**However, they
also may judge the project from their own value system that may not fit project purposes. The point is to observe and measure how well objectives have been achieved and to determine if there have been other expected or unexpected results. Investigation of the causes of success and failure will help future planners to improve project designs.**

Evaluations are especially helpful if the project methods have been experimental, with no past history of success or failure in a similar environment. Planners and project managers should exchange information with those in nearby regions in order to compare methods and results.

A SUMMARY CHECKLIST

*** Are project objectives measurable and realistic?**

*** Are they compatible with community needs?**

*** Were community members involved in establishment of project objectives?**

*** Was a cost-benefit analysis which includes an environmental analysis used to help select the best project design to achieve objectives?**

*** Is an effective technical assistance and training program integrated into the project design?**

* What assistance can be provided by financial, governmental, and other institutions or groups?

* Is there a reasonable plan to monitor and evaluate the project?

This chapter has outlined a planning process. Chapter 4 contains some suggestions about the broad framework of understanding needed for planning. The chapters following explore some of the technical issues that might be encountered in planning an agricultural project. Chapter 10 concludes with a checklist for sustainable projects, examples of traditional systems, and a look at long term evaluation.

CHAPTER 4

OTHER CONSIDERATIONS FOR PLANNING

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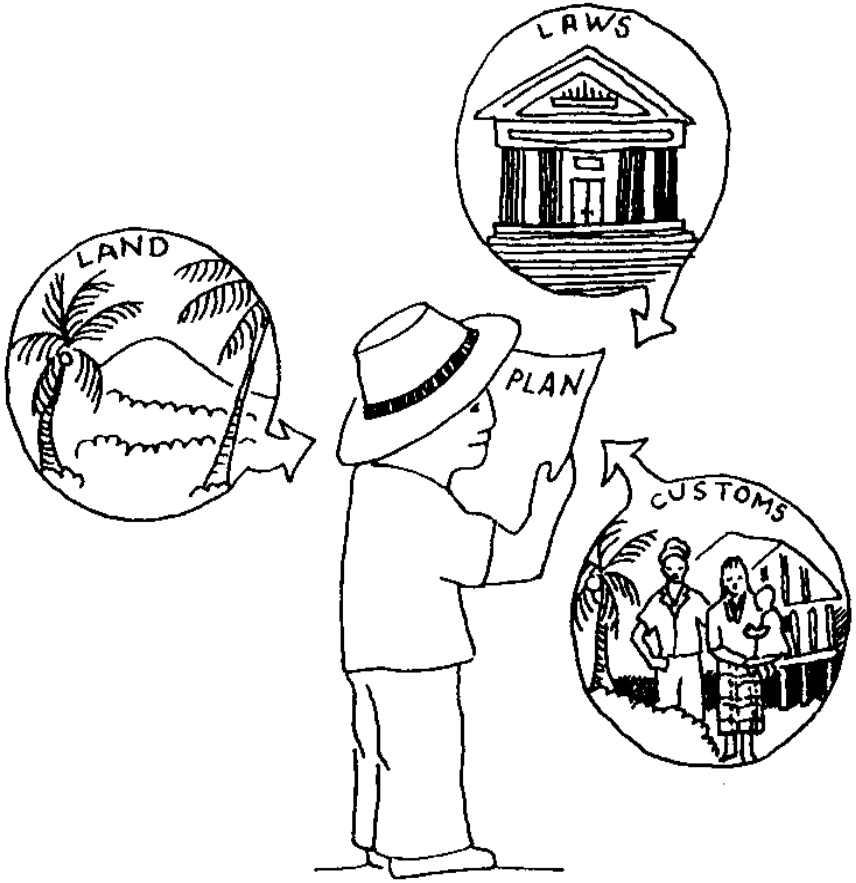

INTRODUCTION

Chapter 3 reviewed the process of planning. The suggestions in that chapter, however, are not a prescription. They need to be adapted to the local situation. In addition, there are some other considerations that affect planning a project. There are some natural limitations, involving biological and physical relationships. These will be discussed in the chapters providing technical background for

planning. This chapter will discuss legal constraints to agricultural activities; socio-cultural considerations; and related to these, the special considerations of women's activities in agriculture.

<OTHER CONSIDERATIONS FOR PLANNING>

Legal limitations, unlike natural limitations, are established by people to meet specific conditions and, therefore, can be modified by people in response to changes in legal, social, and economic situations. Socio-cultural conditions have been established over time by practical use. Considerations concerning women in agriculture are not new but their importance is newly recognized.

LEGAL CONSIDERATIONS

Among the important institutional considerations in planning small-scale agricultural projects are the laws that affect the use of land and other resources.
Often in the rural areas of developing countries the legal status of land ownership is ambiguous. Vast areas of farm land used by low-income farmers is unregistered, with usage passing from generation to generation without legal protection. These lands are usually marginal, lacking fertility and irrigation, and otherwise undesirable for agricultural production. Where statutes are clear with respect to land ownership and distribution, for example, in a land reform program, enforcement is always mixed. There may be a correlation between the level of poverty of the low-income farmer and the issue of security of land titles. Political considerations color the

execution process producing uneven results. Also land prices can make it difficult for governments to acquire land for distribution. As regards laws that address ownership, use, and the sale of the products of natural resources, the development worker may be faced with dual legal systems in some jurisdictions: a common law system inherited from the colonial period and customary law deriving from indigenous concepts of ownership and usage. In parts of Africa, for example, land ownership may reside in the person of the tribal chief. Accordingly the use of the land and distribution of products will be subject to his regulation. At the national level a price structure established by the government to hold down the cost of food in the urban areas may make a small-scale commercial agricultural project unprofitable. Law always affects development projects at some level, too often with negative results.

A development worker should consult with local authorities to be sure that a small-scale agricultural project can be implemented within the existing land tenure jurisdiction and patterns of land ownership.

SOCIO-CULTURAL CONSIDERATIONS

Legal considerations, as discussed above, are formal rules that guide social conduct. Less explicit, but equally important, are guidelines derived from other cultural practices of a society--from tradition, religion, and folklore. As with laws, these social considerations must be reflected in the decision-making process. Failure to do so can lead to adverse reactions that can severely affect the project. Cultural considerations determine, in part, the options available

to a planner of environmentally sound small-scale agricultural projects. From the flood plains of the Mekong River Basin to the fragile desert environments of northwestern Africa, situations can be found in which social patterns affect implementation of particular agricultural practices.

Social constraints are often difficult to assess. They are not usually susceptible to easy solution and are often ignored. However, to do so is folly. To increase the possibility of environmentally sound resource management in agriculture, it is essential to include local people in planning objectives of the project. Training and public education are also important.

Other socio-cultural factors such as household relationships, division of labor between men and women, and decision making in relation to agricultural activities are sometimes critical to project planning and should not be overlooked. Some projects increase the burden on women by increasing their responsibilities and working time involved, when the objective of the project is to reduce the burden.

WOMEN AND AGRICULTURE

In many areas of the developing world, women constitute one-half or more of the agricultural labor force and may be responsible for producing as much as 90 per cent of the food. It is essential to recognize this in those regions where women traditionally are the farmers, producing food crops, managing small livestock, and sometimes cultivating cash crops. Women need to have a role in decision-making about agricultural innovations and development interventions. They need to have access to training, extension

programs that are sympathetic to their traditional role, and they need credit.

In the past, when new options existed, they have been more often available to men rather than women. For a large majority of women, especially in rural areas, innovation, training, and development interventions have not improved their quality of life. In many cases just the opposite effect has been the result.

DIVISION OF RURAL LABOR BY TASKS,
BY SEX: ALL AFRICA

Percentage
of Total
Labor in Hours

Men Women

Cuts down the forest; stakes out fields 95 5
Turns the soil 70 30
Plants the seeds and cuttings 50 50
Hoes and weeds 30 70
Harvests 40 60
Transport crops home from the field 20 80
Stores the crops 20 80
Processes the food crops 10 90
Markets the excess 40 60
Carries the water and the fuel 10 90
Cares for the domestic animals 50 50

Hunts 90 10
Feeds and cares for the family 5 95

Source: UN Economic Commission for Africa, 1975, Women in Africa.

If there is to be a shift to a better understanding, the following are some of the constraints that need to be addressed:

*** Most of the power is in the hands of men; therefore men have access to new opportunities.**

*** Women tend to be viewed as consumers rather than as producers.**

*** Women's chores such as food processing, fetching water and fuelwood, child care, and cooking are generally not considered to be productive contributions to the economy.**

*** When these chores offer income-producing potential, they are usually undertaken by men.**

The preceding table demonstrates the division of labor between men and women in Africa, where women traditionally play a dominant role in agriculture.

ECONOMIC CONSIDERATIONS

The local people and the development worker must select from alternative plans of action. Choosing among alternatives requires some economic considerations. Economics involves patterns of analysis, sometimes referred to as benefit/cost analysis.
To make an economic analysis of alternative courses of action, three general objectives form a basis of choice. The objectives are to:

- provide the greatest possible benefits for the costs incurred
- bring the best possible rate of return on investment
- achieve a specified "production goal" at the least cost

Analysis of these objectives can give the local people and the development worker a better understanding of the economic implications of selecting a particular course of action.
To analyze the first two objectives, likely consequences of alternative courses of action and costs of implementation must be determined to the extent possible. Some information can be obtained from previous local experience. If the course of action is newly adopted, the development worker can seek available prediction techniques.
To satisfy the third objective, goals should be established for various levels of production. These goals are most effective if set according to values of local residents, coupled with long-range goals derived through the political process.
Benefits/costs analysis has often been viewed as a purely financial approach rather than as a tool to use in a more human-centered development process. This view can be dangerous for at least two reasons: 1) it can cause the planner to overlook the

importance of economic effects; 2) it can lead to a failure to recognize that cultural, social, and ecological factors also can (and should) be considered in benefits and costs terms. Planners must be able to bring a benefits/costs approach to all facets of the planning process if they are to be able to judge project feasibility in terms of impact on the community.

PART III: BACKGROUND FOR PLANNING
CHAPTER 5

SOIL MANAGEMENT
THROUGH REDUCTION OF EROSION

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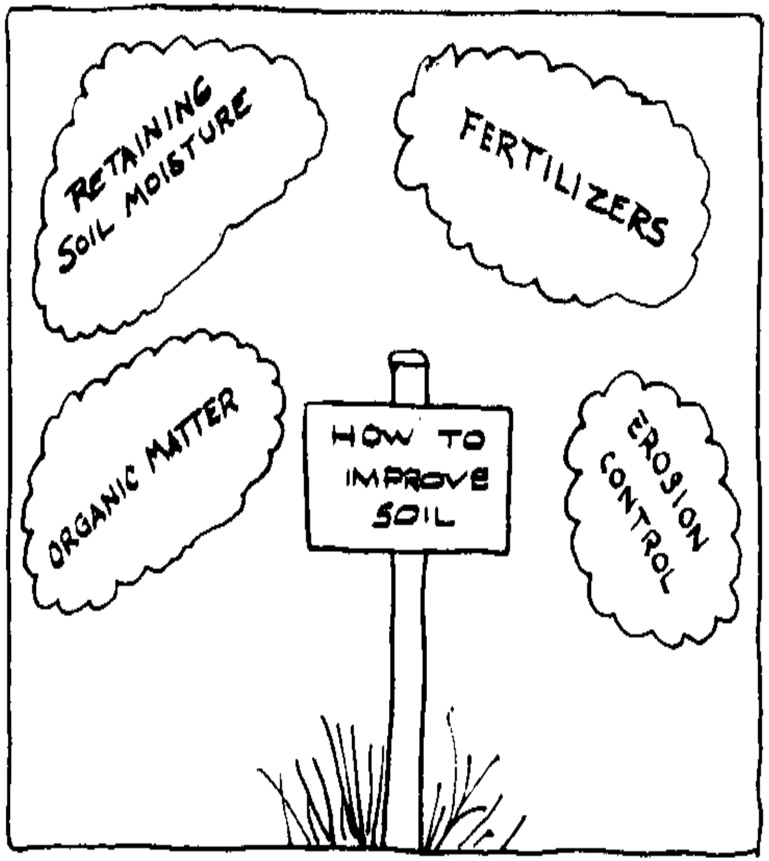

Soil contains the nutrients and water that plants need for growth and serves as the medium or substrate in which they grow. The primary purpose of soil management is to provide a continuously supportive and productive soil for plant growth through proper provision of water and nutrients and soil conservation practices. When the soil is left without vegetative cover, erosion may result. Since erosion is the most serious environmental problem facing many farmers around the world, this chapter provides background

for planning agricultural projects in areas that are prone or subject to erosion, and need controls to reduce erosion. Before beginning a project, it is necessary to understand the process of erosion and its effects both upon the project and the environment.

<SOIL MANAGEMENT THROUGH REDUCTION OF EROSION>

EROSION: WHAT IS IT?

Erosion is movement of soil by water, wind, ice, or other geological processes. It is a function of climate, topography (slope), soils, vegetation, and human actions, such as cropping methods, irrigation practices, and equipment use. Usually erosion control becomes more necessary as the slope of the land increases because the slope helps the soil to move.
There are three stages of water-caused erosion: sheet erosion, rill erosion, and gully erosion.

Sheet Erosion

Intense rainfall or large rain drops displace particles of soil. Topsoil is dislodged by this impact. As water accumulates, it begins to remove soil more or less uniformly over a bare sloping surface. Moving down the slope, the water follows the path of least resistance, such as channels formed by tillage marks, stock trails, or depressions in the land surface. Sheet erosion is the first stage of damage and as such can be hard to identify. Those seeking to develop a piece of land should check carefully for signs. One simple method for assessing erosion problems is to observe from the low end of the field what is happening during a heavy rainstorm; i.e., is the run-off water dark with accumulated soil?

Rill Erosion

Concentrated runoff may remove enough soil to form small channels, tiny gullies, or rills in a field. While rills are often the first visible sign of erosion, they can be covered up by tillage practices. Learn to recognize the signs of rill erosion and watch for them. Under continued rainfall, rill erosion increases rapidly. Steeper or longer slopes increase the depth of the rill. The erosion potential of flowing water increases as depth, velocity and turbulence increase. Sheet and rill erosion together account for most of the soil movement on agricultural lands.

Gully Erosion

As water accumulates in narrow channels, it continues to move soil. This is the most severe case of erosion and can remove soil to depths of 1 to 2 feet, or up to several hundred feet in extreme cases.

Laterite Formation

There is a widespread belief that tropical soils, once cleared, are irreversibly transformed into hardened plinthite or laterite. Actually, only a small proportion of tropical soils (for example, only 4 per cent of the land in the Amazon) is subject to laterite formation.

Where there is soft plinthite in the subsoil, and when the topsoil has been removed by erosion, hardening to laterite can take place. Therefore laterization is more likely to occur in soils where erosion is extensive.

SOIL LOSS

The main factors that affect erodability of a soil are the physical structure and chemical composition of the soil, the slope of the land and the management (how is it used) of the land. (FAO 5.3) Soil loss is directly related to the following:

- intensity and amount of rainfall
- quality of the soil and how much it is subject to erosion
- length of slope
- degree of gradient (steepness) of the slope
- quantity of vegetation cover
- kind of crop system (monoculture or crop associations and/or sequences)
- system of soil management (especially related to soil cover)
- erosion control practices (discussed later in this chapter)

These factors determine how much water enters the soil, how much runs off, and the potential impact for erosion. It is essential to evaluate present and potential erosion in planning a project.

EROSION BY WIND ACTION

In arid and semi-arid regions, wind erosion can be extremely serious. Topsoil blown away from the land can leave the land unproductive and increase the number of particles in the atmosphere, thus affecting local climate. Wind erosion can also:

- cover and kill plants
- disturb organisms living in the area
- increase labor and cost of cleaning those areas which are covered by soil
- reduce amount of solar energy (sunlight) available to plants
- increase evaporation, surface drying

Extreme wind erosion, coupled with climatic changes and human activities, can contribute to the formation of deserts. For example, people contribute to increased wind erosion and hasten desertification by cutting woody species for firewood, overcultivation, and other practices such as improper cattle management that leads to overgrazing. In many cases, such practices are the result of increased population pressures, but also because impoverished farmers are pushed to adopt these practices by social, political, and economic factors.

SOIL COVER AND WHY IT IS IMPORTANT FOR CONTROL OF EROSION

A good soil cover is the most important control of both wind and water erosion. A cover directly on the soil or close to it is the most effective. Soil cover serves the following functions:

- interrupts rainfall so that the velocity is slowed down before it hits soil particles thereby reducing splash and dislodging effects of rain

- decreases runoff velocity by physically restraining water and soil movement

- increases ability of the soil to store water by providing shade, humus, and plant mulch

- improves surface soil porosity by root systems that help break up the soil and facilitate water infiltration

The leaves and branches of a crop provide a canopy or cover over the soil and protect the soil from heavy rainfall and wind. For example, corn forms a canopy several feet above the ground. However, this crop leaves soil bare before seed germination and during early crop establishment. Shorter crops, such as some grasses or legumes (beans, vetch), and crops such as sweet potatoes and squash, provide cover closer to the ground surface and have an even better potential to reduce erosion. Soil loss from a grass and legume meadow is substantially lower than in a cornfield.

<CANOPY OF TREES AND CROPS>

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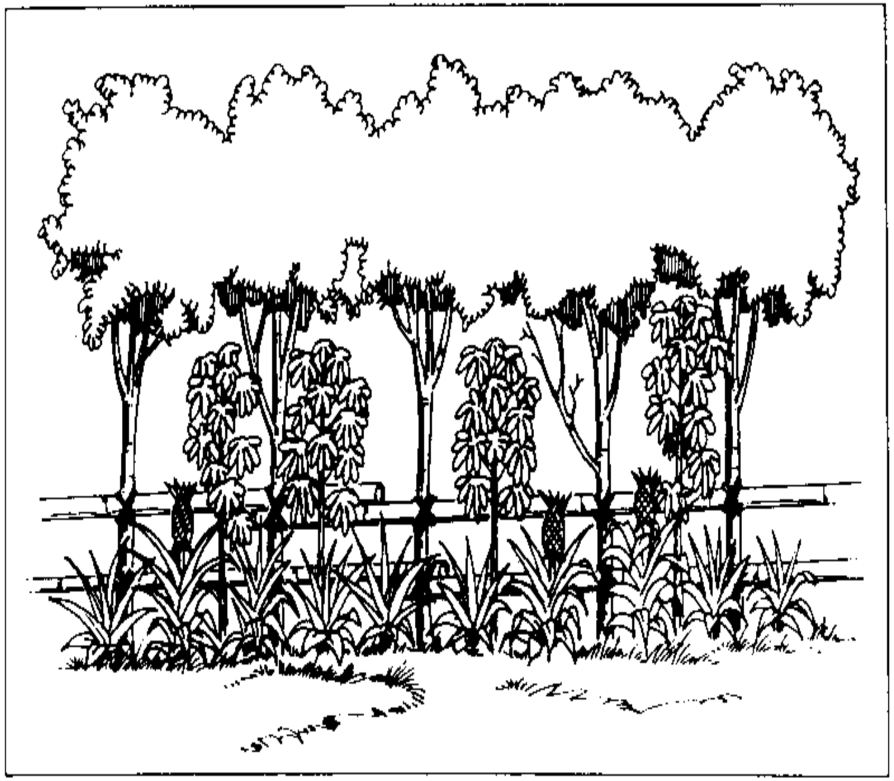
CANOPY OF TREES AND CROPS



Source: Sommers 5.8

Ideally, projects should be designed so that some kind of vegetative cover remains in place at all times. This may not be possible in all ecosystems. If an area is cleared, plan to cover the cleared area with vegetation as soon as possible. If this is not possible at least take time to check, and encourage weeds to grow naturally in the fallow field. This is helpful in three ways:

*** The cover reduces the possibility of soil erosion.**

*** The weeds can be plowed under to provide nutrients (green manure) for later crops and improved soil structure.**

*** The balance of the ecosystem may be reestablished to ensure that the disturbance will not have lasting, negative effects.**

HOW EROSION CAN BE CONTROLLED

Erosion can be controlled by reducing the mechanical forces of water or wind, by increasing the soil's resistance to erosion, or by doing both. Water erosion can be controlled by preventing splash erosion by providing crop cover or a layer of mulch (crop residue or other organic materials) through which the rainfall then trickles (infiltrates) into the soil.
Another means of preventing erosion by water is to constrain any run-off that continues to exceed the rate of infiltration. This can be done with physical barriers such as contour-bunds, tied-ridges, terraces reinforced by rocks, ridges, or living barriers composed of natural or planted grasses or shrubs. Strip cropping with furrows in between using sprinkler irrigation or trickle irrigation can also help control water erosion. Mulches and cover crops sometimes deter both water and wind erosion. Wind erosion can also be reduced by planting trees and/or shrubs as a windbreak. (See figure below) A windbreak in addition can provide other benefits (firewood, fodder,

food, wood poles) if multiple-use trees are planted. Stubble mulching is also used in some areas to control wind erosion.

<FIGURE 1>

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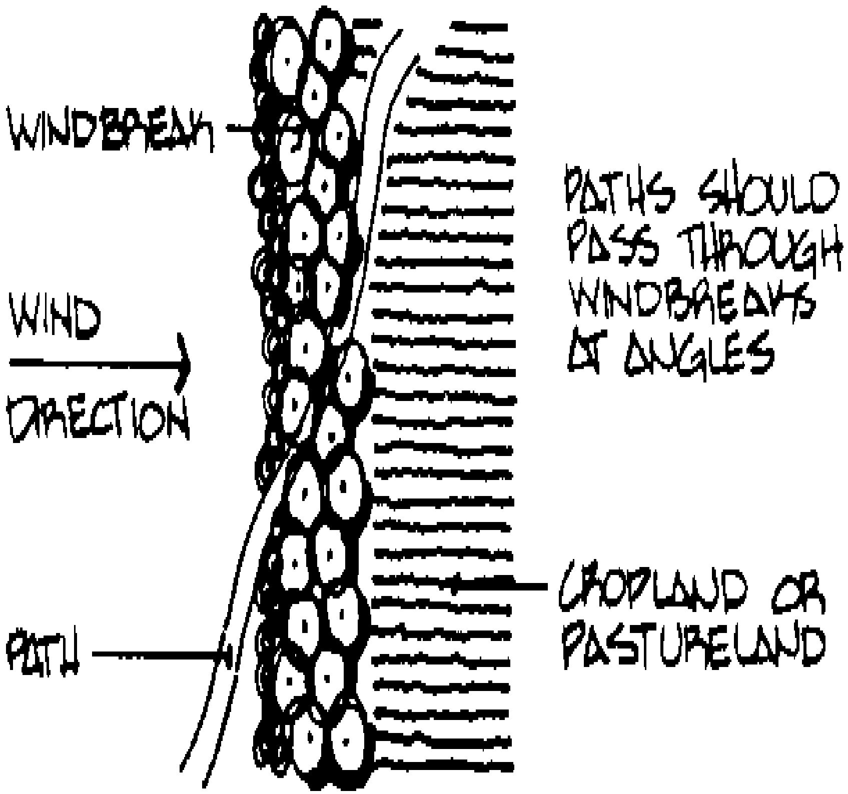

There are several ways to control erosion caused by water. The

implementation of each of these control measures may be a project in itself, or the measures may be included in agricultural projects.
Some common methods are:

- increasing vegetation cover
- using plant residues to protect soil (mulching)
- using improved tillage techniques such as conservation tillage
- rotating crops and planting cover crops
- reducing erodability of soil, for example, by adding organic matter
- planting deep rooted trees for slope stability
- using mechanical support carefully
- and other practices such as terracing, using diversion channels, contour plowing and planting, strip cropping, contour strip cropping, tie-ridging, and reducing of field lengths

HOW PLANT RESIDUES COMBAT EROSION

Plant residues are, for example, corn stalks, wheat chaff, weeds, and similar remains left in the field after crops have been harvested. They can provide effective erosion control by reducing the raindrop impact on the soil and reducing runoff.
The practice of leaving plant residues on the field is called mulching. Mulching is particularly useful for protecting young plants from high soil temperatures, retaining soil moisture, and contributing to soil fertility as the residues decompose.
Mulch can be left on the surface, or it can worked into the

topsoil by plowing, discing, or harrowing. When this latter practice is followed, the amount of organic matter in the soil increases and the soil structure or composition and water infiltration improve as well as does the water-holding capacity of soil. On the other hand, working mulch into the soil reduces the percentage of surface cover and loosens soil so that it is somewhat more susceptible to wind and water erosion. Some pests as well as disease-causing fungus and bacteria may thrive in the mulch and can be difficult to control.

The decision to plow plant residues into the soil or to leave them on the surface depends upon the erodability of the soil in the area, the kind of organic materials, the amount of runoff expected, and the tillage practices used. The cost and availability of the labor to do the plowing are also factors. Greatest protection from erosion may be provided by not plowing mulch into the soil. Yet, even when mulch is worked into the soil, more soil can be saved than would be possible if mulch were not used at all.

Some crop residues may have negative effects as a mulch.

Local farmers can be a good source of information on this point.

<EFFECTS OF MULCHING>

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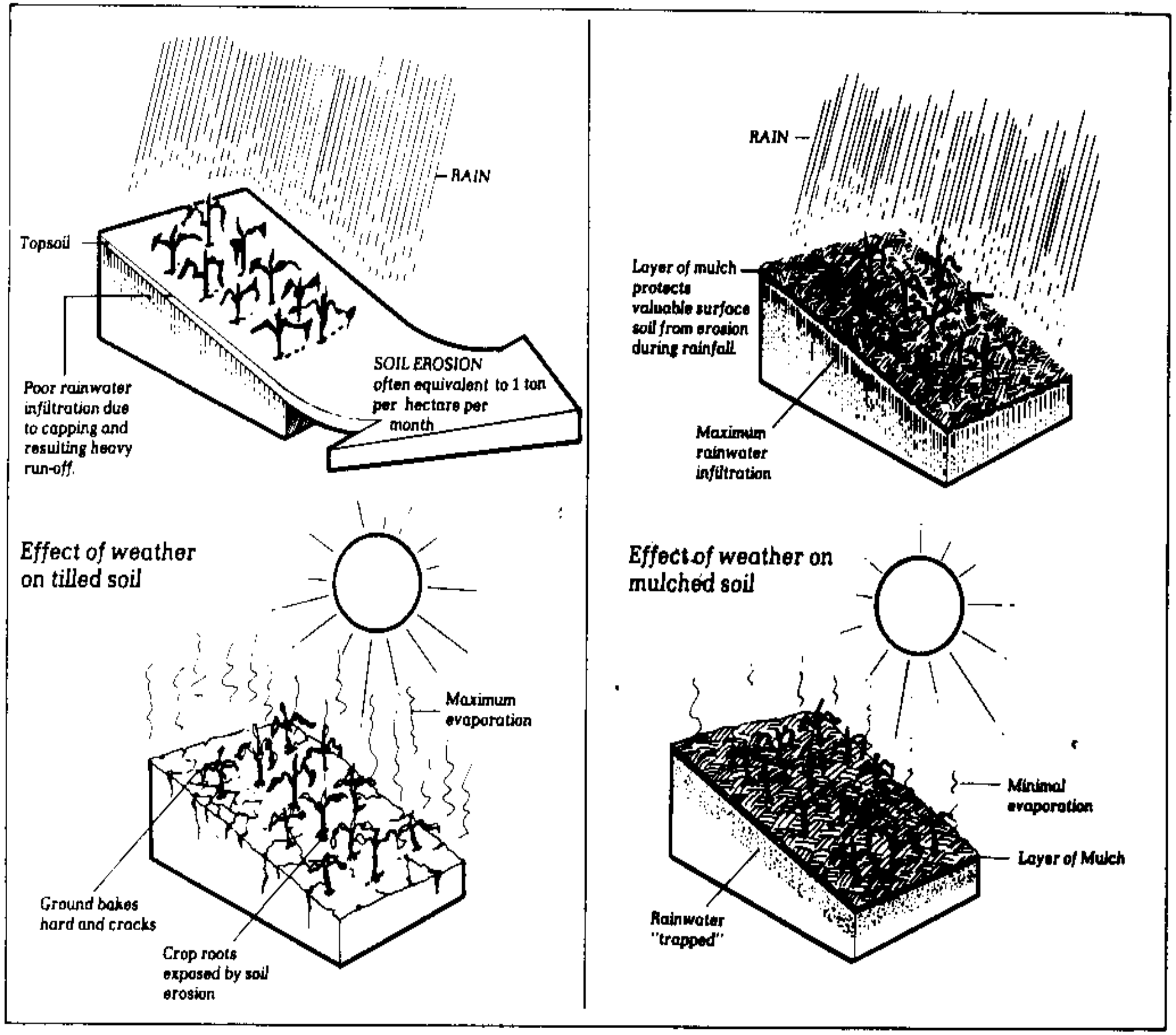
EFFECTS OF MULCHING



Source: Wijewardene and Waidyanatha 9.17

IMPROVED TILLAGE METHODS FOR EROSION CONTROL

As farmers are well aware, conventional tillage methods leave a bare soil surface and expose soils to erosion until the crop is established.
Tillage methods can affect the runoff velocity of water, the rate of infiltration of water into soil, and the degree of soil compaction. Compaction, which occurs naturally in soils with a high clay content, and hampers root and plant development, can be worsened by the use of heavy field machinery, thus further increasing the chances of erosion.
Following are three tillage techniques that can reduce erosion: reduced tillage, conservation tillage, and no-till.

Reduced Tillage

Soil is tilled as little as possible to produce crops under existing soil and climatic conditions. Fields may be plowed or harrowed, but with chisel plow rather than with moldboard plow.

Conservation Tillage

Plant residues are usually left on the surface as a mulch to control weeds and to conserve soil and water. Plowing and planting are done in one operation with crop residues mixed into the soil surface between rows.

No-Till

Crops are planted directly into the field or plot left untilled

after the last harvest. No-till is done by planting in narrow rows between previous crop residues. The surface mulch of weed and crop residues is vital to the sustained success of 'no-till' and reduced tillage systems. In the tropics, in addition to protecting the surface soil against the impact of raindrops, the mulch helps develop and maintain the soil surface and ensure rapid infiltration of water. In some regions no-till needs to be supplemented by carefully designed chemical weed control programs and increases in the rate of fertilizer application. Such additions require more capital and also sophisticated management and planning.

Studies indicate that erosion associated with conventional tillage can be reduced 50-90 per cent by a switch to any of the above conservation tillage practices.

Most development workers who work with farmers in rural situations and plan projects should become familiar with these practices, and new advances in this area. For example, improved tillage practices have been hampered in many areas by lack of low-cost, efficient tools for planting through the plant residue. However, new implements have been designed and tested to overcome this limitation such as the stick, the punch planter and the single row rolling injection planter (RIP), developed by the International Institute of Tropical Agriculture in Ibadan, Nigeria.

CROP ROTATION AND EROSION CONTROL

Crop rotation is one way to reduce soil erosion. Since the use of different crops in rotation reduces the amount of time a field is left without an adequate vegetative cover, erosion is reduced. In rotation of legume forage crops with non-forage crops, erosion can be reduced 25-30 per cent over continuous cropping. The forage crops can also supply nitrogen for the crops that follow. In addition, if the rotation is planned wisely, certain crops can be chosen for their ability to assist the resistance of soil to erosion under succeeding crops. The greatest of these residual effects is derived from grass and legume meadows. Because they are sod-farming crops, they provide cover and help build up the soil even when they are later plowed during conventional tillage. There may also be residual effects in rotations using non-sod-forming crops. For example, corn leaves soil less erodible than soybeans, but more erodible than small grains. In addition to planting crops with different harvest times, crops can be planted between rows of permanent plant barriers such as broomstraw, elephant grass, or tree crops such as Leucaena. This technique, called "alley cropping," will be discussed in Chapter 9.

SOME SUPPORT PRACTICES FOR EROSION CONTROL

Support practices for erosion control may require moving the soil, sometimes using machinery. The most common practices--contour plowing and planting, and terracing--are practiced on long and steep slopes. These practices reduce erosion by slowing down the velocity of water and its soil transporting capacity. In semi-arid regions, these practices or variations of them can be used for conserving water.

Contouring

Crops are planted horizontally on the contour of the slope, rather than up and down the slope. This practice has the effect of creating ridges across the land which reduce the rate of runoff. Because small barriers are provided by the rows the water moves less quickly, erosion is reduced, and the soil is able to absorb more water. Average rates of erosion on contour-farmed land are about 61 per cent less than on similar cropland planted without contours.

However, contour planting needs to be planned carefully. On a very steep slope or in areas of heavy rainfall and easily eroded soils, water can build up in each contour, spill over, and break across contour lines. The volume of water can build up with each broken row, and the result can be more erosion, not less.

Contour Strip Cropping

Contoured strips of crops are alternated to reduce the effect of row breakage. For example, when sod and crops are planted in alternating strips, the sod reduces water flow and serves as a filter to catch much of the soil washed from a strip crop row. Strips structured close to land contours give good erosion control.

Terracing

Terracing is a very old practice, especially in mountainous

areas. Terraces are costly in terms of the labor needed to build them and require constant maintenance. When used with contour farming practices, terraces are more effective for erosion control than strip cropping alone. Terraces reduce effective slope length and retain much of the soil moved between terraces. They can trap up to 85 per cent of the sediment eroded from a field. Terraces are also used in semi-arid regions for conserving both water and soil. However, in tropical climates where topsoil is thin, poor soil is sometimes brought to the surface. Raised beds also help control erosion.

THE EFFECTS OF SOIL MANAGEMENT/EROSION CONTROL

It is important to understand the relationship among soil, water, and methods for erosion prevention and control, in order to develop alternative land management techniques. The following questions are provided as a starting point for considering projects in which susceptibility of the soil to erosion is a significant limiting factor for crop production:

*** Would improved tillage practices provide better erosion control? If so, would there be obstacles--money, customs--or other constraints to changing practices?**

*** Is the site subject to wind or surface water erosion or land-slipping? For example, does the site have a steep slope? Is it a windy area without protective windbreaks? Is there evidence of past landslides?**

*** Are there periods during the year when the soil of the project site is unprotected by vegetative cover and subject to sheet, rill, or gully erosion?**

*** Will erosion cause silt to form in downstream water bodies such as streams, lakes, and reservoirs?**

*** Will use of mechanical equipment on the project site damage the soil structure and leave the soil more susceptible to erosion.**

*** What is the major factor limiting agricultural production in the area? Is erosion a major constraint to increased agricultural production?**

*** What are the social, cultural, physical and economic costs of erosion?**

*** Can the project be set up to include a training course for local project participants?**

*** How have farmers traditionally adapted to erosion problems?**

*** What other soil management practices may be appropriate?**

SOME ALTERNATIVES

Other tillage methods can be undertaken to protect soil from

erosion. These include:

- improving soil fertility
- timing of field operations
- plow-plant systems
- grassed outlets and grass waterways
- ridge planting with tie-ridges
- construction of ponds for runoff collection
- changes in land use
- long low bunds, e.g., in the Sahel

These practices are described in the following table, which is based on material from the U.S. Department of Agriculture and the U.S. Environmental Protection Agency. The left-hand column gives the name of the practice; the right-hand column describes the advantages and disadvantages of each as an erosion control method and describes the potential effects of such a practice.

SUMMARY OF EROSION CONTROL PRACTICES

Practices Highlights of Practices

No-till Most effective for grasses, small grains, and with crop residues; reduces labor and time required for agriculture; provides year-round control. Not effective when soil is too hard to allow root development.

Conservation tillage Includes a variety of no-plow systems to retain

some crop residues on surface; more adaptable than no-till but less effective.

Sod-based rotations Good meadows lose almost no soil and reduce erosion of the next crop; total soil loss is greatly reduced but is unequally distributed over rotation cycle; may aid in disease and pest control.

Crop rotation Much less effective than above; can provide more soil protection than a one-crop system; aids in disease and pest control.

Improved soil Reduces soil loss as well as increasing production fertility of crops.

Plow-plant systems Rough, cloddy surface increases the infiltration rate and reduces erosion; seedlings may be poor unless moisture is sufficient; mulch effect is lost by plowing.

Contouring(*) Can reduce soil loss up to 50 per cent on moderate slopes, less on steep slopes; less effective if rows break; cannot use large farming equipment on steep slopes; must be supported with terraces on long slopes.

Graded rows Similar to contouring but less likely to have breaks in rows.

Contour strip Rowcrops and hay in rotation in alternate 15 to cropping 30 meter strips reduce soil loss to about 50 percent of that with the same rotation that is only contoured; area used must be suitable for across-slope farming.

Terraces Reduce erosion and conserve moisture; allow more intensive cropping; some terraces have high initial costs and maintenance costs; cannot use large machines; support contouring and agronomic practices by reducing effective slope length and runoff concentration. In tropical climates where the topsoil is usually very shallow, terracing often leads to bringing to the surface, soil which is very poor. This can have worse effects than erosion.

Bund terracing A technique for terracing by creating bunds along contours, then planting seedlings on the bunds to create a terrace. This technique is used to replace labor-intensive terracing in Kenya and is called Fanya Juu (does by itself).

Alley cropping Rotations of crops are grown in between hedgerows of fast-growing leguminous shrubs or non-leguminous fallow shrubs planted along the contour with the hedgerows pruned from time to

time to provide mulch and organic residues.

Live mulch system Where crops are grown in rows on ground covered by leguminous cover crops that are killed by an herbicide along the rows where the crops such as maize are planted. Can minimize erosion on steep slopes; most suitable where there is adequate rainfall.

Grassed outlets Facilitate drainage of graded rows and terrace channels with little erosion; are costly to build and maintain.

Ridge planting Reduces erosion by concentrating runoff in mulch-covered rows; most effective when rows are across slope; earlier drying and warming of root zones.

Contour listing Minimizes row breakover; can reduce yearly soil loss by 50 per cent; disadvantages same as contouring.

Change in land May be the only solution in some cases. Where use other control practices fail, may be better to change to permanent grass or forest; lost acreage can be supplanted by intensive use of less erodible land. Leaving the land to fallow is a common practice in some areas.

Other practices May use contour furrows, diversions, sub-surface

drainage, closer row spacing, intercropping, and so on.

(*) A simple means of finding the contour is with the "A" frame technique. This method is described in a brochure by World Neighbors (see list of agencies in Appendix B). World Neighbors also has slides or filmstrip about the technique.

CHAPTER 6

WATER SUPPLY AND MANAGEMENT

An understanding of the relationship between water and agriculture is key to planning environmentally sound projects. With this knowledge a development worker can judge a proposed water supply or control practice in terms of its impact on the environment in which the agricultural project is taking place.

As the primary transport medium on agricultural lands, water can be both friend and enemy. Water carries or moves nutrients through the soil to plants and within the plants themselves. Water removes soil particles by the process of erosion. It also moves agricultural chemicals from the fields into the surrounding environment where they can cause serious problems. An understanding of how water moves and what its effects are on agricultural lands is the key to knowing how, when, and where a given project may interfere with these processes.

<THE WATER CYCLE>

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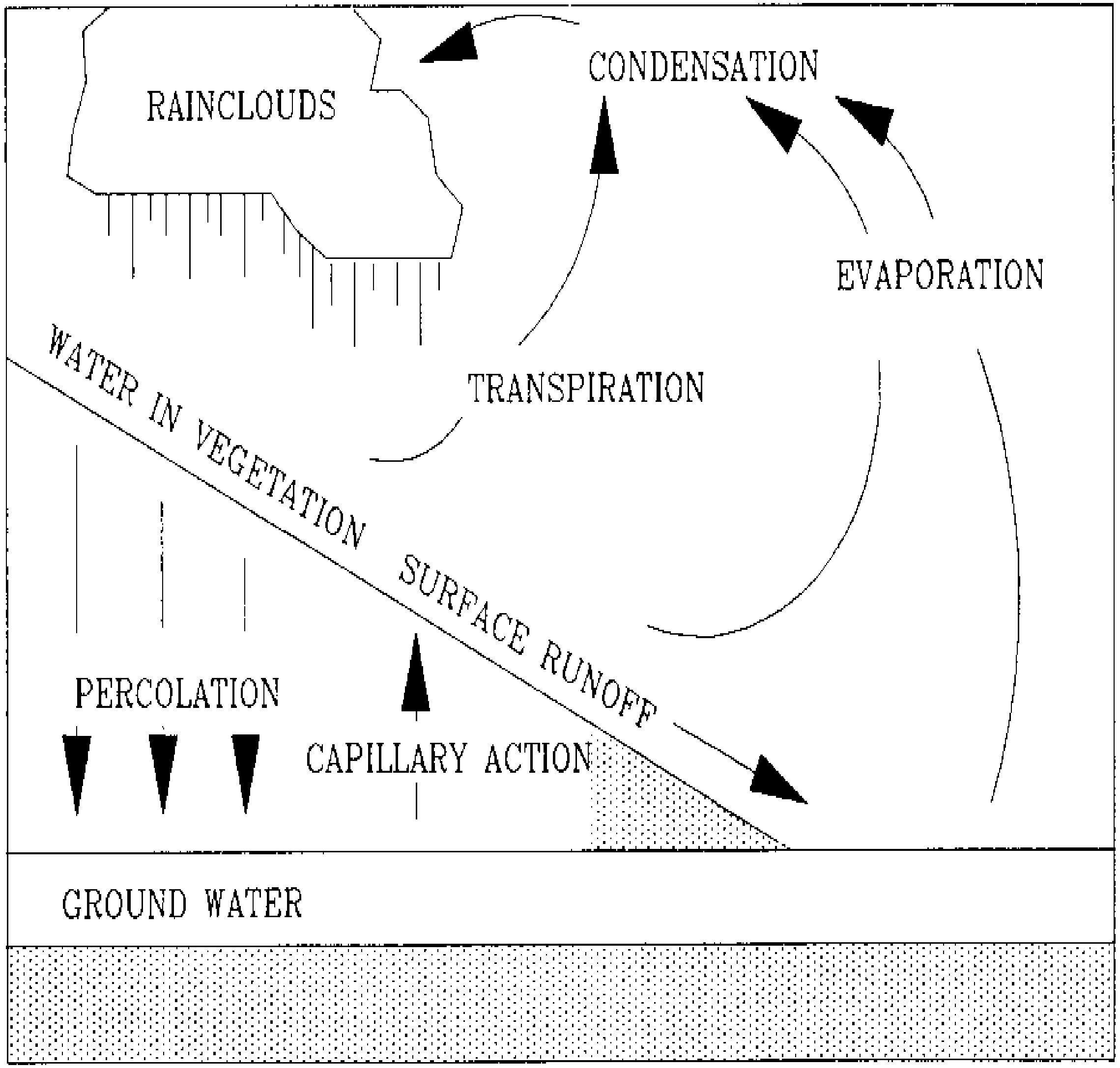
THE WATER CYCLE



THE MAJOR SOURCES OF WATER

Surface water

Lakes, ponds, streams, and rivers provide water to plants either indirectly through evaporation and later condensation over agricultural lands as rain, or directly, by tapping and channeling for irrigation purposes.

Rain

Rainfall is the climatic factor that most drastically affects agriculture in the tropics. Rain falls directly on plants and moves down, or percolates, through the soil to the roots and on to groundwater supplies.
The important characteristics of rainfall that affect agricultural growth are the amount, intensity, variability, and lengths of dry spells and of rainy seasons. The amount of rain varies greatly from season to season and from area to area. In many places, records--if kept--of the amount of rainfall can be used to identify patterns in the amounts of water available and to identify both flooding and drought cycles. It is helpful to establish the amount of rainfall and the amount of evaporation/transpiration (see glossary). In a climate with a well-defined wet and dry season, the growing season will begin when rainfall exceeds evaporation/ transpiration and continue until the soil water reserve is exhausted. Understanding the moisture patterns and any changes in the patterns is of crucial importance for developing cropping systems adapted to local rainfall conditions.

Groundwater

Water accumulates in the soil at various depths depending upon soil and geologic structures. These groundwater supplies are relatively permanent. Groundwater can move up through the soil by capillary action to become available to plants at times when there is not enough rain. Under drought conditions, however, this source may not help. Water held in deep pockets, called aquifers, can be made available by digging wells.

THE WATER BALANCE IN CROPLANDS

The water balance or amount available to the farming system over a specific period of time reflects factors affecting sources of water. What water is left in the soil around the root zone of the crops can be calculated by balancing the following:

- what is left of the water from the rainfall after runoff (water moving below the surface soil, for example, on top of an impermeable layer of clay, towards a stream)

- percolation below the root zone (water seeping down through the soil to the water table or the groundwater supply)

- evaporation (from the soil)

- transpiration (moisture given off by the crop)

The balance between rainfall and evapotranspiration initially determines the amount of water available for crop growth. When rainfall exceeds evapotranspiration the root zone is charged with water. As evapotranspiration begins to exceed rainfall, water available for crop growth decreases. Runoff and percolation also will affect the amount of water remaining in the root zone.
The objective of water management in agriculture is to minimize and utilize the runoff, percolation, and evapotranspiration.
Practices such as mulching and no-tillage can reduce evapotranspiration, whereas terracing can reduce runoff.

HOW WATER MOVES AND THE EFFECTS

Regardless of the source, water moves materials to and from the project site physically and chemically.

Physical Transport

Raindrops falling on unprotected soil dislodge soil particles and carry them over the surface of the land. This surface water runoff can be a major cause of erosion. Erosion has three negative effects:

- loss of valuable topsoil, making land less productive where runoff takes place (however, nutrient laden sediment may enrich soil in lowland areas)

- pollution of streams and lakes downstream from the project site by soil particles that accumulate and become sediment

- washing of fine particles into spaces between larger soil particles creating a physical block which reduces water percolation

Sediment from this process chokes streams, decreases the amount of light that can penetrate the water, and clogs the gills of fish and shellfish. Nutrients and pesticide chemicals adhering to eroded soil particles increase their polluting effects in the water. On the other hand, physical movement of the soil can have beneficial effects. For example, in flood plains many agricultural lands receive fertile top soil as a result of annual floods that transport soil from sites upstream.

Chemical Transport

Many minerals, nutrients, and pesticides or fertilizers and other chemicals are dissolved and carried in water (or leached) out of the soil. This occurs by surface and sub-surface runoff, and also by water seeping down through the soil (percolation). Sub-surface runoff picks up chemicals, nutrients, and sediment, and deposits them in surface waters. A number of negative effects can result from this chemical transport. For example, pesticides can kill aquatic organisms and fertilizers promote growth of algae that may pollute the water. The extent of the impact depends upon the amount of runoff, the chemicals carried, and their concentration in the surface water. Through percolation, water may carry soluble agricultural chemicals directly to wells or to surface streams as part

of the groundwater. Percolation may move nutrients beyond the root zone of plants. The amount and frequency of deep percolation depends upon the water storage capacity of the soil, the vegetative cover, the amount of runoff and rainfall, and the type of soil and geologic conditions below the root zone.
Percolation has beneficial effects as well. One of these is moving dissolved salts deeper into the soil. When this does not occur, salts can accumulate in the topsoil and eventually become toxic to agricultural plants.

THE IMPORTANCE OF IRRIGATED AGRICULTURE

Water management seeks to ensure the best use of available water. In many areas and in many small-scale agricultural projects, the major problem, at least initially, is inadequate water supply. A common answer is irrigated agriculture, although water conserving cropping systems and drought tolerant crops might also be appropriate.

Before a decision is made about irrigation it is important to know the amount and timing of rainfall that can be expected during the growing season and how rapidly this water will be depleted.
Many times even though rainfall appears to be adequate, its monthly distribution should be considered in relation to potential evapotranspiration.
For example, although total annual rainfall as shown in the figure below, is adequate for crop growth, moisture is in excess from September to May but inadequate from May through August, so irrigation is recommended during the period of peak evapotranspiration.

Agricultural lands are irrigated in many ways. The best method to use depends upon:

- supply of water available
- quality of water
- slope of the site
- infiltration and percolation rates of the soil
- water-holding capacity of the soil
- chemical characteristics of the soil (salinity, alkalinity, and so forth)
- moisture requirements of the crop
- weather conditions of the area
- economic resources of the farmers, especially for moving water to the field
- techniques for moving water to the field

<SIGNIFICANT PHASES OF THE WATER BALANCE IN A UNI-MODAL RAINFALL CLIMATE>

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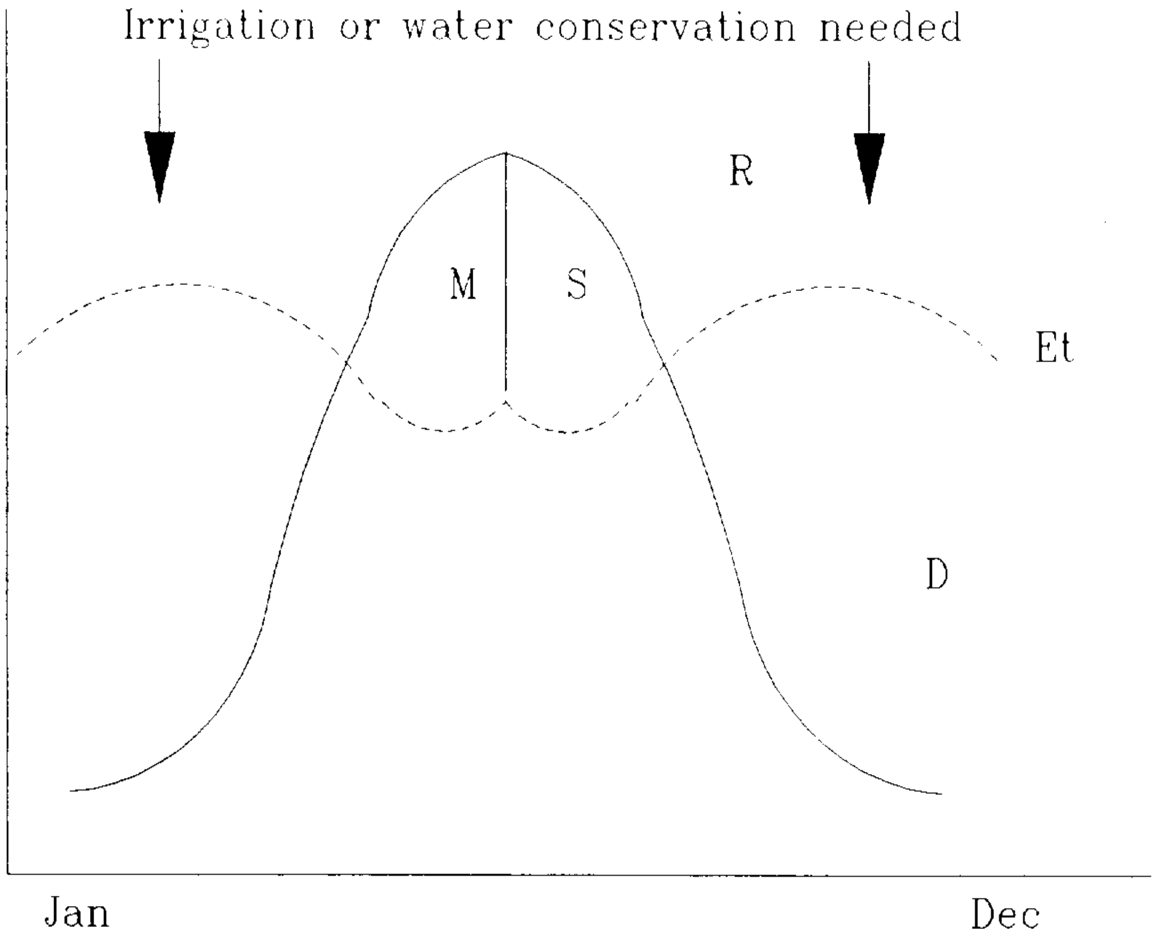
SIGNIFICANT PHASES OF THE WATER BALANCE
IN A UNI-MODAL RAINFALL CLIMATE
(R=rainfall, Et=potential evapotranspiration,
D=moisture deficit, M=moisture recharge, S= water surplus)



WHY IT IS NECESSARY TO PLAN IRRIGATION PROJECTS CAREFULLY

Irrigation projects can have far-reaching effects on the environment of a vast area. Irrigation can affect the water-table depth, water quality, soil characteristics, crop productivity, human health (the spread of diseases such as malaria and schistosomiasis), family structures and mobility patterns, economic status of farmers, water rights, and land ownership patterns. The land ownership issue is very important because once land is irrigated its value is increased dramatically and what was once marginal land, now becomes quite productive and desirable. If the land title is not secure in the hands of the low-income farmers, they could lose the land to an unknown registered owner. These possibilities should be carefully considered. Irrigation projects also can be affected by other factors. Control of water sources needs to be considered. For example, the watershed that will be providing water for the project should be checked to determine if the watershed is protected adequately to ensure water of the quality and quantity needed for proposed crops. Watershed development upstream from the project site could alter the water supply drastically, causing flooding, drought, fluctuations in seasonal flow, or water contamination. Other uses of water closer to the source can affect the supplies and possibly pollute the water.

USING SURFACE WATER FOR IRRIGATION

Using surface water for irrigation can have far-reaching effects. Irrigation water usually is diverted via canals, ditches, and channels from surface waters nearby.

<FIGURE 2>

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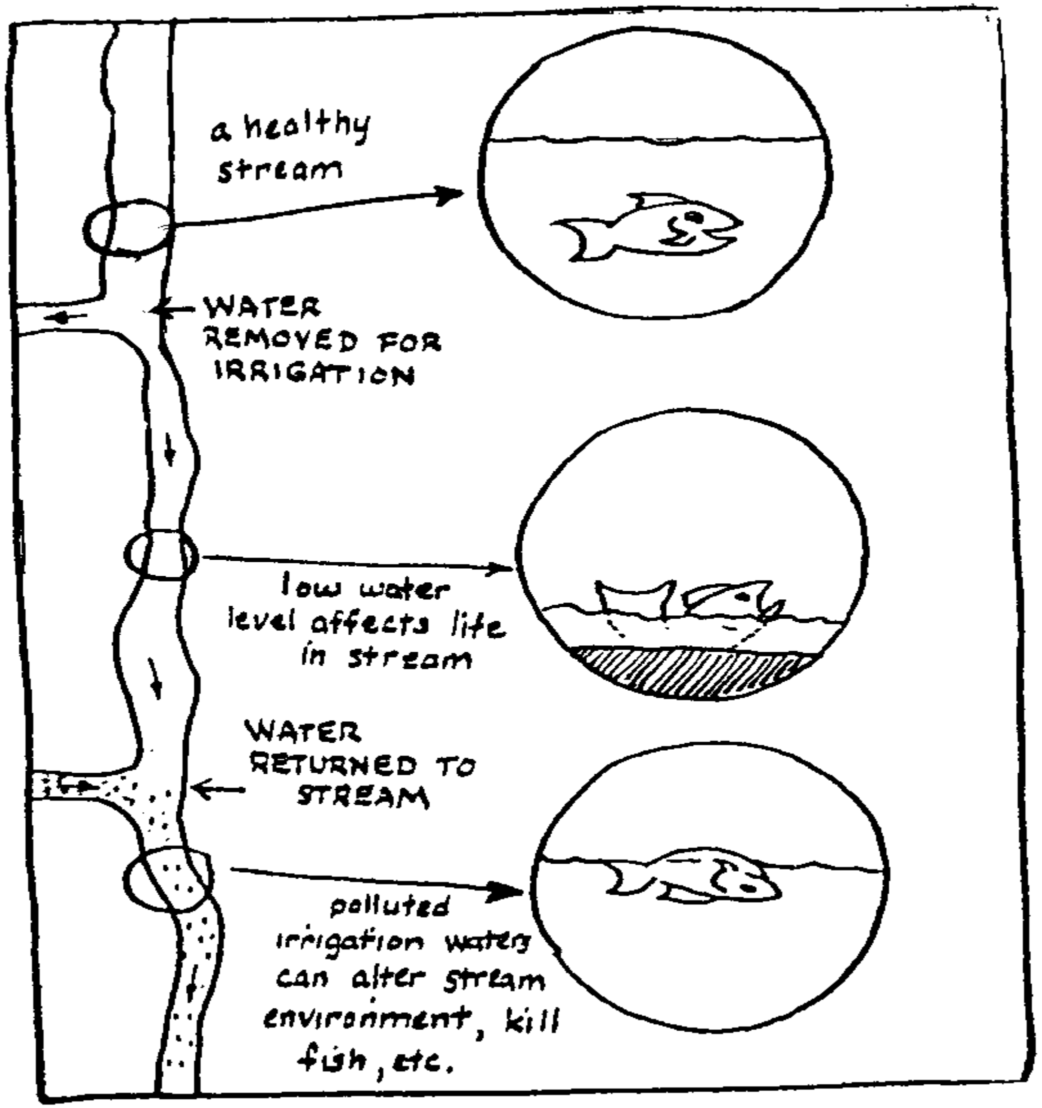

Effect on the Aquatic Environment

*** Removal of water for irrigation can result in reduced flow downstream.**

*** Reduced flow can cause the death of aquatic plants and animals.**

*** Water returned to the stream after irrigation is often of poorer quality than the original water, and may cause death of plants and animals.**

Effect On Farmland

Water carried to irrigated fields is also subject to evaporation from open canals or seepage from canals in areas where the soils are permeable. On the other hand, when irrigation from surface waters spreads out over the land surface, the water percolates downward and can accumulate underground. Over a period of time accumulated subsurface water can raise the water table until it is within a meter or even a few centimeters of the soil surface. High water tables can inhibit the growth of plant roots by waterlogging the soil. Irrigation may also change the wet-dry cycle and increase pest problems and incidence of certain diseases. Many insect populations die back to low levels during the dry season. With irrigation, pests may continue to breed throughout the year.

Salinization and Alkalinization

Improper irrigation can have various negative impacts on the soil that will affect crops. Among these are salinization and alkalinization. Soils that contain more or fewer salts are better for different kinds of crops. The measure for whether soil is alkaline or acid is called pH. The normal pH balance in soils is around 7. If the soil is above normal acidity the pH reading will be higher than 7. If the soil is below normal or alkaline, the pH reading will be less than 7.

Salinization. In soils with drainage problems and improper irrigation the soil surface can become very salty as water evaporates from it leaving deposited salts in the upper layers of the soil (salinization). Salinization is the concentration of salts--sodium, calcium, magnesium, and potassium--in the upper soil layers or on the surface in the form of a white crust or powder. Salinization if uncorrected can drastically reduce crop productivity. When drainage is adequate, salts usually present no problems. Salts can be washed out of the soil by applying water in excess of the rate of evapotranspiration of plants. Where drainage is poor, concentration of mineral salts can occur when surplus water accumulates and raises the water table to within one meter or less of the surface so that increased evaporation leads to salinization.
Inadequate drainage and elevated water tables are the underlying cause of salinization problems in irrigation projects. Awareness of the nature of this problem and its causes is another planning tool. Development workers must check drainage and water table characteristics before developing an agricultural project using surface waters for irrigation. The saline problem can be corrected through

drainage, which could cause saline contamination of groundwater and surface waters elsewhere. An alternative to transporting the saline drainage water elsewhere would be to use it on-site for irrigation of salt-tolerant crops such as barley, cotton, sugar beet, wild rye. Sensitive crops are beans, onions, and most fruit trees.
Salinization can also be caused by small amounts of water if the water is of poor quality. It is a common problem where water supply is limited and there is a need to save it.

Alkalinization. Another possible consequence of improper irrigation is alkalinization which is of particular concern in arid and semi-arid regions. Alkaline soils are those with a high content of exchangeable sodium whether or not in combination with substantial quantities of soluble salts.
Alkalinization is more serious than salinization because it is harder to remedy. Salinization can be remedied by applying water; leaching alkaline soils may worsen their condition. Sodium, unlike other soluble salts, does not leach away because it is adsorbed (clings to the surface of soil particles and combines with water in a chemical reaction) to clay and organic matter. While salts may be leached away by runoff or irrigation water, the sodium remains in the form of sodium hydroxide or sodium carbonate. The presence of the sodium hydroxide causes the organic matter in the soil to dissolve and destroys the soil structure, making it difficult to till and almost impermeable by water. Expert technical assistance is needed to correct this soil condition.
Technical assistance is required to determine whether or not these conditions exist and how serious they are. One easy way to

get help is to take a soil sample to a government office. World Neighbors has a pamphlet describing "How to Take a Soil Sample." See Appendix B for the address.

USING GROUNDWATER FOR IRRIGATION

When water for large-scale irrigation is drawn from groundwater supplies by sinking wells and pumping, the water table is often lowered. This has several possible effects that must be considered by the project planner:

*** Local vegetation may no longer be able to draw on the water table.**

*** Marshes, springs, and wet places may dry up.**

*** River and stream flow may be reduced.**

*** The land may sink, or subside, if too much water has been pumped out too quickly from natural underground water storage areas, or aquifers. This phenomenon is irreversible (that is, it cannot be restored to its former state by natural means).**

*** Heavy withdrawal of groundwater can also lead to saltwater contamination of the fresh water in the aquifer.**

*** If too much water is applied, waterlogging may occur in**

certain areas.

IRRIGATION RETURN FLOWS AND THEIR EFFECTS

Water used for irrigation flows back to water sources through transport processes. This return flow from irrigation can be a significant polluter of surface waters, groundwater, and soil. Small-scale projects usually do not exert excessive withdrawal of water, since normal discharge of groundwater may occur through springs, and through seepage along the sides of streams. However, reduced surface water availability forces areas with marginal water supplies to pump groundwater, which increases water mining and costs of the project due to high energy requirements. Dissolved salts, for example, can be carried to the subsoil or groundwater. Water percolating through the ground carries with it the salts accumulated in the root zone and moves them up or down in the soil profile. Some salts also wash into drainage systems and are returned to main streams.

<FIGURE 3>

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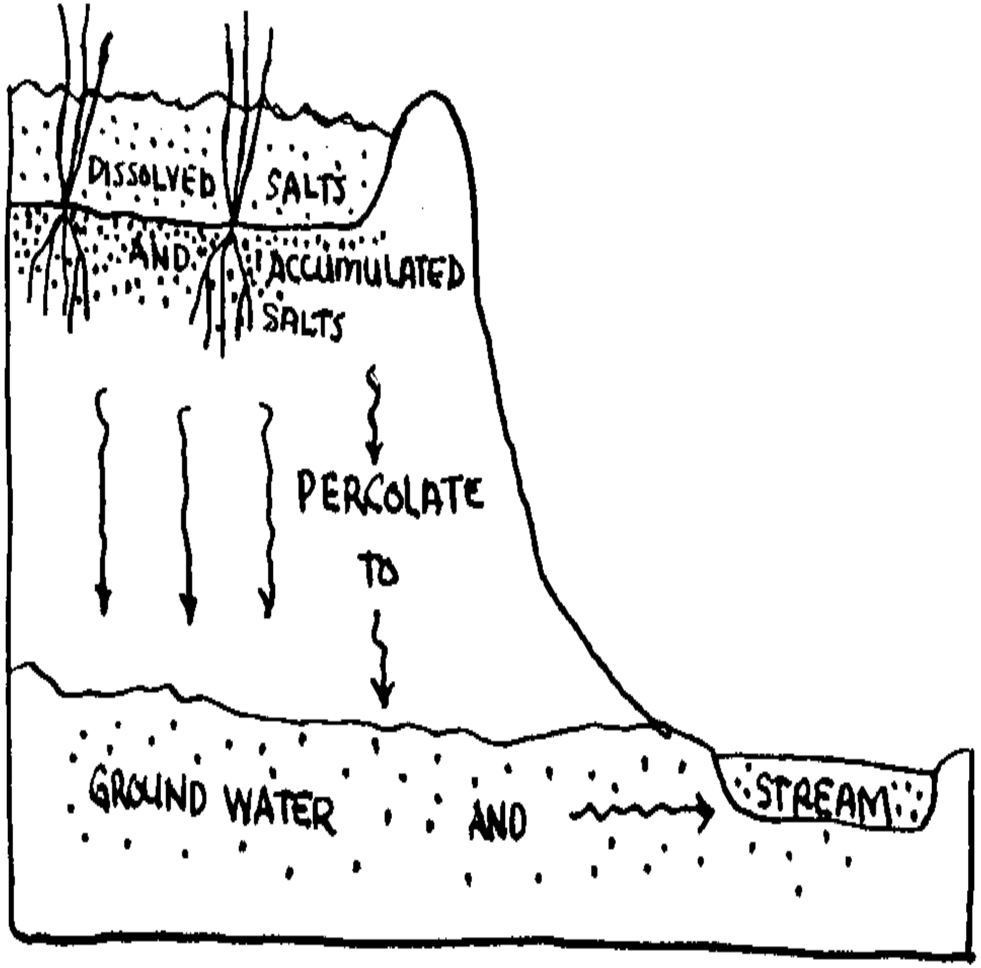

When irrigation water returns to main streams it may have adverse effects:

*** Because of leaching and evaporation in the fields and canals, the salt content of the irrigation return flow may be much greater than that of the initial water used. Too much salt**

can kill fish and other aquatic organisms downstream from the point of return.

*** Return flows can carry pesticides, which can be lethal to beneficial aquatic organisms that provide food for higher organisms in the food web, including humans.**

*** Irrigation flows can carry sediment or silt, which raises the beds of irrigation canals, changes the direction of canals (causing them to meander), clogs drains, and fills the streambeds of reservoirs and lakes downstream.**

<FIGURE 4>

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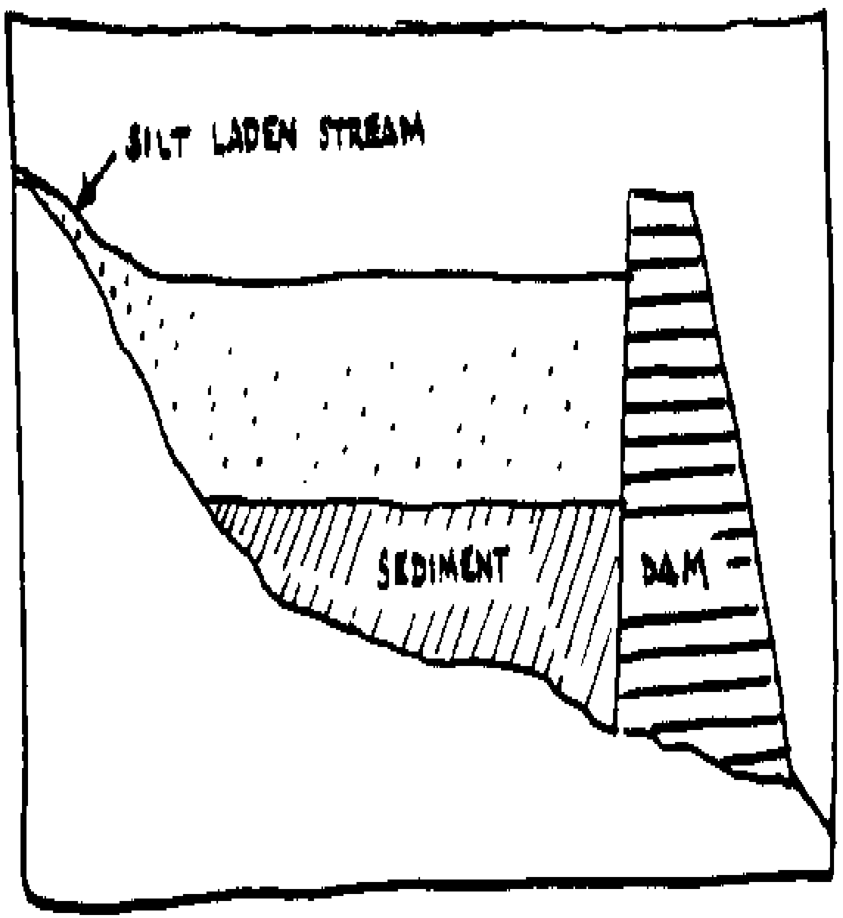

IRRIGATION AND HUMAN HEALTH

The human health implications of irrigation can be extremely serious and can include the following:

*** Irrigation canals can carry chemical pollution from one place**

to another.

*** Canals and ditches can provide new places for the growth, breeding, and reproduction of various disease organisms, or their vectors, and can be instrumental in spreading these diseases, especially if water is used for drinking and/or bathing.**

*** Slow-flowing or stagnant storage ponds, supply canals, or deeper drainage ditches are ideal habitats for disease organisms. This occurs particularly when canals become choked with aquatic weeds, which slow-the flow of water and offer a feeding ground for mosquitoes and other aquatic organisms that transmit disease. Many of the most serious human diseases (for example, malaria, yellow fever, and schistosomiasis) are carried by organisms such as snails and mosquitoes.**

*** Although snails and mosquitoes that spread disease can be controlled by pesticides, these pesticides may also kill the eggs, larvae, and adults of many other species of aquatic animals. Control of disease organisms with chemicals can also harm fish-raising efforts in irrigation canals and reservoirs. Mosquitoes that transmit malaria can develop resistance to specific insecticides over time. Pesticides also accumulate in the food web and can cause harm to humans who use the water or eat fish grown in contaminated water.**

Note: Alternatives to pesticides for mosquito control include

promoting pathogens (i.e., Bacillus turringiensis var. israelensis) insect-eating fish (Gambusia, the mosquito fish), birds and other predators (See Chapter 8 for information on biological pest control methods).

DETERMINING THE EFFECTS OF WATER SUPPLY AND MANAGEMENT PROJECTS

By formulating and answering a series of questions like those given below for each project and site, development workers may be able to anticipate a few of the potential effects of irrigation projects:

*** Is there adequate water for the project, either from precipitation (rainfall), surface water, groundwater, or aquifers?**

*** Are cycles of floods and droughts accounted for in the project design? What would be their impacts on the project when they occur?**

*** Does the project design minimize surface runoff that might carry away valuable nutrients and topsoil and cause pollution downstream?**

*** Do upstream resource uses (construction and forestry activities) affect the quality of the water to be used by the project?**

*** Will the project involve irrigation? If so, the planner should**

be particularly careful to assess the impact of the project downstream and the possibility for increasing habitat for aquatic pest insects including vectors of waterborne diseases, and abundance and quality of the project water source.

*** Will the project affect water-flow patterns of the area? Would these alterations affect the water supply needed by other users?**

*** Are malaria, yellow fever, schistosomiasis, or other waterborne diseases carried by organisms associated with water, prevalent in the region? And will the project in any way result in increased incidence of the diseases?**

*** Will the project reduce downstream water flows and thus affect fisheries, aquaculture projects, the growth of aquatic weeds, the habitat for mosquitoes and other vectors of disease-causing insect pests?**

*** If habitat is increased for disease vectors, could this result in increased use of insecticides or molluscicides with the possible result of chemical poisoning of fish and water supplies?**

*** Could irrigation cause waterlogging of the soil?**

*** Is the soil susceptible to salinization?**

*** Does the soil have a characteristically high pH and could irrigation result in soil alkalinization?**

*** Does the site have lateritic soil or is laterization a potential problem? (See Chapter 5).**

*** Will new wells be sunk? If so, could this affect the water table?**

*** If the water table is affected how will stream levels and wetlands be affected?**

*** Is the project site near the sea? If so, could lowering the water table allow salt water to intrude, contaminating freshwater supplies?**

*** Could downstream water or groundwater quality be affected by high salinity in the return flows from the project site?**

*** What other water supply and management options should be considered?**

*** What alternative designs could minimize possible water supply impacts?**

Other appropriate questions may be added. By considering these questions, the trade-offs necessary to minimize the negative affects of the project can be evaluated.

WHAT ALTERNATIVES EXIST

A number of practices are available to reduce the amount of water used for irrigation (and thus decrease possible negative impacts) or to conserve water. These management methods can be used to lessen water loss from runoff, evaporation, deep percolation, irrigation, and stored soil water. Practices are also available to maximize the efficiency of irrigation and the use of stored soil water:

- control of runoff losses through contour tillage, terracing, use of crop residues, and water spreading (the diversion of surface runoff to sites where the water infiltrates and is stored in the soil)

- control of evaporation losses through mulching

- reduction of deep percolation through the use of horizontal barriers (i.e., asphalt)

- conservation irrigation such as drip irrigation (See Appendix A for references)

- water harvesting (i.e., through construction of small ponds to capture excessive water during rainy season)

- use of drought tolerant crops

- no-tillage agriculture (see Chapter 5)

- relying on summer fallows for dryland farming areas currently being irrigated

There are also several ways to avoid or mitigate negative effects of irrigation on human health. When canals are used, people can take extra care to draw water from uncontaminated stretches of the canal, or from safer sources such as deep wells if such possibilities exist. If alternative waste disposal methods are adopted, disease organism life cycles can be interrupted, preventing the spread of disease. More research on the natural enemies of snails and mosquitoes can identify possible predators such as ducks, geese, or fish. There may also be local plants that serve as molluscicides, such as the soapberry (berry of the dodecandra plant in Ethiopia). The best method may be to deprive disease vectors of a suitable habitat by conveying water in pipes or tile aqueducts and by using buried tiles to drain excess water from fields. On a small scale, the use of enclosed systems for irrigation would not only protect humans from disease but would also prevent seepage and evaporation of water used for irrigation. However, these solutions may be costly or beyond the control of small-scale project operators.

CHAPTER 7

SOIL NUTRIENT MANAGEMENT

Nutrients, such as Nitrogen (N), phosphorus (P), potassium (K)

and others, are essential to plant growth. Planners of agricultural projects should have an understanding of the dynamics and cycles of nutrients in the natural environment in order to devise wise soil nutrient management plans. Understanding the inputs and outputs of nutrients in a crop field will help in devising techniques that keep a good balance of nutrients in the soil. For example, the figure below illustrates how nitrogen is added and withdrawn from the soil through the nitrogen cycle.

<THE NITROGEN CYCLE>

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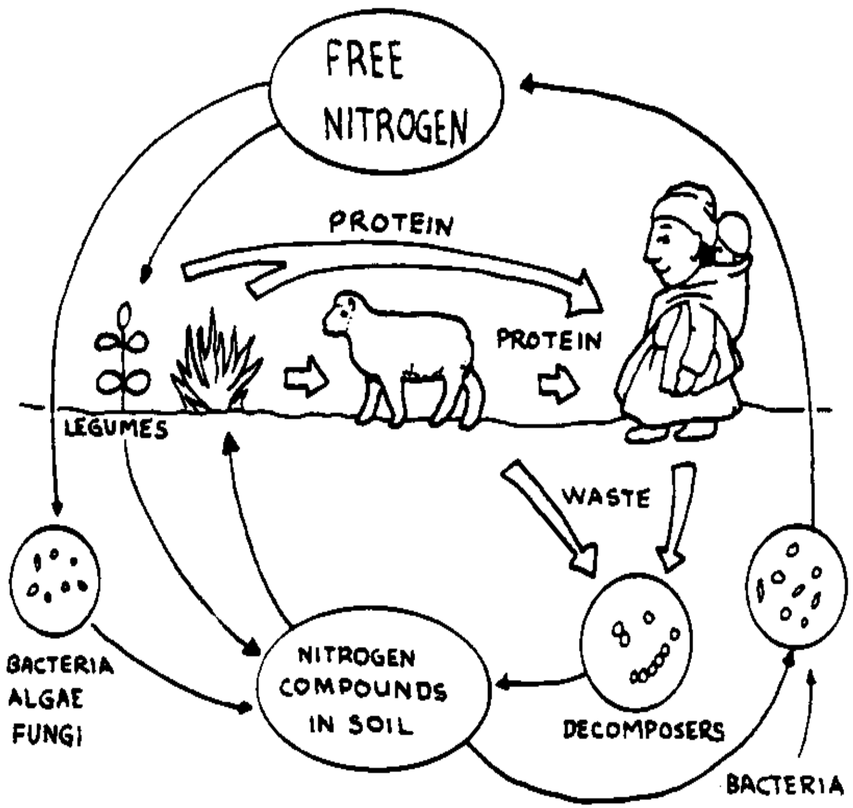
THE NITROGEN CYCLE



SOURCES OF PLANT NUTRIENTS

**In crop lands there are six primary sources of nutrients:
natural soil fertility, plant residues, animal waste, legumes, water,
inorganic fertilizers.**

Natural Soil Fertility

All cropland has a degree of natural soil fertility. Soil fertility refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts. Some soils, such as the flood plains of rivers, are usually very fertile. On the other hand, loose sandy soils, which contain little or no organic matter, and usually not very fertile.

<NITROGEN PRODUCTION FROM CROP RESIDUES>

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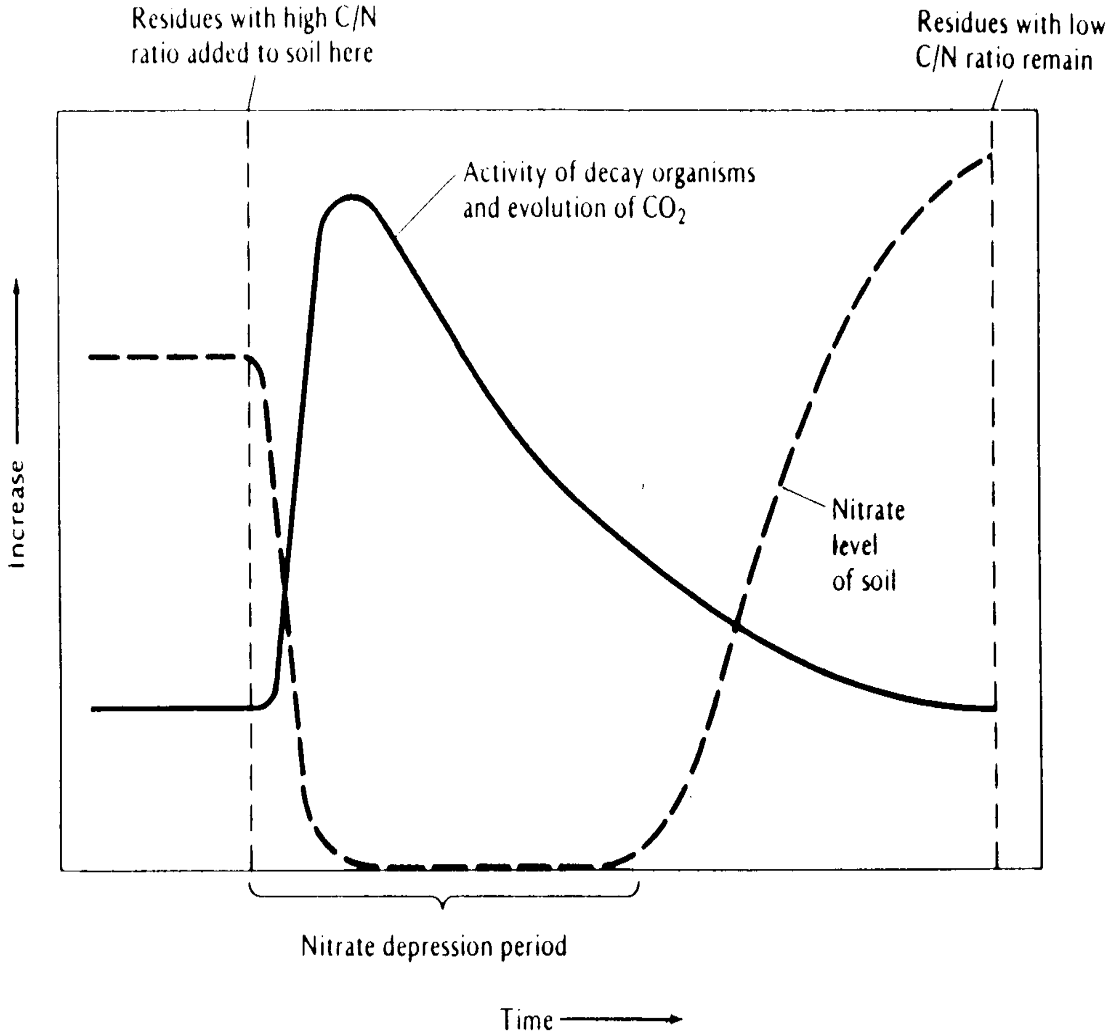

Source: Brady 7.2

Organic Matter

The Significance of the C/N Ratio. There is a close relationship between the organic matter and nitrogen content of soils, expressed as the ratio of Carbon to Nitrogen or C/N. C/N is important in controlling the available N and the rate of organic decay in soils. The relationship of these two elements in organic material added to the soil is crucial for two reasons: a) Keen competition among micro-organisms for available N results when added crop residues have a high C/N ratio (more carbon in relation to nitrogen). This means the rate of decomposition will be faster and the availability of nitrate to plant will be depressed until the activity of decay organisms slows down. b) Because the C/N ratio is relatively constant in the soil, the organic matter content of the soil depends largely on the nitrogen level. The figure above shows the trend to be expected when materials with high and low C/N ratio are added to the soil.

Plant Residues. Leaves, roots, and other plant debris build up the soil structure by providing organic matter. As these materials decompose, nutrients are released. The amounts of nutrients vary greatly depending upon the type of plant, temperature, rainfall, and whether the material is plowed into the topsoil or not.
Animal Wastes. Animal wastes such as manure are organic matter that may decompose to provide nutrients to the soil. Manure has been used as fertilizer for centuries and is useful and environmentally sound, if excessive amounts are not used.
The nutrient content of manure depends upon the animal, the type of feed given, and the amount of water consumed by the animal. Disease organisms that affect humans can be carried in animal excrement, therefore, only manure from healthy animals should be

used. Extra precaution is necessary when using animal manures if these diseases are a problem in the area. Local authorities usually are aware of these problems and can provide information. Aerobic composting, as discussed below, can kill the pathogenic bacteria, eggs and spores found in animal manures. Other by-products that may be used for fertilizer are bone meal, blood meal, and fish meal. Cover new manure as soon as possible and mix it with the soil. As much as 1/4 of the nitrogen content can be lost in one day due to ammonia volatilization if the manure is not handled properly. Temperature and moisture affect decomposition of manures. Therefore timing of the application of manure may vary with climatic zone. In a semi-arid area, for instance, where high temperatures are coupled with high aeration of the soil, manure applied too early before the onset of rains, can lose a large part of its nutrients from rapid oxidation of the organic matter.

NUTRIENT CONTENT OF ANIMAL MANURES

Animal % of Dry Weight
N P K

Dairy Cattle 2.4 0.6 3.0
Beef Cattle 2.0 0.8 1.7
Poultry 3.7 1.7 1.9
Swine 5.9 2.5 4.1
Sheep and Goat 3.0 1.1 4.8

Legumes. Legumes, including peas, beans, groundnuts, and alfalfa,

contain nitrogen-fixing bacteria in their root systems. These plants fix nitrogen from the air into proteins that become available to the plants when the bacteria die. Bacteria can fix enough nitrogen to support a grass and legume meadow if no other nitrogen source is available. The nitrogen usually is produced as the plant needs it. Plants with poor growth will not fix much nitrogen. If there is a high level of nitrogen available in the soil, the bacteria fix less. Nitrogen then is not a limiting factor.

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 mutually beneficial system. Such multi-cropping, or polyculture practices can reduce or eliminate the need for chemical fertilizers. It is important to exploit the ability of the cropping system to reuse its own stored nutrients. In complex crop mixtures, closed canopies and larger root areas usually promote nutrient conservation and cycling.

In addition to their compatibility in the field, maize and legume combinations complement each other nutritionally. By eating both, human beings can receive nearly their complete protein requirements--without adding meat or dairy products. Other plants have similar relationships, both symbiotic and nutritional. Often, traditional crop patterns adapted by local farmers turn out to be the best use of the land as well as the best combination for providing essential proteins for human diets. Development workers planning to introduce new species should consider the potential of indigenous crop mixtures as a starting point for the design of soil management practices. In combination with other crops grown locally, indigenous crop mixtures can provide adequate nutrition and even improve local

diets.

Precipitation and Run-on Water

Rainfall can provide nitrogen and phosphorus to cropland, but in very low amounts compared to other sources. The nutrient content of precipitation is influenced by the weather, and by the presence of industry, cities, disposal sites, power plants, feedlots, etc. For example, phosphates, that may be present in dust, ash or smoke, are made available to plants when dissolved in rain.

Nutrients in soil and organic matter that are suspended in run-off water, that is, eroded and carried from elsewhere, may be a significant input in certain situations. For example, rice-growing areas subject to inundation or flooding from silt-laden rivers or riverain cropping systems that involve planting on previously inundated land, may have sufficient nutrients from this source when the seasonal river flow declines.

Inorganic Fertilizers

Inorganic fertilizers consist of chemicals with little or no organic matter. Chemical fertilizers supply nutrients that are readily available after application, in amounts and ratios that are more readily controlled.

Inorganic fertilizers are expensive, often unavailable, and generally do little to improve the structure of the soil. Many farmers have difficulty calculating how much chemical fertilizer to apply. This can lead to under-fertilization or over-fertilization either of

which do not produce desired results. Many tropical soils cannot hold the chemical nutrients long enough for the plants to use them. Often the first rain washes them out of the soil. However, in some areas organic fertilizers are not available or not in sufficient quantities. In that case, correct application of inorganic fertilizers is necessary and critical.

EVALUATING THE SOURCE OF NUTRIENTS

The choice of nutrient source depends on the situation. Even soils that are naturally very fertile may be depleted of nutrients by continuous cropping.
The need for fertilizer, i.e., anything added to the field to increase the natural fertility of the soil, depends on:
- ability of the soil itself to provide essential nutrients to crops (soil fertility)
- nutrient demands of the crops

The choice of fertilizers depends on availability, costs, and the fertilizer's effect on the soil. Whether nutrients are organic or inorganic does not matter to the plant. Plants can use fertilizers from any source. However, other effects of inorganic fertilizers are often unknown. In the long-term perspective they can reduce the diversity of microbes in the soil. They may also be hard to obtain and/or expensive. Wherever possible it is best to use organic fertilizer. Potential organic fertilizers exist wherever there are animal and plant wastes. They are relatively cheap although they require larger inputs of labor. They have the added advantage of contributing

organic matter to the soil. In the warmth and moisture of the humid tropics most soils are very highly weathered, sandy, and coarse textured. In such highly weathered soils, organic matter, in addition to adding nutrients to the soil, plays a very dynamic role in the colloidal complex that holds nutrients and retards leaching. In these soils, organic matter decomposes rapidly so that its nutrients are available quite quickly. One of the best practices for fertilizing with organic materials is composting.

<ELEMENTS OF A COMPOST PILE>

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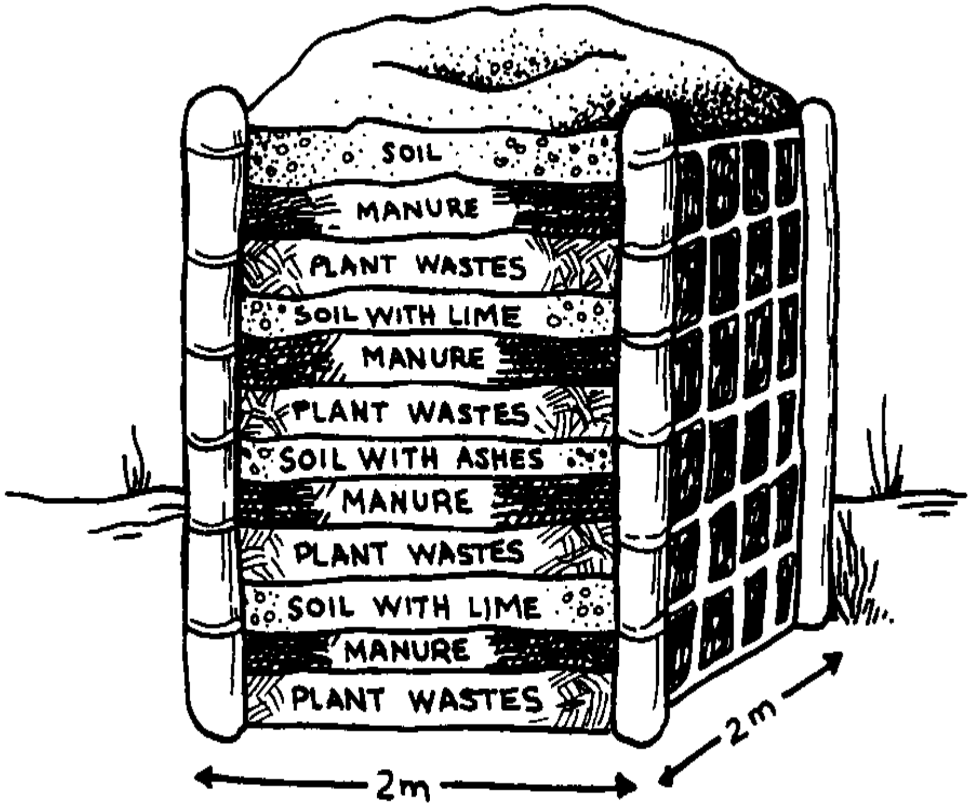
ELEMENTS OF A COMPOST PILE



Composting

Composting is a natural process whereby organic wastes are microbially decomposed. It has the following advantages:

- uses waste material and is of low cost

- can yield organic matter for fertilizer within several weeks, depending upon the ingredients used, the climate, and so forth
- generates heat sufficient to kill insect eggs, larvae, weed seeds, bacteria, and other pathogens that may cause human disease
- stabilizes the volatile nitrogen fraction of manure by fixing it into organic forms
- the final product is easy to store and handle

Composting also has some disadvantages:

- is labor intensive to produce
- requires space to store
- requires water
- is bulky and less convenient to transport and handle than solid inorganic fertilizers
- is dependent on supplies of manure and organic matter
- is more feasible for smaller areas, such as, kitchen gardens or small plots

In many countries, composting in some form or another is practiced traditionally. Examination of local methods can provide good guidelines for project planning in terms of available ingredients, length of preparation time, receptivity of residents to the practice, and so on.

CHEMICAL COMPOSITION OF SOME COMPOST MATERIALS

Carbon:nitrogen ----- kilos/ton-----
Material Ratio N [P.sub.2][O.sub.5] [K.sub.2]O

Grass Hay 80:1 9-11 2-5 11-16
Legume Hay 12-24:1 20-27 5-7 16-21
Straw 75-150:1 5-9 1-3 9-14
Cow Manure & Bedding 15-25:1 3 .5 2
Seaweed 19:1 .5 .35 2
Human Faeces 5-10:1 2-3 1-2 .5-.9
Sugarcane Fiber 200:1 .11 .01 +
Filter Mud 22-28:1 .5 .9 .05
Maize Stalks 60:1 - - -
Fish Scrap - 1-3 .9-3 -
Vegetable Wastes 12:1 - - -
Groundnut Shells - .35 .06 -

THE EFFECTS OF FERTILIZERS ON THE ENVIRONMENT

Both fertilizers and naturally occurring nutrients are subject to all the natural processes that tend to reduce nutrient levels--leaching, runoff, and erosion. In addition, other sources of nutrient loss in agricultural systems are:

- nutrients in the crop material that leaves the farm
- nutrients in stock or stock products that leave the farm
- leaching of nutrients below the root zone
- loss of nitrogen to the atmosphere through volatilization

(escaping as a gas) or through burning of vegetation or crop residues
- losses through run-off water (erosion)

If these processes can be halted or slowed, the chances are greater that the nutrients present in the soil and those applied in the form of fertilizers will remain available for plant growth. Ensuring that nutrients remain in the soil for crop use lessens the likelihood of excessive nutrients entering the larger environment and thus causing pollution.

<LEACHING>

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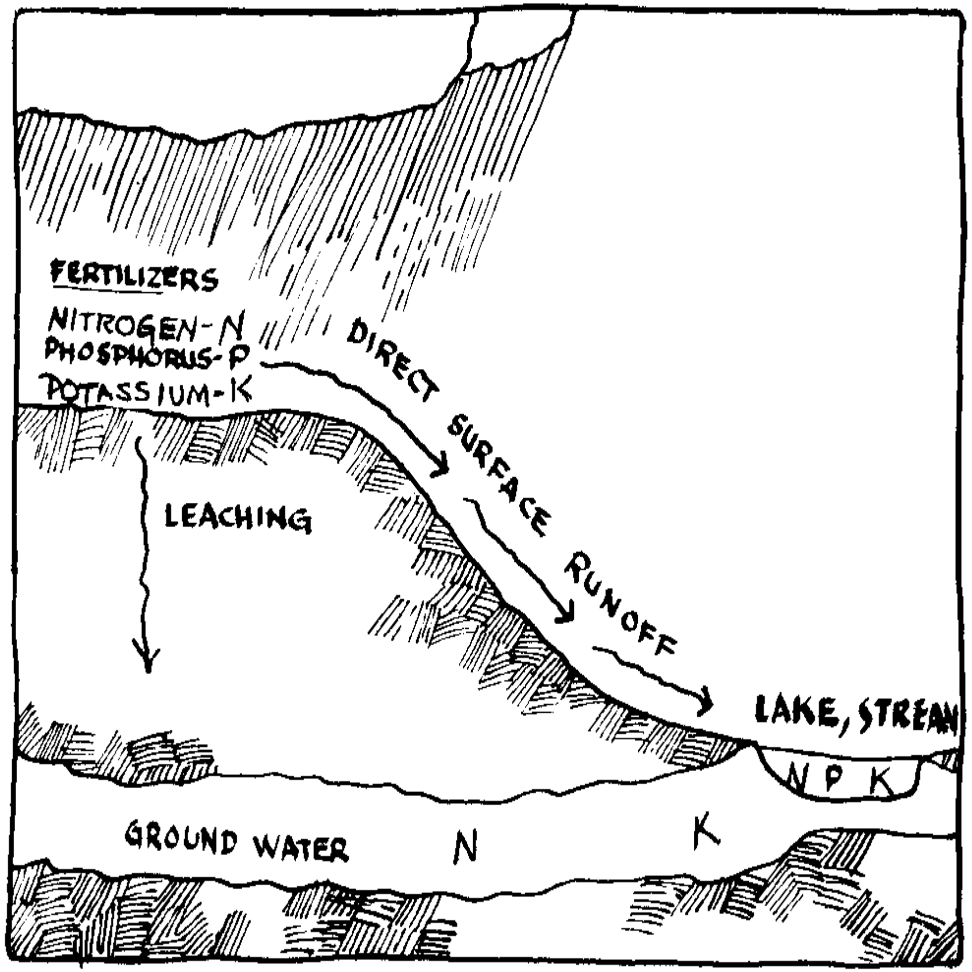

Leaching

Leaching is the process by which soluble chemicals move downward through the soil in water that is percolating through the soil. Nitrates are the most easily leached nutrients and are commonly found in drainage waters. Leaching from cropland depends upon the

type of crop grown, as well as the soil type and its drainage characteristics, and on the amount of available water passing through the crop root zone. Leaching effects are particularly important early in the rainy season in the humid and subhumid tropics, when the main flush of mineralization of soil organic matter occurs. Under perennial crops with permanent, deep root systems, leaching is of minor significance.

Runoff

Runoff occurs when it rains so hard and fast that the ground cannot absorb the moisture fast enough. When fertilizers are left on the soil surface, the first rainfall can carry away a substantial portion of the nutrients. Fertilizers during periods of light rains move into the soil dissolved in the available water. The loss of fertilizer may be much less if the fertilizer is incorporated into the top few inches of the soil before rains begin. Being soluble, nitrates are easily leached into the soil. The concentration of nutrients in runoff water will vary greatly from field to field, depending upon soil characteristics, slope, crops grown, type of manure or fertilizer used, and rainfall conditions. Organic fertilizers mixed with the soil can increase the soil's capacity to absorb water.

Erosion

Although sediment transport through erosion depends upon the volume and velocity of water flow, it can be the major transport process for phosphorus and organic nitrogen clinging to or adsorbed

on sediment particles. When the velocity of water is reduced, the large particles of sediment fall out of solution. The remaining sediment is usually finer and has a higher capacity (more surface area to which to adhere) to adsorb phosphorus, so that transported sediment is richer in phosphorus and nitrogen than the original soil. Organic matter is often transported along with sediment, causing further nutrient losses from the fields. Nutrient losses from cropland can be controlled by proper management practices such as those described in Chapter 5 for sound erosion control.
For example, leaving plant residues on a field can reduce erosion rates of 25-65 tons/hectare/year to 12.5 tons/hectare/year, and at the same time provide nutrients to the field and thereby reduce the need for inorganic fertilizer. Other soil management/erosion control methods, such as crop rotations with sod, contouring, and terracing, can reduce nutrient losses as well.

THE EFFECTS OF MOVEMENT OR LOSS OF SOIL, NUTRIENTS

Nutrients, including fertilizers, in solution or suspension in the groundwater or surface water bodies, can result in two problems:

*** Nutrients may reach toxic levels and become a health hazard to humans and animals.**

*** When added to water systems (i.e., ponds, small lakes), nutrients may accelerate the eutrophication rate to the extent that it becomes harmful to the environment.**

Eutrophication

Eutrophication is the enrichment of a body of water by nutrients with resulting increases in growth of aquatic plants. When nitrogen and phosphorus enter the water in high levels as a result of runoff or other transport methods from agricultural lands, over-fertilization of the water systems stimulates an exploding growth of algae populations.

Algae can:

- cause taste and odor problems
- create obnoxious conditions in impounded water such as small ponds
- block passage of the sun's rays and interfere with photosynthesis of bottom vegetation
- clog the screens of water treatment systems

When these massive algae populations suddenly die off, their decomposition releases gaseous substances and depletes oxygen levels in the water, with harmful effects to fish and other aquatic organisms.

Health Effects

Fertilizers usually contain nitrogen, phosphorus, and potassium. Of these, nitrogen in particular has been associated with health problems. Nitrogen, which occurs as nitrites, nitrates, and/or

ammonia, may be converted to another form by chemical reactions occurring naturally in the environment.

Nitrites. The nitrite form of nitrogen is very toxic; if taken by humans in drinking water or in food, it enters the bloodstream where it interferes with the ability of the blood to carry oxygen. Nitrites can also combine in compounds that may cause cancer in humans.

Nitrates. Nitrates are much less toxic than nitrites. Healthy, mature animals with single stomachs are able to expel nitrates in their urine. However, cattle, young animals, and children can convert some nitrates to nitrites in their stomachs, a condition that can be harmful.

Both nitrites and nitrates occur naturally in foods and water, but only in small amounts. Only small amounts can be tolerated by humans. The World Health Organization has fixed the Drinking Water Standard for nitrates at 0 to 50 parts per million (ppm) as recommended levels, and 50 to 100 ppm as acceptable. In many developing countries, however, these levels are exceeded, especially where drinking water supplies are contaminated by nearby concentrations of nitrogen, such as manure piles in farm barnyards.

Obviously project plans must include consideration of fertilizing practices in terms of the location of compost piles, manure accumulations, and slope of fertilized fields in relation to housing and water supply.

Ammonia. Ammonia, like nitrate, can be converted by specialized

bacteria to toxic nitrite. Ammonia occurs naturally. It is generated by micro-organisms as they break down organic matter on the bottom of stagnant lakes. Dissolved ammonia can occur at levels that are toxic to fish. Another problem with nitrogenous fertilizers is that the addition of a common fertilizer, sulfate of ammonia, may acidify an already acid soil. However, this may benefit a basic soil.

Phosphorus. Phosphorus usually enters water as a soluble phosphate compound that is completely available for algae growth. Phosphate may also enter the water adsorbed on sediment or on particles of organic matter. The phosphates are then slowly released. These phosphates then contribute to problems associated with eutrophication.

MANAGEMENT OF NUTRIENT-RELATED FACTORS

Erosion control practices may be an that is needed to control the loss of phosphorus and nitrogen. If nutrient losses persist, however, other nutrient management practices may be necessary such as fertilizer management, crop rotation, legume cropping etc.

One must be careful that solving one problem does not create another. As an example, in certain areas of the state of Texas, USA, terraces were built to retain moisture. While the terraces did hold water, this moisture control caused nitrate leaching, which contaminated the groundwater supplies of the area.

Managing Fertilization

To prevent the build up of nutrients in soil and their subsequent loss through leaching, farmers should apply only the needed amount of fertilizer to croplands. Failure to estimate fertilizer requirements accurately leads many people to over-fertilize. The best way to prevent overfertilization and the leaching that results is to estimate the need for fertilizers and apply only that which will be used by the crop. The table below provides general guidelines for the nitrogen requirements of selected crops. It should be kept in mind, however, that most of these generalizations must be evaluated for each locality.

GENERAL CROP NITROGEN REQUIREMENTS

Kilos of nitrogen
Crop per hectare per year

Grass (2-3 times as a top dressing) 100-150 (maximum)
Small grains 20- 40
Potatoes 120-160
Leafy vegetables 120
Root crops 80
General home vegetables 100

Symptoms of lack of fertilizer will emerge when the seedlings are a few inches tall. Fertilizer can be applied at this time in between the rows. At this point, when the soil is deficient in a particular nutrient, the crop plants will develop specific symptoms. Thin stems and yellowing of leaves is typical of nitrogen deficiency,

whereas purpling of leaves signals phosphorus deficiency. The effects of some elements are greatest when fertilizer is applied near the time of fastest vegetative growth, that is, several weeks after the plant emerges from the soil. This is not true for phosphorous, which needs to be applied early for root development. With late application, less fertilizer is used and it is used more efficiently. However, late application can set back development of the crop. One practice is to put half the fertilizer on the field at one time early in the growing season and the rest later.

Soil fertility and physical conditions may be estimated by observing certain biological indicators such as the prevalence of specific weeds. Although weed growth may be determined by more factors than just soil conditions, at times the dominance of one specific weed species can be well correlated with salinity, drainage, nutrient levels, or soil texture characteristics. The development worker is advised to consult local farmers, extensionists, or technical experts to interpret the indicators.

Project planners who are not agricultural experts will probably want to consult others for advice on actually choosing fertilizers and using them in crop production. Local farmers, extensionists, and agricultural experts have experience in determining what kind and how much fertilizer is needed.

Crop Rotations

The average amount of fertilizer needed on fields often can be reduced by rotating crops. Crops that require high nitrogen levels, such as maize, sorghum, and cotton, can be rotated with legumes

such as soybeans, beans, or alfalfa, or with crops that require smaller amounts of nitrogen such as small grains. Crops can be alternated by growing season to reduce the need for other fertilizers. The particular cropping sequence appropriate in a rotation will vary with the climate, soil, tradition, and economic factors. Some crop yields are affected by the previous crop. For example, yields of almost any crop after barley are usually lower than after corn, soybean or wheat.

<CROP ROTATION>

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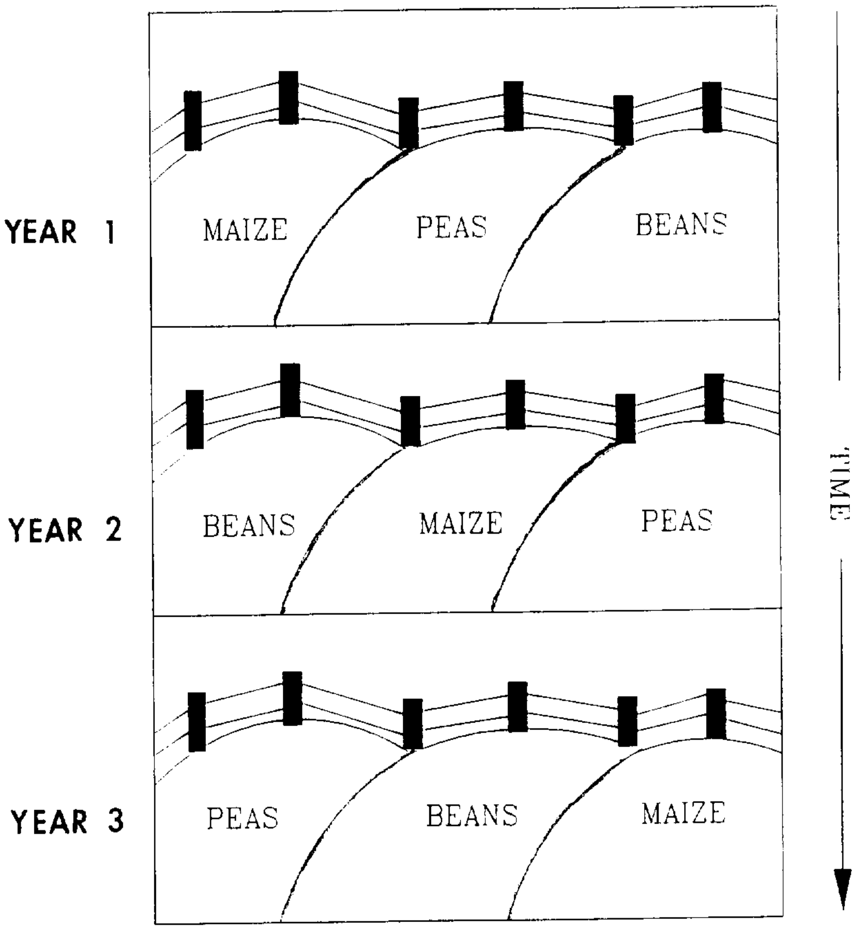

Animal Wastes

Animal manures can be good fertilizers, but there are problems associated with them. If manure is applied as it becomes available nitrogen will be released slowly before planting. This is not always possible. Storing manure, however, is difficult and costly. It is also

difficult to determine how much nitrogen is being applied when animal wastes are used, especially since the nitrogen amount varies with the animal and its diet. The best way to use animal manures to prevent nitrogen loss to volatilization is to plow it into the soil directly, or add it as a slurry, so that it soaks into the soil. One of the advantages of animal wastes as fertilizers is that they release nitrogen slowly enough that little is lost through leaching.

Plowing-Under Green Legumes

Before chemical fertilizers were developed, many farmers would grow a legume on a field and then plow it into the soil to serve as a nitrogen source for later crops. The main disadvantage is an economic one--no crops can be harvested from the field that season. However, compared with the cost of using chemical fertilizers and their potential impacts upon the environment, this practice is useful when a farmer has enough land to leave fields fallow. In areas where chemical fertilizers or animal wastes are not available, this is one way to add nitrogen and organic matter to the soil. In general, immediate benefits from incorporation are only observed with young legume green manures. Most other residues have high C/N (Carbon/nitrogen ratio, see beginning of this chapter for explanation) and "tie-up" nitrogen during a period of time.

Controlling Surface Applications

The type of fertilizer must be chosen carefully, and it must be applied at the right time. For example, nitrogen, which moves

quickly through the soil, should be applied just before or during the growing season. Phosphorus and potassium fertilizers can be applied after the growing season or sometime before the next one. It is usually best to mix fertilizers into the soil right after application to reduce loss of nutrients to erosion.

THE EFFECTS OF NUTRIENT MANAGEMENT

By answering questions such as those below for each project and site, the development worker can estimate the potential effects of fertilization projects on the environment. If the answers are not readily apparent, go back and think about the project site again. Consult local experts in the field if the answers point out major problems. Use the questions as guidelines to plan projects that will be both environmentally sound and successful.

*** Is manure available for use as a fertilizer in the project? If used, would this practice result in the spread of weeds and/or disease through human contact with the manure?**

*** Will plant residues be used for fertilizers and soil structure enhancement? What is the C/N ratio of these materials?**

*** Will new plant species or varieties be introduced? This could have long-term environmental repercussions and the potential effects should be carefully reviewed.**

*** Could the new species out-compete traditional crops in the**

region?

*** Do the new varieties need more fertilizer than traditional crops?**

*** Will the new varieties require more pesticides, and/or the use of heavy farm machinery, which could lead to other problems?**

*** Could new pest species be attracted into the region along with the new crop?**

*** Will the project involve the use of inorganic fertilizers?**

*** Could this practice lead to nitrite toxicity for people or animals?**

*** Are precautions being taken to avoid over-fertilization?**

*** Could the project enhance loss of nutrients via runoff, erosion, or leaching?**

*** Could nutrient transport cause eutrophication?**

*** Are there other nutrient management considerations?**

*** Does the success of the project depend on inorganic fertilizers? If so, do farmers have a reliable source? Have they been trained in its use? What are the projected costs of**

fertilizers?

* What alternative project designs could be used at the site to minimize nutrient loss?

ALTERNATIVES FOR NUTRIENT CONTROL

The following table lists ways to manage nutrients in agricultural projects. The left-hand column names the practice; the right-hand column describes the advantages, disadvantages, and potential effects of each as a nutrient control method.

CONTROL OF NUTRIENT LOSSES

Practice Advantage/Disadvantage

Timing nitrogen application Reduces nitrate leaching; increases efficiency of nitrogen use. However, may
encounter labor shortages.

Rotating crops Reduces fertilizer requirements; reduces
erosion and need for pesticides. But may
decrease production of saleable crops.

Eliminating excessive Reduces cost of fertilizers; can cut nitrate
fertilization leaching.

Using animal wastes Enables slow release of nutrients; economic

gain for small farms; improves soil structure; extends the period of residual effects of applied nutrients on subsequent crops. However, there are labor costs and problems with spreading.

Plowing under green Reduces need for nitrogen fertilizer; not legume crops always feasible; amounts of nitrogen difficult to determine; ties up available land.

Controlling fertilizer May decrease nitrate leaching; not yet release time economically feasible.

Incorporating surface Decreases nutrients in runoff; may add applications costs; not always possible; no effect on yields.

Timing fertilizer plow-down Reduces erosion and nutrient loss; may not be convenient.

Source: U. S. Department of Agriculture, 1975.
Adapted from Control of Water from Cropland, Vol. I, A Manual for Guideline Development.

CHAPTER 8

PEST MANAGEMENT

"Pest" is a human-oriented term. It has been defined as "an organism that reduces the availability, quality, or value of some human resource. This resource may be a plant or animal grown for food, fiber, or pleasure (or) a person's health, well-being, or peace of mind." (Gips 8.8, Flint 8.7) What is considered a "pest" then is based on human needs and values and thus can change from situation to situation. Most organisms and animals are not pests and are considered beneficial.

The use of chemicals that control pests and herbs developed in the 1940s and accelerated in the following decades. The use of pesticides and herbicides has now spread throughout the world. It is only in the past twenty-five years that the horrors of using pesticides have become known and documented. Balancing against the great benefits that pesticides and herbicides offer is the negative impact of direct contact in applying the chemicals, and of secondary effects on humans through the water, food, and meat that we eat, as well as damage to the environment.

Pests, however, are a particular problem in farming systems. Changes in cropping systems often lead to changes in the numbers or kinds of pests and associated natural enemies (predators and parasites) in the agricultural ecosystem. Planning environmentally sound agricultural projects requires looking beyond the types of pests and predators present and considering how measures used to control pests will affect the total ecosystem. Too often failure to take this broad approach has resulted in damage to the environment and in less than successful projects.

In many agricultural projects, pests are controlled only by the use of chemical pesticides. Some chemical pesticides, however, cause environmental problems as a result of their toxic or residual effects and are a cause of sickness and death to humans. In a small-scale project, it may be possible to control pests by using less damaging alternatives such as promoting biological control, planting different crop mixtures, using less persistent and less toxic pesticides, finding more species-specific pesticides, or growing resistant crop varieties. It should be recognized, however, that some alternative methods require more sophisticated management.

<PEST POTENTIAL RELATED TO CROPS>

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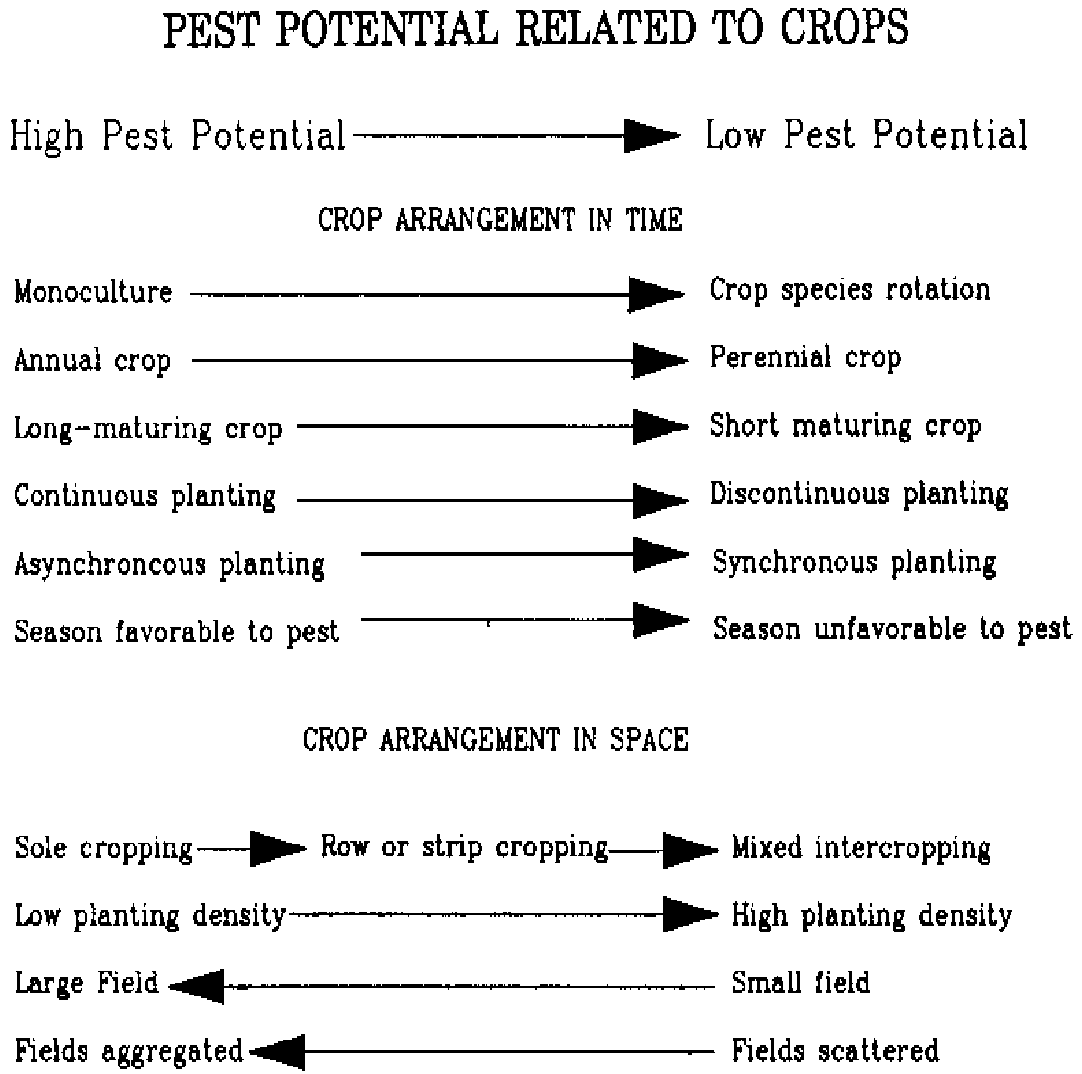

Some birds and rodents if they reach pest proportions can cause great damage and losses in agricultural systems and thereby significantly reduce the amount of food available for people and livestock. Various methods can be used to control pests--from scarecrows

and netting to trapping and killing them individually. It is more common, however, to poison these animals, even though poisoning is potentially a far more dangerous practice to people and other non-target organisms. Whenever possible, trapping and other mechanical control practices should be used to control larger pests.

When properly managed, the pests that are edible can provide an important source of protein and income to local people.

ENVIRONMENTALLY SOUND PEST MANAGEMENT PRACTICES

The best way to lessen or avoid unwanted environmental effects from pesticide use is to minimize their use. Feasible alternatives to pesticides often exist and should be investigated by the development worker. For example, there may be combinations of local plants that can control pests. In some areas, the use of resistant varieties and delayed or early planting can reduce crop damage by pests. It is important for the development worker to understand how to use alternative control methods. In the long run, it may be better to protect and enhance the natural predators and parasites of pest species than to use chemical pesticides. Insect pests can become resistant to certain pesticides and may do so after only a few applications. Predator species, on the other hand, may have longer life-cycles and may be more sensitive to repeated pesticide applications.

Find out what kinds of pests are a problem before using a pesticide and try to use pesticides that are both species-specific and short-lived. Broad spectrum pesticides kill beneficial as well as pest organisms and are not recommended. Also find out what other pesticides are being used locally to control disease vectors or other pests. If pesticides are already in use some resistance may already exist among pest species.

If possible consult local specialists and authorities before deciding on a particular pesticide for use on agricultural lands. Some countries have very specific laws governing the use of particular pesticides, and these should be taken into account before any time or money is spent obtaining or using chemical pesticides. Some countries outlaw certain pesticides and export them to other countries.

Contact government agencies and local universities or the regional office of the Pesticide Action Network (PAN) for information on local pest species and alternative control practices. A list of regional offices of the Pesticide Action Network (PAN) that can provide technical information or answer specific questions is in Appendix B.

Because of the potentially harmful effects of chemical pesticides, development workers should take care to investigate alternative measures and use them wherever possible.

ALTERNATIVES TO PESTICIDES

Local Plants

Many farmers know the plant species in their area that have insecticidal properties. There are about 1,600 plant species known to possess pest-control properties. Try to find indigenous plant materials and use them rather than chemical pesticides. Two such plants with insecticidal properties are tobacco and pyrethrum (derived from chrysanthemums). Both are now widely distributed throughout the

tropics. Another plant used is the derris root. It produces a chemical called rotenone which is used as a poison especially for ridding fish ponds of trash fish. Some plants, like the neem tree have multiple types of pest-control action. When a local plant which has insecticidal properties is pointed out, try making a solution from crushed leaves or stems and spray it on a small test area. If this seems successful, it may be cheaper to use than commercial pesticides, easier to get, and environmentally safer. Even if the test is not successful there may be other ways of utilizing the tree or plant for pest-control. Local farmers often have this information.

Crop Management Practices

Rotation. Crops usually are rotated for economic and nutrient management reasons. Crop rotation also can be used as a method to control insects, weeds, and plant diseases. Many traditional agricultural practices rely upon crop rotations to provide weed, disease and insect control. Crop rotations, including non-host crops, have proven effective against soil-borne pathogens (cabbage black rot, bean bacterial blight) and corn rootworms and should be explored with local experts, and with local farmers who rotate their crops.

Resistant Varieties. There are also crop varieties that are resistant to attack by disease or insects. These varieties sometimes need the help of pesticides, but in greatly reduced quantities.

Intercropping. Intercropping and polyculture can also reduce the spread of pests and disease organisms. By interspersing non-susceptible

crop plants with host plants in the same field, the spread of the pest and disease organisms among susceptible crops can be considerably reduced. Moreover, the intercrop may also provide a more favorable habitat for the growth and reproduction of pest and disease organisms than the primary crop. It may also provide habitat for beneficial insects and other organisms. For example, alfalfa strips interplanted among cotton rows attract lygus bugs away from cotton, avoiding damage. Surrounding melon or squash fields with a few rows of corn, acts as a trap crop for melon flies.

Planting Time. Another crop management practice is to change planting times to prevent attack by insects and disease. Insect reproduction cycles are often attuned to the growth of plants. If crops can be planted a few weeks before or after the normal time, farmers may be able to by-pass the stage of the insect that causes the most damage to the crop. Early maturing varieties may escape insect attack.

Early planting can be effective in avoiding the egg-laying period of a pest by allowing crop maturation before pest attack occurs. However, because it requires knowledge of insect species and their life cycles, the advice of entomologists or other scientists from local universities and government agencies may be needed.

Plant Spacing. Modifying the spacing of crop plants by decreasing or increasing plant densities may provide a measure of pest control by affecting the micro-environment of the pest, the vigor of the plant, and the duration of crop growth. For example, densely planted stands of grain crops suffer less from chinch bug attack, whereas narrow-row planting of cotton can discourage boll weevil infestations.

Destruction of Alternate Host Plants. It may be found that the crop pests are breeding or spending part of their life cycle on another plant species. If the alternate host is another crop, it may be best not to grow both in the same area. If the alternate host is a weed, it may be possible to control it and thus reduce the pest population. Control of the sugar beet curlytop virus involves destruction of the Russian thistle, the alternate host of the insect vector, the beet leafhopper. Many weeds, however, especially flowering Compositae (sunflower family) and Umbelliferae (carrot family), can provide alternate food (pollen, nectar) to a number of important parasites and predators. For example, biological control of crickets in Puerto Rico depended on the presence of two weeds that provided nectar to the parasitic wasps. In this case, it was desirable to have more weeds of this type. On the other hand, if a certain type of crop is preferred by a pest, one way to control the pest is to plant that crop along with the desired crop and sacrifice the alternate crop that serves as a trap to the pest. Pests and diseases can also be controlled by growing, in sequence or rotation, crop plants that are not susceptible or do not constitute alternative hosts.

Mechanical and Traditional Control Practices

Sometimes the easiest, least costly, and most environmentally sound means of controlling pests on agricultural lands is by using mechanical and traditional control methods. Some of these methods for weed control, for example, involve:

- pulling weeds by hand or cutting them down
- covering weeds with mulch to prevent growth
- burning a field prior to planting
- flooding the field
- normal tillage practices such as plowing and harrowing

Mechanical and traditional practices can be very effective in those countries where labor is available and money and pesticides are not. For example, insects can be killed by trapping; rats can be smoked out, trapped or clubbed; and birds can be shot or trapped in nets and removed from the field. Hunting and/or simply shooting nuisance birds or game animals can also be effective.

Biological Control Methods

Pests can be effectively controlled by supporting the resident or introduced natural enemies of pests. Many of these methods are "new" as far as research is concerned. However, in agricultural areas that retain a diversified environment, biological control is an everyday occurrence. Birds eat insects, cats eat birds, and so on. Each predator has its prey and helps control the population of that prey. In practice, biological control is the use or encouragement of natural enemies for the reduction of pest organisms as well as introducing crop varieties that are resistant to pests discussed earlier.

Natural enemies act as mortality agents that directly respond to the size of the population. Thus natural enemies act as density-dependent

factors. This relationship between pest density and the intensity of attack by natural enemies is called a functional response. For density-dependence to happen in agroecosystems it is necessary to let the insect pest population build up sufficiently to stimulate the corresponding build-up of the beneficial predator or parasite population. This will not happen if pesticides are used on the pest as soon as it appears. Thus, a certain amount of injury to the crop may occur. A small test plot may demonstrate the effectiveness and the negative possibilities before introducing the technique widely. Observation and discussion with farmers can help to determine the maximum pest population that can be tolerated at a particular time without crop damage becoming too serious before other controls are sought. Natural controls may take over before this happens.

Research into the use of biological suppression controls has expanded to include other methods, including the use of sex attractants, insect growth regulators, sterilized male insects, repellants, and warning or aggregating chemicals (pheramones) that influence the behavior of insect colonies. These methods have worked well in some small-scale applications but may or may not work in other situations. They should be considered as alternatives that may be used alone or in combination with other pest control practices.

INTEGRATED PEST MANAGEMENT: WHAT IS IT?

The best way to control pests on agricultural lands may be a combination of the chemical, biological, cultural, and mechanical control techniques described here. Using a combination of these pest

control practices has the following advantages:

- prevention of adverse impacts upon the environment from the continuous use of pesticides
- prevention of the development of resistance to particular pesticides in pest species
- provision of a backup pest control system in the event that any one method fails

<INTEGRATED PEST MANAGEMENT>

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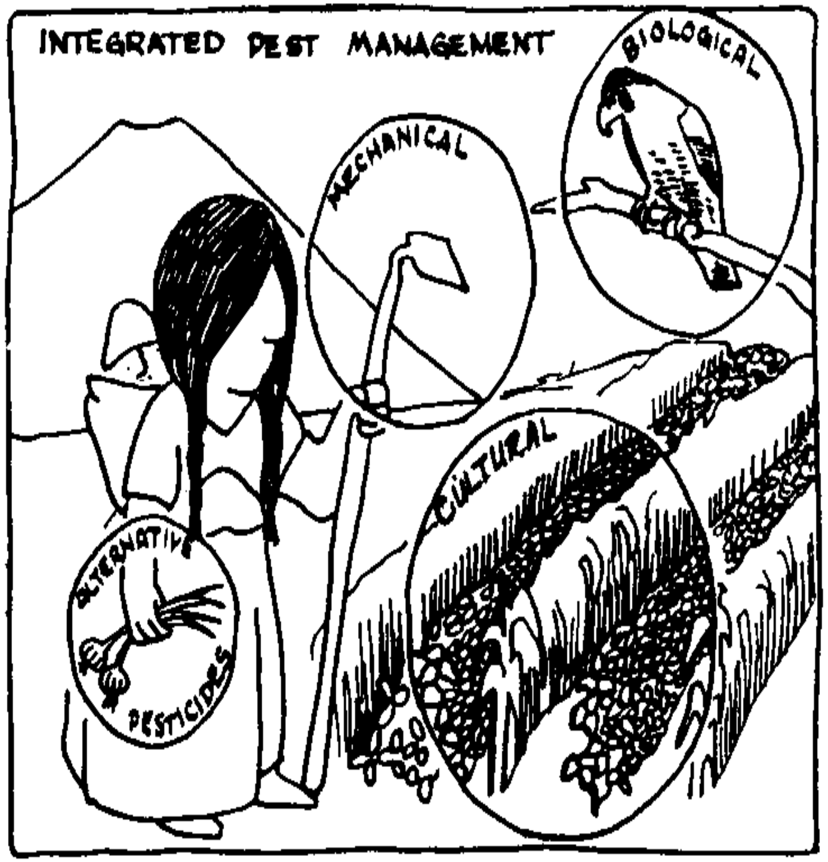

Ideally integrated pest management requires well-trained pest managers who understand the complex factors of ecosystem interrelations. However, even without such resource persons there are merits to introducing and experimenting with some alternative means of control as described in the previous sections, when the results of pesticide use are sickness and death to people.

Some of the most characteristic features and goals of the integrated pest management Approach are:

*** The focus is on the entire pest population and their natural enemies operating within an ecosystem. The agroecosystem is the management unit.**

*** The objective is to maintain pest levels below a pre-established economic threshold. The goal is to manage rather than eradicate the pest population.**

<ECONOMIC THRESHOLD OF PEST MANAGEMENT>

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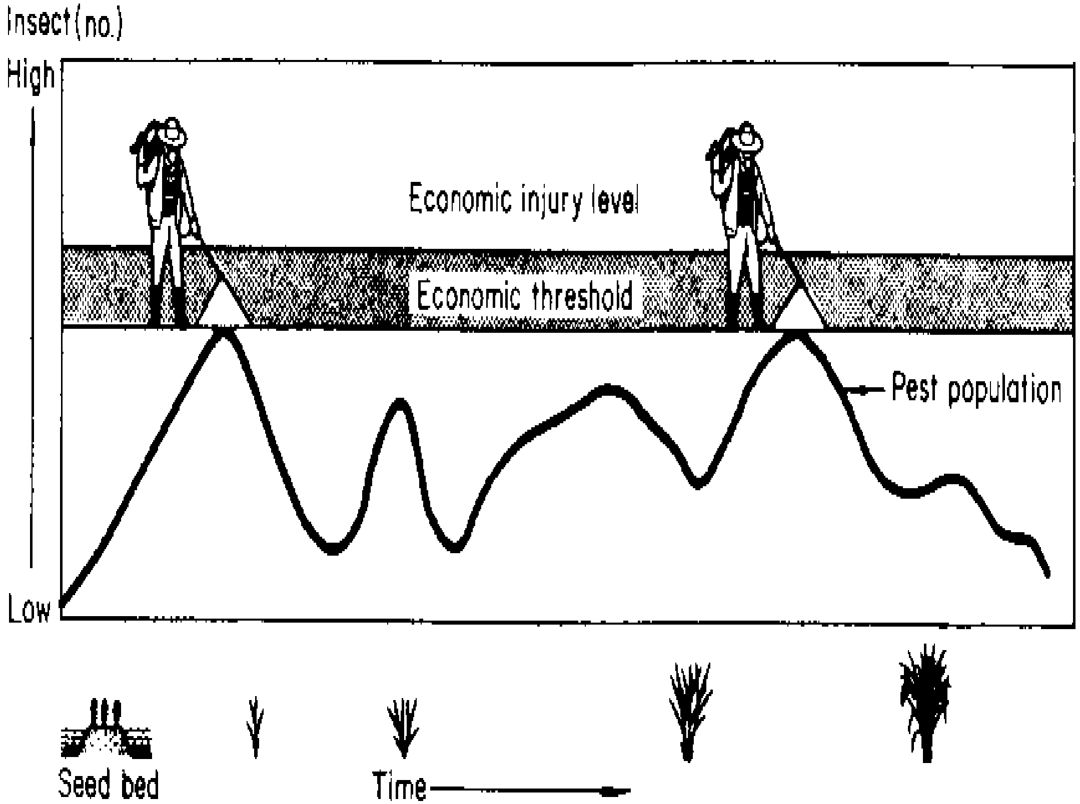
ECONOMIC THRESHOLD OF PEST MANAGEMENT



Source: Reissig 8.18

*** Control methods are chosen to supplement the effects of natural control agents (parasites, predators, weather, etc.).**

*** Alleviation of the problem is long-term and regional, rather**

than localized and temporary, and the harmful side effects on the environment are minimized. Thus, integrated pest management should be part of government policy.

*** Monitoring is essential. Pest population numbers need to be regularly monitored, and also the environmental factors influencing pest abundance in order to determine when to apply control actions. How monitoring is conducted depends on the crop, the pest species, the climate, the human skills, and economic resources. Simple monitoring procedures that involve no special equipment or expenses have been designed for farmers with limited resources. For example, with rice, a system based on plant tapping can be used to sample for the green leafhopper. Each week a farmer randomly picks 20 hills across the paddy. He slaps the plants with force several times with the palm of the hand. He then counts both adults and nymphs that fall on the water. Finally, he calculates the average green leafhopper numbers per hill, and based on this data makes decisions whether or not the pest needs to be controlled.**

<MONITORING BY PLANT TAPPING>

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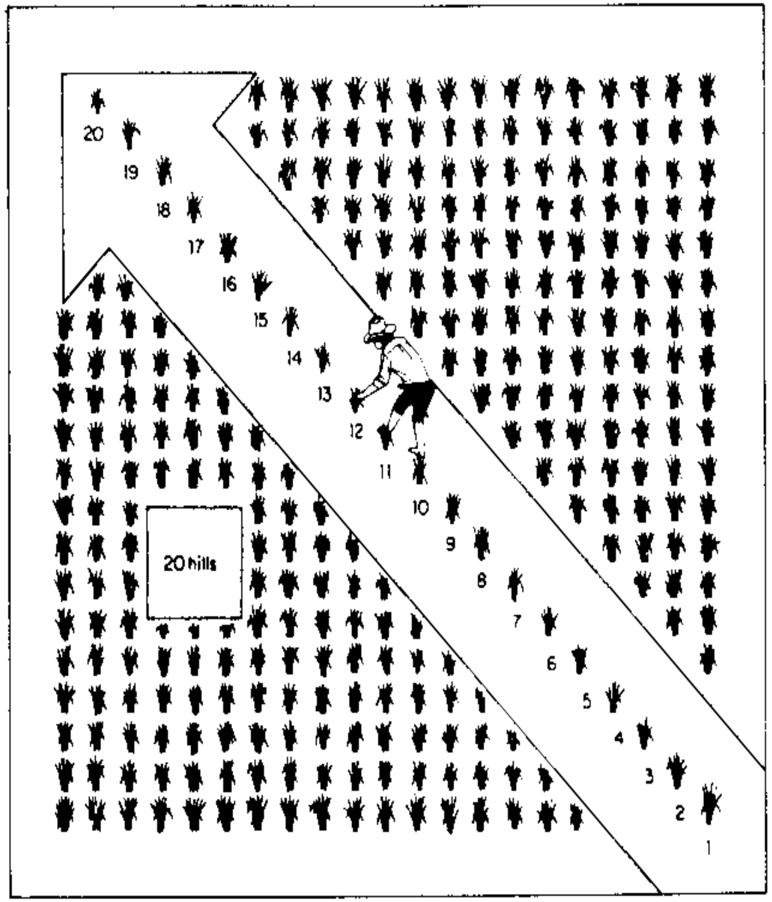
MONITORING BY PLANT TAPPING



Source: Reissig 8.18

DEFINITION OF A PESTICIDE

"Pesticide is an umbrella term used to describe any chemical that controls or kills a pest, be it insect, weed, disease, or animal.

Pesticides are generally classed by the type of pest they control: insecticide (insects), herbicide (weeds), fungicide (fungus), rodenticide (rodents), nematicide (nematodes), acaricide (mites, ticks and spiders). Pesticides are also defined by their method of dispersal (fumigant) or mode of action, such as an ovicide, which kills the eggs of pests. Although they do not specifically kill pests, insect growth regulators are considered pesticides because they modify the insect's growth in such a way as to halt its deleterious effects." (Gips 8.8)

<FIGURE 5>

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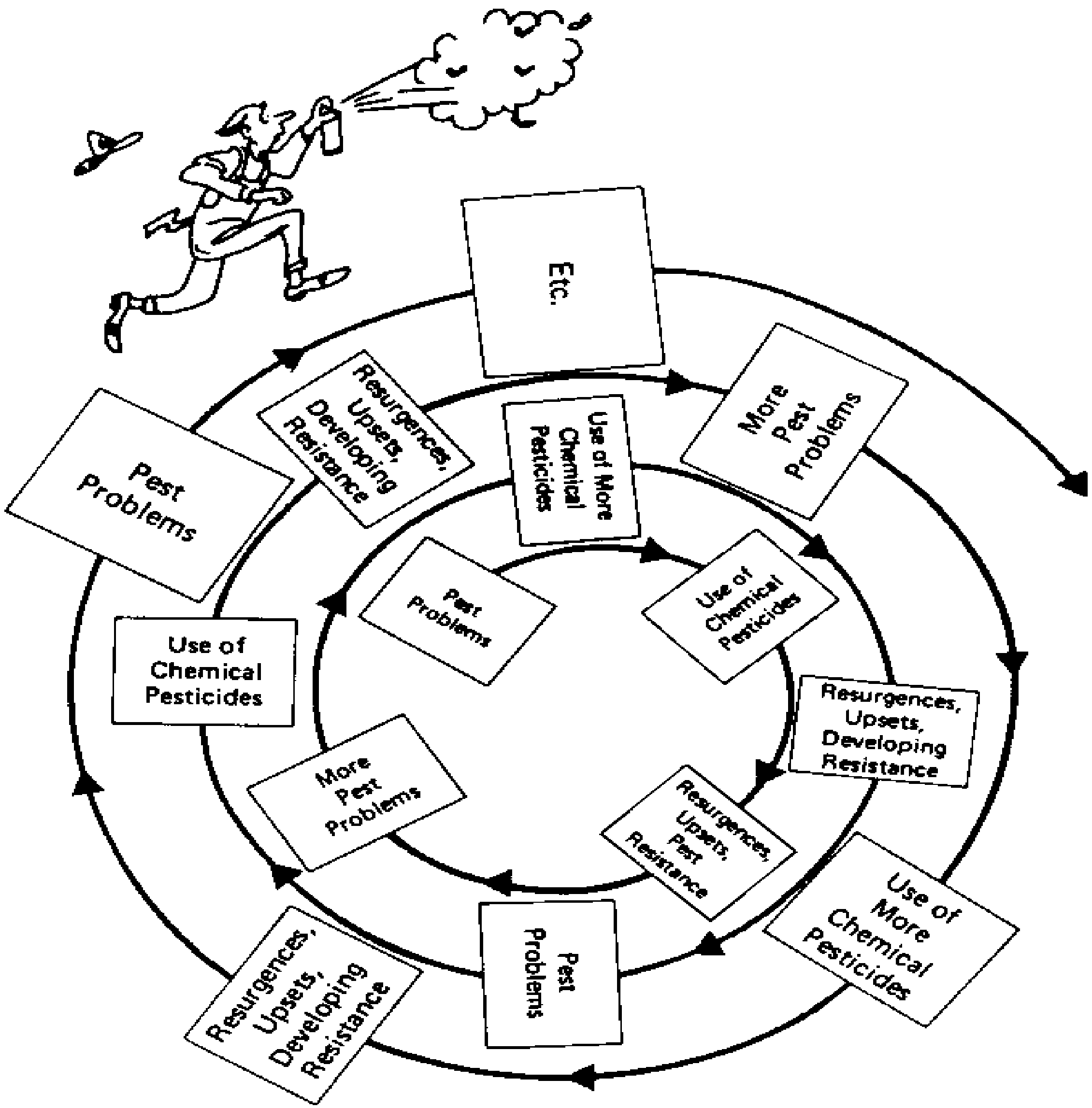

Source: Nebel 8.15

Pesticides used today belong to three principal groups of chemicals:

*** Organochlorides are derivatives of chlorobenzene that are highly toxic and have long-lasting effects. Included in this type of chemicals are DDT, chlordane, aldrin, dieldrin, endrin, toxaphene, lindane, heptachlor, among others.**

*** Organophosphates are highly toxic to men and other warm-blooded animals. Examples are phosdrin, parathion, methyl parathion, azodrin or nuvacron, lorsban.**

*** Carbamates are derived from carbonic acid. Like organophosphates, they have inhibitive or disruptive effects on the central nervous system, which controls all bodily functions, they are very poisonous and take immediate effect. Examples are temik, furadan, lannate, sevin, baygon. (Source: Secretariat for Ecologically Sound Philippines.)**

EFFECTS OF PESTICIDE USE

The use of pesticides should be limited to epidemic situations in which all other measures fail to provide control. Pest management programs should seek to reduce both the frequency of application and the dosage. Following are some of the common effects of dependence on pesticides.

Effects on People

Pesticides can be inhaled by humans or taken into the body through the skin. Body contact is a particular problem during the application of pesticides. Failure to take safety precautions and to handle certain pesticides carefully may even result in death. Thousands of individuals suffer from pesticide poisoning every year. Many die annually. Fatalities have mainly occurred among people who handle pesticides--farmers, crop dusters, farm workers, and workers in pesticide manufacturing factories. More and more concern is also focussed on the issue of poisonings attributed to eating food crops and meat containing pesticide residues.

Effects on Soil Fertility

Each square meter of fertile agricultural soil contains millions of life forms--insects, earthworms, oligochaete worms, nematodes, protozoa, algae, fungi, bacteria, and yeast cells. All these organisms are absolutely necessary for soil fertility maintenance. The organisms are involved in: the conversion of bound nutrients into forms available to plants; the break up of organic matter; the fixation of nitrogen; and the aeration of the soil. Their presence ensures that ecological balance or equilibrium is maintained. Continuous use of pesticides that do not decompose rapidly can alter this soil organism community and, ultimately, may reduce soil fertility. Populations of earthworms, critical to some ecosystems, may be drastically decreased by chlordane, endrin, parathion, carbametes and most nematicides. Some fungicides and herbicides seem to affect mostly the microflora, thus upsetting the dynamics of most nutrients in the

soil.

Effects of Pesticides on the Balance of Nature

Most organisms in nature are regulated by natural enemies keeping them in a state of balance with their environment. Overuse or misuse of pesticides can interfere with this natural control system. When this happens, pest problems can actually be worsened. During the last three decades, despite a tenfold increase in insecticide use, crop losses to insect pests have nearly doubled. Two major factors account for this near doubling of crop losses:

- more than 300 species of insects, mites and ticks have developed genetic resistance to pesticides
- pesticides have inadvertently destroyed natural enemies of certain insect pests, resulting in pest resurgence and/or secondary pest outbreaks

Some Other Effects of Pesticides

Certain pesticides can also alter the chemical makeup of plants. Some organochlorines can increase amounts of particular mineral elements in corn and beans. Herbicides, especially 2,4-D, can induce accumulation of nitrates in plants, with possible toxic effects on livestock and other animals. These changes in plant constituencies can alter the physiology of certain crop plants, such as

corn, making them more susceptible to insect or pathogen attack. In particular, 2,4-D can render some crops more susceptible to pests and disease.

Effects on the Aquatic Environment

Pesticides transported from treated fields into the aquatic environment by runoff and erosion are distributed throughout water, mud, and the organisms living in both. The buildup of pesticides in a given body of water depends on:

- how much pesticide is entering the aquatic system
- the persistence of the pesticide
- the tendency of the pesticide to bioaccumulate, or build up within an organism and food chains
- the sites or organisms in which the pesticide concentration is being measured

Pesticide Persistence

Pesticide persistence is the length of time a pesticide remains biologically active, or toxic, to target pests. Most pesticides are rated according to their persistence, as indicated in the table below.

PERSISTENCE OF CHEMICALS

Duration of Chemical Examples

Activity Group

**Non Persistent 1-12 weeks Organo-phos- Malathion,
phorous com- methyl para-
pounds; thion, para-
Carbamates thion carbaryl**

**Moderately 1-18 months -- 2,4-D, atra-
Persistent zine**

**Persistent 2-5 years Organochlor- DDT, BHC,
ine(1) comp- lindane, al-
ounds drin, dieldrin,
endrin, chlor-
dane, hepta-
chlor, cam-
pheclor**

**Permanent Degraded to Compounds Phenyl mer-
(residues) (permanent res- containing cury acetate,
idue mercury, arsenate of
arsenic or lead lead**

(1) A number of organochlorine compounds are in the "non-persistent" or "moderately persistent" classifications, e.g., methoxychlor, dicofol, chlorobenzilate.

In general, persistent pesticides (those which remain biologically

active for longer periods) are less soluble and volatile but have a strong tendency to become adsorbed (attached to particles of soil). The best known of the persistent pesticides are the organochlorine insecticides (DDT, Aldrin, Endrin, Heptachlor, etc.), the herbicide simazine, and the fungicide benomyl. These can remain up to 14-17 years in the soil. The longer the pesticide persists, the greater the likelihood that it will move from the target area via soil, water, air, or organisms, and influence adjoining ecosystems.

HOW PESTICIDES MOVE ABOUT THE ENVIRONMENT

Pesticide Pathways

Pesticides are applied in either liquid or powder form. Both forms can be sprayed on the soil or plants. During application, some of the pesticide is lost to the air through drifting or volatilization. After application, the pesticides can travel in various ways in the environment:

- biological degradation by soil microorganisms, chemical degradation on the soil surface, or foliage photo-decomposition as a result of sunlight

- volatilization

- absorption by plants (which may be eaten by animals and/or humans)

- adsorption onto soil particles (especially clay and organic matter) that may move with erosion

- dissolution in water (rain or irrigation) that becomes surface runoff or that infiltrates into the soil, later appearing in surface water or groundwater supplies.

Pesticides take one pathway rather than another depending on a number of factors. Principal among these are: characteristics of the pesticide itself; the soil type; the strength and amount of rainfall; the type of erosion control measures being used; and the temperature. In general, pesticide compounds that are more water-soluble and less persistent will move primarily in runoff water. Those that are more firmly adhered or adsorbed to soil particles will generally move with sediment.

Distribution in Soil

Organic content and texture are the most important soil characteristics influencing how pesticides move in the soil. Other soil properties--pH, moisture content, temperature, mineral content--may also influence pesticide persistence and movement. For example, the greatest persistence of organochlorines is found in soils rich in organic matter, with high clay content and with acid pH. Water and pesticides compete for adsorption sites on soil particles; therefore, as moisture in the soil decreases, the amount of pesticide adsorbed may increase. Some pesticides in the soil are subject to leaching. Leaching of pesticides is influenced by the amount and

rate of water flow, and the formulation, concentration, and rate of degradation of the pesticide. Pesticides may move laterally through soil as well, appearing in surface or sub-surface runoff. Cultivation of the soil can also enhance loss of volatile pesticides.

Distribution in Water

Pesticides enter lakes, ponds, rivers, and other waterways from runoff of treated areas, from drift, or from direct pesticide (mainly herbicide) applications. The quantity of a pesticide that moves into a water course from treated areas depends upon topography, intensity and duration of rainfall, soil erodability, and land management practices. Improved erosion control practices can be very important for keeping pesticides from entering the larger environment. Sound project planning requires consideration of the methods for erosion control in light of their applicability for pesticide control.
If pesticides enter a body of water in a dissolved state, the pesticide in solution will move as the water moves. The pesticide may: remain in solution in the water; precipitate out of the water and end up in bottom silt; be taken up by aquatic organisms; be biologically or chemically degraded; or more commonly become adsorbed onto live or dead particulate matter which eventually settles to the bottom as sediment. Pesticides adsorbed on sediment will disperse with the sediment. The finest particles (those carrying the greatest concentration of pesticide) will be transported the farthest and will typically be the last to settle out of the water to the bottom in lakes or quiet water. Systems with running water which flushes away pesticide pollutants tend to be more resilient

than those where water is static.

<FIGURE 6>

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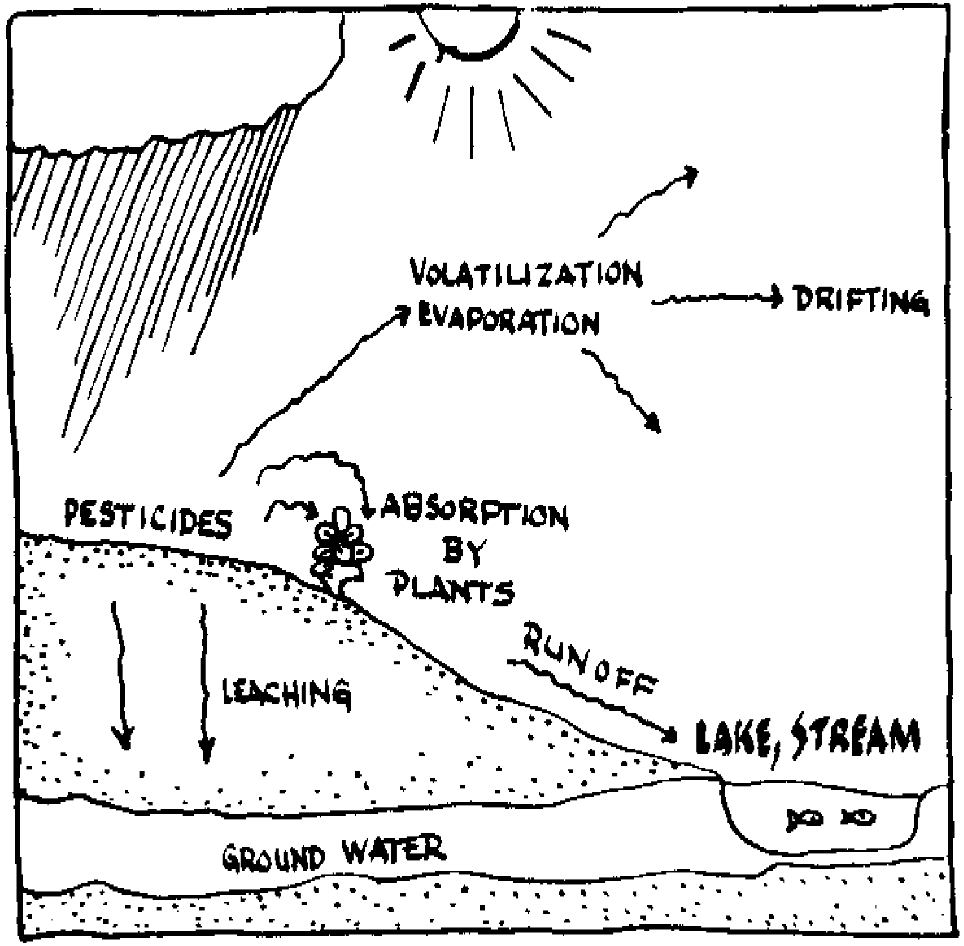

Until they chemically degrade, pesticides will not disappear. Because the system is dynamic, even those deposited in bottom muds may be later churned up and carried downstream. Also, pesticides continually separate from muds and remain in the water. Once in the water, the pesticides may reach the surface and volatilize (become gaseous) or be degraded by sunlight. On the bottom of a water body, there is often a lot of microbial activity in the organic matter. At the bottom, biological decomposition consumes oxygen, thereby creating anaerobic (without oxygen) conditions that favor the degradation of many pesticides.

If pesticides must be used, try to use those that will degrade rapidly in water in order to protect nearby aquatic environments. Also, keep in mind that the products of pesticide degradation may be toxic. Information appropriate for your region is available by writing to the Pesticides Action Network (PAN). Addresses of the regional offices of PAN are in Appendix B.

SOME FACTORS THAT SHOULD BE CONSIDERED BEFORE APPLYING PESTICIDES

Local Experience

Check with local farmers or extension agency personnel to see what local experience has been with given pesticides. There is no prescription for the persistence and potency of pesticides. It can vary depending upon local conditions.

Alternative Pest Control Measures

Check the variety of alternative non-chemical control measures that may meet project needs. Become familiar with possible negative effects of the pesticides you may be considering. Some of these alternatives are described elsewhere in this chapter.

Synergism

Consider the possibility of relationships between two or more pesticides used in the same area before applying more than one to a field. When two or more pesticides are applied at the same time, their combined toxicity may actually be greater than the sum of their individual toxicities. This is called synergism.

Timing of Application

If possible, apply pesticides well before heavy rains if they are to do the most good in controlling target organisms. The rate at which pesticides are washed off the land is usually high at first. This rate of loss, however, decreases reaching a steady rate, unless changed by weather, soil, temperature, soil moisture level, acidity, or cultural practices. Some pesticides have greater losses if they are applied to wet soil rather than dry, especially if runoff occurs soon after application. When pesticides are incorporated into the soil, the loss to runoff is not as great as when they are just left on the soil surface.

Pesticide Movement

Explore the ways in which pesticides might move through the environment to help design projects that will contribute less to pollution. Runoff travelling from cropland to open water can carry pesticides. As the water crosses other lands, some pesticide is left behind. While the total amount entering the water is decreased, nearby land may also be contaminated by pesticides. This pollution can have damaging impacts on animals and humans.

Precautions Necessary

If you are going to introduce pesticides it is important to provide training to those who will be applying them. Include precautions regarding bodily exposure of those applying chemicals and exposure of others in the area. At the very least, read the directions on the label carefully. These will instruct on the way in which the chemical can be safely applied, the time that needs to elapse following application before the area is safe, and the relation of using the chemical to the maturing of the crop. Also, read the precautions on the label and understand the steps to take in case of emergencies such as swallowing some, or coming in physical contact with the chemical. Never reuse pesticide or herbicide containers.

CHECKLIST FOR PROJECTING THE IMPACTS OF CHEMICAL PESTICIDE USE AND THE POTENTIAL FOR ALTERNATIVES

Addressing questions such as the following will provide the

project planner with a background for making informed judgments concerning environmentally sound pest control.

*** Are chemical pesticides suggested for the project?**

*** Have all pest management options been considered?**

*** Are alternative pesticides available that are relatively safer to use?**

*** Are there plants with pesticidal properties which could be used? Are they locally available?**

*** Are the pesticides to be used in the project recommended for use on these particular crops by the manufacturers? By the government?**

*** Are similar pesticides being used locally for health purposes, such as malaria control?**

*** Can a species-specific pesticide be used?**

*** Does the project design recognize the possibility that target species will develop resistance to the pesticide and larger quantities may be required each year to control the pest?**

*** Is it possible to change pesticides to reduce the likelihood of target species developing resistance to an important pesticide?**

If so, can a schedule for implementation be developed?

*** Is the pesticide persistent in soil? Will it tend to accumulate in the soil?**

*** Might the pesticide suggested for use kill beneficial soil micro-organisms?**

*** Does the pesticide tend to bioaccumulate (biologically increase) or biomagnify (biologically grow) in organisms? If so, which organisms would it affect in the immediate area, if any?**

*** Is there a body of water nearby? If so, are people downstream highly dependent upon aquatic resources such as fisheries, aquaculture, and drinking water which might be contaminated by an accidental discharge of pesticides because of the project? What effect would contamination of the water have on health, finances, and other?**

*** Is it likely that erosion will carry pesticides into downstream water bodies? If so, could such pesticides affect fisheries, aquaculture projects, and domestic water use?**

*** Have adequate precautions been taken to protect workers from pesticide poisoning during transport, storage, and application of pesticides? Are instructions available in local languages with culturally sensitive symbols?**

* Can pesticide applications be timed to avoid rapid loss to wind and rain?

* Is it possible to develop plans that can be put into effect easily and simply in case of an emergency, such as accidental pesticide pollution or physical contact?

* What alternative project designs could be used at the site to minimize environmental impacts from pesticide use?

CHAPTER 9

AGROFORESTRY SYSTEMS

Agroforestry systems are production strategies designed to promote a more varied diet, new sources of income, stability of production, minimization of risk, reduction of the incidence of insects and disease, efficient use of labor, intensification of production with limited resources, and maximum returns with low levels of technology. Some form of agroforestry has been practiced by many traditional agriculturalists. For a number of reasons such as commercial plantation development, cattle raising, deforestation, and population pressures, these practices may have been abandoned. Recognizing the value of combining trees with crops and livestock as a means of conserving soil, increasing the multiple uses of land, rehabilitating degraded sites, and diversifying to reduce risk is leading development workers to consider introducing or reintroducing agroforestry practices with improvements based on research and experience.

This recognition has grown out of a combination of acknowledging traditional experience and scientific research. Traditional bush fallow and shifting cultivation could be said to be a precursor of the modern understanding of agroforestry. The clearing of woody vegetation for crops for a period of years and reestablishment of forest in the fallow period was a combination of agriculture and forest in sequence that has been practiced in many regions. Taungya is an early form of agroforestry that introduced tree seedlings planted by foresters combined with growing of crops in the cleared area until the tree canopy provided too much shade. Traditional kitchen gardens have typically been a mixture of shrubs, food crops, and medicinal plants in a multistoried arrangement. For some species of coffee and cacao interplanting with shade trees has been a necessity.

Some more purposeful combinations of trees and crops practiced today are introduction of fodder trees in fields; dispersing indigenous species in fields for nutrients and fodder, as for example Acacia albida in millet fields; use of trees for shelter belts and hedgerows.

Alley cropping is a recently introduced system that involves planting and intensive management of relatively close-spaced rows of nitrogen-fixing trees and shrubs such as Leucaena and Gliricidia, with a crop such as maize in between. (Winterbottom 9.19)

DEFINITION AND CLASSIFICATION

Agroforestry denotes a "sustainable land and crop management system that strives to increase yields on a continuing basis, by

combining the production of woody forest crops (including fruit and other tree crops) with arable or field crops and/or animals simultaneously or sequentially on the same unit of land, and applying management practices that are compatible with the cultural practices of the local population." (International Council for Research in Agroforestry, 1982)

There are several ways to classify and group agroforestry systems (and practices). The most commonly used are: structure (composition and arrangement of components); function (the use of trees); ecologic (ecosystem or climatic zone); and socio-economic scale and level of management.

Structure

Agroforestry systems can be grouped as:

- agri-silviculture: the use of land deliberately for the concurrent or sequential production of agricultural crops field and tree crops) and forest crops (woody forest plants)

- silvo-pastoral systems: land management systems in which forests are managed for the production of wood, food and fodder, as well as for the rearing of domesticated animals

- agro-silvo-pastoral systems: systems in which land is managed for the concurrent production of agricultural (field and tree crops) and forest crops (woody forest plants)and for the rearing of domesticated animals

- multipurpose forest tree production systems: in which forest tree species are regenerated and managed for the ability to produce not only wood, but leaves and/or fruit that are suitable for food and/or fodder

Function

The functional basis for classifying agroforestry systems refers to the main output and role of various trees, especially the woody ones. These would be productive functions (production of "basic needs" such as food, fodder, fuelwood, and other products), or protective roles (soil conservation, soil fertility improvement, protection offered by windbreaks and shelterbelts, and so on). The functional basis is discussed in detail later in this chapter.

Ecologic or Climatic

On an ecological basis, systems can be grouped for any defined agro-ecological or climatic zone such as lowland humid tropics, arid and semi-arid tropics, tropical highlands. They can also be based on climatic zones defined by rainfall patterns or other groupings that serve the purpose.

Socio-Economic Scale and Level of Management

The socio-economic scale of production and level of management of the system can be used as the criteria to designate systems as

commercial, intermediate, or subsistence.

Each of these ways of looking at agroforestry systems is useful and applicable in specific situations, but for each there are limitations so that no single way of grouping is universally applicable. Classification depends upon the purpose for which it is intended.

SOME ADVANTAGES OF AGROFORESTRY SYSTEMS

By combining agriculture and forestry/tree crop production, the various functions and objectives of forests and food crops production can be better achieved. There are advantages of such integrated systems over agriculture and/or forestry monocultures. (Wiersum 9.18)

Ecological Advantages

*** A more efficient use is made of the natural resources. The several vegetation layers provide for an efficient utilization of solar radiation, different kinds of rooting systems at various depths make good use of the soil and short-lived agricultural plants can profit from the enriched topsoil as a result of the mineral cycling through treetops. By a three dimensional use of space, total growing capacity is increased. By including animals in the system, unused primary production can also be utilized for secondary production and nutrient recycling.**

*** The protective function of the trees in relation to soil, hydrology,**

and plant protection can be utilized to decrease the
hazards of environmental degradation.

It should be kept in mind, however, that in many agroforestry systems the components may be competitive for light, moisture, and nutrients; trade-offs must be considered. Good management can minimize this interference and enhance the complementary interactions.

Economic and Socio-Economic Advantages

* By ecological efficiency the total production per unit of land can be increased. Although the production of any single product might be less than in monocultures, in some instances production of the base crop may increase. For example, in Java it has been demonstrated that after introduction of the tumpang-sari or taungya system, dryland rice production increased significantly.

* The various components or products of the system might be used as inputs for production of others (for example, wooden implement, green manure) and thus the amount of commercial inputs and investments can be decreased.

* In relation to pure forestry plantations, the inclusion of agricultural crops with trees, coupled with well-adjusted intensive agricultural practices, often results in increased tree production and less costs for tree management (e.g., fertilization and weeding of agricultural crops may also

benefit tree growth), and provide a wider array of products.

*** Tree products can often be obtained throughout the year providing year-round labor opportunities and regular income.**

*** Some tree products can be obtained in the agricultural off-season (e.g., dry season), when no opportunities for other kinds of plant production are present.**

*** Some tree products can be obtained without much active management, giving them a reserve function for periods of failing agricultural crops, or special social necessities (e.g., building a house).**

*** By the production of various products a spreading of risk is obtained, as the various products will be affected differently by unfavorable conditions.**

*** Production can be directed towards self-sufficiency and marketing. The dependency on the local market situation can be adjusted according to the farmer's need. If so desired, the various products are entirely or partially consumed, or delivered to the market, when conditions are right.**

SOME CONSTRAINTS OF AGROFORESTRY SYSTEMS

There are a number of limiting conditions or constraints to implementing agroforestry systems. These constraints should be

recognized and efforts made to overcome them, if agroforestry is to be applied successfully.

*** A major ecological constraint is that agroforestry systems are ecosystem-specific and on certain low grade soils the choice of suitable plant species might be limiting, although many trees are better adapted to poor soils than annual crops.**

*** The competition between trees and food crops, and the priority that must be given to them to meet basic needs, may exclude poor farmers, who have very little land, from tree growing.**

*** In promoting tree planting, short term benefits as well as long term benefits are needed. Economic or production incentives need to be included.**

*** A common economic constraint is that some newly established agroforestry systems might need substantial investment costs to get started (e.g., planting material, soil conservation, fertilizer). For these investments, credit may be needed. In most agroforestry systems one may need a few years before the first yields are obtained. In some cases, financial support is needed to provide for this waiting period.**

*** Size of plot may affect the kind of inputs. In areas with a high population pressure and poor soils, the private landholdings might be too small as viable production units. In**

this case some kind of cooperative effort might be necessary.

*** Availability of seeds and/or seedlings is a critical variable for agroforestry projects. Check with government offices, university forestry or botanical departments, or nongovernmental organizations involved in species research for the best species to meet your needs. Then check on availability of seeds and/or seedlings. In most cases, longer run planning includes developing small nurseries along with planting and maintaining trees.**

*** Management of livestock sometimes can conflict with agroforestry ventures especially in areas where cattle or goat herding is being practiced.**

*** Wildlife is a problem in some areas. Where elephant herds still exist they have threatened forestation projects.**

*** Pests may also threaten agroforestry projects--both tree and ground crops. Current infestation of locusts in some areas of the Sahel in Africa are a problem.**

*** In areas with complex clan or communal land systems, developing agroforestry systems may be difficult. Tenure rights are a fundamental consideration in agroforestry. They may be a limiting factor.**

*** Tree tenure is also a possible constraint. In many cases,**

land on which trees may be planted and protected is not owned by those who planted them. The planters, then, may not be legally entitled to harvest the trees or the produce of the trees. Further, in some countries there are laws that restrict the harvesting/cutting of trees for any purpose regardless of who owns the land on which they are planted. It is therefore necessary to check before undertaking a tree planting project to see:

- who owns the land
- what are the regulations about protecting the seedlings
- what are regulations about harvesting the trees and/or produce of the trees

*** Factors that may limit the participation of people and affect their motivation need to be considered. In addition to land and tree tenure these include other socio-political policies of the government as well as some traditional social mores.**

*** In all cases, it is essential that the local population is directly involved and traditional farming knowledge taken into account in the planning and design of the system. (See Chapter 3) Agroforestry is a complex form of land-use and requires adequate farming knowledge. Local knowledge and experience is still available about traditional agroforestry systems. For developing new agroforestry techniques, knowledge of traditional land use and farming systems and additional education and/or extension work is essential.**

<WOMEN GROWING SEEDLINGS>

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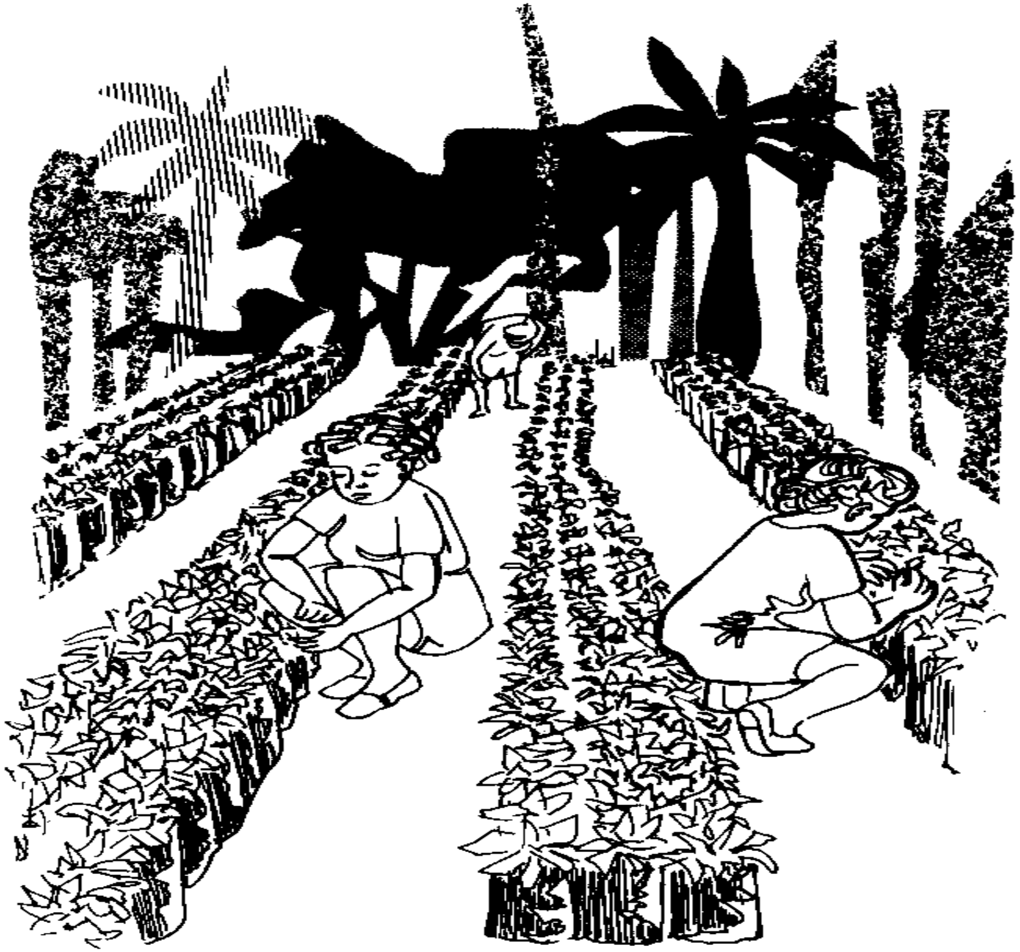
WOMEN GROWING SEEDLINGS



"... vamos haciendo los viveros..."

Source: Mujeres en Desarrollo 9.8

ROLE OF WOMEN IN AGROFORESTRY

Women have traditionally been involved in both agriculture and in the use and management of trees. Most often women harvest the products of trees. Yet women have often been ignored in the design of agroforestry projects. There are significant examples of women taking the initiative to create possibilities for tree planting and relating trees to the farm system. Notable among these are the Green Belt Movement of the National Council of Women, Kenya, The Forestation and Ecological Education Project of Mujeres en Desarrollo (MUDE) in the Dominican Republic, and the Chipko movement in India. Projects that involve participation of women from the outset have been more sustainable. (Fortmann and Rocheleau 9.2)

<TREES HAVE MANY USES>

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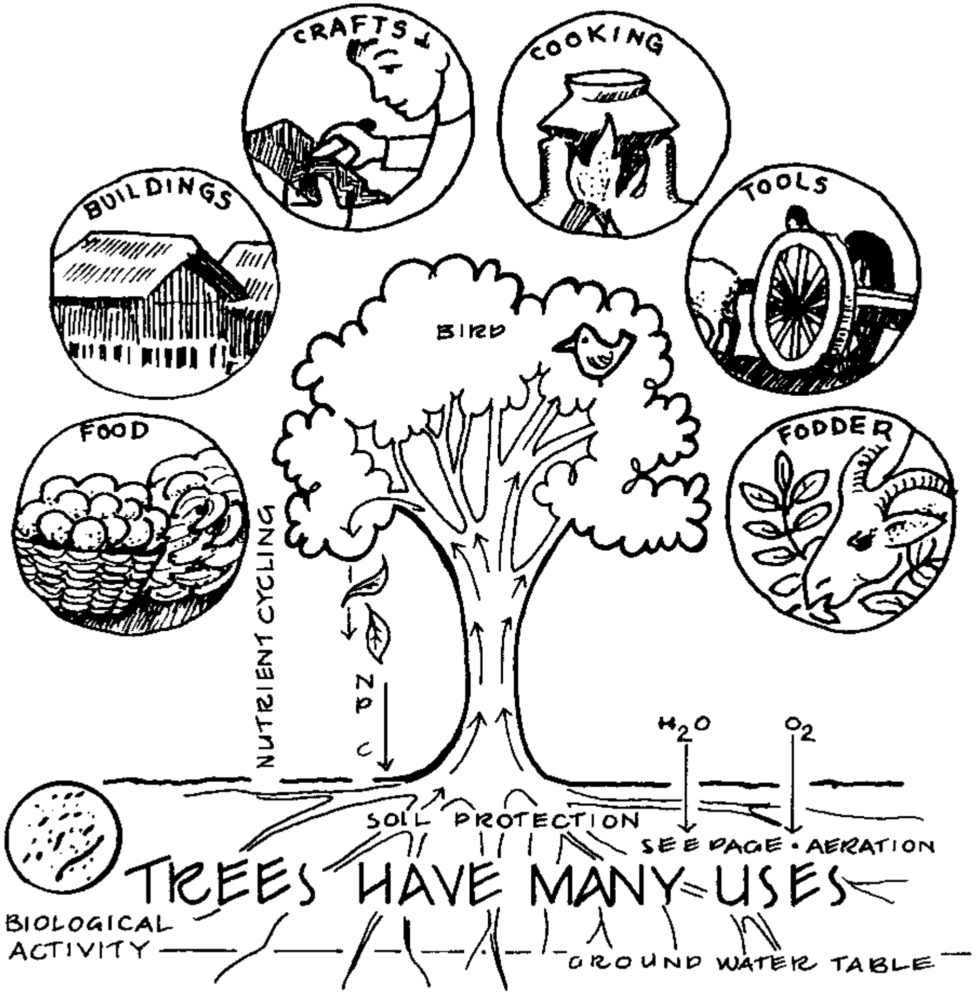

THE ROLE AND EFFECT OF TREES

Agroforestry systems are multiple use systems in which the tree components provide most of the multiple benefits. The management of the tree component can affect, directly or indirectly, the other ecosystem components, for example soil conservation, nutrient

recycling, the hydrological cycle, as well as bio-components (other crops, weeds, insect populations, micro-organisms). Thus, through management of trees these other components can to some extent be controlled.
Perhaps the most important ecological role of trees in farmlands is their effect on soil conservation.

Effect on Soil Conservation

Inclusion of trees usually increases organic matter content, and improves physical conditions of the soil. (Wiersum 9.18)

<LINKAGE INTERACTION>

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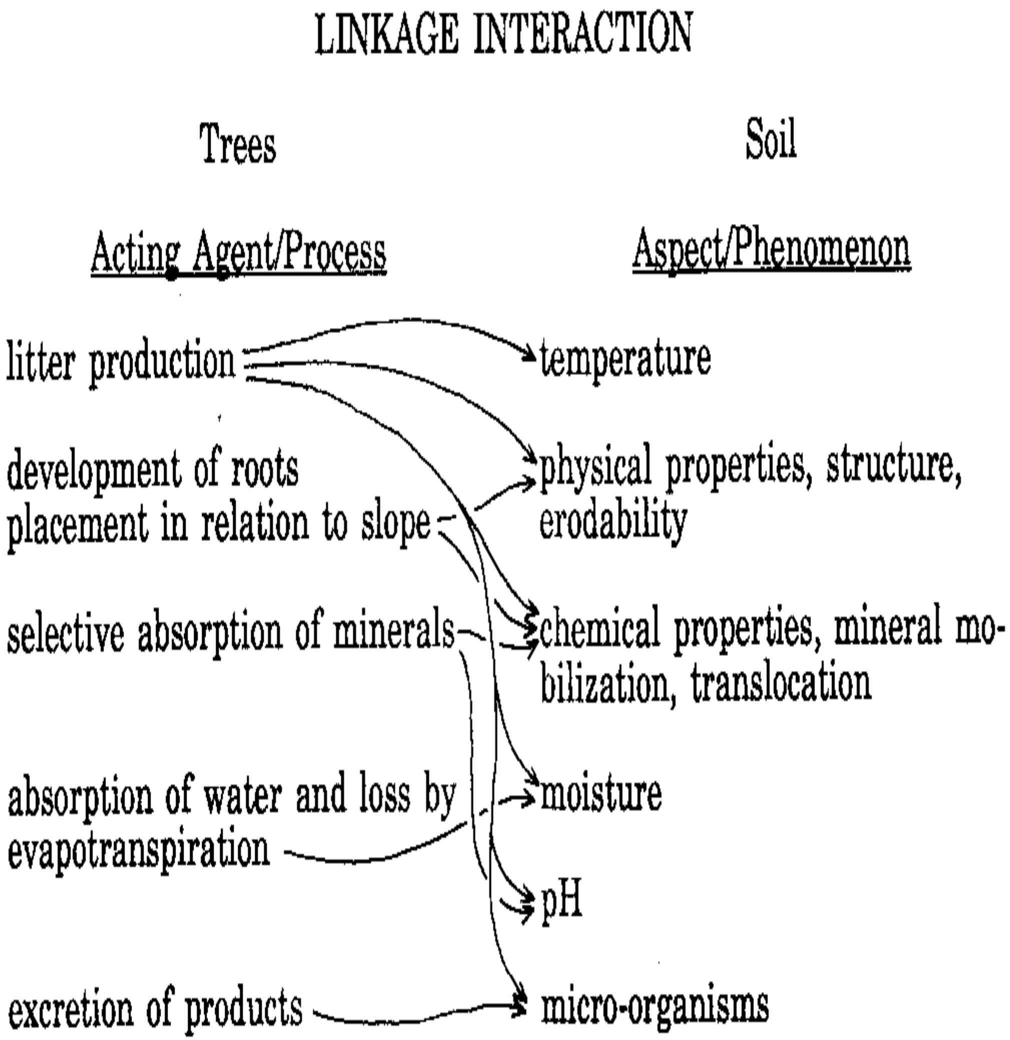

Effect on Nutrient Recycling

Below is a schematic presentation of nutrient relations and advantages of ideal agroforestry systems in comparison with common

agricultural and forestry systems.

<COMPARISON OF SYSTEMS>

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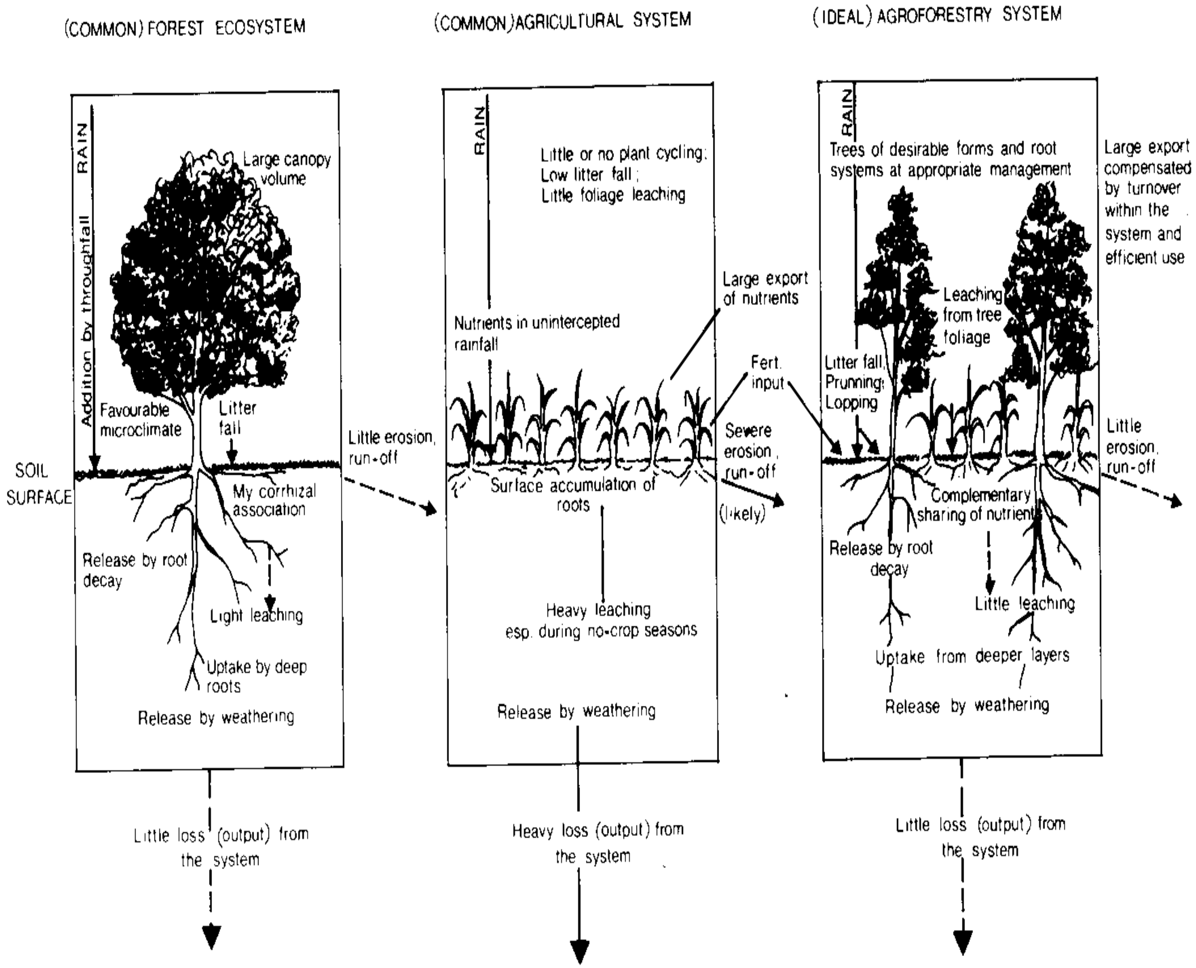
COMPARISON OF SYSTEMS



Source: Lockevetz 9.7

Effect on Hydrological Cycle and Erosion

Trees also influence hydrological characteristics from the micro-climate level up to the farm and local levels.

<EFFECT ON HYDROLOGICAL CYCLE AND EROSION>

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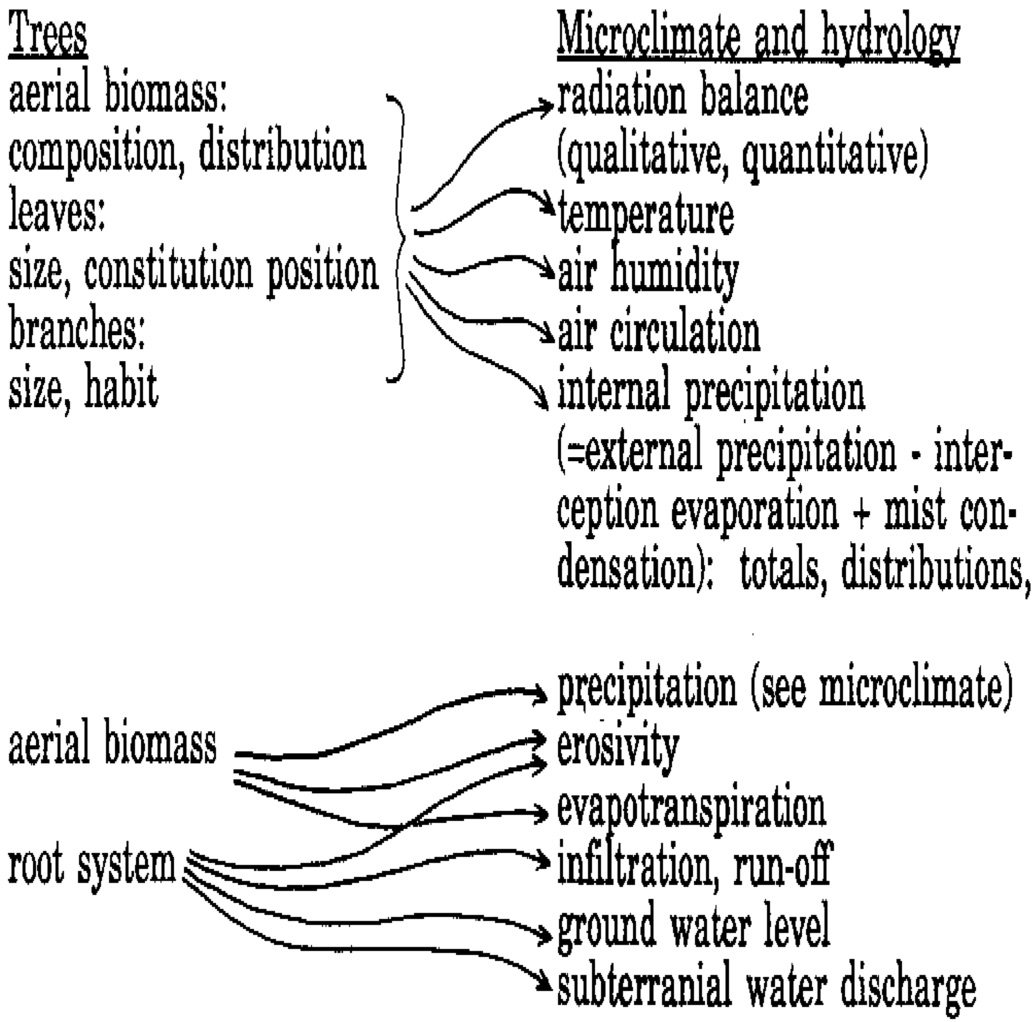

A summary of linkages between agroforestry, land management, and soil conservation is found in the table on the following page.

EXAMPLES OF TRADITIONAL AGROFORESTRY SYSTEMS

Traditional agroforestry represents centuries of accumulated experience of interaction with the environment by farmers without access to scientific information, external inputs, capital, credit, and developed markets. Shifting cultivation (swidden agriculture and the slash and burn system) was among the earliest forms of agroforestry systems. These methods were sustainable under conditions of low population pressures and long fallow periods.

LINKAGES BETWEEN AGROFORESTRY, LAND MANAGEMENT, AND SOIL CONSERVATION

Factors AGROFORESTRY FARM/RANGE MANAGEMENT SOIL CONSERVATION
Affecting
Sustainablity
and FARM RANGE
Productivity

Soil Moisture - Alley cropping, line plantations - Use of compost, cover- - Controlled grazing - Incorporating organic matter into
Retention and dispersed trees to provide: crops the soil

*** Organic matter - Crop-residue left in fields - Rotational grazing - Preparing micro-catchments, contour ridges or other micro-site**
*** Shade to reduce surface - Mulch - Fire Management improvements.**
temperature

Soil Fertility - Nutrient cycling and Nitrogen - Crop rotation (including - Use of Animal - Contour vegetation strips fixation legumes) Manure

Water Erosion - Surface Runoff reduction - Contour farming - Range rotation - Berms, ditches, ridges Control through:

*** Establishment of trees/ - Maintaining soil tilth - "Grazing reserves" - Benches or terraces**
shrubs along physical - Waterway and gully control
conservation features - Maintaining maximum - Contract grazing - Protection of stream banks
plant cover linked to vegetation
*** Trees along canals and rehabilitation or**
waterways protection.

Wind Erosion - Wind reduction through: - Maintaining maximum - Controlled lopping - Windbreaks
Control plant cover for fodder
*** Dispersed Trees - Natural vegetation strips - Palisades, other physical**
left when clearing new land treatment in extreme cases
*** Borderline Trees - Minimum till cultivation - Dune stabilization**

Access - Live fencing - Stock driveways left - Herding as opposed - Layout of soil conservation
Control when laying out fields. to letting animals plantings to reinforce
roam freely fencelines and livestock trails.
- Alignment of livestock trails - Borderline Trees - Tethering or
corraling livestock

Source: Weber and Stoney 3.8

Throughout the tropics, traditional agroforestry systems may contain well over 100 plant species per field. These are used for construction materials, firewood, tools, medicine, livestock feed, and human food. In Mexico, for example, Huastec Indians manage a number of agricultural and fallow fields, complex home gardens, and forest plots totalling about 300 species. Small areas around the houses commonly average 80-125 useful plant species, mostly native medicinal plants. Management of the noncrop vegetation by the Huastecs in these complex farm systems has influenced the evolution of individual plants and the distribution and composition of the total crop and noncrop communities. Similarly, the traditional pekarangan system in West Java commonly contains about 100 or more plant species. Of these plants, about 42% provide building materials and fuelwood, 18% are fruit trees, 14% are vegetables, and the remainder constitute ornamentals, medicinal plants, spices, and cash crops.

Javanese agroforestry systems usually consist of three stages--kebun, kebun-campuran and talun--each stage serving a different function (Christanty 9.1). The first state, kebun, is usually planted with a mixture of annual crops. This stage has a high economic value since most of the crops are sold for cash. After two years, tree seedlings have begun to grow into the field and there is less space for annual crops. The kebun gradually evolves into a kebun-campuran, where annuals are mixed with half-grown perennials. The economic value of this stage is not as high, but it has a high biophysical value, as it promotes soil and water conservation. After harvesting the annuals, the field is usually abandoned for two to three years to become dominated by perennials. This stage is

known as talun, the climax stage in the talun-kebun system. The talun has both economic and biophysical values.

To begin the process after clearing the forest, the land can be planted to dryland rice (huma) or wet rice paddy (sawah), depending on whether irrigation water is available. Alternatively, the land can be planted with a mixture of annual crops, the first stage (kebun). In some areas the first agroforestry stage (kebun) is developed after harvesting the dryland rice (huma) by following the dryland rice with annual field crops. If the kebun is mixed with tree crops or bamboo, it becomes second stage (kebun campuran), a mixed garden. After several years perennials will dominate and create the third stage, a perennial crop garden (talun). (See figure on page 17.)

Agroforestry systems are also widespread among many tribal groups, for example, in the Amazon region, the Himalayas, the Philippines, and the Sub-Saharan countries of Africa. Unlike other shifting cultivators, the Bora in Brazil do not have a transition between cropping and fallow, but rather a continuum from a cropping system dominated by crops to an old fallow composed entirely of natural vegetation. This process may take as long as 35 years or more. Given current population pressure trends and deforestation rates in the area, this system may not be sustainable in the future.

DESIGN OF AGROFORESTRY COMBINATIONS

Arrangement of component plant species in space and time is also an important but difficult factor in agroforestry because of the

many variations in the types of agroforestry practices and the conditions under which they are practiced. When attempting to improve such systems or to devise new ones, it is therefore necessary to know about both the short-term productivity of the plants and the long-term sustainability of the system. Thus, depending on whether the tree/crop interaction is favorable or not, plant arrangements have to be devised to maximize the beneficial interactions and minimize the undesirable ones. There are also several other factors to be taken into account, such as:

- growth habits and growth requirements of the component species when grown near other species
- simplicity of management procedures for the whole system
- realization of additional benefits such as soil conservation

Species and plant arrangement patterns in agroforestry are very situation specific.

One way to develop agroforestry is to imitate the structure and function of natural communities. In the humid tropics successional ecosystems can be particularly appropriate models for the design of agricultural ecosystems. In Costa Rica, plant ecologists conducted spatial and temporal replacements of wild species by botanically and/or structurally/ecologically similar plants. Thus, successional members of the natural system such as Heliconia species, cucurbitaceous vines, Ipomoea species, legume vines, shrubs, grasses, and small trees were simulated by plantain, squash varieties, yams, sweet potatoes, local bean crops, Cajanus cajan, corn/sorghum/rice,

papaya, cashew, and Cassava species, respectively. By years two and three, fast-growing tree crops (for example, Brazil nuts, peach, palm, rosewood) may form an additional stratum, thus maintaining a continual crop cover, avoiding site degradation and nutrient leaching and providing crop yields throughout the year.

Some agroforestry systems are given below based on materials published by the International Council on Agroforestry (ICRAF), Kenya. (Spicer 9.12) Information about the choice of species and their planting and management schedule needs to be sought locally or regionally. Some of the techniques discussed below are described on pages 53-58.

1. Alley Cropping in High Potential Areas

Alley cropping is appropriate for home gardens and for cultivated arable land. This system can be helpful in the following ways:

- providing green manure or mulch for companion food crops; in this way plant nutrients are recycled from deeper soil layers
- providing prunings, applied as mulch, and shade during the fallow
- suppressing weeds
- providing favorable conditions for soil macro- and micro-organisms; when planted along the contours of sloping land, to provide a barrier to control soil erosion

- providing prunings for browse, staking material and firewood
- providing biologically fixed nitrogen to the companion crop

Trees and shrubs suitable for alley cropping should meet most of the following criteria:

- can be established easily
- grow rapidly
- have a deep root system
- produce heavy foliage
- regenerate readily after pruning
- have good coppicing ability
- are easy to eradicate
- provide useful by-products

Multipurpose species are generally preferable because they give the alley cropping system flexibility. Leguminous trees and shrubs, because of their ability to fix atmospheric nitrogen, are preferred over non-leguminous species.

2. Contour Planting

Contour planting is useful where there are the following conditions:

- poor or easily depleted soils
- sloping (erodible) land as well as non-erodible land
- medium to high population density

Contour planting can help in the following ways:

- to restore/improve soil nutrient and increase organic material content
- to reduce soil and water run-off
- to spread the risk of crop failure during extremely dry seasons by moderating the effects of excessive moisture evaporation on exposed land
- to add wood products for home consumption or sale

The appropriate farming systems in which to utilize this system are permanent crop cultivation, medium to small farm size, and medium to high labor input available per unit of land. Fast growing species can be established at the start of the growing season which gives them the opportunity to establish while livestock are kept out of the arable areas.
3. Fodder Bank - Cut and Carry

Establishment of fodder banks is useful where there is high population density and nearby markets for livestock products. Fodder banks can improve fodder availability and quality, particularly during the late dry and early wet season. They also seem to restore/improve soil nutrients and organic matter content. Creating these banks of trees will facilitate ease of fencing. Pure stands (blocks, strips, lines) of trees (mainly leafy fodder) can be planted near cattle kraals, in homestead gardens, in arable lands and grazing areas, along watercourses and around the margins of

watering places.
The appropriate farming system for fodder banks is on the small farm where there is intensive land use, a kraal feeding system and high labor input per animal.

4. Fodder Bank - Grazing

Fodder banks for grazing are usually located in grazing areas. They may be on hills (especially pod species), on uplands, along watercourses, and on borders of watering places.
Fodder banks for grazing will improve fodder availability and quality in low to medium population density areas, and restore/improve soil nutrients and level of organic materials.
A mixture of trees (pods and leaves) and grasses (fenced) can be planted in blocks. Pod and foliar species should be planted in hedges. Scattered trees need to be protected by thorns. The pod species will provide a feed supplement for cattle during the early rains.
Species selected must be adaptable to local climate and soil as well as having other attributes such as palatability, high protein content, ease of establishment by direct seeding, transplanting or truncheon setting. Pod trees for hills and uplands seed from August to December. Self-seeding varieties in watering places must be tolerant of up to 6 months waterlogging. They should have a limited water uptake rate in order not to have a detrimental effect on the hydrology of the area. Foliar species should be maintained at the lower levels.

5. Fruit Improvement

In the homestead arable area and garden it is useful to add fruit-producing trees. Scattered trees, planted near the home will allow for protection from animals. Fruit trees may also be planted to create boundaries around the homestead. This will improve nutrition, produce fruit for sale, provide shade, and firewood. Use of the system is limited by the availability of improved fruit varieties. There needs to be adequate extension support to help with choice of varieties and management, e.g., propagation, grafting and budding, planting, mulching, watering, and control of weeds, pests, and diseases.

6. Hedges/Living Fences

Hedges and living fences are useful in areas with medium to high population density and where animals roam freely in the area. Live fences or hedges provide an alternative to constructed fencing for:

*** The demarcation of boundaries; for example between/around schools, farms and fields (particularly paddocks in grazing schemes).**

*** Protection from the ravages of free-grazing livestock; for example crop lands, orchards, nurseries, woodlots, dams, protein banks (grazing schemes), vegetable gardens and homes.**

In addition hedges can offer secondary benefits, such as reducing the adverse influence of wind, and they provide not only organic material to adjacent soils but also multiple tree products (firewood, poles, fruit, fibre, medicines, etc.) to the local community.
The appropriate farming system for living fences is the small to medium sized farm with permanent crop cultivation.

7. Mixed Intercropping

Mixed intercropping is most useful in poor or easily depleted soils, on flat to gently sloping land, in areas of medium population density. This system will serve to restore/improve soil nutrients and increase organic materials.
The appropriate farming system is that with permanent crop cultivation, medium to small farm size using medium labor input per unit of land and no animal cultivation (at high tree densities).

8. Multistorey Planting of Domestic/Industrial Tree Crops

Multistorey tree crops are best suited to home gardens and as the upper storey of productive trees in hedges or plantations. Multistorey planting fits well in areas with high population density and high rainfall. It will contribute resources for tree products, some of which will supply household requirements. This may also reduce cash expenditures, and add to cash income. Multistorey tree crop systems are appropriate for small sized farm systems with high labor input per unit of area.

9. Tree Planting Around Watering Places and Dams

Tree planting around watering places and dams is appropriate where there is a high population density or presence of animals in the area. Planting trees will reduce the damage to the watering place and dams that is caused by livestock. It will also provide materials for wood products for home consumption or sale. Trees can be laid out in strips or planted in woodlots. A mixture of trees and grasses is helpful. Planting can also be spaced and mixed with multistory species. The appropriate farm system is a small to medium sized farm with permanent crop cultivation.

10. Selective Clearing

Selective clearing is useful in areas with substantial acreage of native woodlands. It is particularly useful in resettlement areas where there is a low population density. Selective clearing will conserve functional indigenous vegetation, biodiversity, and help to ensure future supplies of woodland products and germ plasm. In this system selected trees are left in croplands. Strips of trees and shrubs are left around newly opened plots, between fields and along roads, tracks and watercourses. The appropriate farm system is the medium to large farm with low labor input per unit area.

11. Woodlot Planting for Fuelwood and Poles

Woodlot planting for fuelwood and poles is appropriate for

deforested areas, and for all areas with a market for poles and/or firewood. Such woodlots can produce fuelwood/poles to meet household and/or household industries requirements. They may also add to the cash flow of the family. Woodlots should be fenced. Where possible "live fences" should be established within the protection offered by the fence. Firebreaks are recommended. The appropriate farm system is the medium to large farm with low to medium labor input per unit area. The system is also appropriate for tobacco farms (for barn construction as well as curing) and small industries e.g., brick works or small mines.
More detail about these systems is available from the International Council for Research in Agroforestry, Nairobi, Kenya. (See Appendix B for address.)

PART IV: CONCLUSION

CHAPTER 10

CONCLUSION: A CHECKLIST FOR SUSTAINABLE DEVELOPMENT, EXAMPLES OF TRADITIONAL SYSTEMS, AND LONG TERM EVALUATION

This manual has reviewed the relation between the environment and agricultural projects. With a framework for planning, the background technical information and other considerations have been provided. This is only a start. Now you have to adapt the information here to the local situation and seek the specific technical assistance

and information identified with the help of this manual.
The technical guidelines and information are designed to give the development worker a better understanding and to indicate the possible effects. In most cases the decisions to be made involve trade-offs. For example, should the community introduce high priced inorganic fertilizer that will produce quick results but is expensive and does not improve the quality of the soil; or alternatively, should they try to introduce techniques for organic fertilizing that will improve the soil but incur increased labor costs and sometimes sacrifice alternative uses of the local materials?
The ideals sometimes advocated here also may not be possible. Decisions about trade-offs should be made by those who will bear the benefit or burden of the results. The enlightened development worker will contribute to community understanding through consciousness raising and training.

A CHECKLIST FOR DEVELOPING SUSTAINABLE AGRICULTURAL PROJECTS

This checklist of concepts helpful for developing ecologically sustainable projects has been prepared to assist you in utilizing the information in this book.

* Use land according to its use capabilities, thus avoid if possible slopes prone to landslides. Where these are in use, maintain cover to conserve the soil.

* Ensure that, with the exception of edible and useful products

harvested or taken out of the system from time to time, as much recycling of materials and wastes as possible occurs.

*** Control pests by biological and mechanical methods insofar as possible.**

*** Utilize local resources, including human and animal energy, without increasing the level of technology significantly wherever possible.**

*** Do not overlook local varieties of crops, and conserve local wild plants and animals that may be important food sources, as well as genetic resources.**

*** Satisfy local consumption first in utilizing production.**

*** Focus on species with multi-use potentials in combining nutritional needs (legumes, fruits, vegetables, animals with high protein yields per unit weight) with other uses for example, crafts, construction materials, and drugs, especially in densely populated areas).**

*** Combine a variety of species with different properties, products, and contributions.**

*** Exploit the full range of ecosystems which may differ in soil, water, temperature, altitude, slope, fertility, etc., within a field or region.**

*** Involve community and farmers in the design, implementation, management, and evaluation of the program.**

*** Involve women, as well as men, in decision making and training.**

*** Include cultural values (religious or other) and beliefs in the development of plans for conservation of species and undisturbed wild spaces.**

*** Build upon existing social organizations and mutual assistance customs for environmental rehabilitation and conservation.**

*** Consider the non-quantifiable and indirect benefits and costs in any economic analysis for decision making.**

*** In all cases, focus on minimizing negative impacts while trying to introduce improvements.**

*** Check the land tenure problems of the farmers and include consideration of them in planning.**

*** Ensure the program has a sufficiently long-term horizon.**

To this checklist, however, the development worker may want to add others. Other guidelines may be based on such things as: 1) the goals or philosophy of the the local residents and the sponsoring

agency or individual, and 2) the realities of the context within which the project will occur (limits of time, funding, scope). For small-scale, community-based efforts that emphasize low-input appropriate technology and/or appropriate development philosophy, some points that should be considered are:

- optimal use of locally available material and human resources
- strong community involvement and support
- community-identified and/or community realized needs
- high potential for enhancing community self-reliance in both short and long-range terms
- technologies that can be taught from one farmer to another so that a multiplier effect is achieved
- availability and allocation of funds
- high priority on use and adaptation of traditional technologies
- necessity to complete activity during a certain time frame

The sequence of principles developed by World Neighbors (Bunch 10.2) is reproduced on the next page. These principles can help achieve the main goals of any agricultural program which are:

- that farmers develop the ability to solve their own problems
- that they learn about and adapt appropriate technologies that build on traditional practices
- that the program achieves early but relevant success

As boundaries within which the project must operate regardless

of specific design aspect, these principles serve two major purposes: first they provide a framework for designing projects; second, they can be used to enable the planner to make wise choices regarding feasibility among possible project designs. For example, the planner following these guidelines knows that any design he or she comes up with must include a strong community participation and/or involvement component; the planner judging a project against these guidelines must take a closer look at an effort which does not indicate community support.

<GOALS AND PRINCIPLES OF SMALL SCALE PROJECTS>

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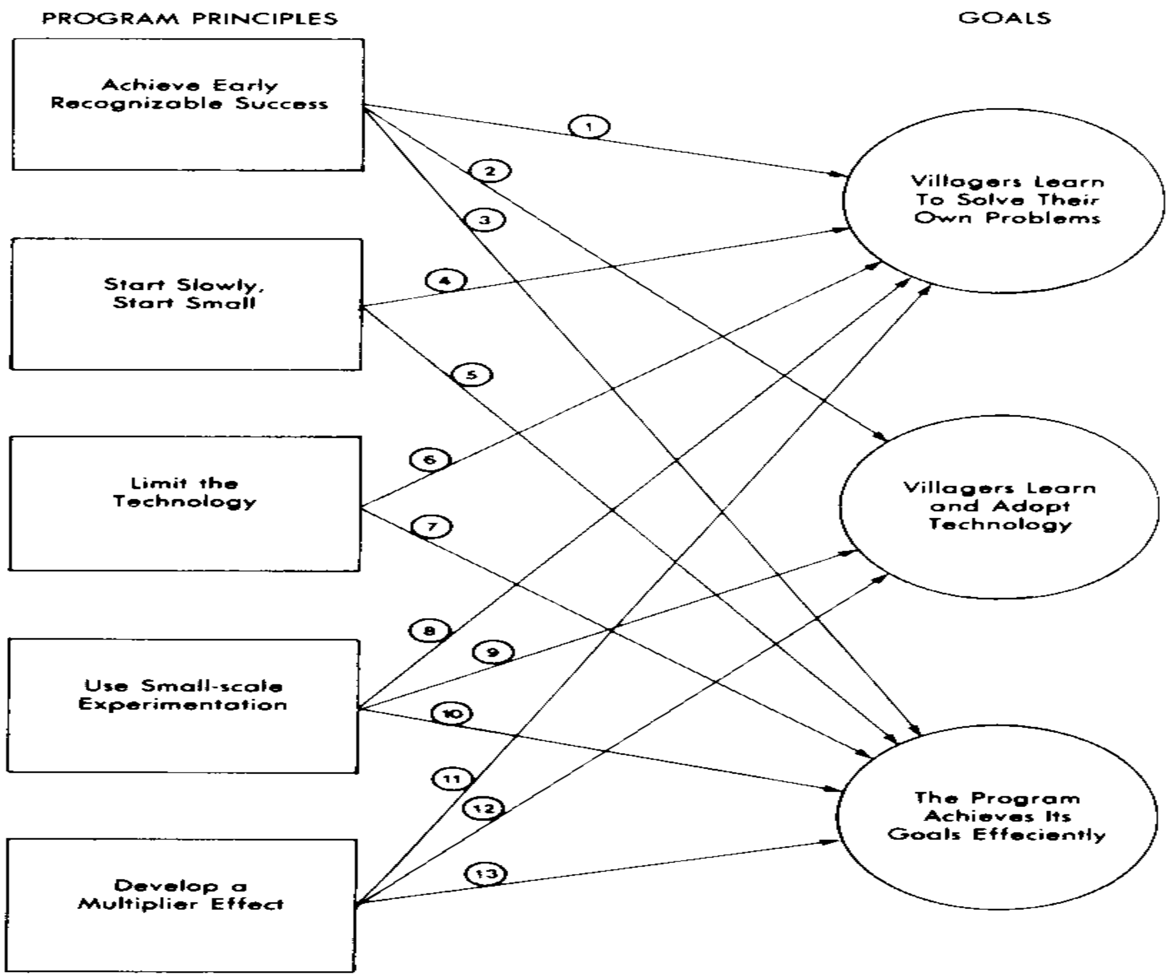
GOALS AND PRINCIPLES OF SMALL SCALE PROJECTS



Source: Bunch 10.2

Source: Bunch 10.2

EXAMPLES OF TRADITIONAL RESOURCE MANAGEMENT SYSTEMS

The following table provides examples of resource management strategies followed by traditional farmers in developing countries, to cope with environmental constraints in a variety of circumstances. It is important that you consider the perspective of traditional systems that have already solved some of the resource management questions raised in the earlier chapters. (Altieri 10.1)

SOME EXAMPLES OF SOIL, SPACE, WATER AND VEGETATION MANAGEMENT SYSTEMS USED BY TRADITIONAL AGRICULTURALISTS THROUGHOUT THE WORLD

Objectives or Stabilizing Agricultural Systems
Environmental Processes or Practices
Constraint

Limited space Maximum utilization Intercropping, agroforestry, multistorey
of environmental cropping, home gardens,
resources and altitudinal crop zonation, farm
sources and fragmentation, rotations, etc.
land

Steep slopes Erosion control, Terracing, contour farming, living
soil improvement and dead barriers, mulching,
water levelling, continuous crop,

conservation, diversification and/or fallow cover, stone walls,
of integrated land use (planting so
production that each crop has maximum
location advantage)

Marginal soil Sustain soil fertility Natural and/or improved fallow,
fertility and recycle crop rotations and intercropping
organic with legumes, litter gathering,
matter composting, manuring, green
manuring, grazing animals in
fallow fields, night soil and household
refuse, mounding with
hoe, ant hills used as fertilizer
sites, use of alluvial deposits,
use of aquatic weeds and muck,
alley cropping with legumes,
plowed leaves, branches, and
other debris, burning vegetation,
etc.

Flooding or excess Utilization of Raised field agriculture (i.e.,
water water bodies in chinampas, tablones), ditched
an integrated fields, diking, etc.
manner with
agriculture

Salinity or Lowering of Planting of appropriate tree
water logging water table species.

due to high
ground water

Excess water Optimum use of Control of floodwater with
available water canals and checkdams. Sunken
fields dug down to ground water
level. Splash irrigation. Canal
irrigation fed from ponded
groundwater, fed from wells,
lakes, reservoirs, etc.

Unreliable rainfall Best utilization Use of drought tolerant crop
of available species and varieties, mulching,
moisture use of weather indicators, mixed
cropping that best utilize end of
rainy season, use of crops with
short growing period

Wind velocity, Microclimatic Shade reduction or enhancement,
temperature, or amelioration plant spacings, thinning,
radiation extremes use of shade tolerant crops, increased
plant densities, mulching,
management with
hedges, fences, tree rows; weeding,
shallow plowing, minimum
tillage, intercropping, agroforestry
alley-cropping, etc.
Pest incidence Crop protection Overplanting, allowing some

(invertebrates, maintenance of pest damage, scaring away
vertebrates) low pest popula- pests, setting traps, hedging
tion levels and/or fencing, use of resistant
varieties, mixed cropping, enhancement
of natural enemies,
hunting, direct picking, use of
poisons, repellents, planting in
times of low pest potential, etc.

LONG TERM EVALUATION OF LOCAL AGRO-ECOSYSTEMS

The long-term performance of local agricultural systems can be evaluated by four properties: (See Conway 10.4)

* Sustainability: Relates to the ability of an agricultural system to maintain production through time in the face of long-term ecological and/or socio-economic constraints. Sustainability of small-scale farming systems depends on the accessibility to resource poor farmers of technologies and resources.

* Stability: Expresses the consistency of production of a cropping system through time under a given set of environmental, economic, and management conditions. Production trends can be expressed as yield by area, season, or year.

Both stability and sustainability have two dimensions--time and disturbance. These terms then have two connotations--persistence

and resistance. Persistence is the tendency of the system to look the same through time; resistance is its capacity to withstand disturbance.

*** Resilience: Relates to the ability of a system to recover from disturbances of perturbations. Perturbations can be salinity/acidity problems, pests, flood/drought, etc.**

*** Equity: Is a measure of how equitably the products of the farm (income, productions, etc.) or the inputs used (labor, land, etc.) are distributed among the local producers and consumers and between men and women.**

ADDITIONAL ASSISTANCE OR INFORMATION

At this or any point in the planning process, there may be reasons for seeking additional assistance. For example, preliminary investigation may show clearly that the area requires access to more specialized expertise, as in the case of working with a degraded watershed. Consultation with specialists such as local or regional water resource managers, ecologists, sociologists, resource economists or agricultural extension officers would be recommended before going very far with the planning process.

Second, even when and if the project seems to be relatively simple and easily tackled, it is a good idea to seek an objective appraisal. The development worker can do this by summarizing the findings to date, making recommendations based on those findings, outlining planned activities, and getting in touch with experts who

are familiar with community based projects. If possible, the development worker should provide a community profile and natural environment information. These can provide an excellent base from which to offer assistance even from a distance.
There are a number of other ways to bring valuable technical expertise and insight to the planning process:

*** Seek advice from local residents. Their knowledge of local conditions and past environmental impacts is not usually available elsewhere and is a resource that is much too important to be overlooked.**

*** Contact local universities and government agencies, and local representatives of international organizations as well as local NGOs, churches and missionaries. Often they have a great deal of pertinent information on local soils, climate, terrain, and upon plants and animals native to the region. Or they may have insights and valuable suggestions about other resources.**

*** Using local resource people, organize an interdisciplinary team to observe possible project sites. The team can then discuss the project from their respective viewpoints. Collectively, the team may be able to identify potential effects that will have to be accounted for in the project design. Depending upon the type of project, the team might include representatives from several of these fields: ecology, hydrology, soil science, entomology, and so on.**

* As planning and investigation continues locally, get in touch with other organizations. Network with nongovernmental organizations in the area or region.

Through outside assistance the planner can test the reality and feasibility of the project. Some planners may prefer to have the project reviewed only after the needs identification and assessment process is complete. Other planners may choose to have the material reviewed at several points. For those who wish to use such services, they may be available locally, or through international non-governmental organizations. A list of organizations that can help is included in Appendix B.

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APPENDIX B

LIST OF RESOURCE AGENCIES

ACORDE
Apartado Postal 163C
Tegucigalpa, HONDURAS

African NGOs Environment Network (ANEN)
P.O. Box 53844

Nairobi, KENYA

APPROTECH Asia
Ground Floor
Philippine Social Development Center
Magallanes Corner Real Street
Intramuros, Manila
PHILIPPINES

Center for Education and Technology (CET)
Casilla 16557 Correo 9
Santiago, CHILE

Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE)
Turrialba, COSTA RICA

Coordination in Development, Inc.
CODEL
475 Riverside Drive, Room 1842
New York, New York 10115, USA

Environment Liaison Centre (ELC)
P.O. Box 72461
Nairobi, KENYA

ENDA-TM
Environment and Development in the Third World

SENEGAL
Box 3370
Dakar, SENEGAL

ZIMBABWE
P.O. Box MP 83
Mt. Pleasant
Harare, ZIMBABWE

INADES-FORMATION
African Institute for Economic and Social Development

IVORY COAST
08 BP 8
Abidjan 08, IVORY COAST

KENYA
P.O. Box 14022
Nairobi, KENYA

Information Centre for Low External-Input Agriculture (ILEIA)
Kastanjelaan 5
P.O. Box 64
3830 AB Leusden, THE NETHERLANDS

Institute for Alternative Agriculture, Inc.
9200 Edmonston Road, Suyite 117
Greenbelt, Maryland 20770

Institute for Consumer Policy Research
Consumers Union
256 Washington Street
Mt. Vernon, New York 10553, USA

International Alliance for Sustainable Agriculture (IASA)
Newman Center
University of Minnesota
1701 University Avenue, S.E., Room 202
Minneapolis, Minnesota 55414, USA

International Council for Research in Agroforestry (ICRAF)
P.O. Box 30677
Nairobi, KENYA

International Institute for Environment and Development (IIED)
1717 Massachusetts Avenue, N.W.
Washington, D.C. 20036, USA

International Institute of Tropical Agriculture (IITA)
PMB 5320
Ibadan, NIGERIA

International Organizaton of Consumers Unions (IOCU)
P.O. Box 1045
10830 Penang, MALAYSIA

International Rice Research Institute (IRRI)
P.O. Box 933
Manila, PHILIPPINES

Kenya Institute of Organic Farming (KIOF)
Box 34972
Nairobi, KENYA

Pesticide Action Network International (PAN)
Regional Centers:

AFRICA (English)
Environment Liaison Centre
P.O. Box 72461
Nairobi, KENYA

AFRICA (French)
ENDA/PRONAT
B.P. 3370
Dakar, SENEGAL

ASIA/PACIFIC
International Organization of Consumers Unions
Regional Office
P.O. Box 1045
10830 Penang, MALAYSIA

EUROPE

PAN-Europe
22, rue des Bollandistes
1040 Brussels, BELGIUM

LATIN AMERICA
Fundacion Natura
Casilla 243
Quito, ECUADOR

NORTH AMERICA
Pesticide Education and Action Project
P.O. Box 610
San Francisco, California 94101, USA

Rodale Institute
222 Main Street
Emmaus, Pennsylvania 18098, USA

Sahabat Alam Malaysia (Friends of the Earth)
37 Lorong Birch
Penang, MALAYSIA

Volunteers in Technical Assistance (VITA)
1815 North Lynn Street, Suite 200
Arlington, Virginia 22209, USA

APPENDIX C

GLOSSARY

absorb - To suck in as in a blotter.

adsorb - To adhere to the surface of as ions on molecules.

aerial biomass - Total weight and molecules of living materials.

aquifer - An underground layer of rock that is porous and permeable enough to store significant quantities of water.

artificialities - Mechanisms, techniques, and processes introduced by humans.

biodegradable - Refers to substances that can readily be decomposed by living organisms.

biodiversity - The critical multiplicity of species that creates and maintains ecosystems.

biomass - The total weight of all the living organisms in a given system.

biotic - Living or derived from living things.

capillary action - The movement of water upward against the force of gravity, through small openings. The liquid is pulled upward by

electrical attractions between the water molecules and the sides of the holes.

carrying capacity - The maximum number of individuals of a given species that can be supported by a particular environment.

climax community - A natural system that represents the end, or apex, of an ecological succession.

colloidal - Made up of solid, liquid, or gaseous substances of very small, insoluble particles.

denitrification - Reduction of nitrates to gaseous state by certain organisms that produces nitrogen.

desertification - The process whereby lands that have been disturbed by natural phenomenon (e.g., drought, flooding) or people initiated processes (e.g., improper farming practices) are converted to deserts.

double cropping - Growing two crops in the same year in sequence, seeding or transplanting one after the harvest of the other (same concept for triple cropping).

ecological niche - The description of the unique functions and habitats of an organism in an ecosystem.

ecosystem - A group of plants and animals occurring together plus

that part of the physical environment with which they interact. An ecosystem is defined to be nearly self-contained, so that the matter flowing into and out of it is small compared to the quantities that are internally recycled in a continuous exchange of the essentials of life.

eutrophication - The enrichment of a body of water by nutrients, with the consequent deterioration of its quality for human purposes.

evaporation - Vaporization of water from surfaces.

evapotranspiration - The conversion of liquid water to water vapor by transpiration followed by evaporation from the leaf surface.

externalities (economic) - The portion of the cost of a product that is not accounted for by the manufacturer but is borne by some other sector of society. An example is the cost of environmental degradation that results from a manufacturing operation.

farming system - The manner in which a particular set of farm resources is assembled within its environment, by means of technology, for the production of primary agricultural products. This definition thus excludes processing beyond that normally performed on the farm for the particular crop or animal product. It includes farm resources used in marketing the product.

food chain - An idealized pattern of flow of energy m a natural ecosystem. In the classical food chain, plants are eaten only by

primary consumers, primary consumers are eaten only by secondary consumers, secondary consumers only by tertiary consumers, and so forth. See also food web.

food web - The pattern of food consumption in a natural ecosystem. A given organism may obtain nourishment from many different trophic levels and thus give rise to a complex, interwoven series of energy transfers.

green revolution - The realization of increased crop yields in many areas owing to the developing of new high-yielding strains of wheat, rice, and other grains in the 1960s. The second green revolution is use of the techniques of genetic engineering to improve agricultural yields.
groundwater - Water that has accumulated in the ground and is replenished by infiltration of surface water.

growing season - Used in a general way to refer to the period of the year when (most) crops are grown, e.g. the rainy season.

growth cycle - The period required for an annual crop to complete its annual cycle of establishment, growth and production of harvested part.

habitat - Place where plant or animal lives.

hectare - A metric measure of surface area. One hectare is equal to 10,000 sq. m. or 2.47 acres.

herbicide - A chemical used to control unwanted plants.

humus - The complex mixture of decayed organic matter that is an integral part of healthy soil.

hydrological cycle (water cycle) - The way water moves in a cycle in all its forms, on the earth.

infiltration - The process whereby water filters or soaks into soil as opposed to running off the surface.

intercropping - Two or more crops grown simultaneously in the same, alternate, or paired rows in the same area.

laterite - A soil type found in certain humid tropical regions that contains a large proportion of aluminum and iron oxides and only a small concentration of organic matter. Laterite soils cannot support sustained agriculture.

leaching - The extraction, usually by water, of the soluble components of a mass of material. In soil chemistry, leaching refers to the loss of surface nutrients by their percolation downward below the root zone.

legume - An plant of the family Leguminosae, such as peas, beans, or alfalfa. Bacteria living on the roots of legumes change atmospheric

nitrogen, [N.sub.2], to nitrogen-containing salts that can be readily assimilated by most plants.

limiting factors (law of) - A biological law that states that the growth of an organism (or a population of organisms) is limited by the resource that is least available in the ecosystem.

litter - The intact and partially decayed organic matter lying on top of the soil.

mineralization - The process of gradual oxidation of organic matter present in soil that leaves just the gritty mineral components of the soil.

mixed cropping - Two or more crops are grown simultaneously in the same field at the same time, but not in row arrangements. (Sometimes called mixed intercropping.)

monoculture planting - Growing a single crop on the land at one time, particularly the repetitive growing of the same crop on the same land year after year.

mulch - Leaves, straw, peat moss, or other material spread around plants to prevent evaporation of water from soil and roots.

multiple cropping - Growing more than one crop on the same land in one year. Within this concept there are many possible patterns of crop arrangement in space and time.

natural selection - A series of events occurring in natural ecosystems that eliminates some members of a population and spares those individuals endowed with certain characteristics that are favorable for reproduction.

organic farming - A system of farming using no chemical fertilizers or pesticides.

outputs - The products (for rainfed agriculture, crops), services (e.g. water supply, recreational facilities) or other benefits (e.g. wildlife conservation) resulting from the use of land.

percolation - The process of water seeping through cracks and pores of soil and rocks.

photosynthesis - The process by which chlorophyll-bearing plants use energy from the Sun to convert carbon dioxide and water to sugars.

pollution - The impairment of the quality of some portion of the environment by the addition of harmful impurities.

population - The breeding group to which an organism belongs in practice. A population is generally very much smaller than an entire species, because all the members of a species are seldom in close proximity to each other.

predator - An animal that attacks, skills, and eats other animals; more broadly, an organism that eats other organisms.

primary consumer - An animal that eats plants.

rainfed farming - The growing of crops or animals under conditions of natural rainfall. Water may be stored in the crop field by bunding, as with lowland rainfed rice, but no water is available from permanent water storage areas.

salinization - When irrigation water is applied to farmlands, much of it evaporates, leaving the salts behind. Salinization is the process whereby these minerals accumulate until the fertility of the soil is severely impaired.

shifting cultivation - Several crop years are followed by several fallow years with the land not under management during the fallow. The shifting cultivation may involve shifts around a permanent homestead or village site, or the entire living area may shift location as the fields for cultivation are moved.

slash and burn - A specific type of shifting cultivation in high rainfall areas where bush or tree growth occurs during the fallow period. The fallow growth is cleared by cutting and burning.

soil-moisture belt - The layer of soil from which water can be drawn to the surface by capillary action.

soil structure - The manner in which soil particles are loosely stuck together to form larger clumps and aggregates usually with considerable air space in between.

strip cropping - Growing two or more crops in different strips across the field wide enough for independent cultivation. The strips are wide enough to give greater association among the crops in the strips than between the different crops.

structural diversity - A measure of the way in which the canopy or soil cover is organized in layers in a cropping or forestry system.

substrate - The foundation provided by the soil to support plant growth.

succession - The sequence of changes through which an ecosystem passes during the course of time. Primary succession is a sequence that occurs when the terrain is initially lifeless, or almost so. Secondary succession is the series of community changes that takes place in disturbed areas where some regrowth is taking place.

surface water - Includes all bodies of water--lakes, rivers, ponds, streams - on the surface of the earth in contrast to ground water that lies below the surface.

sustainable - A measure of the constancy of agricultural production in the long term.

sustainable use - Continuing use of land without severe or permanent deterioration of the resources of the land.

symbiotic - The intimate association of two organisms that provides a mutual benefit to both.

temperature inversions - A meteorological condition in which the layers of cool air remain stagnant leading to concentration pollutants.

threshold - The level of population of insect pests beyond which any increase will cause damage.

threshold level - The minimal dose of a toxic substance that causes harmful effects.

toxic substance - Any substance whose physiological action is harmful to health.

transpiration - The passage of water through the tissues of plants, especially through leaf surfaces.

trophic level - Level of nourishment. A plant that obtains its energy directly from the sun occupies the first level and is called an autotroph. An organism that consumes the tissue of an autotroph occupies the second trophic level, and an organism that eats the organism that had eaten autotrophs occupies the third trophic level.

vector - An animal, such as an insect, that transmits a disease - producing

organism from one host to another.

volatilization - Process of a liquid or solid becoming gaseous.

water pollution - The deterioration of the quality of water that results from the addition of impurities.

ABOUT THE AUTHOR

Miguel Altieri is an Associate Professor and Associate Entomologist at the University of California, Berkeley. Dr. Altieri, a native of Chile, earned a Ph.D. in Entomology at the University of Florida in 1979 and studied agronomy and agroecology in Latin America.

Dr. Altieri's research has centered on methods to enhance naturally occurring and introduced biological control agents of pests, and interactions of plants and pests, in annual agricultural systems and orchards. His research has been based in North, South, and Central America.

Dr. Altieri has published extensively in the fields of agroecology, sustainable agriculture, entomology, alternative agriculture, and pest management. Among his publications are the following books: Agroecology: The Scientific Basis of Alternative Agriculture, Weed Management in Agroecosystems: Ecological Approaches, and Agroecology and Small Farm Development.

ABOUT THE EDITOR

Since 1977, Helen Vukasin has been active in the field of environment and development. In 1979 she became associated with CODEL and helped to develop the CODEL Environment and Development Program. Working with indigenous organizations in developing countries, the Program fosters natural resource management in small-scale development projects particularly emphasizing people's participation in the process.

In addition to serving as a consultant to CODEL, Ms. Vukasin is currently a Program Associate with the Development Institute of the University of California at Los Angeles. She is actively interested in gender issues in natural resource management and in contributing to knowledge about ways to foster people's participation in development and environment activities.

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