CHAPTER I

INTRODUCTION

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In formulating the strategy for the expanded Commonwealth programme on science and technology in 1984, the Kendrew Report on "Science for Technology for Development" (1984) and the 13th biennial meeting of the Commonwealth Science Council in Ottawa, Canada, recommended inter alia the promotion of:

- methods for extending and expanding agriculture on unsuitable lands;
- agricultural research in a few areas where a major impact is possible;
- fresh incentives to good agricultural scientists for enhancing their own agricultural research;
- the study of the relationship of water resources, soil water and agrometeorology to plant growth and reproduction;
- programmes to arrest the present degradation of tropical forests.

In 1981, the African Natural Products Programme of the Commonwealth Science Council (CSC) was established with the objective of exploiting the rich, untapped resources of Africa. This coincided with the recognition by CSC of the increasing problems of severe food shortage, high imported energy prices, depletion of indigenous fuelwood resources, the loss of productive land through desertification and the threats of extinction of diverse plant genetic resources. Agroforestry, an integrated land use system comprising of trees, crops and/or animals, and providing for resource conservation, was seen by CSC to offer an appropriate scientific approach to the issues of natural resource 'exploitation' and conservation in Africa. The agroforestry programme was developed further by CSC in 1983 at a meeting in Malawi, and because of the strong interest and history in agroforestry research in Asia, has now also extended to this region.

This initiative coincided with the launch of the "Decade of the Tropics" programme by the International Union of Biological Sciences (IUBS) in 1983, to improve the efficiency of food production in the tropical zone in view of a burgeoning human population with increasing land shortage, living in an area of low productivity and income, and threatened by famine because of low agricultural productivity and increasing global food demand (Solbrig and Crolley 1983).

One of the segments of the "Decade of the Tropics" programme concerns soil biological processes and tropical soil fertility (Swift 1984). The objective of this programme segment is to determine the management options for improving tropical soil fertility through biological processes in three broad 'zones':

- the humid tropics dominated by rain forests;
- the sub-humid tropics dominated by broad-leaf tree savannas;
- the semi-arid tropics characterised by thorn or other xeromorphic bush savanna.

It aims to gain an understanding of the soil system, nutrient cycling, modification of soil physico-chemical properties, biological processes in relation to management, and soil biological processes in relation to cultivation.

The Tropical Soil Biology and Fertility (TSBF) programme outlines principles and management options that are already known (Table 1), testable hypotheses in relation to these principles (Table 2) and three levels of increasing intensity of research (Table 3). Some illustrative examples by which management practices can manipulate soil biological processes have been taken into consideration in formulating the TSBF programme (Table 4). In view of this and of the Commonwealth Science Council's long-standing interest in agroforestry systems for food, fodder, fibre, biomass, energy and optimisation of land use, the Council organised a workshop and planning meeting in Lucknow, India, in March 1986, on "Amelioration of Soils by Trees". The proceedings and recommendations of this workshop and meeting have been published (CSC 1986). This volume represents the collection of papers refereed and edited, that were presented at the workshop and meeting on the "Amelioration of Soils by Trees".

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TABLE 1

Principles (P) and Management Options (MO) in relation to Tropical Soil Biology and Fertility (Swift 1985)

P1: The release of nutrients (N, P) from above- and below- ground litter can be synchronised with plant growth demands.

MO1: The efficiency of nutrient availability to the plant can be manipulated by varying the quantity and quality of litter (e.g. crop residues, manures, etc) and the time of its input in relation to the onset of rain.

P2: Soil organic matter constitutes both a sink and a source of plant nutrients (N, P), and hence acts as a regulator of temporal and spatial patterns of nutrient availability. The quantity and quality of soil organic matter is influenced by the nature of the above- and below- ground litter input.

MO2: The quality and quantity of soil organic matter, and thence the timing, location and magnitude of nutrient availability can be regulated by management of litter inputs.

P3: The pattern of root growth in time and space acts as a regulator of the availability of nutrients to plants in present and future seasons.

MO3: Management practices which retain root litter in the rooting zone, and relate new plantings to the location of previous ones, will improve soil fertility.

P4: Surface litter and soil organic matter influence soil water fluxes and moisture regimes.

MO4: The soil water regime may be improved by management of litter inputs both through direct effects and by indirect influence on the soil fauna.

TABLE 2

Testable Hypotheses in relation to Tropical Soil Biology and Fertility Principles (Swift 1985)

H1: The rate of decomposition and nutrient release of a particular litter within any site is primarily controlled by moisture, and is most closely related to the onset of rainfall (P1).

H2: Increasing the proportion of low-quality (eg low N and P, high lignin content) litter inputs at the onset of rains extends the time period of availability of nutrient to the plant (P1).

H3: The availability of nutrients to plants (eg from inorganic fertilizers) can be delayed through microbial immobilisation on low-quality litters, thence decreasing the risk of losses through leaching (P1).

H4: Increasing the proportion of low-quality litter results in increased soil organic matter pools particularly of the more recalcitrant fractions (P2).

H5: Increased availability of nutrients to the plant (eg from inorganic fertilizers) results in increased quality of litter inputs and reduces the recalcitrant pool of soil organic matter (P2).

H6: Increased soil organic matter results in an increase in the time period of nutrient availability to plants even in the presence of high-quality litters (P2).

H7: Below-ground litter is a more important source of immediately available nutrient than above-ground litter (P3).

H8: Below-ground litter contributes a relatively greater component to soil organic matter formation than above-ground litter (P3).

H9: Detritivores affect the vertical distribution of litter in the soil, and thence the availability of the nutrient to plants on release (P3).

H10: Above-ground herbivores change the timing of litter inputs and positively raise its quality, thence increasing the rate of decomposition and nutrient release and decreasing the contribution to soil organic matter formation (P1, P2 and P3).

H11: Surface mulching encourage soil fauna which positively influence the structure and hydrological characteristics of the soil (P4).

H12: Maintenance of litter in the rooting zone improves the physical structure of soil (P3 and P4).

TABLE 3

Levels of Increasing Intensity of Research in the
Tropical Soil Biology and Fertility Programme (Swift 1985)

Level I is the minimum level of participation in the programme, and involves an investigation of the various features of nutrient cycling in the plant-litter-soil system:

- site characteristics (site selection and description, soil characteristics, climate and soil environment, vegetation, soil fauna);
- organic matter and nutrient element inputs (above-ground inputs, below-ground inputs);
- decomposition (above-ground resources, below-ground resources);
- plant growth and nutrient uptake (above-ground, below-ground);
- soil processes (soil organic matter fractions, nutrient availability, soil water regime and nutrient leaching).

This is to be achieved by means of a broad comparative study of natural and managed ecosystems.

Level II involves the specific experimental testing of one or more of the testable hypotheses, in addition to the minimum Level I description.

Level III involves the intensive investigation of one or more of the testable hypotheses in addition to the minimum Level I description, as well as detailed study of some particular aspects of soil biology, such as:

- input of N by dinitrogen fixation
- uptake of nutrients by mycorrhiza
- gaseous loss of N
- soil organic matter quality, stability and labolity
- soil fauna studies
- soil microflora studies.

TABLE 4

Major Soil Biological Processes with Examples of Management Practices by which the Process can be Manipulated (Swift 1984)

	Soil Biological Process	Management Practice
1.	Root turnover	Fertilisers increase root production
2.	Root exudation	Crop species differ in the nature and amount of exudates
3.	N_2-fixation	Legume fallows
4.	Nutrient translocation	Tree fallows induce upward movement of nutrients
5.	Litter decomposition (comminutron)	Insecticides reduce detritivore populations
6.	Litter decomposition (enzymatic catabolism)	Tillage increases biological oxidation
7.	Humification	Incorporation of low quality residues promotes synthesis of organic colloids
8.	Nutrient immobilization	Incorporation of low quality crop residues
9.	Grazing by soil fauna	Insecticide treatments decrease faunal mobilization and increase microbial immobilization
10.	Soil organic matter decomposition	Lime application increases rate of soil organic matter decomposition
11.	Mineralization and mobilization	Burning increases mobilization
12.	Solubilization	Addition of S increases solubilization of rock phosphate by Thiobacillus
13.	Nitrification	Drainage increases nitrification
14.	Denotrification	Increased by nitrate fertilization in humid soils
15.	Oxidation or reduction of S, Fe, Mn, etc	Incorporation of nutrient rich residues increases reduction processes

16.	Nutrient uptake	Mycorrhizal inoculation increases nutrient uptake
17.	Soil particle aggregation	Addition of crop residues (animal and microbial effects)
18.	Soil surface capping	Heavy grazing bares the soil surface and increases microfloral capping
19.	Soil pore development	Addition of organic residues maintains populations of macrofauna
20.	Soil particle movement	Termites reverse clay illuviation; tillage pesticides destroy termite nests
21.	Toxification of soil	Reduced by crop rotation