





BAIF DEVELOPMENT RESEARCH FOUNDATION

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This manual

The aim of this manual is to highlight a range of topics that are essential for environment-friendly farming. The main text is supplemented with relevant facts, statistics and definitions as box items.

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Sustainable Farming

1. Introduction

World agriculture has undergone a major transformation during the past four decades. Production per unit area of land has increased as a result of the adoption of improved farming practices. In India, as in other countries, per ha yields of almost all the crops have increased several folds. These remarkable increases have been achieved with a package of practices that includes the use of external inputs and improved crop varieties. This form of energy-intensive agriculture uses fertilisers for crop nutrition, agrochemicals for plant protection and mechanisation for farm operations. These practices may yield short-term economic gains, but lack long-term ecological sustainability.

Sustainability, therefore, is vital to our approach to today's agriculture. Interest in sustainability has been growing over the vears out of the concern for our fastdepleting natural resources. Of particular concern is agricultural land and irrigation water, the quality and quantity of which have been declining almost unchecked. Unsustainable farming practices have rendered vast areas of land unsuitable for cultivation and plunged groundwater to alarmingly low depths. In such a scenario, the ultimate goal of development initiatives is not only to meet the immediate needs of the rural poor, but also to reverse the trend of natural resource depletion. Achieving this goal requires adoption of sustainable farming practices.

Survival

India's food grain production has increased from 48 million tons in 1951 to 200 million tons in the year 2000. The sustainability goal for India is to ensure the survival of its rich species diversity in an environment unharmed by human activity.

Species profile of India

Species	Number
Flora	45,000
Plants	15,000
Fauna	75,000
Mammals	350
Birds	1224
Reptiles	408
Fishes	2546

More than 3000 higher plant species in the country are in some degree of threat.

About 150 of them belong to the 'endangered' category.

India is one of the 12 megadiversity centres of the world and is home to 167 crop species and 320 wild relatives of cultivated crops.

2. Crop Production Systems

A farm production system may have a single crop species, more than one species or one combining crops and animals. Growing the same crop species over and over again usually leads to a rapid decline in the sustainability of the land. Inclusion of different crop species and animals in production systems improves sustainability. Cropping systems where more than one species is grown simultaneously within a season in intercropping or in sequence in a crop rotation during a year are desirable because of their greater sustainability.

Most small farmers do not depend solely on crops; they also have livestock in their production systems. This integration of crops and animals within a farm is called a mixed farming system. In such systems, interaction among production components is essential for the attainment of sustainability. The interaction in a farming system, for example, is the use of straw and other harvest residue as fodder while returning dung and animal waste to the cropping area to maintain or enhance soil fertility.

In recent times, this systems approach is further enlarged to include trees. This is called agroforestry, which is a system combining annual crops, trees, other perennial herbs and animals. Although agroforestry systems resemble traditional farms in many ways, their design combines intensive management with sustainable resource use to maximise production per unit area of land.

Crop production systems

Monocropping: growing the same crop every season in almost the entire farm

Intercropping: having more than one crop on the same land at the same time

Crop rotation: growing crops one after the other in a planned sequence

Mixed farming system: livestock / poultry with crops in the same farm

Agroforestry: a system that combines perennial species, annual crops and small animals. Pasture grasses, horticultural crops, multipurpose trees and medicinal herbs are the important perennial components of agroforestry systems

Agroforestry systems are based on constituent species or spatial arrangement of species in the field.

Silvipasture is the combination of forestry trees and pasture; alleycropping is the growing of crops in the alley between tree rows.

3. Sustainability

Sustainable agriculture or farming has many definitions, probably because of the different aspects on which individuals place emphasis. Nevertheless the essence of most of them is the same: achieving yield stability, reducing input use, conserving natural resources and enhancing the environment. In fact, field experiences help understand the meaning of sustainability better than definitions.

There are many examples of successful sustainable farming. A farmer struggling with declining yields, in spite of following high-input modern agriculture, reverted back to natural farming practices and realised production stability. Another succeeded in converting a barren wasteland into a lush green farm of fruit trees and annual crops. The experience of a third farm is that it incurred heavy financial losses while relying on a single crop species year after year, but became profitable by including several crops, trees and livestock in the farming system. The success of all these farms was not due to a single factor, but a combination of practices that resulted in increased farm output as well as sustainability.

3.1 Resource use

Achieving sustainability in agriculture requires making efficient use of physical and environmental resources that are used in crop production. The relevant physical resources for this purpose are water, land and material containing crop nutrients. These resources

A definition

Sustainable agriculture is the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving the natural resources

Sustainability concerns

Monocropping increases the incidence of pest and disease outbreaks, depletion of certain nutrients and yield decline in the long run

Soils lose their ability to naturally replenish fertility because of the adverse effects of agrochemicals on beneficial soil organisms

The use of heavy machinery for cultivation operations results in excessive soil erosion as well as the formation of hardpan

The area of land afflicted with serious soil problems of salinity and alkalinity in the country is 8.5 million ha

are usually limited in availability. On the other hand, environmental resources such as light and carbon dioxide are in abundance. The efficiency with which resources are used for producing biomass and the sources from which some of them are obtained determine the sustainability of crop production systems.

3.2 Efficiency

Food and other material of plant and animal origin are primarily biomass, which is the product of combining carbon dioxide and water with energy from sunlight. Only a fraction of the available light energy is harvested into biomass by crops. Inclusion of perennial species in a farming system can help increase this efficiency. Similarly, appropriately designed farming systems can increase the efficient use of land, nutrients and water. Annual crops, for example, occupy the land only during a part of the year, usually for about four to five months in the rainy season. If a post-rainy season crop is grown on the same land with irrigation or on leftover soil moisture, it almost doubles the period of land occupied by crops. This is further improved if a third crop is raised, but it is rare in dry areas.

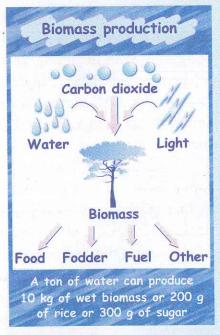
The increase in the number of days the land is occupied by crops in a year also increases the light, water and nutrient use. In this regard, perennials have a distinct advantage as they occupy the land throughout the year. Roots of most annual crops absorb only the water and nutrients in the upper 30 cm layer of the soil. But in tree-based

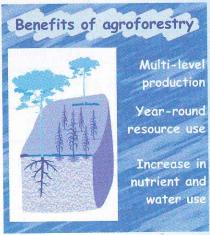


Groundwater is like a global bank account from which the world is overdrawing; 66% of that overdraft is in India

Out of the land area of 329 million ha in India, more than 130 million ha is wasteland

Current global deforestation rate is 23 ha per minute or 12 million ha per year





systems, roots reach deeper soil layers, thereby enhancing water and nutrient use efficiency. The result of increased resource use efficiency is more biomass production, a key determinant of sustainability.

3.3 Source

Requirements for crop production, such as water and nutrients, can be obtained from internal or external sources. In the case of water, the primary source is the moisture remaining in the soil. The origin of this water may be rainfall or irrigation. Sustainability of a farm is high if it meets its water requirement internally. This would require harvesting the rainwater and saving it in the soil or in water bodies like ponds and wells within the farm. Water thus collected should be irrigated with adequate moisture conservation practices. This enhances the sustainability of the farm, as it does not have to depend on external sources for irrigation water.

Crop nutrition can also be met to a large extent from internal sources through recycling and the use of biological inputs. When a farm uses chemical fertilisers, besides the farmer depending on an external source, there are other factors that affect sustainability. The use of energy for the production and transport of fertilisers, non-renewability of some of the raw materials used for their production and the adverse effects of chemical application on biological activity of the soil have a negative effect on sustainability. Similarly, chemicals used for crop protection also reduce farm sustainability.

Annual runoff and erosion Runoff Production Soil loss mm tons/ha system 43.6 0.45 Groundnut 9.1 0.10 Leucaena G. nut - Leuc 19.9 0.22 agroforestry

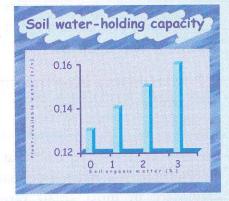
Agroforestry

and mulching

Land under the annual crop, groundnut, suffers much more soil loss than that under leucaena tree. Combining these two species in agroforestry reduces erosion which is further improved by mulching.

1.4

0.06



Chemicals increase crop yields, but they...

pollute the environment
taint food with residues
contaminate water bodies
cause yield decline later on
affect soil biological activity
add to cost of food production
use non-renewable raw material

4. Achieving Sustainability

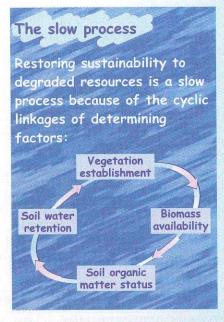
Sustainability in agriculture is not achieved through a single or few actions, nor is it realised in a short span of time. There is often a tendency to introduce a few practices for one or two cropping seasons and claim that sustainability has been achieved. Unfortunately, this does not happen that easily in nature. Agricultural sustainability is the combination of many farming practices, persisted with over a long period of time, and is the result of hard work and determination. It does not end at a particular stage; one has to keep on improving the practices and solve problems as and when they arise. In order to achieve agricultural sustainability, a farmer has to (a) minimise external input use, (b) maximise benefits from natural processes and (c) optimise the use of internal resources.

4.1 Minimising external input use

a. Water

Water is the most critical input for dry land agriculture. It is a resource that is managed carelessly in most small farm situations. Every farm must attempt to retain as much rainwater as possible within its borders. This would require physical structures like bunds and farm ponds, and soil management to improve water-holding capacity. Water loss by evaporation can be minimised by mulching and establishing trees as windbreaks. Growing crops that require less water also minimises water requirement.

In spite of all precautionary efforts, many farmers have to resort to irrigation





equirém	ent (mn
Flood	Drip
300	184
90	42
1760	970
2150	940
	Flood 300 90 1760

Water use efficiency of flood irrigation is about 35% while that of drip is 90%

because the water received through rainfall is simply inadequate. In such situations, they can still save water by adopting efficient irrigation methods. Water use efficiency can also be improved in most crops by irrigating at critical stages of crop growth.

b. Energy

Modern agriculture uses up huge amounts of energy, most of which comes from external Inputs such as fertilisers and sources. pesticides take up large amounts of energy during their manufacture, storage and transport. After they reach the farm, there is further energy requirement for application with implements and power sprayers. Similarly, pumping water, ploughing, weeding, harvesting and threshing make use of energy. Although these operations cannot be done away with, the quantum of energy used can be minimised with practices such as zero or minimum tillage and the use of energy-efficient farm implements.

c. Fertilisers

Every crop removes substantial amounts of nutrients during the time it is in the field. If the productivity of the land is to remain unchanged, the nutrients removed by the crop have to be replenished. In the past, this happened naturally in traditional farming systems because frequent long fallow periods allowed the land to get back its fertility. Moreover, incorporation of straw and other harvest waste helped maintain the fertility. Presently, however, the pressure on land has forced continuous cropping without a fallow. This is further aggravated by not returning any biomass back to the land

Water for crops

Water requirement to produce one ton of maize or sorghum grain is usually in the range of 600-1500 m

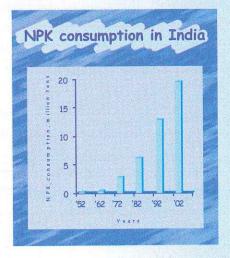
Quality of irrigation water is becoming a major concern as its sources are polluted with chemicals and salts

Water stress during the active branching / tillering stage, and at flowering seriously affects yields

Energy in agriculture (MJ/ha)

Energy	1970	1992
Diesel and		
electricity	345	4379
Human		
and animal	2937	2493

Agriculture is increasingly becoming dependent on external energy sources of diesel and electricity



because the harvest residue is used as fodder and fuelwood. Consequently, nutrients depleted by continuous cropping have to be replenished through external application of chemical fertilisers. Modern agriculture is heavily dependent on the application of fertilisers that result in impressive increases in crop yields, usually within a single cropping season.

The preferable option to replenish soil fertility is to apply organic manures, but they are generally unavailable in required quantities. Their cost per unit of nutrient, kilogram of nitrogen for example, is more than that of fertilisers. Because of their bulkiness, transport and field incorporation costs are also high. Fertilisers have become an alternative in such a situation. Minimising the use of fertilisers with the aim of increasing sustainability is not an easy task. It has to be done gradually, in combination with increased application of organic matter and biofertilisers.

d. Seed

Traditionally, farming communities produced their own seed and exchanged among themselves. Seed from one year was stored and sown the next year. This also served the purpose of germplasm conservation. Over the years, seed production has become a specialised activity and nowadays most farmers are dependent on commercial seed suppliers. As a result, many native crop varieties have been lost and biodiversity has been reduced. Improved varieties, though high yielding, tend to be susceptible to pests and diseases. In many



Genetic diversity of India Rice ... 50,000 varieties Sorghum ... 5000 varieties Mango ... 1000 varieties Pepper ... 500 varieties Cattle ... 27 breeds Goat ... 22 breeds

species, the trend has been to introduce hybrids instead of varieties. Unlike varieties, hybrids do not produce seeds that are high yielding like their parents. Therefore, farmers have to buy seeds from the commercial suppliers every year.

Relying on a few crop varieties or hybrids and having to buy seed regularly from external sources is an unsustainable practice. A sustainable option is for each farmer to produce at least some of the seed Awareness has to be created among farmers about the value of native crop varieties so that their protection becomes a community initiative. Farmers can achieve this, individually or as a group, by taking the responsibility of maintaining seeds of a particular crop or variety. Of particular interest should be seed of varieties that are not easily available elsewhere. During some seasons, when rains fail or the crop is affected by pest outbreak, local varieties yield more than the improved ones. Therefore, the safer option is to have a mixture of species consisting of both native and improved varieties.

e. Agrochemicals

Most improved crop varieties have been developed with the primary objective of high yields. In this process, their ability to protect themselves against pests and diseases has declined, necessitating the extensive use of crop protection measures. It is here, agrochemicals have played a major role in controlling pests, diseases and weeds. While ensuring high crop yields, agrochemicals are also responsible for causing pollution,

Declining diversity

Whereas 30,000 varieties of rice were grown in India 50 years ago, most of the production now comes from less than 50 varieties

In China, 10,000 wheat varieties were cultivated in 1950, but the number of varieties in use had come down to 1000 by 1975

The decline in the diversity of maize in Mexico is such that only 20% of the varieties cultivated in the 1930s are grown at present

Chemicals in agriculture

Indian agriculture used about 50,000 tons of agrochemicals in 2000–01

Annual crop losses due to pests, diseases and weeds have been estimated to be about Rs. 50,000 crores in the country

Of the 700-plus chemical pesticides currently in use, 33 are extremely, 48 are highly, 118 are moderately and 239 are slightly hazardous to human health

contaminating food and destabilising ecosystems. Additionally, they add to the cost of production and increase the dependence of farmers on external inputs.

The efforts of a few farmers in a locality not to use agrochemicals will be futile; it cannot succeed unless farmers in a very large area use non-chemical means of crop protection. A practical approach would be to use chemicals only when they are absolutely essential, and to depend on biological and cultural measures for routine crop protection.

4.2 Maximising beneficial processes

a. Photosynthesis

Photosynthesis is the natural process in which carbon dioxide in the atmosphere is fixed with water and light energy to form carbohydrate. This natural process is the first stage of biomass production. Human food, fodder or feed for animals, fuelwood, timber and organic manure for soil fertility are among the many uses of biomass. Biomass needs are traditionally met through crop residue, trees on farm and community lands and forests. However, availability of biomass from non-agricultural sources has been declining as a result of deforestation and uprooting of trees.

Reliance on an external source like forest for biomass is an unsustainable practice. Another factor affecting sustainability is the low priority farmers give for incorporation of biomass for improving soil organic matter. The strategy should be to maximise carbon fixation so that there is

Chemical pollution

Agrochemicals are among the leading pollutants of the environment in India and many other countries

Coconut water, cow urine and many fermented extracts have hormonal properties and can be used in agriculture

Number of plant species having biocontrol properties

Property	Number
Insecticidal	1000
Anti-feedant	380
Repellent	300
Growth regulator	30

Energy

India is heavily dependent on biomass energy and the annual requirement of fuelwood is 80 million m

Only about 5% of the available solar energy is converted into chemical energy in plant biomass production

An annual crop produces about 10 tons of dry biomass in a season of four months while a crop like sugarcane produces more than 20 tons during a 12-month period

adequate biomass even for purposes that are low in priority. Trees, perennial vines, herbs and species growing on residual moisture produce biomass even during the dry season. Therefore, they should be included in a treebased farming system to maximise carbon fixation.

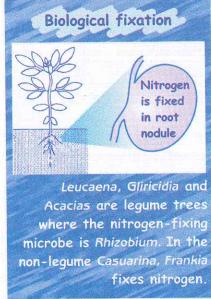
b. Nitrogen fixation

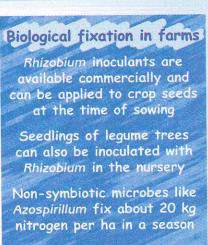
Being a constituent of proteins, nitrogen is essential for all life forms. Although the air around us has 79% nitrogen, most organisms do not have the ability to use it directly. Fortunately, a few microorganisms convert the gaseous nitrogen in the air into a form that can be used by other plants. This process is called biological nitrogen fixation.

Some nitrogen-fixing microorganisms form symbiotic relationships with certain plants in which the microorganisms provide nitrogen and in exchange receive energy from the plants. Plants having the ability to form such a relationship with these microorganisms are called nitrogen-fixing plants. The most widely known plant-microbial association is between legumes and *Rhizobium* bacteria. Pulse crops such as pigeonpea, greengram and blackgram as well as multipurpose trees like leucaena, gliricidia and sesbania are among the legume species of importance.

There are legume-Rhizobium associations that fix more than 200 kg nitrogen per haper year. The quantities fixed under tropical conditions are usually 20-50 kg nitrogen per haper year because of high temperatures. This beneficial process has to be taken advantage of in agriculture by







including pulse crops and tree legumes in cropping and agroforestry systems, respectively. *Azatobacter* and *Azospirillum* are other nitrogen fixing microorganisms that are used widely in agriculture.

c. Biomass breakdown

Besides nitrogen fixers, many others engage in activities that benefit agriculture. Significant among them is the biomass breakdown by earthworms and microorganisms. In nature, biomass is continuously broken down to release its constituents. The nutrients among these constituents are absorbed by plants and reassembled into biomass. Although biomass can be broken down by physical and chemical methods as well, it is the biological breakdown that is important for sustaining agriculture. The key biological agents in this regard are microorganisms and earthworms.

Methods of composting make use of microbial proliferation for the breakdown of organic matter. In commonly used methods, microorganisms found in nature bring about the composting. This, however, may be a slow process at times because microorganisms in the atmosphere have to come in contact with the material being composted and multiply in large enough numbers for active composting to begin. Dung hastens this process as it is a rich source of microorganisms and their nutrients.

Nowadays, earthworms and microbial cultures are used to accelerate the process of biomass breakdown. Although all earthworms break down biomass, efficient

Burning breaks down biomass rapidly, resulting in the loss of organic matter and nutrients like nitrogen.

Composting reduces such losses by inducing biological breakdown of biomass under controlled temperature, aeration and moisture.

Fermentation is a more controlled breakdown of biomass that minimises loss of nutrients and organic matter.

Composting requirements

Required	Obtained by
Material size	Chopping
Nitrogen	Bran, dung, urine
Temperature	Heaps <30 cm tall
Aeration	Turning, air vent
Organisms	Earthworm, EM

Composting

Biomass dumped into a pit composts on its own in the crude method. There is little or no turning of the material, but pipes may be inserted for aeration. This method requires 6-8 months for composting. Regular turning for aeration reduces the time required to four months. In improved methods like NADEP biomass, dung and soil are placed in layers in aboveground enclosures. This shortens the time required to two months and improves the quality of compost.

species among them have been identified for wider use. Earthworms are particularly effective when crude biomass has to be broken down. Their activity results in microbial proliferation, aeration and mixing of materials. If the favorable temperature and moisture for worm activity are maintained, vermicomposting usually results in high quality organic manure within a reasonable period of time.

A microbial option available for breaking down biomass into organic manure is the Effective Microorganisms (EM) technology. It involves the use of a culture solution containing naturally occurring beneficial microorganisms. The important microorganisms in EM are yeast, lactic acid bacteria and photosynthetic bacteria. Depending upon the substrate and environmental conditions, the breakdown process with EM is totally or partially fermentation. Therefore, the loss of biomass in the form of heat is greatly reduced. EM can also be used as a soil spray to increase nutrient release from soil, but this must be accompanied by regular incorporation of organic residues to prevent the depletion of natural soil fertility.

d. Nutrient and water mobilisation

Another benefit of microorganisms is the ability of some of them to help increase nutrient and water uptake by crops. Mycorrhiza and phosphate solubilising bacteria are soil microorganisms that mobilise the phosphorus in the soil and increase its absorption by plants. In addition to water, the extensive network of mycorrhizal structures in the soil absorbs

Vermicomposting

Earthworms are used for biomass breakdown. As turning is not done, height of heap/bed has to be less than 50 cm to minimise heat build up. Sometimes material is pre-treated before introducing earthworms. Time required for vermicompost to be ready for use is usually 6-12 weeks.

EM fermentation

Inoculant of EM having aerobic and anaerobic microbes is used for breakdown. Beds of less than 50 cm height preferred to minimise heat build up. Biomass is mixed with bran and dung, and moisture adjusted to about 30%. Beds are firmed up and kept covered. The ensuing anaerobic fermentation produces high quality manure in four weeks.

Fermentation requires quality biomass, a nitrogen source like bran or dung, and suitable moisture and temperature. If these cannot be met, mixing the biomass with dung and EM inoculant and turning the heap regularly produces compost in 4-6 weeks.

nutrients. These nutrients are passed on to crop roots, thereby enhancing the effectiveness of crops to utilise soil resources. Efficient strains of these soil microorganisms are used as biofertilisers in agriculture.

e. Species antagonism / repellence

There are organisms - insects, fungi, bacteria and viruses - that are predatory or parasitic on crop pests and disease-causing organisms. Similarly, birds feed on pests like caterpillars and control them. This antagonism between species is made use of to protect crops biologically. Associated with this is the spray of extracts of species such as neem and tulsi on crops as insect repellents. If the benefits of using natural organisms and substances for crop protection are maximised, the need for unsustainable chemical use can be minimised.

4.3 Optimising internal resource use

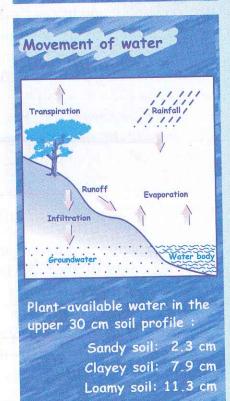
a. Water

There is often a tendency to over-exploit the resources within the farm to an extent that they lose sustainability. A familiar situation in the dry tropics is the ground water. If this water remains unused, it is a resource remaining idle when there is a pressing need to use it for food production. On the other hand, unregulated use of ground water leads to drop in water levels and eventually the wells dry up. The optimum level of ground water usage is one where the depletion is matched by annual recharge during the rainy season. This may mean that a farmer can cultivate only a portion of the land under

Biological crop protection

Freshly prepared water extracts of crushed neem seed, tulsi leaf, garlic and chillie can be sprayed against many pests. The same material extracted by fermentation with Effective Micororganisms (EM) can be stored for 2-3 months.

Organism	Acts as
Trichogramma spp	Pest
Coccinella spp	Predator
Bacillus thuringensis	Parasite



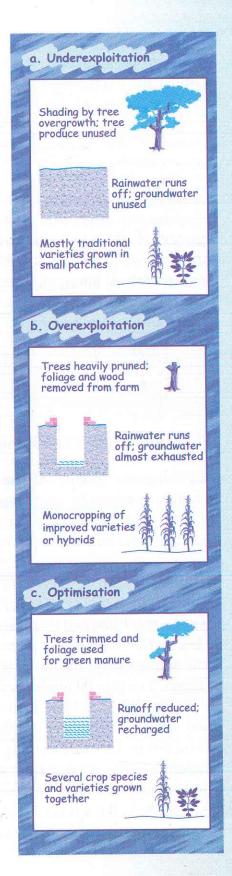
irrigation. Nonetheless it is better than cultivating the entire farm for a few years and thereafter not having any water for agriculture.

b. Soil

The living part of a soil is the organic matter, mainly the humus and soil organisms. Managing the soil for sustainability requires maintaining the soil organic matter content. Believing it to be an improved practice, many fertile soils are ploughed frequently with heavy implements, exposing the organic matter to processes of degradation. Fertilisers and agrochemicals inactivate soil organisms and thereby inhibit the soil's ability to restore natural fertility. Optimum use of soil for sustainability requires conserving moisture by mulching the surface and adopting minimum tillage. Incorporation of organic matter should be a regular practice. Additionally, favorable soil conditions for microbial activity must be maintained by minimising the use of agrochemicals.

c. Perennials and native crop varieties

A feature of traditional farms is the presence of trees and other perennial vegetation on or around cropland. If there are too many of them, agricultural activities may suffer due to shading and other hindrance. But removing all of them is also undesirable, as it can expose the land to elements of weather. The optimal management strategy is to retain the trees, but trim their branches so that shading is minimised. Presence of trees will also reduce moisture and soil loss by acting as windbreaks. The tendency to favour



newly introduced high-yielding varieties results in the depletion of valuable native germplasm. The strategy should be to introduce improved varieties and systems of agriculture while ensuring adequate safeguards for existing vegetation and native varieties.

4.4 Farming and natural cycles

Agriculture is sustainable when it is in harmony with natural cycles, especially those of carbon, nitrogen, water and energy. Their release into atmosphere and waterways by practices such as burning and tillage has a negative effect on sustainability. Conserving them together in biomass of plants, animals and soil organic matter should be the goal of sustainable farming.

5. Sustainability Estimation

Preserving the quality of land and other resources associated with farming is the primary requirement for sustainability. Although most farmers know this, livelihood compulsions force many of them to indulge in practices that are not necessarily sustainable. In this context, an index useful to any farmer is the sustainability value of his or her farm. However, not often does one come across quantified sustainability values of farms. The general tendency is to describe the sustainability as high or low, depending upon the practices adopted. sustainability is not something that can be measured with a standard tool like a weighing machine and expressed in units of tons or metres. It is a relative measure for the comparison of two or more farms.

Waste not ...

If water is available, farmers tend to irrigate more than the required amount, believing it will increase yields. In the long run, however, excessive irrigation leads to problems like water logging, nutrient toxicity and soil salinity.

The estimated nutrient loss through soil erosion is equivalent to almost 75% of the fertiliser produced in the country. Controlling soil erosion saves nutrients, water and land.

The ideal nitrogenphosphorus-potassium
fertiliser ratio for most
crops is 4:2:1, but the
general usage is 10:4:1.
Excessive nitrogen is a waste
because it gives luxuriant
early growth, but does not
result in high grain yield.

More than 30% of fresh fruits and vegetables produced in India is lost due to poor post-harvest handling and storage. Similarly, 20-30% of the grain harvest is lost in storage because of unsatisfactory storage conditions. Rodents and insects are the major storage pests.

The sustainability of a farm is the summation of many components. There is no standard or absolute measure for these components. Nevertheless scores can be assigned in For example, it is relative terms. known that a farm having crop diversity has greater sustainability than one practising monocropping. Accordingly, in a scoring system of 1 to 10, a farm growing seven crop species during a season will have a higher score than one growing only two species. But then, perceptions of people with regard to sustainability vary: a person may grade a farm growing three different species 8.0 out of 10; another person may want the farm to grow at least ten species to earn a value of 8.0. Similarly, views of people may differ as to whether the emphasis should be on ecological or economic parameters.

Notwithstanding the differing views, a specific scoring scheme for a set of components can be developed for the comparison of farm sustainability. Such a comparison is valid so long as the same scoring scheme is used to estimate all the farms being compared. They cannot be used, however, to compare sustainability indices estimated with a different scheme elsewhere. The first step in sustainability estimation is to identify the relevant components and assign them scores based on a predetermined scoring scheme. summation of these scores, expressed as a percentage, is the sustainability index of the farm. The status, scores and sustainability index values for four components of a farm while it was practising traditional farming and after the introduction of intensive agriculture are shown in Table 1.

Table 1. Sustainability changes from traditional to intensive farming.

Components	Traditional farming (Status 1)	Score	Intensive agriculture (Status 2)	Score
1. Species diversity	Several crops, many trees and herbs, but not all are useful	6.0	Monocropping, some trees / shrubs retained along border	5.0
2. Crop	Green manure, farmyard manure and a little fertiliser	8.0	Fertiliser use increased; manure / compost still used	6.0
3. Crop protection	Crop rotation, natural pest repellents, and some chemicals	7.0	Mostly chemical-dependent, crop rotation practised	6.0
4. Farm output	Not enough food for family, fodder and fuel inadequate	3.0	More than enough food and fodder, so surplus sold	9.0
Total score (out of 40)	24	Totalscore	26
Sustainabilit	y Index = 24/40 × 100	60	Sustainability Index	65

Components favouring sustainability during the period of traditional farming were species diversity, reliance on manures for crop nutrition and use of non-chemical methods for crop protection. However, farm output was low and food and fodder produced were inadequate to meet even the farmer's own requirements. The farm had a sustainability level of 60% (Status 1 in Table 1), but its main weakness was not being able to produce enough.

As a result, the farmer had to introduce intensive agriculture to increase production by adopting monocropping with high doses of chemical inputs. The outcome of these interventions was the increase in farm output to an extent that the surplus could be sold. In terms of sustainability, the large increase in the

score for farm output more than compensated the marginal decline in the sustainability of other components. Hence the overall sustainability index of the farm rose to 65% (Status 2).

The drop in scores observed for some components, though marginal, is indicative of where the farm is headed and a forewarning of more serious consequences likely to follow. If remedial measures are not initiated in time, the farm may end up with a sustainability index of 45%, which is the undesirable Status 4 (Table 2). In fact, this situation is worse than where the farm was before the introduction of intensive farming technologies. Knowledge of such a possibility will help initiate corrective measures so that the farm sustainability can increase as in Status 3.

Table 2. Desirable and undesirable farming situations.

Components	Desirable farming (Status 3)	Score	Undesirable farming (Status 4)	Score
1. Species diversity	Few crops with legumes in the system, trees for biomass	5.0	Monocropping, emergence of weedy shrubs	4.0
2. Crop nutrition	Biomass recycling for manure; rational use of fertiliser	7.0	Very high doses of fertiliser; hardly any manures available	4.0
3. Crop protection	Integrated pest control with minimum chemical use	7.0	Dependent on repeated high dosage of chemical application	3.0
4. Farm output	Crop yields high; besides food, biomass for other uses	9.0	Just about enough food for family: high production costs	7.0
Total score (d	out of 40)	28	Totalscore	18
Sustainabilit	y Index = 28/40 × 100	70	Sustainability Index	45

Ideally, only technologies of proven sustainability should be introduced, but this does not always happen. Efforts to increase food or profit inadvertently lead to undesirable consequences. Hence the sustainability status should be assessed periodically to identify weaknesses and take remedial measures. In the above example, such measures raised the sustainability to a desirable 70%.

The ultimate goal of the farmer should be to raise it further. This would require a production system with several crops, recycling of biomass and adoption of biological methods of crop protection. Failing to do so could lead to dependence on high dosages of chemicals, soil problems such as salinity and water logging, and crop yields that are unattractive in relation to the input cost and effort. Naturally, farmers will be unable to sustain such a high-input farming operation for long.

The above example illustrates the sustainability changes with regard to four components. In reality, the sustainability of a farm is influenced by many components. They can be broadly categorised into bio-physical and socio-economic components. Bio-physical components determine the ecological stability of the farm while socio-economic components reflect the social well being of the farm family.

Examples of these components are given in the table below.

Bio-physical components	Socio-economic components
>Species diversity	>Livelihood assurance
>Crop nutrition >Crop protection	>Market opportunities
>Soil and water >Farm energy	≻Gender issues
>Farm output	>Information sources

Sub-components can be identified under each of the main components. For example, the sustainability of species diversity can be estimated in terms of its sub-components a) number of crop species grown in the farm, b) presence of non-crop vegetation within the farm and c) cropping strategies like crop rotation and tree-based farming adopted by the farmer.

A standard list of components or sub-components for the purpose of farm sustainability estimation does not exist. It has to be developed based on the key determinants under a set of conditions and an appropriate scoring scheme should be drawn up. Estimates of sustainability indices can be used to advise farmers on the weaknesses of their farm, the consequences of continuing with them and what they can do to change the situation. Because this is not usually done in small farms, they experience problems in the long run.

6. Organic Farming for Sustainability

Among the sustainable practices, the most widely known is organic farming. Other such options are permaculture, nature farming, biodynamic farming and ecological agriculture. All of them resemble organic farming in many ways. The main feature of organic farming is that it does not allow the use of chemicals as fertilisers or as pest and disease control agents. As a result, the produce is free of chemical contaminants and has high consumer preference.

Organic farming requires the use of biological inputs for crop production, especially biomass, as the major source of crop nutrients. Unfortunately, biomass availability is a constraint in dry areas and this limits the prospects for organic farming. There are farms practising organic farming with manure obtained from external sources. Continued reliance on such sources for long is an unsustainable practice. External organic sources may be relied upon for some time, but eventually the requirements should be met within the farm.

7. Sustain the Interest

Sustainability in farming cannot be achieved through short-term measures or within a short period of time. Those wishing for it have to sustain their interest and determination through experiences that may not always be pleasant. But the eventual reward is a resourceful farm that has the ability to withstand environmental stresses and meet not only the current needs, but serve the future generations as well.

Emerging concerns

The effect of changes in the environment on agricultural production is a matter of great concern. Important among them are the heat, the hole and the haze.

Heat

Greenhouse gases like carbon dioxide and methane in the atmosphere are increasing rapidly. The ensuing rise in temperature may affect crop production directly by its effect on crop physiology or indirectly by affecting land and water availability.

Hole

Ozone layer protects the earth from excessive ultra violet rays. Recently, certain chemicals depleted this layer and made holes in it. Entry of ultra violet rays through the holes can affect the production of crops that are sensitive to these rays.

Haze

Excessive release of dust particles, chemicals and emissions can form a haze in the atmosphere. If that happens, it can affect agriculture by changes in weather patterns, acid rain and crop growth.

BAIF BOOKSHELF

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About BAIF

BAIF is a voluntary organisation engaged in the implementation of rural development programmes that offer opportunities of gainful self-employment to the rural poor. A priority of these programmes is the promotion of appropriate sustainable farming technologies that rehabilitate degraded natural resources and improve their productivity. Among the introduced technologies is tree-based farming that helps increase production on wastelands. In these tree-based farming systems, a small farmer can harvest fruits and nuts from horticultural crops, food and fodder from annual crops and fodder, fuelwood and green manure from multipurpose trees. Besides the range of products harvested, these systems increase the efficiency of resource use and add stability to ecosystems. The long-term benefits of BAIF's interventions are ecological and economic sustainability for the well being of small farmers, the largest segment of the population of India.

Established in 1967 by late Dr. Manibhai Desai, a disciple of Mahatma Gandhi, BAIF believes in sustainable resource management and associated human values. Together with tree-based farming, the programme spectrum of BAIF includes cattle development, water resource management, improved agriculture, community health, women empowerment and environmental protection. Combinations of these activities are packaged as comprehensive tribal rehabilitation or rural development programmes. Presently, the benefits reach more than one million rural families in about 15,000 villages spread over eight states in India.