

4. Conservation Techniques

about section 4

This section of the Training Manual explains the concept of conservation and brings together a variety of conservation techniques. It is not intended to be treated as a textbook or field manual, but should instead be used as a source book, encouraging users to ask questions, discuss ideas and to seek advice from technically qualified people. Section 4 is complementary to Sections 1, 2 and 3, which illustrate how to use the advantages of women's groups in tackling issues pertaining to natural resource conservation.

It would be an impossible task to include all the possible conservation practices in one brief section. The techniques included have therefore been selected to give a flavour of what can be achieved rather than describe each technique in detail. The scope of techniques listed and discussed will depend on several factors such as land size, economic factors, skills and resources available and the magnitude of the problem. This section also includes several case studies.

Conservation of natural resources

Natural resources such as the soil, water, minerals and biodiversity are our natural heritage, sustaining our lives on earth. The human population is therefore dependent on the conservation of these resources, which require the maintenance of an ecological balance.

How does natural resource degradation begin?

Although the causes of degradation of natural resources are many, some of the most common are:

- inappropriate use of land leading to excessive erosion and degradation of soil
- consumption pressures on resources from increasing numbers of human and livestock population
- deforestation for a number of reasons
- floods caused by silting up of water bodies.

What are the symptoms of natural resource degradation?

Soil erosion results in the loss of topsoil which manifests itself as reduced productivity. This is immediately felt in rural areas with a predominantly agriculture and livestock economy. Intensive cultivation of high yielding crops, which draws heavily on soil nutrients, results in depleted topsoils unless fertilisers or manures are used. In the case of overstocked pastures, vegetative cover is lost very quickly, exposing topsoil to erosion from the direct impact of rain and floods. This in turn results in the formation of gullies and silting downstream. Such an impact is obvious, even on gentle slopes, and becomes severe when slopes are steep. When soil is lost or topsoils lose their nutrients, land use undergoes a change. Crop lands become lowgrade pastureland and pastures turn to scrub.

Erosion also causes silting, which in turn degrades waterways and reduces water reservoir life, thus damaging aquatic resources such as fisheries. Soil erosion therefore adds further to the maintenance cost of the local communities and exposes them to increased impact of natural calamities such as floods. A downwards spiral is quickly apparent.

Soil conservation

Preventing soil erosion is much easier than curing it, since soil washed away from fields and into the valleys below can never be brought back. However, once erosion has been controlled, it is usually possible to restore fertility to the land.

Where traditional soil and water conservation techniques are used, the most logical step is to use them as the starting point. However, these techniques are often not widely known outside the immediate area due to poor documentation.

Where soil and water conservation projects have to start from scratch, the local population should be involved, as closely as possible, in the planning and design, using a participatory approach.

Ideally, techniques should be simple enough for farmers to apply with little or no external support. Moreover, the maintenance requirements of soil and water conservation structures should be minimal, otherwise farmers will be unlikely to maintain them due to time and labour constraints.

Soil conservation means:

- increasing soil productivity and preventing removal of precious topsoil
- conserving soil fertility and nutrients
- conserving soil moisture.

The choice of technique

The techniques used depend entirely on the cooperation of the farmers and other land users. In order to involve the farming community there needs to be a clear commitment to the participation of the landusers from the outset. This may sound easy and indeed sensible but the many failures in soil conservation projects throughout the world all have a common feature: the farmers were interested not in soil conservation but in increased productivity, better yields, new varieties, a reduction of the labour required and better access to markets among other factors. While the soil conservation problem may seem like a priority to the outsider, in reality it is a symptom of other weaknesses in the farming system.

The key to successful soil conservation therefore rests in its subtle integration into the overall farming system already in existence. The old approach, on the other hand, viewed soil erosion as 'the problem' and soil conservation as 'the answer', and encouraged the use of expensive and labour intensive methods such as terraces and drains.

Nowadays there is a shift of emphasis that includes two key principles:

- that it is possible to combat land degradation through the adoption of management practices which yield production benefits and at the same time are effective conservation measures
- that rural people, educated or not, have a greater ability than previously assumed by outside experts, to analyse, plan, implement, and evaluate their own development projects.

Several key concepts underlie the new approach to better land husbandry:

- loss of soil productivity is much more important actual than loss of soil
- land degradation should be prevented *before* it happens instead of trying to cure it afterwards, ie, the focus needs to be on sustaining the productive potential of the soil
- soil and water conservation should be promoted as an integral part of a productive farming system rather than as a separate land management exercise
- to be attractive to farmers, any proposed soil conservation activity must provide short-term benefits such as higher yields, greater availability of fodder, or fuelwood, and reduced costs.

Conservation techniques

Conserving soil

The following is a list of methods used in soil conservation, grouped in terms of different land use categories. Most of the terms/techniques used here are explained in the glossary at the beginning of this section, except for a few which are elaborated on in the text.

Arable soils:

- contour farming
- contouring with vegetative barriers, for example, vetiver grass
- contouring with earth banks and waterways
- earth banks on field boundaries
- furrowing, ridging, ridge tying
- tillage practice, subsoiling
- vegetative ground cover, mulching, manuring
- grass cover, grass strips, grass barriers
- improved farming (cropping) systems
- agroforestry
- terracing
- land levelling, smoothing

Non-arable soils:

- vegetative barriers on the contour;
- earthen or rock barriers
- afforestation, reforestation, re-vegetation
- area closure to livestock
- reduced grazing pressure, stall feeding, zero grazing
- pasture improvement
- silvipastoral plantations
- buffer zones
- trail, rural road and forest road treatments

Drainage lines:

- gully control structures
- checkdams, silt traps
- diversion drains
- stabilisation of natural drains

Wastelands:

- vegetal cover
- bunding
- gully plugging
- contour trenching
- stone dykes
- vegetal barriers

Gully plugging

Torrential flows of water cut into the soil forming rifts, which gradually deepen into gullies. Gully plugs can be vegetative or mechanical barriers placed across the gullies to slow the water flow and check further growth of the gully. Vegetative gully plugs are made by planting of hardy grass species such as *Chrysopogon*, *Vetiver* or *Munj* grass. The gully plugs need to be close to the gully head, and a series is usually required. These step series of plugs are usually labour intensive and require careful planning.

Different types of mechanical gully plugs:

Drop structures

A series of small masonry drop structures can be used to check the further growth of an already wide gully to slow down the flow of water. This also contributes to surface water storage for short periods and enhances groundwater recharge.

Brush checkdams

These are gully plugs made of different brushes, bamboos, local vegetation, tree logs, etc. A barrier is erected using these materials to help reduce the erosive velocity of the water.

Boulder/Gabion structures

These are constructed using locally available boulders that are placed to form a stone wall across the gully. Gabion structures are boulders surrounded by a wire mesh. Both structures act as barriers to reduce the force of flowing water and thereby soil erosion. As silt fills the structure, its height needs to be increased. Silt deposited on the upstream side of the barrier helps to conserve moisture for a longer period, which ultimately raises the moisture regime of the area.

Earthen bunds

These are simple traditionally built structures made from soil and boulders.

Contour trenching

These are dug across the slopes of hills to catch any run-off and to reduce soil erosion. The trenches are rectangular in shape and the soil excavated from digging the trench is formed into a berm (narrow path) on the downside of the trench. Grass and legume seeds can be sown on the berms during the rains which not only protects the berm but also provides forage. The number of trenches of a fixed dimension per hectare is determined by the slope/gradient of the area, average rainfall on a normal rainy day (over 24 hours) and the type of soil.

Box 7: Vegetative systems of soil conservation

In some cases, the use of vegetative treatments is intimately mixed with cultural practices, such as in contour cultivation with grass strips. In other instances, vegetative measures stand alone as in the establishment of permanent cover. Vegetative measures have been shown to be highly effective in minimising erosion by reducing the impact of raindrops as they strike the soil. Mulches, certain agroforestry options and permanent cover crops can all perform this function.

Plants can also be used to form a physical barrier to slow down run-off and arrest existing soil erosion. The species used in this manner include napier grass, vetiver grass, and the tree species *Leucaena*. The use of different species in this capacity will vary, depending on circumstances. The particular features of vetiver grass, discussed in detail in Box 8, make it particularly well suited for this application.

Vegetative systems, of whatever species, have a number of advantages over structural systems:

Cost: vegetative measures for soil conservation can generally be promoted at low cost. The cost of establishing vetiver grass hedgerows in India, for example, is estimated to be US\$18 per hectare. In many cases, the major expense in promoting these measures is for extension advice.

Adaptability: unlike structural measures requiring detailed engineering and site planning, vegetative approaches are relatively insensitive to issues such as correct alignment on contours, irregularities in field boundaries and minor errors in placement.

Conservation techniques

Farmer-controlled: because vegetative methods are relatively inexpensive and do not require use of machinery or sophisticated surveying, individual farmers are able to take the initiative in adopting conservation measures. A particular advantage is that the cropping area sacrificed to the conservation measure is considerably less than with the typical structural approach, and is especially true in the case of grass contour hedgerows. Farmers' willingness to devote arable land to essentially permanent cover is often largely dependent on the degree to which livestock are integrated in the farming system.

Box 8: Vetiver grass

Vetiver grass, which belongs to the same part of the grass family as maize, sorghum, sugarcane and lemongrass, is a practical and effective barrier to soil erosion and is used in many locations around the world. Although other grasses and trees have been used for this purpose, there are certain characteristics that make vetiver grass special:

- it reduces erosion when in a hedge just one plant wide
- it is able to survive drought, flood, windstorm, fire, and grazing animals
- it does not appear to compete seriously with neighboring crop plants for moisture or nutrients in the soil
- it is cheap
- it is easy to establish and to maintain
- it seems to be largely free of insects and diseases
- it can survive on many soil types, regardless of fertility, acidity, alkalinity or salinity
- it is capable of growing in a wide range of climates, ie, where rainfall ranges from 300mm to 3,000mm and where temperatures range from slightly below 0°C to above 50°C.

In the Asian region, vetiver is currently known to exist in Bangladesh, Burma, China, India, Indonesia, Japan, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka and Thailand.

In Sri Lanka

Vetiver has traditionally been used to stabilise slopes and terraces in tea plantations around Kandy. In 1989, in an attempt to address soil erosion from hillside tobacco fields, nurseries were established to supply vetiver planting material to farmers. It has also been used extensively by tobacco cultivators who discovered that couch grass, a creeping weed almost impossible to keep out of crops, could not penetrate a vetiver hedge.

In India

In several parts of India, vetiver has demonstrated that it can hold back more than just soil; the moisture that gushes off the land in flash floods is also trapped. In parts of Andhra Pradesh, farmers using vetiver lines got a harvest while their neighbours faced only crop failures. In some villages, water levels rose dramatically after vetiver hedges were grown.

Soil fertility

The productivity of soil and its ability to produce biomass depends upon many factors, namely soil fertility, water supply, slope of land, height of water table, soil depth, climate, and cultivation practices. Any factor may be responsible for low yields; often, more than one is involved. However, low soil fertility is a major cause of low biomass production.

Under natural conditions, all the plant material produced on a piece of land is returned to the soil and thus fertility is maintained. This is seen in virgin forests or grass lands that have been untouched by biotic interference. In fact, in these situations fertility tends to improve over time.

Under agricultural practices part of the plants produced are removed from the land for human and animal use. In such a situation soil fertility decreases. Repeated cropping over years with similar crops or high productivity crops tends to deplete the land of soil nutrients, thus reducing the productivity of topsoil. However, the nutritive quality of topsoil can be rebuilt using the following methods:

Arable lands: crop rotation and mixed cropping
mulching of crop residues and green manure
fallow land cultivation with grass and legumes
animal manure and chemical fertiliser

Watersheds: water harvesting measures
watershed reclamation measures (silviculture, silvipasture, agroforestry horticulture).

Box 9: Indigenous knowledge of soil fertility

- indigenous practices on farm lands in India included the collection of animal manure which was spread on fields to enrich the soil. This acted as an excellent bio-fertiliser
- in southern of India, stray cattle were penned on agricultural fields in the dry season to provide manure to enrich the soil before it was ploughed
- the roots and stocks of the rice plants or sugar cane were left behind in the fields after harvesting the crop. These were then either let to rot or were burnt on the field, leaving a ready source of manure in the field for the next crop.

(Contributed by Suvarna Rani, India)

Conserving soil moisture and groundwater recharge

The moisture retaining capacity of soil has a direct bearing on its productivity. Conservation of soil moisture is therefore essential for the beneficial use of land. All of the methods used to improve soil fertility also contribute to improved soil moisture availability, and so soil conservation is really about the control of soil moisture. Indiscriminate use of groundwater where its use far exceeds the recharge capacity, or excessive surface run-off from barren lands, results in falling groundwater levels which in turn has a bearing on the productivity of the land. Groundwater recharge for barren lands can be achieved by afforestation, vegetal cover and checkdams.

Conservation techniques

Box 10: Indigenous methods used to conserve soil moisture in Sri Lanka

Women in Sri Lanka have traditionally formed bunds of coconut husks around roots of trees to retain moisture and control run-off. In some cases shallow trenches are dug around trees, about 0.5m to 1m away from the trunks, and filled with organic residuals to control run-off, retain moisture and improve infiltration. This conserves water in the soil for off-season use.

Barricading the run-off is achieved by appropriate planting and accumulation of debris across the slopes. For this purpose, women plant shrubs along narrow terrace bunds. The species selected – *Gliricidia sp.*, *Croton laccifer*, *Tithonia diversifolia* – survive during seasonal droughts and, apart from controlling surface run-off, produce mulch for their lands.

Crop residues and paddy straw are spread over land to minimise soil moisture losses through direct evaporation. Along with conserving soil moisture such methods also enhance soil fertility.

(Contributed by Anoja Wickramasinghe, Sri Lanka)

Box 11: Groundwater recharging in Madhya Pradesh, India

In Chirula village in Datia district of Madhya Pradesh, a medium stream, 12m to 15m wide runs past the edge of the village. Although the soils of village cropland were fertile the agricultural productivity was very low because of an acute shortage of water for irrigation. This was due to the wells being mainly dry during the summer months.

During January-June 1990, two checkdams were constructed on the stream, both of which were full by the end of July. The spillway height of the structure was 1.5m above the stream bed and the impounded length of water was approximately 600m for the first checkdam and 800m for the second. The groundwater charging in the first year itself raised the water levels of wells on either side of the impounded water by 1.5m to 2m. An area covering approximately 50 hectares of wheat crop was provided with four irrigations during 1990-91 and the recharging of wells after withdrawal of water was very swift. Earlier these wells had provided one or at best two irrigations.

The following year, two more checkdams were constructed, and the situation today is that the wells on either side of the stream cater for a cropped area of approximately 100 hectares. There is adequate water for paddy during the summer and a wheat crop in winter, followed by a green fodder crop on 20 to 25 hectares. The total cost of the four structures was approximately Rupees 200, 000 which makes it the most cost-effective irrigation facility developed in Datia district.

Water conservation

There is a long history of the existence of water harvesting in Asia, both for crop cultivation and drinking water. Harvesting water involves its collection either through diversion or by storage. The choice of a water harvesting system is a response to the source and availability of water, and topographic characteristics. Availability of water depends on the average annual precipitation, groundwater potential and water carried by rivers. Because of its long history, harvesting water techniques in use today comprise both traditional methods and more recently developed systems.

Traditional methods

The evaluation of large-scale canal irrigation systems in recent years has revealed that it is not usually possible for these systems to reach remote and harsh terrains. Moreover, with administrative convenience usually being the guiding principle, variations in natural resource base, agro-climatic conditions, soil characteristics and social dynamics are often ignored. In addition, these systems usually tend to benefit only the rich farmers. The majority of small and medium farmers in Asia therefore continue to depend on indigenous water harvesting structures. While these mostly exist in their traditional forms, others have been modernised to some extent. These systems are essentially site-specific and are limited by regional conditions.

Checkdams

A checkdam is a barrier built across the direction of the flow of water in a stream to store some of the excess flow that takes place during the monsoon. The advantage of these structures is that they store surface water for use both during and after the monsoon, and aid in groundwater recharge of the area. This water source can also be used for fish farming. Checkdams therefore serve two main purposes. They:

- decrease the damage caused by uncontrolled floods
- provide a dry season water supply.

Checkdams can be of various sizes and built using a variety of materials including stone, clay and cement. Individual farmers can build small checkdams of clay, whereas masonry and cement concrete structures require some degree of construction skills and financial input.

Before building a checkdam, the following points should be borne in mind regarding site selection:

- the structure should be able to store a high volume of rain water
- it should provide a long length of stored water
- there should be a high percentage of cropped area on either side of the length of stored water
- risk of submergence of cropped lands during flash floods should be minimal
- it should have a high cost-benefit ratio.

Major benefits of checkdams

Some of the major benefits of a checkdam constructed using the above mentioned designs are:

- an improvement in the local moisture regime, which results in increased biomass production

Conservation techniques

- an increase in groundwater recharging, thus making available greater amounts of water for irrigation and household use from the farmers wells. A single crop production can easily become a two- or three-crop cycle per year
- fish farming becomes possible
- availability of drinking water for animals
- the water is available to the farmer on call, so that he can extract it when he actually needs it. This is not the case in canal irrigation
- a short gestation period: a medium structure catering for 20 to 30 hectares can be built in just two months.
- no displacement of people
- the cost of construction is generally recouped in one or two seasons due to increased agricultural production.

Diversion systems

Diversion of natural springs and rivers is the most widespread system in the hilly regions and plains of Asia. It is commonly seen in the Himalayan region stretching between the gorges of the Indus and the Brahmaputra and, in the Western Ghats running along the west coast of India.

The different types of diversion systems are:

- channels
- roof-top harvesting
- checkdams and other diversion systems on river beds.

At higher elevations, the main system of water harvesting is by diversion through channels. These channels are usually unlined and are constructed along the slope's contours to distribute water to the fields located at suitable levels. At lower elevations, the diversion channels utilise the sloping terrain to carry water, or else the depth of the channel itself is reduced gradually to facilitate gravity flow.

In the Himalayan region, the diversion system is known by different local names such as *kuhl*, *gul*, *kulo* and *diggi*.

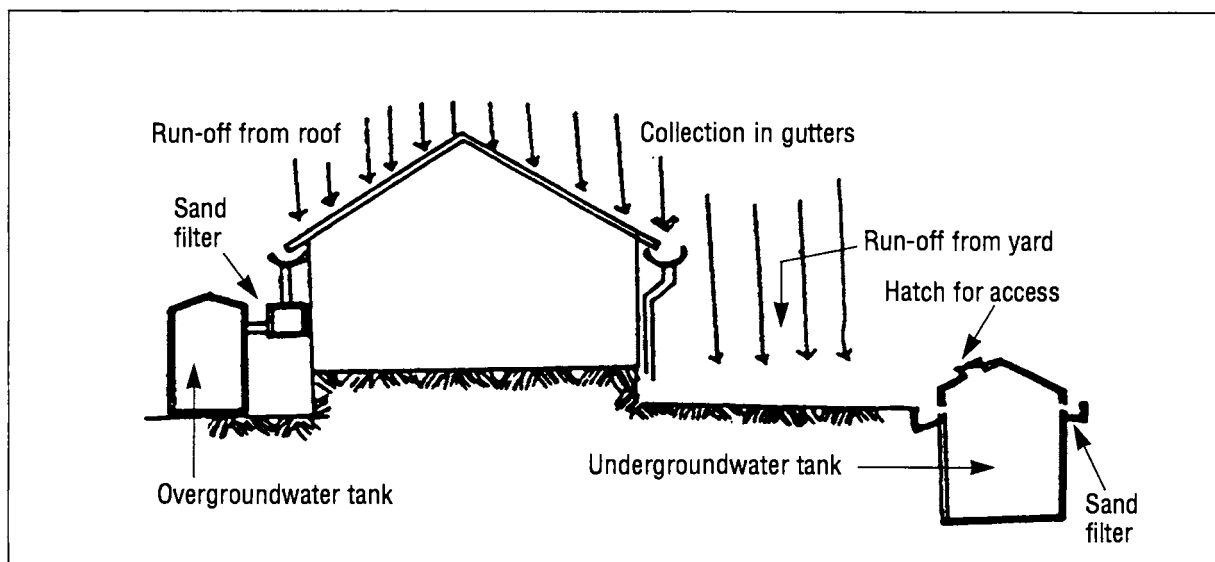
Another water harvesting system gaining popularity in this region is that of roof-top harvesting. Rainwater is diverted from the roof-top through tin pipes into a small tank and is used for household purposes and growing vegetables (Figure 12).

Open pipes made from split bamboo or arecanut are also used to bring water from natural springs for drinking and other household purposes.

Diversion by checkdams is another widespread system in the foothills and sloping plains. A river and its major branches is diverted at different points by temporary weirs made of stone and mud. They are referred to as *pat*, *dong*, *kalvai* and *korambo*.

Down on the plains, rivers usually carry more discharge than the hill springs and so diversion structures are more sturdy and complicated. The materials used to construct the diversion structures on river beds to check waterflow, range from clay, stone, cement and bamboo to palm and banana leaves. Malaysia has heavy rainfall for seven to eight months each year and therefore diversion of rainwater to paddy fields and rubber and palm plantations is the predominant water harvesting system. Small earthen and stone checkdams are also constructed on individual fields to store rain water.

Figure 12: Roof-top harvesting



Diversion systems tend to enlist local support in the construction and maintenance of channels, and to ensure equitable distribution of water. Regular interaction and cooperation is essential not only with a village benefiting from a particular stream or river but also with villages located downstream that depend on the same water source for irrigating their fields.

6 Water irrigation at Sarai village in India

Summary: An ancient water irrigation system used by more than one thousand families is informally but successfully maintained by individual farmers.

The area

Sarai village is situated at a distance of 10kms from Tehri township in the Tehri district of Uttar Pradesh in India. Sarai has approximately 1, 200 households belonging to a variety of caste groups. The majority of Sarai's villagers are dependent on agriculture. Because of the area's sloping terrain, step cultivation is practiced and paddy, wheat and other crops are grown. The average landholding size is two acres.

In Sarai, the waters of a fast-flowing mountain stream have been partially diverted. This water is used to irrigate 200 acres of agricultural land belonging to 1, 000 families. The diversion structure is a simple stone and lime mortar wall. The water is then brought down by gravity through unlined channels to the agricultural fields. Excess water runs off into the Bhagirathi river.

Institutional Arrangements

This irrigation system has long been in use and its exact age could not be recalled by the villagers. Since its inception, there have been only minimal changes to the system.

The *Gram Sabha* (village council) deals with matters pertaining to irrigation. The village council is an informal body of nominated village elders and also deals with other aspects of village life such as social problems. *Gram Sabha* meetings are open to all villagers and decisions are reached by consensus. This being an informal system, there are no written rules and regulations.

The cost of maintaining the physical structures is borne by the user community. A token water tax is collected by the village council from each of the users, and the amount is in proportion to their land holding. The responsibility of maintaining the field channels lies with the individual user through whose field the channel passes.

Distribution of water is done on an hourly basis. Three hours of water supply constitute a unit, locally known as a 'pahar. One pahar usually irrigates half an acre of land. A maximum of four 'pahars' are allocated to a farmer. While major conflicts regarding the supply of water have not occurred, minor conflicts do arise. This happens when an individual neglects to perform his duty by failing to turn-up for the voluntary labour contribution, or does not bund his fields properly, thus causing damage to other plots. In such cases, the village council uses social pressure or minor fines to settle the matter.

Dong irrigation system in Assam, India 7

Summary: The Dong system is an ancient but now largely unused water irrigation system in Assam. However, part of the system is still in use during the summer months. Because it is used by more than one village, maintenance and overall management depends very much of the mutual cooperation of everyone involved.

Background

Dong is a traditional system of irrigation practiced by the Bodokachari tribal community in the north-eastern part of Kokrajhar district. Presently, the system has fallen into disuse in most places. In areas where it is still functioning, the water is used only for *sali* (summer) cultivation. The origins of this system can be traced to the frequent flooding of the Brahmaputra river, which forced many of the Bodokacharis on the northern bank of the river to move up into the hills. They are known to have cultivated a number of traditional varieties of rice and even harvest three crops a year. This was achieved by utilising the water of the streams leaving the Bhutan hills and entering Assam.

Dong System of Irrigation

The streams leaving Bhutan lose their course in the boulders. The dong system involves tapping the water upstream. Boulders are used to direct the flow of the stream into an unlined main channel. At places, cross bunds are also constructed to regulate the flow of water. A major part of the channel is rocky but at certain places where the soil is loose, bamboo mats and weeds are used on the sides of the channel. The size of the main canal may vary from one dong to another, depending on the location of the water source and the agricultural fields. It is not unusual for the Bodos to dig canals varying in length from 1km to 20kms. The depth and width of the canal is generally 8ft and 5ft respectively.

Institutional Arrangements

Since the dong system serves more than one village, it requires co-operation among villages for the successful overall management of the system. For this purpose, each dong system has a dong committee with representation from each village served by the dong. In addition, in each village, committees are informally elected by the entire village. The dong committee is responsible for the overall management of the irrigation activity. The responsibility of guarding the channel is assigned to different villages on a rotation basis. In case of breaches in responsibility, a signal is sent to all villages and the dong committee meets immediately. The labour for any repair work is organised and undertaken immediately. The main channel is repaired annually before the monsoons, with a member from each household providing voluntary labour for the purpose. In the case of anyone failing to turn up for the annual maintenance of the dong canals, fines are levied.

Depending on the availability of water, the number of households and the land cultivated in each village, the dong committee allocates a share to each village. Each village committee takes on the responsibility of internal distribution. Both committees take decisions on water distribution by consensus.

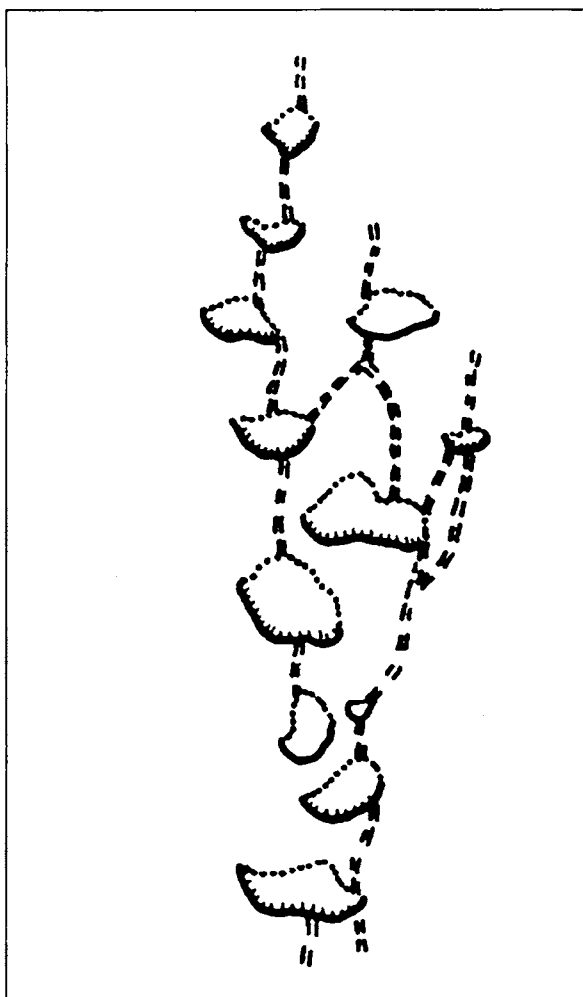
Storage systems

In regions with low rainfall (less than 1, 200mm annually), non-perennial rivers and undulating terrain, the predominant water harvesting structures are the storage works. The design of these structures depends a great deal on the physiographic features of terrain and availability of water.

In India for instance, 90 per cent of the annual run-off in the peninsular rivers occurs during the four months of the monsoons. Hence, year-round and short-term storage systems are very important both for irrigation purposes as well as for drinking water for human beings and livestock. In the plateau region of South India and Sri Lanka, storage works are the predominant water harvesting structures. These storage structures are typically ponds, tanks or other reservoir types.

The rivers and streams in these regions carry a heavy supply of water in the form of flash floods during the months of September to December. A system of interconnected reservoirs divert river water and store rain water. They are locally referred to as *system ery* and *chain ery* respectively

In some areas, the undulating terrain promotes rapid run-off and therefore single-unit or isolated reservoirs are designed to divert and store rain and river water. These are known locally as *ery*, *kulam* and *keri*.



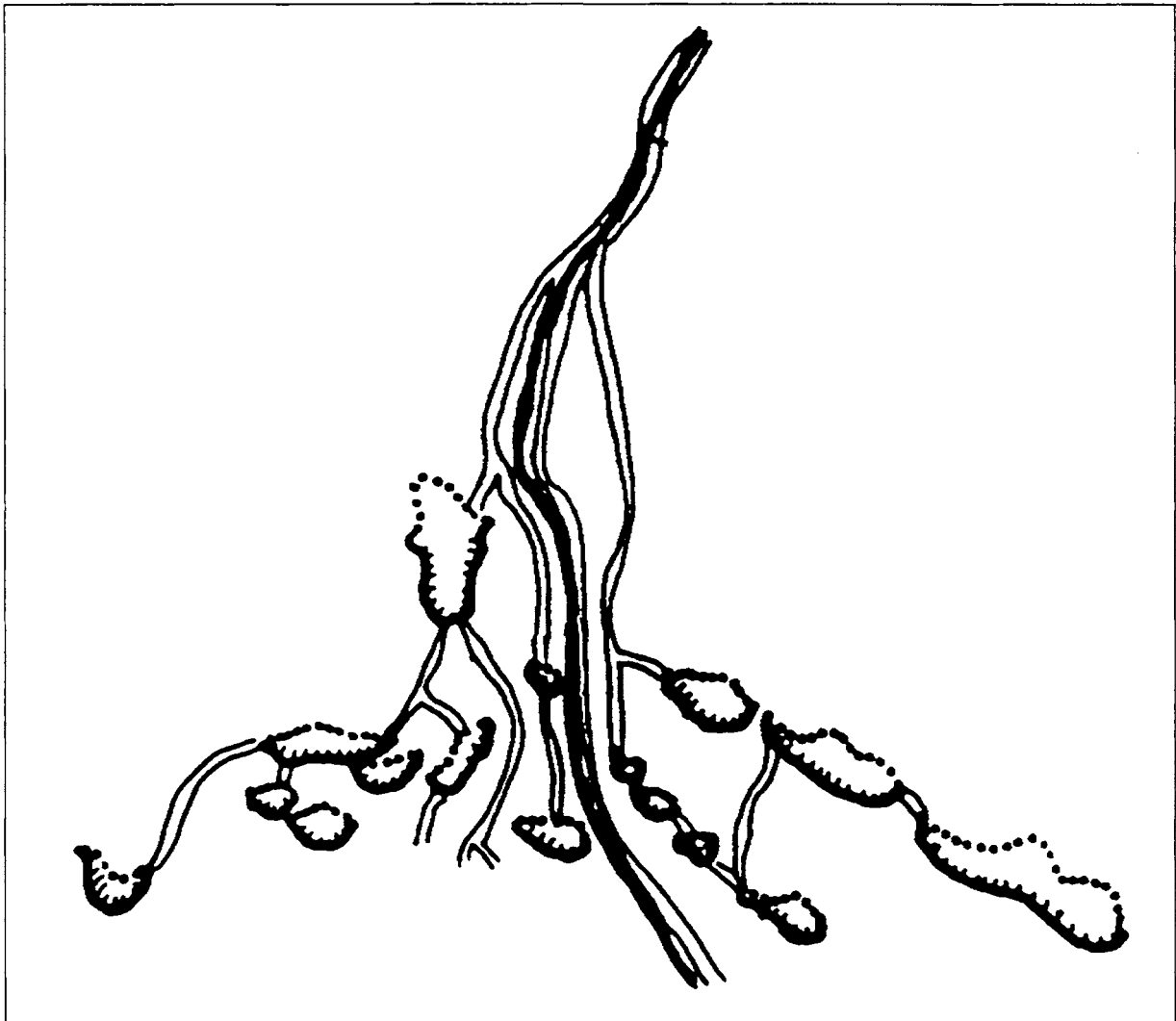
Figures 13: 'System' storage system

These interconnected and isolated storage structures have embankments on three sides. The fourth side is left open to collect run-off. Water stored in the reservoirs/tanks reaches the fields through a canal system or earthen channels. Water from the tank is allowed into the canal by operation of sluice. Spillways are provided for passage of excess water.

Storage structures below the surface or dug out ponds co-exist with diversion channels in the plains of Indus-Ganga which extends to Bangladesh. Natural as well as artificial depressions known as *pokhar*, *talaab*, *jhil*, and *saagar* are fed from all sides and store both rain and flood water.

In the Western Plains of India (including the Thar Desert) and adjoining parts of Pakistan, scanty rainfall (400mm to 800mm annually) and absence of rivers has led to the construction of *in situ* water harvesting structures. These include elevated earthen embankment constructed on one side of a sloping terrain to arrest rainwater run-off as well as depressions. These are locally referred to as *johad* and *khadin* and *topa* and *nadi* respectively. In the arid region of Baluchistan, stone structures called *gabbar baandhs* predominate.

Figures 14: 'Chain' storage system



Another type of storage is the use of submergence tanks, whose use extends all the way from Central India to Baluchistan. They are different from *in situ* water harvesting structures in the sense that they have higher embankments and collect run-off from a wider catchment. They are constructed in a series across the same stream, with cultivation following after submergence of the fields. In India these are referred to as *bundhee* and in Baluchistan, as *khushkaba* and *sailaba*.

The storage structures discussed so far are characterised by multiple use. They are used for irrigating fields, for supplying drinking water for livestock and human beings, for controlling evaporation, for better water distribution and for reducing the loss of water through of run-off. Storage structures are labour-intensive during both construction and maintenance and therefore the involvement of local communities that benefit directly from them is imperative. Annual de-silting and repair of tanks is taken up at the community level and formal or informal groups monitor the distribution of water.

8 Tank irrigation in Chandrapur, India

Summary: Focuses on how two villages collect and store river and rainwater in ancient water tanks situated at the bottom of local foothills. Maintenance is shared between villagers (for the main channels), with individual farmers taking responsibility for the field channels. Use of the water from the tanks is regulated by the local *Panchayat*, with disputes over usage being settled at a local level.

Background

Chandrapur District is located in the eastern part of Maharashtra, India. As part of the Wardha-Wainganga plain, it is characterised by lowland relief and an undulating terrain. The soil is black cotton and average annual precipitation ranges from 800mm to 1m. The chief crop is barley.

Two rivers, Wainganga which flows along the northern boundary of the district and Wardha in the south, have terraces that utilise river water for irrigation. In areas away from the rivers, rainwater is the main source of irrigation. For this purpose, tanks known locally as *malguzari* tanks are constructed at the foothills of the hillocks to arrest run-off and store rainwater. These tanks have earthen embankments on three sides, with the fourth side left open to collect run-off.

Tanks and Bandharas

At the two villages of Bondegaon and Naokhala, rainwater is stored in tanks which are more than hundred years old. At Bondegaon, there are two tanks. The smaller one is called *bodi*. It acts as a desilter and overflow from this goes to the bigger tank located downstream.

To raise the level of water to the level of paddy fields, from the middle of the channel onwards, special weirs or structures called *bandhara* are constructed across the main channel. It is a traditional technique whereby wooden poles are inserted into the bottom of the channel at intervals of 3ft. A net of *sarkanda* (creepers) is woven around the poles and the structure is then plastered, firstly by mud and grass and then mud alone. Nowadays, a modified version, *vasant bandhara*, is in use. H-shaped steel beams are inserted vertically into the bottom of the channel. Wooden planks, 4ft in length, 6" wide and 3-4" thick, are stacked along the beam.

Institutional Arrangements

In both villages, the *Panchayat* is responsible for the overall running of the system. The *Panchayat* fixes the share of water for each farmer according to the land irrigated by him and the availability of water. In a season, a farmer is allowed only two irrigations from the tank. As a general rule, tailenders (farmers furthest from the tank) receive water first. This is to prevent over-use of water by farmers whose fields are located close to the tank. In Bondegaon, if the level of water is below that of the channel outlet, farmers are allowed to pump out water at their own expense. Maintenance of the main channel is a collective responsibility of the villagers. Field channels as well as construction of *bandharas* is the individual farmer's responsibility. The *Panchayat* fixes certain days before the monsoons for cleaning and repair of the channels and the tank. If disputes arise over sharing of water when the flow of water is slow or there is less water in the tank, the matter is referred to the *Panchayat* and settled locally.

Lift irrigation systems

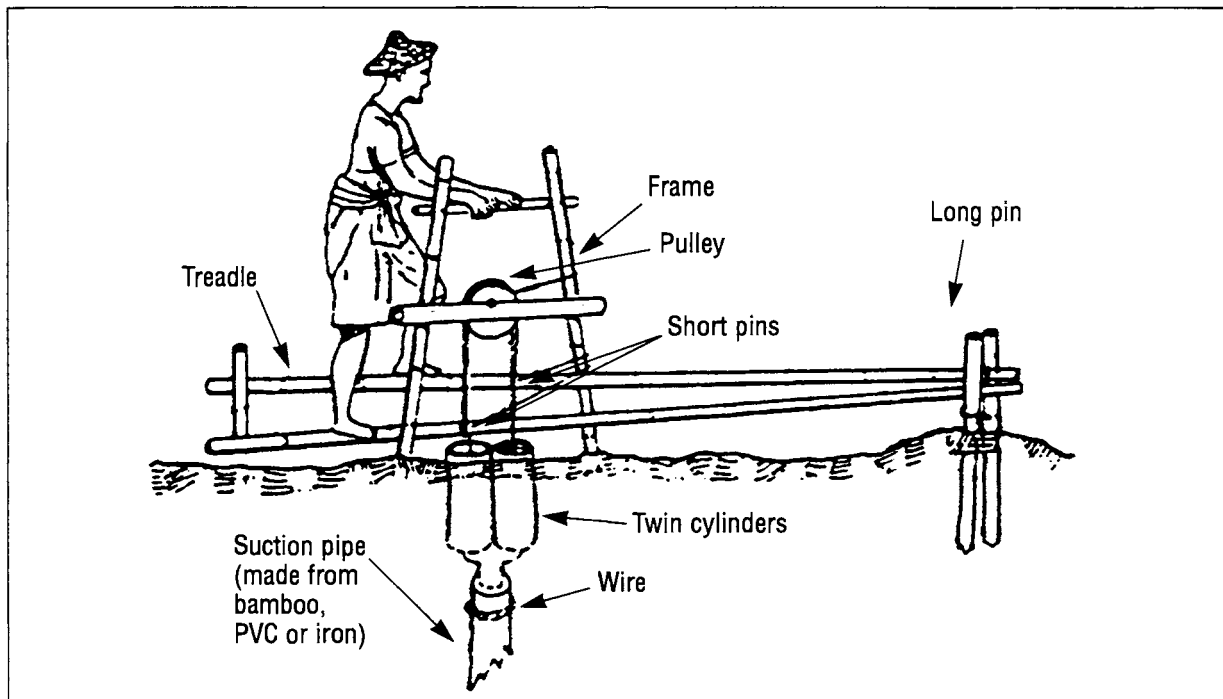
Lift irrigation systems (LIS) include lifting of groundwater for irrigation and drinking purposes as well as for acquiring surface water sources for irrigation.

Dugwells and tubewells are a common feature in all parts of Asia. In the desert regions of India, dugwells are covered to reduce evaporation losses and are locally referred to as *tanka*.

Traditional methods of lift irrigation from rivers, streams, channels and tanks using human and animal energy have in most cases been replaced by diesel pumpsets. However, in Western India (Kolhapur district), the traditional system of *phad* is still prevalent, where eight to 10 bullocks and a similar number of men raise water level to some 14m-15m.

In Bangladesh, a minor revolution has taken place in the field of manual irrigation. The treadle pump – a human powered, twin cylinder pumphead with a bamboo or PVC tubewell – was first introduced in 1979 by an NGO, Rangpur Dinajpur Rural Service. It has since become one of the most successful irrigation pumps made in Bangladesh. A modification of the indigenous *dekhi* system, it is easily operated by both men and women alike to lift water from ponds and channels to the paddy fields.

Figure 14: Treadle pump



Conservation techniques

Notes to trainers

In the context of the community-based nature of the majority of the indigenous systems discussed here, the critical factors for the revival and replication of these systems are:

- **appropriate system**
 - the system should take into account the physical configuration of the area, resource availability, user group size and the local demand pattern
 - it should be comprehensible to everyone. Use of local materials and skills and involvement of users in construction/ installation facilitates this
- **participation of users**
 - in defining their needs
 - in the choice of the water harvesting system
 - in the designing of the distribution system
 - in formulating rules for benefit sharing and management
 - in the decision making process
- **homogeneous group**
 - users belonging to the same caste/tribe
 - users with uniform landholdings, common problems (for example, scarcity, migration) and common needs
- **local institutional arrangements**
 - for demarcation of responsibilities to ensure regular maintenance and overall management of the system
 - for setting up mechanisms for decision making and conflict resolution at the community/local level
 - for defining users' rights, regulating resource use and ensuring equitable distribution
- **stake in the system**
 - ownership of and access to the resource is clear
 - benefits from community effort are transparent and equitable and their continuing into the future is assured
 - ownership/management of the system rests with the community
 - principle of cost sharing and voluntary labour in construction and/or maintenance.

Recently developed systems

Despite the wide range of indigenous systems, there has been a tendency in large parts of Asia to move towards the use of modern systems. In part this is because of government bias in favour of large systems, managed by the irrigation department, and partly due to the shift in cultivation practices towards cash crops requiring large amounts of water – a need not easily fulfilled by traditional systems. In addition, these large-scale irrigation systems require expensive externally financed dams or barrages with all the associated environmental hazards such as resettlement and downstream problems. These schemes now require some type of Environmental Assessment (EA), often referred to as Environmental Impact Assessment (EIA). In many countries these are a legal requirement.

Energy conservation

Energy constitutes a basic need for survival and a critical input to development. Firewood and other biomass such as crop residues and animal dung constitute the principal source of energy in developing countries and are used for cooking and heating. In quantitative terms, rural households are the main users of energy in poor countries, cooking comprising the major energy use.

Energy scarcity affects not only productivities, but basic needs such as family nutrition and health. Reducing fuel use in cooking and spending scarce cash on fuel instead of food, have immediate repercussions on these needs. In terms of the differential impact by gender, fuel scarcity has a disproportionately higher impact on women.

Box 12: The differential impact of fuel scarcity

The symptoms of fuel scarcity results in increased workload for:
● Use of bushes, twigs and roots as fuel	women and children (gathering, preparing)
● Use of residue fuel for cooking	women and children (gathering, preparing)
● Walking long distances to collect fuel	women
● Cutting living trees	women and men
● Use of carts/animals to collect fuel	men
● Purchasing fuel	women or men (depending upon who provides the cash)

Source: *Linking Energy with Survival. A Guide to Energy, Environment and Rural Women's Work*. ILO. Geneva.

There exist several different ways to conserve energy. The two methods discussed below relate to domestic waste management and fuel use.

Domestic waste management

Domestic wastes are produced at several different levels: kitchen waste, used-up consumables, packaging, clothing and animal waste, to name just a few. The nature of waste generated in an area is to a large extent a function of the nature of its economy and level of income. Therefore, whereas in low-income, predominantly agricultural communities most generated waste was accepted back into nature's cycle, waste generated in a high-income, industrialised environment requires special systems of disposal.

An important dimension to waste generation and disposal is the resource-scarce nature of several Asian countries. Depleting national resources and spiralling costs of imports on the one hand and an increasing consumerism on the other, necessitate resource recovery from waste. Even in rural areas, where consumerism may not be an issue, the inability to fulfil basic survival needs such as those of fuel, indicates the need to recover waste. Thus, given the decreasing productivity of soil, harnessing the organic component of city waste for agricultural lands through composting not only addresses the issue of lowered soil fertility but might also help solve the growing problem of waste disposal.

Conservation techniques

Waste, in most Asian countries, as in most developing countries, offers tremendous opportunities for resource recovery. In its waste, Asia has a hidden asset, which currently tends to be viewed only as a liability. With few technical inputs, waste material can be used to overcome the costs and shortages of a variety of raw materials while simultaneously addressing issues of pollution, health and shortage of land for disposal. Depending on the nature of waste, resource recovery from waste can take place at several different levels, to affect urban, peri-urban and rural populations. Some of the common methods are listed below:

Type of waste	Management method	Recovery
Inert	Recycling	Re-used by others
Organic	- Composting - Vermi-culture - Biogas	Farmyard manure Farmyard manure Fuel
Mixed	Landfill	Methane, power
Mixed	Incineration	Power

Recycling of non organic material.

Used and discarded material such as paper, plastic, glass, metal and cloth are separated from other waste and sold to recycling industries (often through a whole network of intermediate traders) where they are used as raw material for the manufacture of a wide range of consumables. This activity is typically carried out in most Asian cities by those surviving within the informal sector.

Collection of reusable items takes place at various stages:

- residential and commercial establishments
- on the streets
- community bins or community waste collection centres
- landfill sites.

Composting of waste

Given the high organic content of waste in several Asian countries, composting of waste is an easily adopted method of producing organic material which can be used for replenishing soil fertility and improving soil structure and moisture retention capacity. Composting entails the decomposition of the organic content of waste under controlled conditions, either through anaerobic or aerobic bacteria, to produce manure. Anaerobic decomposition, which takes place in the absence of oxygen, is a low cost but lengthy process whereas aerobic decomposition is much more rapid.

Resource recovery through composting, therefore, achieves:

- conservation of resources by recycling
- support of nature's cycle by returning to the earth valuable organic material
- reduction of landfill space requirement.

Box 13: Garbage farms of East Calcutta

In Calcutta, India, the municipal corporation leases out plots of mature dump land at the main refuse dumping site in the city. The plots, amounting to about 800 hectares, are used for vegetable farming. The city's refuse forms an extremely productive substratum, where besides vegetable matter and coal ash, there are large quantities of animal dung, sewer sludge, bones and other organic material. Twenty-five varieties of vegetable are grown throughout the year without the addition of chemical fertilisers.

Vermi-culture or vermi-composting

The traditional methods of composting are largely slow and tedious, involving aerobic or anaerobic decomposition which can take between three to six months. In comparison, the recycling of organic waste through selective tropical species of earthworms under semi-natural conditions called vermi-composting, is an economical and speedy method of composting.

During the process of vermi-composting, the worms bring about biodegradation of organic waste and yield organic fertiliser. Under a cover of green manure, earthworms feed on waste to produce castings without any unpleasant odour. One tonne of worms consume about one tonne of organic wastes in a day and produce 40 per cent in dry weight castings.

The climate in several Asian countries is highly appropriate for worm culturing, making earthworm vermi-composting a very feasible activity. Though the technique involves scientific methods of breeding and rearing specific varieties of earthworms under controlled conditions, it is a simple technology, highly cost-effective and easily adaptable and affordable by a majority of small, marginal and sub-marginal farmers.

Box 14: Vermi-composting

In a residential area of Bangalore, waste picker children have been organised around a vermi-composting scheme to improve their earnings and working conditions, reduce waste collection and transportation costs of local municipal authorities and decentralise waste treatment. About 400 houses in the area have been persuaded to separate organic, dry recyclable and toxic waste at source and hand it over to waste picker children.

The organic material is taken to a compost site in a public park, used with the authorisation of the municipal corporation. Earthworms are provided by the University of Agricultural Sciences and the use of earthworms removes the problem of smell since once they act on the waste, the smell is reduced considerably. Additionally, leaf litter is used to cover the pits used for storing the waste. About 200 to 250kgs of organic waste is collected every day from the 400 households, producing about one tonne of compost every two months, which is sold to floricultural farms at Rs 4, 000 to Rs 6, 000 per tonne.

Biogas production

Given the low calorific value, high moisture content and high fermentable matter of most Asian waste, one of the most optimal uses of waste lies in the production of biogas for fuel and the use of residue as manure. A mixture of 60 per cent methane and 40 per cent carbon dioxide, biogas is produced by anaerobic bacteria through the fermentation of organic matter inside an airtight digester. The gas can be used for a variety of purposes from cooking and lighting to running internal

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combustion engines. It has been calculated that two cubic metres of biogas is roughly equivalent to one litre of gasoline or diesel.

Extraction of methane and generation of electricity

Methane can be extracted and supplied as fuel to areas near a landfill site or else the gas can be converted into electricity. Such methane extraction is especially feasible where the organic and moisture content in the waste is more than 40 per cent and the landfill site is properly covered by following sanitary landfill methods. This technique does require complex safety precautions.

Power from incineration

Although power can be generated by incinerating waste, for several areas in the Asian region this may not be appropriate because of the composition of waste. In other words, the low calorific value and high organic content would necessitate the use of extra fuel which would make the generated power impractical as well as very expensive. Where the composition of waste allows incineration without additional fuel, power generation may be viable.

Box 15: Using biogas

Even as most of the rural households in India have yet to get power connections for lighting, tribals living in villages near Bishunpur in Gumla district of Bihar have their homes well lit. The tribals use all the gas generated from biogas plants for lighting since firewood is not scarce and can be used for cooking food. Although a biogas lamp is not as efficient, the light produced is comparable to that of an electric bulb. At present more than 200 houses are benefiting from this kind of lighting in and around Bishunpur

Feedback from different parts of India on the impact of the use of biogas technology on peasant women found that:

- women saved time spent in cooking food
- time saved in cooking allowed women to participate in other activities or better childcare, or even greater leisure
- drudgery in fuelwood collection was reduced
- biogas effectively removed the need for preparing cowdung cakes
- utensils did not get coated with soot when food was cooked using biogas
- biogas provided a smoke free environment inside the home
- smoke induced-lung and throat infections were reduced
- houses remained cleaner
- vegetable cultivation in kitchen gardens using biogas slurry could be taken up as a gainful activity
- food cooked with biogas was free from the smell of kerosene.

Fuel use

The ever increasing scarcity of biomass fuels is well established and documented. 'Free' gathered biomass fuels are expected to become even scarcer in the future with estimates of more than 2, 000 million people in developing countries suffering an acute scarcity of fuelwood by the end of the century. The brunt of this scarcity is borne primarily by rural women, who are normally responsible for fuel collection. Even in areas where this responsibility does not lie with them, they suffer the

consequences of dwindling supply through the necessity of using poor quality fuels which increase health hazards and make cooking more time-consuming.

The household energy sector has a considerable potential for fuel savings, since it accounts for up to 90 per cent of total energy use in poor countries (if biomass fuels are included in the total). Increasing the efficiency in the use of household fuels could improve national energy balance, increase energy availability for meeting different needs and reduce women's workload in fuel collection and use.

In some rural areas fuel savings may be of less interest since fuel is often gathered free by women and children and is relatively abundant. In urban areas on the other hand, where households purchase fuel, savings are likely to be of considerable interest to households. Fuel savings in urban areas are also important from the point of view of the proportion of rural woodfuel resources that are diverted to urban areas.

The different types of household fuels typically used in rural and peri-urban areas include wood, coal and kerosene.

Conservation through innovations in fuel use

Even though reforestation has often been the first response to rural cooking fuel shortages, the relatively long-term benefits from tree planting often seem too remote, especially for poor families. Fuelwood for household use, in any case, is the lowest value product of trees, which are more often that not grown to provide raw material for different industries or fruit. The most commonly used mechanisms therefore have included:

- use of improved cookstoves
- fuel processing to generate biogas. When biomass such as cattle dung is subjected to anaerobic digestion to produce methane rich biogas, a much higher percentage of thermal value is obtained from the same quantity of dung than when it is used as fuel in the form of dry dung cakes
- use of alternate energy systems such as solar energy
- use of indigenous alternate fuels
- women have traditionally innovated processing combinations of biomass to produce fuels that save consumption and cooking time.

Improved cooking stoves

Although conserving biomass has been the main thrust in improving the efficiency of cooking stoves, the scope of such stoves extends to the provision of a better cooking environment, reduction of health hazards and generation of employment.

Improved stoves can broadly be categorised into four groups:

Chimney stoves

The basic design of a chimney stove has a firebox with a door opening at one side and the first pot directly on top. From the firebox the flames and smoke pass through a tunnel and underneath to three pots before leaving through a chimney. The maximum performance of chimney stoves is dependent on the proper draught of the stove, which will vary with the chimney dimensions and installation.

For this type of stove, the removal of smoke and the ability to use a wide range of pots have taken priority over fuel efficiency and cooking speed.

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Chimneyless stoves

Chimneyless stoves are traditional through much of Asia, although improvements have been made to the original design's performance, largely due the addition of a more enclosed firebox.

These stoves are easier and cheaper to build than chimney stoves and they do not have the inherent problems associated with the correct installation and maintenance of a chimney.

Chimneyless stoves with hood chimney system

These stoves emerged as a response to the problems faced with chimney stoves. Most of the problems of mud clad ceramic stoves are caused by chimney fixation, sealing and cleaning. Difficulties faced in shifting the stove from one place to another because of changes in cooking sites on account of weather, are also due to the fixed chimney.

The hood chimney system is such that the stove is independent of the chimney by constructing the hood in the corner of the kitchen used for cooking during the winter. The hood can be permanently fixed with attached chimney or made movable. With this system, any portable or fixed type stove can be used for optimal thermal performance along with removal of smoke.

Box 16: Smokeless stoves in Pakistan

The traditional mud stoves used by 72 per cent of the rural population in Pakistan consume a lot of firewood, which is found with considerable difficulty since only 3 per cent of the country is forested. The stoves also produce a lot of smoke, which is inhaled by the women during cooking. It is estimated that the amount of smoke inhaled by a woman during the day is equivalent to her smoking 200 cigarettes. Smoke inhalation has been the cause of respiratory problems and lung cancer, and has affected women's eyesight.

In 1986, a group of three women from the Paasban Women's Association introduced smokeless stoves in five rural locations. They organised a series of workshops in which women from the communities were trained to build, repair and maintain stoves. In addition, a national training workshop was conducted in which women learnt to be master trainers.

The smokeless stoves have a fuel saving of about 30 per cent. Women in the communities which adopted the new stoves save time and energy by collecting less fuelwood. A woman can now cook two meals using the same amount of wood previously used to cook one meal. Women's health conditions have improved, since they no longer inhale that much smoke. Kitchen walls and utensils no longer become smoke blackened, and women spend less time and water cleaning them.

Charcoal stoves

Charcoal stoves are lightweight, portable, have one fire per pot and no chimney. Design improvements to increase cooking performance centre around changes to the stove body that surrounds the firebox. The most important factors that affect its performance are: wall material (insulated pottery is best), the density of the ceramic material (which should be light and porous), the size of the grate hole and the exhaust gap.

Organic farming systems

What is organic farming and what is its relevance?

Organic farming is a method of growing crops without depending on artificial fertilisers and chemical pesticides, with the aim of maintaining a healthy and balanced environment where plants can thrive.

As discussed earlier in this manual, environmental degradation leads not only to soil erosion but also to declining soil fertility. Soil may be physically damaged when it is repeatedly worked with heavy equipment in wet weather, or when it is compacted around water holes in grazing land. Damage may also occur when soils are deprived of their natural nutrients and their organic matter or humus content.

When little attention is paid to maintaining the humus content of soil, the biological activity of the soil becomes imbalanced, resulting in an increase in pests and diseases, a decrease in water holding capacity of the soil, and an increase in soil erosion. As with the undernourished human being, poorly fed soils produce undernourished crops and animals, which easily fall prey to pests and diseases. Where land is intensively mono-cropped (ie, crop rotation is not practiced), it becomes increasingly difficult to maintain soil fertility.

The nutrients required for plant growth can be replaced by artificial, or chemical fertilisers. Such fertilisers cannot, however, replace the humus content; only crop rotation and other good farming practices can achieve this. In addition, artificial fertiliser is expensive, requires transportation and often has to be imported from abroad. A system based on chemical inputs hence tends to favour rich farmers. By reviving traditional sound husbandry practices, which optimise on the resources available in a region, it is possible to obtain good yields, build up soil fertility and improve soil conditions.

This is particularly relevant in the context of many Asian countries, for example, Malaysia, where commercial agriculture has been adopted extensively, as well as the widespread use of chemical fertilisers and pesticides/insecticides.

Organic farming is based on the principle of mixed farming and makes optimum use of humus through the composting of organic matter produced on the farm by both plants and animals. Benefits of organic farming include:

- improved moisture-holding capacity of the soil
- less soil erosion
- better plant and animal health
- crops are better able to resist drought conditions
- less damage from insects
- better yields, sustainable over longer periods
- little, if any, environmental damage.

However, these benefits need to be balanced against an understanding that if correctly used, chemical fertilisers and pesticides do lead to marked gains in productivity. As is often the case, the stark choice between organic and non-organic is misleading. In fact, the best yield increases are often obtained by the combined application of chemical fertilisers and organic material. As most

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farmers know intuitively, one does not exclude the other. The system of using external inputs, such as fertilisers, together with applications of manure and/or compost is often described as improved land husbandry. This includes the management of crops, bio-control methods and integrated pest management.

Management of crops

This entails using different cropping practices, without the use of synthetic chemicals to control pests, weed and plant diseases. Methods include crop rotation which is a traditional agricultural practice used to control insects, weeds and plant diseases. When a farmer grows one crop continuously on the same piece of land for many years, several things may happen. The soil fertility declines, weeds grow in large numbers, and pests and diseases affecting the crop increase more than previously. However, the situation can be arrested through crop rotation.

Growing a variety of crops in the field improves the nutrient supply to individual crops. Crops with a lot of leaf growth – for example, maize, spinach, cabbage and kale – have different nutrient requirements from root and bulb crops such as cassava, sweet potatoes, onions and carrots.

Other crop management methods used are:

- intercropping
- altering the planting date
- variation in plant spacing
- (more recently) seeking resistant varieties.

Bio-control methods

Enriching soil through composting or mulch

A farmer can use compost to obtain a good crop without having to rely entirely on expensive chemical fertilisers. Compost can be made by converting manure, leaves, crop stalks, roots, kitchen waste and other vegetation into humus, which is valuable plant food. When applied, compost provides food to the plant without first having to be broken down by micro-organisms in the soil.

The making of the compost can be hastened by mixing in top-soil, which contains micro-organisms, vegetation and old manure, under a moist and airy atmosphere. To enrich compost the ash from domestic fires can be added as it contains valuable nutrients. To hasten this process even further, the mixture should be turned every two to three weeks. Processed this way, the compost should be ready for use within six to nine weeks.

By contrast, inorganic fertilisers consist of chemicals with little or no organic matter. Though chemical fertilisers supply nutrients that are readily available after application, they are expensive, often unavailable and generally do little to improve soil structure. Many farmers have difficulty calculating how much chemical fertilisers to apply, often leading to under or over-fertilisation, neither of which produce the desired results.

Over-use of fertiliser is now a major environmental concern as elements such as nitrogen and phosphate washed into water bodies can have unpleasant and dangerous effects both for humans and wildlife

Box 17: Role of earthworms in farming systems

Earthworms perform a key role in substituting conventional management with low input practice, by:

- decomposing organic matter
- generating nutrient rich casts
- opening channels in the soil
- improving soil fertility and structure.

Different earthworm species perform different functions.

Some species inhabit organic matter lying on the soil surface, where they eat fallen leaves and other litter. These species are used for vermi-composting, which is the process of using earthworms and micro-organisms to convert organic waste into compost. Other species live beneath the soil surface where they mix and aerate the soil as they make extensive horizontal burrows. Still other species burrow vertically into the soil creating channels for drainage, aeration and root growth.

Farming practices such as frequent tillage and the use of fertilisers and pesticides, have detrimental effects on earthworms.

Legumes as nutrient suppliers

Legumes, including beans, ground-nuts and peas, contain nitrogen-fixing bacteria in their root systems. Legumes are often grown in association with other crops in intercrop or crop rotation systems to provide nitrogen for other plants. For example, peas or beans are often grown with maize in a naturally beneficial system. Such multi-cropping practices reduce the need for chemical fertilisers. All food crops can benefit from being grown in rotation with leguminous plants, like beans and peas, which take nitrogen from the air and transfer it into the soil through nodules found on their roots. The legumes can be planted to help the soil recover after long periods under food crops. Nitrogen is replaced without using fertilisers for the same purpose.

Alternatives to pesticides

Farmers usually know of the plant species in their area that have insecticidal properties. There are about 1, 600 plant species known to possess pest-control properties, and encouraging farmers to use indigenous plant materials, rather than chemical pesticides will reduce costs and may be safer. Such plants with insect repelling properties include tobacco, pyrethrum, onion, garlic, chillies, the castor oil plant and the neem tree.

Integrated pest management (IPM)

The above systems, which completely eliminate the use of chemicals, may not be suitable under all conditions. It has been found that on a large scale, a judicious use of pesticide is often necessary. IPM draws upon a number of different pest management methods – combining some of the above methods with selective use of pesticides.

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Box 18: Traditional and biological control of pests in Malaysia

Traditionally, farmers controlled paddy field diseases using only locally available materials. Some of the methods used include:

- **Pokok gorah:** a smooth, hard-skinned fruit which grows on the edge of kampung (villages) and river banks. Farmers stick branches with leaves in every corner of the paddy field, where it is believed that the 'heating' nature of the leaves prevents the worms from disturbing the paddy plants.
- **Skins of lemon, lime and pomelo:** fresh or dried, it is thrown into the paddy fields. The acidic content of the skins prevent disturbance of the paddy plants by paddy pests.
- **Kitchen ash:** villagers, especially those who work the paddy fields, keep the ashes from the kitchen for use as a poison against paddy worms. The ash is used only in paddy nurseries (*tapak semaian*) where, apart from killing worms or insects, it acts as a fertiliser for the plants as well as breaking down the soil.
- **Pinang leaves** are cut into half and only the tail-end of the leaves are used. The leaves are tied together with the yellow bamboo shaped like a T.
- **The stems of tobacco plants** are thrown into the paddy fields. It is believed that the foul smell drives away the worms that destroy the paddy plants.
- **Paddy husks** that have been burnt white or black and discarded by rice mills are used by farmers to destroy paddy worms. The husks are sprinkled in the fields or other places attacked by pests. It is believed that the reaction from the husk destroys the paddy disease. Furthermore, the husks help to break down the soil and act as a fertiliser.

Box 19: Bio-control for soil fertility

A case study from Nepal

Nepalese hill farmers sustain soil fertility and increase crop yields using the leaves of a local tree called *asuro* (*Adhatoda vasica* or *Jusiticia adhatoda*) as green manure in paddy rice, potato and corn fields. The leaves are chopped and applied to the surface of fields or flooded paddies prior to planting, where they rapidly decompose. Farmers report that the application of *asuro* leaves to potato fields not only increases yields, but also controls termite infestations.

The *assuro* tree thrives both in prolonged drought or heavy annual rainfall, and tolerates infertile as well as alkaline soils. It has insecticidal, fungicidal and herbicidal properties in addition to its ability to add nutrients to the soil. *Asuro* leaves also kill mosquito larvae in standing water. Paddy rice treated with *asuro* at the rate of 10 tonnes of leaves per hectare outyielded rice treated with chemical fertilisers by almost 40 per cent.

Green manuring in India

Until recently, many Indian farmers relied on farmyard manure and compost as the main organic source of recycled nutrients on their farms. However, since these traditional organic sources have become both scarcer and more expensive, many farmers are increasingly focusing on growing leguminous green manure crops on their own land. Although these crops do not actually recycle any nutrients, they are rich in nitrogen, improve the soil structure and are cheap in monetary terms. A crop commonly used in India is *Sesbania aculeata*. Depending on circumstances, it produces between 8-25 tonnes of fresh organic matter per hectare while providing some 60-90kg of nitrogen (equivalent to 3-10 tonnes of farmyard manure). It grows on water-logged and alkaline soils and should be sown immediately after the onset of the rainy season.

Elimination of pesticides: a case study from Bangladesh

Summary: Through the non-application of chemical fertilisers on her family farm, Salima and her husband demonstrate the benefits to be gained from organic farming, in their particular case, through increases in their fish stocks as well as a much-improved rice harvest.

Background

Bangladesh relies heavily on rice as its major food source, but cannot grow enough to feed itself. Despite the dependence of the country's predominantly rural population on fish to supply more than 70 per cent of their annual consumption of animal protein, the average annual consumption of fish has declined in recent years. The main reasons for this are increased use of pesticides, reduced access to monsoon season flood plains by fish due to new roads and flood control embankments, and overfishing.

CARE-Bangladesh introduced integrated pest management (IPM) into ongoing rice projects in a bid to increase overall food production. Rice pests can normally be controlled by the rice field's own ecology, which comprises a complex population of potential pests as well as predators and parasites of these pests. The predator-prey relationship was enhanced for the farmer's benefit through non-chemical means. Fish were cultivated in the rice fields of small farmers and appeared to have a significant effect on the yield of rice. Much of the increase in rice production was due to better water management induced by the presence of fish.

Organic success

A typical example of a farm family that stocked fish was Salima's family from Manikgonj, 60kms from Dhaka. Salima sold her chicken to buy hatchlings which they stocked in the rice field. Salima and her husband did not apply any pesticide in the rice field, although they had always done so previously.

Some months later the paddy field was full of fish and the rice crop appeared to be better than before. At the time of harvest they collected 700 fish from the small plot and their yield of rice grew from 330kgs to 400kgs, an increase of 23 per cent. After the second season in the rice fields, the fish grew to a much larger size and were able to spawn onto the roots of a water hyacinth placed by Salima in a small, deep area of the paddy.