1989/90 in Nigeria have moved through a complete cycle back to where we were in 1970-73 where the emphasis was on power tillers and tractor hire units. From a technical point of view one could argue that the oil boom years (1974-89) were years of confusion in so far as agricultural mechanization policy formulation is concerned. There was no clear policy on agricultural mechanization and there was a lot of ad hocism on the agricultural mechanization front. It was also the period when there was unprecedented massive importation of tractors into the country. This massive importation has however not changed much the way our agriculture is undertaken for it is still dominated by the handtool technology. It is not even clear how many tractors are available in the country. For although statistics do show that on the average between 1979-85 the country has been either importing or locally assembling about 2000 tractors per annum, our survey of 1985 shows that there were only 15,900 tractors in the country by December 1985. From 1975-83 a total of about 22,000 tractors were sold in Nigeria. (Makanjuola 1984) (Anazodo *et.al.* 1986) (see Table 20). FAO figures do show that the tractor population in Nigeria has never exceeded 11,900 between 1970-1987. If the importation figures are an indication of the tractor numbers available, then the number should be by far above 16000 tractors, otherwise the rate at which tractors get out of use in Nigeria is quite high (Table 21).

Another critical issue, in so far as agricultural mechanization policy is concerned, is the role of Draught Animal Power in agriculture. This is particularly important for the Northern States of Nigeria which are tsetse free and livestock keeping plays an important role in the agricultural system. The use of draught animals started in Northern Nigeria from 1928. (Gwami (1990); Phillip *et.al.* (1988)). It is estimated that up to 1965 only 36,000 farmers had adopted this technology (mostly in ridging) (Gwami 1990).

Further it is estimated that by 1980 only 100,000 farmers were using this technology out of a total of 7.115 million farmers in the Northern States of Nigeria (less 1.5% of farmers) and they were cultivating less than 6% of the total area cultivated per year (see Table 19). The factors which have led to this low level of adoption despite over 60 years of extension effort, and the fact that farmers in the North have a livestock keeping tradition include lack of

appropriate implements, the oil boom in the 1970s which led to farmers preferring the socially more prestigious mechanical power cultivation, etc. among others (Gwami 1990, Phillips *et.al.* 1980, Gefu *et.al.* 1990, Otchere *et.al.* 1988). In addition there is a large scale manufacturer of animal draught implements based in Kaduna (EMCOT Ltd.).

TABLE 19: Estimates of area under different cultivation systems in Northern States of Nigeria

	<i>Cultivation systems</i>		
	Hoe	Animal Power	Tractor
Number of farmers (million)	7.5	0.1	0.015
Area cultivated (ha/farmer/year)	1	5	50
Total area cultivated annually (million ha)	7.5	0.5	0.75
Per cent of total area (%)	86.0	5.5	8.5

Source: Phillips *et.al.* 1988

All studies by socio-economists and livestock scientists do show that this technology ought to be profitable if adopted by farmers. Yet the statistics as in Table 19 do show that 86% of the cultivated land is still cultivated by the back breaking and arduous handtool technology. In addition other studies do show that there is a shortage of labour especially during the peak of the season. (Norman 1975). Why then have farmers not adopted this technology? Millions of dollars have been spent, by the State Governments, Federal Government and donor agencies such as the World Bank in popularizing this technology over the past 60 years but the adoption rates, from the empirical evidence available are quite disappointing. It is important that research is undertaken to determine why this technology has not been adopted inspite of its apparent advantages and long term extension efforts. It certainly has room, in particular in the Northern States, but its adoption rate so far, does show that there is something wrong - whether in the way it is being extended to farmers, cost, or in the technology itself. This requires research. There is no point in spending million of dollars, on this technology, if what can be shown, after 60 years, is an adoption rate of less than 6% of the cultivated land and with 86% of the cultivated land still being cultivated by the handtool technology.

MANUFACTURE OF AGRICULTURAL MACHINES

In Nigeria, three levels of agricultural machinery manufacturers can be identified: (a) modern large-scale tractor assembly plants; (b) medium-scale manufacturers; (c) hand-tools manufacturers. There are at present two tractor assembly plants in Nigeria, namely the National Trucks in Kano and Steyr Nigeria Limited, in Bauchi. The factories were set up to assemble lorries and agricultural tractors, e.g. the Steyr plant in Bauchi has an annual capacity for assembling 8,000 lorries and 2,000 agricultural tractors. The total annual production capacity of the two assembly plants is 5,000 tractors. The two plants

commenced production in 1980. Table 20 shows the relationship between imported completely built units (CBU) of tractors and the units of locally assembled tractors. The high sales of 1980 and 1981 are a result of the Green Revolution campaign efforts of the various governments in Nigeria. The capacity utilization of the assembly plants has ranged from 20-54% and it is apparent that this utilization rate is low. Steyr assembles two basic models, the 60 kW (80hp) two wheel and four-wheel drive types, and the 82 kW (110 hp) two-wheel and four-wheel drive types. The Fiat Company produces also two basic models of comparable sizes.

TABLE 20: **Break-down of tractors sold in Nigeria**

Year	CBU (imported)				Units locally assembled		Total
	M.F.	Ford	J.D.	Others	Steyr	Fiat	
1979	-	-	-	-	-	-	600
1980	500	350	300	-	900	950	3,400
1981	1,550	-	150	355	1,822	1,623	3,400
1982	260	-	570	-	450	570	1,850
1983	-	-	660	-	740	600	2,000

M.F. - Massey Ferguson; J.D. - John Deere

Apart from low utilization of their installed capacities, tractor assembly, like heavy truck assembly which is the main function of the plants, did not do well for many reasons. In particular, local manufacture of components did not develop. Thus with the introduction of Structural Adjustment Programme, the devaluation of the naira and the high bank interest rates, it has become very prohibitive to purchase tractors assembled from imported semi-knocked down parts e.g. the cost of a medium size agricultural tractor and a set of matching implements ranges from US\$25,000.00 to \$40,000.00.

Animal drawn implements manufacturing has enjoyed reasonable success in Nigeria. The pioneer company, John Holt Agricultural Engineers Limited produced about 4000 units of animal drawn implements in 1966. The production went up to between 8000 and 10,000 units annually with exports to ECOWAS countries like Ghana, Mali, Togo, Republic of Benin and Zaire. The most common animal drawn implement is the Ransome Emcot plough and ridger. The other animal drawn implements manufactured are carts and trailers. Manufacture of post-harvest processing equipment has been boosted by the advent of the Structural Adjustment Programme. Efforts are now being made to produce some of these processing machines locally as the cost of importation has gone up considerably. In particular, livestock feed mills, rice dehullers, grain threshers and maize shellers are produced by many

companies. These companies however have difficulties in obtaining credit facilities, raw materials, standard parts and semi-manufactures like bearings, electric motors and small petrol engines.

TABLE 21: Estimated Agricultural Machinery in Use in Nigeria at the end of December 1985

Type of Agricultural Machinery	Total Number in use
Farm Tractor (four-wheeled or two-axle)	15,906
Crawler Tractors	1,256
One-axle Tractors	419
Trailers	4,529
Disc ploughs	9,544
Disc harrows	7,953
Sprayers	6,362
Ridgers	4,529
Grain Planters	1,361
Root and Tuber Crop Planter	5
Cultivators/mechanical weederers	258
Grain Harvesters	163
Grain Threshers	1,022
Grain Shellers	2,710
Crop Dryers	263
Modern Storage Structures	128

Source: Anazodo et.al. (1986)

Hand-tools are produced mainly by local craftsmen and artisans. Their products are, in the main, hoes, cutlasses, and harvesting knives. The needs of the farmers for these categories of hand-tools are met by these manufacturers. The major drawback of this level of manufacturing is the use of metals that are not hard wearing and rust-resistant, and the application of low-level technology. Their manufacturing technology, has in many cases remained that of 19th century. In many cases these are family owned undertakings and the technology is passed from father to son. There has not been any serious attempt to have a vertical integration between these village blacksmiths and the more sophisticated medium and large scale manufacturers of agricultural implements. Further, little has been done to upgrade the skills and plant of these village blacksmiths. An agency may be required to be set up which can help these village level artisans who are now playing a crucial role in manufacturing of handtools (which is crucial for agriculture in the whole country) so that they can improve their fabrication and manufacturing technologies. They should also be assisted by being integrated vertically with the medium scale and large scale manufacturers and also to diversify into other services like repair and maintenance of agricultural machinery and implements including tractors.

RESEARCH AND DEVELOPMENT EFFORTS

There have been quite a number of research and development efforts in Nigeria in the field of agricultural mechanization. These have been undertaken mostly by Departments of Agricultural Engineering in Universities and Polytechnics. Although the National Centre for Agricultural Mechanization is supposed to spearhead agricultural mechanization research activities in the country, it has not been able to perform this function for a number of reasons. The National Centre in an in-house publication entitled *"Brief on Achievements, Capital Expenditure and Constraints in the Establishment of the National Centre for Agricultural Mechanization at Ilorin, Kwara State"* discussed the constraints militating against the development of the centre. These constraints included amongst others:-

- "(i) Failure to promulgate the enabling decree that will establish the Centre as a semi-autonomous unit within the Ministry of Agriculture and Natural Resources.*
- (ii) Failure to appoint a full-time Director for the Centre thereby subjecting it to frequent changes of policies where the supervising senior staff in the ministry is replaced by a new man. Each time there was a change, the new staff needs time to acquaint himself with the project before taking policy decisions on the centre. This slowed down the progress of the Centre.*
- (iii) Inadequate funding leading to non-completion of the physical facilities, non-procurement of adequate laboratory and workshop equipment.*
- (iv) Shortage of experienced staff."*

Thus the contributions of this centre in R&D efforts have so far been quite limited.

Most of the research results in farm mechanization come from Universities and Polytechnics and a great proportion of these activities are devoted to the design and development of equipment and machines. Many of these results have not gone beyond the stage of publication in journals for a number of reasons some of which include:

- (i) Reward system in Universities places a high premium on journal publications without regard to the potential industrial application of the research work.*
- (ii) Scarcity of manufacturing firms with good understanding and mastery of industrial production processes and who have the capacity for taking the risks of developing research results into marketable products.*

- (iii) Scarcity of raw materials and semi manufactures such as bearings, etc.
- (iv) Scarcity of manpower with good experience in industrial research, industrial process, management and marketing.
- (v) Reluctance of banks to support investment in agricultural equipment manufacture.
- (vi) High interest rates resulting in difficulties in raising working capital to produce locally developed machines.

These are some of the factors which have so far impeded the building up of a well developed local research and development capacity.

EMERGING ISSUES FOR CONSIDERATION FROM NIGERIA'S EXPERIENCE

With the adoption of the IMF's advised Structural Adjustment Programme (SAP) and some of positive effects of the activities of the newly established Directorate of Food, Roads and Rural Infrastructure, the National Directorate of Employment and various agricultural promotional schemes of state governments as well as the Federal Government, many Nigerians have taken up agriculture either as a full time employment or to supplement their family incomes. The present momentum can only be sustained on the basis of vast increment of inputs used and the adoption of farming systems that will allow these inputs to be put into effective use. In terms of mechanization there is a need for considerable increment in the quantity and quality of agricultural machinery and implements available for all phases of agricultural operations. With current exchange rates, the amount of local currency required to support the foreign exchange necessary for the importation of agricultural machinery is enormous. There is therefore a need to fabricate/manufacture the machines locally. In order to develop this local capacity, the nation needs to re-examine some of the policies and strategies on:

- farming systems
- research priorities in equipment development
- bridging information gap
- creation of data bank of manufacturing plans
- commercialization of research findings
- expansion of indigenous manufacturing capability and capacity
- industrial extension services
- need to standardize machinery & equipment imported.

Let us consider each in turn.

Farming Systems

During the late 1970s, IITA in Ibadan carried out a number of experiments on zero tillage and developed a variety of equipment pulled manually or by a single axle tractor for planting, fertilizer application and weed control. The rotary injection planter for planting cereal grains through surface thrash was a particularly useful equipment. Despite all the advantages of soil preservation under this system and the fact that there is no need for conventional land preparation of ploughing and harrowing, farmers did not adopt the system. It is important therefore, to re-examine this technology and remove whatever impeding factors farmers faced in adopting it. The main reasons for resuscitating interest in this farming system include among others: the system improves soil fertility and prevents soil erosion and the system is based on low power equipment input. The main machines are the micron sprayers, the single axle tractor as the prime mover and complementing implements like the rotary injection planter and fertilizer applicators. The advantage is that, at the present level of manufacturing capability, all the machines, with the exception of the single axle tractor, and a few specialized parts (e.g. bearings, etc); required by this farming system can be manufactured locally.

Research Priorities in Equipment Development

Hand tools - It is important for research efforts to be directed at more rewarding problems. While the improvement on the hoe handle, shape and quality of hoe blade may raise hoe efficiency, the increase in productivity with this system cannot be spectacular. In short, with respect to the hoe and cutlass, no amount of improvement, in their efficiency and management, no greater effort in terms of use of better materials and no amount of improvement in the design of blades can transcend the technical limitations that result from the fact that these tools still have to be powered by human muscles. Having made this observation, it is important to note that the hoe and cutlass are the only tools available to the farmers. In the recent past, the costs of these tools have risen significantly especially in the case of cutlass which is normally imported into the country. There is therefore a need to develop the local capacity for producing better quality hoes and cutlasses which does not require much R&D effort.

Animal drawn equipment - The use of animal power should be expanded in the tsetse free areas of Northern Nigeria. In order to facilitate the achievement of this objective, efforts on the creating of grazing lands for livestock should be intensified. The design of suitable yokes should be improved so that an increased number of animals can be put to work simultaneously thereby increasing the work output per unit time. However as we noted earlier, there is need also to undertake research on why this technology has not been widely adopted in the Savannah belt despite over 60 years of extension efforts. Currently less than 6% of the cultivated land in the northern states is cultivated by use of this technology (Phillips *et.al.* (1988)). Socio-economic studies have

shown that this type of technology increases both the productivity of labour, as well as timeliness of operations. However its adoption has been quite limited and in most cases only the ridger has been adopted. There is need to determine whether the problem is with the technology itself; method of extension, or there are other unknown factors which impede its adoption. It is obvious that millions of dollars have been spent in research, development, manufacturing and extension efforts on this technology over the past 60 years. The adoption rates are however quite disappointing. It is important to determine what is the problem.

Motorised equipment - Modernization of agriculture cannot take place without some measure of motorization. Refusal to use motorized machine will result in condemning farmers to perpetual menial, arduous, low level productivity jobs, which may consume a lot of energy but which require very little skills. If jobs do not require a lot of skills, workers behave like machines, making only the simplest or no decisions. They can therefore be replaced by motorized machines which when controlled by skilled operators will do the work better, faster and more effectively. With the cost of a conventional medium power tractor and implements ranging from US\$30,000.00 to \$40,000.00, it will be difficult to satisfy the mechanical mechanization needs of the farmers in spite of the renewed interest of the various governments in the tractor hire services. It is therefore important to put emphasis on machines that can be powered by small two and four stroke petrol and diesel engines. With this approach in view three groups of machines are of interest. The first group consists of equipment for transporting people and material in the rural areas. In the Northern States where animal power is available to pull agricultural equipment, the use of animal drawn carts must be expanded. With the high current costs of conventional agricultural tractor, the idea of a multipurpose transport equipment which could double as a vehicle with load carrying capacity of 250 to 500 kg and as a device for pulling agricultural implements becomes attractive. Research activities should therefore be devoted to reactivate interest in this group of equipment. Efforts in this area should start by reviewing past experience in the World in this class of vehicles. The scope of current efforts of the Directorate of Food, Roads and Rural Infrastructure in the development of a tricycle for use in the rural areas should be widened to include the development of the multipurpose transport equipment. The experience gained from the tricycle indicates that a 250 to 350 cc two stroke petrol engine capable of developing 15 to 20 kW will be adequate for the multipurpose transport device. In order to facilitate the evolution, use of existing standard components and sub assemblies like gearboxes, differential units and clutches from the motor cycles, dumpers and similar vehicles should be considered. The search for this multipurpose vehicle should benefit from experiences of similar vehicles such as the small four-wheel tractor manufactured in Thailand, the IRRI three wheel motorized cart, small four wheel tractor developed by IRRI-PAK programme, the Tinkabi tractor manufactured in Swaziland and the Eicher tractor manufactured in Haryana, India.

In order to complement the multipurpose transport vehicle, there will be a need to develop a set of matching soil working, seed planting, fertilizer spreading and similar equipment. The second group of equipment which are mainly post harvest machinery has enjoyed some attention within the country. A number of local designs are available for threshers, shellers, decorticators, mills, pulpers and hullers. The designs need to be expanded to include crop destoners particularly rice destoners as well as water handling equipment like irrigation pumps. The third group of equipment which has not attracted enough attention consists of manual or motorized crop maintenance equipment like dusting equipment, sprayers and spreaders for insect and weed control.

National Centre for Agricultural Mechanization - The National Centre for Agricultural Mechanization as an engineering research centre in agriculture should be resuscitated by:

- (i) enacting the enabling decree to make the centre function
- (ii) providing adequate funding so that the centre can acquire equipment and facilities for workshops, laboratories and field research, as well as staff
- (iii) providing adequate infrastructural facilities on the site.

Creation of a data bank of manufacturing plans - Among the major problems which small scale manufacturers face are lack of in-house capacity and capability for producing technical drawings and technical specifications for machines to be manufactured, lack of financial capacity to engage the services of consultants to produce such drawings and in general lack of access to such information. It is helpful therefore to have a national bank of designs and drawings and technical specifications for a set of equipment needed by the farmer. In order to achieve this objective, the following suggestions are recommended for consideration:

- (i) Establishment of the quantity of equipment requirements of farmers for the various agricultural operations.
- (ii) Documentation of agricultural machines developed by the various research institutes, universities and polytechnics.
- (iii) Preparation of design drawings and technical specifications for all types of equipment required by the farmer.
- (iv) Dissemination of the drawings and specifications among indigenous machine manufacturers.

It is noteworthy to give briefly the experience of the Directorate of Food, Roads and Rural Infrastructures in this area. The Directorate at inception was faced with the problem of promoting indigenous manufacture of equipment for the nation's rural development programme. It was noted that the manufacturers do not have drawings of such equipment and that they lack technical and financial capability and capacity for producing the drawings. The Directorate decided to undertake production of such drawings and the

guidelines for manufacturing of the machines from the drawings. Prototypes of the machines are produced to prove and debug the drawings which are then given to manufacturers to use. Some of these drawings are done in-house while others are done with the help of consultants. The experience so far indicates that this is a very useful experiment as: the in-house ability to produce design drawings for the machines improved continuously with time; the consultants have also benefited considerably from the designs; the manufacturers find the design drawings and technical specifications very useful and cost saving.

The National Office of Industrial Property working in close collaboration with the Standards Organization of Nigeria, the National Centre for Agricultural Mechanization, African Regional Centre for Engineering Design and Manufacture, the Universities and the Polytechnics could coordinate and keep the data bank. It could release periodic newsletters on the information available in the data bank and circulate this information to small scale manufacturers who could then select and request whatever they want for free or for a fee.

Encouragement of local manufacture of agricultural machinery - The Structural Adjustment Programme has created a favourable environment for local manufacturing of equipment. The establishment of the National Economic Reconstruction Fund is designed to stimulate manufacturing capability and therefore create a more favourable environment for the manufacture of engineering products. However attention still needs to be given to some factors which tend to negate the favourable environment.

These include:

- (i) high interest rates which has made borrowing for investment in manufacturing activities quite difficult.
- (ii) difficulties experienced by small scale manufacturers in obtaining loans for working capital from the banks.
- (iii) high cost of manufacturing plant and machinery which have to be imported because the Machine Tool Industry in Nigeria is still in its infancy.
- (iv) difficulties in getting the design data and manufacturing details, and
- (v) difficulties in getting special steels and other raw materials locally for manufacturing, because the existing steel companies do not produce special steels.

In order to further improve the conditions for promoting local

manufacture of agricultural equipment, there is a need for setting up facilities for producing special steels in the country and for developing more industrial centres in different parts of the country. The plan to have industrial estates served with basic infrastructure at every local government headquarters must be pursued more vigorously. In addition, information or data bank on the quantity and types of machines required for ensuring adequate level of mechanization must be established. This will help direct the attention of manufacturers to the essential machines. The usefulness of this information will be enhanced if there is an inventory of existing equipment in use in the country. The National Centre for Agricultural Mechanization or the bank for manufacturing plans suggested above if properly staffed and financed should be in a position to undertake these assignments.

Industrial Extension Services & Basic Industries

The role of the Standard Organization of Nigeria, in these early stages of industrialization should be more of promotion and encouragement of manufacturers as against attainment of higher level of quality in their production. The document entitled "Report on Nigeria Audit of Indigenous and Emerging Technologies/Machinery for Processing Agricultural Raw Materials into Industrial Input Volumes I and II" published recently by the Raw Materials Research and Development Council contains information on agricultural processing equipment for manufacturers is helpful in locating sources from which such equipment can be obtained locally. The coverage of subsequent editions of this document should be expanded to cover the whole spectrum of agricultural machines. In addition the document should be up dated regularly perhaps bi-annually. Each state is expected to have an Industrial Development Centre. These centres are expected to provide industrial extension services in the states. Experience to date shows that the centres are ill equipped, poorly staffed and underdeveloped for this purpose. It is therefore important to have adequate funding and programmes for industrial extension and liaison services for small scale industries in agricultural machinery manufacture and agricultural products processing. The manufacture of agricultural machine and equipment employs the same process, tools and production equipment as for the whole of metal working industry. Agricultural machines manufacture could therefore generate the driving force in stimulating manufacturing activities which the motor vehicle assembly industries may have failed to achieve. If the momentum is maintained and there is vertical integration between the small scale manufacturers and the medium and large scale manufacturers, then an industrial base can be built up.

Need to Standardize Equipment & Machinery Imported

During the oil boom years, there was a great proliferation of the types of tractors and agricultural equipment imported into Nigeria. For example, in 1976, ninety five percent of the tractors were of medium size (about 37 kW) and 2 percent were high (75 to 104 kW). In that same year, about 10 companies

were involved in the distribution of different types of tractors like Ford, David Brown, Steyr, John Deere, Fiat, Massey Ferguson and Deutz. The estimated importation that year was about 2000 tractors. The total tractor stock in Nigeria by that year was estimated at 19,000 units. Thus, with such a small population of tractors, a high diversity in the types and the large number of distributors, it is not surprising that dealers do not stock enough spare parts necessary to keep the tractor in operating conditions. The establishment later on of the two tractor assembly plants was aimed at correcting this problem. Other types of agricultural machines like the combine threshers etc. which have been imported in smaller quantities also showed almost as much variety as the tractors, in the types and sizes that were imported. The problems resulting from such low volumes of sales are poor after-sales service and inadequate supply of spare parts. State governments in order to tackle these after sales problems decided to purchase up to 10 percent of fast moving parts along with new machines. The success of this policy depended on the good judgement and ability of the maintenance engineer to stock the right and proper parts. This also tied down a lot of the operating funds of the Ministries. State Governments also set up mobile workshops to help farmers repair their machines. The encouragement given to dealers to allocate 15 percent of initial cost of machine order to the supply of spares did not yield the expected results because dealers did not cooperate and did not stock spare parts at the level suggested. There is need to examine this issue further. It is important for the government to standardize the tractor fleet to two or three makes and then assist in the establishment of the right dealership for these makes and spares. Nigeria government should decide on this and ensure that either by decree or legislation that the tractor and other expensive agricultural implements are standardized to two or three makes. Care should be taken to avoid creating a monopoly from one or two countries.

Improving Performance of Tractor Hire Units

There is need also to look into ways and means of improving the performance of the tractor hire units be they Government owned and managed or privately owned. Experience with these tractor hire units (THU) so far has been either disappointing in so far as their profitability is concerned. Given the large numbers of smallholder farmers who require services from these units, it is important that we develop better ways of managing them. In the early years, some of THU had begun to show some profits in particular the private ones. What is important in our opinion is to manage such units in a commercial manner, without interference from the political and civil service system. Experience shows that they can be successful if they are managed commercially, supported in training of their operators and are allowed to charge commercial rates for their services. This is an area where the research systems need to come up with better management systems for such THU's.

CONCLUSION

In this paper, we have reviewed agricultural mechanization policies in Nigeria over the past 3 decades. Mechanization wise, Nigeria's agriculture has a dual system with majority of farmers in the south of the country relying on the handtool technology and the farmers in the north relying on a combination of handtool and animal powered technologies. There have been several attempts at introducing mechanically powered technologies in both parts, but so far the situation has not changed much. The formulation of agricultural mechanization policy and working out of an implementation strategy has, by and large, been done in an ad hoc manner without clear objectives both short and long term. It is however the desire of everybody from politicians, military leaders, academics and the common man himself, that the small holder farmer should be liberated from the drudgery of the handtool technology. With the oil boom of 1974-75 there was a massive increase in the tractor stock in the country from less than 1000 tractors by 1971/72, to over 7500 tractors by 1974/75 (FAO, 1972, 1982). However success with mechanically powered mechanization has been elusive.

With a population which is currently over 100 million, and with about 30% of this in urban areas, and this population is expected to increase to about 157 million by 2000 AD with a similar proportion in urban areas, the demand for food and other agricultural products is going to increase quite significantly over the next decade. In the past the oil boom allowed Nigeria to meet its food deficit through importation, but now with the Structural Adjustment Programmes, this is not possible. The food has to be produced locally. There is no way that this food can be produced without increased levels of mechanization of Nigeria's agriculture. Increased population will also put more pressure on the agricultural system, and the slash and burn agriculture practised in the humid south cannot environmentally be sustained. Better ways of clearing land, which are environmentally safe will have to be developed. All this requires increased utilization of agricultural mechanization inputs. It is imperative therefore for the country to formulate better agricultural mechanization policies with clear short, medium and long term objectives. The formulation of such policies will have to be coupled with drawing up of implementation strategies and in all this, the aim should be not only to reduce drudgery to the farmers but also ensure the sustainability of the agricultural resource base i.e. land as well as increasing agricultural production and productivity.

CHAPTER 8

A REVIEW OF AGRICULTURAL MECHANIZATION STRATEGIES FOR SMALL SCALE FARMERS IN SWAZILAND

by

D. Agrippa and P.K. Lukhele

INTRODUCTION:

The Kingdom of Swaziland is a small landlocked country in Southern Africa surrounded on three sides by the Republic of South Africa, and on the remaining side by the Republic of Mozambique. The country has been independent since 1968. With a total area of 17,364km² Swaziland is the second smallest country in Africa. The country is also small in terms of population which is about 800,000 with an average population density of 28 per km². Being an agriculturally based economy, 86% of the population reside in rural areas. Though well diversified and enjoying favourable growth, the economy is also characterized by the familiar dualism which exists between traditional and modern sectors of many developing nations. The modern sector is chiefly engaged in production and processing of primary products for export e.g. timber, sugar, cotton, citrus and pineapples.

The country is physically divided into 4 ecological regions running from North to South. In the West there is the Highveld at 900-1800 meters above sea level; Middleveld, 300-1000 meters; Lowveld 600-700 meters; and the Lubombo region at 300-800 meters which is in the eastern part of the country. The rainfall varies according to the ecological zone as:

Highveld	- 1200mm average rainfall
Middleveld	- 800-900mm average rainfall
Lowveld	- 300mm average rainfall
Lubombo	- 900mm average rainfall

Most of the rain falls in the summer (October-March) while the winter months are usually dry. The agriculture sector plays a crucial role in Swaziland's economy and is by far the most important sector in the economy.

In this paper we shall review the agricultural mechanization policies and strategies in Swaziland with special reference to the small holder sector. Before doing this however we need first to briefly highlight the main features of Swaziland's agriculture. This will be followed by analysis of agricultural mechanization policies adopted by the Government and the implementation

strategies. We should however caution that our analysis concentrates mostly on the small holder sector where Governments efforts have been directed. However this sector produces only a fraction of Swaziland's agricultural output and mostly for subsistence. The bulk of the agricultural production is undertaken in the large scale commercial sector. The picture may not therefore be complete in so far as agricultural mechanization in Swaziland is concerned.

AGRICULTURE IN SWAZILAND

Swaziland's agriculture is characterized by its duality which is based on two forms of land tenure systems. On one hand, is the traditional system of land tenure practised on the Swazi Nation Land (SNL) where all land is held in trust by the King and small scale farmers predominate in these areas and practise mostly subsistence agriculture (Table 22). This Swazi Nation Land now constitutes about 63% of the total land area of the country and is owned communally by the Swazi people and vested in the King who holds it in trust for the Nation (close to 10% of the land under the SNL is managed on commercial basis in the so-called Lifa and Tibyo land or used as Government livestock fattening and breeding ranches). On the other hand are the freehold lease lands owned under the Individual Title Deeds (ITD). About 518,393 ha of this land is owned by foreigners or large multinational corporations growing cash crops such as sugar, citrus, pulp-forestry; and some ranches. A comparatively large number of Swazi nationals have brought land from foreigners and are now farming it as medium and large scale commercial entities. They now farm close to 100,000 ha under this system (Table 22).

TABLE 22: **Land Ownership in Swaziland**

	Hectares	% of Total
Total rural land area	1 643 530	100
Swazi National Land (SNL)	874 924	53
Purchased for SNL since independence	157 743	10
Total SNL	1 032 667	63
Title deed farms		
owned by Swazi citizens	92 520	6
owned by foreign companies	518 343	31

SOURCE: Low (1986)

The ITD farms are predominantly capital intensive and in many cases managed by expatriate managers. They are quite important as they account for about 53% of the Agricultural GDP (AGDP) - (which in turn contributes about

43% of the GDP - including forestry - and employs about 50% of all employees in the wage sector). On the other hand although the SNL constitutes about 53% of the land area it contributes only about 21% of the agricultural GDP, with the remaining 26% of AGDP coming from agro industries. The production of the major commercial crops (excluding forestry products) is shown in Table 23. Thus only maize production (which is mostly a subsistence crop) is dominated by the SNL.

AGRICULTURAL MECHANIZATION STRATEGIES

As with the dual structure of the agricultural sector, the mechanization strategies have by and large followed a dual system with the ITD farms being highly mechanized and the SNL farms relying to a large extent on Draught Animal Power (DAP) and handtool technology. The proximity of Swaziland to South Africa, where the white farmers have had a long tradition of mechanized farming and many Swazi nationals were hired as farm workers and miners there from the last century, has made it easy for many Swazi nationals to adopt the draught animal technology. The adoption of DAP was also assisted by the fact that the Swazi's traditionally keep cattle and hence this made it easier for them to use them for tillage and transport.

TABLE 23: **Production of various crops by ITF & SNL (1981/82) (Tonnes)**

	<u>ITF (%)</u>	<u>SNL (%)</u>	<u>TOTAL</u>
Cotton	5 810 (41%)	8 445 (59%)	14 255
Sugar	408 000 (100%)	0 (0%)	408 000
Pineapples	35 150 (100%)	0 (0%)	35 150
Maize	4 724 (8%)	52 267 (92%)	52 991

SOURCE: **HUNTING (1983)**

As an agency responsible for the development of small-scale agriculture in Swaziland on the SNL, the Ministry of Agriculture and Co-operatives (MOAC) is also responsible for encouraging the development of appropriate mechanization techniques which should hopefully enable the sector to maximise its productivity in food production especially maize and cash crops in the most economic and most effective manner having regard to holding size, labour availability, skills and support activities. The traditional sector consists of about 58,000 small scale Swazi Nation Farms with an average size of less than 3 hectares. These farms are run largely on traditional lines employing family labour and draught animals and producing food mainly for subsistence. About 80% of the crop area is utilized for maize production, maize being the national staple food.

USE OF DRAUGHT ANIMAL POWER

The use of draught animals (mainly oxen) for the first ploughing is still widespread - over 60% of homesteads use them for ploughing and planting although the use of oxen typically results in the maize crop being planted at least 4 weeks after the optimum planting date. Research indicates that late planting can lead to losses of up to 5% in yield for each week of delayed planting. A mechanization study undertaken in Swaziland by a team from British ODA in 1979 found that, at that time, the economic cost of using oxen for first ploughing was double that of hiring of a tractor. There is also a conflict between the use of oxen as the principal source of farm power, and the strategy of cattle destocking to reduce overgrazing of the veld in particular as cattle numbers are already quite high and this is major cause of soil erosion (Ebinu 1985).

Modern industrialization is giving rise to labour migration to towns and to S. Africa leading to a shortage of physically fit men to train and operate the oxen. There is significant and continual leakage in the skills available to train and operate oxen as traditionally women do not perform such tasks. On the other hand, oxen represent a sustainable source of farm power from renewable resources, and cheaper in pure cash terms and thus animal draught power is likely to have a place in Swaziland's small scale agriculture for the foreseeable future.

TABLE 24: Livestock Population on the SNL

	No.	No. per homestead
Total cattle population on SNL	527 593	9.09
Draught oxen	137 342	2.37
Donkeys	16 881	-
Horses and mules	1 316	-
Total No. of homesteads	58 000	-

SOURCE: Swaziland (1984) - Agricultural Census

The use of draught oxen in agriculture in Swaziland has, by and large, evolved on its own. There has been little Government activity in this sector other than the little work undertaken on improvement of the single row maize planter through the foreign funded programmes like the RDA project in 1980/81 and CSREPT - Cropping System Research Project in 1988/89. The bulk of the Government assistance on mechanization on the SNL has been concentrated on the Tractor Hire Scheme. Nevertheless draught oxen cultivate about 45% of the arable land in the SNL and it is estimated there are over 130 000 draught oxen in Swaziland (Tables 24 & 25).

TABLE 25: Level of Mechanization in Swaziland (1988)

(a) Swazi Nation Land (SNL)		Area (10 ³ ha)	%
(i)	Cultivated by draught oxen	45	45
(ii)	Cultivated by Govt. tractors hire	4	4
(iii)	Cultivated by Private tractors hire	14	14
(iv)	Cultivated by own tractor	2	2
(v)	Left fallow due to lack of power,etc.	35	35
(Total potential arable area 100 000 ha.)			
 (b) Individual Title Deed Land			
All cultivated by tractors			100

SOURCE: MOAC - Swaziland 1988

Further about 59% of the small scale farmers on the SNL rely on oxen only for cultivation purposes while another 12% rely on a combination of tractors and oxen (Table 26). It is rare to see any farmer in Swaziland who uses entirely the handtool technology for primary land preparation. The main problem facing oxenization in Swaziland includes oxen teams being often poorly trained and implements drawn by them being of poor design and in poor operating condition. The use of oxen power almost always has an adverse effect on timeliness of planting and consequently, is a major cause of low crop yield. The usual reason quoted for delays in seedbed preparation concern the poor physical condition of draught oxen after the dry winter. Delays can also be caused by lack of manpower on the homestead to span the oxen and carry out the work. Men working in the industrial places cannot always get home at the critical time.

TRACTOR HIRE SCHEMES

Government Hire Schemes

As explained above, the fairly large and strong commercial agriculture, which is almost entirely mechanized, has inevitably affected the pace and rate of adoption as well as attractiveness of tractor cultivation in Swaziland. Almost every family in the SNL has had a relative employed on the commercial agriculture sector either in Swaziland or in neighbouring South Africa. Thus many of them have seen the advantages of using tractors for cultivation and even more important this commercial agriculture sector has acted as training ground for tractor operators, artisans, mechanics, etc. for the nation.

The MOAC has therefore been actively promoting the development of tractor power facilities in the rural areas since 1973. The project history is long and complicated and has its share of problems. It started with the Rural Development Areas Project, initially funded by ODA in 1974 which had 13 tractors in 4 Tractor Hire Pools. The aim of the pools were to demonstrate to farmers the benefits of timely deep ploughing and secondly to provide a transport service for the infrastructural development of the project. Hire charges set were strictly unsubsidized. The idea was to phase out the pools after 6 years (the tractors life span) assuming that the demand for tractor hire, deliberately unsatisfied by the tractor pools would encourage either the establishment of private tractor hire services by individuals or the starting of co-operative tractor hire schemes.

However by 1980 (when six years had elapsed) and despite a heavy demand for tractor hire services, it was not possible for the Government to phase itself out of such schemes due to popular demand. There were quite a number of emergent farmers who had obtained individual title deeds and who owned their own tractors and who provided tractor hire services to the small scale farmers who did not own either draught oxen or tractors. Such farmers however provided the tractor hire services rather late as they had to plough their own fields first.

The Government tractor hire service was thus the only one providing exclusive service. The Government tractor hire service was thus retained for a second period of six years and the number of pools was increased to 10 with 34 tractors obtained through loans from the African Development Bank and the World Bank. However due to the bureaucracy inherent under most civil service systems and the cumbersome financial regulations in Government systems it became apparent that the cost to the Government of running its tractor hire scheme was increasing sharply and utilization rates were low as well as the overall efficiency of the programme.

Consequently in 1982 IFAD funded a project which included a component whose sole objective was the conversion of the tractor pools to a self-financing, self managing operation in order to introduce commercial efficiency, raise utilization levels and thus approach economic viability. The start of this project was however delayed until 1987 during which time the tractor pools all but collapsed through under funding and inherent civil service problems. The project finally started but the Government still questioned the establishment of tractor pools as a self-accounting unit with power to open commercial bank accounts, whilst the pools remained within a Government department. In 1988 the IFAD project commissioned a study by a commercial consulting firm - Cooper and Lybrand to examine the alternatives of operating the tractor hire scheme outside direct Government control. This report has however yet to be accepted and implemented by the Government. Thus the Government Tractor Hire Scheme is still in limbo.

TABLE 26: Tractor Numbers in Swaziland (1984)

	No.	%
Total in country	3520	100%
of which		
- on large scale farms	861	25%
- on Swaziland Nation Land	2083	59%
- on Medium scale ITD (Swazi owned)	576	16%

SOURCE: FAO (1988); Swaziland (1984)

TABLE 27: Method of Ploughing - SNL

Method	No. of Homesteads	% Total
Tractors only	9 063	15.61
Oxen only	34 353	59.17
Tractors & Oxen	6 903	11.89
Other methods (e.g. donkeys)	4 353	7.49
No cultivation	3 389	5.84

SOURCE: Swaziland (1984)

Private Hire Schemes

As can be seen from Table 26, Swaziland had about 3520 tractors in 1984 with around 860 of them being on the large scale commercial farms in the ITD lands. About 2659 tractors according to the 1983/84 agricultural census were used outside the large commercial farms with 2083 of them on the Swazi National Land (SNL). The 576 tractors which are neither in the SNL or ITD's farms are owned by individual medium scale farmers (resident expatriate and Swazi nationals) in an increasingly important sector which produces quite an amount of the marketed food surplus and some of them grow on contract cash crops such as sugar cane, seeds, etc. as well as intensive livestock production. These figures indicate that the tractor number on the Swazi National Land is quite large at 2083 units. Given that the census also shows only about 16 000 ha of land are cultivated by tractors this means each tractor on the average ploughs only about 8 ha per annum (Table 25) on the SNL. Obviously a lot of the tractors on the SNL are owned by individual emergent farmers who

concentrate on their own land first and too often are involved in intensive livestock production as well as growing of cash crops. Therefore such average figures should be treated with caution. It is also clear that a lot of these individually owned tractors on the SNL are in a state of disrepair. Many of them have been bought as second hand tractors - usually those boarded off from the large commercial farms or imported as second hand tractors from South Africa. A more detailed survey of these tractors, what they do and extent of their utilization will have to be undertaken to assist in better policy formulation.

Apart from the census, baseline data on tractor and oxen utilization is lacking. In order to remedy this, the IFAD funded Smallholder Credit and Marketing Project (SMCP) is commissioning a Rural Mechanization Study (ongoing at time of writing) to provide such data. It is estimated that out of the 2083 tractors that the Swaziland census of Agriculture of 1983/84 had found on SNL only about 350 can be said to be fully operational by 1989 (including the Tractor Hire Pool) and collectively they plough about 18 000 ha for primary/secondary cultivation each year. Another 1500 tractors are marginally serviceable covering perhaps about 2000 ha between them.

Assuming a potential productive area of 100,000 ha it is believed that about 65,000 ha was planted in 1988/89 cropping year. Mechanization section of MOAC estimates that around 20,000 ha was ploughed with tractors and 45,000 ha was ploughed by oxen. By deduction this means that 35,000 ha of potentially productive arable land lay fallow in 1988/89. There are many socio-economic reasons why more land is not put into production but it is generally agreed that the shortage of tractors and good draught animals at the critical first rains is one of the major constraints both to the area cropped and the yields because of the timeliness constraint in the rainfed agriculture practised in Swaziland.

Waiting for cattle to regain strength on fresh spring veld grass after a dry winter means for 60% of homesteads no maize planting is done till mid November. According to the Mechanization Section the farm power situation is deteriorating. Despite a high seasonal demand for tractor hire, especially ploughing for maize planting but also increasingly for winter ploughing the number of tractors available for hire is decreasing. This is attributed to the very sharp increase in capital costs and running expenses over the last few years. The cost of a new tractor has tripled in 5 years, while spares/repair costs have more than doubled and indeed the number of second hand tractors in the S.Africa market has decreased and even the few available are quite expensive. Now that a new tractor and plough costs about US\$25,000 it requires good business management skills to hire the unit out at a profit, with high enough utilization rates to repay the loan over the economic life of the tractor.

THE TINKABI TRACTOR

The Tinkabi tractor was originally developed in Swaziland in 1973 as a low cost prime mover for developing countries (Tinkabi is the Swazi word for many oxen). The two Catterick brothers were heavily involved in its development (Catterick 1978). The original tractor consisted of two cylinder four stroke cycle engine. The engine (20 hp) is hand started and is air-cooled by means of a belt - driven fan. The Tinkabi as a manufacturing enterprise was undertaken over a period of about 10 years in Swaziland. This period saw the development of this farm power input for Swazi farmers that included not just the supply of the tractor unit but also a support service covering the provision of credit and after sale training, servicing and provision of spares. Two hundred and eighty one units were sold between 1973 till 1979, of which 197 were sold in Swaziland and the rest to Botswana (5); Kenya (4); Malawi (3); Nigeria (1); Senegal (3); S.W. Africa (1); UK (2); Zambia (36); India (2); Lesotho (4); Mozambique (2); S.Africa (18); Tanzania (2); U.S.A. (1). In early 1980's about 200 more units were manufactured most of which were exported to Tanzania and other countries under a World Bank assisted scheme.

It can be safely stated that the Tinkabi tractor did a satisfactory job in maize shelling, water pumping, generating electricity (as a stationary power source) but it failed to do it's intended primary job of ploughing. This factor accompanied by ever rising financial cost of production meant that Government's support in the manufacture of the tractor became inadequate so production stopped in the early 1980's. A later improved model using the Perkins 31kw three cylinder direct injection water-cooled diesel engine was developed in the mid 80's but it also over-costed itself and production was stopped in 1988. It is encouraging to note however that a number of the original tractors do still exist and do maize shelling in Swaziland. Writtle College (U.K.) made some modifications in 1988 on the prototype and is hoping to do trials and eventually have it produced for horticulture, landscape maintenance, and other smaller farmwork jobs.

One major lesson which can be learned from this Tinkabi enterprise is an individual's role in such projects. For the Tinkabi project was conceived and essentially developed by the two Catterick brothers. They as individuals, were the prime movers behind the whole project and for about 20 years worked tirelessly and with admirable dedication on this project. It may well be that if there were more players in the whole project, it may have developed into something else. However it could also be argued that more players would have reduced the zeal and perhaps even the little progress obtained would not have been there. Perhaps this is one project which requires to be studied further, in particular the individual's role in such a project. This does not mean that we are saying that projects conceived, developed and implemented by individuals should not be encouraged. On the contrary they should be supported, but it is necessary to have the whole system behind the project in addition to having more people actively engaged in the project.

OTHER INSTITUTIONAL LINKAGES

Training for agricultural mechanization personnel is undertaken at the University of Swaziland, Luyengo Campus - in the Faculty of Agriculture. The Department of Land Use and Mechanization of this Faculty offers agricultural engineering courses to students enrolled in the BSc. degrees in general agriculture and in agricultural education as well as those enrolled in the diplomas in agriculture and agricultural education. There is no specialized programme in agricultural engineering/mechanization offered at diploma and degree levels and the few staff in the country trained in this area have been trained overseas through scholarships offered by, among others, USAID and British Council. The Swaziland College of Technology offers a certificate programme in agricultural mechanics and many of the mechanics working in Government departments and the large scale farms are trained in this college. Tractor drivers are recruited locally and intensive tractor operation and maintenance courses of 1 week duration are offered with the help of the main dealers and extension personnel. The large scale farms also do provide on the job training to most of their tractor operators and mechanics.

There is very little research on agricultural mechanization being undertaken in Swaziland. Most of the research work has been undertaken through individual initiatives of staff at the Department of Land Use and Mechanization of the University of Swaziland and also of the Agricultural Research Station at Malkerns. In the former case many of the researchers have been expatriates and the research initiatives have usually stopped when they leave the country on the expiry of their contracts. The National Agricultural Research System in Swaziland is in itself quite small and it concentrates its efforts on the Biochemical and Socio-Economic problems of Swaziland's agriculture. It is unlikely that Swaziland is going to be able in the near future to embark on any large scale research efforts in the field of agricultural engineering given the scarcity of both human and capital resources. In addition manufacturing is quite limited and the Tinkabi tractor was a major undertaking in this regard. Swaziland, being a member with S.Africa, Botswana, Lesotho, and Namibia of the South Africa Customs Union (SACU) and there is free trade between these countries, therefore given the much more developed agricultural machinery industry in S.Africa, it is difficult for any entrepreneur to establish a competitive agricultural machinery and implements industry in Swaziland as he will have to compete with the well established industries in S.Africa.

CONCLUSION

We have in the preceding sections reviewed the agricultural mechanization policies and strategies as they have evolved over the past 2 decades in Swaziland. Given the proximity of Swaziland to South Africa, Swazi farmers adopted the draught animal technology much earlier than in most African countries. The tradition of livestock husbandry which the Swazis have had also

made it easier for them to adopt this technology in particular for tillage. The migration of young men, who have traditionally been responsible for training and harnessing oxen for ploughing, for work in the urban areas as well as in the mines in South Africa would appear to be affecting the future of this technology. Emergent and medium scale Swazi farmers have, by and large, adopted the mechanical technologies for their tillage and transport requirements.

These emergent farmers together with the large scale farms contribute a larger proportion of the marketed agricultural output as well as of the export commodities. There is however a dearth of knowledge on how these large scale farms and the emergent farmers, operate and manage the agricultural mechanization components of their farming enterprises. The fact that they are able to commercially run their enterprises and make a profit indicates that they must be utilizing the mechanization inputs profitably. There are also quite a number of tractor owners who hire out their tractors for ploughing fields owned by the small scale farmers. Such farmers supplement the services provided by the Government Tractor Hire Units which so far have faced a number of teething problems, primarily because of the fact that they have to operate within the civil service administrative and financial regulations. Proposals to delink these units from the civil service and allow them some degree of autonomy are still being considered. Swaziland also happens to be the only country in SubSaharan Africa where there has been an attempt to design, develop and manufacture a small tractor (less than 20 hp) - the Tinkabi. This enterprise has however had to be abandoned after 2 decades of research, development and manufacturing activities. The exact reasons why the project failed have still to be researched on and documented. It is our belief that such a research undertaking will go a long way towards avoiding similar mistakes in the future not only in Swaziland but also in other African countries which might venture into developing small tractors. On the institutional front and linkages between the various sectors involved in the whole agricultural mechanization development efforts, Swaziland would seem to still have a long way to go. It is perhaps in this regard that Swaziland might greatly benefit if there is more cooperation in this field among African countries, by learning how the sister countries in Africa have been handling their mechanization programmes.

CHAPTER 9

AGRICULTURAL MECHANIZATION POLICIES AND STRATEGIES IN TANZANIA

by

G. C. Mrema

INTRODUCTION

Tanzania is located on the eastern coast of Africa between latitudes 2°S to 12°S. Total land area is about 88.6 million hectares with potential agricultural land area being about 45 million hectares (Table 28). Rainfall varies from 600 mm in the central and mid-west of the country to 2000 mm in the South-West and parts of the North-West and East. In some parts of the country the rainfall pattern is bimodal (in particular in the East and North-East) and in others it is unimodal (in the south and west of the country). The population is estimated at 24.7 million by 1990, and growing at the rate of 3.2% per annum. The livestock population is estimated at about 12 million cattle, 1 million donkeys and 3 million sheep and goats. The livestock is concentrated in the central and northern regions of the country (Dodoma, Singida, Shinyanga, Mara, Mwanza, Arusha). Over two thirds of the country (and in many cases the more fertile areas) is tsetse infested and it is difficult to keep livestock in such areas. There are many river basins and it is estimated that the annual discharge into the Indian ocean is in the region of 74 billion cubic metres. The per capita GDP is estimated at US\$200.00 (1986). The country has been facing severe economic crisis in the last decade due to a multiplicity of reasons - drought, wars, falling commodity prices, rising fuel prices, etc. However over the past 3 years the economy has begun to pick again registering a real annual growth of GDP of about 4.7% (GOT (1988)) (Table 28).

The demographic pattern shows disturbing trends. About 49% of the population of Tanzania is in the dependent age groups (i.e. children under 15 years, and old people over 65 years) and 51% constitute the economically active groups of the population (Table 29). Thus the economically active group is expected to not only produce enough food to feed themselves but also for the numerically increasing dependent groups. Further the ratio of the urban dwellers is increasing at a much faster rate than the overall increment of the population (Table 29). The urban population is expected to increase to about 35% of the total population of Tanzania by the year 2010 AD. The implication of this is that by 2010 AD, for Tanzania, the population of urban dwellers will

be more than her total population in 1970. This means therefore that the rural population (with only 54% of them being economically active) will be expected to produce enough food to feed not only themselves but also an ever increasing urban population. A more disturbing trend, is that the migration to the urban areas is mostly by the younger ones (less than 25 years) and the average age of rural population is progressively increasing (Rashidi (1980)). This will have serious implications on the food and overall agricultural production, if the current levels of mechanization are maintained.

STRUCTURE OF THE AGRICULTURAL SECTOR

The most striking feature of the agricultural sector in Tanzania is its diversity in terms of farm sizes and enterprises. The sector can be broadly divided into 4 groups of farmers. The first group are the Peasant Subsistence Farmers (PSF) who produce primarily for subsistence (mostly food crops) - relying only on their own labour and that of their families, using mostly handtools with their technical methods being traditional (i.e. they use their own seeds and do not use any purchased inputs such as fertilizers and crop protection chemicals). Their yields are low, of the order of a few hundred kilogrammes per hectare and enough only to meet the subsistence requirements of the family. The average size of farm holdings for this group of farmers is less than 2 ha. They cultivate about 60% of the arable land cultivated in Tanzania and constitute together with their families about 70% of the population. (GoT (1986)).

The second group are the Small Scale Farmers (SSF) who produce food crops for subsistence and cash crops for the market. In high potential areas, such farmers may cultivate less than 1 hectare (e.g. slopes of mount Kilimanjaro, Meru, and Southern Highlands in Tanzania) whereas in the low potential areas they may cultivate areas from 5 to 10 hectares (central & western Tanzania). They in many cases and for most field operations depend on their own labour and that of their families and sometimes this is supplemented by draught animals where these are available (Tabora, Mwanza, Singida, Arusha, Shinyanga; Mara regions). In other areas they are able to hire tractors to plough their land if these are available. In Tanzania this group of farmers cultivate about 25% of the arable cultivated land and constitute about 20-25% of the rural population. This group of farmers is responsible for production of a significant proportion of the cash crops which are exported (coffee 60%; cotton 95%; tea 30%; tobacco 40%; pyrethrum 60%; cashew 80%) and also a reasonable proportion of the marketed surplus grain which is used to feed the urban population.

The third group are the Middle Scale Farmers (MSF) who produce cash and food crops for export and internal market. In many cases they tend to be local merchants, Government officials and other nonfarm people who have savings and decide to invest in agriculture or some of the Small Scale Farmers who have expanded their scale of operation to become Middle Scale Farmers. Their land holdings vary from 5-50 hectares depending on the location, (high

potential areas 5 hectares, low potential areas 50 hectares or above). They use both divisible (seeds, fertilizers, pesticides, etc.) and indivisible technologies (machinery, etc.) and they employ labour for their field operations. They normally can obtain credit from the credit institutions and in high potential areas of Tanzania they are full time farmers. They are also the ones who are able to own draught animals, or tractors and these may be hired to do contract ploughing for the Small Scale Farmers. In the 1960s this group of farmers was quite active, in particular in the high potential areas, but due to the socialist policies followed during the 1970s many of them abandoned farming or reduced their scale of operation to the level of small scale farmers. However since 1980, this group has increased quite significantly due to a change of policy by the Government.

The fourth and last group are the Large Scale Farms (LSF). These are in most cases large scale capital intensive enterprises owned by the farmer himself or large Trans National Corporations or the State. Their size varies from 50 hectares (in high potential areas) and may be as large as 10,000 hectares. They grow cash crops for export (coffee, tea, tobacco, wattle, beef) or food crops for the internal and/or urban market (wheat, rice, barley, sugar, maize, beans, etc.). Some are owned by the state, (NAFCO, TSC, and SUDECO farms) and other by private companies, (e.g. Tea, Coffee, Sisal, and Dairy Farms). They form an important part of the agricultural sector and are crucial to the economy of Tanzania (they produce about 100% of sisal, 80% of wheat, 60% of rice, 80% of sugar, 70% of tea, 60% of tobacco, 40% of coffee). It is estimated that these farmers cultivate about 500,000 hectares (10% of cultivated land) Yields on these large farms tend to be 90-100% more than SSF (ODI, 1989).

The above structure of the agricultural sector in Tanzania has remained the same over the past 3 decades with the exception of a few years when the MSF's were seriously disrupted. It is these farmers who are expected to produce enough food to feed the ever increasing population (expected to double in the next 25 years) and cash crops which are exported to earn foreign currency for purchasing the necessary inputs required not only by the agricultural sector but by the other sectors. Tanzania, has been forced in some years to import upto 20% of her cereal grain requirements due to drought. There is however still plenty of uncultivated land (and in many cases quite fertile) and she should be able to feed her increasing population by both intensification and expansion of the area under cultivation. Increased levels of mechanization will be required if this is to happen.

To summarize, therefore, the agricultural sector, in Tanzania, faces five major challenges in the next two decades:- (i) the production and productivity by all four groups of farmers (PSF, SSF, MSF, LSF) must increase to provide food for the increasing population and cash crops for export. (ii) in order to achieve an increase in production and productivity there must be a faster technological change in agricultural practices. This means modern farming

TABLE 28: Agricultural Statistics in Tanzania

1. Total Area x 10 ³ ha.	94,509
2. Total Land Area x 10 ³ ha.	88,604
3. Potential Agricultural Area x 10 ³ ha.	45,030
4. Cultivated Area x 10 ³ ha. (including ranches)	5,030
5. Forests, Pastures, and others x 10 ³ ha.	43,574
6. Cultivated Land under	
(a) Large Scale farms x 10 ³ ha. (% of cultivated area)	560(11)
(b) Small scale/peasant farms x 10 ³ ha. (% of cult.area)	4,470(89)
7. Irrigated Land Area x 10 ³ ha.	140
8. % of Total Agric. Area Cultivated	11%
9. % of Cultivated Area Irrigated	2.1%
10. Methods of Land Preparation	
(a) Handtool Technology % Cultivated Area	80%
(b) Animal Draught Power % Cultivated Area	14%
(c) Mechanical Power (tractor)	
% Cultivated Area	6%
11. % Agriculture to GDP	65%
12. % Agriculture to Exports	75%
13. Per Capita GDP (1987) US\$	200
14. % Food Imports to total consumed (average)	10%
15. Principal Export Crops	Coffee, Cotton, Sisal,Tea Tobacco, Cashew, Diamonds

SOURCE: IBRD (1987), SADCC (1988), FAO (1986), GoT (1988)

inputs must be supplied and judiciously used in the agricultural fields. (iii) whatever is produced must be transported, processed, and marketed/exported to the consumer/outside markets with minimum waste. (iv) all the above three must be done in a way which ensures that the agricultural resource base (i.e. land) can continue to produce on a sustainable basis i.e. there must not be environmental degradation. (v) to design and implement with persistence policies that will generate the resources required to revitalize the agricultural sector and enable it to meet the above four challenges, and for Tanzania for the next decade, in circumstances of severe economic austerity. Agricultural mechanization will play a crucial role, in enabling the agricultural sector to meet its challenges.

TABLE 29: **Rural/Urban Population in Tanzania**
(ALL figures $\times 10^3$)

Year	Total Population	Urban Popu.	% of Tot.	Rural Popul.	% of Tot.
1960	10201	491	5%	9709	95%
1970	13300	922	7%	12378	93%
1980	17934	2117	12%	15817	88%
1990	24774	4495	18%	20279	82%
2000	34031	8502	25%	25529	75%
2010	45363	14717	35%	30646	65%

Growth rate 1970-1990 - 3.2%

Urban population Growth rate - 7.5%

EVOLUTION OF AGRICULTURAL MECHANIZATION 1920-1990

Period before Independence 1920-1961

As shown in Table 28 - only about 5.3 million hectares of about 45 million potential arable land in Tanzania is cultivated. Even the remaining 43 million hectares of land area, which is classified as not suitable for arable production receives reliable rainfall, compared to semi arid countries like Botswana and Namibia. It is only in a few areas of the country where there is land shortage. This factor of perceived abundance of fertile land has significantly influenced mechanization policies right from the beginning of this century when the Germans were ruling Tanganyika. The Germans acquired Tanganyika after the

Berlin Conference of 1884 and British got the Zanzibar islands. Tanganyika then called German East Africa included the area now occupied by Rwanda and Burundi (the later two countries were given to Belgians to administer after the 1st World War in 1918 and Tanganyika became a League of Nations Trust Territory under British rule). As with all other colonial powers then, they regarded Tanganyika as an important source of raw materials. The Germans used a dual structure to ensure agricultural production from their colony - large estates were established for crops such as sisal, coffee and tea, and these were farmed by German settlers with partially forced labour, and they encouraged the 'natives' to grow crops such as cotton through indirect coercive methods as imposition of poll tax, hut tax, and sometimes direct coercion. The land acquisition by the German settlers did not create a conflict with the natives as there was still plenty of land. The shortage was of labour, which forced the Germans at times to use coercive methods to get it.

At the end of first world war the British took over Tanganyika and allowed the German settlers to remain and also encouraged British and Asian businessmen and farmers to take up farming in the country. There was not however a large influx of settlers as in Kenya, partially because of the League of Nations mandate (Austen (1968); Ruthenberg (1964); Illife (1971)). Native farmers were also encouraged to grow cash crops - Chaggas and Merus on the slopes of Mt. Kilimanjaro and Meru, Hayas in the West Lake region, Sukumas and Nyamwezi's - north western zone (Mwanza - Shinyanga) and Nyakyusa's in the Southern Highlands (Mbeya). The level of mechanization, was by combined handtool and draught animals on the settler farms; and predominantly handtool on the native farms. The Sukumas however adopted draught animal power during the 1930's. Although the Sukumas occupied a large area South of Lake Victoria (Mwanza, Shinyanga, Taboya regions) a large stretch of this land was uninhabited in the 1920s and 1930s because of tsetse flies. The Sukuma people have traditionally kept large herds of cattle. In the 1920s and 30s the British decided to launch major anti-tsetse fly campaigns (by clearing the trees) and introduced some rudimentary veterinary services. These anti-tsetse fly campaigns were positive, and the Sukumas moved with their cattle to these new areas. Although there were also campaigns to reduce stocking levels, this met with immediate resistance from the Sukumas from a cultural point of view. The Sukumas also at this time adopted draught animal power (DAP) technology and cotton production from small scale farmers increased quite significantly in the 1930s and 1940s. Although cotton cultivation and DAP technology was adopted and is still being used today, this has been done at a great environmental cost - for the two regions Mwanza, Shinyanga, are now almost semi deserts due to the clearing done in the 1930's and 40's (McCall (1974); Ford (1971)).

After the second World War, the British, in order to solve the food-oil shortage in post war Britain, initiated the largest mechanized agriculture scheme undertaken in Africa by then through the Groundnut scheme. Large areas of central and southern Tanzania (Kongwa, Urambo and Nachingwea)

were cleared in 1946-1950, to establish large scale mechanized groundnut production. The plan was to grow groundnuts on large scale farms totalling one million acres. A huge number of tractors were imported - some of them battle tanks rudimentarily converted to crawler tractors to clear the land and start production of groundnuts. This scheme failed after 5 years of trial-due to a number of reasons - lack of proper planning, soil compaction due to the heavy equipment used, poor land planning and soil analysis and poor managerial skills. (Wood (1950); Burch (1987)). The tractors imported were sold to local settler farmers and a few were bought by African merchants, who started partially mechanized agriculture in other areas (Ismani, Geita, Arusha - Moshi areas, Urambo, etc.). When the groundnut scheme was abandoned in 1950 - the situation reverted to what had existed before. The groundnut scheme was however the biggest ever mechanized agriculture project tried in Tropical Africa and that it failed despite the massive British Government financial and technical support indicates the complexities of agricultural mechanization in Tropical Africa. It is a pity that this project, despite being on a much larger scale mechanization wise than any other project which has been attempted by the independent African Governments has not received that much research attention in comparison to those started after independence.

Period after Independence (1961-1990)

On the advent of independence in 1961, a World Bank Mission was commissioned in 1959, and was assigned the task of looking into Tanganyika's economic future. The mission submitted its report in 1960 (IBRD 1960) and recommended more intensive use of the land resources of the country on a more sustainable basis. The mission noted that other than a few pockets where small holder farmers had intensified their agriculture and were producing for the market (Kilimanjaro, West Lake and Southern Highlands) the majority of the other tribes lived in scattered hamlets and practising shifting cultivation in the areas which were more fertile. The mission concluded that it would be impossible to intensify agriculture in such areas and thus it would be quite difficult to improve such farming systems. The mission therefore recommended:

" something more is required whether through intensive campaigns in settled areas, involving a variety of coordinated measures, or through planned and supervised settlement of areas which are at present uninhabited or thinly inhabited. Infact, the Mission judges that the second of these approaches is in general the more promising in the present conditions of Tanganyika."
IBRD (1960)

The World Bank mission therefore recommended transforming the traditional agriculture rather than improving it. The final decision on the World Bank report was left to the Government of independent Tanganyika which duly accepted all the main recommendations of the mission in 1962 and implementation started almost immediately.

With the assistance of various donors, including the World Bank, some 40 settlements were established in various parts of the country with settlers being recruited from the areas of land shortage, urban unemployed and peasants from areas neighbouring the new settlement. The settlements were highly mechanized, with the land being opened up by crawler tractors and initial land preparation being done by tractors. There were settlement managers mostly ex-colonial British agricultural officers who were supposed to manage the settlements and the production process. An example of the over mechanization (Kates et al 1969) was Upper Kiteto Village in Mbulu district - Arusha region where 100 settlers were growing maize on 1600 acres of land with 10 tractors 2 combine harvesters and other assorted implements. Neighbouring private farmers had much less machinery and implements and employed much less labour. However there was euphoria on these settlements, the government was quite keen on their success, donors, some with idealistic views, were ready to help in transforming the type of agriculture (Ingle (1972)). Although over 60% of Government investment in these settlements was in the form of agricultural machinery and implements as well as vehicles and other equipment, there were hardly any agricultural mechanics or engineers employed. The managers themselves were expatriate general agriculturalists and in some cases economists, sociologists, anthropologists and political scientists were employed as settlements managers. This issue of manpower was crucial to the success of these settlements.

There were also a number of other mechanization schemes started during this period (1961-66). An interesting example in this regard, was the pool of 159 tractors bought on credit by the Government in 1963 and handed over to the Victoria Federation of Cooperative Union (VFCU) to hire out to farmers under the Sukumaland Cotton Block Scheme. Under the scheme blocks of 121-202 ha of land were to be cultivated by tractors and individual plots of 1.62 ha were to be allocated to farmers for cotton production. Each tractor was theoretically supposed to cultivate 121.5 hectares per annum. The tractors were serviced and managed at a Central Workshop owned by VFCU. There were a lot of problems, in particular in keeping these tractors operational (mostly technical) and each tractor by 1964/65 managed to cultivate only about 27 ha. Although this scheme continued to operate upto 1968/9, and additional tractors were bought, it had to be abandoned by then and the tractors were sold to progressive farmers and tractor drivers who continued to provide private tractor hire services not only to other farmers in the region, but also to other areas in East Africa (TSAE 1972: Migot Adhola 1969). Other initiatives in mechanization were undertaken by the Tanganyika Farmers Association - a private association of progressive farmers which provided credit facilities for purchase of tractors and had a fleet of combine harvesters for hire by the large scale wheat/maize farmers.

By 1965, it became apparent both to the Government and donors that the village settlement schemes were a failure, and the World Bank attributed the major reason for this failure to the premature mechanization (de Wilde

1967) despite having advised on their establishment earlier on (IBRD 1960). Given the type of investment and the technical skills available (both local and the donor supported technical experts) it is not surprising that these schemes failed. The schemes had been quite expensive and had utilized a significant proportion of Government money, and their production was quite small. It was then realized within Government circles that, if the vast majority of Tanzanians living in scattered hamlets all over the country were to develop then a less capital intensive modality of bringing them together had to be devised than what had hitherto been adopted in the village settlement schemes. The country could not afford the level of mechanization which had been adopted in these schemes. Secondly the manpower available in the country then could not maintain the expensive technology used. It was then that the ruling Party adopted the proposals put forward by the President Nyerere through his essay *Socialism and Rural Development* (Nyerere 1967).

The new policy aimed at bringing the rural peasants, majority of whom were living in scattered homesteads, into communal villages. The new rural development strategy had eight objectives: (i) establishment of self-governing communities (ii) better use of rural labour (iii) taking advantages of economies of scale (iv) easier way of dissemination of information and provision of services (v) avoidance of exploitation (vi) increasing standard of living of the people (vii) facilitation of national planning (viii) facilitation of national defence (Maeda 1976). The Ujamaa villages policy was part of a national policy as enunciated in the Arusha Declaration on socialism and self reliance. The idea of bringing the rural dwellers together, most of who lived in scattered hamlets had been tried before by the German and the British Colonial authorities and on advice of the World Bank by the Tanganyika government under the village settlements agency in 1961/65. Whilst Germans had tried to do this through coercion, the British had tried and used various methods and in independent Tanganyika this was done through provision of higher levels of mechanization (1961-67). Under the Ujamaa villages policy, it was hoped that through political persuasion the peasants will be mobilised and start the villages at their own level of technological development. As production increased they will then be able to purchase tractors and other modern implements and inputs rather than being provided these initially as had been done in the village settlement schemes between 1961 and 1965.

There was no clear policy on mechanization during this period of Ujamaa transformation (1967-1973). Some villages were provided with tractors, others were encouraged to use animal powered mechanization and most continued to use the handtool technology. Some regional authorities bought tractors through the Regional Development Funds (RDF) which were to be hired out to Ujamaa villages and individual farmers. These tractors were controlled from the regional office and had to travel long distances to reach the villages and farms. The programme was quite uneconomical to run and the regional authorities sometimes used promise of provision of mechanization inputs as a means of attracting peasants to settle in Ujamaa villages. It was

also during this period that Rene Dumont visited Tanzania and propounded the ideas he had first raised in his book - *False Start in Africa*. In 1972, the ruling party's National Executive Committee (NEC) meeting in Iringa issued a major policy document on agriculture. This document - called the Iringa Declaration, advocated for increased utilization of modern inputs - fertilizers, crop protection chemicals and better crop husbandry. On mechanization, the document placed more emphasis on utilization of draught animal power for cultivation and its introduction in areas where it was not being utilized. Thus a number of oxenization centres were established all over the country even in areas which were tsetse infested and the people had no animal husbandry tradition. (It should be realized that about 2/3 of Tanzania is tsetse infested - in particular the more fertile southern part of the country). The Ubungo Farm Implements (UFI) factory which had been constructed in Dar-es-Salaam to manufacture farm implements was directed to increase its production of oxen drawn implements.

Although much money was spent in establishing oxenization centres all over the country, it would seem however this had little impact especially in the tsetse infested areas. In some areas such as Mwanza region the percentage of land ploughed by tractors actually increased (TSAE, 1972, 1973, 1974). This was not through Government efforts but more through private initiatives. As we mentioned earlier, the tractors which had been used in the Sukumaland Cotton Block Scheme were in 1968/69 sold to progressive farmers and in some cases tractor drivers. Many of these farmers and drivers developed, over the next eight years, one of the most efficient tractor hire scheme in Africa. They used to plough the land for the farmers in Mwanza/Shinyanga area around August/September/October, thereafter drive across Tanzania to Arusha/Kilimanjaro area where they ploughed in October - December and then drive across the border into Kenya where they used to plough around the Machakos/Taita area in January/February and from there they drove across to Western Kenya (Kakamega, Nyanza Province and Rift Valley areas) where they ploughed in March/April/May and drive back into Tanzania through Musoma around May/June to start the cycle again in August/September in Mwanza area. It was not uncommon between 1969 to 1975 to meet a fleet of 30-40 tractors driving across Tanzania on the Mwanza/Arusha road. They maintained close contacts with the farmers they ploughed for, and I recall between 1970-72 one such driver used to come every October to plough my father's maize fields in Arusha.

At that time, Kenya and Tanzania together with Uganda were under the East Africa Community and there was virtually free movement of people between the 3 countries. It thus made it possible for these tractor drivers from Mwanza area to be able to cross the border to follow the work in accordance with the season. After 1974/75 season however political tensions developed within the East Africa Community and the free movement of people across the border became quite difficult without passports, which the drivers could not be bothered to obtain. After 1976 it became impossible to cross the border as

the East Africa Community collapsed in January 1977 and the border between Tanzania & Kenya was closed until 1983 when it was reopened. The closure of the border and collapse of the community broke their cycle through Kenya and it became unprofitable for them to move from Mwanza area to Kilimanjaro. Unfortunately, there has been no comprehensive study of this venture which may be called tractor taxis. However reports given at the Tanzania Agricultural Engineers Society Conferences indicated that these drivers were able to achieve over 2000 tractor hours per annum and most of them were able to plough 800-1200 acres per annum (TSAE 1972,73,74). These tractors provided a crucial service to many small scale farmers in the areas they transversed at an affordable cost and as it was noted by Alcober *et.al.* (1983) in a survey of small scale farmers in the Mwala/Mbiuni/Makueni area of Machakos district in Kenya. Many small farmers reported in June 1983 that the last time they had their land deep ploughed to break the hard pan was in the early 1970's when the Tanzania tractor drivers used to come to plough for them in January-March of each year. (Alcober *et.al.* (1983))

In 1974/75 the Government decided to seek UNDP/FAO assistance to develop an agricultural mechanization policy. A senior agricultural engineer was hired for a period of 2 years under the auspices of FAO and was required to assist the Ministry of Agriculture in policy formulation; programming and project implementation in the field of agricultural mechanization (Project No. URT/75/018/01/12). An associate expert was hired to assist the expert, and a number of short term consultants were also hired to undertake studies on different aspects of mechanization in the different agro-ecological zones (Dagg 1978, Beeny 1975, Fear 1976). Numerous internal reports were produced between 1975-79, and in 1980, through the FAO expert, the Ministry of Agriculture, presented the results of this project in the form of an agricultural mechanization policy to the Tanzania Society of Agricultural Engineers (TSAE) Conference held in Tanga in March 1980. The policy emphasized animal powered cultivation, with recommendations to open several ox-training centres; use of what is called improved "handtool" and it recommended that tractor powered mechanization should only be introduced in justifiable areas (Dagg 1980). Although the policy was presented as a Ministry of Agriculture Mechanization Policy it was apparent to the participants in this conference that this was a result of the UNDP/FAO study and what was being presented was what had already been tried in several regions since 1967 and there was nothing much to show of these past efforts. There was a heated debate in particular from the national agricultural engineers attending this conference, and the FAO expert could not answer many of the criticisms levelled at the policy presented.

It is not clear what happened to the 'policy' after the 1980 TSAE conference in Ministry circles; however, it appears it was quietly forgotten, the expert left the country on completion of his contract and as it is often with many of these projects, no policy was adopted.

TABLE 30: Tractors in use in Tanzania

1950	2057
1955	2550
1960	2580
1965	3500
1970	6500
1975	9000
1980	15500
1985	18533

FAO Production Yearbooks: Vol. 13, 24, 29, 36, 42;
TSAE (1981)

* Tractors - include both crawler & four wheel tractors but excludes 2 wheel tractors.

Things were however happening on the mechanization front. The Ministry of Industries, had reached an agreement with Finnish Company Valmet, to start assembling Valmet tractors in Tanzania in 1978. By 1981 the company had established jointly with the Tanzania Government, a company to start assembling the tractors from semi knocked down (SKD) components with about 15% local content. The local company TRAMA started assembling the tractors in 1981 and was given monopoly on tractor imports and manufacturing. Valmet had experience with tropical mechanization before, having established itself in Brazil in the 1960s and where it controlled about 40% of the market. They were however new to Africa and initially their tractors were unpopular due to a number of problems - lack of good dealers all over the country, unfamiliarity to tractors drivers and mechanics with the new tractors, etc. However they established a training centre for mechanics and tractor operators and made some modifications to their designs to suit local conditions. They have since 1981 been assembling 300-500 tractors per year.

Also in 1981 the Government decided to transfer TAMTU (Tanzania Agricultural Machinery Testing Unit) from the Ministry of Agriculture and merged it with the Arusha Appropriate Technology Project (AATP) to form a new parastatal called CAMARTEC (Centre for Agricultural Mechanization and Rural Technology). TAMTU had existed since 1957, and was responsible for testing agricultural machinery. However in the 1970s it got involved in research and development activities (mostly in the intermediate technology

field) and started some manufacturing activities - oxcarts and a few ox-drawn implements, inter row cultivators, ox ploughs, etc. Initially it got some technical assistance from ILO and a number of other agencies. However by mid 1970's it was understaffed and nationally many people were questioning the utility of its test reports and its research and development efforts. Some of the implements TAMTU developed received much wider attention, for example, a senior official of the World Bank reported that "TAMTU has developed an inter row weeder at a cost of US\$7 to 15. This instrument can result in a two thirds to three quarters reduction in weeding time". (Lele (1975)). The reality however was far from this claim. AATP had been established in 1977 - through SIDA assistance by the Small Industries Development Organization (SIDO) a parastatal under the Ministry of Industries. Its specific objective was to develop appropriate technologies for the rural areas - biogas, charcoal stoves, solar cookers and driers, windmills, etc. Its research effort was then mostly directed at developing energy saving devices. It had some outreach programmes in some villages but it would seem many of these were working because of the donor support, once this was stopped in the 1980s its projects in the villages collapsed. Nevertheless AATP had quite good PR, in particular to the international experts attending conferences at the Arusha International Conference Centre.

Although the decision to move TAMTU to the Ministry of Industries was a Government decision, some officials in the Ministry of Agriculture were not very happy with this decision (TSAE 1983). They felt, maybe rightly, that putting both the manufacturing and testing of agricultural machinery under one ministry may not be to the best interests of the farmers. Ministry of Agriculture, in addition, was not very happy with the monopoly given to TRAMA Valmet to import/assemble only Valmet tractors. They were thus able to convince the Government to rescind this decision, and in 1984, through a credit line from Italy and in a project implemented by FAO, 200 Fiat tractors were imported for Morogoro region. It was intended to import another 200 tractors for Mbeya region. Fiat through its local company INCAR (Tanzania) had been active in the country in 1950s and early 1960s. However its share of the market by 1973 was insignificant (Dagg 1978). In 1985 following the trade liberalization policy, the other companies - which had not been active in the country from 1978, were allowed to open up (Massey Ferguson, Ford, International Harvester, John Deere) and to import their tractors. Thus the monopoly given to TRAMA - Valmet ended. However TRAMA - Valmet has continued to assemble its tractors in a more competitive market. Also the Mbeya Farm Implements Factory started production in 1982 - but was plagued by a number of teething technical problems. The Ubungu Farm Implements Factory, on the other hand had its management overhauled in 1983, and appears to be doing quite well now in particular in manufacturing of handtools and some animal drawn implements.

There was not much activity in the policy direction between 1982-87. TRAMA-Valmet was assembling tractors internally, the other companies were

allowed to import tractors, and individuals and villages were purchasing these tractors and implements, through loans made available by Cooperative and Rural Development Bank. In 1987 the ruling Party issued a major policy statement on developments in the country for the next fifteen years 1987-2002 (CCM, 1988). This policy statement was important in two ways in so far as agricultural mechanization was concerned. First it recognized the important role of the capitalist farmers in the economy. Hitherto the Party had been apprehensive of capitalist farmers, although it quietly tolerated them. But this time, it clearly pronounced their importance and directed the Government to assist them as long as they did not annex land belonging to the peasants and small scale farmers. As we noted earlier, these capitalist farmers - had been important in adopting mechanized agriculture from the early 1950s but during the period 1967-75 many of them had to lie low due the socialist policy pressure. Secondly the Party recognized the importance of mechanization - both tractor and animal powered and pronounced a policy to be followed on agricultural mechanization.

The Party document spelled out a clear policy on mechanization. To quote the Party document (translated from Swahili by the author) (para 59)

"... Our experience has shown that the system of distributing tractors by giving them to individual farmers and Ujamaa villages, who do not have the basic technology of servicing and utilizing them, will not help that much in revolutionizing the agriculture in the villages. The only sure way, which has emerged in the World, of speeding up the scientific and technological revolution in agriculture and building up socialism is the establishment of mechanization and other input centres whereby the farmers are provided with this service without carrying the burden of servicing these tractors. The centres should be responsible for servicing these tractors. In addition the centres should train the farmers on how to use and service these tractors so that eventually these centres can be run by the farmers themselves. ..." (CCM 1988)

The statement goes on to note that for the first time the Government has set aside money to establish eight such centres and the Party recognizing that science and technology are crucial for the development of rural areas, should ensure that there is a long term plan to ensure that by the year 2002, these tractor centres are able to service at least 50% of the small holder farmers in the country. Concurrently with this the statement goes on to state the importance of animal drawn technology in areas where this is feasible in particular in primary cultivation and rural transport to liberate the peasant, in particular women, from the drudgery of carrying loads on their heads.

This is an important statement, first the detail to which the Party went into in this statement. That the Party could in a major policy statement (covering all sectors - Socialism, Agriculture, Industries, Tourism, Cooperatives, Natural Resources, Defence, Foreign Affairs) which is 95 pages long, devote 3 pages of this for agricultural mechanization is in itself a notable event. The Party being supreme in accordance with Tanzania's constitution, and this policy statement was being presented to its National Conference (which is the supreme policy making organ in the Party) indicates the importance with which mechanization is taken. The policy enunciated by the Party is quite broad. One hopes that in establishing these mechanization centres, the Government will try to learn from past mistakes. Different types of management of tractor hire schemes have been tried - from the settlement schemes (where the Government provided to the settlers tractors almost gratis); Cooperative hire schemes, like the Sukuma Cotton Block Scheme, Regional Development Fund Tractors and private hire schemes. It will assist in planning for future centres if the Government analyzes why most of these past schemes failed and tries to avoid repeating the same mistakes. The Government has of course been facing severe economic problems over the past 5 years, and its ability to embark on a large scale scheme is quite limited and it is too early now to pronounce on the success or failure of these new strategies.

Success cases

We have concentrated in the preceding paragraphs on mechanization of tillage operations firstly because this has been the area of mechanization which has been quite controversial, and also where the most arduous farming operations are involved especially when handtool technology is being used (Nwuba & Kaul, (1986), Mrema (1984)). However on the post harvest front there have been quite a number of successes. This is in particular in the milling of cereal grains. Unlike in other African countries (Zambia, Zimbabwe, Kenya) over 90% of the maize, sorghum and millet flour consumed in the country (and this is the staple diet of the population both urban and rural) is milled by small scale hammer mills. There is only one large scale miller - National Milling Corporation, which supplies about half the requirements of Dar-es-Salaam. There are over 10,000 such small scale millers scattered all over the country and owned by individual merchants, village governments or cooperatives. It is difficult now to find milling of grains being done by the traditional stone method - which used to take so much time and energy of the women population. Four companies in the country are now manufacturing these hammer mills - Jandu Plumbers, Manick Engineers in Arusha, Mangula Machine Tools in Morogoro and another company in Mwanza region. This technology has spread mostly through private initiative and some villages were assisted in buying these milling machines through loans from the Cooperative and Rural Development Bank. Majority of them are driven by small diesel generators - Honda, Lister, etc. and they can mill up to 2 tonnes per day, and each family takes 20-50kgs of maize at a time to be milled by these millers for a price.

A few other innovations on the post harvest front are worth mentioning. These include maize shellers - like the one developed by the Department of Agricultural Engineering of the Sokoine University of Agriculture (Kahungu 1988) which is driven from the PTO of a tractor. Many farmers (in particular medium scale farmers) in the high potential areas are now using this type of sheller for shelling their maize instead of the traditional method of hitting the unshelled maize in a sack. By having these shellers tractor owners can also hire out their tractors for shelling maize during the slack season. Other developments include the coffee pulpers for arabica coffee - used in the Kilimanjaro/Arusha and Mbinga areas. Many of these are now locally manufactured and they go a long way towards reducing the labour requirements for processing arabica coffee. Many of these tasks in post harvest processing have traditionally been done by women and children. With the introduction of compulsory Universal Primary Education in 1978, this did significantly reduce the contribution of children in such tasks. One may argue that by mechanizing such tasks, where the progressive farmers usually hired female labour, then you are reducing the employment opportunities for these poor women. However the cost of labour, in relation to prices paid for the produce in Tanzania, is such that there is no option other than mechanizing if these progressive farmers are to remain in business.

INSTITUTIONAL FRAMEWORK FOR AGRIC. MECHANIZATION

In Tanzania, quite a number of institutions/departments have been involved in mechanization. These have included Government departments in the Ministries of Agriculture, Industries, Economic Planning, Finance, Local Government and Prime Minister's Office; parastatal organizations as well as private and international organizations such as FAO, ILO, etc. The Village Settlement Agency established in 1962 to 1965 on advice of the World Bank, was under Prime Ministers Office between 1961-62, and later on Vice President's Office from 1962-64. It received technical advice however from the Ministry of Food, Agriculture and Cooperatives which was also responsible for the Sukuma Cotton Block Scheme described earlier. In 1966 a new Ministry of Rural Development was created to oversee the settlement schemes, and this was later charged with the implementation of the Ujamaa villages programme when the policy of Ujamaa villages was adopted in 1967. Each of these ministries, including agriculture, had functional officers in the regions. The head of the regional administration in each region, has been the Regional Commissioner (a political appointment) who also doubles up as the Regional Secretary of the ruling party. The regional functional officers however received their money and directives from the Ministry headquarters in Dar-es-Salaam.

Below the regional authorities there were the Area Commissioners who were incharge of districts with each ministry having a functional officer at district level as well as District Councils which were the local Governments. Some districts had two councils - one for the urban area (Town Council) and another one for the rural area (District Council). All these institutions were

supposed to be involved in some form of development and some of the projects in the region and districts were national projects controlled directly from ministry headquarters in Dar-es-Salaam. Quite a number of these district and regional officers had tractors under their control for specific projects. An American Company McKinsey and Co. was hired by the Government to advise on the management/administrative structure of the regions for effective rural development in 1969 (Hyden 1980). They produced their report which was implemented with assistance from several donor agencies. They advised on decentralization of power from the metropolis and each Regional and Area Commissioner was given a Regional Development Director and District Development Director respectively who were to be incharge of all development work in his region/district and all functional officers were required to report to him and obtained their operating funds from district/regional headquarters (Hyden 1980). This was implemented in 1972, and the Regional Development Fund Tractors were then placed under the Regional Development Directors (RDD).

Concurrently with the implementation of the decentralization system on advice of McKinsey and Co. commodity authorities were also established for the development of production, processing and marketing of the various crops. Thus Tanzania Cotton Authority (TCA); Coffee Authority of Tanzania (CAT); Cashew Authority of Tanzania (CATA); Tobacco Authority of Tanzania (TAT); Tanzania Tea Authority (TTA) were all established as parastatal organizations responsible for their specific commodities - right from supply of inputs, extension services, marketing and exporting. These authorities had their regional offices in the regions where their crops were grown who worked independently of the regional and district agricultural officials. They had their own vehicles/tractors - most of them supplied by donor agencies like the World Bank/EEC etc. These authorities were established, in the mould of the Kenya Tea Development Authority which was regarded by senior officials in the World Bank as a successful example of rural development administration (Lele (1975)). In addition to these crop authorities and the regional and district officials there were also, in a number of regions, strong cooperative unions (VFCU, KNCU etc.). It was therefore common, between 1972-79 for a villager, to get tractor services from 3-4 organizations as there was no coordination between the crop authorities, the regional and district authorities and the cooperatives. The cooperatives were abolished in 1975 and most of their activities were taken over by the Crop Authorities.

The crop authorities and the regional development directorates (through the various Integrated Rural Development Programmes (IRDP)) were heavily funded for their development activities by the donor agencies - World Bank, (Tobacco, Cashew, Cotton and a number of regional IRDPs); EEC (Coffee, and a number of IRDPs); ODA (a number of IRDPs); USAID (National Maize Project, and a number of IRDPs); GTZ (a number of IRDPs and Sisal) (GoT - (1976, 77, 78)). Most of this assistance was in the form of loans for technical assistance and inputs in the form of fertilizers, tractors, processing plants and

vehicles for extension and administrative support. As mentioned above there was no coordination at all in the regions and hence despite a massive increase in number of tractors between 1970-80 (when the tractor population in Tanzania more than doubled) (Table 30) there was no major change in the level of mechanization in the country and upto today 80% of the cultivated area is still being ploughed by handtool technology (Mrema 1981, 1984, 1989). A significant proportion of Tanzania's current \$5 billion debt was incurred in the 1970s when this administrative diaspora existed. It is pointless to blame Tanzania Government now while many of the projects were conceived and planned with the assistance of the major donors by their planning departments which are staffed by highly qualified economists and other experts.

In addition to the crop authorities and the regional directorates which were involved with the farmers directly, a number of other institutions under the Ministry of Industries & Trade - were also involved in mechanization efforts. These included the National Development Corporation - whose two companies - Mbeya Farm Implements and Ubungu Farm Implements (UFI) were involved in manufacturing of farm implements. Initially, UFI used to market its implements through the Regional Trading Companies which were quite inefficient, however after 1982 it was allowed to market directly through private retailers and agents. The State Motor Corporation partially owned TRAMA-Valmet - which was involved in assembling of Valmet tractors, and it owned two other companies - until 1986, which had the local franchise for Massey Ferguson and Ford Tractors. The franchise for the International Harvester tractors was under another Ministry of Industries and Trade parastatal - Agricultural Implements and Supplies Co. - AISCO while for John Deere a private company KJ Motors had the franchise. There have also been waves of different makes of tractors coming in the country. There was a wave of Indian Swaraj (35 hp) tractors - 200 of them were imported in 1982/83 which were quite unsuitable for the Tanzania soils. The Japanese, through the integrated rural development project for Kilimanjaro region provided over 300 Kubota tractors which were pooled as a project administered by Japanese experts at least in the first five years and providing tractor hire services to small holder farmers in Kilimanjaro region. There was no follow-up with spares after the Japanese left, as Kubota was quite a new make in East Africa and many of them are now abandoned near Moshi town. One hundred Tinkabi tractors were imported from Swaziland with World Bank assistance and given almost free of charge to institutions which wanted to test and try them (Nyantahe 1985). Many of these have now been converted to stationary power sources for grain milling.

MANPOWER DEVELOPMENT FOR AGRIC. MECHANIZATION

One of the key problems which has affected all agricultural mechanization programmes in Africa has been the lack of appropriately trained manpower and with the right type of managerial and entrepreneurial skills. Indeed looking back at attempts in mechanization in Africa over the last 50 years ,

one wonders if the British and French who were involved as colonial powers and implementers of some of the large projects in the 1950s had the right type of manpower. For what is often ignored or glossed over by many of the experts and researchers (Eicher & Baker (1982); de Wilde (1967); Lele (1975)) is the fact that to date the greatest failure in agricultural mechanization in Africa is the Groundnut Scheme of 1946-51 in Tanganyika. This project was being implemented by hundreds of British "experts". Further many of the recent mechanization projects from 1960 - onwards have been donor assisted and in most cases there has always been an expert or several experts from the donor country/agency on site during the implementation stage. This has been the case whether the projects have been of intermediate technology level or tractorization. The failure of mechanization projects in Africa therefore may well be equally placed on the donor agencies as on the African Governments.

At the lowest level, farmers need to be trained on how to use and service any new agricultural machinery and implement. A serious mistake which has often been committed when trying to introduce draught animal technology in areas where the people have no livestock husbandry tradition is to assume that the training of such farmers on the use of draught animal power can be accomplished in a short period of 2-3 months. For the farmer, in this case, has to be trained on how to take care of the animals, to detect quite early if the animal is sick (and this is crucial in areas where livestock diseases are common) and learn how to harness and use the animal in ploughing. In other cases the farmer has been expected, after such short training, to go out and be able to train his own animals how to plough. Even in areas where farmers have the livestock husbandry tradition not every farmer can train his oxen how to plough. Indeed even in Europe and North America, when horses were used for tillage, most farmers used to purchase horses which had already been trained. It is the complexities involved in training farmers the animal husbandry tradition and how to use them in ploughing that has made some of us be skeptical of the prospects of introducing draught animal technology to people who have no livestock husbandry tradition (Mrema 1981, 1984).

Another area which has often received quite superficial treatment is the training of tractor drivers and operators. Gifford (1981) suggests that a competent tractor operator can be trained in a period of six to eight weeks. Our experience with the TRAMA-Valmet training programme in Tanzania shows that even 9 weeks of training to a driver who has basic driving skills is not enough to make him a competent tractor operator. One thing which ought to be realized at the outset is that most of the tractor drivers come from a technologically backward tradition. Few of them have handled mechanical appliances before. In addition they have to operate the tractors in areas which are far from service centres and as such they have to know more about the machinery in case of a breakdown in the field. Next to the tractor operators are the tractor mechanics/agricultural mechanics. Unfortunately this is a cadre of manpower whose training has been ignored in most countries in Africa. Training for such mechanics, where it is offered, has always been undertaken

as an appendage to vehicle mechanics training. It is only recently that the National Vocational Training Centre which is responsible for all craft training in Tanzania has realized that tractor mechanics require a different type of training from that given to automobile mechanics. They are thus in the process of designing a different and extensive course for tractor mechanics. Hopefully when such mechanics come on the market then the number of tractor graveyards will be reduced.

Higher up the career ladder is the training of the agricultural engineering technicians. Training at this level of manpower started in East Africa not through Government efforts, but through an individual. In 1939 Lord Egerton (a settler farmer in Njoro Kenya) endowed his farm and money to establish a college to train 'sons and daughters' of farmers the 'science and practice' of agriculture. Egerton College was therefore established to fulfill this function. Initially the college was admitting only 'sons and daughters' of the white settler farmers from all over East and Central Africa. However from late 1950s it began to admit African students. One of its most successful programmes was the three years diploma in agricultural engineering. This programme which combined both practical and theoretical skills produced very competent agricultural engineering technicians many of them still working in large scale agriculture throughout Eastern and Southern Africa. No wonder the white farmers in these countries were and have remained quite successful in their large scale mechanized farming. Unfortunately Egerton College has now become a University and has started in addition a BSc. degree in the same area. It remains to be seen if the quality of the diploma programme will remain the same. A diploma programme in agricultural mechanization was started at the Ministry of Agriculture Training Institute (MATI) at Mlingano Tanga. This is a 2 years programme and was started with assistance of the Government of Netherlands and FAO. However the quality of its graduates cannot be compared to those graduating earlier on from Egerton College (Rajabu (1986).

Above the technical manpower is the professional cadre trained to BSc. degree level and above. Most of the BSc. degrees in general agriculture are modelled on the BSc. (Agric.) degrees started in Makerere and Ibadan in early 1950s which in turn were based on the University of London external degree in Agriculture. Emphasis in these programmes is on the 'science' of agriculture and little 'practice' of agriculture is taught. Students do courses from several departments concentrating mostly on the Biochemical and Socio-Economic aspects of agricultural science. Agricultural Engineering courses if offered, are less than 10% of the total contact hours (usually 150-250 hours total). Majority of students registered in these programmes come from peasant/small holder farmer families and they are exposed to the sophisticated agricultural machinery for the first time in their degree training and this exposure is a very limited one. They are expected on graduation to work as extension workers, in research and as farm managers in commercial farms. They are expected to manage the Government tractor hire schemes, where these are available and in most cases with poor technician and artisan support, and poorly trained

tractor drivers. They are the most technically trained in the district yet their exposure to agricultural machinery during training is in most cases very limited. (SACCAR 1990)

When Governments in Africa took over formerly settler owned farms (as it happened in Tanzania in 1970s) they have usually appointed these BSc. (Agric.) graduates as farm managers. Agricultural machinery and implements form over 60% of the capital investment in any large scale commercial farm in Africa. Yet in our appointment criteria we often insist on a graduate who is a high flier in agricultural economics and farm management. This would have been ok if the level of training of our supporting staff had been better. However it is at the lower levels where we are even weaker. Many commercial farms which were once productive in Northern Tanzania (West Kilimanjaro) have degenerated into agricultural machinery and implement graveyards. In an attempt to increase the engineering knowledge of some BSc. (Agric.) graduates, mild specialization in agric. engineering was started for a few students at Sokoine University of Agriculture from 1975. Graduates through this option have performed quite well when it comes to management of large scale mechanized commercial farms. (Dibwe (1983); Materu (1990)). A good proportion of farm managers of the National Food and Agricultural Corporation (NAFCO) in Tanzania which farms over 100,000 ha. are graduates who did the agricultural engineering option in Morogoro (Dibwe 1983).

It is important to realize that agricultural engineering is quite a new profession in both Britain and the former British Colonies where higher education has been very much influenced by the former. Indeed the first BSc. degree in Agricultural Engineering started to be offered in Britain only in 1966 and upto now there are only 3 Universities which offer degrees in agricultural engineering in the whole of the British Isles (Newcastle, Dublin and Silsoe). In some of these Universities quite a number of students taking the BSc. (Agric. Engineering) degree are overseas students. It is only in North America and India (and here it is mostly due to starting of the State Agricultural Universities in 1960s through assistance from USA) that the agricultural engineering profession is quite well developed, and the North American programmes have been offered for over 90 years. In Eastern and Southern Africa, training of agricultural engineers started only in 1976 in Nairobi University. The second programme to be started is that of Sokoine University of Agriculture in Tanzania which started in 1983 graduating its first cohort in 1988. Training of agricultural engineers is an expensive undertaking and where these programmes have started it has been done jointly between faculties of agriculture and engineering. Perhaps our Universities should have started with programmes in agricultural engineering rather than the more conventional fields of engineering like civil, mechanical and electrical.

RESEARCH IN AGRICULTURAL MECHANIZATION

One of the weakest areas of our National Agricultural Research Systems

(NARS) has been in the area of agricultural engineering. Too often these research centres have tended to follow what the international donor agencies want and have employed expatriate engineers to develop the so called 'appropriate' technologies. Millions of donor funds, and supporting national funds have been spent over the past 3 decades in these projects. As Starkey (1986) has noted equivalent to over US\$40 million has been spent on research and development of the wheeled tool carrier all over the world, yet it is one example of a rejected intermediate technology. There are many more such technologies which have costed so much money in research and development efforts but are yet to be adopted. Further research on mechanization policies undertaken in most of Africa has been done by economists who have concentrated on proving how uneconomic it is to introduce tractor mechanization in these parts of the World and how economic the so called appropriate technologies are (Lele (1975); ILO (1976); Singh (1976); Kinsey (1976); Kinsey (1984); Kinsey & Ahmed (1984) Binswanger (1984), Pingali *et.al.* (1987) If they are so economic why then haven't they been adopted by farmers? Such researchers do often blame Governments, extension systems, etc. for non adoption and not the technology itself. The few centres which have been established in Africa on Agricultural Engineering Research (e.g. CAMARTEC in Tanzania) end up concentrating on development of these appropriate technologies with team after team of expatriate researchers supported by the donor organizations. We believe it is now time for these centres to begin research on why these technologies are not adopted, and why have tractorization schemes failed and if there are examples of success why these have succeeded. This type of knowledge will be more useful for the next two decades then trying to reinvent the wheel with these appropriate technologies.

DISCUSSION

Synthesis of Past Experience

We have in the preceding paragraphs reviewed mechanization policies and strategies in Tanzania over the past 50 years. Six distinct periods, can be discerned, in Tanzania, in so far as evolution of agricultural mechanization policies and strategies is concerned. The first is the period before 1930 which may be called the handtool technology period. The predominant type of mechanization technology then, both on the German and later British settler farms, and the native farms was the handtool technology. The settler farmers used various coercive methods to get the natives to work on their farms using the handtool technology. This was followed by the period between 1930 and 1945 which may be called the Draught Animal Power Technology period. During this period, advances in Veterinary Medicine, in particular the control of the tsetse fly through bush clearing made it possible for the pastoral tribes (Sukuma) in the North and North West to live and settle in new areas where they could not do so before because of livestock diseases. They also adopted the ox plough and started cotton production. It is still in these areas where draught animal power is used up to todote. However although they adopted

the draught animal technology, the method they were advised to use by the Veterinary officers to get rid of the tsetse fly has led to one of the greatest environmental disasters in Africa today! Large areas of Mwanza, Shinyanga, Tabora and Singida regions in Tanzania are now almost semi deserts because of the bush clearing which was undertaken in 1930's to get rid of the tsetse fly and the inherent overstocking culture of the inhabitants of these areas!

The third period in Tanzania are the years between 1945 and 1960 which may be called the commercial farming period. The tractor had been developed and perfected in Europe and North America. Settler farmers were therefore encouraged to settle in new areas in East Africa as now they need not rely on the troublesome and "lazy" native labour for their field operations. Hence large scale mechanized farms were established in Tanzania and the native farmers continued to grow their food and cash crops on their small plots. It is also during this period that the British Colonial authorities established the largest ever mechanized agriculture project in Africa - the Groundnut Scheme - which was established in Southern, Central and Western Tanzania. After five years of trying they failed and abandoned the project in 1950. It is also during this period that there emerged a class of African medium and large scale farmers who started growing commercial crops like wheat, maize, beans etc. Also the small holder farmers formed strong cooperative unions which were at this stage mostly involved with marketing of their produce (KNCU - Kilimanjaro Native Cooperation Union, VFCU Victoria Federation Cooperative Union, BCU - Bukoba Cooperative Union). Although some of them had started before 1945, their growth during the period 1945-60 was phenomenal.

There follows then in Tanzania the decade between 1960-70 which may be called the period of the World Bank Transformation Experiment . This was the period when on advice of the World Bank the rural transformation experiment was tried . During this period a large number of villagers and urban unemployed were settled in new areas and provided with capital intensive machinery and implements to transform the rural areas and increase productivity and production. This World Bank induced experiment at mechanized agriculture failed dismally and from the agricultural machinery graveyard of this experiment, there emerged however, maybe the first tractor taxi's in Africa. These were the Sukuma tractor drivers, who bought the boarded tractors and offered ploughing services to small farmers all the way from Mwanza through Arusha/Kilimanjaro in Northern Tanzania to Eastern and Western Kenya. After this follows the period 1970-83 which may be called the Ujamaa period. This was the period when the greatest social engineering work was undertaken in Africa and 13 million peasants living in scattered hamlets all over Tanzania were moved and settled in 8000 or so Ujamaa villages; with the main objective of among other things providing them with social services - schools, health and water, and agricultural inputs to produce communally or individually. It is also a period which may be regarded as one of mechanization diaspora, where different agencies and government

departments tried to provide to these farmers mechanization services - tractor and animal powered (Commodity Authorities; Cooperatives, District and Regional authorities and NGO's). Finally is the period between 1983 to today which may be called the Structural Adjustment period. During this period IMF/World Bank Structural Adjustment experiments are being followed at least on the fiscal front, and private commercial agriculture is being encouraged alongside the small holder/peasant agriculture undertaken by the peasants in their Ujamaa villages.

LESSONS FROM TANZANIA'S EXPERIENCE

What lessons then can we learn from these past efforts in agricultural mechanization in Tanzania? On handtool technology, which is the main type of technology used by the majority of farmers, the type of implements used are by and large the same as those used 50 years ago (i.e. the hand hoe (jembe); the matchete (panga); axe (shoka); and to a lesser extent - slashers, sickles and shovels). The country has set up two large scale manufacturing plants for these implements (the UFI factory in Dar-es-Salaam, and the Mbeya Farm Implements factory). Although several consultancy studies had advised (MoA-GoT (1976); CFTC (1980)) that the manufacture of handtools should be relegated from the two factories to small scale artisans and blacksmiths, it appears however that these suggestions have not been taken up by the government and these two still continue to dominate the market. Artisan production of these handtools is constrained by scarcity of raw materials and lack of tools and expansion of this sector is contingent upon widening markets through development of infrastructure (ILO (1978)). Unlike in West Africa where most handtools are fabricated by artisans and blacksmiths, in Tanzania and East Africa in general, it would seem the manufacture of handtools will continue to be dominated by large scale manufacturing enterprises. It would seem also the scope for improvement of the handtools to increase the labour productivity is limited and it is likely that design of these handtools will remain the same in the next 2 decades as it has been over the past 5 decades.

On draught animal power, it would seem that despite massive research efforts in developing new implements by such organizations as TAMTU/CAMARTEC, University, Uyole Agricultural Centre, etc. (tool carriers, inter row cultivators) and accompanying extension thrust extending over a period of over 60 years these new implements have not been widely adopted by farmers. Where DAP is being used, farmers are still using the traditional 'victory' mould board plough introduced earlier on in this century in Africa. In a few areas DAP is also used for transport with a variety of oxcarts (with wooden, metal wheels or pneumatic tyres). Further even the number of trained draught oxen is quite small. The FAO survey of 1976-79 revealed that there were only under 300,000 trained oxen in Tanzania in 9 regions. Most of them concentrated in the Mara/Mwanza/Shinyanga regions (see Table 31). It is unlikely that the other regions not covered in this survey, (e.g. Dodoma, Tabora, Iringa) have more than 100,000 draught oxen between them. Therefore

the total number of draught oxen by 1988 - even assuming a high growth rate is less than 600,000. This is in a country with over 12 million cattle and where draught animal technology has been in use for over 60 years. It would seem therefore either there is something seriously wrong with the technology and hence the non-adoption by farmers despite the apparent advantages or there is something wrong with the way it is being extended by the extension system.

TABLE 31: Trained Oxen and Ox-implements (1976/79)

Regions/Ecological Zones	Trained	Ox-implements
<u>High Potential Areas</u>		
Kilimanjaro	1,882	1,228
Morogoro	349	107
Mbeya	3,368	18,937
<u>Medium Potential Areas</u>		
Mara	26,244	10,217
Mwanza	23,488	6,077
Shinyanga	102,540	34,332
<u>Low Potential Areas</u>		
Arusha	30,396	35,893
Tabora	45,243	34,753
Singida	52,973	26,868
	295,030	174,554

Source: FAO/Kilimo, "Agro-mechanisation Survey 21/11/76 - 30/06/79. FAO Dar-es-Salaam, 1981

Further despite concentrated effort over the past 50 years in introducing this technology in the other regions where there is no livestock husbandry tradition, it would seem that these efforts have not succeeded. It may well be better therefore to allow such regions to skip this stage of technological evolution and move straight to mechanically powered technologies. Finally if the introduction of DAP technologies is to lead to massive clearance of the trees in order to control the tsetse fly and hence livestock disease as it has happened in Shinyanga/Mwanza/Mara regions of Tanzania, over the past 50 years, then the environmental cost of this is just too much and by and large we may be better off without DAP technologies in such areas.

On tractorization a number of lessons emerge from past experience of

Tanzania. In this regard we have to accept that agricultural production will continue to be undertaken in a dual structure of medium/large farms, and peasant/small holder farms. In land surplus countries such as Tanzania there is no pressure on egalitarian grounds to acquire these large farms and redistribute them to small holders. They will thus continue to operate and appear to be good examples where agricultural mechanization has worked quite well in a number of them. The main lesson here is that mechanized agriculture works well where the managerial and technical staff are able to manage the agricultural machinery and implements which constitute 60-70% of the capital invested. Despite some failures in Tanzania where newly established state farms or acquired settler farms failed to operate profitably, there are however quite a good number of these large farms which are managed and operate efficiently and they are crucial to the economy of the country in certain areas (eg tea, sugar, coffee, sisal, wheat and tobacco in Tanzania). For the small holder farmers, three methods have been used in Tanzania to provide tractor services. First the Government tried to provide the agricultural machinery and implements to farmers settled in the new settlements in the 1960's and in the Ujamaa villages in 1970's and left the management of the machinery to the settler/farmers themselves. The second method was for the Government to control and manage the tractors through the District/Regional authorities, Crop Authorities, or cooperatives who provided the tractor hire service to the small scale farmers. The last method has been for private tractor owners to provide such services without any Government intervention. The Sukuma tractor owners whom we've described earlier appear to have been quite successful in this regard and one sometimes wonders if the border between Tanzania/Kenya had not been closed in 1976/77 how they would have been faring by now.

Preliminary empirical evidence seems to suggest that all the Government tractor hire schemes have been plagued by teething problems and have ultimately failed after a few years of operation. The main lesson however from this analysis is that we do not yet know why they failed or if they were uneconomical. It is difficult to say categorically, from the empirical evidence available whether past attempts at tractorization; (be they through Government subsidies, or Government and Parastatal tractor support and hire schemes) have failed because mechanization for these small holder farmers is inherently uneconomic, or because it suffered from technical, managerial and organisational problems which can be overcome or avoided! Analysis of many past schemes has been just too superficial and in many cases this has been done by economists with pre-conceived ideas on tractorization (Singh 1978). Record keeping in many of the Government and Parastatal tractor hire schemes has been so poor for one to undertake any meaningful study.

In quite a number of cases analysis of mechanization projects has been done many years after the project has collapsed. Singh (1978); Pingali *et al.* (1987) and Kinsey (1984) in 1976-85 all used farm management data obtained by Collinson in 1962-63 season (Collinson 1964) to justify their blanket

prescriptions on the economies of tractor and draught oxen use in Sukumaland in Tanzania. Anybody familiar with the Sukumaland region in 1962-63 and late 1970's will appreciate the fact that the farming systems in this area had undergone tremendous changes in the period 1965-75 especially as a result of the Ujama villages programme. Thus their prescriptions and recommendations would seem to have been based on outdated data. A key problem however which transcends all mechanization schemes, in all countries has been lack of properly trained manpower at operational, artisan, technician and managerial levels. The lesson here is that if mechanization is to succeed then investment in human resources development must be made first.

Finally, another point which is worth noting is the fact that donors (both bilateral and multilateral) have greatly influenced mechanization policies, strategies and pace in Tanzania. Too often these donors, through the international experts and short term consultants they have sent to these countries have had a free reign in policy formulation and programme planning and implementation. We should add here however we are not saying that these experts and consultants should not be sent; all that we are saying is that if these experts and consultants come, and in particular in a technical area like agric-mechanization, and there is no internal capacity to critically analyze and evaluate their proposals/reports, taking into consideration the local reality then the danger of repeating mistakes becomes quite great. All this would seem to suggest that there is no shortcut to having your own critical mass of well trained technical staff. A number of examples can be cited in this regard. One is the different types/makes of tractors available in each country. There are about 12 different makes of tractors found in Tanzania. For some makes there is a whole range of tractors at different power ratings. Many of these tractors, at least in Tanzania, have been imported through donor assistance. For a market with a total of about 18000 tractors we find it difficult, why we cannot standardize to 2-3 makes and 2-3 power ratings. For even in Britain where there are over 500 000 tractors and each year over 22 000 new tractors are added to the fleet, there are only about 8 dominant makes (FAO (1986); Gibb (1988); Kurdle (1975)).

CONCLUSION

Mechanization technologies have perhaps been the ones which have attracted interest from all those who have been involved in Tanzania's development over the past 5 decades - politicians, economists, sociologists, agriculturists, engineers, donors, etc. This has also made them quite controversial. It would seem that the percentage of land cultivated by the three levels of mechanization technology - handtool, animal and mechanical powered has by and large, remained at the same level over the past 30 years (80, 10-14, 6% respectively). This is the case despite an almost three times increment in the number of tractors in the country. Although, politically, policy emphasis has for a greater part of the Tanzania's 30 years of independence, been on animal powered mechanization, the numbers of trained oxen used in agriculture has

shown only marginal growth over the same period and area cultivated by animals has remained the same. Some observers and researchers (Kjoerby (1983); Johnston (1984)) have attributed this lack of progress in animal powered mechanization to contradictions in policy; with the policy makers saying one thing in public, and doing the opposite in practice. This would seem to indicate that at the grass roots level (i.e. districts) the development practitioners are not themselves convinced of the case for draught animals. There is evidence to show that large stocks of ox-drawn ploughs, and ridgers have remained unused, and unsold in godowns of the regional trading companies to the extent that the main manufacturer UFI has faced liquidity problems (ILO 1978). If the policy makers at the national level have been convinced on the need to promote the use of this technology, it would seem lower down the system, at district level, there is still a lot of persuasion which has to be done. Yet, quite a number of villagers have contributed money to buy village tractors in quite a number of villages in Tanzania.

It would appear that in the development process, agricultural mechanization is a conundrum. For inspite of many economic studies and consultancy missions we are still far from evolving an agricultural mechanization policy which appears to be working in particular for the small holder farmers. Further tillage methods have, by and large remained the same with almost entire reliance on the handtool technology. Even more serious, we cannot precisely say what was wrong with our previous attempts at mechanization. All that we have are macro analysis of the projects, often undertaken long after the projects have collapsed and concluding with blanket prescriptions like "inappropriate technologies" etc.

It would seem that agricultural mechanization is one area where everybody is experimenting - the Government, individuals, donors, etc. These are indeed expensive experiments and one way or another we need to get out of the experimentation and develop policies and strategies which can lead to an improvement of the situation. We have had many failures in this long and arduous struggle to mechanize our agriculture. Perhaps the key factor which has been missing in all the previous attempts is the human resources required for mechanization. It would seem, agricultural mechanization can only succeed, if there is a critical mass of properly trained and enterprising managers, who understand the technology involved, supported by competent and hard working technicians, artisans and machinery operators. It may well be more prudent to start with getting this type of human resource before we embark on any large scale mechanization be it animal or mechanically powered. Doing otherwise, it would seem, we shall end up in the 21st century using technologies which were abandoned in the 19th century in other continents.

CHAPTER 10

AN OVERVIEW OF AGRICULTURAL MECHANIZATION STRATEGIES IN ZAMBIA

by

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INTRODUCTION

Zambia shares its borders with Zaire and Tanzania in the north, Malawi and Mozambique in the east, Zimbabwe, Namibia, Botswana in the south and Angola in the west. It occupies 75 million hectares of the Central African Plateau, most of it lying at an elevation between 900 and 1,400 m above sea level. Zambia lies between the 8 and 18° South latitudes and longitudes 22 to 34° East. It enjoys a sub-tropical climate comprising of three distinct seasons. The hot dry season occurs between August and November during which temperatures rise to between 27 to 32°C. A wet warm season from November to April follows with temperatures averaging 22°C. This is followed by a dry cool season between April and July when maximum temperatures vary between 15 and 27°C, and nights with frost may occur in places. Zambia has an annual rainfall distribution that increases from below 600 mm in the south west to above 1,600 mm in the north near Zaire. Based on the rainfall patterns, Zambia has been divided into three major agro-ecological zones. Zone I constitutes those areas with mean annual rainfall of up to 800 mm. Zone II has mean annual rainfall of between 800-1000 mm. Zone II is the main agricultural potential area of Zambia. Zone III is the high rainfall area with annual rainfall above 1000 mm. Because of the very high precipitation in this area, soils are highly leached and therefore acidic, limiting their productivity.

Zambia's economy is predominantly based on mining. Its mineral exports in 1977 (97% of which was copper) accounted for 97% of the total exports. This fell to 88% in 1984 (GRZ/CSO, 1986). Of the US \$1.2 billion export earnings of 1988 for example, more than US \$1.0 billion was from copper exports alone (EIU, 1990). Agriculture on the other hand has been a very minor contributor to the GDP especially at the time of independence. Its contribution has however risen steadily from 8.2% of GDP in 1965 to about 18.9% in 1989 (GRZ/CSO, 1990). The per capita GDP has been decreasing from K382 in 1977 to K270 in 1990 at constant 1977 kwacha.(GRZ/CSO, 1990,1986). This decline has been attributed to the low price of copper which by 1990 had become a mere 25% of its real value in 1970 (Wood et al., 1990). Coupled with it were the soaring costs for oil imports and all

manufactured products. A rapid decline in the economy (about 3% per annum up to 1984) followed (GRZ/CSO, 1986). The cost of production including agricultural production, increased (ILO, 1987) as the means to sustain that production were declining. Consequently, Zambia is going through hard economic times. The population is increasing at a rate above 3.5%. Urbanization is expected to reach 70% by the year 2010. The rural productive population will at that time be less than 15%. Zambia faces a challenge of an ever decreasing agricultural population attempting to meet the food needs of an ever increasing urban population in a declining economy. This paper is an overview of the mechanisation strategies that Zambia has taken to meet this dilemma.

HISTORICAL BACKGROUND

Pre-Independence

Before independence, the majority of Zambia's population relied mainly on subsistence agriculture (Wood et al, 1990., Dodge. 1977). Among the British colonies of Central and Southern Africa, Zambia's contribution to the colonial economy was seen to be its rich copper mines whose deposits extend into the Shaba (Katanga) Province of Zaire. The exploitation of these minerals required the creation of a copper based economy in which the inhabitants were to provide the required large labour reservoir. To achieve this, various schemes were instituted including a head tax (*Musonko*) where every male was expected to pay cash tax every year. This cash tax could only be earned by working for the colonial government, mining companies on the Copperbelt of Zambia, or on settler-owned farms. This was the beginning of the migration to the urban areas. This migration of mainly males also started the gender imbalance which is very evident in many outlying provinces of Zambia such as the Luapula and Western Provinces where women form a majority of the remaining population (LWMP, 1990). The 1980 census (GRZ/CSO, 1986) figures confirm that Copperbelt, Lusaka and Central Provinces which constitute the urban areas of Zambia have more males than females (Table 32).

Whereas labour migration to South African mines depleted rural districts of able bodied males needed in agricultural activities, the internal migration to the Copperbelt created an extra political dimension to the socio-economic life of the country. Large concentrations of economically and politically active populations were being created. The movement for Zambian independence was started on the Copperbelt. This strength that the urban centres in Zambia wield, and in particular the clout which Copperbelt town centres exercise up to now in the country's political and economic life is probably the most significant factor in shaping the agricultural policy of independent Zambia (Dodge, 1984).

TABLE 32: Sex Ratio by Province, 1980

PROVINCE	NUMBER OF MALES PER 100 FEMALES
Central	101.2
Copperbelt	105.5
Eastern	87.7
Luapula	91.1
Northern	90
Lusaka	103.8
North-Western	90.9
Southern	95.6
Western	83.4
TOTAL ZAMBIA	95.8

Source: Central Statistical Office, 1986, Lusaka

As stated earlier, Zambia's main economic activity during the colonial period was the production of copper. The infrastructure was developed to support the mining of copper. Agriculture for the white settler population was a minor activity. Nevertheless the settlers were guaranteed protection from African competition. Even where Africans attempted to enter the commercial market, a price differential was paid for maize produced by white settler farmers over that by African farmers (Dodge, 1977). Africans were left to carry on with subsistence/traditional agriculture as their involvement in commercial agriculture was feared would degrade soils irreparably (Wood et al, 1990). Traditional agriculture included shifting cultivation, which grew increasingly difficult for the women to practise once their husbands (who normally clear new land) had gone to work for the copper mines. Women were therefore forced either to continuously use the same fields whose fertility had been exhausted, or only till a very limited area. Women therefore often tilled the same land repeatedly for progressively lower yield (Milimo, 1985)

White maize to feed the urban population of the Copperbelt was to be grown by white farmers along the line of rail. Any short falls that occurred were to be met by imports from white farmers of the then Southern Rhodesia whose production was supported by good climate and good soils (Dodge, 1977). African participation in commercial agriculture was to be limited to working for white farmers on large commercial farms to earn their head tax. These commercial farms were initially tilled using oxen. Operators of these oxen were expatriates from Zimbabwe and South Africa.

The Colonial government's effort in encouraging African agriculture started after the Second World War. In late 1946, following G.F. Clay's 1945 report "*Memorandum on Post War Development Planning in Northern Rhodesia*", the African Farm Improvement Scheme was introduced for Central and Southern Provinces to provide subsidized purchase of ox-drawn equipment and extension services. The scheme included working out crop pricing mechanism. Equipment supported by this scheme included ploughs, cultivators, wagons and scotch carts. The scheme was introduced amidst an ox-drawn technology brought to the Africans at the beginning of the century through the work of altruistic missionaries in the Southern Province of Zambia. Milimo et al. (1990) reports that it was not in the commercial interest of white farmers to transfer this technology to Africans as this would bring unwanted competition in the agricultural sector. However, agricultural mechanization began to be adopted by the African farmer more after these incentives were introduced, particularly in traditionally cattle keeping areas of Southern and Central Provinces and in Mbala and Isoka area of Northern Province (Milimo, et al. 1990). Use of oxen in Ndola before independence, mainly by the Shona settlers from Zimbabwe has also been reported.

TABLE 33: Maize Production by Province in 1989

Province	1989/90 in 000 bags	%
Central	2573	21
Copperbelt	558	5
Eastern	3149	26
Luapula	429	4
Northern	1147	9
Lusaka	425	4
North-Western	254	2
Southern	3194	26
Western	411	3
TOTAL ZAMBIA	12140	100

Source: Ministry of Agriculture, Early Warning Unit, Lusaka, 1990
Official Crop Production and Sales Data

The production of maize by African farmers in the Southern Province of Zambia increased following adoption of draught animal technology. Maize production from the Tonga Plateau of the Southern Province increased almost four times in fifteen years up to 1933 (Wood, et. al, 1990). The technology adoption itself was principally assisted by a very buoyant market for maize in the large

population centres of the line of rail and the Copperbelt in particular. However, because of this technological advantage, Southern Province maintained its lead in maize production up to the time of independence. At independence up to 80% of the marketed maize was produced by white commercial farmers mainly from the Southern Province.

Post-Independence Strategy

At independence, Zambia inherited an agricultural sector consisting of a highly mechanized commercial sector and a very large subsistence sector. Shortly after independence in 1964, about half the 1,200 white settler farmers left the country for the then Rhodesia (now Zimbabwe) and South Africa (Dodge, 1977). The newly independent state of Zambia had an agricultural sector whose major crop was maize, 80% of which was produced by white farmers, half of whom had now left the country as a reaction to the territory's independence. The new government then faced the responsibility of ensuring uninterrupted production of maize and cheap access to that maize in order to maintain stable copper production. Copper consisted of 97% of Zambia's exports. At independence the world copper market also provided Zambia with one of the most buoyant economies on the continent.

The government sought to achieve reliability in the supply of maize by creating a new class of African commercial farmers whose presence in the country would be assured. This class of farmers would have been created by providing large subsidies to costs of land clearing, purchase of tractors and implements, purchase of inputs like fertilisers and other chemicals, and provision of credit in order to ensure production of cheap maize. To provide for this new cadre of African farmers the government adopted a mechanisation policy where the state encouraged massive importation of agricultural machinery (Table 34) as there were virtually no factories of agricultural machinery in Zambia at the time. This was feasible then as Zambia had sufficient export earnings to finance importation of tractors and other equipment.

Land clearing units were set up to undertake subsidized land clearing for all those wishing to start farming. These units were later transferred to the National Service of the Defence Forces thus restricting easy access to performance data thereafter. The government also sought to secure the supply of maize by itself going into agricultural production. Large state farms and parastatal bodies were formed to engage in agriculture. These ventures are still there (Sindazi, 1987), even though their performance is far below the initial expectations.

In the field of agricultural training, Zambia built a technical level Natural Resources Development College (NRDC) for training Zambians in the field of agriculture. At craft level, the Monze and Mpika Colleges of Agriculture were

opened up to train agricultural assistants. In the field of Agricultural Engineering, graduates of the NRDC had the highest qualification available in the country until the first group graduated with BSc. degree in agricultural engineering from the University of Zambia in 1990. At professional level, the University of Zambia started producing graduates of agricultural sciences with some basic knowledge of agricultural mechanics in the middle of the 1970's. It was not until 1986 that Agricultural Engineering was transferred to the School of Engineering of the University of Zambia.

TABLE 34: Schedule of Farm Tools and Equipment Imported into Zambia 1970-79

Year	Mould board	Cultivator	Ploughs	Harrows	Planter	Handtools	Tractors
1970	3097	508	983	1238	439	107888	686
1971	1412	708	728	672	7835	231580	1174
1972	735	947	350	1353	303	12453	782
1973	5754	526	371	371	221	106959	893
1974	1125	180	343	368	390	483310	696
1975	23	545	885	621	98	102196	777
1976	1009	308	162	528	262	46690	811
1977	2652	3031	1455	761	141	299142	692
1978	13269	189	1359	911	3273	95046	684
1979	11632	1229	1968	6183	109	26416	947

Source: Regional Project on Farm Tools and Equipment Technology, Basic Needs and Employment, ILO/FIN/78/RAF/2

The policy of tractorisation was favoured because of its perceived capability of increasing the productivity of the African farmer. Justifiably, this was possible then. Zambia was in a position to pay for such costs from its copper earnings. Besides, the over-valued currency which was linked to the British Pound supported such moves by making imports cheaper. The policy though appearing pragmatic in intent, was flawed in concept. The negative result of this policy was that no alternative methods of mechanization were pursued.

There were also positive developments resulting from this policy. Zambia emerged with three distinct categories of farmers in this period. These groups were identified according to the size of land they cultivated and the targets of their production. The largest group consisted of subsistence farmers tilling up to two hectares. In 1980, these numbered about 610,000, down from 623,000 in 1971.

The objective of subsistence farmers is to produce for home consumption. Whenever the yields are above average, a little surplus may be sold for cash. The second group of farmers comprises, the emergent farmers. This group in Zambia is defined to include all those farmers who till between two and 40 hectares of land, and whose main purpose for farming is the market. These sell between 50 and 100% of their produce. In 1980, they were estimated to be about 90,000 such farm families. Above forty hectares, the farmer is classified as a commercial farmer. In terms of the technology used in production, the subsistence farmer uses hand tools only. The emergent farmer uses oxen, tractor power, or hiring such services for working the farm. The commercial farmer runs a very highly mechanized farming operation, heavily dependent on imported technology and inputs.

EFFECTS OF ECONOMIC DECLINE

Following the end of the 1973 Middle East war, the oil prices began to rise, the copper prices began to fall as a result of declining economic activities in the major world industrial centres. Coupled with this was the technological substitution of copper wire which was taking place during the late 1970s. A falling value for the only major export commodity, and the soaring costs for its oil imports and all manufactured products caused a very rapid decline in the economy (about 3% per annum up to 1984) (GRZ/CSO, 1986). The cost of production including agricultural production, rose (ILO, 1987). The government began to subsidize the high cost of living using the accumulated foreign reserves and external borrowing in anticipation of a recovery in copper prices. The urban population which in 1963 was only 20.5% had now increased to 30% and was also more politically conscious. In the interest of political stability the government offered massive subsidies on food production inputs including milling companies. Agricultural equipment, fertilisers and other chemicals, handling and transportation of the agricultural produce, the milling and distribution of the maize meal were all subsidized in order to keep maize flour prices low. Dodge, (1977) estimates that the subsidy on maize alone to be in the region of 110% of the value paid to the farmers.

As Zambia's economic condition worsened, the country could no longer afford to import all the spares for the large variety of agricultural equipment that had entered the country either through the open market or through donor assistance programmes. A survey undertaken in 1985 indicated that at least 23 makes of tractors alone were in use in the country (Tembo, 1985). The land clearing units established in every province could no longer maintain their equipment. Tractor owners had no more spare parts available (Milimo, 1985. GRZ, 1990). Agricultural inputs like fertilisers could no longer easily be imported due

to lack of hard currency. Faced with declining agricultural production, balance of payment problems and pressure from the donor community, Zambia reviewed its agricultural mechanization policy. In 1985, a sub sector study was undertaken through the funding from Swedish and Dutch Governments. Their recommendation was for increased utilization of the oxen technology. Many studies prior to this Dutch/Swedish study had shown that in circumstances of the worsening economic situation in Zambia, cultivation by oxen had become more competitive than tractor cultivation. (See Table 35). A study by IRDP in the Northern Province even claimed that the area cultivated increased by between 20 and 30% within two years of purchasing oxen.

TABLE 35: Tractor versus Oxen for Land Preparation Costs in 1980 Based on Analysis

Farm Size ha.	Cost/ha. Kwacha	Break even Yield/ha 90kg Bags of Maize
Tractor ploughing		
20	678	50
50	451	33
100	375	28
Oxen Ploughing		
4	312	23
6	283	21
8	269	20

Source: FOA/UNDP, 1981 (1 Kwacha approx. US\$1.25 in 1980)

OXENIZATION POLICY

For the first time in independent Zambia a specific policy on mechanisation was enunciated for inclusion in the National Development Plan (1986-90). The old tractorization programme was to be officially dropped and replaced by oxenization policy. However farmers with sufficient resources for investment in capital intensive farming were to be encouraged. In fact to assist these farmers, the number of tractors makes would be reduced to three, concentrating in the power range of 35 to 40 hp. Effort was to be made to establish local manufacturing/assembly plants for the few selected makes FAO estimated that there were 4500 tractors in the country in 1989. The government itself retained some of the programmes of machinery hire services like the land clearing services now under the National Service. The FAO for example continued funding another

such unit in the Eastern Province upto 1990. The structure of agricultural engineering department in the Ministry was rearranged, requiring graduates of agricultural engineering to become Provincial Agricultural Engineers. Positions of

TABLE 36: **Estimated 1985 Numbers of Implements**

Implement	1985
Ox-ploughs	110000
Ridgers	30000
Cultivators	20000
Ox-carts	10000
Hoes	3000000

Source: GRZ, 1985 - Ministry of Agriculture and Water Development, 1985
Investment Plan, Animal Draught Power

District Agricultural Engineers were to be filled up by NRDC graduates. Based on 1985 estimates (Table 36) of oxen drawn implements, targets for different ox-drawn implements were included as shown in the Table 37. Institutions dealing in any aspect of agricultural engineering, such as the Research Centre at Magoye in Southern Province, the Department of Agricultural Engineering at the University of Zambia, Kasisi Agricultural Training Centre were all to be involved in the implementation of the new policy. In the changed economic times, oxen technology had now become more competitive than tractorization. In retrospect, this was the same policy (though slightly modified) which the colonial government implemented in the late 1940's through the African Farm Improvement Scheme in the Central and Southern Provinces, which had a measure of success and now was being tried for the whole country 20 years after independence.

TABLE 37: **Projected Annual Market for Implements (with Village Workshops)**
(Total for the Country)

Implement	1986	1987	1988	1989	1990
Ox-ploughs	13851	12978	13388	15133	17269
Ridgers	2000	2000	2000	2000	2000
Cultivators	1500	2000	2500	3000	3500
Ox-carts	1000	1500	2000	2500	3000
Hoes	200000	200000	200000	200000	200000

Source: GRZ, 1985 - Ministry of Agriculture and Water Development, 1985
Investment Plan, Animal Draught Power

IMPACT OF TRACTORIZATION

The tractorization programme in Zambia was not a complete failure. Statistics show that the number of commercial farmers increased by 38% between 1970 and 1988. A number of African farmers entered commercial farming as a result of government subsidy schemes (Table 38). Subsistence farmers decreased by 0.5% per annum during 1969 to 1980. The middle group of farmers also increased by over 13% (Wood, 1984). Area cultivated by commercial farmers has increased by almost 48% between 1965 and 1988 (GRZ/CSO, (1990). Large parastatal estates producing a variety of crops such as sugar, coffee, wheat, or tea using highly mechanized methods were started during this period. These schemes are still operating. The total land under cultivation almost doubled from the 1980 levels to just over 1.0 million hectares by 1989 (FAO, 1990), while total cereals output has more than doubled during the same period. Average yields peaked in 1988 at 1710 kg/ha.(FAO, 1989).

TABLE 38: Summary of Area, Production and Sales of Maize by Commercial Farmers

Crop	No. of Holdings	Holdings Reporting	Area Harvested	Total Production 90 kg bags
1940-41	-	-	13729	173000
1945-46	-	-	19797	395000
1950-51	-	-	39783	467000
1955-56	-	-	47383	956000
1960-61	-	-	42700	1427000
1965-66	-	-	71689	3413868
1970-71	1090	846	39940	2020400
1975-76	1527	1096	103650	4647840
1980-81	1835	1569	67860	3044772
1985-86	1972	1463	67739	3500140
1987-88	2115	1577	74763	3231122

Source: Central Statistical Office, Lusaka, September, 1990
Agricultural and Pastoral Production (Commercial Farms)

Under pressure from the donor community subsidies on agricultural machinery for the private farmers were removed. However, the producer price for maize remained so low that it became uneconomical for commercial farmers to continue maize production. Many of them switched to growing high valued crops such as soya beans and wheat. The amount of wheat produced in 1989 increased by 1360% over the 1976 figure of 3,459 tonnes (FAO, 1990). At the same time the slowly rising producer price for maize was perceived by peasant and

emergent farmers to be high enough to make maize cultivation profitable at their level of inputs. The government encouraged this trend by supporting small farmers using credit schemes mainly administered through government banks like the Lima Bank, National Commercial Bank and through the Zambia Cooperative Federation (ZCF). Commercial banks also joined in the credit support to small scale farmers on the strength of credit guarantees offered by the government. The success of this policy by the government is evident. In 1990, 80% of the marketed maize was produced by the peasant and emergent medium scale farmers, a reversal of the 1964 production ratios, when large scale farmers dominated the production of maize.

This worked in favour of the government whose aim was to keep maize meal prices as low as possible for political stability. Government sensitivities towards the price of maize meal is justified. When the government attempted to remove subsidies on the price of maize meal in 1986, food riots erupted on the Copperbelt and the capital, forcing the government to rescind the decision. The donor community was at the time urging removal of all subsidies from consumption items. Four years later, the government again attempted to remove the subsidy on maize meal. Again the decision was met with violent protests by the large urban population which had then (1990) swelled to 50% of the total population. This time the protests went further by demanding political reforms. The government conceded to political change but maintained the reduced maize meal subsidy as a long term good for the country. The maize subsidy is to be phased out by 1992. How then does a government faced with such a volatile urban population which is forecast to reach 70% by the year 2010 plan to provide sufficient food to this rising population (estimated at 3.67%), and especially so, cheaply?

THE CHALLENGE

In Zambia, most small scale farmers already use hybrid seed. This is as a consequence of the government's efforts through its extension and financial programmes which promoted the use of hybrid seed with fertilizers under its *Lima* programme. This programme was a deliberate effort to introduce small scale farmers to modern and hopefully commercial ways of farming (Wood, 1984). The results of this programme include relatively high (by African standards) yield levels which peaked at 30 bags per hectare in 1988. From these results, any additional benefits obtainable from using seed technology appear to have already been exploited by the largest group of farmers in maize production. Another possibility that could increase production would be the use of fertilisers. Here again small scale farmers are all, by and large, using chemical fertilisers (Table 39). For the levels of production, intensification may already have been achieved when yields per hectare are considered.

TABLE 39: Fertilizer Consumption 1978-87 (In Metric Tonnes)

1978	130077
1979	145368
1980	196361
1981	218790
1982	217751
1983	165796
1984	143891
1985	211179
1986	190703
1987	243825

Source: GRZ Statistical Office, 1989. Bulletin

Zambia's increasing urban population will continue to depend on the food product produced by an ever diminishing rural population whose productivity should of necessity increase drastically. In the year 2010, only 30% of Zambians will live in the rural areas. Of these, 50% will be in the dependent age group (below 15 and above 65 years of age). This labour force will be mainly women according to current demographic data. At present levels of productivity, only 60% of the total population will be fed. Conversely, the farmer's productivity will need to increase by another 70% before the year 2010 if food self sufficiency is to be maintained. This can come up either by increasing the area under cultivation or by increasing the yield per hectare. Intensification through fertilizers and seed technologies has almost levelled off. The benefits from the fertilizers is expected to decrease with the removal of subsidies on fertilizers which is making it less affordable to the small scale farmers. Increasing area under cultivation is therefore the only viable alternative. This is possible through the promotion of the right technology to the small farmers. The technology that these farmers can afford to pay for profitably at the moment is oxen technology.

Under the current economic conditions obtaining in Zambia, a mechanization policy based on increased utilization of draught animal technology would seem to be the best option in the short term. Higher levels of technology would invariably mean importation, not only of the equipment, but also of the spares for that equipment on an uninterrupted basis. Given the current foreign currency shortages this may not be that feasible at the moment. However higher efficiencies in utilizing current tractor stocks could also contribute to increased agricultural production. Oxen technology would have the benefit of sustaining the available locally based ox implement manufacturing capability. Donors' willingness to support programmes that assists the "poorest of the poor" only made it easier to

choose this option. The Dutch government agreed to support the policy of oxenization for the National Development Plan Period 1986-90. The support of this mechanization policy was to cost \$17.6 million in foreign currency and K23,935,000 (equivalent to US\$500,000.00 in 1990) in local currency. At the end of the plan period it is expected that a total of 14,240 new farmers will have started farming with oxen becoming emergent farmers. The programme of oxenization would thereafter be self supporting according to the objectives of the project.

In the 1989-93 National Development Plan, the government policy on mechanization is that oxenization must be encouraged. A series of measures have been instituted using, among others, Dutch financial and personnel support. An Animal Draft Power Project has been operating since 1986 whose task it is to develop the use of animal power for all stages of food production, from tillage operations to food processing. The projects tasks include the promotion of the manufacture of ox-drawn equipment at established industries, establishment of village workshops to service the farmers' equipment and some support to private production of oxen for use in Animal Draught Power Programme. The programme aimed at increasing the number of trained pairs of oxen by 12,527 (Table 40), benefitting some 14,240 farmers directly. An extra 12,650 hectares of land would come under cultivation as a result of the oxenization programme. The programme also includes training of animals, training of private commercial animal trainers, and blacksmiths.

TABLE 40: Target Numbers of Trained Pairs of Oxen by Province, 1985-1990

Province	1985*	1986	1987	1988	1989	1990
Central & Lusaka	14461	15907	17498	19248	21173	23291
Copperbelt	660	792	954	1140	1368	1642
Eastern	18911	21275	23934	26926	30292	34079
Luapula	235	284	344	416	503	609
Northern	2096	2389	2724	3105	3540	4036
North-Western	145	265	482	877	1597	2906
Southern	47995	50394	52914	55937	59278	62984
Western	4991	5490	6039	6643	7307	8038
TOTAL	89494	96796	104885	114292	125058	137585

Source: GRZ (MoA), 1985, Animal Draught Power Investment Plan. Ministry of Agriculture estimates

*Estimated actual numbers existing as of 1985

NEW STRATEGIES

To strengthen the oxenization programme Zambia obtained from the EEC and Sweden foreign currency support for the local manufacture of agricultural equipment by private companies, most of which is in animal power technology. However, this support extended to the manufacture of other agricultural inputs provided the companies could raise adequate cover in local currency. From 1990 steel imported into the country for the purpose of manufacturing agricultural equipment was exempted from customs and excise duty. This step removed a major inconsistency which made imported equipment cheaper than that manufactured locally. Even with these incentives, companies are still unable to use more than US \$20 m, made available for this purpose. The reason was, as part of government's effort to limit excess liquidity in the economy very stringent credit and banking regulations limiting borrowing by companies and lending by banks were instituted. Here again is an example of a well-intended agricultural mechanization policy being drastically affected by fiscal policy measures.

A third component of Zambia's strategy in providing food for its rapidly growing population is by shifting its focus to the emergent farmers. These are the farmers in-between the traditional peasant farmers and the commercial farmers. It is this group that has shown the potential and capacity to expand agricultural production. This class of farmers use oxen and sometimes tractors in their operations. This focus is intended to ensure that government resources will be used where they will produce maximum results. It should be noted that Zambia's expenditure on agriculture is still low. Starting with 3% of annual budget in 1965, it reached 19% in 1989. The target is for expenditure on agriculture to reach 30% by 1990.

Fourthly, Zambia has now realised that maize cultivation has been over stressed. This has tended to encourage maize cultivation at the expense of other crops even in areas which are marginal for maize. In the last few years farmers encouraged to cultivate crops like sorghum and millet in drought prone areas which are better suited to such crops. Commercial production of these crops has been increasing since 1981 (GRZ/CSO, 1990). Between 1981 and 1989 production of sorghum and millet increased by 130 and 18% respectively. Conversely, in areas of medium and high rainfall, production of maize is being promoted. Sometimes this is concurrently being done with the oxenization package. The results of this strategy has resulted in the Eastern Province increasing its maize output to surpass Southern Province which was hitherto referred to as the "maize belt of Zambia". The success of the oxenization programme will be measured by the increase in oxen sold and used for agriculture in those areas where cattle rearing has not been part of the culture of the people. Evaluation of the performance of the project has not yet taken place. Therefore, no information is yet

available on its contribution to the Zambia's quest for food self-sufficiency.

The final strategy adopted by Zambia in its efforts to provide cheap maize meal to the largely urban areas has been the introduction of hammer mills. More than 90% of maize produced in Zambia is milled by large industrial milling companies. These companies are now either owned by parastatals or by the cooperative movement. In 1986 following the food riots, the government nationalised the milling companies and handed them over to parastatal companies to operate. At the end of 1990, transport and handling subsidies alone amounted to about 74% of the price of maize meal. To reduce this, hammer mills have been provided through government and donor support to every community that requests one (including District Councils) with as low as 10% down payment on the cost of the mill. The maize marketing monopoly by cooperative movement was discontinued. Consumers could now buy maize directly from farmers and mill it into maize flour for consumption without going through the large industrial milling companies. The milling companies on the other hand have also been permitted to obtain their maize supplies directly from farmers instead of through the Cooperative Unions (or National Agricultural Marketing Board before them). Therefore through this measure of liberalisation of the maize marketing coupled with the hammer mill programme, it is hoped would effectively lower the cost of maize meal in Zambia. Already hammer mills are being installed in the urban areas on the line of rail including the politically volatile Copperbelt towns.

SENSITIVITY TO MONETARY POLICY

Zambia's strategies for sustaining the food supplies for an increasingly urban population remain vulnerable to other policy considerations. For example, the 1990 policy on money supply negatively affected the strategies enunciated above. Firstly, the acquisition of oxen, ploughs, cultivators, animals, and other inputs like chemicals and seeds are all made on credit from commercial and government banks whose credit ceilings have been severely curtailed. As a consequence Zambia is expected to import maize in 1991 (GRZ, 1990) because the area planted is far less than the minimum required for self-sufficiency. This has affected both commercial and peasant farmers who use hybrid seeds requiring fertilisers. Secondly, the Zambia Seed Company, hitherto the sole marketing agency for seed in Zambia was unable in 1990 to buy all seed from seed growers due to lack of credit. Hence seed distribution was poor during the 1990/91 planting season. Most commercial farmers run on operational credit obtained from commercial banks seasonally. During 1990, coupled with the liberalisation of maize marketing, the Zambia Cooperative Federation which is charged with the nationwide buying and distribution of crops (maize) could not obtain credit for the purchase of crops and payment of trucking charges, resulting in poor collection rates to safe storage

of the 1989/90 crops. In the short term this monetary policy seems to stifle the seemingly good strategies of agricultural policy of the government. This illustrates the fact that agricultural mechanization strategies can only be part of the overall strategy to provide sufficient food to the country.

CONCLUSION

Zambia's adoption of increased utilization of draught animal power as a policy was not a selection of possible affordable alternatives but rather the only option which is affordable and for which external funds were available for launching it. Research has shown that it would be cheaper for the small and medium emergent farmer to use oxen than to use a tractor at current economic conditions. Such research, on the other hand, has not conclusively shown the success of such a programme as Zambia has now adopted. Tractorization as a policy could not be sustained by direct subsidized importation because of weakening economy like Zambia's. Its effectiveness as a short term strategy (comparatively speaking) for raising food production has been demonstrated over the last two decades. But it is also very sensitive to economic pressures and external trade. A tractorization policy for Zambia should encompass assembly or manufacture of tractors and its implements in Zambia not only for the Zambian market but also for other countries in the regional groupings like SADCC or the PTA if it is to remain viable and self sustaining. It still offers a better chance to the country for meeting the growing food needs of the rising urban population. Oxenisation if accepted by the Zambian farmers will form a stable agricultural base for the rural community, but in terms of providing future security for food production a higher level technology will be required. Optimization of oxen productivity coupled with a decreasing rural population will soon outstrip the usefulness of oxenization in meeting the growing food needs. Tractors have the capacity to increase the area of tilled land over very short periods. Zambia can buy time with oxenization as she waits for her economy to pick up. Food production is affected by many other factors like price, credit, markets, extension, and other incentives.

From a mechanization point, Zambia presents an interesting case. For its export earnings it relies on mineral exports, and insignificant agricultural products. Agriculture has been used to produce food and other commodities for the internal market and the importation of agricultural inputs has been financed through funds obtained from exporting copper. Compared to other African countries Zambia uses relatively higher doses of fertilizers and other biochemical inputs in her agriculture and as we pointed out earlier she has perhaps reached the plateau in terms of exploiting these technologies. She will have thus to adopt a more extensive type of agriculture rather than an intensive one. With a decreasing rural population and increasing urban one, this will mean increased reliance on mechanized agriculture.

The current oxenization policy is essentially a holding action and Zambia would have to evolve a policy whereby there is an efficient medium and large farm sector, which optimally utilizes the agricultural mechanization inputs, to produce not only food but agricultural export crops which should eventually replace copper as the main foreign currency earner. It seems there are no options other than following such a policy. Further as the copper mines are depleted, it will be necessary for the country to find alternative employment opportunities for a majority of its urban population. It is unlikely that such a politically conscious, and comparatively skilled labour force as the one found in the Copperbelt will readily agree to move into handtool or animal powered agriculture even though there is land. Zambia therefore faces hard choices in the next 2-3 decades in so far as agricultural mechanization is concerned. Let us hope that current efforts (though late) of training competent manpower for agricultural mechanization will provide the country with the required expertise to choose the right option.

ADOPTION OF RESEARCH FINDINGS IN AFRICA: THE NIGERIAN EXPERIENCE

by

J.Y. Yayock and S.M. Misari

INTRODUCTION

One of the main features of African agriculture is its low productivity. This is so, notwithstanding the fact that the continent is endowed with a generally favourable agricultural resource base. Primarily as a result of small and fragmented land holdings, the use traditional farming practices, and the near total dependence on human muscle power for virtually all the farm operations, the typical African farmer produces an amount of food that is barely enough to feed his household. This has aggravated the food problem in most African countries that a significant proportion of the population is said to be either undernourished or chronically malnourished. Although other factors have in some countries greatly influenced food production (e.g. civil wars, droughts, floods, etc.), however many African countries have of late become increasingly dependent on imported food to feed their populations. There is thus the "African food crisis", the "African economic crisis" in the World media, all of which can be said to emanate from the sorry state of our agriculture.

With the population of Sub Saharan African countries increasing at a very high rate, the food and agricultural production problems are likely to become even more serious as we turn into the 21st century. This is occurring when the level of science and technology in the World has made important breakthroughs such that the problem in other continents is not one of food shortages but of food surpluses and how to dispose such surpluses. This is occurring in continents which are endowed with less favourable agricultural resource base than Africa. The breakthrough in biochemical technologies has been spectacular in particular in the last 50 years. Some of such technologies have begun to trickle down to the African farmer and as such there are more farmers using improved seed varieties, better crop and livestock husbandry techniques, as well as better crop and livestock protection measures. Although the level of adoption of these Biochemical technologies in Africa cannot be compared with that of the other continents, it suffices to say that there has, at least, been some adoption. It is to the physical technologies however that the level of adoption, by a majority of African farmers, has been dismally low. Thus a majority of the farmers are still using the handtool technology with entire reliance on human energy, in most field operations-a technology, which farmers in other continents were using three to four centuries ago.

Why then has the rate of adoption of these agricultural mechanization technologies been so low in Africa? As has been stated elsewhere in this volume, despite over 60 years of popularization of draught animal power technologies in the Savannah belt of Nigeria -- the level of adoption is still very low with less than 6% of total cultivated land area in these Northern states being tilled using this technology and less than 100 000 farmers have adopted this technology (see paper by Mekanjuola *et.al.*). This is so despite numerous socio-economic studies which have conclusively shown that adoption of this technology leads to not only an increase in overall production and productivity, but also significantly reduces the drudgery of performing field operations compared with using the handtool technology. Why then have farmers not adopted such a useful and good technology? The main objective of this paper is to try and present some thoughts on the problems associated with extension of agricultural mechanization technologies to small holder farmers. It is not intended to cover the problems in this area for the whole of Africa, as we shall confine ourselves to our experience in Nigeria. Our analysis is also not exhaustive and our intention is to examine this problem of extension of physical technologies from an agricultural extension specialist point of view and hopefully at the end of it all we shall all be a little bit more knowledgeable of the problems involved. We shall first briefly analyze the Nigerian research institutional framework and the research/extension linkages and finally we shall focus our analysis to the problem of dissemination of research findings in particular on the physical technologies.

INSTITUTIONAL ARRANGEMENT FOR AGRICULTURAL RESEARCH AND EXTENSION

Before dwelling on Nigeria's experience in technology dissemination and transfer, it is pertinent to have an insight into the country's technology development process. In recognition of the strategic importance of technological development in procuring raw materials for overseas industries, the British Colonial Government evolved, in the early 1900s, an implicit research and development policy involving mainly export crops. Soon after independence in 1960 and resulting from the country's participation in the 1963 United Nations' conference on the application of science and technology as well as the UNESCO conference on research and training in Africa, the need for greater focus on agricultural research and development as a tool for rapid national development became more apparent. This subsequently led to the creation, in 1966, of the first science and technology central supervisory organ - the National Council for Scientific and Industrial Research. Since then, to date, there have been as many as six different organs of government charged with overseeing research and technology development. The existing central supervisory organ, the Federal Ministry of Science and Technology (FMST), was created in 1985. While the FMST is responsible for the overall coordination of the technology generation aspect of the agricultural system, its dissemination, adoption and utilization rests largely with the Federal Ministry of Agriculture (FMoA) as well as the different state Ministries of Agriculture.

Also of relevance is the fact that the bulk of training institutions which are involved in considerable generation of technology and the dissemination of research results are supervised by yet a different ministry - the Federal Ministry of Education (FMoE). The present state of institutional arrangement for agricultural training, research and extension may be briefly highlighted as hereunder.

Training and Research Institutions

As of today, Nigeria has 26 commissioned research institutions and centres of which 19 deal wholly or partially with agricultural problems. These are in addition to 16 university faculties of agriculture, two fully fledged Universities of Agriculture, about 60 other agricultural institutions offering middle-level technical training, one international agricultural research institution as well as a number of other national and regional training and research outfits. Specific to agricultural mechanization, virtually each of the 28 degree-awarding institutions and not less than nine of the commissioned research institutes, plus well over two dozens Polytechnics are involved in training and research in this area. While the FMST is charged with the overall supervision of the national agricultural research system, university level training is coordinated under the FMoE. Coordinating research activities specific to agricultural mechanization towards ensuring the effective dissemination and adoption of new and improved technologies is the National Centre for Agricultural Mechanization (NCAM) established under the FMoA.

Agricultural Extension and Research Liaison Services

These service-oriented units are presently integral components of the various broad-based and multi-disciplinary zonal Research Institutes charged with the dissemination of research results in specified geo-political areas of mandate. The best known Agricultural Extension and Research Liaison Services (AERLS) unit was carved out of the Institute for Agricultural Research (IAR), Samaru, in 1975 as an autonomous institution and charged with the servicing of the same mandate area as the IAR - until the re-organization of the national agricultural research system in 1975. Today, the original AERLS has assumed national responsibility in coordinating the extension activities of zonal AERLS.

Specific Programmes for Technology Adoption

Over the years, both State and Federal Governments in Nigeria have vocalized a wide range of agricultural research and development strategies, up to and including large-scale and completely mechanized farms. However, it is evident from existing policy documents that the federal and state governments believe that a major constraint to increased agricultural production is insufficient knowledge by peasant farmers of improved agricultural techniques. Consequently, a number of programmes and projects have been promoted in

recent years by state and federal governments with the aim of providing this knowledge and making it available to the peasant farmers in the country. Among such programmes are the following:

- (i) National Accelerated Food Production Programme - Launched in 1972, the National Accelerated Food Production Programme (NAFPP) had been, at least on paper, the most all-encompassing effort in the development of Nigerian agriculture up to the early 1980s. The programme was regarded as a major strategy to improve production conditions for specific and specified food crops. Using a concerted action in research, extension and agro-service, the results of scientific crop research and improved production technologies were planned to be brought to the farmers in a short period with the expectation of mass adoption.
- (ii) Agricultural Development Projects - Supported jointly by the State and Federal governments on the one hand and the World Bank on the other, the Agricultural Development Projects (ADPs) have become the focal points of all agricultural development activities nation-wide. Established in the mid-1970s to increase agricultural production, the ADPs presently constitute the direct link with farmers in terms of input delivery and extension services.
- (iii) River Basin Development Authorities - Presently numbering 11 and under the Ministry of Water Resources, River Basin Development Authorities (RBDA) are charged primarily with water resources development.
- (iv) Directorate of Food, Roads and Rural Infrastructure - This Directorate (DFRRI) was established in 1985 with the main aim of removing bottlenecks in the transfer of proven technologies and support in rural infrastructure rehabilitation.

Approaches to Technology Dissemination

For several decades now, the tendency in Nigeria has been towards emphasizing the development and transfer of biological-based technologies such as improved seed varieties, animal species, fertilizers and management practices. Proven research results and improved technologies emanating from the country's numerous research institutes, universities and polytechnics are normally translated into production packages for specific crops and animal species and transmitted to the various extension agencies who are then charged with the responsibility of disseminating the same to farmers and other end-users. The approach to technology dissemination employed by the Samaru-based AERLS up to 1987 and which strategy has been mostly continued since then by the various zonal AERLS, involves assembling proven research results and tested technologies from the various research institutes, universities and

polytechnics located in and/or relevant to the area of mandate being serviced and putting them together for adoption in the form of "recommended practices". The target is usually farming families in an area, although priority is often given to the so called "progressive farmer", largely because of the limited number of available extension field staff.

Quite often, field plots are used to demonstrate the potential of the new agricultural techniques. Both the print and electronic media are sometimes used to achieve awareness and posters, agricultural exhibitions and shows as well as such other extension approaches are used to persuade farmers to carry out trials on their own fields. Periodic visits by extension agents to individual farmers during the trial period are undertaken to facilitate the adoption process. In carrying out these responsibilities, the AERLS units are expected to liaise closely with State MoA in general and the ADPs in particular. In addition, they are to identify problems requiring solutions through basic research which are communicated to the research centres. Other key responsibilities of AERLS include the conduct of applied research on farmers fields and investigating into ways of improving extension services in the country (Yayock 1983). The integrated rural development programmes currently being pursued in Nigeria are characterised by a preference for achieving increased agricultural productivity through improvements of existing peasant systems rather than by radical changes. A key element in the ADP operation is the Training and Visit (T&V) system which aims at providing an effective link between extension and research activities towards ensuring a continuous flow of practical recommendations suited to the farmer's needs. The adoption of the T&V extension approach by the ADP's is most probably a result of the cofunding of these ADP's by the World Bank as this approach, can by and large, be regarded as the 'officially' adopted method of extension by this international agency. The T&V system was originally developed in India (Benor 1978) and it is claimed it was quite successful there. However some observers have noted that it is quite expensive method of extension especially to farmers who have their farms scattered all over the place. It is too soon to say now if this method will produce the same results in Africa as it is claimed to have done in India. In addition it may well produce some impressive results under the ADP system especially in the beginning when the World Bank funding is still available. It remains to be seen whether the state and federal governments can sustain such a system when the World Bank assistance is terminated.

Problems of Biological Based Technologies

Probably, as in many other developing countries, the Nigerian agricultural research system is often blamed for failing to make an impact on the nation's agricultural output. This is not to deny the fact that dramatic improvements in agricultural technologies have been demonstrated to be possible as can be seen from Table 41. Dramatic increases in the productivities of virtually all the major

crops have been achieved under research station conditions. Indeed, there is evidence to suggest that aspects of several improved technologies and recommended practices emanating from the national research system have been and are being adopted by a reasonable number of farmers. However, the problem remains that of only very few farmers having the willingness or even the capability of following in any significant manner, available improved technological packages - with the possible exception of maize. The reasons for this problem is the subject of considerable contention, with some charging the farmers as being tradition-bound and, therefore, unwilling to change their ways. Others blame the problem on ineffective extension services. And yet many argue that the credit system is unsuitable whilst a school of thought puts the blame on inadequate farm inputs. There is no doubt that one or a combination of these explanations has been valid at different times and locations.

TABLE 41: Yield (kg/ha) performance of major food crops at three levels of technology under sole cropping

Crop	<u>Farmer's Practice</u>		<u>Research Station Practice</u>
	Traditional Technology	Improved Technology	Improved Technology
Sorghum	785	1,680	3,920
Millet	740	1,344	2,800
Maize	1,046	3,000	7,840
Rice	940	4,445	3,360*
Wheat	1,750	2,500	4,500
Cassava	5,750	11,263	22,580
Yam	5,272	9,004	20,070
Groundnut	586	1,120	2,240

*Refers to upland rice; best swamp rice yields of 4,800 kg/ha and irrigated yields of 5,600 kg/ha have been recorded (Yayock and Karikari (1989)).

It should be appreciated that the Biochemical technologies by their very nature are divisible and avail to the farmer an opportunity to experiment on his own without taking much risk. Thus a farmer may buy a quarter of a kilogram of a new seed variety and plant it in a corner of his field whilst planting his traditional seed in the remaining part of the field. If there is a remarkable and quite apparent increment in yields he may well adopt this new seed variety in the next season. If however there is no apparent increment in

yields or if the new variety demands higher labour input than he can provide given all his other tasks he may well not adopt it, the key issues in this regard is that he has had the opportunity to test the new technology at a minimal cost and risk to himself.

However, a very important but less frequently mentioned explanation for the relatively poor performance of Nigeria's agricultural sector relates to the development of technologies that are inappropriate and/or unacceptable to a majority of farmers. A major aspect of the agricultural process that has not received as adequate attention as the biological-based system relates to the physical technologies (mechanization and irrigation). Drawing from the experience of the more technologically developed world, it is evident that a more balanced combination of biological and physical/mechanical technologies can result into a rapid agricultural transformation in Africa. The fact is that the development, progressive improvement and eventual adoption of mechanical/engineering technologies for the various farm operations invariably ensures, among other things, their speedy completion, enhanced job quantum as well as the preservation of human muscle power (Kaul 1989).

AGRICULTURAL MECHANIZATION DEVELOPMENT

In quite a number of African nations there are networks of agricultural mechanization research and development programmes established with the country's or with donor assistance to enhance farmers' productivity. These local and donor supported research efforts have yielded some results in terms of the development of prototypes of agricultural equipment and implements, many of which have a potential in contributing immensely to increased and sustained food production (Kaul and Misari 1989; Olugbemi and Kaul (1989)). In the specific example of Nigeria, the broad policy for agricultural mechanization has been to consider the totality of the agricultural production process towards applying engineering solutions to specific aspects and problems. The overall research thrust is aimed at reducing human drudgery, minimizing labour costs and enhancing productivity and efficiency. While the major focus is on agriculture, considerable attention is also given to other sectors of the agricultural process, especially in terms of identifying operational constraints and management. Most of the research projects undertaken on agricultural mechanization have focussed on small-scale farmers, indigenous food habits, adaptability to local soil, weather as well as socio-economic conditions and involving as much locally obtained components and materials as is possible. In virtually all departments of agricultural engineering in Nigeria's universities, polytechnics and research institutes, there are a large number of different prototypes of agricultural equipment and implements which have been designed and developed, and in some cases have been widely field tested and demonstrated to farmers but which have not yet moved to the next stage of development - commercialization and ubiquitous manufacturing and dissemination. Significant amounts of national and donor funds have been spent in these research and development efforts and yet the results of all these

efforts is not apparent in our rural areas as the farmers are still using the centuries old handtool technology in most field and post harvest operations (Mohammed (1989); Kaul (1989); Yayock (1989 a,b)). What then are the constraints to widescale adoption of mechanization technologies? What makes the dissemination of agricultural mechanization technologies lag so much behind the biological based technologies?

Constraints in Adopting Agricultural Mechanization Technologies

The following would seem to be the major constraints which have led to low adoption rates of agricultural mechanization technologies:

- (a) **Controls of importation** - Given the chance, the average Nigerian consumer would prefer a piece of imported agricultural equipment to one that is locally fabricated, not necessarily because of its reliability, durability or performance, but it would seem to us, primarily for its physical appearance. In the absence of any policy provisions for the localization of the imported technology, it would literally amount to economic suicide for a local manufacturer to commit huge financial resources to the mass production of a particular agricultural equipment prototype which his/her competitor in business is easily able to import and sell. The implication is that until and unless there is a deliberate and clear-cut policy by the government to control the importation of certain types of agricultural machinery and equipment, the dream of mass-adoption of locally generated technologies would continue to be elusive. By control here we do not necessarily mean outright banning of importation of equipment which are locally produced but other fiscal measures can be used like huge excise and customs duties; and/or importation quotas, etc. Such controls should be accompanied by provision of assistance to the local manufacturers to increase the quality of their products through enactment of legal standards and other provisions. Control through fiscal measures will also allow the local traders who are importing the foreign manufactured implements to take up the distribution of locally manufactured implements as their profit margin will then be reasonable and leave the manufacturer to concentrate on manufacturing.
- (b) **Commercialization of Research Results** - Partly because of the long-term nature of investments in the commercialization of agricultural prototypes and partly as a consequence of uncertain market situation as earlier mentioned, entrepreneurs are often quite reluctant to commit resources to the mass-production of new and improved equipment and machines. With the get-rich-quick syndrome of the typical entrepreneur and especially given an uncertain political environment, there is no known easy solution to the dilemma of mass-production of prototypes in the absence of controls on importation. An additional factor is the weak

operational linkages that exist between the various sectors in the nation and various nations, the African Regional Centre for Engineering Design and Manufacturing (ARCEDEM) and potential entrepreneurs. In the specific case of Nigeria and largely as a consequence of inadequate support, the effect of NCAM in the transfer of tested technologies is yet to be felt.

Drawing from the successful experience of establishing a seed production unit in the late 1960s, for rapid multiplication and direct distribution to farmers of large numbers of recommended crop varieties released by it, the IAR, today, finds itself in exactly the same situation in respect of labour-saving mechanical devices. Even with the strenuous efforts made towards having interested entrepreneurs to mass-produce some of the equipment prototypes developed by the Institute (as shown Table 42), no major success has so far been recorded. Consequent upon this unbearable situation, the IAR is presently in the process of setting up a prototype production unit, akin to the seed production unit - which was later taken over to become the nucleus of the National Seed Service of the FMA. Once established, such a prototype production unit would be of service not only to other Nigerian institutions, but should also serve the training needs of the African region.

- (c) Appropriateness of Imported Technology - Through the regular testing of imported machinery, the IAR has firmly established that the design and production of a large number of equipment and machinery do not normally take into cognisance the nature of the soil, environmental conditions as well as the agricultural production system outside the place of development and manufacture. This is evident from the poor performance, frequent break-downs, as well as the wear and tear of components for an over-whelming number of the imported equipment and machinery tested. Through its regular testing programme, the IAR has, thus, to some extent, been able to advise against the importation of unsuitable equipment. In addition, through the release of test results, some manufacturers have been motivated to modify on their equipment designs in order to suit local farming systems, conditions and practices.
- (d) High Cost-Benefit Ratio - An important consideration that influences the adoption of a new technology, whether imported or locally developed, is the financial capability of the prospective user. For example, a farmer may realize and appreciate fully the advantages intrinsic in a particular agricultural equipment and still snub it, purely on the grounds of its high price tag. Indeed, some of the farm equipment currently manufactured locally are too expensive for the average end-user - a situation which will undoubtedly hinder their adoption. In order to reduce overhead costs and, thereby bring down prices, it would be desirable to mass-produce such equipment and machines for sale in the African region where conditions are relatively similar. To overcome this problem of high initial

capital costs three approaches have been used. First is to design equipment of smaller size suitable for use by one farmer and hopefully cheaper due to scaling down of size. However due to their inherent nature, scaled down mechanization technologies do not often lead, to commensurable reduction in cost and in many cases the scaled down device does not perform as well as the full scale model. This in many cases has led to non-adoption of such appropriate technologies. The second method is to encourage cooperative or multi-farm ownership of equipment and machines. There are of course a number of management problems in such ventures and this can only work in specific areas and under specific local conditions. The third method is to provide for local hire services through Government or private ownership. Experience so far in the whole of Africa, especially with tractor hire services, shows that these are beset with so many problems in particular the Government owned schemes. This is perhaps an area where research can assist in developing better management techniques for equipment hire services be they public owned or privately owned.

TABLE 42: Some prototype equipment designed and fabricated at IAR, Samaru, indicating their advantage over traditional methods*

Prototype Equipment	Operations Performed (kg/man-hr)	Prototype Output (kg/man-hr)	Traditional Output
Multi-crop Thresher	Threshing & winnowing of:		
	- Wheat	40	5
	- Sorghum	30	20
	- Millet	30	15
Groundnut sheller	Shelling & practical cleaning	30	1
Groundnut thresher	Picking pods from harvested plants	30	2
Straddle Row Weeder	Weeding on ridges	0.1(ha/hr)	0.02(ha/hr)
Maize sheller (manual)	Shelling of maize	14	9

Source Kaul and Misari (1989) and Kaul (1989)

- (e) Standardization of Products - The standardization of engineering products is a generally accepted tool towards ensuring the quality and functional performance of finished agricultural equipment and machines. In the absence of any national standardization of agricultural machinery, many institutions have independently developed or improved on prototype equipment that perform similar functions, but which are different in design and specification. Such variations are manifested in the materials used, sizes of the various components, arrangement of the parts as well as their effective and efficient performance. Thus, in order to ensure sustained production of quality and functional agricultural prototypes and spares and in order to gain a wider market, it is necessary to evolve acceptable national standards as well as restricting the types and makes of machinery which can be imported/manufactured.
- (f) Trained Manpower - The availability of trained manpower is a crucial factor in the successful adoption of research results, the adaptation of appropriate technologies as well as the overall effective promotion of research and development work. As of today, there is a dearth of trained and experienced specialist manpower for virtually all the training and research institutions in the country. The situation is, indeed, becoming of increasing concern, especially in the context of the high mobility of the more experienced staff to more lucrative and satisfying involvements, both within and outside the country. In no disciplinary area is the problem of trained manpower more acute than in agricultural, applied sciences and engineering. A possible way of resolving this serious constraint is through a total invigoration of and support to postgraduate training programmes of some selected African universities towards serving the training needs of the region. It is also important, in this regard, to ensure that the manpower involved with extension of agricultural engineering technologies is conversant with the technologies they are extending. Many of the frontline extension workers are normally trained to certificate and diploma levels in general agriculture. Although they do a few agricultural engineering courses, this is not sufficient to make them conversant with most agricultural engineering technologies. It is necessary therefore through short courses (1 - 3 months) that they are continuously trained to understand basics of operation and maintenance of such engineering technologies so that they can extend the information to farmers. Alternatively specially trained agricultural engineering extension workers could be trained and employed specifically for the engineering technologies just like we have veterinary frontline extension personnel. The lack of knowledge of engineering technologies by the frontline extension workers is perhaps one of the major constraints in dissemination of these technologies. The situation is similar to a car dealer employing a salesman who does not know how to drive a car! Coupled with training of frontline extension workers on engineering technologies, there is need also for the design and development engineers to understand more the whole agricultural

production system. It is only by understanding this system that they can design and develop appropriate implements for use by farmers. It is necessary therefore to offer short courses as well as introduce more agricultural courses in the engineering programmes.

CONCLUSION

The problems encountered in dissemination of engineering technologies to small and large scale farmers have been described above. It would seem, extending such technologies, compared to the traditional biochemical technologies is much more difficult. In the more advanced countries the development of implements and machinery has been left to the private companies and public research and extension system has been more involved with the development of the management systems for such technologies. In Africa however the private companies hardly do any research to be able to develop the necessary hardware which their counterparts in the more developed countries have been so successful at. Thus this is left to the public research system to initiate research to develop the 'hardware'. A major problem would seem to be that the public research system has been unable to get the private and public companies to commercialize and start large scale manufacturing of the prototypes developed. In addition even where such technologies have been imported the public system has not been able to develop an efficient management system of such technologies (i.e. the software) which they can then extend to farmers. These problems necessitate a different approach in the extension and research efforts in the field of agricultural engineering. In the initial stages however concerted efforts have to be made in training the frontline extension workers to have a basic understanding of the engineering technologies as well as the research and development engineer to have a better understanding of the agricultural system. The problems however are many and we are just beginning to tackle them. Collaborative efforts between the different disciplines involved will be necessary if we are to overcome the constraints which have so far impeded the adoption of engineering technologies by African farmers.

CHAPTER 12

FORMULATION AND IMPLEMENTATION OF AGRICULTURAL MECHANIZATION STRATEGIES IN INDIA

by

S.K. Misra

INTRODUCTION

India has experienced spectacular development in agriculture since she launched her first five year plan in 1951 e.g. food grains production has increased from a level of 53 million tonnes in 1951/52 to 173 tonnes in 1989-90. This has been possible as a consequence of the progressive policies of the government to promote R & D and education; investments in production facilities for agricultural inputs, and industrial goods; rural extension services; rural credit lines, etc. The farmers, on one hand, and trade and industry, on the other hand, have played an equally complementary role in this direction. The agricultural sector provides food to the growing population; employment for 75 per cent of the population; raw materials for industrial production; foreign exchange through agricultural exports, investible surpluses to the pool of domestic savings and a vast market for domestic manufactured products. The most important feature of Indian agriculture has been that the benefits of the green revolution have not been monopolised by the big farmers alone but these have permeated down to all categories of farmers. Even costly machinery like tractors, threshers, etc, which are directly related to the economies of scale, are available to the small farmers. The landless farm labourers and farm women have also gained from the utilization of the new technologies, in terms of higher and better health through cheaper food and reduction in drudgery in performing the arduous farming tasks. The agricultural mechanization inputs wherever adopted, have helped in, among other areas in: increasing production; attaining higher levels of productivity; increasing rates of economic returns; reducing the risk of pre harvest and post harvest crop losses; increasing employment opportunities for skilled, semi-skilled and unskilled labour and in reducing the drudgery of field tasks and and overall improvement in the working environment. This has been possible because of improvements in timeliness of operations; precision of operations; and increment in rate of work. Our main objective in this paper is to highlight the main developments and achievements in the field of agricultural mechanization which India has achieved over the past 50 or so years.

INDIAN AGRICULTURE

In order to appreciate the initiatives and current programmes in mechanization, a brief introduction of agriculture in India is necessary. India has diverse soil and climatic conditions comprising of 15 broad agro-climatic zones and various agricultural crops can be grown. The total area of the country is about 329 million ha while the total net sown area is about 149 million ha. The population in 1990 is estimated at 811 million which is projected to increase to between 945 and 995 million by 1995. About two-thirds of the present population is dependent upon agriculture, out of which 41.6% of total population being cultivators (i.e. those who own their own farm or lease land) and 24.9% being agricultural labourers (i.e. those who are solely employed in agriculture). The total rural population is 76.7 per cent. The female sex ratio of the country is 933 per 1000 males. The literacy in male and female is 47 and 25 per cent respectively. The climate is broadly described as tropical monsoon type. The average rainfall is about 1170mm. The total annual precipitation is estimated to be 400 million ha of water. The annual rainfall, however, fluctuates from region to region both in space and time. On the basis of rainfall, the country can be divided into 3 broad zones:

- (a) Dry (below 750mm) : 30 per cent of land area
- (b) Medium (750-1150mm) : 42 per cent of land area
- (c) High (1150mm and above) : 28 per cent of land area.

About 75 percent of the annual rainfall is received from June-September, with south-west monsoon phenomenon, while the post and pre-monsoon rainfall accounts for 10-11 per cent each, the rest 3-4 per cent are winter rains.

Soils & Land Tenure

The soils of India are normally categorised into 13 types. Alluvial soils occupy 43 per cent of total area followed by black soils (13.7 per cent) and red (sandy and loamy) soils (10.2 per cent). Thus, two-thirds of the total area of the country is under these three soils. Laterite and desert soils occupy almost one-sixth of the area of the country. Alluvial soils are one of the most important soils in terms of economic importance. In the pre, as well as, post independence period, India experienced remarkable change in the nature and extent of tenancy. After independence, radical land reform measures were introduced in the country. These legislations, inspite of numerous difficulties in their implementation, have resulted in substantial decrease in tenancy and significant increase in self ownership. According to 1985-86 agricultural census, marginal farmers operating less than one hectare of land constituted about 58.1% of total number of

operational holdings but the area cultivated by them was only 13.2% of total cultivated land. The medium and semi-medium farms (between two and ten ha) form the most important group of operational holdings. The details of operational holdings are given in Table - 43.

Cropping Pattern

During the past three and a half decades, the cropping pattern has undergone a tremendous change. To start with, the process of change was set in motion in 1950s and early 1960s. It gained momentum with the expansion of irrigation facilities and the advent of High Yielding Varieties (HYVs) of wheat in late 1960s and of rice in 1970s. The percentage of area under some important crops to gross cropped area is shown in Table - 44.

TABLE 43 - Distribution of land holdings (1985-86)

	No. of holdings: x 10 ³ Area : x 10 ³ ha	
Category of holding	No of operational holdings - 10 ³ (% of total No. of holdings)	Area cultivated x 10 ³ ha (% of total area)
Marginal (less than 1 ha)	56,748 (58.1%)	21,606 (13.2%)
Small (1 to 2 ha)	17,881 (18.3%)	25,533 (15.6%)
Semi medium (2 to 4 ha)	13,253 (13.5%)	36,579 (22.3%)
Medium (4 to 10 ha)	7,920 (8.1%)	47,008 (28.7%)
Large (10 ha & above)	1,929 (2.0%)	33,187 (20.2%)

Seeds

The HYVs of wheat and rice have made greatest impact on cereal production. The progress made in coverage of areas under wheat, rice and maize HYVs is indicated in Table - 45.

TABLE 44 - Cropping Pattern

% land sown to crops (1986-87)			
Crop	1986-87	Crop	1986-87
Rice	23.2	Sugarcane	1.8
Wheat	13.1	Cotton	3.9
Maize	3.4	Jute	0.5
Barley	0.7	Tobacco	0.2
Pulses	13.2	Potato	0.5
Oil	10.4	Onions	0.1

TABLE 45 - Area under High Yielding Varieties (HYVs)

Crop	1960-61	1970-71	1980-81	1985-86	1988-89
	(Area x million ha)				
Rice	0.89	5.59	18.23	23.47	29.0
Wheat	0.54	6.48	16.10	19.08	22.0
Maize	0.21	0.46	1.60	1.80	2.50

The country has a seed act which specifies that no person can sell the seeds of notified kind/varieties unless such seed meets minimum standards of germination and purity.

Fertilizers

The use of chemical fertilizers in the country has also increased significantly. After the introduction of HYVs, the use of phosphatic fertilizers and micro nutrients have increased tremendously. The fertilizers consumption in the country during the period 1951-89 is given in Table - 46. About 80% of fertilizer consumption is used in irrigated areas. There is wide inter-state variation in fertilizer consumption ranging from 160 kg/ha (in Punjab) to about 5 kg/ha (in Assam). There are 45 fertilizer testing laboratories with an analyzing capacity of 74000 samples per annum and 454 soil testing laboratories with analyzing capacity of 6.4 million samples per annum.

TABLE 46 - Consumption of chemical fertilizers
(‘000 Tonnes)

Year	N	P ₂ O ₅	K ₂ O	Total
1951-52	58.7	6.9	-	63.6
1955-56	107.5	13.0	10.3	130.8
1960-61	210.0	53.1	29.0	292.1
1968-69	1208.6	382.1	170.0	1760.7
1973-74	1829.0	649.7	359.8	2838.6
1978-79	3419.5	1106.0	591.5	5116.9
1983-84	5204.4	1730.3	775.4	7710.4
1988-89	7246.1	2721.6	1068.2	11035.9

Pesticides

The consumption of pesticides has gone up mainly due to increased use of HYVs as well as multi-cropping system and also increase in the irrigated area under cultivation. The pesticides consumption in the country is given in Table - 47

TABLE 47 - Consumption of Technical Grade Pesticides:

(‘000 Tonnes)

Year	Consumption
1950-51	2.35
1960-61	8.62
1970-71	24.32
1980-81	45.0
1985-86	52.0
1988-89	84.67

Irrigation

While the river systems irrigate the whole country, tanks and wells have traditionally served areas which are in the drier parts of the country, wells and tube wells are mainly found in the alluvial plain and nurture the largest area under irrigation in the country. Net areas irrigated by different systems is given in Table - 48. The most significant development in irrigation is the increase in the contribution made by the tube wells and pump sets. Assured irrigation from these sources has contributed greatly to the phenomenal increase in productivity and output. The present population of irrigation pumps and their annual production is estimated to be 10.5 million and 0.6 million units respectively.

TABLE 48 - Area irrigated by different systems(Area $\times 10^3$ ha)

Source	1950-51	1960-61	1970-71	1984-85
Government Canals	7158	9170	11972	12933
Private canals	1137	1200	866	858
Tanks	3613	4561	4112	3972
Tube wells	NA	135	4461	5843
Other wells	5978	7155	7426	7601
TOTALS	17886	22221	28837	31207

Electrification

Since independence, power has been given a very high priority in the planning process. In fact, highest proportion of plan expenditure has been incurred on power, followed by irrigation. Table - 49 shows the growth of electric power consumed in the country.

Table 49 - Electric Power Consumption

(in million kwh)

Year	For agricultural consumption	Total consumption	% share of agricultural consumption of total
1980-81	14489	82367	17.59
1981-82	15201	90245	16.84
1982-83	17817	95589	18.64
1983-84	18234	102344	17.81
1984-85	20960	114068	18.40
1985-86	23422	122999	19.10
1986-87	28218	136081	20.74
1987-88	34814	146206	23.81

Yields

Table - 50 gives the yield per hectare of principal crops. All India rice yield is

1688 kg/ha. Average rice yield in Punjab (which has highest degree of mechanisation) is 3082 kg/ha. This shows that the country has still a long way to go to enhance average yields on an all India basis. Mechanization can play a very important role in this regard.

Horticulture

The area under fruits in 1986-87 was around 2.94 million ha and under vegetables 4.31 million ha. The use of machines in horticulture is much lower. The fruit and vegetable production during 1988-89 was estimated to be around 25.5 and 50 million tonnes respectively indicating a low productivity in this area.

Table 50: Average yield of principal crops

Crop	1950-51	1960-61	1970-71	1980-81	1988-89	
Rice	711	1013	1123	1336	1688	
Wheat	663	851	1307	1630	2241	
Maize	547	926	1279	1159	1401	
Pulses	441	539	524	473	589	
Oil Seeds		481	507	579	532	827

Market Support

The role of co-operatives in the marketing of agricultural produce has been progressively expanding and this has helped farmers to obtain better prices for their produce. As an integral part of the strategy to increase agricultural production, the Central Government announces every year support prices in respect of wheat, rice, coarse grains, pulses and oil seeds. For agricultural commodities like potatoes, onions, ginger, etc, market support is provided through declaration of market intervention prices.

Plasticulture

The use of plastics is crucial to Indian agriculture in view of the changing technological scenario for boosting crop yields and productivity. The consumption of plastic was a bare 5000 tonnes in 1959. It has now touched 500,000 tonnes and within a few years it is expected to reach a million tonnes. The greenhouse/low tunnels, mulching and nutrient film technology are at an advanced stage of development. Plastic films for lining of canals and farm ponds, sprinkler/drip

irrigation and packaging of fruits and vegetables have achieved a fair level of adoption.

REVIEW OF INDIAN AGRIC MECHANIZATION PROGRAMMES

Five Year Plans

With the expansion of irrigation facilities, introduction of high yielding and short duration varieties of crops, fertilizers and plant protection requisites becoming increasingly available, a base for intensive farming in the country was created. The emphasis during the first plan (1951-1956) and second plan (1956-61) was on introduction of improved manually operated and animal drawn implements and tools. This trend continued to be in evidence during the third plan (1961-66) as well. It was naturally difficult to embark on programmes of popularisation of power operated machinery in the absence of indigenous production and for lack of well tested equipment. The demand for such power operated machinery (tractors, power tillers, etc) was met through importation. The popularisation of improved implements such as mould board plough, cultivators, chaff cutters, winnowers, etc, nevertheless contributed towards modernisation of farming techniques.

Towards the end of the second plan, of indigenous agricultural implements were conducted, and research centres for development of new and improved implements were set up, and a system for production and distribution of such implements and organisation of training facilities for artisans engaged in the manufacture of improved tools was created. The imperative need of a purposeful and large scale farm mechanisation programme, however, came to be realised during the Third Plan and this was in a large extent due to the recognition of the importance of farming practices based on technological devices. It came to be appreciated that along with the inputs like seeds, chemical fertilizers, pesticides, etc, supply of farm machinery and improved implements must also be organised. Steps were taken to develop indigenous capacity for manufacture of agricultural machinery and it was realised that farmers must be supplied with credit for acquisition of such farm machinery. During the third plan, sixteen research, testing and training centres were set up. At these centres work on development of new and improved implements and research on agro-implement-practices and management was initiated. Facilities for training of village artisans on the repair and production of improved implements were organised by setting up 46 workshop wings attached to Extension Workers' Training Centres. Centres were also established for training of farmers and extension workers in the operation and maintenance of tractors and agricultural machinery. One of the centres later developed into a testing laboratory for testing and evaluation of tractors, power

tillers and other power machinery. The centre was modelled on the lines of the National Institute of Agricultural Engineering at Silsoe U.K. Another significant step taken was the exemption of wheeled tractors and power tillers from the licensing provisions of the Industries Act which enabled intending manufacturers to enter the market. Government also liberalised the allocation of foreign exchange for importation of capital goods in favour of agricultural machinery industries.

The Government promoted the establishment of State Agro Industries Corporations in 17 major states with a view of making available services of costly machines to small farmers, manufacturing of improved implements and tools developed by research institutions, assisting in the efficient distribution of inputs like seeds, fertilizers and pesticides and, promotion of agro-based industries having a bearing on production, preservation and supply of foods. These corporations were Government owned companies and they undertook various activities in the farm machinery area, important among which were hire-purchase-sales of agricultural machinery, assembly-distribution and after-sales-service of imported tractors and custom agricultural services.

By the end of fourth plan (1969-74) the above measures yielded results and total availability of farm machinery increased substantially. In the fifth plan (1974-79) a special programme of introduction of improved implements for rice cultivation and a programme of trials and installation of hydraulic rams was initiated. However, the size of programmes was not adequate. Under the scheme of training and financial assistance to unemployed engineers for setting up Agro Service Centres, and for technical services for machinery hiring, etc, about 3000 agro service centres were set up in different parts of the country. However these centres faced a number of problems and it was subsequently established that custom hiring centres alone were not economically viable. During the sixth plan (1980-85) and seventh plan (1985-90), a large programme of demonstration and subsidised sale of improved implements and hand tools for small and tribal farmers was undertaken under which 82900 demonstrations were organised on farmers' fields to educate them about the benefits and economics of using the improved tools and on operation, adjustment and care aspects. In addition about 500000 improved tools were also supplied to small and tribal farmers at subsidised prices.

Two committees were set up by the Government to advise on various aspects of popularization of agricultural machinery. The Agricultural Implements and Machinery Review and Release Committee with responsibility of taking stock of technological developments and recommending suitable implements for different agro-climatic regions was constituted. A non-statutory Central Agricultural Implements and Machinery Council was also set up for advising the

Government on target for production, ensuring production and supply, effecting norms for efficiency in production, standardisation, distribution and pricing, promoting research, extension and adoption of agricultural machinery and implements etc.

Research and Development

The Indian Council of Agricultural Research (ICAR) is the main co-ordinating, promotion and funding agency for agricultural research and extension education and it attaches due importance to farm machinery education and research in the country. There are 19 Departments/colleges offering under-graduate and/or post graduate programmes in agricultural engineering producing about 400 BSc. graduates and 70 post graduates annually, at the same time contributing through basic and applied research. Agricultural engineering covers a wide range of activities which includes farm machinery and power, soil and water engineering, post harvest technology, dairy and food engineering, rural industry development, integrated rural energy systems, rural sanitation, rural transport, rural housing and aquacultural engineering. Considering the need for research and extension in these fields, a Central Institute of Agricultural Engineering (CIAE) was set up at Bhopal (Central India) in the year 1976 under the aegis of ICAR. The Institute has a Crop Production Engineering Division which undertakes research, design, development, laboratory and field evaluation of machinery and prototype manufacture of various farm tools, implements and machinery required for small, medium and large farms under dry and irrigated farming conditions.

The Farm Implements and Machinery Scheme has 16 co-operating centres located in various State Agricultural Universities and ICAR Institutes with co-ordinating cell at CIAE. The scheme has the objective of conducting research on the development of farm implements and machinery, manufacturing of prototypes, feasibility testing of improved implements, identification of implement packages for various food, oilseeds and pulse crops, development of training methodology and upgrading of skills of village artisans. The Agro Industrial Extension Division of the Institute works as a vital link between research and manufacturers in getting the proven prototypes commercialised. The division helps the manufacturers in improving the quality of the agricultural machinery already being manufactured by advising them on improved fabrication techniques and utilization of better materials. The Institute is also organising short term (1-3 months) and long term (more than 3 months) training programmes for national and international participants financed by RNAM, FAO, British Council and World Bank. The Institute has developed a number of useful technologies and equipment on all aspects of agricultural engineering.

The Central Mechanical Engineering Research Institute (CMERI) under the aegis of Council of Scientific and Industrial Research (CSIR) is another important institution engaged in applied research in the area of farm machinery. In a span of about 20 years, it has handled about 33 projects which includes development of a popular brand (Swaraj) indigenous tractor and 2 models of tractor-driven combine harvesters. In addition the tractor manufacturers in the country have set up modern R & D facilities. In the initial stages these departments concentrated on increasing the local content in the tractors manufactured. However, with the passage of time and increasing competitiveness, there was need to undertake real R & D work in tractor industry to change/amend designs to suit Indian operating and maintenance conditions. A number of current tractor models owe their development to local R & D efforts, including some diesel engines and hydraulic systems. The Gujarat State Agro Industries Corporation has set up a very good Agro Equipment Centre to undertake applied research (industrial designing) for commercialisation of institutional research (basic research). It involves selection of materials and processes, preparation of working drawings, manufacture of the commercial model and preparation of manuals etc.

Standardisation

The Indian Standards Institution (ISI) established in 1947 has contributed significantly in the development of the farm machinery industry in the country. At the insistence of the Union Ministry of Agriculture, a Farm Implements and Machinery Committee was set up in ISI in 1959. Initially, only hand tools and animal drawn implements were standardized. The work was progressively intensified and at present the following sectional committees have been set up and are dealing with various aspects of farm equipment relating to crop production and processing:

- (i) Agricultural tractors and power tillers committee;
- (ii) Soil working equipment committee;
- (iii) Sowing, fertilisers and manure application equipment committee;
- (iv) Crop protection equipment committee;
- (v) Irrigation equipment committee;
- (vi) Harvesting and threshing equipment committee;
- (vii) Farm transport equipment committee;
- (viii) Agricultural produce processing equipment committee;
- (ix) Horticultural equipment committee;
- (x) Agricultural Produce Milling Machinery committee;
- (xi) Seed processing and technology committee;
- (xii) Plantation and forestry machinery committee.

The ISI formulated over 300 standards on agricultural machinery covering

raw materials, components, entire equipment, test methods, glossary of terms, safety etc. These standards have been formulated to provide:

- (i) Recognised level of quality
- (ii) Framework for mass production and interchangeability
- (iii) Incorporation of the latest results of research and development.
- (iv) Simplification of production process and enhancement of labour productivity.
- (v) Ensuring consumer protection
- (vi) Lowering the cost of production

The ISI has also been empowered by the Government to operate ISI Certificate Mark Scheme on a voluntary and self-supporting basis. Under this scheme, the ISI grants licences to manufacturers for the use of ISI mark on their products which means that the Institution is certifying the quality of that product to the relevant Indian standards. Under this scheme, before a licence is granted, ISI carries out a detailed inspection of the manufacturing and quality control facilities owned by the manufacturer and after satisfying itself, the licence is granted. Validity of the licence is for one year and during the course of the year, the ISI arranges a minimum of six surprise inspections to the manufacturer's premises and thorough inspection is carried out during these visits.

During inspections, samples from the available certified stock of material as well as current production are drawn and sent to ISI laboratories. In addition samples are drawn regularly from open market or from recognised consumers for independent testing at ISI laboratories. Complaints are investigated and action is taken immediately. Apart from any immediate correction action taken on the basis of inspection and available test reports, at the end of the expiry period of the licence, ISI reviews the performance of the manufacturer on the basis of the inspection reports, test reports for factory as well as market samples, and decision to renew the licence is taken and this exercise is carried out every year. A wide variety of agricultural implements and machinery are covered under ISI Certification Mark Scheme. For the farmers who are not conversant with the suitability and quality of the equipment available in the market, certification mark is the answer. The institutions who provide finance to such farmers generally insist on providing finance to purchase certified equipment only.

Tractor testing

In 1943, when the question of importation of tractors came up for consideration by the Government and it was found that very little data was available in the country on which the drawing up of specifications for tractors and agricultural machinery most suitable to Indian conditions could be based. Indeed up to that

time the available records were nothing but stories of repeated failures of tractors which were imported with great expectation but soon found unsuitable. A committee set up by the Government in 1953 recommended that "..... the proposal for setting up tractor testing station should be finalised and the station should be set up as soon as possible. We feel that such an organisation is essential for exercising proper control over the various types and makes of tractors being brought into use". Accepting the recommendations, the Government decided to set up a tractor testing station at Budni and for this purpose obtained services of an expert from the Commonwealth Relations Office in U.K., who after a detailed study, defined the scope of work of the proposed testing station to include the following functions: To conduct tests on all makes of tractors, implements, engines, pumping sets imported or manufactured in the country; to find out their suitability under various soil and climatic conditions prevailing in the country; a special test procedure to be evolved; publication of test results; regulation of the importation of agricultural machinery on the basis of the conclusions arrived at by the above tests.

The Budni testing station has received assistance from Government of U.K. and under Japanese Grant Aid by way of supply of the special purpose equipment needed for testing of tractors. The test laboratory is now recognised by OECD for official testing of tractors. On the recommendations of the Agricultural Implements and Machinery Council, the Government in the year 1975 decided that all indigenous tractor manufacturing units should submit their tractors for testing at Government testing station at Budni once in two years so that they could upgrade the quality of their products by rectifying the defects observed during such tests. The sample for such tests are selected at random by an engineer of the testing station from the production line. Also there is a condition incorporated in the letters of intent/licence registrations at the time of its issuance that the tractor should be tested at Budni test station before commercial manufacturing is started. Thus, the policies of tractor testing in India are consumer oriented which works to the advantage of the farmers.

Training for Agricultural Mechanization

The setting up of the three farm machinery training institutes by the Government of India, first one at Budni (central India), second at Hisar (north India) and the third one at Anapurnapur (south India), have been a major step in training farmers and personnel of Government departments in proper selection, operation and utilisation of tractors and other power operated machinery. Agricultural machinery utilisation course (series 'A' course), which is of 3 months duration is meant for owners and operators of tractors, progressive farmers desirous of taking up mechanised farming, nominees of the state farms, seed farms, co-operatives, and

other organisations. The course content has theory (60 hours), demonstrations (100 hours), audio-visuals (20 hours), and field practice and other practicals (285 hours), making up a total of 465 hours. A significant part of the course is devoted to proper operations and maintenance of tractors and allied equipment. The focus of this course is utilisation of knowledge on farms. The refresher course on agricultural mechanisation (series 'B' course) is of 3 weeks duration and the content of the course is tailored to the need of the candidates who come on sponsorship. The subjects available are land shaping and land development machines, combine harvesters, irrigation machinery, power tillers, hydraulic systems and electric motors. The curriculum is spread over 160 hours containing theory, demonstrations, audio-visuals and practicals.

The technician course (series 'C' course) is of one and half months duration and meant for technicians of agro-industries corporations, co-operative institutions, state farms and also private mechanics. The course content is divided into theory (30 hours), demonstrations (45 hours), audio visuals (15 hours) and practice (135 hours), adding to a total of 225 hours. The under-graduate trainees course (series 'D' course) is meant for students of agricultural engineering during summer holidays. It is of one month duration. The content of the course is spread over 140 hours, with theory (6 hours), demonstrations (36 hours), audio-visual (8 hours) and practice (90 hours). The TRYSEM (Training of Rural Youth For Self Employment) course (series 'E' course) is of four months duration intended to help the rural youth gain useful skills and create avenues for self employment. After training they are helped in formulating a project proposal and obtaining financial assistance from banks at subsidised interest rate, for setting up repair workshop, cycle workshop, gas welding, flour mills, tyre and tube repair shops, implement rental shops, etc. The last course i.e. Trainers Training Course (series 'F' course) is of one month duration and meant to assist government departments and training institutions in creating their own training infrastructure to multiply the benefits of training in boosting farm mechanization.

All the above courses are open to foreign trainees also. The requests are processed by Ministry of Agriculture. These Institutes have adequate lodging and boarding facilities. Special training courses for foreign nationals are also organised by Central Institute of Agricultural Engineering, Bhopal and Indian Agricultural Research Institute, Pusa Road, New Delhi. These courses are designed on request to meet specific needs of the trainees. Most of the tractor and power tiller manufacturers organise their own training courses. Their on-the-spot training programmes for the tractor/power tiller owners, are quite frequent. They also use free-service visits as an opportunity for training farmers/operators.

Extension Services

There are three organisational systems devoted to agricultural extension namely (i) Union Ministry of Agriculture and State Departments of Agriculture (ii) ICAR extension system and (iii) voluntary bodies, business houses and other non-governmental organisations. A major effort in the past few years has been devoted to reorganisation of the agricultural extension set up in the major states of the country under the Training and Visit system (T&V) which seeks to bring about improvements in the extension services (Bernor 1984). As an integral part of the Training and Visit system of agricultural extension, a Monitoring and Evaluation (M&E) cell has also been created. From both the reports of the M&E units, and from independent evaluations it would appear that, by and large, the T&V system has got fairly well established in almost all the states.

The ICAR transfer of technology programmes are being implemented through ICAR institutes and agricultural universities. Some of the agricultural universities have created Farm Advisory Units (FAU) at district levels. There are four ICAR extension programmes in operation. These are (i) National Demonstration Project (NDP) (ii) Operational Research Project (ORP) (iii) Scheme of Farm Science Centres (KVK) and (iv) Lab-to-Land Programme (LLP). NDP was the first extension project launched by ICAR in 1964. It is intended to demonstrate the production potentiality of new technologies and to influence both the farmers and the extension agencies. ORP aims at disseminating the proven technology in a disciplined area among farmers on a watershed basis covering a whole village or a cluster of villages and concurrently studying constraints - technological, extension or administrative, as barriers to the rapid spread of know-how. This programme was launched in 1975. KVKs came into existence in 1974. There are 101 KVKs at various places in the country. They impart skill oriented and need based training in different agricultural operations to the farmers and farm women on the principles of teaching-by-doing and learning-by-doing. There is a proposal to establish one KVK in each district of the country in the next few years. The LLP was launched in 1979 adopting about 50000 small farmers and agricultural labourers to educate them on the latest agricultural and allied technologies and to encourage them to adopt these for their socio-economic development.

Credit

In India agricultural loans have been organised extremely well by the Government through a sound credit system which is responsive to the needs of the farmers and agricultural development in the country. The rural credit system is well streamlined through cooperative and commercial banks, regional rural banks and the National Bank for Agriculture and Rural Development (NABARD). It is estimated that about 95 per cent of tractors and power tillers, etc are purchased

by the farmers through bank loans. Regular directives are issued by NABARD to various financial institutions to finance equipment and machinery of established standard and quality. Banks normally insist on the borrowers buying machines which carry the ISI mark. NABARD has constituted an extension group for disseminating the principles of Development Through Credit among rural masses. These include:

- (i) Credit must be used in accordance with suitable methods of science and technology.
- (ii) The terms and conditions of the credit (techno-economic parameters) must be fully respected.
- (iii) Work must be carried out with desired skill so as to realise optimum increase in income and productivity.
- (iv) A part of additional income created by credit must be saved.
- (v) Loan installments must be repaid on time and regularly to facilitate recycling of credit.

Currently NABARD is able to allocate for farm mechanization purposes about US\$111 million (IR2 billion) per annum which participating banks seek as refinance. The credit requirement for agricultural machinery for the 8th plan period (1990-95) has been estimated to be US\$6.23 billion (IR 112 billion). The gap is certainly large. This gap is supported by banks whose deposits are good. The difference between the two types of financing is in the rate of interest. NABARD refinancing cannot exceed 12.5% interest to the ultimate borrower whereas other banks may charge about 14.5% interest. NABARD has established a Research and Development Fund with a view to acquiring new insights into the problems of agricultural and rural development through in depth studies and applied research and trying out innovative approaches backed by technical and economic studies. For farm mechanization, some R&D proposals like development of paddy transplanters, fertiliser injectors, bio-gas plants, studies for minimum size of tractors for different holdings etc, have been sponsored under this fund. The important factor is that the project should benefit a large section of farmers and which may have future potential for growth.

Licensing Policies

At present an industrial licence is required for the manufacture of tractor and combines. In the case of other agricultural machines, no industrial licence is required. These units are only required to be registered with the Secretariat of

Industrial Approval or the respective State Industries Departments. The manufacturing of all manually operated tools, animal drawn or power driven implements is reserved to the small scale sector. Government's policy towards permitting foreign equity participation is selective and based on national priorities. The technical collaboration is considered on the basis of annual royalty payments, which are linked with the value of actual production. As regards to the importation of technology and upgrading of production system, the approach of the government is flexible. Importation of capital; goods for modernisation and upgrading of the industry by the existing manufacturers is considered on merit. In the case of tractor industry, there is flexibility on the range of models and size horsepower which can be manufactured. Manufacturers are also permitted to manufacture self propelled combine harvesters under the Broad Banding Scheme subject to certain approvals. Currently the importation of tractors and other farm machinery is severely restricted. The country is self sufficient and actually exports these goods.

Fiscal Incentives

The Government has exempted the following agricultural machinery from excise duty: Tractors with engine capacity of up to 1800cc.; power tillers, electrically powered centrifugal pumps used for irrigation purposes; all implements used in agriculture and horticulture; spare parts of all implements used in agriculture and horticulture, balers, mowers; harvesting and threshing machinery; processing machinery used for cleaning and grading of seeds and food grains; electrical motors used for manufacturing of submersible pump sets and monoblock pump sets.

EFFECTS OF POLICIES & STRATEGIES ON AGRICULTURAL MACHINERY UTILIZATION

In 1947, animals were almost the exclusive source of draught power and the multi-purpose wooden plough was the most common implement. Only a few farmers had taken up the improved tools like mould board plough, hand operated rotary chaff cutter, sugar cane crushers, etc. Irrigation pump sets were not common and tractors were almost unknown (e.g. there were then less than 8000 tractors in the whole of India). All crops were harvested manually with the sickle and the wheat crop was threshed by animals. The produce was manually winnowed and post harvest losses were considerable. Agriculture was an arduous task and rural youth were not interested to work in the fields. The situation has over the past 40 years significantly improved due mostly to proper planning and concerted efforts by all concerned (see Table 51). The following is a brief summary of the achievements in agricultural mechanization.

Tractors

Tractor production in the country started in September 1960. By the year 1961-62, only 880 tractors were produced, and this was done by assembly of imported tractor components. Owing to inclination towards mechanization by many farmers, Indian manufacturers were permitted to import a few reputable models of tractors from various countries and the tractor testing station at Budni tested these tractors to identify models which could be recommended for progressive manufacturing in the country. This approach proved useful in two ways - the Indian manufacturers with ready access to the foreign know-how were able to start commercial production with minimum gestation period and the farmers were able to get tractors of proven design. The foreign collaboration arrangements were approved by the government keeping Budni test reports in view. In mid 1960, the Central Mechanical Engineering Research Institute was working hard to develop indigenous technical know how for producing a low horse power tractor. They were successful and a public sector company, Punjab Tractors Limited took up its manufacture.

Currently, there are 19 companies licensed to manufacture tractors. Their total licensed capacity is 203050 tractors per annum. Out of these 15 companies have set up manufacturing facilities which have a total installed capacity of 112050 tractors per annum. They produce tractors of 12 to 75 horse power range. It is estimated that there were about nine hundred and fifty thousand working tractors in the country at the end of 1989. With the increase in tractor population, the gross cropped area per tractor has been reduced from 14800 ha in 1951 to about 200 ha in 1990. The average annual growth in tractor production during the period 1961 to 1966 was 48.2%. In terms of growth rate in production, India's record is unmatched. India has emerged as one of the leading tractor manufacturing countries in the World. Starting with a meagre annual production of 880 tractor in 1961-62, the production output has passed the 112,000 tractors number during 1989-90. A list of major tractor manufacturers in the country is given in Table 52.

In India, 30 to 39 hp tractors are the models most preferred models by farmers followed by 40 to 49 hp and 15 to 19 hp tractors. On the average the price is esimated at about US\$140.00 per hp (Rs 2500.00). The general-purpose tractors are the most preferred ones because of their inherent advantages of being suited both for dry and wet land cultivation. However, tractors specially suitable for wet land cultivation, orchards, high clearance and wide tread units, etc will soon enter the market because of the increasing purchasing power of farmers in these specialised agricultural production segments. Farmers also prefer tractors fitted with a self starter, draught and depth control systems, cushioned seats and higher number of forward speeds. One area that may soon see major changes will be in

the availability of a wide range of tyres to make the tractor operation more specifically suitable for different kinds of soil and operating surface conditions. Engine models may also see improvements in terms of fuel efficiency, smoke, noise and vibration levels and weight to power ratio. Provision of front PTO and side PTO may also become available soon because of popularity of front mounted vertical-conveyor-reapers to the farmers. The tractor industry, having established a good home market, is now poised for a major export drive. Some established models have already been exported to Ethiopia, Kenya, Mauritius, Sudan, Tanzania, Zambia, Zimbabwe and Swaziland though in small numbers.

Power Tillers

India being one of the major rice growing countries and also having a very large numbers of small and medium size farms, led to the power tiller being considered to be the most ideal machine. As a consequence of this, private manufacturers were encouraged to collaborate and manufacture power tillers in the country. The first licence was granted in 1964-65. The present licenced capacity is 31000 tillers per year in 5 units. However, only 2 of them are in production and contribute over 90 per cent of the total sales which was about 16000 units during the year 1989-90. A list of power tiller manufacturers who have been granted licence is shown in Table 53. The reasons for low sales include: limited use of power tiller for custom hiring, cost of power tiller being high and need to walk behind the machine while working in the field.

Combine Harvesters

Self propelled combines for harvesting cereal crops are manufactured in the country under license whereas tractor drawn combines and reapers are reserved for manufacturers in small scale sector. The licensed capacity of the self-propelled combines is 546 units per year. The Government does not encourage import of combines or expansion of already created capacity as popularisation of combines may jeopardise the employment opportunities of casual labour force, more particularly migratory labour in the harvesting and processing sector of the agricultural industry.

Plant Protection Equipment

Until 1946, all plant protection equipment were imported. Local manufacturing started in the year 1946-47 and the Government banned the importation of these equipment. Presently, about 50 companies are manufacturing a complete range of plant protection equipment some of which are exported to different parts of the world, ranging from small nursery sprayers to power operated ones. The present

population of sprayers in the country is estimated to be 2.5 million units. The annual production is about 250000 units valued at US \$25 million. With increased emphasis on agricultural production, this industry has assumed great importance. The production of agricultural sprayers has shown a rising trend during the last few years and it is estimated that annual requirements will increase to approximately two to three million in a few years time. The Government provides a 50% subsidy on this type of equipment to enable small farmers to purchase sprayers of certified quality.

Table 51 - Selected Agricultural Mechanization Inputs in Use in India 1945-1985

	1945	1956	1966	1977	1985
Draught Animals x 10 ³	59333	70690	78517	8260	180500
Tractors x 10 ³	5	21	54	270	608
Bullock Plows					
- Wooden x 10 ³	27306	36142	39880	40766	-
- Iron x 10 ³	487	1376	3521	6258	-
Irrigation pumps (Diesel & Electric)	21	160	886	4482	-

Implements

It is estimated that there are about 17000 manufacturers of agricultural implements in the country with an estimated turn over of US \$195 million per annum. The implements manufactured include hand tools and equipment: ranging from spades/shovels, garden tools, all types of hoes, paddy weeders, seed dressing drums, rice transplanters, seed drills, sprayers, dusters, sickle, rotary paddy threshers, tubular maize shellers, ground nut decorticators, winnowing fans, chaff cutters, seed cleaners etc. Animal drawn implements include: blade harrows, mould board ploughs, disc harrows, cultivators, ridgers, bund formers, puddlers, land levellers, seed-cum-fertiliser drills, animal drawn carts, water lifting devices, reapers, etc. Power operated equipment: ranging from all types of ploughs and cultivators, fertilizer spreaders and distributors; seed cum fertiliser drills, all types of planters for grains, and sugar cane, all types of sprayers; all types of pumps, all types of irrigation equipment, combine harvesters, post harvest processing equipment, as well as seed cleaning, grading and packaging equipment.

TABLE 52: List of Major Tractor Manufacturers

S. No.	Name	Name of Collaborator	Model	HP	Licensed Capacity
1.	Escorts Faridabad	Motor Import Warsaw, Poland	E-330 E-335 E-345 E-355	35 35 35 47	25000
2.	Escorts Tractors Ltd. Faridaba (Haryana)	Ford Motor Co.	Ford 3600	47	25000
3.	Eicher Goodearth Ltd. Faridabad (Haryana)	BEBR Eicher Tractoren, Fabrik	Eicher-241 Eicher-242 Eicher-352	24 24 35	30500
4.	Mahindra & Mahindra Ltd. Bombay, Maharashtra	I.H. UK	B-275 IH-444 IH-500	35 45 50	25000
5.	HMT Ltd., Pinjore (Haryana)	Motoknow Praha Czechoslovakia	HMT-2511 HMT-3511 HMT-5911	25 35 58	18208
6.	Punjab Tractors Ltd. Ropar (Punjab)	Indigenous	Swaraj-735 Sartaj Swaraj-855	39 19 55	12000
7.	Tractors & Farm Equip. Ltd. Madras (Tamil Madu)	Massey Ferguson UK	MF-1035 MF-1040 MF-245	 47	35 39 12000
8.	Gujrat Tractors Corp Ltd. Vadodara	Motokov Praha Czechoslovakia	Hind-G-453 Hind-50 Hind-G-614	46 50 61	7000
9.	Harsha Tractors Ltd. Ghaziabad U.P.	Promoshexposts USSR	Harasha	31	10000
10.	Kirloskar Tractors Ltd. Nasik Road Maharashtra	K.H.D. West Germany	D-3006k D-4006k D-6006k D-1006k	35 43 75 100	10000
11.	United Auto Tractors Ltd. Hyderabad (A.P.)	Industrial & Exports, Romania	U-445 U-650	45 65	5000
12.	Pittie Tractors Ltd. Pune, Maharashtra	-	Pittie-2500 Pittie-4500	22 39	10000
13.	Bihar State Agro Ind. Corpn. Patna (Bihar)	-	Zetor-2511	25	10000
14.	Auto Tractors Ltd. Pratapgrah, U.P.	Leyland, U.K.	Pratap-284	28	12000

*All manufacturers have installed capacity of about 50-60% of their licensed capacity

The manufacturing of the above implements/equipment is carried out using semi-automatic, automatic and special purpose machine tools depending upon the volume of production, the degree of precision required and the magnitude of

investment. The manufacturing process varies from product to product but the most common operations involved in the manufacture of the implements are blacksmiths, press work, machining, assembly, painting and packing. On the basis of investment the industry can be classified as medium (US \$1.7 million), small (US \$0.17 million) and tiny (US \$10000). The number of workers employed ranges from 4 to 50 workers and capacity utilization varies from 50 to 80 per cent. Some of the medium scale industries are exporting their products to other states and neighbouring countries. The numbers of a selected agricultural machinery and implements in India over the period 1945 to 1990 is shown in Table 51.

EMERGING LESSONS FROM THE INDIAN EXPERIENCE

India has made remarkable progress over the past 4¹/₂ decades in agricultural mechanization. This progress is in all areas, manufacturing of agricultural machinery, implements and equipment, as well as in increased utilization of these devices on the farm. This has been at all levels of mechanization - handtools, animal powered implements to mechanically powered machinery and implements e.g. the number of draft animals in use has increased by about 50% between 1945 to 1985, while the number of tractors has increased by 2160% over the same period. Even more remarkable growth rates are shown for all the other agricultural implements and machinery.

TABLE 53: LICENSED/INSTALLED CAPACITY OF POWER TILLERS

S.No.	Unit	Collaborator/Make	Licensed Capacity	Installed Capacity
1	V.S.T. Tillers Tractors Ltd., Bangalore	M/S Misubishi Japan	5000	5000
2	Kerala Agro Machines Corpn Athani	M/S. Kubota	12000	3000
3	J.K. Satoh Agro. Machinery Ltd. Kanpur	M/s. Jay Kay & M/s. Sathoh, Japan	6000	6000
4	Krishi Engines Ltd. Hyderabad	M/s. Krishi (Akitu) Japan	5000	1000
5	Bihar State Agro Inds. Dev. Corpn. Patna	Kubota	5000	16000
TOTAL			31000	31000

In India, mechanization of agriculture can be divided into the following four stages:

- First stage at which simple but improved manual and animal drawn tools are used,
- Second stage at which manually operated, animal drawn and simple, low cost power operated implements and equipment are used,
- Third stage at which relatively more advanced and power machinery are used, and
- Fourth stage at which complicated and specialized machinery and equipment are used.

Mechanization has often erroneously been associated with large scale tractorization in farm operations or introduction of big machines like combine harvesters etc. Mechanization, in its true meaning, is the application of engineering and technology developments to do a better job, more precisely and to improve productivity - be it with handtools, animal drawn equipment, power tillers, tractors, processing equipment, etc. In most of the developing countries, like in India, a selective mechanization approach, would seem to be the best. The following would seem to be the major lessons emerging from India's experience in agricultural mechanization.

Need for Agricultural Mechanization Studies

The Indian experience shows the importance of undertaking adequate agricultural mechanization needs study. A series of such studies were undertaken in India on a continuous basis by different working groups right from the 1940's. These working groups which drew representation from all sections - manufacturers, farmers' associations, state governments, research and development establishments, training institutions including Universities, were charged with the responsibility of formulating five year plan proposals on Agricultural Machinery and Implements and their proposals were after due consideration by the Planning Commission of the Government of India incorporated in the various national five year plans right from 1950's. The planning for agricultural mechanization had both short term (usually achievable within 5 years), medium term (usually achievable within 10-15 years) and long term (requiring more than 15 years to achieve) objectives. The planning also encompassed all forms of mechanization from handtools to mechanically powered implements.

One observation which can be made for most, if not all, developing countries, is that not adequate attention has been paid to mechanization policy in general and choices and appropriate levels of mechanization. The development of mechanization is in most cases focussed on only one option i.e. tractor importation, instead of examining a range of alternative packages of technology. A national level mechanization study is

the first essential step, in order to formulate a comprehensive plan for the systematic development of agricultural machinery and allied engineering industries. A micro level survey to form a long term mechanization strategy and policy for modernization of agriculture needs to be given top priority by developing countries. This study should come out with precise needs of the farmers and estimates of demands on a long term basis keeping in view the national agriculture policy. Another example is the growth of agricultural mechanization in South Korea, which has been very rapid during the last two decades due to favourable Government policies, among other things. In order to promote agricultural mechanization in that country, the Government enacted the Agricultural Mechanization Promotion Law on December 5, 1978, which gave both short and long term objectives. Similar planning is also essential in the other developing countries if they are to make rapid progress in the area of agricultural mechanization.

Establishment of Farmers Agro Service Centers

The second lesson from the Indian experience is the need to establish Farmers Agro Services Centres (FASC). Such centres should be established to supply farmers with the essential inputs for their agriculture. Small farmers have low investment capacity and lack access to new technologies. Unexploited agricultural production potentials, difficulties in meeting the requirements of essential inputs and services, unremunerative prices for marketable surpluses due to poorly developed facilities for storage and processing of primary products, lack of proper tools and equipment for improving the efficiency of operations and reducing drudgery, are some of the major areas requiring attention. It is in this context that the setting up of very larger numbers of Farmers' Agro Service Centres (FASCs) is crucial. Such centres should be set up to provide all services to farmers - including agricultural mechanization inputs. The centres as set up in India provide among other services - the following: selling of implements and other low cost equipment required for all field operations; distribution of seeds and fertilizers, feeds for livestock, animal health requisites, packaging and storage materials, as well as pesticides. The centres also provide technical services such as rental of animal drawn implements, provision of hiring services - for costlier machinery such as power tillers/tractors, threshers, sprayers, mobile pump sets, etc. In the more developed areas such centres provide more professional services like construction of irrigation canals, and simple irrigation structures, electrification of farm and rural structures, agro processing activities, drilling for water and installation of pumping equipment, raising of seedlings for horticulture and afforestation and even fabrication and manufacture of simple tools and implements (e.g. biogas plants etc.). The FASCs should be set up by - private entrepreneurs, village artisans, unemployed technical personnel, cooperative and marketing societies, or registered voluntary organizations engaged in agricultural and rural development. These FASCs should in so far as it is seemingly possible operate on purely commercial basis and should charge for their services on a competitive basis. Government departments, operating under the civil service regulations should not be involved directly in such ventures, but should assist individuals or groups of individuals to provide such services. Local government may assist by building the required infrastructure and then renting it out to the individuals concerned to provide such services.

For handling promotional functions such as training of entrepreneurs, manpower development, information dissemination, consultancy services, organization and management of technology transfer, setting up of pilot units, etc. a National Agro Service Agency may be useful. Such an agency will facilitate setting up of a very large number of FASCs and in sustaining and developing their activities with a relatively low government assistance. This proposed agency should form the apex national body for promoting agro services and agro industries. It would also help to provide base data for drawing up specifications of agricultural machinery most suited to local conditions. For setting up the agency, financial assistance initially can be sought from international funding agencies. On a long term basis, this agency should operate on self supporting basis. Every FASC should be required to be registered with this agency as a member. The membership fee should be related to investment/turnover of the FASC. The agency could also take a very small margin on supplies routed to FASCs through it. The agency should get its expenditure on training of entrepreneurs reimbursed from the Government. The sale of project profiles to the entrepreneurs could be another source of its revenue. To ensure that the assets created through use of grant-in-aid or loans from the government/financial institutions are utilized for the purpose for which these were given, guarantees equal to the grant-in-aid/loan amounts should be obtained. Failure to utilize the grant-in-aid/loan for at least a period of 3 years for the purpose it was given, should attract recovery within suitable financial penalty. There will also be a need to set up a monitoring and evaluation mechanism at district, regional and national levels.

Training of Manpower

Training of manpower is crucial for any successful development of agricultural mechanization. India realized this quite early and invested in training of its manpower in this area. In this regard the first Agricultural Engineering Educational Programme at BSc. level in India was started in 1942 at the Allahabad Agricultural Institute, Allahabad, Uttar Pradesh. The Indian Institute of Technology, Kharagpur, West Bengal, was the second institute to start a bachelor's programme in agricultural engineering in 1952. There has been a significant development of training, research and extension facilities in India from 1960, when the first Agricultural University was set-up at Pantnagar (Uttar Pradesh). By 1986, there were 27 State Agricultural Universities (SAU) in the country. As many as 10 institutions are now offering the undergraduate and postgraduate programmes in the field of agricultural engineering, many of them specializing in agricultural machinery engineering (Farm Power and Machinery). The total output of graduates in this specialization from all over India is estimated at over 350 BSc. graduates, with over 60 graduating each year with MSc. in Farm Power and Machinery (Singh 1988, Singh et.al. 1984, Ojha 1983). In addition, to the professional manpower there are over 400 institutions offering technician training at diploma level in agricultural engineering and mechanical engineering which produce each year 400 and 10 000 technician graduates in the two fields respectively all of whom find employment or are self employed in the agricultural machinery and implements manufacturing and servicing industries. Below these technicians are vocational training centres which produce 20 000 artisans each year (mechanics, welders, etc.) all who work

in the agricultural industry. There are also quite a number of institutions offering short term and on the job craft courses. Thus the Government of India and state governments set up numerous training facilities for all the three levels - artisans, technicians and professionals and this manpower has played a crucial role in the development of agricultural mechanization in India. It is important if the other developing countries wish to develop agricultural mechanization for them to set up the necessary training systems for all the levels of manpower required.

Research and Development Efforts

Research and development efforts in the field of agricultural machinery engineering, and agricultural mechanization is being carried out by many organizations in India. It is to the credit of these institutions that there has been significant progress in design and adaptation of machinery and implements to the Indian situation such that India today is one of the leading manufacturers of agricultural machinery and implements in the World. The production of tractors for example in 1990 in India is more than $2\frac{1}{2}$ times the total production of Great Britain which is a leading producer in the European Community market. Research and development efforts are spearheaded by:

- (i) Agricultural Engineering Colleges and Departments in State Agricultural Universities system
- (ii) Commodity Institutes of Indian Council of Agricultural Research (ICAR), numbering more than two dozens, Council of Scientific and Industrial Research (CSIR), (The Central Mechanical Engineering Research Institute (CMERI))
- (iii) Private Organizations including tractor, engine, pump and other farm machinery and implement manufacturers
- (iv) State Governments: Directorates of Agricultural Engineering and Engineering Sections of the State Directorates of Agriculture
- (v) State Corporations: Agro-Industries Corporation, Khadi and Village Industry Corporation, State Farm Corporation, National Seed Corporation, etc.
- (vi) Voluntary organizations and Individual Entrepreneurs.

All these research establishments work in close collaboration with the manufacturers and the farmers associations as well as the extension services.

Manufacturing Capacity

As already mentioned India has over the past 4 decades built up an impressive capacity in manufacturing agricultural machinery, implements and equipment. The current licensed capacity for manufacturing tractors is over 200,000 tractors per annum of different horsepower with an installed capacity of about 115,000 tractors. Almost 95% of these tractors are sold within the country with only a small percentage being exported. The manufacturers of agricultural machinery and implements are both state

owned companies, private companies and individual entrepreneurs. All of them have received Government assistance in various forms in setting up their manufacturing enterprises. This includes research and development of prototypes, credit facilities, marketing assistance, quality control and testing facilities in state agricultural machinery testing centres as well as by the Indian Standards Institute, publicity, education of manufacturers and their workers, and assistance in procurement of raw materials. Some of the manufacturers have signed technology transfer agreements with foreign multinationals as shown in Table 52. The manufacturers have been integrated in the agricultural mechanization policy fora and they have been quite active.

Assistance to Farmers

The final part in promotion of agricultural mechanization in any country, is the assistance provided to the farmers themselves. This has ranged from education to the farmers on what is available on the mechanization side, how to use these new machinery and implements, assistance to small scale entrepreneurs and farmers in setting up their farm machinery repair facilities, capital subsidy for purchasing machinery and equipment, in the form of low interest loans, etc. There is also an extensive network of agricultural engineering extension workers who provide technical advice to the farmers. These are employed by the state governments, agricultural universities and the research system. All these provide invaluable service to farmers and have played a crucial role in the promotion of agricultural mechanization in India.

Agric. Mechanization & Employment

There has been an imaginary fear about employment problem as a consequence of adoption of tractor farming. India's experience has established that this is not true. Punjab, Haryana and Western U.P., which have higher tractor intensity than the other states face agricultural labour shortages throughout the year, more particularly during the harvesting, paddy transplanting, weeding and sugar cane harvesting seasons. During these seasons, the labour wages shoot up to 2 to 3 times more than the average wages. Studies also indicate that the family labour per crop-hectare declined by about 6%, permanent labour increased by 32% and casual labour increased by 18% with the shift from sole animal to tractor plus animal technology. Indian experience also indicates that small farmers owning tractors offer their machines for custom hiring for upto 700 hours in a year. This enables them to earn additional income of upto US\$1,000.00 per year. Introduction of agricultural equipment also generates increased employment in production of equipment, their distribution, after-sale-service, repairs, operation, etc. A study done on the basis of a 14000 tractor manufacturing capacity plant in India indicated that every tractor so manufactured generated additional 0.8 man-years of employment of various categories.

CONCLUSION

India has made impressive strides over the past 4 decades in her agricultural mechanization efforts. The progress has been both in the power (energy) intensive

operations - e.g. primary and secondary tillage (i.e. there are virtually very few farmers who till their land using the hand hoe); transport, milling; pumping and other post harvest operations, as well as the control intensive operations e.g. seeding, weeding, pest control, etc. Equipment and implements which have significantly increased the productivity of labour and timeliness of operations in performing the various tasks have been developed, manufactured and adopted by farmers. The emphasis in this case has been to develop equipment and implements which can be powered by all three forms of power - e.g. human, draught animals and internal combustion engines. Further agricultural mechanization has been developed as part of the entire agricultural system and not in isolation. Careful planning has been used with short, medium and long term objectives. Coordination at national level has been quite effective and all the active players in this process have been involved in the formulation of agricultural mechanization policies and strategies. Even more impressive progress is going to be made in the coming decade. As has been mentioned elsewhere in in this volume, in the 1950's and early 60's the agriculture and food situation in India was similar to what pertains to Sub Saharan Africa today. The situation then was of extreme starvation, hunger and massive food imports. In the last two decades India has managed to transform her agriculture and today she can boast of strategic grain reserve of over 30 million tonnes, and other impressive agricultural statistics. There may be equity problems within the country, but at least the country does not need to import food. The drought of 1984 was even more severe than some of the droughts which occurred in the 1950's, but the country was able to ride over this using her own internal reserves. This transformation of the agricultural situation in India has been brought about by using improved plant materials (high seed varieties as well as drought tolerant varieties); fertilizers and plant protection chemicals; irrigation and agricultural mechanization. The utilization of above inputs has been facilitated by the creation of an efficient input supply and output recovery system. All the above are crucial to India's agricultural development.

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**THE ROLE OF SMALL FOUR WHEEL TRACTORS
IN AGRICULTURAL AND INDUSTRIAL DEVELOPMENT
IN THE TROPICS**

by

R. Holtkamp

INTRODUCTION

In less than a century, the "motorized soil-tillage implement referred to as a tractor" has become the most important piece of mechanical equipment in the entire field-work inventory of modern farms in industrialized countries. Tractors are also credited with playing a similarly crucial role in the mechanization of farms in tropical and subtropical countries - primarily developing nations. Site and infrastructural circumstances allowing, 35-50 kW tractors have emerged as the "standard". For most ranges of farming activity, particularly soil tillage and transportation, such tractors provide adequate tractive and propulsive power. However, the economically justifiable mechanization of most small-to-mid-size farms (defined as having up to 2 - 10 or more hectares, depending on the country in question) cannot be achieved with such "standard tractors".

While production-enhancing agricultural inputs like seed, fertilizers and pesticides can be increased in arbitrarily small increments, most technical expedients are either not divisible at all (from a techno-economic standpoint) or only in a few big steps. In South and South-East Asia, single-axle tractors and power tillers have achieved widespread acceptance for use in irrigated rice production. Indeed, single-axle tractors are subject to certain limitations with regard to soil tillage in rain-fed agriculture: they have limited performance capabilities; the level of physical exertion required of the user can be higher than when draught animals are used; under adverse conditions, the tractor turns out to be either under-powered or very hard to control.

The usual mechanization sequence, i.e. manual labour - animal power - (single-axle tractor) - standard tractor, has a technological flaw: a gap that could be bridged by a small four-wheel tractor. In Europe, 9-22 kW tractors played a key role in the mechanization of individual family farms. At first, tractors were regarded as little more than a substitute for a team of draught animals. Later on, though, the Little Grey Fergies (Ferguson) saved the way for a thorough going

accommodation of all agricultural production methods to the key piece of equipment "tractor", with its now customary (and still expanding) capabilities. During the 1960s, the demand for small tractors declined so rapidly in Western Europe, that the major manufacturers discontinued their respective models. Several countries in South and East Asia are presently undergoing a course of development similar to that experienced by postwar Europe. Increasing numbers of small 4-wheel tractors of Japanese or indigenous origin (particularly in India and the People's Republic of China) are emerging as the nuclei of mechanization for individual farms - either as the next higher level of technical progress following single-axle tractors, or as the result of direct transition from animal traction.

For Africa in particular, a major potential demand derives from the availability of inexpensive small tractor with an engine output of up to about 26 kW which could be acquired by numerous small farms. At the same time, such small tractors would be required to stand up to the difficult tropical and subtropical service conditions. They would have to be equally robust and easy to operate, service and repair. Additionally, the developing countries naturally are interested in manufacturing their own tractors in order to help build up and expand their local industry and crafts & trades sector while avoiding complete dependence on imports. Such "felt needs" are discussed in detail in publications by Boshoff and Joy (1960), Kilgour (1976), Crossley (1977), Catterick (1978), GTZ (1980), Wills (1980, 1985).

In connection with the development cooperation projects of practically all industrial nations, there has always been a large number of programs devoted to the "design, testing and dissemination of small/basic tractors in developing countries". Some such programs have been implemented on modest budgets, while others have enjoyed massive funding. Examples include: Bouyer, Tinkabi, Multitrac, Centaur, Self Help, NIAE Monowheel and Snail. Up to now, none of those programs has met with lasting success.

The experiences related above are interpreted heterogeneously:

- Judging by the technical and economic superiority of standard tractors, small tractors are assumed to have lost their *raison d'être*.
- On the other hand, despite past experience and the tractors already available in some countries, there appears to be no end to people's attempt to achieve the "fourfold goal; durability, low cost, simplicity and local manufacture."

The importance of small tractors in the mechanization of agricultural production in developing countries differs from country to country. That subject is

investigated in detail in order to clarify its ramifications with regard to at least the following: individual farms, rural crafts & trades sector, the industry in developing and industrialized countries and the public authorities at all levels in the agricultural and industrial sectors.

REASONS FOR MECHANIZATION

Mechanization has been a major factor in the development of agriculture in industrialized countries, and it enjoys a high place value in connection with the intensification of agricultural production in developing countries. Indeed, the number of tractors and combines in service often serves as a measure of the "modernity" or "progressiveness" of a country's agriculture (Sievers (1983), Binswanger (1984), and Farington (1984)). One of the main reasons for increasing a farm's degree of mechanization has always been and still is to raise its labour productivity, i.e. to achieve a higher output (expanded acreage or higher yield per worker) and/or better income per man-hour of work (ha/h, t/h). In doing so, the farmer substitutes capital in place of scarce/expensive manual labour. Increasing the degree of mechanization, e.g. by buying a tractor, substitutes capital for labour. Numerous pertinent studies (e.g. Abercrombie (1973), McNerny and Donaldson (1973), Binswanger (1978), Bergmann and Mai (1984)), have documented this effect - familiar in industrialized countries - for developing countries, too.

In his analysis of publications dealing with the effects of tractor utilization in South Asia, Binswanger (1978) differentiates two universally applicable categories:

Category 1: Higher degree of mechanization as a result of the desire to achieve higher yields. Insufficient (pulling) power is presumed to be a constraint to agricultural production, regardless of factor prices and endowments. Deeper tillage and more accurate work (sowing, distribution of pesticides, threshing and cleaning) are supposed to have the effect of directly increasing the size of the standing crop and/or net yield. Better efficacy allows better timing and, as the case may be, more intensive cultivation (multiple cropping) the main objective being maximum yield, as opposed to optimal intensity of a particular production method or farm unit. Macroeconomic cost factors are given too little consideration. The protagonists of this thesis frequently cite a 1967 diagram by Giles (1967) in which a correlation between power available per hectare (hp/ha) and main-crop yields (kg/ha) is offered for some 40 industrialized and developing countries. That diagram gave rise to the call for a "minimum power requirement" of 0.5 hp/ha. Giles (1975) however, modified that interpretation in 1975 and later on called it a "misunderstanding" (Giles

(1984)). Nonetheless, emphasis is still placed on the important complementary contribution of mechanization along with other intensification measures, especially: irrigation; use of high-yielding varieties (HYV); use of fertilizers and pesticides; as well as better farm management.

Category 2: Higher degree of mechanization as a result of factoral exchange (substitution effect). According to this view, any work done by the tractor, combine harvester or the like could also be taken care of by a combination of manual labour, draught animals and appropriate implements. The transition to a stage of mechanization marked by higher efficiency and higher capital input is determined by the cost and availability of other production factors (Binswanger (1978)).

DIFFUSION AND PRODUCTION OF TRACTORS

In 1985, nearly 25 million tractors were in service around the world, more than 20 million of them (81.5%) in industrialized countries and nearly 5 million (18.5%) in developing countries. Japan has the highest specific tractor population density (390 tractors per 1,000 ha. arable land plus permanent crops). On a regional basis, Western Europe has the most tractors per unit area of land (85 per 1,000 ha.), while developing countries in Africa have the least (1.5 per 1,000 ha.). Global tractor production (excluding single-axle types) for use in agriculture amounted to approximately 1,600,000 in 1985 down roughly by 250,000 from 1980. This included some 316,000 small tractors with engine power ratings of 26 kW or less. Thus, small tractors accounted for barely 20% of total production. Only four countries produce an extraordinarily large percentage of small tractors: over 80% in India and Japan and over 50% in China and Korea (estimated), in addition to 100% of Thailand's admittedly quite modest domestic production. All other tractor-producing countries turn out about 10% (Italy) or significantly less small tractors.

Nearly 95% of all small tractors built in 1985, (i.e. 296,000 out of 316,000 Table 54), were produced in India, China and Japan. Accordingly, products from these three countries represent the lion's share of small tractors now in use in developing countries. Seven developing countries have their own small-tractor production facilities: India, China, Korea, Turkey, Brazil, Thailand and Swaziland ("special case" Tinkabi). All but the last two of these countries count as "threshold countries" producing in 1985 more than 97% of all small tractors of non-Japanese origin.

Table 54: Global production of four-wheel tractors with engine power ratings of up to 26 kW (1985)

Country	Quantity	% of total production
India	72,250	22.9
China	50,000 ¹	15.9
Thailand	500 ¹	0.2
Korea (D.R.)	2,500 ¹	0.8
Brazil ²	2,790	0.9
Turkey	1,000 ¹	0.3
Developing countries	129,040	40.9
Japan ³	173,852	55.0
Germany (Fed.Rep.of) ⁴	2,468	0.8
Italy	8,550 ¹	2.7
Great Britain ⁵	1,900 ¹	0.6
Total	315,810	100.0

Excluding countries producing less than approx. 500 ea./a

¹⁾ estimate ²⁾ ≤ 27 kW/37 hp ³⁾ ≥ 22 kW/30 hp
⁴⁾ ≤ kW/34 hp ⁵⁾ ≤ 30 kW/41 hp

Degree of indigenization: The term "local content" is used to denote the share of components originating in the same country in which final assembly occurs. The information can be stated either as a weight percentage or, better, as a share of net value added, in which case the local labour costs would be included. Rough classification according to local content would rank the tractor-production figures as follows:

100% : India, China, Brazil
 25-60%: Argentina, Mexico, Algeria, Turkey, Pakistan, Korea, Thailand
 15-25%: Tunisia
 ≤ 10% : Egypt, Tanzania, Iraq, Syria

Tractors are/were assembled from ckd and/or skd parts in Colombia, Morocco, Nigeria, Republic of South Africa, Thailand and Korea, in addition to some makes and/or models in Mexico, Pakistan and Turkey. In order to protect their own industries, Brazil, India, China and Japan do not allow large-volume importation of tractors.

HISTORY AND PRESENT STATUS OF SMALL-TRACTOR PRODUCTION AND USE IN SELECTED COUNTRIES

India

In terms of domestic production and sales, India is the developing world's leading tractor manufacturer. Indigenous production began in 1961, and the country's 1985 tractor output amounted to 85,000 ea., with small tractors (26 kW or less) constituting the largest group by far units (about 80%). Together, the country's seven leading tractor makers (accounting for about 95% of all indigenous tractors) marketed in 1986 twenty-one different tractor models with power ratings ranging from 10-44 kW. Tractors with power ratings of between 18 and 20 kW (25-27 hp) account for some 30% of the total market, i.e. all types up to 20kW/27 hp make up one-third of the market. The next-higher power range consists solely of tractors rated at exactly 26 kW/35 hp - which commanded half of the entire Indian market in 1986! Tractors with more than 26 kW accounted for about 17% of the 1986 sales volume.

The primary cultivating requirements for small-area rain-fed conditions, i.e. for tillage implements with drawn tools, are decisive for the tractor's technical complement:

- maximum tractive power, meaning high weight per unit of power in combination with adequately dimensioned driven wheels,
- a maneuverable tractor-implement unit, meaning quick and easy lifting of implements with the aid of a hydraulic system.

Additionally, many tractors are also used for powering threshers and pumps, usually by means of a belt and pulley (possibly coupled onto the p.t.o. shaft). Rain-fed soil cultivation (even without roots) involves much higher dynamic peak loads than those encountered in a wet rice paddy. The chassis and drive gear must be sized accordingly.

People's Republic of China

The production and use of small four-wheel tractors in the the People's Republic of China is closely linked to the country's overall agricultural and economic policies. In the past, this has led to a number of complete and radical changes in agricultural production systems - with corresponding effects on mechanization. Recent developments in the production of tractors in the People's Republic of China must be viewed in connection with changes in the land tenure system that have taken place since 1980. The functional scope of the people's communes was reduced to such an extent that they no longer constitute a major source of demand

for "large" tractors with power outputs exceeding 21 kW. The production of "large" tractors (> 20 kW) decreased from 125,600 in 1979 to 28,600 in 1986 (cf Table 55). At the same time, the sale of small tractors was booming, up from 217,000 in 1980 to 822,000 in 1985. Unfortunately, no differentiation is made between two-wheel and four-wheel tractors, but the 10% share listed by Kong *et.al.* in 1983 for small four-wheel tractors is probably still roughly correct. Accordingly, more than 700,000 single-axle tractors and over 70,000 four-wheel tractors with power ratings of 26 kW or less can be assumed as the 1985 production figures. Hence, China's 1985 single-axle tractor output was already higher than any tractor production level ever achieved in Japan.

TABLE 55: Production of single-axle and four-wheel tractors in the People's Republic of China (1976-1986)

Year	Four-wheel	Single-axle*
1976	73,700	240,000
1979	125,600	317,500
1980	97,700	217,900
1981	52,800	198,900
1982	40,300	298,300
1983	37,000	497,700
1984	39,700	688,600
1985	45,000	822,500
1986	28,600	774,500

* = incl. small 4-wheel tractors up to about 15 kW/20 hp

Source: State Statistical Yearbook: China (1987)

The 1980 transfer of responsibility for production from the people's communes to smaller units (mostly family farms) has resulted in a gradual shift towards single-farm forms of mechanization in which single-axle tractors and, to the extent available and economically feasible, four-wheel tractors of up to 16 kW are viewed as the central pieces. Their potential is being successively implemented and expanded. The product array, i.e. the available line of tractors and agricultural machines and implements, will eventually be brought more in line with such specialized demand:

- Light, simple tractors that could hardly deny their single-axle heritage. Engine ratings range from 9 to 12 kW (Taishan 12, Dong Fang Hong)
- Light, more sophisticated tractors, some with four-wheel drive, designed for use in rice paddies (Feng Shou), similar to Japanese

- products.
Heavy, simple tractors with high power-to-weight ratios for tillage with drawn implements under rain-fed conditions. Similar to Indian products in the same size category.

All three include a high percentage of transportation work.

Thailand

The production and use of small four-wheel tractors in Thailand has attracted lots of attention and is often cited as a model for other countries in Southeast Asia and elsewhere. The two main factors governing agricultural production in Thailand have engendered two very disparate forms of mechanization: first, the traditional working of rice paddies, particularly in the central plains to the north of Bangkok, where single-axle tractors and small, lightweight four-wheel versions predominate; then the highlands, mostly in the north and northeast, where increasing mechanization has led to substantial expansion of farm acreage, almost all of it now being worked with imported 44-60 kW tractors.

Work on the design of lightweight four-wheel tractors began in the 1950's, a prototype called the "Iron Buffalo" made its debut in 1958. In the subsequent years that name became much more popular than the tractor itself. A domestic single-axle tractor "industry" began to emerge in the early 1960's. By the late 1970's annual production had reached a level of about 40,000 units, with 25 manufacturers covering 95% of the market. The country's first indigenous four-wheel tractors appeared in 1969. Depending on the source quoted, the production figures ranged from 4,000 to 7,000 per year between 1978 and 1982.

Some manufacturers of single-axle tractors first began with four-wheel tractors referred to as Ayudhayas (after the town in which they are manufactured). In addition to single-cylinder engines, two-cylinder types with a side flywheel are also used; power outputs range from 9-15 kW. Power transmission to the gearbox is effected with V-belts. Up to now all indigenous tractors have been built with chain-and-sprocket gearboxes with up to three gears. The differentials are taken from old trucks or passenger vehicles and then overhauled and modified as necessary for installation in the tractors. The steering gears and some front axles are also taken from used vehicles.

The very simple design, coupled with the use of second-hand parts, makes the finished product very inexpensive, with prices ranging around US\$4,000. Admittedly, though, the utility value is limited to main tasks like rice puddling and transportation (the latter only with rubber tyres). Except for some very gradual changes, the practice of using new and used parts together remains to this

very day the main feature of such tractors. Since the early 1980's the domestic market has been in a process of radical change - with no end in sight. Even before that, considerable numbers of used tractors (as many as 2,000 per year) with engine power ratings of about 44kW, most of them Fords and Massey Fergusons, were being imported from Great Britain. Suddenly, in 1981, three times as many tractors (both single-axle and four-wheelers) were imported as in the previous year. Large numbers of new Chinese single-axle tractors and several thousand used small tractors of Japanese origin have also appeared. Their selling price often amounted to only a third to one-half of that being asked for corresponding local products.

This, of course, has had a devastating effect on Thailand's tractor industry. Within a single year, the production of single-axle tractors dropped by 10,000 units, and the four-wheel tractor market showed a similar reaction a year later: annual production dropped to about half of what it had been and continued to fall to about one-tenth of the original level (roughly 500) by 1985. While the production capacity and output figures for single-axle tractors eventually balanced out at about 40,000 units per annum, the number of four-wheel tractor producers dropped from 12 to 3 by 1985. There was no notable increase in demand prior to 1986, and there has been little, if any, further development of the products since 1981. Probably no other country with a fairly extensively mechanized agricultural sector has reached that stage with so little government interference, at least not in the form of furtherance.

Even more so than in the People's Republic of China single-axle tractors and small four-wheel tractors belong to one and the same technical and functional category in Thailand, while large tractors constitute a class of their own. Single-axle tractors have taken over the work that used to be done by draught animals - and do it according to the same principles: rice paddies are tilled right after the summer's monsoon rains; plows and rakes have remained essentially unchanged. Now, though, instead of the hooves of animals doing the stamping and mixing, the puddling is done by cage wheels.

The new and used Japanese-built tractors that have been imported in substantial numbers since 1980 have power outputs (9-15 kW) similar to those of their Thai counterparts, but that is about all they have in common. The Japanese products have numerous functions like multi-speed p.t.o.'s, hydraulic attachments, etc., and some have front-wheel drive and/or transmissions with anywhere from 8 to 16 gears. Moreover, they are much more comfortable, convenient and quiet-running. Another conspicuous difference between Japanese and Thai tractors is that most of the former are equipped with power tillers for rotary cultivation. That reduces by 50% or more the necessary number of tillage passes; the basic cultivation process is changed from drawn tools to power-driven ones. In a

nutshell; tractors imported from Japan were technically superior in every respect to Thai products with comparable power ratings; and at second-hand-tractor prices, they also had a cost advantage. Even the fact that prior use had detracted from their original life expectancy was hardly a problem, because it was still longer than that of the local products.

Other developing countries

With regard to agricultural mechanization, the Democratic Republic of (South) Korea is following the same course as Japan, but with a roughly 20-years lag. The country's industrial achievements has put the government in a position where it can provide massive assistance to the agricultural sector, with emphasis on capital-intensive production techniques. Four companies make and market four-wheel tractors with engine power ratings of between 10 and 35 kW. Local manufacture accounts for 63-100% (average: 86%). The tractors are built on license in a joint-venture basis using parts made by foreign manufacturers:

- Daedong, with Kubota and Ford
- Tong Yang, with Iseki
- Gold Start (ex Hyundai), with Mitsubishi and Fiat
- Kotje, with Hinomoto
- Korea Heavy Industries (KHIC), with Fiat

The number of four-wheel tractors produced each year (4,800 in 1986) is supposed to be increased by 1,000 annually until 1991. It has been estimated that at least two-thirds of them will have engine ratings of less than 26 kW. Four-wheel tractors are supplanting single-axle tractors on South Korean farms.

In some countries, particularly within Africa, there have been and still are various government and private initiatives aimed at promoting the use and production of small tractors. In Zambia, for example, nine small tractors were subjected to detailed testing between 1979 and 1981 (Aked (1981), Aked and Cullen (1981)). Each tractor accumulated between 300 and 500 hours of service. Then, the tractor's serviceability under Zambian conditions was evaluated with the following results:

- suitable: Agrale 4100 (Brazil), Tinkabi (Swaziland), Swaraj 720 and 724 (India), Yanmar (Japan);
- unsuitable: MF 210, Belarus T 25, Bouyer TE ("in need of further development").

Unfortunately, such clear-cut statements are rare.

Both Cameroon (Balo (1982), Schulz (1983)) and Tanzania (Hartmann (1986)) reportedly have been working on the design and comparative testing of small tractors, but no follow-up measures (dissemination) have, to our knowledge, been taken to date. In Cameroon and Tunisia simplified standard tractors with an engine power rating of 31 kW were tested in 1978 (Zaske, (1978)). Several times already, Egypt has negotiated the signing of an agreement covering the production of an approximately 30 hp tractor. Discussions were held with Deutz in 1977 subsequent to negotiations with Hefty (USA) (Krause and Gego (1977)) and prior to dealing with Renault. In 1986 Deutz returned with a type-DE 3607 tractor, a modified version of its D 3607. It was intended that a two-cylinder 22 kW engine already being built in Egypt would be installed in that model. Some 800 tractors with 18 kW/24 hp were imported in 1988 from the People's Republic of China.

Japan

Judging by the total number of units produced, Japan is second only to the Soviet Union as the global leader in tractor manufacturing. Fifty-five percent of all small four-wheel tractors produced in 1985 (173,000 of 316,000) were made in Japan. The first single-axle tractors were mass-produced in 1925. Between 1960 and 1970 the number of single-axle tractors (power tillers) in service in Japan rose from about 500,000 to over 3.2 million. Within a single decade, draught animals were almost totally replaced by tractors. More than 500,000 single-axle tractors were produced in Japan in 1968.

The first four-wheel tractors with engine power ratings of 7-15 kW appeared in early 1960's. They were copies of imported products and, as such, hardly suitable for working in rice paddies, because they were excessively heavy and lacked waterproof bearings. The breakthrough came after 1972 as a result of important innovations like compact construction, high-lug tires and four-wheel drive for Japanese-built tractors. By way of analogy to the Japanese products, such tractors are now referred to the world over as "compact tractors". The production figures practically exploded - from 33,757 in 1971 to 286,349 in 1976, and the in-service inventory passed the one-million mark in 1978. The number of tractors with power ratings of 22 kW and below, as a percentage of overall four-wheel tractor production, declined from 97% in 1976 to 80-85% about a decade later. Roughly half of the tractors produced are exported, with more than half of the exports going to the U.S.A.

The technical characteristics of Japanese-built compact tractors include a number of peculiarities. One of the most important criteria was the desire to have a tool with which to work (mainly till) rice paddies in an optimal fashion while putting enough power and convenience at the farmer's/driver's disposal. At the same time, the tractor had to be suitable for working in small fields and

negotiating narrow paths and crossings. Thus, the following characteristics apply in general:

- low total weight and power-to-weight ratio
- compact construction with correspondingly short dimensions
- several P.T.O.-shaft speeds
- large number of gears, including creeper gear
- dis-engageable front-wheel drive
- multi-cylinder diesel engine.

The p.t.o., transmission and front-wheel drive functions are intended for service with a power tiller in rice paddies. The weight and compact construction reflect the size of the field and the given working conditions.

Over-capacities began appearing in the Japanese tractor industry in or about 1976. A large percentage of all tractors produced are thus now exported. With the exception of those sold directly under manufacturers' names, the exported tractors are marketed in the colors of the importing country's manufacturers, e.g. Mitsubishi through Case/IH, Yanmar producing for John Deere, Shibaura for Ford, etc. Most Japanese-made four-wheel tractors are not used for field work in industrialized countries. Instead, they are used mostly for municipal tasks like mowing lawns and playing fields and in combination with small construction machines. The standards set by such user groups (in industrialized countries) are similar to those of Japanese farmers with regard to versatility, maneuverability and convenience of operation.

It is important to note that single-axle tractors had already taken the place of draught animals in all accessible rice-growing areas before four-wheel tractors came on the scene. The latter amounted to a kind of "upward mobility" in the sense of substantially easier work, more power available, and the chance to use implements with higher power requirements, e.g. multi-row rice transplanters. In contrast to, say India or Western Europe, Japanese farmers did not start motorizing with small - compact - four-wheel tractors. In fact, the process of motorization (as part of or resulting from intensification in general) had already taken place, i.e. the farmers were already experienced in the use of machines. Despite the larger number of components and functions, the manufacturing costs remained relatively low thanks to mass production and lightweight construction. The tractors were sized to accommodate the load cases normally encountered in rice cultivation, the peak dynamic loads of which are substantially lower than those encountered in rain-fed farming. Moreover, the average tractor accumulates a meager 67.5 operating hours per year indicating the level of subsidization of agriculture in Japan!

Federal Republic of Germany

Within the brief span of 15 years (1950-1965) practically all draught animals were replaced by so-called "Bauernschlepper" (farmer's tractor). For a while, tractors with engine power ratings of 26 kW or less accounted for about 90% of all tractors sold. By 1960, though, their market share had dropped to 80%, and it took only 10 more years for the situation to be totally reversed: more than three out of every four new tractors registered in 1970 already had more than 26 kW, and that category rose to about 90% in 1976 and has remained there ever since. Very few makes now include models with 26 kW or less in the Federal Republic of Germany, and most of them are either smallest member of a "family of tractors" with higher engine outputs (meaning that the "baby of the family" has a throttled engine and small tires) or one of several types that have remained essentially unmodified for 20 or 30 years.

It was not until the early 1980s that some new efforts were invested in (re)designing small tractors. In February 1988 the Institute for Agricultural Machinery, Munich Technical University, introduced the prototype of a "small research tractor" (Kirste (1984)). The purpose of such work has been to achieve:

- lightweight construction, with advantages in connection with price, fuel consumption and ground pressure; lightweight passenger-vehicle-type engines and transmissions and appropriate material (plastics)
- the option of shutting off unneeded features to lower the tractor's energy consumption and increase its longevity
- convenient operation (well-arranged levers, noise abatement)
- compliance with legal restrictions on noise emission and exhaust-gas pollution.

From that point on, though, Germany's case differs from others by reason of its characteristic dovetailing of crop farming and animal husbandry, which has had a substantial influence on the development and dissemination of small tractors in that country.

Large agricultural estates were able to employ several stages of technology at once, but small and medium-size farms, many of which were encumbered by a high location-dependent share of meadows and pastures, could not. Such farms, especially those using teams of horses or oxen, had to change from one source of traction to the other as quickly as possible. The power requirement was decided by analogy to the farm's previous draught-animal inventory; "single-furrow" or "double-furrow" tractors with 8-13 kW hp were chosen accordingly. With hardly an exception, the small-to-midsized farms in the Federal Republic of Germany proceeded from the use of draught animals (horses, oxen, cows) to small tractors

(Bauernschlepper) and then on to more powerful agricultural tractors. Hardly any tractors with engine power ratings of 26 kW or less are still used alone on a farm.

Table 56: Small tractors as percentage shares of total exports and first registrations in Great Britain

Year	Exports	First registrations			
	Total	<25 kW = %		Total	<30 kW = %
1975	134,440	5,245	3.9		
1980	100,961	297	0.3	20,750	166 0.8
1981	87,282	76	0.1	21,315	405 1.9
1982	74,296	62	0.1	25,568	614 2.4
1983	68,040	1,067	1.6	28,485	997 3.5
1984	83,705	4,521	5.4	25,548	1,073 4.2
1985	76,798	1,197	1.6	24,623	1,211 4.9
1986	60,491	1,663	2.7	18,775	1,164 6.2

Source: AEA & VIC (1987)

Great Britain

The share of newly registered tractors belonging to the less than 30 kW category has been on the rise since 1980, gradually increasing from 0.8% to 6.2% of total tractor stock in the country. While that does not suffice as a basis for long-term trend analysis, it does show that Great Britain is the only (or just the first?) country in Europe in which the trend has been reversed after nearly 20 years. The situation in the USA is similar. At present (1989) Great Britain has more sales agencies for Japanese-built tractors than any other country in Europe. Five of them operate under their own names, and three other makes carry the trade names John Deere, Ford and Massey Ferguson. About 2,500 Japanese tractors were imported in 1985, nearly all of them with power ratings of 26 kW and below. Some 60% are used for tending municipal grounds, sports facilities and recreation areas, 20% in the construction sector, and the remaining 20% in agriculture. The latter 500 tractors account for about 40% of new registrations in their size category (cf. Table 56).

United States of America (USA)

After accounting for only about 10% of new sales in 1976, tractors with less than

28 kW engines bounced back to account for roughly 50% share of the market in 1985. The large demand (upwards of 50,000 annually) is covered almost exclusively by imports, especially from Japan. Most imports are transacted under the name of one or the other old-established North American manufacturer. Many tractors with engine power ratings of less than 30 kW are put to one or the other non-agricultural use. Crucial areas include horticultural farms and the grooming of lawns and sports grounds, in addition to municipal work like street cleaning and snow plowing. Many "weekend farmers" use such tractors, as do some large farms to complement their large-tractor fleets. High tractive power is just as unimportant as sustained maximum output. Convenience of operation (incl. low noise and vibration levels), hydraulic versatility, multiple P.T.O. speeds, compact design and maneuverability are the criteria cited most often by both American and Japanese buyers.

SMALL TRACTORS FOR DEVELOPING COUNTRIES

The preceding section dealt with the production and use of tractors in various countries, with special attention paid to small tractors. In addition to the makes and models discussed in that context, there is also a wide variety of "small tractors specifically developed for or adapted to tropical and subtropical conditions" (cf. Table 57). Three types require special mention: the Bouyer (France) and the Tinkabi (Swaziland), being the only two tractors in platform-tractor category ever to be produced in significant numbers, and the Multitrac (F.R.G.), which is still at the development stage. According to the available information, it must be assumed that none of the other types will ever rise above their present status (prototype or pilot production). What all of them have in common is the widespread assumption that the lack of appropriate technology ("gap below the standard tractor") has a limiting effect on the extent to which the productivity of rural areas can be increased. Technical progress in the design of small tractors is seen as the best remedy. The significance and expense of the next steps (production and marketing) are often underestimated. Consequently, very few such tractors have ever got past the prototype stage.

BOUER/CFDT

This small tractor with a front platform was developed as a joint effort of the French cotton company CFDT (*Compagnie Francaise pour le Developpement des Fibres Textiles*) in Paris, the tropical farm machinery center CEEMAT (*Centre d'Etudes et d'Experimentation du Machinisme Agricole Tropicale*) in Antony near Paris, and the Bouyer Company in eastern France. The BOUYER TE was designed for use by CFDT's contract farmers. Apart from the usual characteristics of a small tractor (simplicity, robustness, etc.), this one features exceptionally high ground clearance (580 mm) in combination with a wider-than-average track of 1400-1600 mm,

TABLE 57: **Survey of type-specific case studies**

Make/Model	No.in Table 58	Design Origin (country)	Period of design/prod.	Prod. Qty
<u>Platform tractors</u>				
Bouyer, takeover	26	France	1972-1984	1261
by CFDT	27	France	1984-	320
Tinkabi	29	Swaziland	1968-1985	800*
Prod. resumed	-	(with 31 kW)	1987-	
Multitrac	30	FR of Germany	1977-	25
<u>Others</u>				
Lister Pico	31	Great Britain	1980-	P
Centau	32	Great Britain	1980-	P
AGRITOM PO26	28	France	1986-	P
AFCOM	35	Cote d'Ivoire	1977	P
<u>Universal tractors</u>				
Self Help	17	U.S.A.	1962-	250*
Agro Util	18	U.S.A.	1970-	50*
Kabanyolo	23	Uganda (EAU)	1960-1972	P
Goldoni	20	Italy	1978	P
Renault Afrique	24	France	1976	P
Gutbrod SSFT	21	F.R.G.	1978-1980*	P
Howard	22	Australia	1972-1978*	P
Buffalo	19	U.S.A.	1960-1978	P
Economy	-	U.S.A.	1962-1980*	P
Farmking	15	Great Britain	1985-	50
Br. Leyland 184	14	Great Britain	1960-1985	s.t.
<u>Basic tractors >35 hp</u>				
Desophisticated tr.	-	F.R.G.	1976-1980	P
Farewell/Tugwell	-	GB/Zambia	1986-	
Zambezi	-	Zimbabwe/India	1983-	
<u>Three-wheel tractors</u>				
NIAE Monowheel	39	Great Britain	1962-1967	P
Farmboy	38	GB/Switzerland	1971-1974	P
Poynter Triple	40	Australia	1972	P
Combiculteur	36	France	1976-1979	15*
Agrostar	37	CH/ Australia	1975-1983	P
Motorcycle tractor	40	Netherlands	1964-1976	P
<u>Tool-carriers</u>				
Tuff-Bilt	34	U.S.A.	1965-	s.t.
ENTI	33	Netherlands	1983-	500*
Normandia	-	France	1979	P

Table 57 continued

<u>Special designs</u>				
Amex	25	Great Britain	1978	P
Snail/Spider	45	Great Britain	1972-	P
Pangolin	43	Cote d'Ivoire	1974-1977	P
Quadtractor	-	U.S.A.	1978-1982	400
JAC Prod. resumed	44	Australia	1986-	P
Rokon	42	U.S.A.	?-1985*	s.t.

Interpretation: No. in Table 57 = the line in Table 58, showing the respective technical data
 s.t. = several thousand, exact quantity unknown
 * = estimated
 P = only a few prototypes

corresponding to two rows of cotton (Wieneke and Friedrich (1982)). A total of 1,261 BOUYER TE tractors were delivered by 1984, 853 of them were still in service and another 315 on order by 1985. The manufacturer - Bouyer - went bankrupt in July 1984, at which time CFDT assumed responsibility for supplying spare parts under its own name and has since continued to make addition TE's in small lots (beginning at about 20 each) from external parts.

TINKABI

The first prototype, which was introduced in October 1969, had rudder steering and chain-driven wheels. A pilot lot of nine prototypes was finished in 1973 and distributed for intensive testing. One prototype went to Silsoe, England, for tractor testing according to the OECD testing code at the former NIAE (National Institute of Agricultural Engineering, now AFRC Engineering).

After having been "declared dead" several times in as many years, production of the TINKABI stopped in 1985. The total number of tractors produced until then most likely amounts to somewhere between 500 and 800. Then, in early 1987, the TINKABI reappeared as the AG 3124 packing 31 kW engine, with substantially larger tractor tires of the driven wheels (11.2/10x24) and equipped with a category-1 three-point linkage. The new version still had a front platform and a hydrostatic drive, but came with a new top speed of 20 km/h.

Most TINKABIs in Swaziland are used on farms ranging in size from 10 to 15 ha, with main crops consisting of corn (maize), cotton, peanuts (groundnuts) and beans. All of the farmers had long years of experience with draught animals. The fields are therefore free of major obstacles. Primary and secondary tillage and hauling are reported to be the main tasks for tractors. Quite a few TINKABIs have been equipped with flywheel-driven hammer mills and put out for hire. However

as Agrippa and Lukhele have reported in this volume (Chapter 8) the Tinkabi appears to have performed better in stationary jobs rather than in tillage.

Multitrac

In 1977, the Federal Ministry of Economic Cooperation (BMZ) in Bonn provided public funding via the "Deutsche Gesellschaft fuer Technische Zusammenarbeit" (GTZ) in Eschborn for designing, testing and disseminating of a "universal farm implement" (UAG). With a single exception, the tractor attributes envisioned for the "UAG" were about the same as those listed above for the "Bouyer" and "Tinkabi" tractors: simple, robust, inexpensive, platform-type, etc. However, in contrast to those other approaches, it was not a product, i.e. a platform tractor with a certain set of technical data, that was to be introduced and propagated, but rather the know-how for its manufacture.

A Y-shaped universal frame made of ordinary structural steel carries the components (engine, transmission, axles, etc.) that are available at the respective place of manufacture and/or use. Consequently, tractor production can be based on existing indigenous facilities, structures and capabilities. Theoretically, the frame-construction principle allows the use of myriad different combinations of engines, transmissions and axles, depending on local availability and prices. Worldwide response to the new MULTITRAC exceeded all expectations. This tractor, it seems, was the answer to many people's problems. The elaborated information (production documentation, etc.) was supposed to give potential buyers from developing (and industrialized) countries the know-how they would need for manufacturing their own technically, constructionally and financially made-to-measure MULTITRACs in compliance with their own domestic situation. However, that development-political approach proved impracticable in the presented form. Namely the four prototypes were not being understood as mere examples of how to implement the basic idea, but rather as a complete take-it-or-leave-it line of tractors from a new West German specialist manufacturer. Only about 25 MULTITRACs have been produced to date, so little on-the-job experience has been gathered. In 1988 some tractors were exported to Nigeria and Cameroon

Comparative Profile

Types of construction

All small tractors mentioned in the study were arranged according to their respective types of construction. At first glance, the diversity may seem somewhat bewildering, but it actually breaks down to only three basic types: universal tractors, platform tractors and single-axle tractors - plus a "potpourri" of special designs.

- Universal tractors: front engine, driver's seat at rear, most implements attaching at rear;
- Platform tractors and vehicles: front or rear platform (the latter configuration showing close resemblance to a pickup truck), with hauling as the main task;
- Special designs: e.g. tool carriers, hillside tractors, three-wheel versions, motorcycle tractors, prime movers with winches;
- Single-axle tractors, power tillers and rotary motor hoes.

Practically every conceivable kind of small tractor has already been tried out in connection with agricultural mechanization in the tropics and subtropics.

Technical data

The technical data of forty-five small tractors were analyzed for the purpose of defining the range of technical characteristics (cf. Table 58). Differentiation is made between series products and prototypes/discontinued series products. The comparative summary yields the following situation (cf. Holtkamp (1988, 1989) for details):

Weight (static weight of tractor)

The weights of the 45 chosen types of tractors range between 400 kg and 2,000 kg. On the average, standard tractors weighed a good 200 kg more than prototypes/erstwhile series products. In the 25-30 kW power range, the new European small tractor has a static weight of about 1,800 kg, with considerable tolerance in both directions. While the difference has diminished in recent years, Japanese tractors in the 1,050-1,700 kg range tend to weigh between 300 kg and 400 kg less for a given engine output.

Power-to-weight ratio

Like the reference variable, the static weight, these values also tend to be considerably higher for series-built tractors. The less than 20 kW range shows an enormous amount of scatter (12-145 kg/kW), while the range above 20 kW is within the limits 45-80 kg/kW. The latter is true of small tractors built in Western Europe. There is also a conspicuous "gap" extending from 13 to 16 kW (18-22 hp). Tractors situated to the left of the gap are hardly suitable for rain-fed tillage operations. The power-to-weight ratios of Japanese-built tractors are concentrated within the 50-70 kg/kW interval. This is attributable to their compact, lightweight construction in combination with multiple cylinder, high-speed, lightweight diesel engines.

Wheelbase

The wheelbase range starts at about 1300 mm for 8 kW and extends to nearly 2,000 mm at 25 kW. On the average, standard products from developing countries and Europe have wheelbases that are about 200 mm shorter than those of prototypes. The wheelbase of the average Japanese tractor is shorter by another 150 mm or so. Surprisingly, the wheelbases of tractors in all four groups converge closely at about 25 kW (interval: 1,800-1,900 mm).

Hydraulic lifting power

Of the 45 tractors in Table 58, 28 are equipped with a rear hydraulic, but lifting-power data is only available for 16 of them. The values range from 250 daN to 1,900 daN (1daN = approx. 1 kg). The factory data may be assumed to list the maximum lifting power, as opposed to the continuous lifting power, which may be as much as one-third lower than the maximum lifting power.

Performance, functions

Apart from the customary technical data, additional information concerning the following items was gathered:

- performance (in particular the area worked per unit of time)
- the resultant working time requirement (reciprocal of above)
- specific fuel consumption.

All of these quantities depend on the implements in use, i.e. their kind, size, effective width, speed and depth -in addition to local conditions. Here, too, only the general range of published information can be recounted. Consequently, no significant differences between small tractors with comparable engine output ratings can be inferred from them.

DISCUSSION AND CONCLUSIONS

Demand and agricultural uses for small tractors

It would appear that the increasing use of small four-wheel tractors in developing countries is concomitant to and a result of - as opposed to a precondition for - gradual intensification of agricultural production. The purchase of a farm's first small tractor reflects prior changes in that farm's factor endowments and their availability. The goal would seem to give the farm a new and better combination of production factors capable of optimizing production, minimizing risks and maximizing profits. Any investment in farm mechanization stands in direct

competition with potential investments in yield-increasing measures like irrigation, seed, fertilizer and pesticides. When intensification efforts are just getting under way, measures of the latter kind not only offer better cost-benefit ratios, but are also more feasible for small farms, thanks to their largely unlimited economic divisibility.

Many of the farms getting their first (small) tractor already have draught animals or a single-axle tractor. Most small four-wheel tractors purchased in developing countries are intended to serve as the farm's only tractor. Firstly, the tractor is supposed to supplement the work of draught animals (in rain-fed farming areas) and of single-axle tractors (in rice-growing areas, where they have already replaced draught animals). Later, though both are completely replaced by small four-wheel tractors. Nearly all small tractors (like draught animals and single-axle tractors) are privately owned - an indication of a family-farm structure. Unlike large tractors, the typical small tractor is operated by the owner himself or by a member of the family. While small tractors are frequently used to complement large ones in Western Europe and North America, that practice is still rare in developing countries.

Farms with limited acreage and capital (= the typical small farm) are equally limited in the amount that can be spent on motorization within a given time span. Options include making use of a farm-credit program (to the extent available) or buying a small or used tractor. Since it often makes little sense from an economic standpoint to mechanize a single small farm with a four-wheel tractor (even a small one might be too expensive!), only multi-farm cooperation can enable the farm to gain access to the production factor "agricultural tractor". Also, multi-farm use of machinery makes it possible to monitor, plan and adapt the farms' production operations and capital goods to the altered production techniques. Small tractors are and always have been most popular in Europe (particularly in the Federal Republic of Germany and Italy), India, China, Japan, and the USA.

Irrigated rice growing by reason of the given agrarian structure and topography, inherently involves very small areas. Small tractors, with their low power-to-weight ratios, are at an advantage over large ones. They are powerful enough to plow the soft soil or drive a power tiller. The process of motorization began with the introduction of single-axle tractors to replace draught animals for puddling work. Then, the single-axle tractors, most of which now have engine power ratings of 13 kW or less. While they at first result in only insignificant technical changes, i.e. even the hourly performance increases only slightly, the work is a lot easier, so that more hours can be put in, thus increasing the daily performance. Considering today's production techniques, small tractors therefore serve as an indicator of intensive production, the desire to achieve a lighter workload, a

shortage of labour and/or the farm's financial capabilities (including off-the-farm income).

Rain-fed farming poses a different situation: single-axle tractors are not powerful enough for large-area cultivation, because the soil resistance is two to eight times higher than in a wet rice paddy. Drawn implements like plows and cultivators require tractors with relatively high pulling capacity. Tractors with 30 kW, or even better 40 kW, are technically superior to smaller ones. If the family's combined on-the-farm and off-the-farm income does not allow the purchase of a new large tractor, and/or if no used tractor is available, a small one (if one can be found) will have to do at first. In northwestern India, northern and eastern China, as well as in parts of Turkey and Brazil, small tractors with a high power-to-weight ratio are quite common. Most of them have 20-26 kW engines and therefore belong to the "medium-size" class for their own particular range of application.

On a small farm, the first small tractor (new or used) constitutes a technical and financial step into a new kind of technology. It shows that the farm is taking part in economic progress. The second tractor after five to ten years can be expected to have at least 25 kW, probably more. In the meantime, new production methods will have been adopted, and the draught animals will have been reduced in number or abolished altogether. The initial excess capacities are successively reduced by off-the-farm contract work or area expansion, i.e. by taking back leased land and buying or leasing more land. Depending on the main crops, local conditions, producer prices, etc., at least 6 to 8, or better 10 to 15 hectares of cash crops with a corresponding arable-land area of at least 15 to 25 ha are regarded as minimum acreage for the cost-efficient use of small tractors under rain-fed farming conditions. In many developing countries, that would constitute a large-scale farm.

In most cases, the adequately cost-efficient use of a tractor (on the basis of annual operating hours) is not achievable by merely attending to scheduled work, even on other farms, too. The tractor would also have to be used for transport duties and other jobs that are not, or at least less, time-dependent. Farms with integrated crop and animal production require year-round supply and disposal operations that set up good working conditions for small tractors, which, with their compact dimensions, have advantages over large tractors in barns, stables and farmyards. On a typical farm, a small tractor may face "competition" from manual labour; draught animals; single-axle tractors; large four-wheel tractors; transport vehicles, e.g. pickups; stationary drive units.

Non-agricultural uses for small tractors

In industrialized countries, most new small tractors are put to non-agricultural

uses. The same trend also appears to be emerging in developing countries. Some uses for small four-wheel tractors include:

- upkeep and maintenance of sporting, recreational and touristic facilities
- community-level tasks (cleaning streets, plowing snow)
- construction
- transportation and
- military activities.

In the latter two areas, small tractors are used almost exclusively as truck tractors for shuttling work on paved grounds; in the other areas they are also used for powering mobile or stationary equipment.

Manufacturing

According to their type of construction and historical background, small tractors the world over can be divided up into four main groups:

Group 1: Developed from single-axle types, frame construction, engine power ratings up to 13 kW (southern and eastern China, Thailand).

Group 2: Four-wheel tractors originating in the same production facilities and on the basis of the same duty profiles as single-axle tractors, but with a high technical niveau from the very beginning, monocoque construction, high piece numbers, engine power range primarily from 10-20 kW with upward trend (Japan, market leaders in the U.S., just beginning in Korea).

Group 3 Independent or license-aided types of universal tractors, monocoque or half-frame construction, large series engines beginning at 20 kW. Extensively identical to larger tractors (India, eastern and northern China, Federal Republic of Germany, eastern European countries, various types in Turkey and Brazil).

Group 4: Same as group 3 but with narrow track, designed especially for use in orchards and vineyards as well as on plantations, often having four wheels of equal size, sometimes with articulated steering (Italy, Federal Republic of Germany, a few in Brazil, Turkey and the Soviet Union).

In the less than 26 kW power range, none of the tractors belonging to category 3 or 4 have undergone any nominal re-engineering in industrialized countries. Any tractors belonging to that category that are still (or again) on the market are therefore based on two-decades-old technology - with the exception of some Japanese products sold under the names of venerable old firms. Recently,

however, there have been signs of new activities among West European manufacturers that would affect, but not necessarily be limited to, the 26-37 kW power range. If so, international work-sharing in the production of small tractors could develop according to the following breakdown:

- a) Tractors for irrigated rice paddies, mostly less than 18 kW/25 hp, will be made in Japan and, with increasing frequency, under license in other Asian countries (China, Korea, Thailand). Some indigenous Chinese products will be offered, possibly also some from Thailand. Assuming certain changes in the existing agrarian structure and production techniques, larger tractors may also gain acceptance among rice growers.
- b) Tractors for rain-fed farming, higher than 20 kW with upward trend, made in India, in parts of southern and eastern Africa; some built in Brazil, Turkey and Pakistan.
- c) Tractors for complementary and/or non-agricultural uses in the U.S. and, increasingly, in Western Europe, made in Japan, some being marketed by old-established manufacturers.
- d) No more small less than 26 kW tractors built in Europe or North America that would appear suitable for use in developing countries. Conversely, the next power category, i.e. 30-40 kW, could regain new status in Europe as well as in developing countries. The narrow-gauge models can be expected to defend their position in this power category.

The importance of choosing suitable implements cannot be over-estimated. While the three-point linkage (four different categories: 0 through 3) has emerged internationally as standard equipment for the attachment of tools and implements, the mere fact that both the tractor and the implement belong to the same category is no guarantee that they will also fit together. Standardized linkages are more universal, but also more expensive than special-purpose designs.

Small tractors are the result of attempts to satisfy a real or perceived need. The user's requirements should be the decisive criteria. In the course of the last 100 years, very few of the many technical solutions that have been tried out at different times in different parts of the world have actually gained lasting acceptance:

- Universal tractors in combination with a standardized implement linkage setup have gained by far the most widespread acceptance;

- Wherever they make sense both technically and financially, special-purpose tractors have gained relevance:
 - system tractors
 - narrow-gauge tractors and articulated-steering versions
 - tool carriers
 - hillside tractors
 - row-crop tractors
 - all-terrain transport vehicles
 - off-the-road motorcycles etc.
- Other approaches are found to lead in the wrong direction. This does not include only "dead-end designs" like most three-wheel versions. Tractors that have served well and gained acceptance in other places may turn out to be technically unsuitable or out-of-date, non-competitive or otherwise inadequate or out-moded when they are "transplanted".

Costs and Prices

Low manufacturing costs are necessary for producing a competitively priced tractor - assuming the absence of protectionist measures that shield it from competition. Renius (1985) mentions the following factors as points of departure for reducing the cost of tractor manufacture in industrialized countries:

- rationalization of production (low labour costs)
- large series (low fixed costs)
- modular design (minimum number of individual parts)
- value analysis (minimal technical input)
- lightweight construction (low material costs)

For small tractors built in developing countries, the importance of some factors varies, and there are additional possibilities of cost reduction:

- Labour-intensive production methods are preferable to capital-intensive methods and usually on par with them with regard to economic criteria;
- Lightweight construction could be an unsuitable approach due to the possibly questionable quality of the available primary raw materials and the probably tough duty requirements.

Design simplification, including omission of functions is a recommended means of reducing production costs, but only to the extent that basic functions are not impaired (cf. Table 58). Even for small tractors, such basic functions normally call

for a hydraulic three-point lift, a power takeoff shaft and a transmission with an adequate number of speeds. The cost-reducing effect of numerous attempts to do away with some major components by opting for a three-wheel design has consistently been over-estimated, while the resultant limitations on such tractors' utility value have been underestimated.

The use of used parts in "new" tractors has caused more than one product to be dubbed a "junk tractor". Be that as it may, that practice does yield substantial savings. Tractors from Ayudhaya, Thailand, stand out as a good example of products comprising both new and overhauled parts. Frequently, reconditioned parts are erroneously referred to as "robust". The lower purchase price approximately corresponds to the parts shorter service life.

The potential advantages of buying and selling used tractors on a broader scale, however, are seen in a more positive light. Especially if the tractor has had a general overhaul, its various components can be expected to have more or less equal life expectancies. For a farm in a technological transition phase, e.g. when it is in the process of converting from animal power to tractor power, the reduced longevity of a used tractor has little if any limiting effect, since the tractor will hardly be used to capacity during the first few years, anyway. An assured supply of spare parts is just as important as for new tractors. Small tractors tend to gain little acceptance in rain-fed farming regions where ample numbers of used large tractors are available.

The use of mass-produced parts from the motor vehicle and tractor industry is viewed by many as a magic formula for reducing the cost of production. Indeed, even old-established tractor manufacturers buy cogwheels, gaskets, filters, V-belts, fuel systems, electric systems and even complete engines, transmissions and axles from specialized suppliers. Since the cost-cutting effects of mass production are already being exploited, new products like small tractors can hardly be competitive unless they too utilize such parts. Wholesale prices are only available to wholesale buyers, of course. If components are bought singly or in small numbers, the buyer must expect to pay spare-parts prices.

Production in the developing country instead of in the industrialized country of origin should help reduce the cost of manufacturer thanks to lower wages. On the other hand, that has not always been the case in practice, at least not from an economist's standpoint, namely when the cost of labour was over-estimated in comparison to the cost of materials. Because of the "double assembly costs", locally assembled tractors consisting of ckd/skd imports can initially be expected to cost 3-6% more than cbu imports. The use of locally available parts does not always have the effect of cutting costs. Frequently, such parts are imported for no particular purpose and therefore sold exclusively at "spare-parts

prices". The breakthrough depends on indigenous production of essential components.

In 1985/86 the World Bank had 16 developing countries compared with regard to how they price and market agricultural tractors. Table 60 surveys the tractor prices being asked in those countries and states them both in absolute terms and as grain-equivalent units. The tractor in question was chosen as a typical representative of the 60-65 hp category, and the prices are based on the currency exchange rate applicable to the importing of tractors. In the autumn of 1985, the least expensive tractors, costing about US\$ 130 per hp, were to be found in Turkey and Pakistan, while those being offered in Equatorial Africa were the most expensive (more than US\$ 300 per hp).

The order or priority in the first column of Table 60 is totally different, if the selling price per horse power is related to the prices that the farmers get for their products. Measured in "grain-equivalent units", the cheapest tractors are found in Korea, where a 47 hp tractor goes for 16 tons of rice. By contrast, an Egyptian farmer would have to pay 89 tons of rice for a 65 hp tractor, which amounts to about four times the horsepower-specific price paid by the Korean farmer. The difference is chiefly attributable to state-controlled producer prices for rice and wheat, which are well above the world price in Korea, but well below it in Egypt. This makes no account of differences in the cost of producing rice (substantially higher in Korea).

In the course of its service life, the typical agricultural tractor in an industrialized country needs repairs and spare parts costing between 1 and 1.5 times as much as its original purchase price. In developing countries, the factor is more like 2.5. Though most tractors come with a package of spare parts and fast-moving parts corresponding to about 10% of their value, they are often inadequate with regard to type and extent. A relevant study conducted by the World Bank (Agrisystems (1986)) sharply criticizes the international tendering approach as the "worst possible solution for the end user". Tendering keeps manufacturers from building up a permanent spare-parts and repair services organization. Short-term advantages (cheapest offer) are soon eaten up by long-term drawbacks like inadequate spare-parts supply. In that connection, the bilateral and multilateral organizations concerned with international cooperation stand accused of short-sightedness: as soon as a project with a "tractor-supply component" has been completed, the supply of spare parts usually dries up.

Conclusions

- a) Practically all conceivable designs for mobile, fieldgoing prime movers with 2, 3 or more wheels and answering the description of a "small tractor" have

already been tried out. Investing more effort into new small-tractor designs would appear to make little sense.

- b) Small tractors have gained acceptance where they offer advantages in day-to-day use - not necessarily in manufacturing and marketing - in comparison with other sources of energy and/or traction. The production techniques, local working conditions and, above all, the price prove to be the decisive factors. Small tractors lose their price advantage wherever there is a "second-hand tractor market" and large tractors are technically suitable. The economic equivalence of large, second-hand tractors and new small tractors underlines the fact that the latter are not what is needed for effecting the economically appropriate mechanization of small-to-tiny individual farms. Small tractors and second-hand tractors can help small farms get tractorized (four-wheel type) more easily than they could with a new 40-50 kW "standard tractor". In rain-fed farming, small tractors supplement large ones and can have a quite useful farm development function.
- c) Any farmer buying his first small tractor should own or have access to enough suitable land and already have been practising in the intensive, "large-scale" production of cash crops. Small-tractor programs and other mechanization programs are usually quite similar, both in their objectives and their implementation.
- d) The production of agricultural tractors does not always start with "small ones", but depends on the size category with the demand. Consequently, domestic tractor producers certainly need not begin with a small tractor. Nor should any project be based on the assumption that demand could or should be stimulated merely by putting tractors within the buyers' reach. The planning that goes into the establishment of local manufacture should allow for, among other things, the fact that more foreign currency will be required during the first seven to ten years than would be necessary to merely pay for imports. That at first seemingly contradictory observation is rooted in the need to continue importing while still spending extra money on research, development and the requisite production facilities.
- e) Points of departure for economic cooperation projects include the establishment of the requisite marketing infrastructure, followed by establishment of the necessary production and engineering capacities. Unless the overriding objective is to increase the percentage of local manufacture, assembling tractors from imported parts would have very limited positive effects; the contribution toward cost reduction and the establishment of local capacities is usually over estimated.

- f) In the past, the actual agricultural users of small tractors - a farm-size category defined more by income than by acreage - have rarely been explicitly named as the target group of projects concerning either financial or technical cooperation. In some countries or regions, that group may account for a relatively small share of the total number of farms, but there are millions of them in the Third World per se, and they therefore possess a considerable developmental potential. What they are not is small farmers: Small farmers can only be reached by a combination of administrative and organizational measures, e.g. multi-farm use of agricultural machinery, in addition to such project approaches as those defined above - not by churning out new prototypes.

TABLE 58

Table 58: Technical Data for a Selection of Four Wheel Tractors up to 26 kW

No.	Make/Model	Cat.	Power kW	Gears f/r	Speeds max km/hr	Tyres front	Tyres rear	Track min mm	Track max mm	Wheel base mm	Static weight kg	Hydraulic lift daN	Power-to weight ratio kg/kW
1	AGRALE 4100	1	11	7/3	13.2	4.00x15	8.00x24	-	1100	1205	1100	330	100
2	AYUDHAYA UTAMCO	1	10	4/1	35	5.60x13	9.00x20	-	1400	800	500	500	80
3	AYUDHAYA AT 1800	1	11	2/1	28	5.50x13	9.00x20	-	1140	1495	1000	-	91
4	BASAK. 17	1	12	4/1	15.7	4.400x12	7.00x18	-	-	-	800	-	67
5	EICHER CHANDI	1	10	6/1	26	5.50x16	11.2/10x28	1275	1461	-	1445	h	145
6	EICHER GOODEARTH	1	18	8/2	23.6	5.50x16	11.2/10x28	1270	1420	1844	1650	h	92
7	EICHER GOLD	1	26	8/2	25.2	6.00x16	12.4/11x28	1278	1432	1946	1805	h	69
8	SWARAJ 720	1	11	6/2	25.5	5.50x16	11.2/10x28	1200	1470	-	1250	800	114
9	SWARAJ 724	1	16	6/2	-	5.50x16	11.2/10x28	1300	1900	-	1780	1000	111
10	SWARAJ 735	1	24	8/2	30	6.00x16	12.4/11x28	1300	1900	-	1925	1000	30
11	DONG FANG HONG	1	11	8/2	23.8	4.00x12	7/30x16	-	960	1400	950	420	86
12	FENG SHOU	1	13	8/2	23/7	4.00x14	8.3/8x20	950	1250	1400	880	h	68
13	SN 25	1	18	-	21.2	-	-	1000	1400	1550	1120	650	62
14	LEYLAND 184	1	22	9/3	-	5.50x16	11.00x24	1120	1830	1715	1360	1300	62
15	FARMKING	2	17	3/1	21.3	6.00x16	11.2x24	1220	1930	1780	1185	h	70
16	DEUTZ DE 3607	2	22	8/2	27.2	7.00x28	11.2/10x28	1130	1520	1800	1560	1900	71
17	SELF HELP	2	9	6/2	-	4.00x12	8.00x16	-	-	1370	517	-	57
18	AGRO UTIL	2	13	4/1	-	4.00x12	8.3x24	1016	1372	1575	693	-	53
19	BUFFALO	2	13	hydr	12	-	-	-	-	1676	715	h	55
20	GOLDINI	2	13	6/3	21.6	5.00x15	9.5x20	-	-	1500	820	-	63
21	GUTBROD	2	16	4/1	-	4.00x12	7.5x15	795	1120	-	610	h	38
22	HOWARD	2	5	4/2	9.1	-	-	700	900	-	480	-	96
23	KABANYOLO	2	10	6/2	29.2	4.00x12	7.00x16	-	1230	1410	525	-	53

cat. = category

TABLE 58 Continued

No.	Make/Model	Cat.	Power kW	Gears f/r	Speeds max km/hr	Tyres front	Tyres rear	Track min mm	Track max mm	Wheel base mm	Static weight kg	Hydraulic lift daN	Power-to weight ratio kg/kW
24	RENAULT	2	11	4/2	16	4.00x10	6.00x16	-	810	-	480	-	44
25	AMEX	2	16	4/1	20.1	4.00x15	7.50x16	-	1040	1520	454	250	28
26	BOUYER	2	18	6/3	22.2	5.00x15	9.50x24	1430	1600	-	1120	-	62
27	CFDT	1	23	6/3	10.9	5.00x15	9.50x24	1430	1600	-	1120	-	49
28	AGRITOM P.D.26	2	19	8/2	18	5.00x15	9.50x24	-	1350	1800	1160	h	61
29	TINKABI T. 172	2	12	hydr	12	5.00x15	6.00x14	-	1800	2100	1050	h	88
30	MULTITRAC 2502	2	24	4/1	13.2	4.50x16	9.50x25	-	1390	2100	1260	650	53
31	LISTER PICO	2	25	6/1	22.7	6.50x16	11.2/10x24	-	1524	2300	1740	1195	70
32	CENTAUR	2	9	3/1	16.1	6.00x16	9.50x24	-	1370	1830	1064	160	118
33	ENTI	1	19	hydr	16	7.00x12	9.50x24	1350	1650	-	1050	800	55
34	TUFFBILT	2	17	h+3	9.5	4.80x12	8.3/8x24	914	1830	1830	680	318	40
35	AFCOM	2	11	4/1	13	6.00x16	7.50x18	-	1600	1750	870	h	79
36	MOUZON SATEC	2	9	V+5	13.3	5.00x10	7.50x18	1300	1700	-	920	h	102
37	AGROSTAR	2	12	4/2	20	3.00x12	8.3/8x24	1180	1680	-	1000	h	83
38	FARMBOY	2	10	-	18	5.00x13	9.5/9x24	-	-	-	1040	-	104
39	NIAE MONOWHEEL	2	8	2/1	12	5.00x16	8.00x24	-	1520	1676	825	-	103
40	POYNTER TRIPLE	2	9	2/2	10.4	6.00x16	11x24	1524	1930	-	585	-	65
41	ZUGM. WAGEHIGEN	2	5	2/0	10	4.00x12	6.00x16	-	-	-	379	h	76
42	ROKON	2	7	V+3	65	6.70x15	6.70x15	-	-	-	84	-	12
43	PANGOLIN	2	11	4/1	14	7.00x16	7.00x16	-	1000	700	600	-	55
44	JAC/DUADRACTOR	2	6	3/1	-	6.50x15	6.50x15	1219	1524	-	408	-	53
45	SPIDER	2	5	-	24.7	5.00x15	7.50x16	-	1500	1800	710	-	142

Cat. = category 1 = series products 2 = prototype or discontinued series h = hydraulic syst. with unknown lifting power.

TABLE 59: Potential Means of Cutting Production Costs

<i>Omit</i>	<i>in favour of</i>
- electric system incl. battery and starter	starting by hand or spring-loaded starter
- hydraulic system	lifting the implements by hand or using only trailer-type (drawn) implements
- power takeoff shaft	belt pulley (very limited option, only possible in combination with a flywheel)
 <i>Simplify</i>	 <i>by</i>
- hydraulic system	opting for no hydraulic control
- transmission	making do with fewer speeds
- electric system	opting for lighting only
- power takeoff shaft	limiting it to a single stub/speed
- disc clutch	opting for a pulley clutch (also easier to install)

TABLE 60: Tractor Prices in Selected Developing Countries

Country	Retail Price US\$ per hp	Rice equivalent per tonne hp	Maize	Wheat
Turkey	130	0.45	1.21	1.03
Pakistan	136	0.85	-	1.30
Morocco	149	-	0.74	0.88
Brazil	176	0.91	1.71	0.93
India	177	0.76	1.41	0.98
Thailand	181	1.76	1.97	-
Malaysia	192	0.86	-	-
Indonesia	198	1.25	1.93	-
Sudan	200	-	-	-
Mexico	212	1.66	1.50	1.85
Egypt	212	1.37	1.92	2.65
Kenya	249	-	2.28	1.58
Korea	281	0.34	0.61	0.70
Nigeria	302	0.57	1.09	0.82
Cameroon	308	0.85	2.13	-
Tanzania	317	-	1.03	-

Source: IBRD (1987)

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CHAPTER 14

SYNTHESIS OF THE AFRICAN EXPERIENCE IN AGRICULTURAL MECHANIZATION

by

G.C. Mrema

INTRODUCTION

In the preceding chapters, seven case studies from seven Commonwealth African countries (i.e. Botswana, Ghana, Kenya, Nigeria, Swaziland, Tanzania and Zambia) have been presented. Coupled with these seven case studies there are also chapters giving the experience of India, and FAO in this area as well as a chapter on the role of small tractors in agricultural mechanization in the developing countries of the tropics. Each case study has been prepared, taking cognizance of the experience within each country with little cross reference to the experiences in other African countries. The objective of this chapter is to highlight those common factors and experiences that cut across the case studies and identify the major problems as well as the successes in the agricultural mechanization saga in Africa. This chapter therefore builds on the first two chapters which gave an overview of agricultural mechanization in the World and in Africa respectively and chapter 3 in which FAO's experience on formulation of agricultural mechanization policies has been presented. This chapter is divided into three main parts, first we shall have a section dealing with the lessons which can be learned from past attempts in mechanizing agriculture in Africa, and this will be followed by a section dealing with what in our opinion should be the future agenda for mechanizing agriculture in Africa, and finally we shall have a concluding section which will highlight the main conclusions of this workshop. However before we go into this let us first attempt to give the main reasons why there is a need to mechanize agriculture in Africa.

WHY MECHANIZE AGRICULTURE IN AFRICA?

Governments (both colonial and independent African Governments) as well as individual farmer's efforts over the past ninety years have been directed in one way or another at mechanizing agriculture in Africa. These efforts have in many cases been augmented by the donor community assistance. The main thrust of

these efforts has aimed at replacing the cutlass and hoe cultivation with draught animals, small tractors or large tractors. It would seem there are five major reasons for this: first to increase the productivity of labour; second to increase the land under cultivation; third to improve the quality of farming operations; fourth to reduce drudgery and hence make agriculture more attractive; and finally the need for timely completion of certain key agricultural operations due to the limitations imposed by the weather. One or all of the above five reasons have been used to justify agricultural mechanization projects and programmes on the African continent. These reasons have been used for both the large scale agriculture, as well as for small holder and the peasant subsistence farmers. Further all who have been involved in agricultural development in Africa, agree that there is need to mechanize it, the major point of difference among the development experts and policy makers has been on how to do it.

The first reason - increasing the productivity of labour is quite obvious - farming carried out using the handtool technology with entire reliance on human muscle power is in most cases quite inefficient. A family using this type of technology can rarely till more than one hectare especially in the tropics (Boshoff and Minto (1975); Mrema (1981, 1983); Nuuba and Kaul (1986)). There is a physiological limit to what a normal human being can do in agriculture using the handtool technology. Draught animals and internal combustion engines do significantly increase the output of human energy expended in agriculture. The second reason is also quite apparent for Africa. With the exception of a few areas where there is land shortage and which are over populated there is still a lot of land in this continent which could be opened up and brought under cultivation to produce food and fibre for economic development. A major limitation which has hindered this has been lack of power - be it human, draught animals or mechanical. As it has been noted in some of the case studies presented in this volume, by and large, the rural areas in Africa are not really areas with a labour surplus as in essence, the population of the most economically active age groups in the rural areas has actually been stagnating or decreasing over the past thirty or so years. A significant percentage of the most active age group has migrated to urban areas leaving in the rural areas the less active age groups economically (old people and young children). Indeed in most of the rural areas of Africa there are no land less labourers waiting to be employed a situation which is common on the Asian continent. The overall annual population increase in Africa has been in the region of 2.5 - 4% for most countries, while the urban population increase has been at about 6 - 12% over the past 4 decades. Additional land can therefore be brought under cultivation if the human energy expended by those remaining in the rural areas is augmented by other sources of energy - draught animals or mechanical power, hence the need for agricultural mechanization.

The third reason of improving the quality of farming operations follows from the first and second reasons and is quite apparent. The achievement of a higher quality of work through deeper ploughing and more thorough incorporation of weeds and crop residues as well as better infiltration (and hence the resulting agronomic benefits); row planting and correct placement of fertilizers through use of machinery; as well as superior and thorough crop protection and harvesting operations can all occur if higher levels of mechanization inputs are used in agriculture. The fourth reason - timely execution of agricultural tasks is crucial in Africa where rainfed agriculture is the norm, and the rainfall tends to be unreliable and erratic in most cases. The untimely completion of such tasks as planting can mean complete loss to the crop whereas untimely completion of subsequent operations such as weeding, and harvesting can lead to substantial reduction in the harvest. The final reason, reduction in the drudgery in performing agricultural tasks is also quite apparent. Agriculture carried out by entire reliance on the human muscle power is both difficult and arduous in particular in the hot climate common to most of Africa. Many of the young, economically active as well as educated men and women, have sought to escape this by migrating to urban areas and hence the significant increments of the urban population. Agricultural mechanization often leads to the reduction in the drudgery of agriculture operations and this results in making agriculture more attractive in particular to the young and educated.

The main question in so far as African agriculture is concerned is therefore what level of agricultural mechanization is appropriate? It is accepted by everybody that if Africa is to feed her ever increasing population and achieve some measure of economic development then there must be significant increment in the utilization of agricultural mechanization inputs in her agriculture. The main policy question then is should Africa move through the evolutionary path of agricultural mechanization technological development by first encouraging ubiquitous adoption of draught animal technology before mechanical technologies as has been advocated by among others the World Bank (IBRD (1987, 89) Pingali *et al* 1987; Johnston (1984))? Or should she aim at skipping the draught animal technology stage and move straight into mechanical technologies as some agricultural engineers would prefer (Giles (1967, 1975); Rana (1971)). This latter option would also seem to be favoured by quite a number of politicians on the African continent as can be evidenced from some of the policies adopted over the last two decades and as is obvious from the case studies presented in this volume. The key question therefore is whether change in agricultural mechanization should follow a nymphatic or metemorphic process?

LESSONS FROM PAST EXPERIENCE IN MECHANIZATION

Pre-Independence Period

Efforts at agricultural mechanization in Commonwealth Africa (and the same can be said of the Francophone African Countries) begun during the colonial period. In West Africa (Nigeria, Ghana, Sierra Leone, Gambia), where the main agricultural products of interest to the colonial authorities were perennial crops (cocoa, palm oil, rubber) initial efforts were directed at provision of improved hand tools to facilitate better harvesting, and handling of the produce (Hallett, (1970); Wood (1970)). These efforts were sponsored mostly by the main processor companies - United Africa Co., (U.A.C.) and Cadbury Brothers Ltd. As the crops involved were perennial, the demand for mechanization inputs was comparatively little other than in harvesting and the objective of the processor companies was to improve the harvesting process to ensure better quality produce (Hallett (1970)). Some of these companies tried to establish large scale plantations but these were, by and large, not that successful and the bulk of the produce they processed originated from small holder farmers. The UAC group, developed some improved equipment and tools for smallholder agriculture - eg. machete factory (Martindales); corn mills, and hand presses for palm oil as well as medium scale oil mills (pioneer oil mills) (Hallett (1970)). In the 1930's and 40's efforts were directed at introduction of some cash crops in the more arid areas of West Africa - cotton in Northern Nigeria and Ghana, and groundnuts in the drier zones of the British West Africa colonies. These crops which were annual, required higher levels of mechanization and it is in the cultivation of these crops that draught animal technology was introduced. They were grown mostly by small scale farmers. The mechanization efforts in West Africa therefore were directed at cash crops which were in high demand in the World market, and there was little effort to mechanize the production of food crops during the colonial period.

In Eastern and Central Africa, where there was a much larger white settler community, agriculture developed in a dual structure. On one hand, there were the white settler farmers, who were given large land holdings in all the countries in this region, and who grew both cash and food crops. The food crops were grown mostly for feeding the urban population (maize in Zambia, Kenya, Zimbabwe, wheat in Kenya, Tanzania etc) and the cash crops were grown for export (tobacco - Malawi, Tanzania, Zimbabwe; coffee - Kenya, Tanzania; tea - Kenya, Tanzania, Malawi; sugar cane in nearly all the countries; Pyrethrum and sisal - Tanzania, Kenya). On the other hand, there were the peasant farmers who were growing food crops mostly for subsistence. In a few cases these were able to sell a small proportion of their output through the Asian merchants and/or cooperatives and which was used to feed the urban population supplementing the production of the white farmers. Beginning from the 1930's, as it happened in

West Africa, these small scale African farmers were encouraged to grow some cash crops - cotton in Tanzania and Uganda, coffee in Tanzania, Uganda, and later on through the Swynerton plan in Kenya, tobacco in Tanzania, Malawi, Zambia etc. It is then in the cultivation of these cash crops that some form of mechanization - draught animal power was introduced - Sukumaland in Tanzania and Northern Uganda, Zambia etc. Thus the introduction of draught animal mechanization was aimed at promoting the cultivation of cash crops rather than food crops.

The mechanization of agriculture on the white owned farms throughout Eastern and Central Africa, proceeded at the same pace as mechanization of agriculture in Britain/Europe. The number of tractors in all the countries in Eastern and Central Africa increased by 400 - 800% during the period 1940-60 (see chapters 4-10). A larger percentage of these tractors were used on the white settler farms. It is significant to note that while tractor numbers increased at record levels in Eastern and Central Africa during the period 1945-60, in West Africa the increase was not that high, only showing significant increments after these countries attained their independence in the 1960's (see chapters 4-10). At this time also the British Government, as a consequence of severe shortages of various commodities (cooking oil and rice etc.) in both Britain and the colonies, established several large scale mechanized farms in the colonies. These included the Tanganyika Groundnut scheme, the Sokoto Rice Scheme, the Gonja Agricultural Corporation in Ghana and some farms in Northern Botswana. All these were established through assistance provided to several large trading companies e.g. United Africa Company (Hallett (1970) Wood (1970)).

The large scale farms were involved with highly mechanized agriculture by any standard seen in the colonies by then, and a comparatively large number of tractors were imported into the colonies. These large schemes failed due to a number of reasons - among them inappropriate machinery and equipment. A point to note here also is the fact that the increment in tractor importation into the colonies in Africa and Asia was in a way catalyzed by surplus production of these tractors in the UK in the 1950's. A number of North American tractor manufacturing companies had set up manufacturing units in UK in the period 1945-55 through subsidies provided by the British Government and assistance through the American financed Marshall Plan which aimed at reconstructing Europe following the Second World War. By the early 1950's it became apparent to these European subsidiaries that the demand for tractors both in Britain and other European countries was declining due to saturation of the market in the period 1945-50 and hence the only place where they could open up new markets was in the colonies. (Neufeld (1969); Kurdle (1975); Cook (1981); Burch 1987)).

Consequently in addition to assistance provided to the white settle farmers and other large scale farms established (e.g. the Tanganyika Groundnut scheme)

to acquire tractors, a number of tractorization projects, for African farmers were also initiated in most of the British colonies in Africa. Some of these projects have been described in the individual country case studies in this volume. The British Government set up a Colonial Agricultural Machinery Advisory Committee in 1951 with the terms of reference which included inter alia — the review of mechanization of agriculture in the colonial territories; to stimulate trials of existing types of agricultural machinery, and to encourage manufacture of new types (Mayne (1954, 1955; 1956); Burch (1987); Gibb (1988)). It is through these efforts in metropolitan Britain that agricultural machinery testing units such as TAMTU in Tanganyika were established in the 1950's. Most of the programmes directed at mechanizing the African agriculture were implemented through Government tractor hire schemes (Hall, 1968) and in a few cases through the provision of soft loans to emergent African medium scale farmers as has been described in the individual country case studies in this volume.

In conclusion therefore, the agricultural mechanization policies and strategies followed by the British colonial authorities in her African territories, concentrated on production of cash crops both on the white settler farmers and the small holder African farmers. The period before the second world war, the type of mechanization which was dominant on the white settler farms was the draught animal technology augmented by the handtool technology through employed native farm workers. Coercive measures were often used to get this native labour to work on the white settler farms (poll tax, or head tax etc.). Also through clearing of the bush to get rid of the Tsetse fly, draught animal technology was introduced in a few areas mostly for the production of cash crops such as cotton, groundnuts, tobacco by African small holder farmers. In humid zones of West Africa, where the cash crops were perennial (rubber, cocoon, palm kernels etc) through the produce marketing companies, improved handtools and equipment were provided to the African farmers, primarily to improve the harvesting operation as well as the quality of the harvested produce. However a majority of the native population remained, during this period, as peasant subsistence farmers, relying entirely on the handtool technology and were untouched by the modern mechanization technologies being introduced then.

During the period after the Second World War there was ubiquitous expansion of the use of mechanical technologies in agriculture in particular on the settler farms in Eastern and Central Africa. The British authorities also embarked on a number of large scale semi state mechanized farms to produce essential products like oil seeds which were in short supply in Britain and Europe as a whole (e.g. Tanganyika Groundnut Scheme). These large scale schemes were however not successful due to among other reasons, inappropriate machinery and equipment. However mechanization of most field operations on the white settler farms proceeded almost at the same pace as mechanization of similar tasks on

British farms and the number of tractors in use increase quite significantly during the post war years in most of the British colonial territories in Eastern and Central Africa. Draught animal technology was therefore replaced by mechanical technologies on most of these white settler farms in less than a decade (1945-55). An extensive dealer network was set up in most of the colonies to sell and service the agricultural machinery implements and these were staffed by technicians hired from UK and the Indian continent. Due to the common currency used in all the British colonies, (all of them were in the sterling pound area) tractors and implements manufactured in Britain dominated the market. Two particular manufacturers were dominant - Massey Ferguson and Ford and it is perhaps through this early domination of the market that these two particular makes of tractors have come to be regarded as the best tractors throughout the Commonwealth Africa.

Although draught animal technology, had been promoted to African farmers in 1930's and 40's through livestock diseases control measures such as clearing of the bush to get rid of the tsetse fly, this however had limited success and there were only pockets where the use of this technology was widespread (eg Sukumaland in Tanzania; Northern Nigeria and Ghana etc). Even in these areas use of draught animals was restricted to primary tillage and in a few cases transportation. In the 1950's the Colonial authorities established a number of government operated tractor hire schemes such as the Busoga and Bunyoro district programmes in Uganda, Groundnut cultivation in Nachingwea Tanzania, (Hall, 1968), the Sokoto rice scheme in Northern Nigeria, and the Gonja Development programme in Northern Ghana, among others. Such schemes were then taken as good examples of mechanized agriculture by the emerging African elites who were engaged then in the political struggle for independence.

Although many commentators have tended to describe the white settler farmers found throughout Eastern and Central Africa then, as highly efficient and generally they appeared to be quite successful in their mechanized agriculture operations it is not clear if this success could be attributed to more efficient management and utilization of the agricultural machinery and implements investment or due to the monopoly situation they enjoyed then. The investment in machinery and implements constituted about 50 - 60% of the capital investment in their farming enterprises (as most of these settlers had obtained the land *gratis* and paid little or no land tax). Most of these settlers were concentrated in the high potential areas of Eastern and Central Africa and through their Farmers Associations had a monopoly in marketing their agricultural produce in the urban areas (eg food crops etc) as well as in the export market for cash crops. They were thus able to influence the price paid for their produce. Many of them produced high valued cash crops (e.g. coffee, tea, pyrethrum etc) or if they produced food crops they, by and large, dominated the local market as they produced a larger

proportion of the marketed surplus. There was considerable research being undertaken on the agronomy as well as plant sciences of the crops being cultivated by these settler farmers by both the Government as well as private research establishments. There was however little research on the farm management as well as the machinery management and utilization rates on these farms.

Further the management on most of these farms could be categorized as management by fear. Strict discipline was enforced on the farm workers through 'fear' and wages paid to the farm workers were quite low. The farming enterprise 'succeeded' or 'failed' depending on the discipline imposed on the semi illiterate and illiterate farm workers by the white farmer and his wife and if it was a very large undertaking his assistant farm managers. If there was any knowledge to be gained on how these farmers managed their farm machinery and other investments this was not collected and documented as the research system was too weak in this area. It is therefore difficult, in the absence of empirical data, and given the advantages they had (low salaried workers, monopoly of the market, high potential areas) to conclusively say if these white settler farmers were as commercially successful as it is often claimed of them. They did however significantly influence, by their presence, directly and indirectly the agricultural mechanization policies and strategies which were to be followed by the independent African Governments during the period immediately after attaining independence.

Post Independence Period

At independence in the early 1960's, therefore, most African governments inherited a dual structured agricultural sector. This was particularly the case for the Commonwealth African countries of Eastern and Central Africa. On one hand there were the large and medium scale farms in most cases owned and managed by white settler farmers, which were comparatively highly mechanized and which produced high valued export cash crops (tea, coffee, tobacco, sugar, sisal pyrethrum etc) and in quite a number of countries they also produced a significant proportion food crops (maize, wheat and livestock products) which were internally marketed. These farms had been mechanized in the immediate post second world war years (1945-60) and they dominated the economies of many of these countries. On the other hand there were the majority of the African farmers who were mostly peasants producing for their own subsistence. They grew food crops, and only in relatively good years they were able to market any surplus to meet their social obligations. In a few areas some of these peasant farmers had developed to small holder farmers producing a variety of cash and food crops for the market (cotton and groundnuts in East and West Africa; coffee, tea in East and Central Africa). They relied mostly on the handtool technology. In a few areas the use draught animals for primary cultivation had been introduced and adopted. In

West Africa, the situation was rather different. White settler farmers didn't settle there, but the agricultural merchandize trade was dominated by produce from perennial crops - cocoa, palm oil, rubber etc and production of annual cash crops was concentrated in the less heavily populated drier areas (cotton and groundnuts). The perennial cash crops required less mechanization inputs, and the food consumed in the humid zones (where a larger proportion of the population lived) was dominated by root crops (yams and cassava). Production of both the cash and food crops was therefore done using the handtool technology and was dominated by small holder farmers with the exception of the drier areas where the draught animal technology was used to a limited extent. A number of medium scale African farmers (mostly retired civil servants) had emerged in most of these countries but their contribution to the overall agricultural production was still small.

The independence movement in many of the African countries had been dominated by urban dwellers, who although they formed less than 10% of the total population in most countries, they were nevertheless better organized than their rural kinsmen. The independent African governments in most of the Commonwealth Eastern, Central and Southern Africa faced a number of economic problems which in turn critically influenced the agricultural mechanization policies and strategies which were adopted. These included increased rural-urban migration (the restrictions which the colonial authorities had imposed to reduce this type of migration could not be maintained by the independent African Governments), and the white settler farmers who were important in a number of these countries in the production of the marketed food surplus, (which was used to feed the increasing urban population) were threatening to migrate to what they perceived as more secure countries (Rhodesia and S. Africa) or back to Europe. Many of the African leaders who took over from the colonial authorities had seen the white settlers within a period of less than 2 decades change their agriculture from one dominated by handtool and draught animal technology to one which was highly mechanized. Some of these leaders had also studied in Britain and USA during the period 1940-60, when similar transformation of the British agriculture was occurring. The tractor was perceived then in the 1960's as the symbol of modern agriculture by most African leaders, as well as the British and local experts. There was a need, according to most African leaders, to liberate the small farmer from the backbreaking handtool type of agriculture! This would not only increase agricultural production for food to feed the increasing urban population, and cash crops for export but would also lead to a reduction in rural-urban migration.

African governments in the late 1950's and early 1960's had little choice in the formulation of agricultural mechanization policies and strategies. An agricultural mechanization strategy based on comparatively large scale

introduction of tractors was selected in most of these countries. The selection of such a strategy is not surprising as the socio-economic situation prevailing in these countries dictated, by and large, that such a strategy had to be adopted. For these countries were facing an increasing urban population which was also politically conscious, and which had to be fed; in some countries the white settler farmers who were responsible for the production of a significant proportion of the marketed food surplus were leaving (eg. Zambia, Kenya); there was an increased need for social services as well as building of the physical infrastructure and this could only be done with imported capital and technology which had to be financed through foreign currency earned by exportation of cash crops. Further due to the surplus production of agricultural machinery and implements in the developed countries (the market for machinery there was then saturated) donor agencies were more than ready to provide commodity assistance in the form of agricultural machinery and implements (Burch (1987)). As the tractor was perceived as the symbol of modern agriculture, no political leader could refuse such assistance. A number of government tractor hire schemes had been started by the colonial authorities in the 1950's and these were regarded by many African leaders as good projects which copied and expanded.

Consequently large scale (by African standards) tractorization programmes were initiated in most of the independent African countries in the early 1960's. Settlement schemes were started in nearly all the countries in the Commonwealth Africa in new lands or in the abandoned white settler farms, (see relevant chapters) and in some countries large scale mechanized state farms were started (Tanzania, Ghana, Zambia). In quite a number of countries the white settler farmers were hired to manage the state farms or the settlement schemes. In some countries such as Ghana as reported by Twum and Gyarteng in chapter 5 the policy was to reduce the rural population to 25% of the total population by creation of a number of large scale mechanized state and cooperative farms. In addition with independence there were then more donors/countries ready to assist/sell tractors and other agricultural machinery and implements. The monopoly enjoyed by the British manufactured models of tractors (Ford and Massey Ferguson) was broken, and this led to proliferation of makes and sizes of tractors from all over the World (French, Russian, German, Canadian, Polish, Chinese, Italian etc) most of them imported without the necessary dealer and maintenance back up services. All this led to the agricultural machinery and implement graveyards found then all over Africa.

It is quite apparent that this relatively large scale introduction of tractors in African agriculture in the late 1950's and early 1960's be it on state, settlement, cooperative farms or through government tractor hire projects, was, by and large, and to put it mildly not successful. It was indeed a futile exercise, for there were no essential supporting services as well as technical management to manage such

schemes. As we pointed in chapter 1, mechanized agriculture was then and still remains to a large extent a new type of farming in most of Tropical Africa. For even the white settler farmers, had hardly by the early 1960's practised it for more than two decades. Introducing such a system in a highly bureaucratic management system is fraught with many problems. As a prominent British scientist, with considerable experience of Africa has observed:

"In fact mechanized farming is a highly individualistic business. The farmer needs complete control over all the means of production and should be able to take hour-to-hour decisions according to the state of the soil and the weather. He should have a direct (and this usually means financial) interest in the correctness of his decisions, so that he has to share or bear the loss if he is wrong. If his farm is too large or complex, he may be unable continuously to comprehend everything that is happening on it through the day. In other words, though centralized services may provide technical and economic information, help him to buy and maintain equipment, protect his crops and sell the produce, in his work as a producer the individual farm manager in a large-scale scheme is likely to do best if he can operate as a farmer, and not merely as a salaried employee ..."

(Bunting (1970))

It would seem most African governments expected - managers of large scale mechanized agriculture to operate as salaried employees and even worse as civil servants rather than farmers. The failure of this gigantic experiment in tractorization in the early 1960's has had the most pronounced influence on agricultural mechanization policies and strategies up to today!

It was on these machinery grave yards that those who had advocated a more evolutionary path in mechanization of the African agriculture begun to be heard by African political leaders. Prominent among these was the French agronomist, Prof. Rene Dumant who in his book, *Falses start in Africa* stated:

"The problem of mechanization is crucial, because African elites are seduced by the idea of modern machines. It is difficult to convince them that agricultural progress does not depend on immediate and complete mechanization ... It is not that mechanization is impossible on African soil. Machines will be in wide use in the future, but there are still too many obstacles ... A whole series of agricultural and general advances must be made before mechanization can logically be introduced. On the other hand, draught animals, wherever feasible, present only advantages, and can achieve the intermediate stage of agriculture, often the most useful and indispensable" (Dumont, 1966).

But Prof. Dumont was being rather unfair to the African elites, and one doubts if he were in their position whether he would have acted differently. For here they were, ruling newly independent countries with a politically conscious urban population which was exerting considerable pressure to act its food at a cheap and affordable price. On the other hand the peasants in the rural areas were still producing using the centuries old handtool technology, realizing a surplus only in good years weatherwise. Many of these politicians and elites had also seen the draught animal technology being introduced in their rural areas since the early 1920's, but the rate of adoption of this technology still remained quite low. Most of these elites had seen the white settler farmer within a very short period, transforming their agriculture from one which was dominated by draught animal technology to one which depended on modern agricultural machinery and implements and producing comparatively impressive results. It was therefore logical for these elites to be attracted to modern agricultural machinery as perhaps the only way through which they could solve the food and overall agricultural production predicament they found themselves in!

Not all experts agreed with Dumont (Giles, 1967) in advocating the evolutionary path in agricultural mechanization by advocating greater reliance on draught animal technology and less on tractors and modern machines. Others were more cautious arguing that there was no empirical evidence for justifying greater reliance on one or the other type of technology. A World Bank mission to a number of African countries in 1965-67 led by the then Chief of Economic Affairs had the following to say on agricultural mechanization:

"Past experience hardly makes it possible to prescribe exactly under what conditions mechanization is likely to prove economic. The many factors affecting costs and output and their relationship vary too much. No doubt mechanization can play a role in breaking bottlenecks in agriculture, but experience does indicate that the conditions essential to its successful introduction are by no means easy to meet. In most cases prudence dictates that mechanization be tried on a pilot scale in order to determine whether the requisite conditions for success exist and whether people will take advantage of mechanization by working and producing more rather than less. This will avoid serious waste of resources and provide the time to develop the managerial and technical skills that will be needed for operations on a progressively larger scale. The more recent ventures with mechanization in Tanzania and Ghana have again demonstrated the possibility of substantial misapplication of resources when a more cautious approach is discarded. It is extremely risky to devote a large proportion of scarce material and personnel resources in efforts to mechanize a small fraction of the country's farm land when it is not sure that these efforts will really result in an increase in net output.

One is impressed by the diversity of experiences with animal-drawn and tractor-drawn implements in tropical Africa and by the fact that no comprehensive effort is apparently being made to analyze these experiences and make the conclusions of this analysis available to all the countries of tropical Africa. The chronic tendency to repeat mistakes will remain as long as there is no proper and easily accessible record and analysis of past experience. The urgency of improving and increasing the equipment of African agriculture cannot be denied. Unfortunately, all the experience of the past has provided warnings of difficulties, but few concrete guidelines for a more positive approach. In many cases, for instance, it is difficult to determine whether mechanization has failed because it was inherently uneconomic, or because it suffered from certain technical and managerial problems that could have been avoided or overcome"

(de Wilde (1967))

A quarter of a century later, we are still as ignorant of the problems of agricultural mechanization in Africa as de Wilde's mission was in 1966. However the experimentation has been going on, and our national governments, donor agencies, (including the World Bank itself), and individual farmers have spent billions of dollars experimenting with one type or the other of mechanization technologies. Farming is, however, still being undertaken by a majority of our farmers using the same handtool technology they were using twenty years ago and over the past 100 years.

There have been costly mistakes in this mechanization saga, as well as some successes. Unfortunately it is the failure cases which have received most attention in the literature. Some of the failure cases could have been avoided if only analysis of past similar failed projects had been more comprehensively undertaken. Perhaps a time has now come when we should take a more objective review of the agricultural mechanization policy debate in Africa and try to be as analytical as it is seemingly possible. It is however difficult to be strictly objective in this debate given the sometimes sharply divergent policies which have been prescribed in the past in particular between socio-economists and agricultural engineers (Ge mill and Eicher (1973)). Nevertheless we shall try and hopefully put an end to what Prof. Kaul has called chapter 3 of this volume the 'cyclic' nature of reviewing the problem. We shall in the following sections discuss some of the major issues, and analyze some of the technologies involved, both of which have influenced in one way or another, policy formulation on agricultural mechanization over the past three decades.

Handtool Technology

It is an undisputed fact that the handtool technology is predominant type of technology in use in agriculture in most countries of Sub Saharan Africa. Areas cultivated by use of this technology vary between countries, and range between 40% of the total cultivated land in a few countries (Botswana, Zimbabwe) to about 80 - 85% in a majority of the countries in SSA. Even in areas where higher levels of mechanization technologies are used, there are still quite a number of field operations which are undertaken with entire reliance on this type of technology. The maximum net energy output from a fully grown up male adult rarely exceeds 1500 kcal (6.3 MJ) per day (Passmore and Durmin (1955); Boshoff and Minto (1974); Nwumba and Kaul (1986)). To till one hectare of land requires a net energy input of between 40 - 200MJ (Nwuba and Kaul 1986, Wilcocks (1984)) depending on the moisture content of the soil. Assuming a maximum output from an adult man, and the most favourable soil condition, it will take such a man 7 days to till one hectare at 100% efficiency. Such efficiencies can rarely be attained using the hand hoe and efficiencies of the order of 20 - 30% with such type of technology are common and with this it requires up to 40 days to till one hectare even with the most favourable soil condition. It is unlikely that the efficiency of the hand hoe in tillage can be increased however one tinkers with it in research and development efforts. The Nigeria observation (Chapter 7) that no realistic increment in alternatives to the hand he can be found would seem to hold true with this type of technology in particular for the power intensive field operations such as tillage, weeding etc.

As we have pointed out elsewhere (Mrema, 1983) the time taken to perform a field task is essentially linked to human energy demanded by that task, however, what is critical to a farmer in deciding if he should acquire a particular implement, is the rate at which the energy is demanded. A tolerable rate of energy demand is 3Kcal/min (210J/s) for a grown up adult male, and this level of energy demand by a piece of equipment will be preferable even if the output of the new introduction per unit time is not that dramatic. The minimum energy demand for tillage with the hand hoe is in the region of 6 - 10kcal/min (which is 3 -5 times the tolerable 1 level) (Passmore and Durmin (1955)). It is no wonder therefore that many African farmers prefer a hoe with a short handle for tillage and weeding, (even though this is less efficient engineering wise than a long handled one) simply because it has lower energy demand rate. Engineers who have therefore advocated for a long handled hoe as more efficient, have ignored the fact that such a hoe demands energy at a much higher rate than the tolerable limit (Nwuba Kaul (1986)). It is unlikely therefore for the power intensive operations such as tillage, weeding etc that a handhoe can be designed which will demand human energy at the tolerable level while at the same time be able to achieve higher work rates. There is no choice therefore for such operations other than moving to

higher levels of mechanization using additional energy sources (draught animals or mechanical power).

Human muscle power can however be used at much higher efficiencies in certain operations if simple machines are available. This is particularly the case for those stationary operations which are common in post harvest processing. Simple devices which demand human energy at a rate closer to the tolerable levels and which also increase the work output would appear to have a high potential for further development and adoption. Indeed some such devices are already widely used in many parts of Africa e.g. manually operated arabica coffee dehullers (pulperies) found all over East Africa; grain threshers; maize shellers, winnowers; palm oil presses; forage choppers; cassava graters etc. What needs to be done with such devices is to develop them by making them more robust (a key feature to many farmers); reduce the cost of fabrication/manufacturing through mass production, and have a more effective extension system. As it has been noted in the various case studies (Ghana, Tanzania, Kenya) a lot of these equipment are in use. A key feature about them, and hence their higher adoption rates is that they have met the key engineering requirement - higher work output as well as satisfying the ergonomical characteristics which is quite important (i.e. tolerable rate of energy demand from the operation).

Draught Animal Power (DAP)

The World Bank in its much publicized document, "Sub Saharan Africa: From Crisis to Sustainable Growth - A Long Term Perspective Study" has the following to say on agricultural mechanization:-

"In many parts of Africa it will be necessary to raise the productivity of labor by using improved agricultural equipment. Past experience has shown that full-scale mechanization is not the answer for the short or medium term. Tractor plowing and bulldozer land clearance have accelerated soil degradation in many areas. Maintenance of machinery has been poor, partly because of lack of foreign exchange for spare parts. Animal power is often a more profitable alternative. In addition many small "appropriate technology" projects run by private voluntary agencies have introduced simple mechanical devices that require little maintenance and are cheap and easy to use. The jab planter is an example of a hand tool that can halve the time needed to sow a hectare by hand. Animal-drawn equipment, such as plows and seeders, has an enormous potential. So too do improvements in on-farm storage facilities and machines for dehusking and the initial conditioning and processing of crops".

IBRD (1989)

We certainly agree with the World Bank that where Draught Animal Power (DAP) can be economically and environmentally sustained then this type of technology can go a long way towards increasing the productivity of labour, improve timeliness of field operations to exploit the short rainy seasons, and relieve the farmers from the tedium of performing field tasks in particular the power intensive ones such as tillage using the back breaking hand hoe. However, we should caution that DAP is not the panacea to the African agricultural mechanization problem. There are just too many social, technical and environmental constraints to its ubiquitous adoption in Sub Saharan Africa.

Despite having been introduced in Sub Saharan Africa over 70 years ago, DAP use in agriculture is still quite limited with less than 15% of the cultivated land being tilled using this technology. The number of draught animals in use all over the World is estimated at about 400 million (including oxen; (almost 80% of the total); horses, buffaloes, mules, donkeys and camels) (Rwamaswamy (1985)). Of these about 16 million (less than 5% of the World total) are found in Sub-Saharan Africa. Ethiopia accounts for 9 million draught animals (6 million oxen, 3 million donkeys) and the remaining 7 million draught animals are found in Tanzania and Niger (1.0 million each); Mali and Senegal (1.5 million each) with the remaining two million in Nigeria, Gambia, Botswana, Swaziland, Kenya (all with less than 0.5 million). The number of draught animals in the other African countries is quite small (usually less than 200,000) (Anderson (1985); Mungai (1984); Monnier (1975); Ramaswamy (1985)). DAP is utilized mostly in the arid and semi arid regions of Africa. It has not been adopted in the humid and semi humid zones and it is in these areas where there is a potential for expanding the area under cultivation.

A number of factors have hindered the widescale adoption of DAP in Africa and we have reviewed these elsewhere (Mrema and Hatibu, 1985). Briefly these include, among others:

- i) Livestock diseases: A significant proportion of SSA is tsetse infested and this makes the keeping of livestock in such areas difficult. These areas also happen to be the more fertile ones in the humid and semi humid zones. Introducing trypanotolerant breeds of cattle such as the West African Ndama breed does not entirely solve the problem due to the low power output of such cattle (Sargent *et al* 1981).
- ii) Lack of tradition of keeping livestock: Even if the tsetse fly problem can be overcome, experience has shown that introducing the draught animal technology to a people who have no livestock husbandry tradition is a daunting task. For it is actually two

technologies which are being introduced here - that of keeping livestock (by and large in a hostile environment to livestock) and that of using the livestock for draught purposes. Some observers have down played the significance of this problem (Pingali *et al* 1987) but the emperical evidence would seem to show that the extension effort required has to be sustained for about a generation for significant levels of adoption to occur (Barett *et al* (1982); Anderson (1985); Mrema and Hatibu (1989)).

- iii) Inadequate power from the draught animals: The maximum draught force which a pair of draught oxen can produce is a function of a number of factors, among others; body weight; anatomy of the animals (i.e. distance between front and rear feet); method of harnessing and soil type (Devnani (1982); Lawrence and Pearson (1983); O'Neill and Kemp (1989)). The most important factor however is the body weight and it is estimated that a pair of draught oxen can develop a draught force equivalent to 5-12% of the total body weight. The short horned Zebu cattle, (which is the most common in Africa) weighs about 400 kg each and will provide a draught force of about 0.2 kN. The draught force requirements in clayey soils is in the region of 1.2 - 1.5 kN. It is no wonder therefore that farmers in Eastern and Southern African who use DAP have to wait until the onset of the rains and the soil has been softened, before they can start ploughing and even then using two, three or four pairs of oxen. The advantages of time by land preparation are not therefore reliazed.
- iv) Poor Nutrition: Draught animals are required to undertake the most difficult task at the end of the dry season when the pastures are poor and they are usually in their weakest state. It has been argued that supplemental feeding can alleviate this problem. However given that grain is in itself in short supply even for human feeding, this would seem not to be a plausible recommendation.
- v) Lack of implements: Although there has been quite a lot of R & D work done on DAP implements many of these innovations have still to move from the prototype stage. As it can be evidenced by papers in this volume, it is only the victory mouldboard plough and ridger which have been widely adopted in areas where DAP is used. The problems of development and adoption of implements have been reviewed by among others Vail (1973); Kjoerby (1981); Starkey (1986))

These are some of the problems which DAP technologies face in Africa. Unlike in Asia where DAP has been used for centuries, this technology is quite a new one in most of Sub Saharan Africa (with the exception of Ethiopia) having been introduced in the 1930's and 40's in most areas where it is used. In addition, in Asia DAP is used mostly in wetland/irrigated cultivation where the power requirements are much lower, and the fields have been cultivated over a long period compared to dryland cultivation common in Africa. Further close to 70% of the draught animals used in the world are found in Asia (with India alone having close to 100 million); they do however plough less than 25% of the cultivated land. We do not dispute the fact that close to 70% of the farmers in India are small scale farmers and they rely on DAP for their field tasks, however the total area they cultivate is about 23% of the total cultivated by land and the rest is cultivated tractors and power tillers (Table 43; Balis (1978); Sarma (1980)). India and China have often been cited as examples of where DAP is extensively used, however the role of DAP in agricultural production in these two countries has often been exaggerated ((see chapter 12); Tam (1985); Sarma (1980)).

Finally an important factor in so far as DAP is concerned is the environmental cost in particular in Africa. In the case study for Tanzania (Chapter 9) we have already mentioned the serious environmental degradation which has occurred in Sukumaland, owing to clearing of trees to get rid of the tsetse fly. The environmental question is a major issue in Africa in particular given its fragility. Farming systems using DAP technologies in Eastern Africa and Western Africa are different in at least one important aspect. In Eastern and Southern Africa, farmers using draught oxen are largely dependent upon their own farming areas for the supply of replacement oxen. They have only limited access to surplus male stock from pastoralist areas. This within-system dependence obliges those agricultural systems to support both parent and replacement stock, thereby increasing the gross feed demands of the draught animal component on the farming system (Uchendu & Anthony - (1973), Pollard (1981)). This is in contrast to West Africa where large-scale pastoralist areas bordering on the settled agricultural zones are the major sources of working oxen. Farmers in these West Africa agricultural areas therefore purchase their oxen and oxen sales provide a major income source for pastoralists adjacent to these farming areas. While such payments are a burden on West African farmers compared to their counterparts in Eastern Africa, West African farmers keep fewer stock overall and are therefore relatively better able to provide comparatively better level of feeding for their stock.

Agricultural systems using DAP are areas of relatively high and usually rapidly increasing population densities. For these reasons it is more likely that West rather than Eastern African agricultural systems using DAP will be able to maintain current levels of ownership of draught animals per farm without confronting major shortfalls in feed supplies for their stock (Anderson 1985;

Mrema and Hatibu (1989)). Proponents of DAP have also argued that draught animals, in addition to providing power, also provide manure and could if properly fed provide other livestock products. We agree with them that organic manures from livestock (be they draught or dairy) are valuable and every kilogram in them should be used. However we should also realize that the nutrients in these organic manures are nutrients already in the system which are just being recycled. If the soil fertility of part of an area is increased by using organic manures, then the soils of another area within the same farming system must be depleted by the animals feeding on the pastures there. It is no more possible to raise the soil fertility of an area as a whole by using organic manures alone than it is to design a perpetual motion machine. Thermodynamically this argument of manure from draught animals is invalid and weakens the case for DAP in particular given the fragility of the environment if one consider the entire system and its sustainability!

In conclusion therefore DAP technology has a role to play in African agriculture, there is no question about this. However it is not the panacea to the African agricultural mechanization problem. Its limited adoption so far despite over 70 years of extension effort, and its apparent advantage over the handtool technology, in particular for the power intensive field operations, would seem to indicate that there are quite a number of both technical and socio-economic problems which have to be solved before the farmers can accept this technology. It would be prudent, therefore, before embarking on any large scale popularization programme for this type of technology in a particular area, that careful studies are undertaken on the social, economic and even more important both the short and long term environmental effects of widescale adoption of such a technology given the projected human and livestock population densities, and livestock disease control measures, etc. Such studies have rarely been undertaken for most projects which have aimed at introducing this technology to a new area.

Mechanically Powered Mechanization:

Mechanically powered mechanization in the African context, has often been assumed to be the same as tractorization. Whereas in number terms tractors are the most widely used type of mechanically powered technology in Africa, there are nevertheless other forms of mechanical technologies used e.g. hammer mills for milling grains in Eastern Africa. As it is evident from the case studies tractorization is however a controversial issue in Africa. It has become even more controversial after the failure of Government sponsored tractorization projects in a number of African countries in the 1960's. There has certainly been a lot of published work in the literature describing the failure cases! But has tractor mechanization been that much of a failure in Sub Saharan Africa? The preponderance of literature on the failure cases would seem to suggest this is the

case (Hall (1968); Kline et al (1969); Clayton (1973); Westley and Johnson (1975); Kolawole (1972, 1974), Monnier (1975) Kinsey (1976; 1979; 1984); Beeney (1975); COMSEC (1977); Muchiri and Johnson (1975); Singh (1976; Mrema (1981); Kjoerby (1983); Johnson (1984); IBRD (1987; 1989); Pingali *et al* (1987)). An objective analysis of the literature, as well as of tractor mechanization in general in Africa would seem to indicate that though there are quite a number of failure cases, there are also quite a number of success cases which have not attracted that much research attention.

Tractors were introduced in Africa during the colonial period as we have pointed out in previous sections. Whereas the colonial authorities had also a fair share of failed tractorization programmes some of which were on a gigantic scale (eg the Tanganyika Groundnut Project of 1940's) these do not seem to have attracted that much research attention as the failure cases which occurred after independence. There have been five routes through which tractors have been introduced in Africa.

- i) Private Medium and Large Scale Farmers
- ii) Private Tractor Hire pools
- iii) Cooperative Owned Tractor Projects
- iv) State and Parastatal Farms
- v) Government Tractor Hire Pools.

During the colonial period, route (i) and (ii) were the principal routes used for introducing tractors in Africa (other than route through big projects like the Tankangika Groundnut Project). After independence, all the five routes have been used. However it is those projects falling under (iii)-(iv) which have received most attention. An examination of the seven case studies presented in this volume (Botswana, Ghana, Kenya, Nigeria; Swaziland, Tanzania and Zambia) shows that other than Ghana (and here only during the Nkrumah period 1957-66) there is no country which had more than 5% of its tractor pool in the Government or Cooperative tractor hire pools. Even when the tractors in the state and parastatal farms are included it is unlikely that the total number of tractors in each country under category (iii)-(vi) would exceed 25% of the total tractor stocks. Majority of the tractors are owned by either medium and large scale private farmers, or private tractor hire pools. (in most countries over 75% of the tractors stocks).

The private farms, as well as in some countries parastatal farms (eg sugar estates) play a crucial role in the economies of most of the African countries for they produce a significant proportion of the major export crops (coffee, tea, sisal, tobacco; sugar, pyrethrum, cocoa, palm oil etc.) as well as the marketed food surplus (maize, wheat, rice). Most of these farms are relatively highly mechanized (at least most of the power intensive operations are mechanized) and before

categorizing tractorization in Africa as a failure, it would have been better if the data from such enterprises, in particular on how they manage their machinery pools were collected and analyzed. It is however, by and large, difficult to gain access to data on privately owned medium and large scale farms, and often from Government and parastatal farms; and hence it is difficult to pass judgement on the economic and social costs as well as technical efficiencies of these farms. However since quite a number of them are privately owned and have been in business for quite sometime and in some cases in countries with severe economic problems, it would seem they are making some profit. It is unfortunate that such undertakings, where it appears at least some form of successful mechanized agriculture is being undertaken, have not received that much research attention, in particular on how they are able to manage their agricultural machinery and implements.

Coupled with these medium and large scale farmers, there are also hundreds (and in some countries thousands e.g. Kenya) of small and medium scale farmers who own tractors and in addition to ploughing their own farms provide tractor hire services to other small scale farmers. All the case studies presented in this volume do indicate that these private tractor owners do provide a crucial service to many small scale farmers. Many such tractor owners operate old tractors some as old as 40 years; and that they are able to run them is an indication of their ingenuity and business skills. Indeed, the oldest working tractor in Africa, it is claimed, is the "Massey Harris" owned by a medium scale private farmer in the Iringa region of Tanzania which is believed to have been imported into the country in the late 1940's. The owner of this tractor was sponsored to go to Britain by the Massey Ferguson Co. to attend the Golden Jubilee of founding of the company in 1985 (Reiners 1989). It is not uncommon when one drives in the rural areas of Eastern & Central Africa to see farmers driving old Fergusons and Fordson majors most of which were manufactured in the late 1950's or early 1960's. There is no question that most of the Government and Cooperatively owned tractor hire units have not been successful, but these constitute only a small proportion of the total tractor stocks in most countries, and such failures should not be used as a reason for blanket policy prescription against use of tractors in African agriculture.

What lessons then can we learn from the tractorization efforts of the past 3 decades? We estimate that the Sub Saharan African countries have spent over US\$25 billion (in 1985 US\$) in importing tractors and other mechanically powered machinery and implements over the past 30 years (1960-90). A review of the literature on most tractorization projects shows that the major problem which has been cited has been the inefficient utilization of these tractors. This is particularly the case for cooperative and government operated tractor hire schemes, where utilization rates as low as 100 hours per year have been reported (see various case

studies in this volume). There are however government and cooperative operated tractor hire schemes where high utilization rates have been reported: e.g. Kenya over 500 hours p.a. (Downing and Goldsacks (1968)); Nigeria 400-500 hours p.a. (Purvis (1960); Kolawole (1972)); Tanzania - 800 hours (Simalenga *et.al.* (1989)). For privately owned tractors higher utilization rates have been reported: e.g. Nigeria 1000 hours p.a. (Kolawole 1974); Kenya 1000 hours (Chapter 6); Tanzania 1200 hours (Simalenga *et.al.* (1989) & (Chapter 9). This compares quite favourably with utilization rates of 600-800 hours per annum reported in the developed countries (Gohlich (1984)); Gibb (1988).

It would seem there are five main reasons which cause the low utilization rates of tractors in Africa: namely:

- (i) Seasonal restrictions
- (ii) Lack of technical know how
- (iii) Policy imperfections
- (iv) Technical design problems
- (v) Land planning/tenure & Equity Problems

One or all the above have contributed in one way or another to the low utilization rates of tractors in Africa. Let us consider each in turn:

- (i) **Seasonal Restrictions:** Agriculture in most of Africa is rainfed and the seasons are short. This severely restricts the numbers of days/hours for which the tractors can be used. This is further compounded by the fact that most tractors in Africa are supplied with only primary tillage implements (ploughs and harrows). Where tractors have been supplied with trailers they have also been used for transportation of people and goods. Use of tractors for transportation has in most cases been ignored in most economic studies. Given the poor infrastructure in many rural areas of Africa, the tractor and trailer is often the only means of transportation of people and goods in some areas which is an important economic contribution. A number of studies have reported that tractors are used for as much as 50-60% of their annual time for transportation (Kolawole (1974); Simalenga *et.al.* (1989); Chapter 5). Economic studies which only consider the hectareage ploughed by a tractor do grossly under estimate the economic contribution of the tractor in the local economies. Tractor utilization rates can also be increased significantly if post harvest processing implements/devices are provided (e.g. maize shellers, hammer mills, etc.) Further utilization rates can be increased quite significantly if the tractors are used during the off season for public works - rural roads

maintenance, construction sites (transportation of sand and other construction materials, etc.) by provision of the necessary additional implements. Finally in countries with different agro ecological zones, the tractors can be moved from one place to another just like the Sukuma tractor drivers were doing in the 1960's and early 1970's as described in Chapter 9. This constraint therefore can be overcome if there is proper planning and a system is created to facilitate the use of the tractors in other tasks other than primary tillage.

- (ii) **Lack of technical know how:** A key problem, which has affected all the past attempts in introducing mechanical technologies Africa is the lack of the technical know how to operate, maintain and repair as well as managing such technologies. This is a major problem and has to be tackled first before any large scale tractorization projects are initiated. At operational level we have made the mistake of assuming that a tractor driver is the same as a tractor operator. One becomes a tractor driver in all Commonwealth African countries after obtaining a driving licence, which is obtained after going through a test conducted by traffic policeman who in most cases tests one for adherence to the highway code and being able to drive the tractor on a road. However the tractor is normally purchased for tillage and other field operations and it is on the field that it is required to perform at its peak load and hence it can be damaged quite easily if the tractor operator is not skilled. Further there are no craft courses for tractor and agricultural machinery mechanics in most countries and it is assumed that an automobile mechanic can handle tractor repairs. Lack of properly trained manpower at this level has significantly contributed to machinery graveyards found all over Africa.

Even more serious is the lack of managerial skills and knowledge in many mechanized agriculture programmes. Management of tractorization programmes as well as large scale farming enterprises has been, in many cases entrusted on accountants, economists and general agriculturists. These are backed by poorly trained operators and technicians thus compounding the problems even further. In many medium and large scale farms in Africa agricultural machinery and implements constitute about 50-60% of the capital investment and this is imported capital! Even in small holder agriculture, the major capital investment made by such farmers is in the purchase of the indivisible inputs such as agricultural

implements and machinery. It is only in the few areas where there is population pressure and hence scarcity of land that the cost of land becomes equal or higher than the investment in agricultural machinery and implements. Yet we have in many cases entrusted the management of such investments in machinery to general agriculturists and economists who have limited knowledge on their technical operation and management. This is like entrusting your body for treatment to a doctor who does not know anatomy and physiology. In a few cases mechanical engineers have been appointed as managers of such projects. However although their technical expertise on the tractor operations is better, they however lack the agricultural knowledge which is essential in the management of any tractorization project. Properly trained agricultural engineers have often performed better in managing such schemes.

Even more serious is the lack of knowledge on how to efficiently manage and utilize agricultural machinery and implement resources in the tropics. In many cases we tend to rely on management technology developed for the temperate climates in managing mechanized agriculture in the tropics. Mechanized agriculture is a new type of farming in most of Africa and knowledge generation has been quite poor in most cases. This lack of knowledge is particularly critical in the case of small holder agriculture where multi-farm use of such resources is essential. Finally is the lack of entrepreneurial skills by many of the managers be they engineers, agriculturists or economists. In many cases in Africa such managers tend to operate as salaried employees rather than enterprise managers. This may well be a result of the organizational and production systems which we have established over the past 50 years.

- (iii) **Policy Imperfections:** This has contributed to failure of tractorization projects through such measures as inadequate allocation of foreign currency for importation of spare parts as well as fuel and oils which has led to many tractors lying idle for months on end as is evident from the case studies presented in this volume. The problem of spare parts is compounded even further by the different makes and models which are being imported. It is not uncommon in Africa for a country with a market of only 1000 tractors per annum to import over 20 different makes and models each requiring its own stock of spare parts. Both national governments and donors have contributed to this state of affair. For even larger markets like UK with over 600,000 tractors and an annual market of over 20,000 tractors have only 4 dominant makes and this is a country with excellent infrastructure for servicing

them. If African countries are to succeed in their tractor projects then there is need to standardize their tractor fleets to 2-3 makes. Further the question on fuel costs has often been used by proponents of alternative forms of mechanization as a major reason for advocating against tractorization projects. The fuel consumed in agriculture in most African countries is less than 5% of the total fuel imported (Mrema 1983). A country like Tanzania, even if it had all its current stock of 20,000 tractors working and each tractor was being utilized for 1000 hours per annum will still end up spending less than 10% of her total energy imports on running these tractors. Countries like USA which have highly mechanized agriculture, spend less than 5% of their total energy in agriculture, and the bulk of this is in the biochemical inputs like fertilizers, etc. (Fluck & Baird (1979); Stout (1979)).

Another policy imperfection is the establishment of tractor hire schemes under the Government system. Experience has shown that the civil service system cannot manage an economically viable tractor hire programme/project as is evident from the many projects which have failed all over the world. The earlier Governments realize this and look for alternative means of providing tractor hire services the better for tractorization projects in Africa! Governments in Africa however will have to be assisted through research in finding alternative and more viable means of providing tractor hire services in particular to small holder farmers. Finally although many experts have advised African Governments against subsidizing importation of tractors through fiscal measures, this is however unfair. As is clear from the paper by Holtkamp (Chapter 13), tractor prices in Africa are already quite high and the level of subsidies is quite low. Most other countries in the world through fiscal measures, higher prices paid for farmers produce, tax relief or direct grants have subsidized the acquisition of agricultural machinery by farmers. The European Community Countries through the Common Agricultural Policy are particularly notorious in this regard. It is therefore unfair to advise African countries against subsidizing importation of tractors. Such advisers will be doing a better job if they spent their time advising these countries on how to utilize more efficiently the agricultural machinery and implements they import.

- (iv) **Technical Design Problems:** With the exception of a few tractors imported from India and other Asian countries almost all the tractors imported into Africa originate from Europe or North

America. Even where there are local assembly plants as in Nigeria and Tanzania these are assembled from SKD components imported from Europe. The same applies to the implements which go with these tractors. All these were designed for European and North American farming conditions. In so far as tillage is concerned (which is the main function of tractors in Africa) the conditions in Europe and North America are quite different from those in Africa. For in addition to having a much more developed infrastructure for repair and maintenance as well as technical know how, farmers in Europe and North America are tilling land which has been tilled for centuries with no tree stumps, etc. In Africa in addition to the soils being harder and thus requiring a higher draught force, the land is often full of stumps and is not properly cleared of bushes. This inevitably leads to a higher load on the prime mover as well as breakages of the implements. A simple puncture in the field can lead to the tractor lying idle for 2-3 days while the puncture is being mended and this is in an environment where the chances of getting a puncture are quite high.

Further over the past twenty years tractor design in Europe and North America has changed so much, that one may argue that these have now become inappropriate for the African condition. Concern in Europe now is for operator comfort and safety and this has led to inclusion of power steering, automatic transmission, and other electronic sensing and control systems. Tractors designed in the 1950's and 1960's had more mechanical parts and control systems and even before the operating and maintenance of these simpler tractors had been mastered in Africa we now have a change to even more sophisticated tractors. It is due to the sophistication of the modern tractor that some have advocated for the design of simpler tractors for the developing countries. Holtkamp in Chapter 13 has highlighted some of the areas which could be simplified on the modern tractor for the developing countries. Due to this sophistication of the modern tractor, some donor agencies have included the provision of mobile workshops in many of their aid programmes with tractor components. In addition to increasing the costs, too often these mobile workshops have ended up breaking down before even the tractors themselves. What is required for Africa are simpler tractors, more like the tractors of the 1960's with simpler components which can be easily repaired given the level of technology found in Africa now. These should be provided with a comprehensive range of tools for field repair (e.g. inclusion of a simple compressor would go a long way

towards reducing idle time caused by punctures). If the tractor operators are properly trained then the idle time caused by breakdown will be greatly reduced.

(v) **Land Planning/Tenure and Equity Problems**

Another problem which has often been cited as hindering the successful and efficient utilization of tractors in African agriculture is the small and fragmented land holdings owned by many peasant farmers. We agree that land use planning in Africa is still in its infancy and in many places the shifting type of cultivation is still being practised. However as population increases, it is unlikely that this type of farming system can be sustained. More settled type of agriculture will have to emerge from the current practice. Other than a few areas, land is still not a big problem in Africa. It will assist therefore if Governments in Africa can institute land planning measures, such that any new lands which are opened up for agricultural production are properly planned to facilitate some form of mechanization (be it by draught animals or mechanical power) while at the same time ensuring that soil and water conservation structures are incorporated to ensure long term sustainability of the production system. This can be done using technology which is currently known, provided we train the manpower to do this.

Finally is the inequity problems which can be caused by introduction of mechanized agriculture in Africa. This has been a major concern of socio-economists in so far as agricultural development is concerned in the developing countries. In the 1950's and 1960's there was fear, among social scientists, that increased utilization of mechanized inputs in agriculture, in the so called labour surplus countries, would lead to massive unemployment, increased poverty and rural-urban migration (Clayton, 1973, Abercombie (1973), Binswanger (1978), Gemill & Eicher (1973), ILO (1973), Lipton (1977)). Fears were particularly expressed for the Asian continent where there is a real "Labour Surplus" compared to available land. However as subsequent studies have shown, even in the Haryana/Punjab regions of India where tractors have increased from 60,800 in 1972 to 215,000 by 1981 (almost equal to USA level on a per hectare basis in 1976) the labour displacing fear of tractor mechanization appears to have been unfounded. The negative displacement impact of labour by tractors has been offset by faster agricultural growth and increased use of hired labour as a result of increased yields/intensity in cropping. (Westley 1986).

It is unlikely that introduction of tractors in Africa where labour is usually in short supply at the critical times, and there is still new land to be opened up can lead to unemployment. Indeed wherever medium and large scale farms have been established in any rural area in Africa, these have usually led to increased employment of the rural unskilled labour. Increased agricultural production leads to increased employment, and labour may be displaced in one part of the agricultural system, but usually it is redeployed in other parts of the system. As Hueg (1976) has noted, even in highly mechanized agriculture as that of USA:

"Employment in agriculturally-related enterprises makes up 28% of the nation's labour force. Four percent of the nation's working force are on farms and for each farm worker, seven others provide backup in service, research, education, marketing, processing, and distribution. The present ratio of 1 to 7 will change to 1 to 10 or 12 by the year 2000."

For technologically less developed countries such as those in Africa, it is likely that for each farmer/worker actually producing efficiently on the farm, there will be 15 to 20 others providing backup service in transportation, repair and maintenance of agricultural machinery and implements, input delivery and output recovery systems and others such as hawkers, teachers, social workers, etc. Given the current stage of development of agricultural mechanization in Africa we have not yet reached a level where we need to worry about its unemployment effects. Our problem is one of production to feed the ever increasing population. There are of course a few areas in Africa where due to land shortage, unemployment may increase. It will be unfortunate however if agriculture is perceived as a gigantic programme of relieving the nation's unemployment problems using the back breaking and arduous handtool technology.

To conclude on this tractorization debate in Africa, it would seem all the above problems, have led to some institutions in the World to question the feasibility of introducing such technologies in African agriculture. The above problems are not insurmountable, most of them can be successfully tackled given the state of technology currently available in the World. It is pertinent, at this juncture to caution, those who advocate in the medium and long term greater

reliance on other forms of technology other than mechanical technologies in African agriculture. It will be naivety in our opinion to expect African political leaders and elites to accept that African agriculture should rely more on the so called improved handtools and draught animal technology. As Dumont (1966) noted, the African elite is seduced by the idea of modern machines. Even where there has been public endorsement of draught animal technology at the highest state level as in Tanzania and Zambia (Johnston 1984; Kinsey 1984; Kjoerby 1981) the reality is that officials at the lower levels still plan and push for tractorization projects! Modern media and telecommunication developments (newspapers, radio, television, etc.) are such that it will be futile to expect the African elite to accept the idea that DAP is technically and economically more efficient form of mechanization for the African agriculture. A recent publication n "Developing World Agriculture" by Grosvenor Press International and edited by Dr. Andrew Speedy had all its pictorial advertisements and figures on mechanical technologies (tractors, sprayers, etc.) yet the two articles on mechanization in this publication concentrated, by and large, on the virtues and economics of DAP and handtool technology (Speedy (1989), Mathews (1989), Sims *et.al.* (1989)). Such contradictions do not at all help the policy formulation process for agricultural mechanization in Africa.

It would seem to us that that both medium and long term policy options for African Governments and the collaborating donors should aim at improving the efficiency of utilization of mechanical technologies in African agriculture, rather than trying to discourage their use! There is a lot of scope for improving utilization of tractors in Africa even if the current numbers are maintained. As is evident from table 61, the number of cultivated hectares per tractor in a number of African countries is the same as in countries such as India. Yet the percentage of cultivated land where primary tillage is done by tractors in both Kenya and Tanzania is much less than in India (see Chapters 6, 9, 12), which means therefore we could do a lot more to improve the utilization of our tractor fleets! There are many other areas in Africa where mechanical technologies are successfully being utilized as is evident from the case studies in this volume. This is particularly the case in the post harvest area. Statements on tractor mechanization in Africa such as those quoted earlier on would seem to be too persimistic on the medium term prospect of this type of technology on this continent. There have certainly been quite a number of failures in this area in Africa, but these should be put in their proper perspective for there are also quite a number of success cases as is evident from the case studies! What is required is to undertake research on both the failure and success cases and hopefully from both of these lessons for better operation and management of tractorization projects can be isolated, and better planning can be undertaken in the future! It is to the research and development efforts that we turn next.

TABLE 61: TRACTOR NUMBERS IN SELECTED AREAS: (1985)

AREA	NO. OF TRACTORS	CULTIVATED AREA X10³ HA.	HECTARES PER TRACTOR
Africa	506 288	184 869	365
- Arab Africa	190 200	25 547	134
- South Africa	182 500	13 169	72
- Sub Saharan Africa	133 588	146 153	1 094
India	607 773	168 951	278
China	873 000	100 883	116
U.S.A.	4 676 000	189 915	41
Brazil	770 000	75 780	98
Cuba	68 585	3 236	47
North Korea	70 000	2 144	31
Netherlands	192 000	892	5
Tanzania	18 550	5 190	279
Zimbabwe	20 300	2 739	135
Kenya	7 000	2 370	339

Source: FAO (1986); Mrema & Hatibu (1989)

RESEARCH AND DEVELOPMENT EFFORTS

One of the weakest areas of the National Agricultural Research Systems (NARS) in Africa is in the area of agricultural engineering research. Indeed since their establishment in the 1940's most of them have not had agricultural engineering units established within them. In a few countries where such units have been established (e.g. CAMARTEC in Tanzania) these have often been under the Ministry of Industries and as such have been divorced from the main line agricultural research system. A few countries have established small units, within the NARS and in many cases these have operated as projects funded by foreign donors and staffed by expatriate staff on contract. Such units have usually ceased to exist once the foreign funding has stopped and the expatriates leave and thus

there has not been the continuity required to undertake research in this key area of agriculture. Further such agricultural engineering units, when established have in many cases concentrated their efforts on testing or designing one or two types of technologies (e.g. biogas, tool-carriers, etc.) and the research agenda has often been set up from what is the perceived need of the farmers by the foreign expatriate researchers. As Kaul has noted in chapter 3 there have been waves of research efforts on 'intermediate' or 'appropriate' technologies over the past three decades, usually conceived around the prevailing fashionable word in the donor community which have disappeared once the fashion changes (e.g. energy, post harvest losses, environmental sustainability, gender issues, etc.). As Starkey (1986) has noted equivalent to US\$40 million has been spent all over the world on research and development of the animal drawn tool carrier yet it is one example as he put it of a 'perfected yet rejected appropriate technology'.

In addition to these 'waves' of research in design and development of particular equipment there have also been some research efforts by socio-economists on the appropriateness of particular mechanization technologies in the African agricultural system. In many cases these have aimed at proving how uneconomic one type of mechanization system is (usually mechanically powered) as compared to another (usually animal powered technologies) (Ahmed and Kinsey (1984) Kjoerby (1983)). It is rare to see research undertaken in this field where socio-economists have attempted to mix technologies from the two systems. It has always been complete packages of one system vs another. In addition research on failed tractorization projects has in many cases been undertaken long after the project has failed usually relying on data recollected by project managers, tractor mechanics, operators and farmers. Given that record keeping in most such projects in Africa has been extremely poor, one wonders how these socio-economists could come up with such strong recommendations as they have done in certain cases (Singh (1977); Pingali *et.al.* (1987); Kinsey (1984); Clayton (1973)).

A major weakness of past research efforts by both socio-economists and engineers has been in concentrating all their research efforts at designing and developing or evaluating new 'hardware' (new machinery and implements). Very little research has been undertaken on the 'software' aspects. As has been noted in the various studies presented in this volume, by far, private tractor hire operators provide the bulk of tractor hire services in Africa. Government tractor hire units do not constitute even 10% of the private tractor hire services in most countries. How have these private tractor owners been able to run their tractors, which are usually 20-30 years old, and facing even more adverse economic constraints than the Government schemes? Chancellor (1986) has noted that 60% of the land tilled by tractors in India is done by privately owned tractor hire services; while for Indonesia the figure is 40%, etc. What management system do these private tractor owners use to be able to provide such services and remain in

business while Governments fail? It is by learning how such success cases operate - the management system used, the type of operators they use that we can plan better mechanization projects and programmes. Concentrating our research efforts only on the failed schemes is in our opinion a wrong approach. As de Wilde noted in 1967:

".... There appears to be a need for an international center, whether within ECA or FAO, which would be specially concerned with the problem of agricultural equipment in Africa. Such a center should serve to collect, analyze and disseminate all relevant information on experiences with various types of traction and equipment under different conditions. On the basis of continuing evaluations of such experiences it would recommend and sponsor further experimental and developmental work to devise improved types of implements and machinery. The center should not discourage countries from trying various forms of mechanization and animal traction, but seek to assist them from the very beginning in keeping records that are sufficiently detailed and uniform to permit adequate evaluation and comparison. In the past records have been kept so poorly that it has been extremely difficult to determine the relevance of experience in one area for the problems of another. Costly and avoidable mistakes have been made again and again. Thus the center should strive to get international agreement on the types of records that should be kept - e.g., the climatic, soil and farming conditions under which machinery is used; the number of hours during which machinery is operated and which are needed for various tasks; the time and expenditures required for repairs, etc. The center should also assist in providing such personnel as are required to keep records of this type.

Such a center would have at least two important advantages. First, it would be able to determine under what conditions and within what limits existing types of machinery and equipment found useful in certain areas and under certain farming conditions could also be effectively and economically employed elsewhere. Secondly, it would promote and coordinate, in close cooperation with departments of agriculture, manufacturers and farmers, work on the development of types of equipment that would be better suited to the various conditions prevailing in tropical Africa. The emphasis would then no longer be primarily on attempts to adapt the pattern of African agriculture to the requirements of existing machinery, but rather on efforts to devise implements and equipment that would meet the needs of the types of farms and kinds of farming obtaining in Africa. To be sure, development work of this character has been and is being done in a number of places, but it is on too small a scale, is often inspired too exclusively by engineering

considerations, and the results are not adequately disseminated. The entire problem of machinery and implements in African agriculture is too important and too difficult to be left to uncoordinated, haphazard and wasteful experimentation and development. ..." Pg. 130-131 of de Wilde (1967 a)

Despite such advice emanating from a mission led by a senior World Bank official, both the World Bank itself, other bilateral and multi lateral donors, as well as the national research systems are still as ignorant of the problems of agricultural mechanization in Africa as de Wilde's mission was in 1966/67. If any research has been undertaken by the international donor agencies this has often been through flying visits by the international experts to several countries in Africa over a period of several months and usually to check on failed projects and from the reports/publications emanating from such visits blanket prescriptions have been made on the whole question of agricultural mechanization in Africa (Kline et.al. (1969), Pingali et.al. (1987)).

The International Agricultural Research Centres (IARCs) are in an even worse position in so far as research on agricultural engineering problems of African agriculture are concerned. In 1984 IITA had two posts for agricultural engineers, however during the restructuring which occurred in 1985/86 both posts were abolished and IITA now does not have an agricultural engineer on its staff (IITA 1988) and does not appear that it will in the near future do even minimal research in this area according to its strategic plan for 1988-2000. The Technical Advisory Committee of CGIAR system which manages these IARCs claims that the development of new machinery has generally been met by manufacturers (CGIAR (1981, 1989)). But in Africa the manufacturers are not there even just to copy what has been developed elsewhere, leave alone to do research! As long as the CGIAR and IARCs continue to ignore agricultural mechanization as a major constraint to agricultural production and productivity in Africa, then this continent will continue to miss the impact of the other Biochemical technologies developed by these centres in the next 2-3 decades as it has happened in the last 3 decades. Leaving research on this very important aspect of agricultural technology to manufacturers is in our opinion a serious mistake. IARCs research efforts need not be in developing new hardware (just as they do not get involved in developing new chemicals and fertilizers) but in developing software required for using and managing agricultural mechanization technologies in the African situation. ^{2A} An active agricultural engineering unit was established in IRRI - Philippines for rice mechanization (Khan (1981)) and appears to have been quite successful in developing machinery for this crop.

However we understand this is now being a restructured with a view of reducing its activities. As Gifford has noted in Chapter 2, the total investment in

agricultural machinery and implements in the developing countries is likely to be in the region of US\$30 billion by the year 2000. Africa's share of this investment may be in the region of 30-40%. Helping African countries to utilize and manage such a huge investment should be a worthwhile exercise! A start can therefore be made by helping African institutions engaged in Agricultural Engineering research to develop and enhance their research capacity. In Commonwealth African setting these would seem to be, other than the few units established under NARS, the departments of agricultural engineering in the various universities found in the region. Although established primarily for education and training, they have over the past 20 or so years developed their human resources to critical mass which can now be exploited for research in this area! Such departments in collaboration with Environmental Science departments either in the Universities or the NARS can also undertake research on the environmental impact of different mechanization technologies and given their independence from the Government bureaucracy can sensitize the public as well as the politicians on the issues involved!

HUMAN RESOURCES FOR AGRICULTURAL MECHANIZATION

As it has been noted in all the case studies a major weakness of all agricultural mechanization efforts in Africa has been the lack of trained personell. The lack of trained personell coupled with the inadequate knowledge base on tropical agricultural mechanization have perhaps been the major contributors to the failure of many agricultural mechanization projects. As we have already mentioned mechanization of tropical agriculture is a fairly recent development and the knowledge base is quite weak. In most cases machinery and implements developed for temperate agriculture have been imported and used without any modification in Africa and in many cases these have been entrusted to operators, technicians, and managers with little technical training. During the colonial period, the colonial authorities established two institutions in Eastern and Central Africa - Egerton College and Gwebi Agricultural College to train 'sons and daughters' of farmers the science and practice of agriculture. A key programme offered in these two institutions has been the three years diploma programme in agricultural engineering. In the early days these two colleges admitted only the sons and daughters of the white settler farmers from Eastern and Central Africa! Many of the graduands from these colleges went and worked as farm managers on the white settler owned farms and estates. It is no wonder therefore these farms were successful. For although the curricula in agricultural engineering followed those of similar programmes developed in UK and the textbooks and instruction offered was by and large the same as those used in the UK, at least those who graduated from these two institutions had the knowledge for managing mechanized agriculture in the temperate - context.

After independence quite a number of agricultural colleges/faculties of agriculture have been established all over Africa. Majority of the enrolled students originate from the peasant and small farmer families and their technological background is therefore weak. The emphasis in the curricula for most of the diploma and degree programmes is for work as extension agents and officers in the ministries of agriculture concentrating on the small holder and peasant farmers. A significant proportion of their time is spent on understanding the science and practice of the divisible technologies (i.e. biochemical technologies). Thus they are relatively quite weak in the physical technologies (agricultural and irrigation engineering). It is as a consequence of this weakness that a number of agricultural engineering departments/colleges offering diploma and degree programmes have been started in the 1970's and 1980's. As is evident from the case studies the impact of manpower trained through such programmes is just now beginning to be felt (Kenya, Ghana, Zambia, Tanzania). These colleges/departments have to be strengthened if mechanized agriculture is to succeed in Africa, be it draught animal or mechanically powered! Coupled with training of manpower at the higher level, lower level training - agricultural mechanics and technicians - must be strengthened and expanded. India's case offers an example to be emulated where colleges of agriculture and engineering each year graduate thousands of agricultural mechanics and technicians as well as hundreds of professional agricultural engineers. It is only by having a critical mass of such manpower that we can ever hope to succeed in our agricultural mechanization endeavours. Agricultural engineers, have however to integrate themselves closer to the agricultural industry. The tendency in the initial stages has been for many of them to relate more closely with the traditional engineering disciplines. As we have pointed out elsewhere, (Gerrish and Mrema (1987)) agricultural engineers need to understand the agricultural system prevailing in Africa if at all they are to contribute to its development.

MANUFACTURING OF AGRICULTURAL MACHINERY AND IMPLEMENTS

Manufacturing of agricultural machinery and implements throughout Africa is still in its infancy. All the countries of Sub Saharan Africa rely on importation of such machinery and implements to a greater extent. Even handtools and animal drawn implements are still being imported. A significant difference between Eastern and Western Africa is that whereas in the former all the handtools and animal drawn implements are manufactured in large modern factories or imported, in the latter case a significant proportion of handtools and even animal drawn implements are fabricated by village blacksmiths and artisans. However the efforts of these village artisans and blacksmiths are not integrated with the modern industrial sector. West African countries may well learn from the more developed countries where even in UK, a larger percentage of agricultural machinery and implement manufacturers are all small scale employing less than 10 people. There is need

therefore to have vertical integration in the manufacturing system. In Eastern Africa a realization of the role of such small entrepreneurs and fabricators is now beginning to be realized. An example of this is the Jua Kali enterprises in Kenya and the SIDO efforts in Zambia and Tanzania. It is by developing these small scale fabricators and manufacturers that a truly indigenous agricultural machinery and implements manufacturing capacity can be developed. Experience from India shows that it is such enterprises which have managed to sign licencing agreements to assemble/manufacture various agricultural machinery and implements. The path chosen in some countries starting with large scale turn key factories, is in our opinion fraught with many problems.

ENVIRONMENTAL IMPACT OF AGRICULTURAL MECHANIZATION

Inappropriate agricultural mechanization often leads to serious environmental problems. The environmental degradation may be a direct result of using inappropriate implements or misuse of implements or may be an indirect consequence of agricultural mechanization. Tillage done using inappropriate implements or done using appropriate implements but undertaken by improperly trained tractor/draught animal operators can lead to serious environmental degradation. Other mechanization methods which have led to serious environmental degradation include extensive bush clearing using heavy equipment or using crude methods as was done in East Africa to get rid of the tsetse fly and hence facilitate livestock keeping and introduction of draught animal technology. The consequences of inappropriate mechanization on the environment are not immediately apparent and in some cases it may be years before they are seen. Soil conservation methods on the other hand are, by and large, labour intensive and hence making them unpopular among farmers and it will require a lot of research and developemnt efforts before they can be mechanized at an affordable cost. The environmental impact of agricultural mechanization in many situations in the tropics is still unknown. A number of environmental experts have been quick to condemn one type of mechanized technology or another as causing environmental degradation while a careful study usually reveals it is not the technology which causes the environmental degradation, but how it is used. Again this reemphasizes our earlier point that more research on agricultural mechanization in the tropics needs to be undertaken as our current knowledge base on many issues in this area is just too weak. Research efforts by Kayombo *et.al.* (1986), (1991); Lal (1985); and Mahoo (1990) on the compaction effects of heavy equipment and effect of forest clearing in the humid tropics are examples of research which needs to be undertaken in this area.

CONCLUSIONS

At the end of chapter one we presented the four conflicting views which have often been used as a basis for giving blanket policy prescriptions on the whole question of agricultural mechanization in Africa. It would seem from the case studies presented all the four views have been tried at one time or another in all the countries, sometimes with disastrous results and at other times with some success. The main lesson here is the danger of trying to prescribe a blanket policy for agricultural mechanization for a whole country or even worse for a whole continent. The case studies have demonstrated situations where highly mechanized farming enterprises relying almost entirely on mechanical technologies existing side by side with highly productive small holder agriculture relying entirely on handtool technology (Kenya, Tanzania). They have also demonstrated cases where draught animal technology has been adopted in a particular district, while another district just 20-40 kms away this technology has not been that widely adopted (Zambia, Tanzania, Ghana). Further the case studies have shown that while appropriate technologies in the form of 'micro' or 'mini' tractors have not been successful in the tillage operations, the same however have been used quite successfully in other operations such as in grain milling (e.g. Tinkabi). In addition, although draught animal technology is normally assumed to be environmentally less degrading, the case studies have shown the serious environmental degradation, which can occur in the long term, if land is cleared improperly to get rid of tsetse flies and introduce livestock keeping for, among other reasons, draught power purposes.

A key factor which transcends all the case studies is the lack of knowledge and technology for managing mechanized agriculture (be it draught animal or mechanically powered) in the tropical environment found in Africa. For most of agricultural mechanization technologies introduced into Africa have been designed for temperate agriculture. Importing the hardware together with the software for managing it in the form of technical expertise from the temperate regions does not necessarily solve the problem for most of the failed mechanization projects have had this technical expertise presence at least initially. What is required therefore is to adapt the hardware in the form of agricultural machinery and implements so imported to suit the local conditions as well as develop the software in the form of operating and management system taking cognizant of the local socio-technical development as well as the environmental conditions. There is need therefore to intensify our training efforts for the right manpower for agricultural mechanization at all levels. Coupled with this, there is need to undertake more fundamental and applied research not only on the hardware (new implements as well as modifications to existing range of agricultural machinery and implements) but also on the software aspects (management systems for mechanized agriculture be it animal or mechanically powered).

This workshop brought together, perhaps, the first generation of African agricultural engineers to specifically deliberate on the policy and strategy aspects of agricultural mechanization in Africa. Most of them are young, in their late thirties or early forties and in this regard many were born when the first tractors were being introduced in Sub Saharan Africa in the late 1940's and early 1950's. They are as such as old as mechanized agriculture is in Africa! This demonstrates that mechanized agriculture is quite a new type of technology in this continent. The conclusions of the workshops have been published elsewhere (COMSEC (1991)) and we do not need to repeat them here. So far emphasis in agricultural development in Africa has been concentrated in so far as labour productivity is concerned on the land augmenting (yield increasing) type of technology as embodied in improved seeds, fertilizers and irrigation development in a few cases. In the absence of extensive irrigation development, and with reliance on rainfed agriculture, it is unlikely that the land augmenting technologies such as improved seeds and fertilizers alone will improve productivity and total production in Africa if we continue to rely on the handtool technology which is now the predominant form of mechanization technology. If timely land preparation as well as planting is to be achieved then higher levels of mechanization technologies have to be used. This will lead to not only better field operations but reduction of drudgery to the men and women involved with agricultural production in Africa. Introduction of higher levels of mechanization will require a critical mass of qualified and enterprising managers who understand the technology involved supported by competent and hard working technicians and artisans. This is the only way through which our mechanization efforts can succeed! As we approach the 21st century and as our population increases, agricultural production in Africa will have to be carried on to a greater extent than now in relatively more productive farm business using advanced technical methods including much more effective management than so far of our land and water resources. The rural areas will require better communication and better infrastructure and there will be more towns where there are now at most villages. The transition like all development will be untidy and turbulent, and it may be painful at least to some! The main aim should be to make the transformation of the rural areas as tidy as it is seemingly possible. It is our hope that the recommendations emanating from this Zaria Workshop will contribute towards making this transformation of our rural areas as tidy as it is possible.

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LIST OF ABBREVIATIONS

AATP	-	Arusha Appropriate Technology Project
AISCO	-	Agricultural & Industrial Supplies Company (Tanzania)
ALDEP	-	Arable Land Development Programme (Botswana)
ARAP	-	Accelerated Rainfed Arable Programme (Botswana)
ARS	-	Agricultural Research Station (Botswana)
ATIP	-	Agricultural Technology Improvement Project (Botswana)
BCU	-	Bukoba Cooperative Union (Tanzania)
CAB	-	Commonwealth Agricultural Bureau
CAT	-	Coffee Authority of Tanzania
CATA	-	Cashew Authority of Tanzania
CCM	-	Chama Cha Mapinduzi (Tanzania)
CKD	-	Completely Knocked Down
CGIAR	-	Consultative Group on International Agricultural Research
COMSEC	-	Commonwealth Secretariat
DAP	-	Draught Animal Power
DLFRS	-	Dryland Farming Research System (Botswana)
ECA	-	Economic Commission for Africa
EEC	-	European Economic Community
EFSAIP	-	Evaluation of Farming Systems and Agricultural Implements Project (Botswana)
FAO	-	Food and Agricultural Organization
GDP	-	Gross Domestic Product
GoB	-	Government of Botswana
GoG	-	Government of Ghana
GoK	-	Government of Kenya
GoN	-	Government of Nigeria
GoT	-	Government of Tanzania
IARC	-	International Agricultural Research Centres
IBRD	-	International Bank of Reconstruction & Development (World Bank)
ICRA	-	International Course for Development Oriented Research in Agriculture - Wageningen, Netherlands
IFAD	-	International Fund for Agricultural Development
ILO	-	International Labour Organization
IRDP	-	Integrated Rural Development Programme
KNCU	-	Kilimanjaro Native Cooperative Union
LSF	-	Large Scale Farmers
MATI	-	Ministry of Agriculture Training Institute
MIAC	-	Mid America International Agriculture Consortium
MSF	-	Medium Scale Farmers
NAFCO	-	National Agriculture and Food Corporation (Tanzania)
NARS	-	National Agricultural Research System
NDP	-	National Development Plan (Botswana)
NGO	-	Non-Governmental Organizations
ODA	-	Overseas Development Administration (UK)
PSF	-	Peasant Subsistence Farmers
RIIC	-	Rural Industries Innovation Centre (Botswana)

RDD	-	Regional Development Director (Tanzania)
R&D	-	Research and Development
SACCAR	-	Southern Africa Coordinating Centre for Agric. Research
SACU	-	Southern Africa Customs Union
SADCC	-	Southern African Development Coordinating Conference
SIDA	-	Swedish International Development Agency
SNL	-	Swazi Nation Land
SSA	-	Sub Saharan Africa
SSF	-	Small Scale Farmers
SKD	-	Semi Knocked Down (Components)
SUDECO	-	Sugar Development Corporation
TAMTU	-	Tanzania Agricultural Machinery Testing Unit
TAT	-	Tobacco Authority of Tanzania
THS	-	Tractor Hire Services
THU	-	Tractor Hire Unit
TTA	-	Tanzania Tea Authority
TSAE	-	Tanzania Society of Agricultural Engineers
UFI	-	Ubungo Farm Implements
UNDP	-	United Nations Development Programme
UNIDO	-	United Nations Industrial Development Organization
USAID	-	United States Agency for International Development
VFCU	-	Victoria Federation of Corperative Unions

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AGRICULTURAL MECHANIZATION POLICIES AND STRATEGIES IN AFRICA:

Case Studies from Commonwealth African Countries

In this publication sixteen leading African agricultural engineers present their views on the evolution of agricultural mechanization policies and strategies in Africa since the colonial times. Agricultural mechanization remains quite a controversial input in African agriculture in particular that of small holder farmers. Conflicting policy prescriptions have been given for the African agricultural mechanization problem by, among others, socio-economists, agricultural engineers and politicians from the academic and donor community as well as the national governments. The failure of the many Government sponsored tractorization projects initiated in the late 1950's and early 1960's has greatly contributed to this policy and strategy conundrum.

Agriculture in most African countries is still undertaken by using the centuries old handtool technology with entire reliance on human muscle power in about 60-90% of the cultivated land. Whereas, everybody agrees that this has to change, the main question has been on how the change should come about. Should African countries go through the evolutionary path - from handtool through animal powered to mechanically powered agricultural mechanization as it has happened in the developed countries. Or should they aim at skipping the intermediate stage - animal powered mechanization. The experience of seven African countries (Botswana, Ghana, Kenya, Nigeria, Swaziland, Tanzania and Zambia) in agricultural mechanization policy formulation is presented in this volume. There are also chapters on the experiences of India and FAO as well as on extension of physical technologies and the role of small tractors in tropical agriculture. This is the first book to present the full range of experiences in agricultural mechanization policy formulation in Africa. It is aimed both for development practitioners and policy makers as well as students of agriculture, agricultural engineering and economics.

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