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Improved agroforestry technologies for conservation farming: pathways toward sustainability

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There is a dynamic flux transforming the theory and practice of conservation farming for hillslopes in the tropics. Much of the conventional wisdom of even 10 years ago has been challenged by recent research and farmer experience. The 'new' conventional wisdom that replaced it (centering on pruned tree hedgerows) is also now under serious revision. In such a fluid environment it is not certain that the 'best management practices' recommended today will stand the test of experience tomorrow.

This paper proposes a simplified model for comparative analysis of the pathways toward farming-systems' sustainability on sloping lands. The pathways break into two streams based on the fundamental distinction of whether or not external inputs are available to the farmer. In the case where nutrient inputs are not feasible, continued land use depends on strategies based on fallowing. Initially, these are natural fallows. Intensification evolves toward improved fallows, or economic fallows (such as tree crops in agroforests). Because nutrients are a more fundamental limitation in such situations, farmers do not perceive soil erosion as important.

When external nutrients can be applied, continuous cropping becomes feasible. At this juncture farmers become concerned about soil conservation, to stabilize the land resource and better protect their investment in nutrient application. Their choices of contour farming options then depend strongly on the relative labour demands of the available alternatives.

This dichotomy of pathways suggests that: (i) the use of pruned tree hedgerows in a fallow-rotation system, as a means of improving fallows on degraded lands, may prove more suitable than they have proven to be in continuous cropping situations; research should focus on this proposition more intensively, (ii) low-maintenance contour hedgerows will find widespread use on sloping lands that are continuously cropped, but

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ways must be found to avoid or alleviate the upper-alley scouring effect that degrades soil resources in the alleyways. To shifting cultivators, simple contour farming techniques will not be perceived to be as useful as improved fallow methods that directly address soil fertility decline, and (iii) more attention should be given to the concept of agroforests on degrading lands and specifically to how farmers can be assisted to develop economic fallows by cultivating perennial mixtures for cash income.

Conservation farming research must find a proper balance between the fallow rotation and continuous cropping pathways. Although strong emphasis on the latter is justified, most smallholders on sloping land have no access to external nutrient supplies. Research on improved fallow technologies must have clearer objectives and more vigorous attention. The concept of hedgerow intercropping for fallow rotations may provide optimism that this work will pay off in adaptable solutions.

Paradigm shifts in hillslope conservation farming

The theory and practice of conservation farming for hillslopes in the tropics is undergoing dynamic revision. Paradigm shifts are occurring at several levels. The body of conventional wisdom has been seriously modified in recent years. We may identify three paradigm shifts of particular significance: (i) the engineering approach has yielded to the biological approach for soil conservation on smallholdings, (ii) the top-down watershed management approach is yielding to a bottom-up approach with a farmer and community focus, and (iii) the pruned leguminous tree hedgerow concept of contour farming is diversifying toward a much more robust array of hedgerow options.

This paper argues that in the light of the current flux in knowledge, there is need for clearer models to articulate and rationalize conservation farming options. This would help clarify the contrasts among alternative pathways toward sustainability, and better define the array of recommendation domains.

A preliminary framework for the general pathways toward sustainable systems is presented. Emphasis is on key trends in researcher and extensionist knowledge and perceptions, and their test on the template of farmer experience. The key elements of the respective pathways are reviewed, focusing on the comparative advantages and disadvantages of each pathway, and highlighting urgent future directions for research and development. Recent trends toward either (i) low-labour 'minimalist' technologies (e.g. natural vegetative strips, vetiver strips), or (ii) perennial value-added systems, including timber production, are reviewed. Attention is directed to the issue of upper terrace scouring, recently recognized as a constraint on the sustainability of most contour-hedgerow systems.

The first paradigm shift

Biological and soil engineering have both been a part of soil-conservation practice since the beginnings of this interdisciplinary field. The legacy of conservation practices in larger-scale mechanized farming systems in the temperate zones had a dominant influence in shaping the course of conservation practices in the tropics, until quite recently. The principles of soil and water engineering that underpinned temperate conservation highlighted the construction of terraces, terrace bunding to physically store and constrict water movement on the landscape, and drainageways at an appropriate grade to safely carry runoff away. These practices were tested and promoted in numerous conservation research projects with tropical smallholders. And they often worked. But it only gradually became apparent that they were seldom compatible with smallholder circumstances, because they were too expensive, complex, or laborious to build and maintain.

The superiority of biological alternatives gained strong appreciation only recently. A major impetus for this was the recognition of the role of agroforestry in soil conservation (Young, 1989). It was known that vegetative strips on the contour provided an effective filtering mechanism to reduce runoff and soil loss. And it was known that over time they promoted formation of terraces naturally. Unfortunately the filter strip approach was dominated by the terrace construction/bunding/drainage approach. In many conservation projects, the change from bench terracing to vegetative filter strip solutions is still in progress (or has not even begun!).

The second paradigm shift

A set of new ideas in soil conservation has recently gained prominence. The focus is squarely on the farmer, rather than on the techno-solution (Lundgren and Young, 1992; Shaxson *et al.*, 1989). Douglas (1992) has discussed these ideas as a set of 13 common principles on which consensus has emerged from the frustration of past failures. Key among these for the purposes of this paper is that the focus for soil conservation should be on the maintenance and enhancement of crop productivity, rather than on soil loss: conservation should be carried out only in the context of the goals of the smallholder. It should provide a basket of choices rather than a 'wonder' solution. And planning should be at farm-field level rather than the watershed.

These principles could transform the practice of research and extension in conservation. They have wide support in the international development community. But their application at the project level is still far from being realized.

The third paradigm shift

The most recent upheaval involves alley cropping (or contour - hedgerow intercropping on sloping lands). This is the agroforestry practice of planting leguminous trees on the contour to provide green-leaf manure to fertilize annual crops, and serve as a barrier to soil loss. Early work (in the 1970s) indicated that hedgerows may enhance and sustain crop yields through the additional nitrogen supplied from biological fixation, the pumping of nutrients from deeper soil layers, and the control of soil erosion (Kang *et al.*, 1990). It was conceived as a 'simultaneous fallow' that could enable permanent cropping and overcome the need for fallowing in shifting cultivation systems.

The virtues of the system also came with vexations. One and one-half decades of research and on-farm experience with the alley-cropping system is leading to a much more conservative estimation of the potential of alley cropping (Ong and Huxley, 1995). Benefits in controlling soil loss are impressive, and annual crop yields often increase in the short term. But often the trees compete with the crops for light, nutrients, and water, offsetting the nutrient and mulching benefits of the prunings (Garrity *et al.*, 1995; Agus, 1993).

Consistent yield gains are most frequently observed on soils in humid areas with fairly high base status (Garrity *et al.*, 1993). But in environments with strongly acid soils and low base saturation, crop yields are often unaffected or reduced (Garrity *et al.*, 1995). In semiarid environments the trees exploit soil water more effectively than annual crops, and often reduce crop yields substantially (Rao *et al.*, 1992).

Results tend to vary with hedgerow species, crops grown in the alleys, and management regime applied (e.g. frequency of pruning). Thus, the global research record on alley cropping is not easy to generalize. But two conclusions are widespread:

- Even where results are positive, it is unrealistic to expect pruned tree hedgerows to maintain an adequate nutrient supply to maintain annual cropping on an indefinite basis without external nutrient application. If nutrients are not added, hedgerow intercropping is seldom a viable replacement for fallow rotation. Rather, it is an intermediate pathway between fallow-rotation, and continuous cropping with inorganic fertilization. In the absence of nutrient importation, contour-hedgerow systems may prolong the cropping phase, and/or shorten the fallow phase. This does intensify land use and increases average yield per hectare per year over the crop-fallow cycle. But it is not a reliable substitute for fallowing.
- Farmer adoption of alley cropping, or continued adherence to the system after adoption, has been limited. This is usually attributed to the added labour requirements in pruning the hedgerows. But it may also be influenced by the farmers' observation that yields do decline. In such cases fallowing the hedgerows is the rational approach.

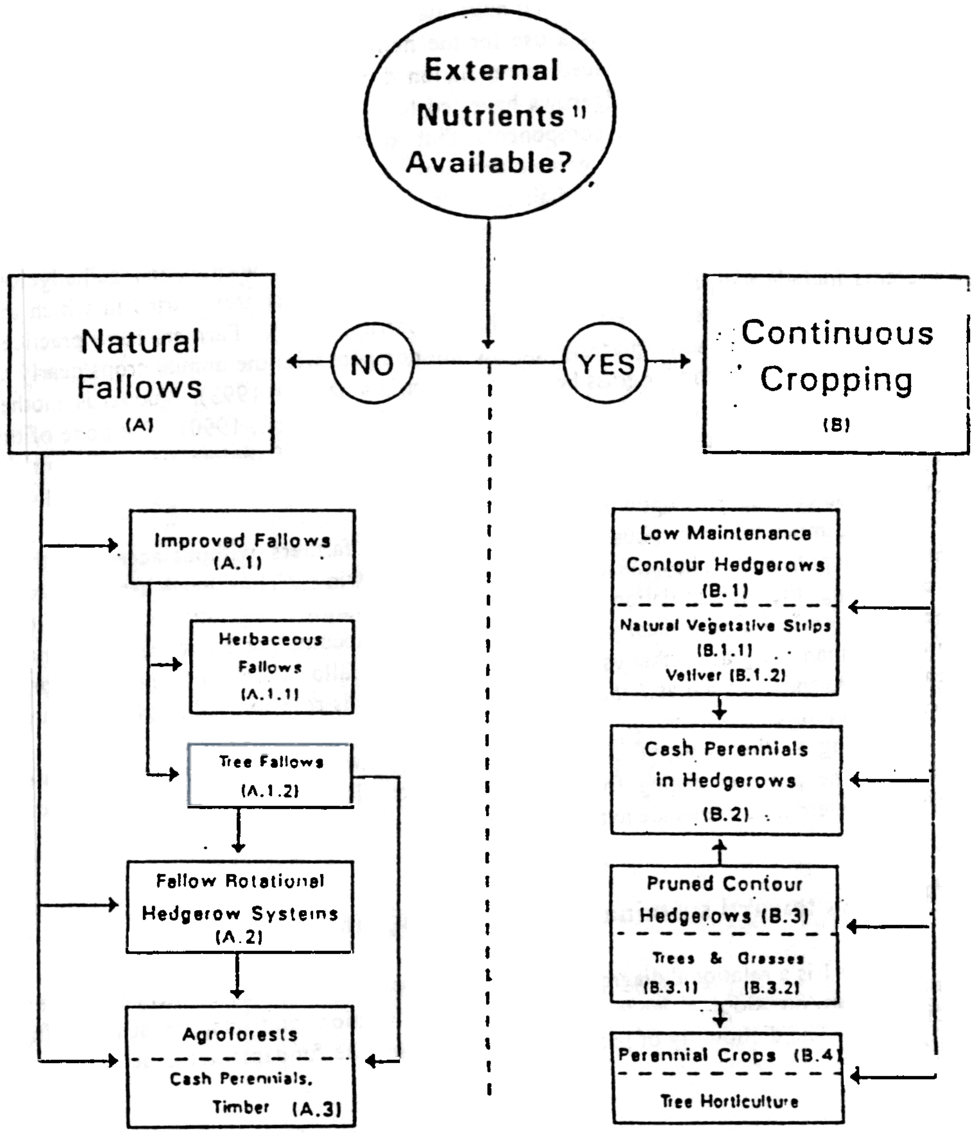
In continuous cropping systems, pruned tree hedgerows may retain an important role where the soils are conducive, external nutrients are supplied, farm size is small (because of pruning labour), and there is a use for the hedgerow prunings as ruminant fodder. This, however, is a much reduced extrapolation domain than initially conceived. The limitations of pruned tree hedgerows have led to increased interest in a wide range of other alternative hedgerow components that perform the same soil-conservation functions with less labour and greater economic benefits. The options include fodder grass strips, and cash perennials such as coffee, fruit trees, mulberry, and many others (Garrity *et al.*, 1993). The overriding concern of many farmers is minimizing both soil loss and the labour invested in maintaining the hedgerows. Low-maintenance hedgerow systems include natural vegetative strips (NVS), which are contour strips in which the local grass species are allowed to reestablish (Garrity, 1993). Farmers have practiced NVS indigenously in some places. They do not compete with the annual crops nearly as vigorously as tree or fodder grass hedgerows (Ramiaramanana, 1993). Vetiver is another option in the class of low-maintenance hedgerows (Smyle *et al.*, 1990). But none of the alternatives to pruned tree hedgerows solve the problem of maintaining soil nutrient balances. Fertilization (manure, fertilizers, additional plant residues) is still required with all these other hedgerow options.

What must the enormous population of upland farmers without access to these nutrient inputs do? They must still depend on fallowing. They need better ways of accelerating the accumulation of nutrients in the fallow vegetation. Pruned tree hedgerows may be periodically fallowed. They will accumulate far more biomass and nutrients than the grasses that usually invade degraded fallows, and will tend to suppress undesirable species such as *Imperata cylindrica*. But this role for hedgerows has hardly been explored (Garrity, 1995).

Turning to the issue of discriminating the pathways toward sustainable farming systems, the point emerging from the above discussion is the central importance of whether external nutrients are available to the farmer or not.

Pathways toward sustainability on sloping lands

Figure 1 is a relational diagram that tries to illustrate the major pathways available to smallholders on sloping lands to meet their production and income sustainability objectives. The dichotomy of pathways proceeds from the fundamental issue of nutrient supply.



1) Manure, fertilizer or off-field plant residues

Figure 1. Pathways towards sustainability on sloping lands.

When the farmers' circumstances prevent them from supplying external nutrients, their means of maintaining sustainability will be quite different from situations where they have access to them. These farmers cannot crop continuously. Resting the land periodically in natural fallows (A in Figure 1) is the age-old protocol employed. But if they face land constraints, they will need ways of fallowing that accelerate the regeneration of the productive capacity of the system, and/or provide economic returns from the species that occupy the fallow. If the farming system is in natural fallow, and no external nutrients are available, the viable options (shown in Figure 1) are downward toward improved fallows (A1), fallow-rotational hedgerow systems (A2), and agroforests containing cash perennials (A3).

How do farmers move into a situation of external nutrients? Often this occurs as a consequence of the development of markets for commodities with a substantial return to fertilizer inputs - vegetables, horticultural crops, cash perennial crops. Credit mechanisms appear as these opportunities develop. When continuous cropping becomes feasible (see B in Figure 1), then further evolution is needed to maintain soil fertility investment through some form of contour farming. Pathways on the right side of Figure 1 are viable options if the use of external nutrients is possible.

The transformation to continuous food cropping radically changes the dominant pathways to sustainability, with a shift toward conservation practices that may minimize erosion under cropping, or toward perennial crops that provide income with less stress on the soil resource. Continuous cropping may be maintained through the installation of effective vegetative barriers. A wide range of options is available. They range from low-maintenance natural vegetative strips (B1), that may be enhanced by value-added cash perennials (B2), to pruned leguminous tree hedgerows (B3). A further transformation may lead to commercial perennial crop production or tree horticulture (B4).

Note that there is a correspondence between the options opposite to each other on the left side of the figure (pathways without external nutrients) and on the right (those which have them). This indicates the potential for a parallel transfer in land use from left-to-right, or right-to-left, depending on changing nutrient circumstances at the farm level. Examples are the transformation between fallow rotational hedgerow systems (A2) and contour-hedgerow systems (B3), or between agroforests (A3) and fertilized perennial crops (B4). Agroforests (or mixed perennial systems) are observed where nutrient inputs generally are not applied. Monoculture tree cropping tends to evolve when nutrient inputs are used.

There are obviously many other factors besides nutrients that influence the pathways to sustainability. Some of these factors actually determine whether external nutrient use is feasible, profitable, or necessary (e.g. input and output markets for high return commodities). Three factors of key importance are: (i) whether primary tillage is done by hand, or by draft power (animal or tractor), (ii) whether farm size (more accurately the land/labour ratio) is large or small, and (iii) the degree of land tenure security.

Land-use systems are a continuum, not classes with discrete boundaries. Different parcels within a single farm, with different soil quality or location, may be managed in contrasting ways, and thus may occur on both sides of the diagram (e.g. continuous commercial cropping near the residence, with food crops or perennials in fallow rotation further away). We now proceed to a closer examination of the diagram's pathways.

Natural fallows

Natural fallows[1] work eminently well in regenerating soil fertility, if the local fallow species diversity and soil quality have not been degraded. Szott *et al.* (1991) have shown that in a humid rainforest environment there was little or no advantage in replacing the natural woody perennial fallow with either a cover crop or fast-growing leguminous trees. But in much of the tropics, natural fallows in shifting cultivation systems have been degraded to the point where grasses, particularly *Imperata cylindrica*, dominate the abandoned fields. Annual nutrient accumulation in *I. cylindrica* fallows levels off after one to two years and is far inferior to that of woody vegetation. The result is a fallow incapable of regenerating adequate nutrient accumulation, yet very laborious to re-open for cultivation.

The farmer's approach to natural fallows is not passive. Plot selection is carefully assessed, and grassland or land infested with ferns is avoided whenever possible (Cairns, 1994). *Chromolaena odorata* is an important example of a pioneer fallow species that naturally suppresses *I. cylindrica* under some conditions, accumulates many times more biomass, regenerates crop productivity much more efficiently and is thus highly desired by shifting cultivators (Dove, 1986; de Foresta and Schwartz, 1991). *Lantana camara* fits the same niche at higher elevations in Timor, Indonesia (Donner, 1987). *Eupatorium inulifolium*, a non-native sepcies, proved very beneficial in shifting cultivation systems at higher elevations in West Sumatra (Cairns, 1994). Introduced in the late 19th century, it spread widely. Farmers found that it reduced the necessary fallow period by half. This is a major contribution since shifting cultivation land pressure was serious (Stoutjesdijk, 1935). Cairns' (1994) work showed that *E. inulifolium* fallows accumulated over 150 kg N ha^{-1} and 20 kg P ha^{-1} in two years. Nearby *I. cylindrica* fallows accumulated only 25 kg N ha^{-1} and 6 kg P ha^{-1}.

Improved fallows

Clearly, there is potential to improve the benefits of fallowing through manipulation of natural succession and through the establishment and management of fallow species. But improved fallows involve increased investment of labour, management skills, and planting materials. The basis for an improved fallow is that these investments pay off by increasing the efficiency of the fallow phase.

1 The term 'fallow' is used in this paper to designate the period between annual cropping cycles. 'Natural fallow' refers to a fallow in which the land is occupied by vegetation that regenerates naturally.

Managed fallows: herbaceous cover crops and improved pastures

Considerable agronomic work has been done to exploit the principle that leguminous cover-crop species may accelerate the regeneration of the productivity of land. They have proven advantageous for short fallow periods of less than two years. Beyond that time further benefits are not realized. Susceptibility to uncontrolled fire, lack of seed supply, and uncontrolled grazing have been the primary constraints to adoption of legume cover crops.

Improved fallows of leguminous trees

Shifting cultivators in many indigenous systems deliberately select and protect some of the trees remaining in the fallow. This maintains a desirable species diversity and enhances biomass accumulation. There are also cases where farmers deliberately stimulate the colonization of fallowed land with tree species to create conditions that accelerate the regeneration of the land between cropping cycles. In the village of Naalad, Cebu (Lasco, 1991; Kung'U, 1993) farmers broadcast *Leucaena leucocephala* seed on steeply sloping land that is being fallowed after maize and tobacco cropping. Farmers claim that the *Leucaena* sp. accumulates nutrients for the next cropping phase, improves soil fertility, and provides woody stakes for contour erosion structures. A broadcast-seeded *Leucaena* sp. fallow system is also practiced in parts of eastern Indonesia. MacDicken (1991) has developed a tree fallow rotation system suited to the circumstances of shifting cultivators in Mindoro island in the Philippines. He has emphasized the suitability of these systems to upland cultivators in harsh environments, and the lack of research attention given to them.

These systems are particularly suited to communities that practice hand tillage, either because cultivation is on steep slopes, or animal draft power is unavailable. (The random distribution of the woody vegetation complicates the use of the plough.) There are many areas where shifting systems are practiced where animal power is not or cannot be used. Introduction of this type of system may be promising for such conditions. But why are such systems not practiced more widely?

Identification of appropriate tree species for local agroecological conditions is one constraint. Clearly, the *Leucaena*-based systems were broadly limited to soils that are not strongly acid. This may explain their use in central Philippines and eastern Indonesia. But elsewhere in Southeast Asia, strongly acid soils tend to dominate (IRRI, 1986). These areas tend to have been settled more recently and have lower population densities. There may have been less pressure to identify tree fallow solutions to declining soil quality.

A critical factor in selecting an appropriate tree species for managed fallows is re-establishing a tree population with minimal effort at the end of the cropping period. As a prolific seeder, *Leucaena leucocephala* was an exceptionally suitable species for this purpose. It is easy for farmers to harvest seed and broadcast it to re-establish adequate plant populations. Tree species suitable for developing tree-based fallow systems on acid soils are urgently needed. But there has been very little work on identifying and testing species for such conditions. *Acioa barterii* is a non-leguminous species that farmers in southeastern Nigeria have cultivated as a fallow regeneration species for strongly acid soils (Kang *et al.*, 1990). But this species is planted in rows, and is pruned during the cropping period and allowed to regrow during the fallow period, rather than re-established from seed. The *Acioa* system is therefore a tree fallow, but with the trees in hedgerows.

Fallow-rotation hedgerow systems

Much of the research and extension work on alley cropping during the past 20 years was based on the premise that pruned hedgerows of leguminous trees would enable continuous cropping without additional fertilizer application. They were conceived as 'continuous fallows', constantly producing nutrient supplies for the annual crops through nitrogen fixation and nutrient pumping from deeper soil layers. Thus, they seemed to be an elegant solution to the nutrient supply problem without resting the land or applying fertilizers. There are some reports that yields may be maintained with alley cropping for many years (e.g. Watson and Laquihon, 1987). But in most cases this expectation has proved unrealistic (Garrity, 1993; Garrity *et al.*, 1995). There is clear evidence that alley cropping cannot be expected to maintain the levels of all critical nutrients at adequate and stable levels for continuous crop production. In fertile soils which normally develop only mineral nitrogen deficits, such as certain young volcanic soils, continuous pruning applications may suffice. But in the vast majority of soils, such as the strongly acidic soils which experience severe phosphorus deficiency (such as the Ultisols and Oxisols), as well as the many Entisols, Inceptisols, and Alfisols that reveal a range of nutrient limitations under cropping, tree prunings do not provide the quantities or the balance of nutrients suited to continuous cropping.

Farmers in many alley cropping or contour hedgerow projects eventually abandon their hedgerow fields. They will come back and open these fields again after a resting period. This is a realistic reaction to the inability of the hedgerow fields to maintain yields.

Researchers and extensionists have tended to view hedgerow fallowing as a failure. It was not contemplated in their initial expectations. But experience now indicates that these expectations were unrealistic. We thus see the origin of another paradigm: Contour hedgerows may be managed in a fallow rotation system.

The concept is that by hedgerow installation the farmer will not avoid fallowing. Rather, fallowing the hedgerows will enhance the regenerative process, reducing the length of the fallow period and lengthening the cropping period. It will also reduce labour in re-opening the land because of weed suppression, and may produce wood, fodder and other products of economic value.

Fallow-rotation hedgerow systems are a variant of managed tree fallows. Figure 2 illustrates the two phases of the system. During the fallow phase the branches of the hedgerow trees tend to spread laterally over the alley, suppressing grassy vegetation, and producing leaf litter and woody biomass. At the beginning of the cropping phase the reservoir of nutrients is either used as mulch or carefully burned. Larger tree branches may provide fuelwood or stakes for cash crops. Subsequently, during the cropping phase, which may last several years, the trees are pruned severely to minimize competition with the annual crops.

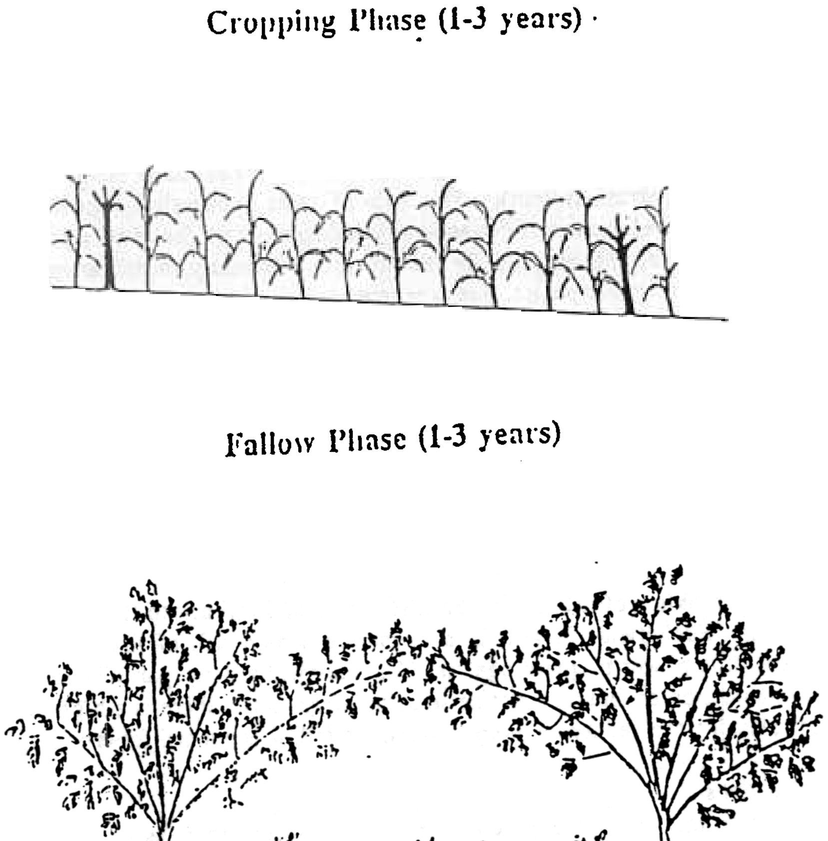


Figure 2. Fallow-rotation hedgerow system.

The value of fallowed tree-hedgerow systems may be greatest in environments where woody natural fallows will not regenerate rapidly, or at all. This is particularly the case in *Imperata* grasslands. The planted tree-hedgerow system will produce much larger accumulations of biomass and nutrients during the fallow period than a grass fallow. It may also largely suppress the grass, saving labour in opening the land, and in subsequent weedings during the cropping phase through reduction in weed seed density in the soil.

During the 1930s and subsequently, *Leucaena* hedgerows were promoted and widely adopted on Flores island (Djogo, 1988). In semiarid West Timor, Indonesia, traditional or 'adat' law has compelled shifting cultivators for generations to plant trees before ending the cropping phase. The practice tended to decline, however, as traditional law eroded. In 1948 (Ormeling, 1955), the local government of Amarasi District in West Timor initiated a major programme requiring farmers to plant *Leucaena* along contour lines (known as the Amarasi system). This proved quite successful, especially as *Leucaena* enabled the development of cut-and-carry fodder systems for cattle raising. It also served as live fences, and security for land tenure. Currently, much attention is directed to diversifying the tree species, due to severe psyllid infestation of the *Leucaena* stands (Djogo, 1988).

Duguma (1993, pers. comm.) has reported large fertility effects on the annual crops grown after a hedgerow fallow is opened. Van Noordwijk (1994; pers. comm.) found that the presence of *Gliricidia* trees in the fallow tended to shift the herbaceous plant community toward *Chromolaena odorata* and away from *Imperata cylindrica*, a favourable species shift for fertility regeneration. Since the trees are planted in hedgerows these systems are suitable for animal draft as well as manual tillage.

Limitations

The ubiquitous problem of fire is probably also the main drawback to fallow rotation hedgerow systems. Such fields in grassland areas face a high risk of fire, which the farmer may have little power to guard against. The trees will at least partially suppress the more flammable grasses, but may not do so completely. Also, there is a high labour requirement in slashing the hedgerow biomass when the fallow is opened for cropping.

Future directions

Tree hedgerows may be more practical in fallow rotation than as continuously-pruned hedgerows during the cropping phase. This model needs serious research as an alternative to the conventional alley-cropping concept. There is great potential for both strategic and farmer participatory trials.

Agroforests

Shifting cultivators often enrich their fields with perennial species that will earn future cash income. For example, most of the rubber produced in Indonesia comes from rubber trees planted on land destined be fallowed after one or two years of food crops. In these systems, practiced over 2.5 m ha on the islands of Sumatra and Kalimantan, the rubber trees grow up along with secondary forest vegetation (Gouyon *et al.*, 1993). The family returns years later to tap these trees. Meanwhile, the family continues food production in new swiddens opened up further from the village (Figure 3).

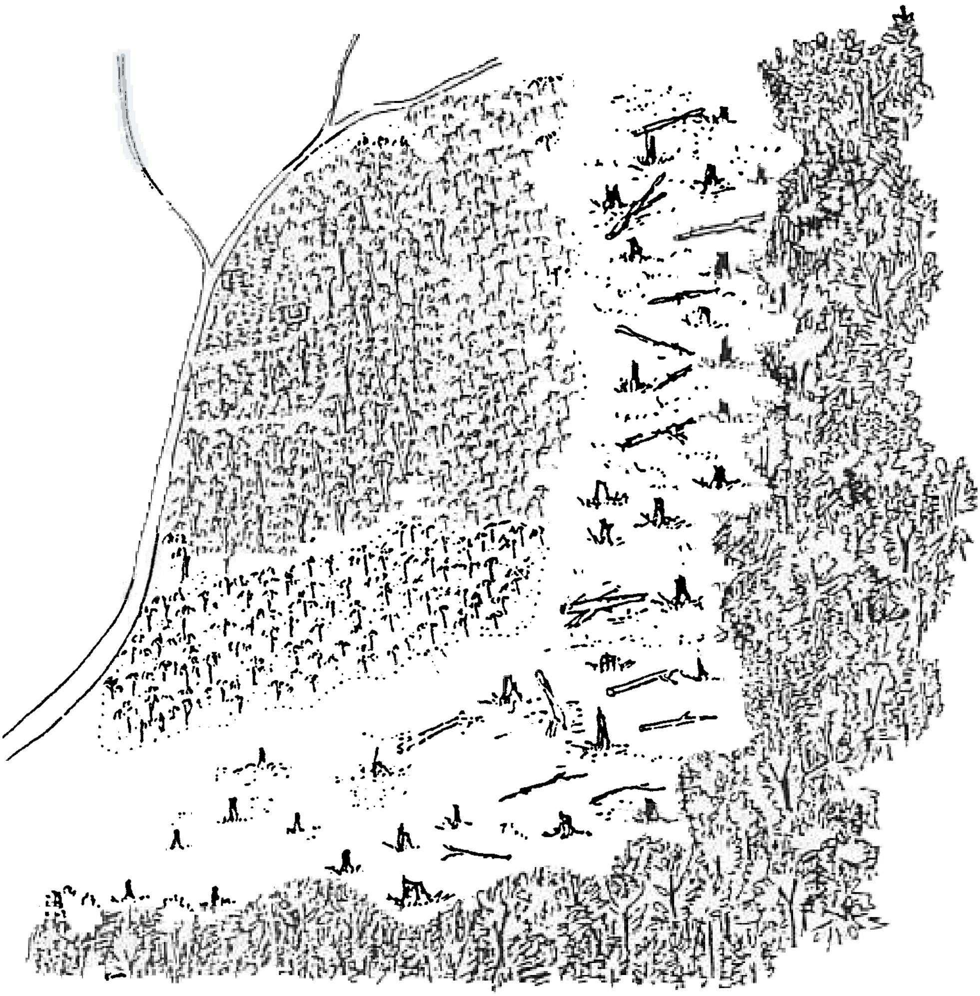


Figure 3. Rubber agroforestry: traditional alternative to slash-and-burn.

In southern Sumatra an extensive area of *Shorea javanica* or damar agroforest was established by indigenous shifting cultivation (Michon, 1991). The trees produce a useful resin sold on the international market for the manufacture of industrial paints. In other areas of Sumatra and Kalimantan durian agroforests were established on a large scale through slash-and-burn systems.

These 'enriched fallows' are a sustainable mode of land use following food cropping. Indeed, they may be maintained indefinitely. They enable shifting cultivators to escape total dependence on annual crops for their livelihood, and evolve major parts of the landscape into perennial species. Stable markets for the tree commodities are a key requirement for sustainability of these systems.

A recent variant of this system is the culture of timber trees in swidden fallows in frontier areas (Garrity and Mercado, 1993). The market demand for fast-growing timber species is growing very rapidly in countries where the natural forests have been depleted. Smallholders in the grasslands of northern Mindanao are planting *Gmelina arborea* as an intercrop with their annual crops of maize, upland rice, and cassava. The trees occupy the fallow period and are harvested in an 8-10 year cycle.

Continuous cropping

We now shift attention to the domain of sloping land farming options when external nutrients are available to the farmer.

Low maintenance contour hedgerows

Farmers who perceive soil erosion to be a problem are interested in vegetative barrier techniques that minimize labour (Fujisaka *et al.*, 1994). In Claveria, Philippines, tree legumes and fodder grasses were tried and adopted by farmers during the first years of the IRRI research and farmer-to-farmer training project. But farmers independently developed and experimented with the practice of laying out contour strips that were left unplanted, and were revegetated by native grasses and forbs.

Researchers found that these natural vegetative strips had many desirable qualities (Garrity, 1993). They entail low pruning maintenance compared with fodder grasses or tree hedgerows, and offer little competition to the adjacent annual crops compared to the introduced species (Ramiaramanana, 1993). They were very efficient in minimizing soil loss (Agus, 1993), and they did not show a tendency to cause greater weed problems for the associated annual crops (Moody, 1992, pers. comm.).

Natural vegetative strips (NVS) were found to be an indigenous practice on a very limited scale in other localities, including Batangas and Leyte Provinces. Adoption is quite simple. Once contour lines are laid out (the slope does not need to be very exact, since they act as filter strips, not bunds) there is no further investment in planting materials or labour. The biomass production, and economic value as fodder, is lower than many other hedgerow options, but the labour is minimized. This is especially attractive to farmers with more than 1 ha of land. Vetiver grass fills a similar niche as a low value-added but effective hedgerow species. But for vetiver the planting materials must be obtained and planted out.

A limitation of low maintenance hedgerow components is that they do not enhance the nutrient supply available to the crops. In this respect they do not differ from many other hedgerow enterprises, including fodder grasses and perennial or cash crops. NVS or other low-management hedgerow options do not ensure the sustainability of continuous cropping. Upland farmers who had adopted NVS in Matalom, Leyte, still tend to fallow these fields. This is evidence that better protection against soil loss does not solve the fundamental problem of crop nutrient supply. Fertility must be managed through the addition of manure and/or fertilizers. The technology has little to offer directly to shifting cultivators coping with a nutrient supply problem.

Shifting cultivators in highland environments in many areas are beginning to grow temperate vegetables (e.g. northern Thailand, western Sumatra, and northern Philippines). Many issues may be raised about the sustainability of such systems, but the transformation may be viewed as a mechanism to finance nutrient importation. Often these systems exhibit immense soil losses, because the vegetables are usually planted on very steep slopes. Curiously, farmers seldom apply significant soil-conservation measures, although the potential to better conserve their enormous investment in nutrients appears obvious.

Vegetative barriers are particularly suited to vegetable systems. The maintenance of nutrient balances is not the problem, because fertilizers are feasible, but the same maintenance is a problem in food cropping systems. Natural vegetative strips may be an ideal alternative. Other low maintenance approaches to 'natural' terracing may also fit.

Cash perennials in hedgerows

Perennials with economic value are an attractive option to many farmers. When trees are combined with NVS or planted grass strips they may provide a serious solution to the problem of taking land out of productive use when hedgerows are established. We observe farmers who have established NVS experimenting with a wide range of perennial crops in hedgerows, including many types of fruits, coconuts, coffee, mulberry, and even fast-growing timber species.

Unlike pruned hedgerows, cash perennials tend to be full canopy trees. Little is known about the tradeoffs between their growth and yield and annual crop losses due to shading and below-ground competition. These interactions will determine the future viability and appropriate species choice in this class of tree-crop systems.