Agroforestry pathways: Land tenure, shifting cultivation and sustainable agriculture

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HILLSIDE AGROFORESTRY IN THAILAND trees boost agricultural productivity

"Agroforestry is a collective name for land-use systems and technologies in which woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately combined on the same management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions among the different components" (after Lundgren, 1982).

• Many people today have great expectations for agroforestry, some of which would seem to be justified on technological grounds. However, if current efforts to understand, develop and disseminate agroforestry technology are to have any hope of meeting even a reasonable proportion of current expectations, its deployment, as a newly organized branch of applied science, must take place with a clearer than usual view of the human context of supposed land-use improvements.

The purpose of this article is to provide some mental images of the scope and potential role of agroforestry to serve as a background to the discussion of tenure issues. The main assumption is that the interactions between agroforestry and tenure issues are basically of two types: first, tenure factors may pose constraints to the realization of the potential ecological and socio-economic benefits of agroforestry in many land-use systems; and second, agroforestry may offer ways of resolving or mitigating some existing tenure problems. Without doubt, tenure issues are far more varied and complex than are reflected here. However, attention is focused on some of the major changes in tenure that arise in conjunction with the main developmental trends in tropical land use. These changes are then viewed in ecological and evolutionary perspectives.

From a project standpoint there are two fundamental ways of arriving at agroforestry: by integrating trees into farming systems or by integrating farmers into forests.

Appropriately selected woody components may contribute to both the productivity and sustainability of farming systems on marginal land in several ways: by enhancing the production of organic matter; by maintaining soil fertility; by reducing erosion; by conserving water; and, by creating a more favourable microclimate for associated crops and livestock. These "service roles" are above and beyond the direct "production roles" trees can also play in supplying food, fodder, fuelwood, building materials and other raw materials for rural industries. In traditional land-use practices, agroforestry is also important in maximizing and diversifying the productivity of even highly fertile lands. Intensive agroforestry systems are most commonly found in areas with a long history of population pressure, indicating their general efficiency as a land-use system.

Whether on marginal or high-potential lands, diversified agroforestry systems may be the most appropriate form of land use where land tenure constraints, lack of marketing infrastructure or an unfavourable political economy make it imperative for small landholders, in trying to reduce risks, to try to satisfy most of their basic needs directly from the land resources under their control (Lundgren and Raintree, 1983).

All tropical land-use systems exhibit varying degrees of "leakiness" with respect to the cycling of nutrients held in the soil-vegetation complex (Nair, 1984), although systems such as irrigated rice paddies, permanent tree crops and forests are inherently more sustainable than others. It is a fundamental contention of agroforestry that trees have good prospects for plugging many of the holes in tropical farming systems. The degree of "infilling" can vary from slight (limited interstitial planting) to virtually complete (as in the home garden model). Essentially, the decision as to how many and which kind of trees it is profitable to add to the existing pattern of land use depends on what useful niches for trees can be identified. An agroforestry "niche" in this sense has three components: a functional *role* within the land-use system; a place within the landscape; and a *time* within the life cycle of a particular land-use system.

Although many of the recent research thrusts in agroforestry have been directed toward the integration of trees into farming systems, agroforestry also has a role to play in the preservation of forests and the improvement of forest management systems. By providing farmers with a means of producing fuelwood, timber, building poles and other forest products on farmland, agroforestry can significantly reduce the demand on forests and natural woodlands. By doing this in ways that enhance and sustain agricultural productivity, agroforestry can also alleviate some of the pressure for the conversion of forest land into farmland. Moreover, the integration of farmers into forest management schemes through the use of "compromise" land-use systems based on agroforestry may be one of the few realistic ways of sustaining forestry production on agriculturally pressured forest land (Raintree and Lundgren, 1985).

A look at some problems and also at opportunities related to the issues of land use and tenure will show that agroforestry has much to contribute to their improvement.

Main stages of intensification in the evolution of tropical agriculture from shifting to continuous cultivation

Source: Raintree and Warner 1985 (after Greenland 1974 and Boserup, 1981)

From shifting to permanent cultivation

Different agroforestry options and development pathways open up from different stages in the intensification sequence outlined in the Figure, which summarizes what appear to be the most promising agroforestry approaches.

Integral taungya. In the classification of swidden systems, a distinction is made between "integral" and "partial" swidden. Partial swidden reflects "predominantly only the economic interests of its participants (as in some kinds of cash crop, resettlement, and squatter agriculture)", whereas integral systems "stem from a more traditional, year-round, community wide, largely self-contained, and ritually sanctioned way of life" (Conklin, 1957).

By analogy with integral shifting cultivation, the proposed concept of "integral *taungya*" is meant to invoke the idea of a land-use practice that offers a more complete and culturally integrated approach to rural development: not merely the temporary use of a piece of land and a poverty-level wage, but a chance to participate equitably in a diversified and sustainable agroforestry economy.

The social aims of the proposed approach are high, and they are nowhere yet fully realized in practice although perhaps the "forest village" schemes in Thailand come closest to the ideal. In some variants of this approach, participation in forestry is made more attractive to traditional shifting cultivators, not only by encouraging them to grow long-term perennial cash crops by widening the between-row spacing of the commercial forest species, but also by allocating permanent agricultural plots for them to use as they see fit. In addition, they are paid decent wages for a variety of work opportunities and are provided with a range of extension and community development inputs such as housing assistance, clinics, schools, and places of worship (Boonkird, Fernandes and Nair, 1984). Far from being an exploitative practice, this Thai variant of the *taungya* system promises to become a model example of "integral *taungya*", although nowhere is it adequately documented in the literature.

There is always the danger, of course, that the ideals of this approach could be subverted and that the banner of "integral *taungya*" could be used in some places as a cover for politically motivated strategies of ethnic containment and confinement in villages.

Enriched fallows. There are two variants of this approach: *economically enriched fallows*, which increase the economic utility of the fallow vegetation by enrichment with trees valued for cash or subsistence purposes; and *biologically enriched fallows*, which enhance and accelerate the vegetative regeneration of soil fertility and control of weeds. These become attractive to farmers somewhere around stages 1-2 and 2-3 respectively in the intensification sequence (see the Figures). Long fallow forest shifting cultivators are not likely to be interested in techniques concerning soil fertility and weed control since these are not yet much of a problem, although they may well respond to opportunities for economic benefits from improved fallows.

From the viewpoint of the shifting cultivator, the forest phase of the *taungya* cycle is equivalent to the fallow phase of the swidden cycle. To marry the two types of production successfully the phase lengths must match. Hence, the entry point of primary feasibility for integral *taungya* would seem to be in stage 1, when fallow lengths are of the same order of magnitude as the growing period for commercial forest trees. However, it could possibly be introduced at stage 2, providing that short-rotation (less than ten years) forest species are selected, or that agricultural practice can be intensified to accommodate the reduction in available fallow land that would accompany the planting of longer-duration forest trees.

If fruit-trees are planted instead of conventional forest trees, very long "fallow" durations may be required to sustain shifting cultivation, since farmers will be reluctant to cut down the fruit-trees in the years of their heaviest bearing (which may extend from ten to 100 years for some trees). Indeed, the planting of fruit- or other trees - economically valuable, long-lasting and continuously productive - may be the shortest route to permanent removal of the land from the fallow cycle. This is not necessarily a bad thing if the resulting land-use mix, including biologically enriched short fallow or other means of meeting the production requirement of preferred field crops, is significantly more rewarding than the continuation of conventional swidden practice.

From shifting to permanent cultivation

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The validity of the economic enrichment approach has been amply proved by such indigenous examples as the fallow enrichment planting of rattan by the Luangan Dayaks of Borneo (Weinstock, 1984), of cedar and bamboo by the Lingnan Yao of China (Lebar, Hickey and Musgrave, 1964), of *Casuarina* by the Siane of Papua New Guinea (Salisbury, 1962), of gum arabic in the Sahel (don Maydell, 1980) and of multipurpose fallow wood-lots - whose species diversity exceeds that of the natural forest - by the Ifugao terrace-builders of the Philippines (Conklin, 1980).

Biologically enriched fallow practices using *Acioa barteri, Anthonotha macrophylla, Alchornea cordifolia, Gliricidia seepium* and *Leucaena leucocephala* have been reported by Benneh (1972); Okigbo and Lal (1979); Getahun, Wilson and Kang (1982); Agboola *et al*. (1982); and Dijkman (1950). For further discussion and examples of fallow enrichment practices see also Olofson (1983); FAO (1984); and Raintree and Warner (1985).

The most obvious implication of these practices for tenure is the increased premium their adoption would place on rights of exclusive harvest and reuse by the management unit that undertakes investment of labour for fallow improvement. Without secure rights of this type, it is unlikely that the benefits would be worth the effort. Yet the potential benefits of the approach would seem to justify efforts to bring about supportive tenure changes, always with the qualification that the system could be abused by individuals as a strategy for grabbing land.

Alley-cropping and other intercropping systems. If the preceding discussion stretches the conventional concept of "fallow" beyond its normal usage, the extension of the approach into the "continuous fallow" processes of alley cropping goes even further. It represents a thoroughly functional reinterpretation of the concept for tropical conditions. The beneficial effects of soil-restoring trees on agricultural crops can be effected by associating the two components in *time*, as in the sequential practice of fallow rotation; or in *space*, through simultaneous association of trees and field crops.

Alley cropping may be defined as a "zonal" approach to agroforestry (Huxley, 1980; Huxley and Raintree, 1983), in which field crops are planted in the alleys between hedgerows of nutrient-cycling trees or shrubs. These are kept pruned throughout the cropping season to control shading and below-ground competition and to provide green manure and mulch material for the benefit of the associated crops. Fodder and fuelwood might be taken as by-products of the system, but the basic aim is to fulfil a "service function" within the arable farming system.

The term "alley cropping" was coined by researchers at the International Institute of Tropical Agriculture in Ibadan (Wilson and Kang, 1980), but the technique itself appears to have originated in indigenous practice some five decades earlier on the island of Timor under the direction of the Raja of Amarasi (Metzner, 1981; Olofson, 1983). The economic benefits of various experimental alley-cropping systems have been examined by Raintree and Turay (1980), Verimumbe, Knipscheer and Enabor (1984) and Ngambeki and Wilson (1984). It has been described in a recent FAO publication as "possibly the most versatile, effective, and widely adoptable of recent innovations in conservation farming" (FAO, 1984).

More intimate "mixed" arrangements of trees and crops are also found in traditional practice, the outstanding example being the association of *Acacia albida* with dryland grain crops in the Sahel (Felker, 1978; Weber and Hoskins, 1983; NAS, 1983), where the yields of crops grown in proximity to trees are typically double those of crops grown in the open. Nitrogen fixation, microclimatic benefits and the peculiar "reverse phenology" of farmers the tree - which leafs out in the dry season and drops its leaves at the beginning of the rainy season, thus nicely accommodating itself to the requirements of crop cultivation - account for part of the yield increase. Another factor, which has important implications for land tenure, is the concentration of manure in the vicinity of the trees as a result of the livestock that gather under their shade in the dry season to consume the nutritious pods produced at that time. Presumably, the benefits to the arable crops would be reduced if traditional grazing rights were to be restricted.

SHIFTING CULTIVATORS IN HONDURAS where land tenure is critical

MAHOGANY TREE AMID PINEAPPLES IN BRAZIL a government donation to farmers

Security of tenure. Since the deliberate establishment of new alley-cropping or other, functionally similar, intercropping systems may represent a substantial investment of labour and other resources, security of tenure becomes an important precondition. This does not necessarily mean that the benefits of chosen multipurpose trees selected (see FAO, 1984, p. 32 for selection criteria) could not conceivably be shared by claimants with different land and tree utilization rights. But it is obvious that incentives for adoption of these more-or-less permanent improvements would be more convincing if exclusive-use rights were granted - although it might be advantageous to allow an exception for controlled grazing by livestock during the dry season. In so far as the planting of trees establishes a legal claim to the land on which they are planted, the management unit in question will, in most cases, also have to be the land-holding unit.

For these reasons, and others associated with the relatively higher labour requirements of the practice as compared to planted fallows, intensive alley-cropping systems are not likely to become very attractive to farmers until the short fallow or permanent cultivation stages (3 and 4) of the intensification sequence are reached. Then, ecological demands and tenure adjustments make it necessary and possible. Assuming once again that the system is not merely used as a way of grabbing land, supportive tenure adjustments would seem legitimate. And alley cropping itself may provide a technical means of making tenure reforms work (Torres and Raintree, 1983).

One way of affecting a smooth adjustment of agro-ecological and tenure factors associated with alley cropping would be to phase the system in, based on the concept of an "optimal pathway of intensification" (Raintree, 1980, 1983b; FAO, 1984; Raintree and Warner, 1985). Starting with a fallow enrichment approach at stage 2, tree species with both economic and biological fallow improving properties could be introduced. By planting the selected trees in hedgerows at appropriate spacing between rows (which could be adjusted for effective erosion control on sloping lands) the way would be clear for an intensification of the fallow practice into semi-permanent or permanent alley cropping at stages 3 and 4. Finally, at stage 5, as population pressure intensifies, the children or grandchildren of the original shifting cultivators could install "green manure factories" and maintain a variety of economically valuable upperstorey trees. In this last phase of intensification the system might come to resemble the architectural complexity and economic efficiency of the multistorey home garden so often found in densely settled areas of the tropics.

If the motivation exists, there is no inherent reason why the scheme of intensification envisaged here could not be run "ahead of itself" to generate higher incomes for industrious rural families well in advance of necessity. Of course, this may result in income disparities, but this would be true of virtually any innovation that enhances productivity. The creation of income disparity should not be used as an argument to crush innovation although projects could take measures to ensure equal access to opportunities for adopting innovative systems. Such measures may necessarily involve land reform.

Tree crop alternatives. Even with the improvements described above, there is a limit to what can reasonably be expected from the intensification of tropical field-crop systems as an enhancement to the use of fertilizers and other modern agricultural inputs.

Several writers have argued the superiority of tree-based cropping systems over arable cropping systems for difficult farming situations (Smith, 1950; Douglas and Hart, 1976; Felker and Bandurski, 1979; Mollison and Holmgren, 1981; Bowers. 1982; Chambers, 1984), but nowhere is the argument more compelling than in humid tropical environments where the temperate cropping system model has established an unjustified hegemony over the imagination of agriculturists and land-use planners.

Perhaps the "forest village" schemes in Thailand come closest to the ideal.

• The really critical problems to be overcome, then, if high productivity resources exploitation systems are to be developed for these life zones, would seem to be those of achieving an efficient economic utilization of the diversity of massive, fast-growing, perennial plant species and vegetational types which these environments are themselves efficient at producing (Tosi and Voertman, 1964).

The viability of production systems in which trees and other perennials, rather than annual field crops, are the main focus of the land-use economy is indicated by the widespread practice of "home gardens". In his study of Ibo farming practices in Nigeria, where population densities may be as high as 1000/km^2. Lagemann (1977) found a strong correlation between population density and the importance of multistorey compound gardens. This is largely explained by the fact, according to Lagemann's figures, that the output from compound gardens is five to ten times greater in monetary terms than from the outfield plots. The returns to labour are four to eight times higher. In Java, where various tree-garden types exist in a mosaic with wet rice paddies and rainfed arable crops (Penny and Singarimbun, 1973; Wiersum, 1982; Hunink and Stoffers, 1984), home gardens may provide more than 20 percent of household income and 40 percent of household caloric requirements (Stoler, 1978).

Highly integrated tree-based economies have been reported from Indonesia, involving the near total exploitation of the lontar palm (*Borassus sudaicus* Beccari) on the islands of Roti and Savu (Fox, 1977) and the domestication of *Shorea javanica* in southern Sumatra (Torquebiau, 1984), a species which silviculturists have regarded as too difficult for plantation purposes. The role of trees in these economies is exceeded, perhaps, only by the tree-based systems of the Pacific atolls and low islands (Barrau, 1971; Schirmer, 1983), where even drinking-water may be provided by a tree - for example, the coconut palm. In this connection, the under-exploited potential of the palms is so striking as to deserve special mention (Johnson, 1983).

Horticultural tree crops for cash purposes are extensively planted by small landholders as an outgrowth of shifting cultivation in many parts of the world, notably the oil palm, cacao, coffee and cola nut plantations of West Africa, covering as much as 67 percent of the land in southern Nigeria (Getahun, Wilson and Kang, 1982); and the coconut, rubber, oil-palm, cacao and coffee plantations of smallholders in Southeast Asia (Pelzer, 1978; Nair, 1979; Liyanage, Tejwani and Nair, 1984; and Dove, 1983).

The transition to tree-crop-based systems is not equally feasible from all stages in the main sequence of intensification in tropical land use. There are few ecological constraints in stages 1 and 2 to the planting of extensive areas to tree crops, although the economic incentives will generally have to be rather attractive since leisure time is likely to be highly valued in integral swidden societies at this stage of development. Nevertheless, as Dove (1983) has pointed out, extensive cash cropping of trees is a common feature of many relatively long-fallow swidden systems. At stages 3 to 5, however, the transition to tree crops is less easily achieved, because of the commitment of land to other uses and the relatively long lag between planting and first harvest. Here *taungya* practices can ease the burden of the establishment phase by providing early returns of interplanted field crops.

Since the planting of trees as cash crops will often take land out of food-crop production, extensive plantings after stage 1 must usually be accompanied by some form of field-crop intensification.

Needless to say, the investments incurred in tree planting require secure and fairly exclusive tenure by the planters over both the trees and the land on which they are planted, although it is again conceivable, as often happens in Africa (Fortmann and Riddel, 1985), that various usufruct and harvesting rights could be subdivided among different claimants. For example, grazing rights could be exercised by livestock keepers, with or without payment to the landholder, once the critical tree-establishment phase is passed.

Interstitial tree planting. It has been repeatedly suggested throughout this article that tree planting need not always compete with field crops for land. The planting of fertility-enhancing trees is one case where crops may actually benefit from association with trees. Examples of such "complementary" economic relationships abound in practice, but they remain underdocumented and little understood, and planners continue to speak of the assumed competition between trees and food crops as if it were, alas, an inescapable fact of life. Examples of "supplementary" economic relationships, in which trees and other crops have negligible or neutral interaction, can also be cited. Even when there is a "competitive" relationship between trees and other crops, a certain amount of controlled mixing may be justified in terms of the net economic yield of land-use systems oriented toward the diversification of production (Arnold, 1983; Raintree, 1983a: Hoekstra, 1983).

The planting of trees in "interstitial" locations within farms, along farm boundaries and internal borders, or along roadsides, watercourses, and on wasted or underutilized lands in the general landscape, offers a special opportunity for supplementary production. Plantings at these locations, almost regardless of the biological competitiveness of the trees, may be undertaken with little or no opportunity cost. For example, a recent aerial photo analysis of a watershed in a fairly densely settled farming community in the subhumid midlands of Kenya indicated that, if existing linear features of the landscape - pathways, watercourses, farm boundaries and internal borders - were fully utilized for planting of appropriate trees and shrubs, some 50 percent of the fuel wood and 40 percent of the fodder requirements of the households in the area could be supplied by these hedgerows, with very little competition with existing agricultural land uses (Rocheleau and van den Hoek, 1984).

Can it be assumed that the tenure issues arising in connection with interstitial plantings will be as benign or readily soluble as the technological problems? Possibly not, since, for example, boundaries per se might be a source of dispute, and trees planted on degraded or "underutilized" lands in the general landscape might arouse the concerns of those currently enjoying gathering or grazing rights there. Perhaps some kind of common property approach to multiple use of these lands would be feasible. To satisfy such contrasting interests the use of appropriately selected multipurpose trees might be advisable. One social organizational approach that might be worth exploring is the partitioning of planting responsibilities and exclusive harvest rights among individual members of an interhousehold working group, organized on a neighbourhood basis and operating at a larger-than-farm scale (Rocheleau, 1984).

FOREST TREES AMID BANANAS IN AMAZONIA a sound economic and environmental combination

WILL THEY HAVE RIGHTS TO LAND? a central question in agroforestry

Alley cropping is possibly the most versatile, effective, and widely adoptable of recent innovations in conservation farming.

As regards boundary disputes *per se*, it is important to remember that trees often take on legal meaning as boundary markers. In the Kakamega District in western Kenya, for example, it is irrelevant where a barbed wire fence is located since the boundaries of a farm are always judged by the location of the obligatory *Euphorbia tirucali* hedge. Even where boundaries are well established, boundary planting of trees may lead to problems with the neighbours. There are, perhaps, two approaches to the resolution or avoidance of such conflicts. One is to plant only valuable fruit- or fodder trees and allow the neighbours to take the share of the produce that extends into or falls on their property. The other approach is to choose trees that are as neutral as possible, offering little shade or other competition to whatever might be on the other side of the boundary. The disadvantage of the second approach is that it may eventually mean that only useless trees can be planted, as in the case of the *Euphorbia tirucali* hedges. Although they can be used for emergency fuel, there are many superior fuelwood species to choose from. Nevertheless, it seems to be the very neutrality, indeed the comparative uselessness of this tree, which gives it its unique legal significance as a boundary marker.

Where land-use patterns and tenure rules are undergoing changes in adapting to population pressures or other factors, the boundary-marking role of trees can have either positive or negative social effects, depending on who is planting them to establish what kind of claims to land, and whether or not such claims are considered legitimate. Trees can be used to consolidate tenure aspects of ecologically necessary and beneficial changes, but again they may also be used for out-and-out grabbing of land.

The planting of trees at interstitial locations within farms might seem to be a wholly positive development, since this is one relatively painless way of increasing the supply of tree products for household consumption, sale or savings on land that is under the direct control of the household. Unfortunately, this is where many of the gender-related tenure problems arise. Everything depends on what kind of trees are planted and where. In the Central Highlands of Kenya, there are men's trees (timber, cash-crop) and women's trees (fuelwood, fodder, subsistence). In Kakamega all trees are owned by men, and there are strong cultural prohibitions against the planting and felling of trees by women. It is said that if a woman plants a tree she will become barren and her husband will die (Chavangi, 1984). Women get around these restrictions, of course, by various ruses, and the wisdom of these cultural rules is beginning to be openly questioned.

Agropastoral interactions

The ecological problems posed by the dry regions of the tropics make the integration of trees into land-use systems especially imperative and, at the same time, rather more difficult to achieve than in the wetter zones.

Two factors are primarily responsible for the difficulties: the first is aridity itself, which increases the risks and the costs associated with successful tree establishment; the second is browsing damage by livestock. The investment requirements associated with the former imply the need for security of tenure over the trees, and the latter implies land-use conflict over customary grazing rights.

Providing that ways can be found to solve tenure problems, the integration of trees into land-use systems in the dry zones offers a number of possibilities for improving the linkage between agricultural and pastoral elements of the economies of these areas, both within and between management units. Moreover, the trees themselves, properly selected and managed for multiple benefits, may provide the means of resolving or at least mitigating some of the most prominent tenure conflicts.

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Mixed farming systems. The expansion of farming into fragile dryland environments poses special problems for crop husbandry, including conservation and efficient use of limited soil moisture, maintenance of soil structure and fertility, control of wind and water erosion, and provision of feed for draught animals. One of the keys to coping successfully with limited soil moisture is the maintenance of adequate soil organic matter and nitrogen. In this respect, a recent analysis of the role of nitrogen in plant water use efficiency by Felker *et al.* (1980), has suggested that nitrogen may be more limiting than rainfall in many arid areas. But conventional methods of green manuring and mulch farming have generally been limited by the difficulty in growing enough herbaceous biomass to return nitrogen to the soil, and by the competition with food crops for water, land and labour.

Multipurpose trees, particularly the nitrogen-fixing species so well adapted to dryland conditions, offer several advantages over herbaceous sources of organic matter, nitrogen and fodder. They are generally more drought-tolerant than herbaceous plants. They have a higher feed value during the dry season - particularly the pod-producing species - and are thus better able to ensure the strength of draught animals at the beginning of the rains. They can be grown at interstitial locations on the farm or in association with crops without replacing them. If appropriately selected and arranged with respect to crops, they can offer microclimatic benefits such as windbreak effects and reduced evaporation. They can produce food, fuelwood, building materials and other directly useful by-products while performing their service roles on the farm. Lastly, as a form of standing capital, they can serve as a source of convertible savings for emergency needs, including what is known as "famine foods".

In this latter role, trees can be a partial substitute for livestock, whose main role in Africa is "savings on the hoof". But they can also strengthen the role of livestock on the farm by enhancing the fodder-manure linkage and, if used as living fences, by providing an affordable means of reducing crop damage by uncontrolled grazing. These benefits can also be applied to livestock owned by others. In the case of interactions between farmers and pastoralists, the growing of additional, high-quality dry-season fodder on the farm and the use of living fences to control livestock access could potentially go a long way toward relieving the main sources of tenure conflict between the two land-use systems. The main constraint to the realization of these benefits is, of course, the need to restrict livestock access, often by social means, during the establishment phase of the trees.

Thus, although we may be able to envisage a partial "technological fix" for certain agropastoral tenure problems, their ultimate solution depends upon social change.

Pastoral systems. While trees may constitute an effective element in reducing disagreement between pastoralists and farmers, pastoralists are not well advised to wait for farmers to come to their rescue by planting trees. Although it will usually require a much greater accomplishment of "social engineering" (Cernea, 1985) to promote effective tree planting by pastoralists, there are a number of pastoral situations in which the need for trees would seem to loom so large as to justify cautious optimism for the success of well-planned projects.

One of these situations is overgrazing around dry-season water sources. The Ferlo Project in Senegal (don Maydell, 1980; NAS, 1983) and the Land Management Near Wells Project in the Niger (Weber and Hoskins, 1983) have been exploring various technical and social models for mitigating the ecological effects of herd concentrations around boreholes.

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Another common situation is overgrazing around pastoral home areas in addition to the problems associated with the provision of feed to young and sick animals that are kept inside (B. Grandin, personal communication). The Masai *olopololi* is a dry-season grazing reserve maintained jointly by several households for such animals in the vicinity of their residential *bomas* (enclosures providing protection against wild animals). Since they are protected from grazing during the rainy season, the *bomas* offer scope for the planting of fodder trees for supplemental feed. Some Masai households in the "group ranches" are beginning to experiment with crop production in small, thorn-fenced gardens near the *bomas*. These would also be natural sites for the growing of supplemental fodder trees to meet dry-season feed requirements (Nambombe, 1984; Mhungu, 1984).

These are the kinds of simple agroforestry suggestions that might be worth exploring with pastoralists. In so far as they are oriented toward the development of small areas under the control of one or a small group of households, they would not seem to pose serious tenure difficulties. The challenge of more general range improvements for the benefit of the mature herd animals presents much more serious problems since it would involve common grazing lands. However, to cite the Masai example again, such pod-producing legumes as *Acacia tortilis* occur naturally on the open range in Masai territory and in some cases their exploitation is controlled by the local group - nowadays the group ranches.

According to the accounts given by Masai informants, the "courtesy" rights accorded by one group ranch to another to utilize the nutritious *Acacia tortilis* pods underwent an interesting change during the recent drought. Normally the neighbours were allowed to shake the trees, causing more pods to fall to the ground for their animals, but as the drought became more serious, the right to the pods was restricted to those that fell to the ground naturally. If, in fact, the Masai are exercising this kind of regulatory control over the use of tree pods, might they not then be encouraged to undertake steps toward the domestication and artificial propagation of this valued range resource?

Pod propagation through herds. But who would undertake such tree planting for the general benefit? As W.R. Bentley (personal communication) has observed, the "tragedy of the commons" in India is not so much a problem of overexploitation as one of underinvestment. Posing the problem in this way suggests that one approach to encouraging greater investment in the commons might be to identify cheaper methods of investment. It is a fact that such valuable rangeland trees as *Prosopis* spp., *Acacia albida* and other pod-producing legumes can be and often are propagated by livestock. The predominant tree in the arid rangelands of Rajasthan in India is *Prosopis cineraria*, an introduced exotic which spread naturally, quite without the benefit of tree-planting projects. What is to prevent a rangeland management project from experimentally supplying a quantity of such pods to pastoralists to feed their herds? No doubt the establishment percentage would be low, but so would the herder's investment; the result, which would be known long after the project had come and gone, might be quite significant. It is so far unknown whether this would work because no project seems to have tried it. The point is that there might be some very simple technological fixes to some of the problems of the commons.

At the other end of the scale is quite another kind of intervention in pastoral rangelands. Interest in dryland biomass energy plantations has quickened in recent years (Foster and Karpiscak, 1983; Felker, 1984). From the pastoralist's point of view, the problem with such schemes is that they tend to represent yet another assault on traditional tenure rights, but is it really inconceivable that pastoral populations could participate in integrated plantation schemes? The problem of identifying a basis of shared interest would seem, from an agroforestry point of view, to reduce it to the problem of identifying the best-suited multipurpose trees. Why not choose an energy tree from among several outstanding desert biomass producers that also happen to produce copious quantities of high-quality dry-season pods? Again, *Prosopis* would seem to exemplify the appropriate ideotype (Felker and Bandurski, 1979; Felger, 1977). The reason for choosing a pod or other fruit-producing fodder species is that the utilization of this by-product need not reduce the eventual woody biomass harvest of the plantation; it could make a big difference in the carrying capacity of the range in dry season; and such a choice might make a great difference to the survival rate of the trees in pastoral areas. In this connection it is interesting to note that energy experts are now coming to the conclusion that if biomass energy sources are to realize their full economic potential, they should be approached in terms of by-product and co-conversion schemes (Williams, 1985; Reddy, 1985).

Could not industrial agroforestry schemes along these lines provide a simple, equitable, all-round solution in developing countries to the related problems of biomass energy supply, decentralization of rural industry, and the participation of pastoralists in national development?

Perhaps it is well to end here, on an imaginative note and with a question, since the purpose of this article has been to raise some questions and provide some images for a positive approach to tenure questions in agroforestry.

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