CHAPTER 5

Shifting cultivation and improved fallows

The term *shifting cultivation* refers to farming or agricultural systems in which land under natural vegetation is cleared, cropped with agricultural crops for a few years, and then left untended while the natural vegetation regenerates. The cultivation phase is usually short (2-3 years), but the regeneration phase, known as the fallow or bush fallow phase, is much longer (traditionally 10-20 years). The clearing is usually accomplished by the slash-and-burn method (hence the name slash-and-burn agriculture), employing simple hand tools. Useful trees and shrubs are left standing, and are sometimes lightly pruned; other trees and shrubs are pruned down to stumps of varying height to facilitate fast regeneration and support for climbing species that require staking. The lengths of the cropping and fallow phases vary considerably, the former being more variable; usually the fallow phase is several times longer than the cropping phase. The length of the fallow phase is considered critical to the success and sustainability of the practice. During this period the soil, having been depleted of its fertility during the cropping period, regains its fertility through the regenerative action of the woody vegetation.

5.1. System overview

Shifting cultivation is still the mainstay of traditional farming systems over vast areas of the tropics and subtropics. Estimates of area under shifting cultivation vary. One estimate still used repeatedly (FAO, 1982). is that it extends over approximately 360 million hectares or 30 % of the exploitable soils of the world, and supports over 250 million people. Crutzen and Andreae (1990) estimated that shifting cultivation is practiced by 200 million people over 300 million-500 million hectares in the tropics. Although the system is dominant mainly in sparsely populated and lesser developed areas, where technological inputs for advanced agriculture such as fertilizers and farm machinery are not available, it is found in most parts of the tropics, especially in the humid and subhumid tropics of Africa and Latin America. Even in densely populated Southeast Asia, it is a major land-use in some parts (Spencer, 1966; Grandstaff, 1980;

Table 5.1. Local terms for shifting cultivation in different parts of the tropics.

	Term	Country or region
A. *Asia*	Ladang	Indonesia, Malaysia
	Jumar	Java
	Ray	Vietnam
	Tam-ray, rai	Thailand
	Hay	Laos
	Hanumo, caingin	Philippines
	Chena	Sri Lanka
	Karen	Japan, Korea
	Taungya	Burma (Myanmar)
	Bewar, dhya, dippa, erka, jhum, kumri, penda, pothu, podu	India
B. *Americas*	Coamile	Mexico
	Milpa	Mexico, Central America
	Roca	Brazil
C. *Africa*	Masole	Zaire
	Tavy	Madagascar
	Chitimene, citimene	Zaire, Zambia, Zimbabwe, Tanzania
	Proka	Ghana

Source: Okigbo (1985).

Ruthenberg, 1980; Kyuma and Pairinta, 1983; Denevan *et al,* 1984; Padoch *et al,* 1985; Padoch and de Jong, 1987).

Despite the remarkable similarity of the shifting cultivation practiced in different parts of the world, minor differences exist, and are often dependent on the environmental and sociocultural conditions of the locality and the historical features that have influenced the evolution of land-use systems over the centuries. These variations are reflected, to some extent, in the various names by which the system is known in different parts of the world (Spencer, 1966; Okigbo, 1985, Table 5.1). The practice is also said to have been widespread in Europe until a few centuries ago (Nye and Greenland, 1960; Greenland, 1974). Under resource-rich conditions, as in Europe, shifting cultivation has slowly been replaced by more technologically-oriented and profitable land-use systems that bear no resemblance to the original system. In developing countries with low population densities, where the farmer had enough land at his disposal and freedom to cultivate anywhere he chose within a specified geopolitical unit or region, the ratio of the length of fallow period to cultivation phase reached 10 to 1. The system was stable and ecologically sound. However, under the strain of increasing population pressure, the fallow periods became drastically reduced and the system degenerated, resulting in serious soil erosion and a decline in the soil's fertility and productivity (see Figure 5.1).

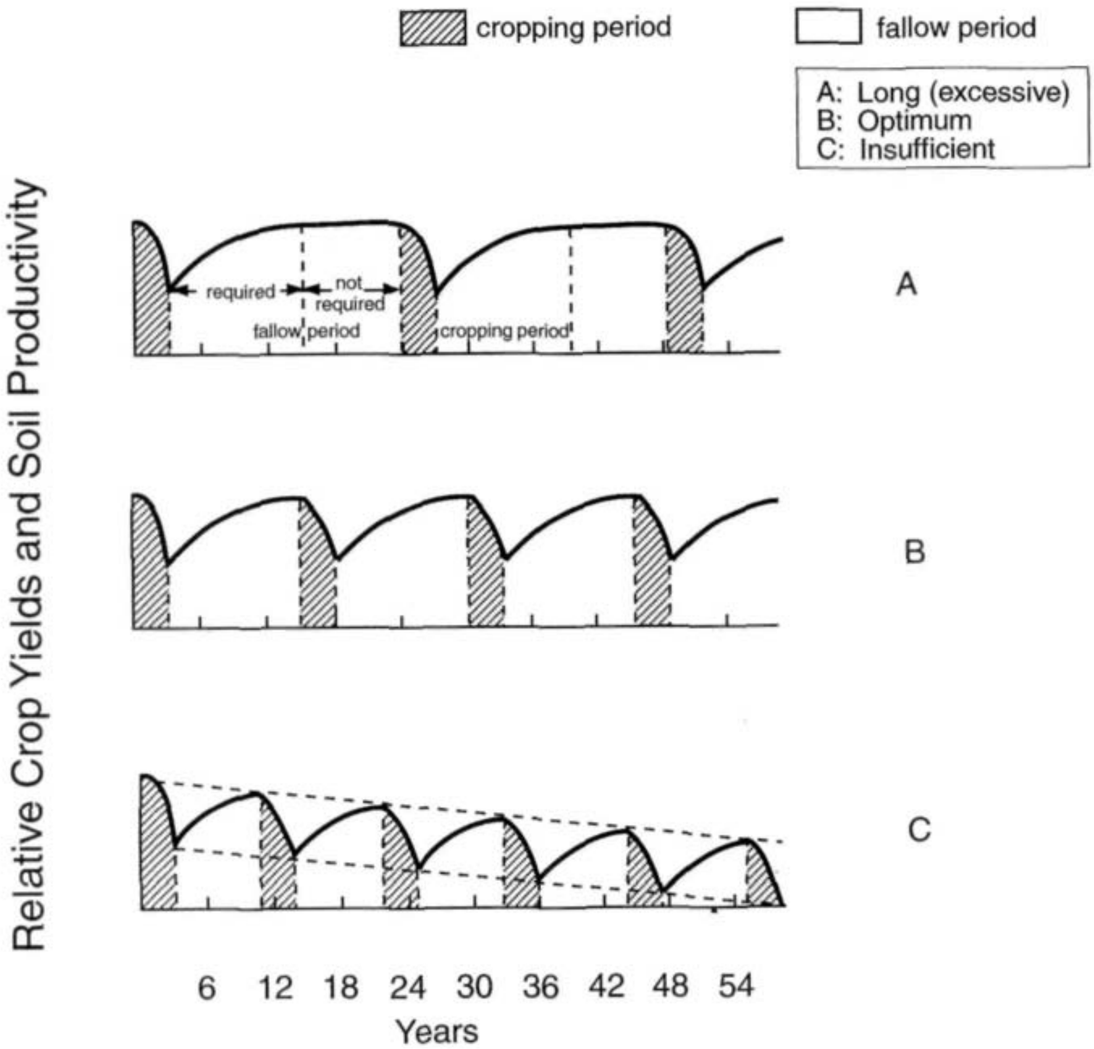

Figure 5.1. Schematic presentation of the changes with time in the length of fallow phase, and consequent patterns of crop yields and soil productivity in shifting cultivation.
Source: *Adapted from* Okigbo (1985) *(after* Ruthenberg, 1980).

The most remarkable differences in the practice of shifting cultivation are, perhaps, due to ecological conditions. In forest areas of the lowland humid tropics, the practice consists of clearing a patch of forest during the dry (or lowest rainfall) period, burning the debris *in situ* shortly before the first heavy rains, and planting crops, such as maize, rice, beans, cassava, yams, and plantain, in the burnt and decaying debris. The crops are occasionally weeded manually. Thus, irregular patterns of intercropping are the usual practices (Figure 5.2). After 2 or 3 years of cropping, the field is abandoned to allow rapid regrowth of the forest. The farmer returns to the same plot after 5 to 20 years, clears the land once again, and the cycle is repeated.

In an example of shifting cultivation as practiced in the savannas, especially in West Africa, the vegetation, consisting primarily of grasses and some scattered trees and bushes, is cleared and burned in the dry season (Figure 5.3). The soil is then worked into mounds, about 50 cm high, on which root crops, usually

Figure 5.2. Photograph: Shifting cultivation in lowland humid tropics.
Improved agricultural practices such as line planting and fertilizer application to crops have been suggested in some shifting-cultivation area; but these are seldom adopted by farmers.

yams, are planted. Maize, beans, and other crops are planted between the rows. The mounds are levelled after the first year of yams. A variety of crops including maize, millets, and peanuts (groundnuts) are planted for the next 2 to 3 years. Thereafter, the land is left fallow and regrowth of coarse grasses and bushes occurs. This period lasts for up to about ten years. Compared with shifting cultivation in the forests, this form results in a more thorough working of the soil for cropping, longer cropping periods, and, ultimately, a more severe weed infestation. Moreover, soil erosion hazards are also higher when the soil is bare after the clearing and burning in the dry season.

Various attempts have been made to classify shifting cultivation, as considered in greater detail by FAO/SIDA (1974), and reviewed by Ruthenberg (1980). In almost all classification schemes, the various categories designate different degrees of intensification of cultivation which can best be evaluated on the basis of the land-use factor (L)[1]:

$$L = \frac{C + F}{C} \qquad \begin{array}{l} C = \text{length of the cropping phase (years)} \\ F = \text{length of the fallow phase (years)} \end{array}$$

[1] A related term used in some literature (e.g. see Table 5.2) is the cultivation factor (R), which is the inverse of L.

$R = \frac{C}{C + F}$ where C and F have the same meanings as in the land-use factor (C = length of cropping phase, F = length of fallow phase).

Figure 5.3. Photograph: Shifting cultivation in savanna.
The vegetation, consisting primarily of grasses and some scattered trees and shrubs, is cleared and burned in the dry season, and crops are grown in the following rainy season(s).

During the early stages of shifting cultivation, when fallow periods are long, $L>10$. However, when a sedentary and permanent cultivation stage is reached, as on the compound farm, $L= 1$. Moreover, the various systems of shifting cultivation are interwoven in the agricultural landscape. This is particularly so in Africa where one can find traditional shifting cultivation and permanent production systems existing together in the same locality. Thus, within the general pattern of alternating fallow and cropping cycles, the nature of shifting cultivation varies from place to place.

The literature on the various aspects of shifting cultivation is voluminous and fairly well documented. Grigg (1974) has examined the evolution of shifting cultivation as an agricultural system, while anthropological and geographical information on the practice has been compiled by Conklin (1963). Sanchez (1973), Greenland (1976), and Ruthenberg (1980) have described the various forms of shifting cultivation. Studies on soils under shifting cultivation have been superbly evaluated by Nye and Greenland (1960), Newton (1960), FAO/SIDA (1974), and Sanchez (1976). An annotated bibliography of shifting cultivation and its alternatives has been produced by Robinson and McKean (1992). Various approaches have been suggested as improvements and/or alternatives to shifting cultivation (FAO, 1985), and most of them emphasize the importance of retaining or incorporating the woody vegetation into the fallow phase, and even in the cultivation phase, as the key to the maintenance of soil productivity. Depending on the ways in which the woody species are incorporated, the alternate land-use system can be alley cropping (Kang and Wilson, 1987), or some other form of agroforestry (Nair and Fernandes, 1985), or even other forms of improved, permanent production systems (Okigbo, 1985). In order to discuss these various options, the major soil management problems in the shifting cultivation areas of the tropics and subtropics need to be reviewed, as well as the role of trees in soil productivity and protection; the former is presented here, the latter is considered in detail in Section IV.

5.2. Soil management and shifting cultivation

Large parts of the humid and subhumid tropics currently under shifting cultivation and related traditional farming systems are covered by the so-called fragile upland soils. These are predominantly Ultisols, Oxisols, and associated soil types in the humid tropics, and Alfisols and associated soils in the subhumid tropics. The distribution and traits of these major soil groups are described in Chapter 14. Many of these soils are also grouped as low-activity clay (LAC) soils because of their limitations, unique management requirements, and other distinctive features that adversely affect their potential for crop production (Juo 1980; Kang and Juo, 1986).

During the past few decades, several institutions in the tropics have been actively engaged in determining the constraints and management problems of these upland soils relative to sustainable food-crop production. The results of these investigations (Charreau, 1974; Lai, 1974; Sanchez and Salinas, 1981; Kang and Juo, 1986; Spain, 1983; El-Swaify *et al.,* 1984) and some of the conclusions are highlighted below. Ultisols and Oxisols have problems associated with acidity and aluminum toxicity, low nutrient reserves, nutrient imbalance, and multiple nutrient deficiencies. Ultisols are also prone to erosion, particularly on exposed sloping land. Alfisols and associated soils have major physical limitations: They are extremely susceptible to crusting, compaction, and erosion, and their low moisture-retention capacity causes frequent moisture stress for crops. In addition, they acidify rapidly under continuous cropping, particularly when moderate to heavy rates of fertilizers are used. For a detailed discussion on tropical soils and their management, see Sanchez (1976).

It is generally accepted that traditional shifting cultivation with adequately long fallow periods is a sound method of soil management, well adapted to the local ecological and social environment. Before the forest is cleared, a closed nutrient cycle exists in the soil-forest system. Within this system, most nutrients are stored in the biomass and topsoil, and a constant cycle of nutrient transfer from one compartment of the system to another operates through the physical and biological processes of rainwash (i.e., foliage leaching), litterfall, root decomposition, and plant uptake. For example, Lundgren (1978) reported from a review of literature from 18 locations around the tropics, that an average of 8-91 ha-^{1} yr^{1} litter was added from closed natural forest, amounting to average

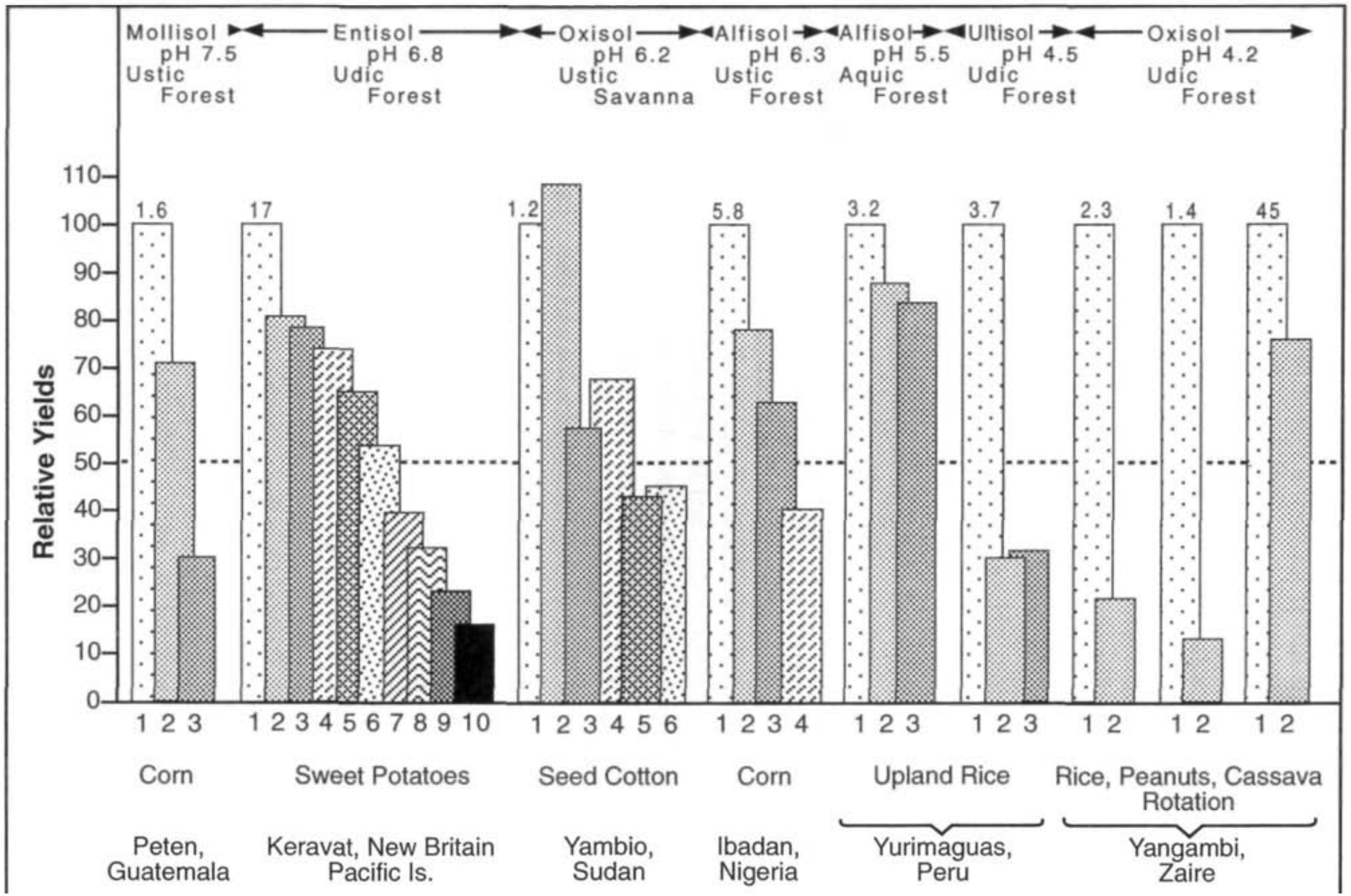

Figure 5.4. Examples of crop-yield declines under continuous cropping without fertilization in shifting cultivation areas as a function of soil, climate, and vegetation. Numbers on top of histograms refer to economic crop yields (t ha '); numbers on x-axis refer to consecutive crops.
Source: Sanchez (1976). (Reprinted by permission of John Wiley & Sons, Inc.)

nutrient additions (kg ha^{-1} yr^{1}) of 134 N, 7 P, 53 K, 111 Ca and 32 Mg. The amount of nutrients lost from such a system is negligible.

Clearing and burning the vegetation leads to a disruption of this closed nutrient cycle. During the burning operation the soil temperature increases, and afterwards, more solar radiation falling on the bare soil-surface results in higher soil and air temperatures (Ahn, 1974; Lal *et al.,* 1975). This change in the temperature regime causes changes in the biological activity in the soil. The addition of ash to the soil through burning causes important changes in soil chemical properties and organic matter content (Jha *et al.,* 1979; Stromgaard, 1991). In general, exchangeable bases and available phosphorus increase slightly after burning; pH values also increase, but usually only temporarily. Burning is also expected to increase organic matter content, mainly because of the unburnt vegetation left behind (Sanchez and Salinas, 1981; Nair, 1984).

These changes in the soil after clearing and burning result in a sharp increase of available nutrients, so that the first crop that is planted benefits considerably. Afterwards, the soil becomes less and less productive and crop yields decline. Some examples of yield decline under continuous cropping without fertilization in different shifting cultivation areas corresponding to various soil, climate, and vegetation types are given in Figure 5.4; a generalized picture of the situation is depicted in Figure 5.5. The main reasons for the decline in crop yields are soil fertility depletion, increased weed infestation, deterioration of soil physical properties, and increased insect and disease attacks (Sanchez, 1976). Finally, the farmers decide that further cultivation of the fields will be difficult and nonremunerative and they abandon the site and move on to others. However, they know well that the abandoned site would be reinhabited by natural vegetation (forest fallow); during the fallow period the

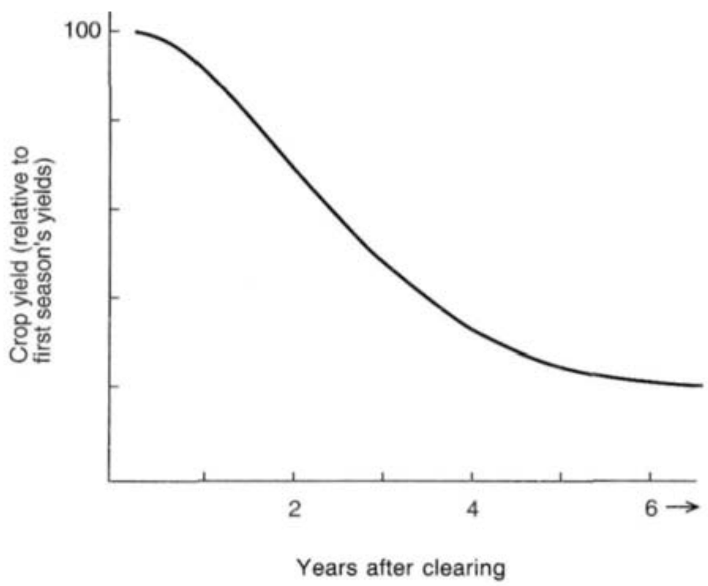

Figure 5.5. A generalized pattern of yield decline of crops grown successively on the same land (in low-activity clay soils) after initial land clearing.

soil would regain its fertility and productivity, and the farmers could return to the site after a lapse of a few years.

This cycle has been repeated indefinitely in many regions where shifting cultivation has continued for centuries, though at low productivity levels. However, over a long period of time, as population pressure has steadily increased, fallow periods have become shorter and shorter; consequently, farmers have returned to abandoned fields before they have had enough time for fertility to be sufficiently restored (Figure 5.1). The introduction of industrial crops and modern methods of crop production have also caused a diminished emphasis on the importance of the fallow period in traditional farming practices.

5.3. The evolution of planted fallows

Levels of productivity that can be sustained in cropping systems largely reflect the potential and degree of management of the resource base. In other words, high productivity comes only from systems where management intensities necessary for sustainability are attained without extensive depletion of the resources. Evolutionary trends in tropical cropping systems show that management intensities capable of sustaining productivity are usually introduced only after considerable depletion and degradation of resources - especially of the nonrenewable soil - have taken place.

As we have seen, the important role of the fallow period for soil-productivity regeneration in traditional shifting cultivation is well known (e.g., Nye and Greenland, 1960). The rate and extent of soil-productivity regeneration depend on the length of the fallow period, the nature of the fallow vegetation, soil properties, and management intensity. During the fallow period, plant nutrients are taken up by the fallow vegetation from various soil depths according to the root ranges. While large portions of the nutrients are held in the biomass, some are returned to the soil surface via litterfall or lost through leaching, erosion, and other processes. In addition, during the fallow period the return of decaying litter and residues greatly adds to the improvement of soil organic matter levels.

Based on the various descriptions of tropical cropping systems (Benneh, 1972; Ruthenberg, 1980; MacDonald, 1982), a framework for a logical evolutionary pathway of traditional crop-production systems in the humid tropics was developed by Kang and Wilson (1987), as shown in Figure 5.6. This pathway highlights the major changes in cropping systems and indicates points at which intervention with planted fallows or other agroforestry methods could be introduced, thus preventing further resource degradation.

The pathway begins with a stage that may be described as a simple rotational sequence of temporal agroforestry. It is characterized by a very short cropping period followed by a very long fallow period. In this fallow period even inefficient soil-rejuvenating plant species are able to restore soil productivity

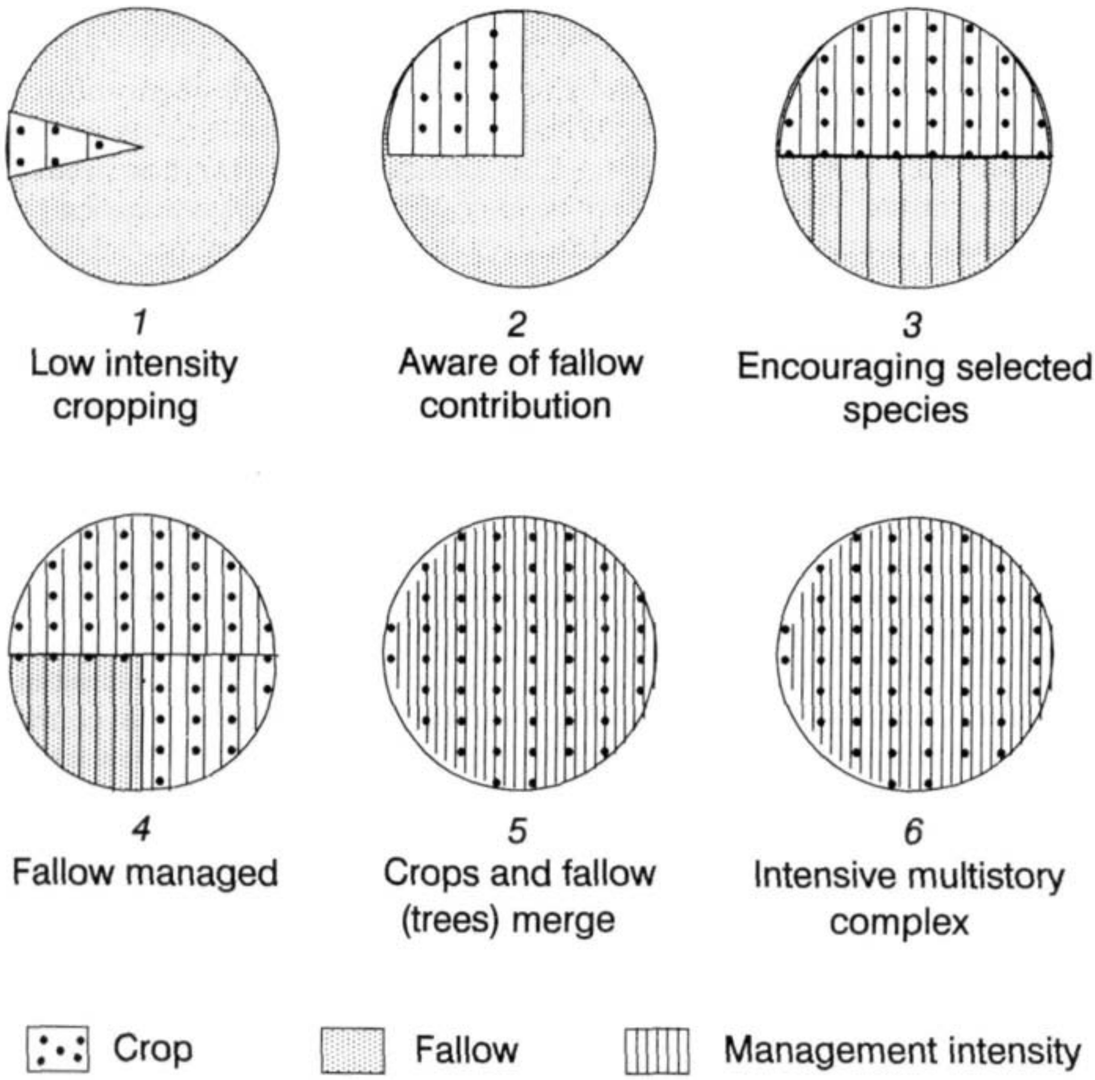

Figure 5.6. Stages in the evolution of managed fallow and multistory cropping in shifting cultivation areas of the humid tropics.
Source: Kang and Wilson (1987).

Here the economic return to the input of labor or energy is high; the management input is low and is confined to the cropping period. In the second stage, which usually is caused by population pressure, the cropping period and the area cultivated are expanded. Returns to energy input begin to fall and management intensity increases. At this stage there is an awareness of the contribution (i.e., soil-rejuvenating properties) of the different species in the fallow system (Benneh, 1972). At the third stage, attempts are made to manipulate species in the fallow in order to ensure fertility regeneration in the already shortened fallow period. A good example of this third stage, taken from southwest Nigeria, is the retention and use of tree species such as *Dactyladenia (*syn. *Acioa) barteri, Alchornea cordifolia, Dialium guineense,* and *Anthonata macrophyla* as efficient soil-fertility restorers (Obi and Tuley, 1973; Okigbo, 1976; Getahun *et al.,* 1982). Additionally, farmers near Ibadan, Nigeria have observed that *Gliricidia sepium,* when used for yam stakes, grew and dominated the fallow and restored soil fertility quicker than did other species. Consequently, they now maintain *G. sepium* in the fallow even when yam is not included in the cropping cycle (Kang and Wilson, 1987). In the fourth stage, mere manipulation of fallow and sole dependence on natural regeneration for the establishment of the desired species are no longer adequate and a planted fallow of selected species becomes necessary. Though the value and feasibility of planted fallows have been demonstrated experimentally (Webster and Wilson, 1980), the practice has not become widespread. This is the stage at which the intervention of techniques such as alley cropping (Chapter 9) and *in situ* mulch (Wilson, 1978) can take place.

At each of these successive stages, length of the cropping period extends progressively and that of the fallow diminishes correspondingly. During these extended cropping periods, soil degradation continues, and the damage done cannot be repaired by the shortened fallow. Even when the most efficient soil-rejuvenation species dominate the fallow, they can only sustain yields at a level supportable by the degraded resource base.

The fifth (merging of cropping and fallow phases) and sixth (intensive multistory combinations) stages could evolve from the previous stages, but there is no clear evidence for this. In many areas where multistory cropping and intensive agroforestry systems with trees and crops (Nair, 1979; Michon, 1983) dominate, there is no evidence of stages four and five. The most plausible explanation is that, as population pressures grow and the area available for stage three shrinks, the area for stage six (which is actually intensively-managed homegardens where fruit trees are always among the major components) expands. As the two stages merge, the more efficient homegarden undergoes modification, which results in the development of the multistory production system.

If one adheres to the above evolution pattern, sustainability with high productivity can be achieved when conservation and restoration measures are introduced *before* resources are badly degraded or depleted. In the humid tropics, the multistory complex, which seems to be the climax of cropping-systems evolution, would be the ideal intervention at stages one or two. However, this may not be possible in all cases, especially where different climatic and socioeconomic patterns prevail. Consequently, other types of agroforestry systems, such as planted fallows, are necessary.

Early attempts to introduce planted fallows in the tropics were dominated by the use of herbaceous legumes for production of green manures (Milsum and Bunting, 1928; Vine, 1953; Webster and Wilson, 1980). Though many researchers reported positive responses, the recommendations were never widely adopted. Later studies indicated that green manuring with herbaceous legumes was not compatible with many tropical climates, especially in areas with long dry periods which precede the main planting season (Wilson *et al.,* 1986); most herbaceous species did not survive the dry season and this did not have green matter to contribute. However, herbaceous legumes such as

Pueraria phaseoloides, Centrosema pubescens, Calopogonium muconoides, and *C. caeruleum* are widely used as ground cover in the tree-crop plantations in the humid regions (Pushparajah, 1982). Following the introduction of herbicides and no-till crop establishment in the tropics, some of the cover crops such as *Mucuna utilis, Pueraria phaseoloides, Centrosema pubescens,* and *Psophocarpus palustris* were found capable of producing *in situ* mulch for minimum tillage production (Lai, 1974; Wilson, 1978).

Various reports have shown that trees and shrubs, due to their deeper root systems, are more effective in taking up and recycling plant nutrients than herbaceous or grass fallows (Jaiyebo and Moore, 1964; Nye and Greenland, 1960; Lundgren, 1978; Jordan, 1985). In fact, Milsum and Bunting (1928) were among the earliest researchers to suggest that herbaceous legumes were not suitable sources of green manure in the tropics. They believed that shrub legumes, including some perennials such as *Crotalaria* sp. and *Cajanus cajan* were more suitable. They even suggested a cut-and-carry method in which leaves cut from special green-manure-source plots would be used to manure other plots on which crops would be grown. *Cajanus cajan,* with its deep roots, survives most dry seasons and has an abundance of litter and leaves to contribute as green manure at the start of the rains. A planted fallow of shrub legumes such as *Cajanus cajan,* already widely used by traditional farmers, was sometimes found to be more efficient than natural regrowth in regenerating fertility and increasing crop yields (Nye, 1958; Webster and Wilson, 1980).

However, with increased use of chemical inputs, serious questions are repeatedly raised as to whether a fallow period is needed and what minimum fallow period will sustain crop production. An objection to the traditional fallow system as illustrated in Figure 5.6 (phases one and two) is the large land area required for maintaining stable production. On the other hand, modern technologies from the temperate zone, introduced to increase food production by continuous cultivation, have not been successful on the low-activity clay soils.[2] Rapid decline in productivity under continuous cultivation continues even with supplementary fertilizer usage (Duthie, 1948; Baldwin, 1957; Moormann and Greenland, 1980; FAO, 1985). From the results of a world-wide survey, Young and Wright (1980) concluded that, with available technology, it is still impossible to grow food crops on the soils of tropical regions without either soil degradation or use of inputs at an impracticable or uneconomic level. They further stated that, at all levels of farming with inputs, there may still be a need to fallow, or to put the land temporarily into some other use, depending on soil and climatic conditions. Higgins *et al.* (1982) have given some estimates of such rest periods needed for major tropical soils under various climates with different inputs. These values, expressed as the cultivation factor R, which is the inverse of the land-use factor L (as explained in section 5.1) are given in Table 5.2. The rest period needed decreases with increasing input levels.

[2] see Chapter 14 for description of LAC soils.

Table 5.2. Rest period requirements of major tropical soils under traditional (low-input) annual cropping.

Values refer to the cultivation factor, R $\frac{\text{Years under cultivation}}{\text{Years under cultivation plus fallow}} \times 1000$

Soil type	General description	% Area in Tropics	Ecozone ->	Rainforest	Savanna	Semiarid
			Growing -> period (# of days per year)	>270	120-270	< 120
Oxisols	Laterite; leached	23		15	15	**20**
Ultisols	Leached; more clay than Oxisols	20		15	15	**20**
Alfisols	Red soils; medium fertility	15		25	**10**	35
Vertisols	Cracking clay	5		40	55	45
Entisols	Alluvial; sandy	16		10	15	20
Inceptisols	Brown; forest soils	14		40	55	75

Source: Young (1989).

To overcome the management problems of the upland LAC soils, which required incorporation of a much-needed fallow component, scientists working at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria in the 1970s devised an innovative agroforestry approach: the using of woody species to manage these LAC soils. This has led to the development of what is now known as the alley-cropping system (see Chapter 9). In both planted fallow and alley cropping, the potential for sustainability is derived from more intensive management; i.e., the noncrop-producing component (the fallow or woody species) is managed in such a way that a large portion of the energy flowing through that sector is redirected towards crop production, and resource degradation and depletion are prevented. When these practices are introduced early on in the evolution of cropping patterns, they will maintain the resource base at a high level, permitting it to respond more effectively to intensive management.

5.4. Improved tree fallows

An improved tree fallow is a rotational system that uses preferred tree species as the fallow species (as opposed to colonization by natural vegetation), in rotation with cultivated crops as in traditional shifting cultivation. The reason for using such trees is production of an economic product, or improvement of the rate of soil amelioration, or both. Examples of this simple kind of rotational tree fallow are uncommon. Bishop (1982) described an agrosilvopastoral system from Ecuador, in which two years of food crops are followed by eight years of a "fallow" consisting of *Inga edulis* interplanted with bananas and a forage legume. The forage legume is grazed by pigs, and the litter from *Inga* is assumed to improve soil fertility. In Peru, biomass production from *Inga* is reported to be greater than that of a herbaceous fallow, as well as equalling or exceeding the natural forest (Szott *et al.,* 1991). Short, sub-annual tree fallows are also possible. Tree fallow amid rice was a traditional practice in North Vietnam (Tran van Nao, 1983). In northwestern India, *Sesbania cannabina,* grown under irrigation for 65 days between wheat and rice crops, added 7300 kg dry matter ha^{1} and 165 kg N ha^{-1} (Bhardwaj and Dev, 1985). In a review of the use of leguminous woody perennials in Asian farming systems, Nair (1988) identified several such examples. In most of those instances, however, the systems combine intercropping with different herbaceous crops in rotation, rather than simply alternating trees with one particular crop every season/year.

These combination cultures involving different species and components can be arranged in time and space. Traditional shifting cultivation systems are temporal, sequential arrangements where the fallow and crop phase alternate (see Table 3.2). The term "improved tree" implies the use of improved tree and shrub species during the fallow phase. However, as discussed earlier, it should also involve various types of improved plant management techniques and improved plant arrangements. Depending on the local conditions, the degree of intensification can progress from a simple two-component mixture of a concomitant type, as in taungya, to space-and-time interpolated multispecies associations as in homegardens. Therefore, the term improved tree-fallow system can in practice imply improved alternatives to the fallow phase of shifting cultivation. Alley cropping (Chapter 9) is thus, in a sense, an improved (permanent) fallow system.

Most reviews on alternatives or improvements to shifting cultivation contain recommendations on tree species considered suitable to alternate and/or intercrop with agricultural species. An ideal fallow species would be one that grows fast and efficiently takes up and recycles available nutrients within the system, thus shortening the time required to restore fertility. In addition to these soil improving qualities, the need for economic products from the trees also is now recognized. Thus, ability to produce some economic products (productive role) in addition to providing benefits (service role) is also an important criterion. An indication of this characteristic is the addition of fruit-and-nut-producing trees to lists of potential fallow species of trees.

Reviewing the tree genera and species that are suitable for maintenance and improvement of soil fertility, Young (1989) listed several species that had been quoted in earlier reviews by other workers. That list contained 31 genera and 53 species. As mentioned earlier, Nair (1988) simultaneously prepared a list of perennial legumes commonly used in Asian farming systems. Although all these species are expected to have soil-improving qualities, these qualities vary considerably and many have yet to be proven scientifically. The most clearly established include those species that are primarily identified by farmers (e.g., *Faidherbia (Acacia) albida)* as well as those selected and improved by scientists (e.g., *Leucaena leucocephala)*. Based on the criteria of dominance in farming systems, scientific evidence, and (unsubstantiated) opinions, a suggested list of trees and shrubs for soil improvement is presented in Table 5.3. Short notes on these species are included in Section III.

Germplasm screening and performance evaluation of several of these multipurpose trees are now a regular part of several agroforestry research projects in many parts of the tropics as discussed in Chapter 20. However, successful examples or case studies of large-scale adoption of improved-fallow models, or for that matter, any viable alternatives to shifting cultivation, are rare.

Discussions on species suitable for improved tree fallows in shifting cultivation areas are usually limited to trees and shrubs with soil-improving qualities. Soil improvement is undoubtedly one of the major considerations. The nature of shifting cultivation itself, however, has been shifting. The traditional situation of long fallows interrupted by short cropping phases has been (or is rapidly being) replaced by shorter fallows. Present-day shifting cultivators do not (often because they cannot afford to) shift their residences as far apart as did previous generations because of shrinking land area per individual family. Therefore, they tend to become more sedentary. This has forced them, as well as the researchers concerned about their plight, to look for

Table 5.3. Trees and shrubs for soil improvement.

Species	Priority
Acacia auriculiformis	I
Acacia mangium	*2*
Acacia mearnsii	I
Acacia Senegal	*2*
Acacia tort Ms	*2*
Acrocarpus fraxinifolius	*2*
Alchornea cordifolia	*2*
Albizia lebbeck	*2*
Alnus spp., inc. *nepalensis, acuminata*	*2*
Cajanus cajan	
Calliandra calothyrsus	*2*
Cassia siamea	
Casuarina spp., mainly *equisetifolia*	*2*
Cordia alliodora	
Dactyladenia (syn. *Acioa) barteri*	*2*
Erythrina spp. *(poeppigiana, fusca)*	*2*
Faidherbia (syn. *Acacia) albida*	1
Flemingia macrophylla	I
Gliricidia sepium	*2*
Inga spp. *(edulis, jinkuil, duke, vera)*	*2*
Lespedeza bicolor	
Leucaena diversiflora	*2*
Leucaena leucophala	I
Paraserianthes (syn. *Albizia) falcataria*	I
Parkia spp. *(africana, biglobosa, clappertonia, roxburghii)*	*2*
Parkinsonia aculeata	
Pithecellobium duke	*2*
Pithecellobium (syn. *Samanea) saman*	2
Prosopis spp., *(cineraria, glandulosa, juliflora)*	*2*
Robinia pseudoacacia	*2*
Sesbania spp., *(bispinosa, grandiflora, rostrata, sesban)*	*2*

[1] Noted as priority for soil improvement (by NFTA: Nitrogen Fixing Tree Association)
1 = first priority; 2 = second priority; Adapted from Young (1989). See Chapter 12 for descriptions of many of these species.

land management systems by which they can get something from the land even during the so-called fallow phase. Intercropping under or between trees in fallow phases is one of the approaches mentioned as an alternative to shifting cultivation (Bishop, 1982). Fruit trees merit serious consideration in this context as potential "fallow" species in areas close to urban centers. Borthakur *et al.* (1979) recommended several prototype farming systems that would allow farmers to have continuing access to and dependence on land even during the "no-cropping" (rather than the fallow) phase as alternatives to shifting cultivation in the northeastern parts of India. But the extent to which such alternatives are adopted by the shifting cultivator will depend more on the social, economic, and anthropological conditions than on the biological merits of the suggested alternatives. Several studies have been conducted on social aspects of adoption of alternatives and improvements to shifting cultivation (e.g., FAO 1985, 1989). In spite of all this research, the shifting cultivator, unfortunately, still continues to be poor, if not poorer than before.

There may be a school of thought that would not subscribe to the philosophy of replacing shifting cultivation by permanent cultivation. Nonetheless, it is infeasible to expect shifting cultivation in its traditional form (with long fallow phases) to continue; any realistic approach to improve it would therefore have to be reconciled with a situation that demands a shorter fallow. In fact, these shortened fallows are becoming too short to be of any real benefit in terms of the expected level of soil improvement even with the most "miraculous" fallow species. These unmanaged shorter fallows are really the root of the disastrous consequences that are attributed to shifting cultivation (such as soil erosion, loss of soil fertility, weed infestation, and build-up of pests and pathogens). It seems logical to accept that managed permanent cultivation systems that encompass some advantages of traditional shifting cultivation, would be preferable to unchecked, fallow-depleted, traditional shifting cultivation. The approaches to fallow improvement, that lead inevitably to permanent cultivation, include improved taungya, homegardens, plantation crop systems, alley cropping, and tree incorporation on farm and grazing lands. These are discussed in the following chapters in this section.

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