AGROFORESTRY, TROPICAL LAND USE AND TENURE

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Background Paper for the International Consultative Workshop on Tenure Issues in Agroforestry. Organized by ICRAF and the Land Tenure Center. Sponsored by the Ford Foundation. 27-31 May 1985. Nairobi.

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Many people nowadays have great expectations for agroforestry. Some of this optimism would seem to be justified on technological grounds, but if the current effort to understand, develop and disseminate agroforestry technology is to have any hope of meeting even a reasonable proportion of current expectations, the deployment of this newly organized branch of applied science must take place with a clearer than usual view of the human context of the supposed land use improvements.

The discussion of agroforestry is preceeded by an attempt to sketch a perspective on two of the most salient aspects of this context: 1) the current unprecedented rate of human population growth, and 2) existing patterns and trends in the development of tropical land use systems.

The purpose of this paper 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 which will occur at the workshop. The main assumption behind the paper is that the interactions between agroforestry and tenure issues are basically of two types: on the one hand, tenure factors may pose constraints to the realization of the potential ecological and socioeconomic benefits of agroforestry in many land use systems and, on the other hand, agroforestry may offer ways of resolving or mitigating some of the existing tenure problems.

Without doubt, the tenure issues are far more varied and complex than what is reflected here. What I have tried to do is to focus attention on some of the major tenure changes which seem to arise as a regular concommitant of the main developmental trends in tropical land use viewed in ecological and evolutionary perspective. It is hoped that the workshop will elaborate on these patterns, bring out important divergences and additional complexities, illuminate the conditions under which they arise, and contribute to a sense of the priorities in dealing with them.

1. HUMAN POPULATION: THE REGIONAL CONTEXT

The prodigous bloom of human population is, in evolutionary time perspective, a recent phenomenon which constitutes an unprecedented challenge to human adaptability, as well as to the resilience of the earth's ecosystems. As Ansley Coale (1974) has remarked: "The present rate of world population increase--20 per 1,000--is almost certainly without precedent, and is hundreds of times greater than the rate that has been the norm for most of man's history. Without doubt this period of growth will be a transitory episode in the history of the population."

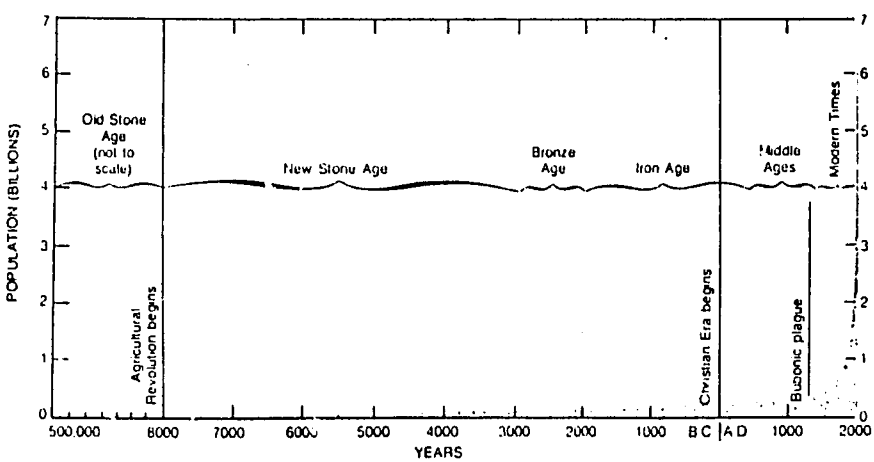

Figure 1. Human population over the past half million years.
Source: Ehrlich et al. 1977

Although the consequences of this bloom in human numbers are debatable it is now generally acknowledged that the human population will grow to about 6.2 billion by the year 2000 and may reach 10 billion by the middle of the next century before there is any hope of stabilization. Regional growth rates are shown in Figure 2. Figure 3 depicts regional trends in per capita food production over the period 1961/65 to 1983.

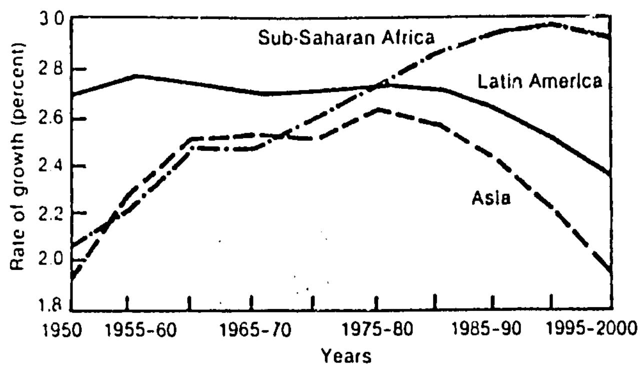

Figure 2. Population growth rates by region. Source: Office of Technology Assessment (1984).

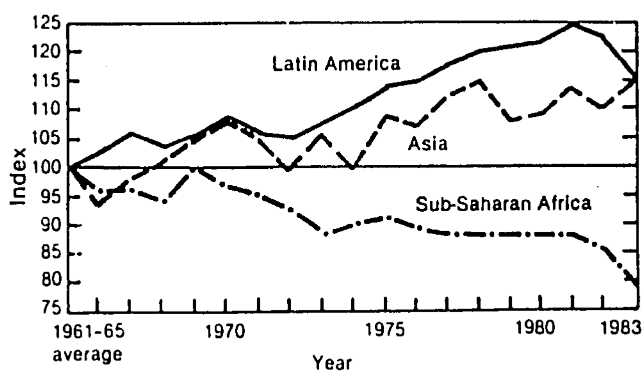

Figure 3. Recent trends in per capita food production by region. Source: Office of Technology Assessment (1984).

If present trends continue

Africa is the only continental region that has experienced a consistent decline in per capita food production over the past 20 years and is clearly in a markedly different situation from the other regions, but Asia and Latin America are by no means assured of a smooth transition to the steady state. Using a different regional breakdown, the FAO (1981) study of Agricuture: Toward 2000 has estimated the population affected by serious undernutrition if present trends continue.

Table 1. Incidence of serious undernutrition 1974/76 and 2000, by region. A calorie intake of less than 1.2 of the basal metabolic rate is taken as the criterion of serious undernutrition. Source: FAO 1981 (Appendix Table 7).

	Millions of Seriously Undernourished People	
	1974/76	2000
Far East	304	392
Near East	19	23
Africa	72	127
Latin America	41	46

The largest growth in the number of seriously undernourished people occurs in Africa, but the greatest number of affected people is in Asia. Latin America experiences only a modest increase in the number of affected people in this trends scenario.

A somewhat different perspective is obtained by considering the carrying capacity of the land. Harrison (1984) has published an estimate of the number of countries whose populations are in danger of overshooting the carrying capacity of their lands, based on an assessment of the soil and climatic potential for production of 15 major food crops at three different levels of technology. Table 2 presents some of the major conclusions of this baseline calculation.

Table 2. Regional enumeration of countries whose populations have exceeded (1975) or are likely to exceed (2000) the carrying capacity of the national landbase at three different levels of technology (baseline calculation). Source of data: Harrison (1984).

	Number of Critical Countries by Region (% of regional population affected)				
	SE Asia	SW Asia	Africa	C America	S America
1975					
low input	6 (50%)	15 (71%)	22 (50%)	11 (16%)	--
med. input	1 (0.2%)	12 (33%)	7 (7%)	4 (3%)	--
high input	1 (0.2%)	9 (14%)	2 (0.1%)	1 (0.2%)	--
2000					
low input	6 (18%)	15 (74%)	29 (60%)	14 (24%)	--
med. input	2 (8%)	15 (74%)	13 (14%)	7 (11%)	--
high input	1 (0.2%)	12 (34%)	4 (1.4%)	2 (0.3%)	--

Assumptions: 1) that all potentially arable land is used only to grow food crops and no land is set aside for forestry or other non-food crop production and 2) that food is equally distributed in each country at the level of minimum calorie requirement. Definitions: low input = traditional varieties and cropping patterns, no fertilizer, pesticide or long term soil conservation measures; medium input = basic package of fertilizers, pesticides and improved seeds, with existing crop mixes on half the land and the most productive mixes on the other half, and with simple conservation measures reducing land degradation by half; high input = full use of fertilizers, pesticides and improved varieties, with optimal crop mixes and comprehensive conservation measures reducing land degradation to a negligible level.

The situation in Southwest Asia (or the Near East region) appears more critical in Harrison's calculations than in the previous table and seems somewhat impervious to technological improvement, althought it must be recognized that several of the countries in this region are not dependent upon agrarian economies. South America, here differentiated from Central America, has no critical countries even in 2000. As Harrison notes, however, the South American results may be misleading, since they are based on the undesirable and perhaps unlikely assumption that more than half of the region's 943 million hectares of rainforest will be cleared by the year 2000, and they also mask the fact that some 12 percent of the land, mainly in the Andean region, has populations which had already exceeded the carrying capacity of the land at low input levels in 1975.

As Harrison is quick to point out, the assumptions on which these calculations are based are frankly unrealistic. Land is also needed for non-food production uses (including forestry), for conservation measures, and for production of other food crops not included in the 15 staples on which the production assessments were made. It is also highly unlikely that the assumption of equal distribution of food will be met in reality. To arrive at more realistic projections, the potential production figures were reduced, conservatively, by one third. In this adjusted calculation, the total number of critical countries in 2000 rises from 64, 36 and 19 to 75, 43 and 28 at low, medium and high input levels, respectively. Further adjustments in the projections, to reflect the current regional rates of expansion of cultivated land, indicate that by 2000, if not earlier, all regions would become critical at low input levels, Central America at intermediate levels, and Southwest Asia even at high input levels.

Is this a realistic picture? In support of the view that it is, Harrison cites the fact that, of the 90 dveloping countries studied in the Agriculture: Toward 2000 report, as of 1978/79 four out of five were not self-sufficient in basic foods.

As regards the forestry sector, the FAO (1981) study noted that fuelwood consumption in developing countries in 1979 was already some 100 million

m^3 short of the estimated requirements and that an estimated 250 million people live in areas of fuelwood shortage. By the end of the century, due to the shrinking of the fuelwood resource base, the shortfall may rise to 1,100 million m^3, with some 3,000 million people facing acute fuelwood shortages. The nutritional and health consequences of inadequately cooked food could be serious (FAO 1981). To this must be added the deterioration of the productive potential of tropical land which accompanies the reduction of woody vegetation in the agricultural landscape.

Some of the main dimensions of the tenure problem are succinctly summarized in the FAO (1981) study, as follows:

> The total number of agricultural households will grow very much faster than the arable land exploited in every region except Latin America. As a result, the average size of holdings will decline, substantially in Africa and the Near East, and also in Asia. Accordingly, the number of landless agricultural labourers will increase, partly because the area of land held by some individuals or families will become too small to be viable and partly because larger landholders will buy up the land of economically weak farmers.
>
> Because ownership of or access to farmland is usually the main influence on incomes of agricultural people, an inevitable outcome of unmodified trends would be a worsening of the present highly unequal distribution of production assets and incomes. Such trends aggravate social tension in rural areas and conflict with objectives of greater equity in social and economic relations which are coming increasingly to the fore.

All of this adds up to a rather bleak picture of the human condition at the turn of the century . . . if present trends continue.

Alternative futures

Although there is a certain demographic inevitability in the continued rise of population before it eventually levels off, no one really expects that the response trends will continue unmodified. Man is, after all, a highly adaptive creature. Possessed of what Malinowski called "the curse of foresight and imagination," the shape of mankind's future is, to a very large extent, a question of effort.

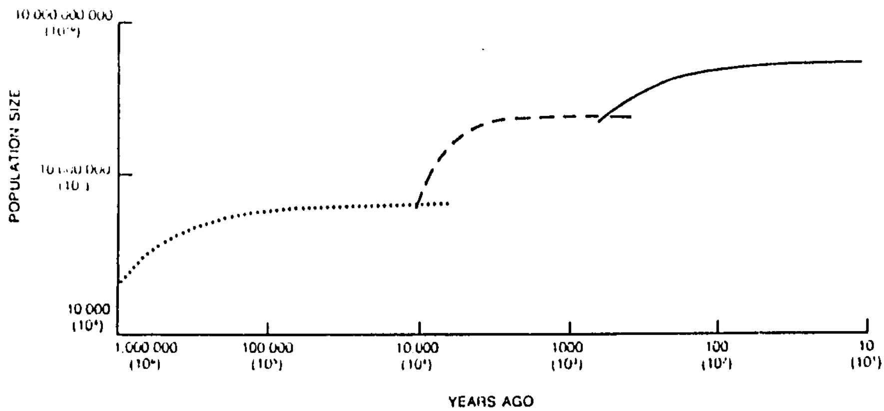

Figure 4. Log-log plot of human population history showing the impact of technological "revolutions." Source: Ehrlich et al. (1977).

In the past, man has been able to adapt technologically and culturally to the growth of human population and these adaptations have, in turn, generated their own growth dynamic. The question today is whether there is sufficient technological scope and political will to carry the projected population through the transition to a sustainable future.

The FAO (1981) study of Agriculture: Toward 2000 advances two rather ambitious change scenerios which, if realized, would substantially mitigate the effects of population growth in the developing world. Both of these scenarios envisage increases in the level of inputs to agriculture which recent history gives us little encouragement to believe possible. Nevertheless, the direction of the needed changes in land use are reasonably clear.

Where will the production increases come from?

There are basically three possibilities: 1) bringing more land into cultivation, 2) increasing the frequency of cropping on existing agricultural lands (i.e. intensification of shifting cultivation), and 3) increasing the yields per unit of cultivated land (technological intensification). The projected regional contributions from each of these sources are shown in Table 3.

Table 3. Contributions to growth in agricultural output, by region (scenario A). Source: FAO (1981).

	Expansion of land in cultivation	Increase in cropping intensity	Increase in yields per unit of land
ASIA	10 %	14 %	76 %
AFRICA	27 %	22 %	51 %
LATIN AMERICA	55 %	14 %	31 %

In Asia, where some 79 percent of the arable land is already in cultivation, most of the production increase will have to come from technological intensification of agricultural practice resulting in higher yields per unit of land, although there is modest scope for intensification of shifting cultivation and expansion into new agricultural land. Substantial proportions of the targeted increases in Africa may come from expansion of cultivated (in most cases marginal) land and intensification of shifting cultivation, but the major part of the projected growth must come from increases in the yields per unit of land. Latin America, with a mere 25 percent of the arable land in cultivation as of 1980, has the greatest hypothetical potential for expansion of the area under cultivation. As already noted, however, much of this expansion would require conversion of the main global reserves of tropical rainforest to agricultural uses of doubtful sustainability. In any event, a hefty increase in the productivity of agricultural land will also be required in the Latin American region.

2. TROPICAL LAND USE SYSTEMS: THE ECOLOGICAL CONTEXT

How do the potential sources of production increase relate to the existing pattern of land use in the tropics? What tenure problems crop up within and between different land use systems? A brief overview of tropical land use systems and their main tenure problems in this section will set the stage for the consideration of agroforestry potentials and tenure problems in the final section of this paper. For the sake of brevity, the focus is restricted to the tropics, where most of the developing countries are situated, although the perspective could probably be generalized to the subtropics without many modifications.

Figure 5 gives an overview of the major systems of tropical land use. More complete classifications of tropical land use systems have been published (Allan 1965, Gourou 1966, Ruthenberg 1971, Benneh 1972, Watters 1960, Spencer 1966, Unesco/UNEP/FAO 1977, 1979) but most of the subclasses are least in implicit in Figure 5. The intention, in any case, is not to be exhaustive but rather to highlight the salient characteristics of the most pervasive systems in broad outline.

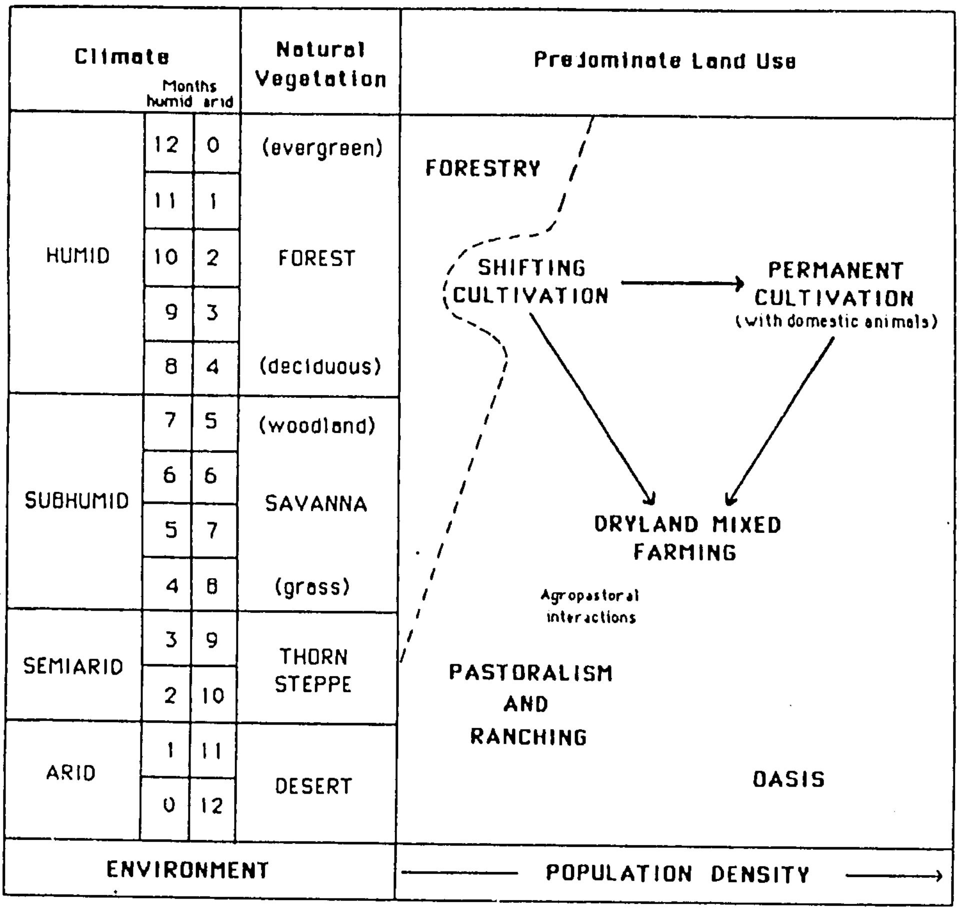

Figure 5. The human ecology of tropical land use, showing the predominant land use systems and development pathways as a function of environment and population density. The boundaries of the different systems are only approximate.

Table 4. Potential sources of production increase in relation to existing land use systems and major tenure issues.

SOURCES OF PRODUCTION INCREASE	TENURE ISSUES
1. Expansion of cultivation	
1.1 Extension of shifting cultivation into forests	shifting cultivators vs. foresters
1.2 Extension of dryland farming into grazing lands	farmers vs. pastoralists, local grazers & gatherers
1.3 Extension of farming onto sloping lands	farmers vs. foresters, local gatherers & grazers
2. Increase in the frequency of cropping	
2.1 Intensification of shifting cultivation (shortening of fallow period)	common vs. household rights to fallow land
3. Increase in yields per unit of land	
3.1 Technological intensification of shifting cultivation	common vs. household rights to improved land
3.2 Technological intensification of permanent farming	gender and inter-household conflicts, social stratification, landlessness
3.3 Tree crop alternatives	long term vs. short term rights in land, tree tenure

Expansion of the area in cultivation

Expansion of shifting cultivation into forest reserves

In the humid tropics the main source of tenure conflict between farmers and foresters is the expansion of shifting cultivation into reserved forests, either through spontaneous "encroachment" on forests by shifting cultivators in search of land to cultivate or through the officially sanctioned modification of shifting cultivation known as "taungya." In the first type the forest land in question is subject to conflicting tenure claims, the longstanding traditional claim of the shifting cultivators to tribal land vs. the modern legal claim of the state to rights of forest exploitation. For traditional shifting cultivators this conflict may arise even at low levels of population density before land pressure has become serious. A more clearly defined case of "enroachment" arises in connection with land hunger among more settled agricuturalists, who deliberately enter what they acknowledge to be reserved forest in search of land.

In the second type, one of the main forestry responses has been the "taungya" system of plantation establishment, whereby farmers are given temporary access to land for cultivation and sometimes a modest wage in return for their labour in the planting and aftercare of commercial forest seedlings. Kio (1972) has defined taungya as the "method of employing shifting cultivators to raise forest trees" (Enabor, 1974). Enlightened variants of the taungya approach do exist and are discussed in the next section, but the tenure arrangements of classical taungya are remarkably similar to classical landlord-tenant relations, only in this case the feudal landlord is replaced by the state forestry agency:

> The system is frankly exploitative in concept and operation and cashes in upon the needs of the landless and poor people to serve its own ends. The much vaunted incentives are only a cloak for uninhibited exploitation, as the savings effected by the Forest Department are many times more than the expenditure incurred on elementary conveniences provided to the working force (Seth 1981, quoted in Foley and Barnard 1984).

Foresters have enumerated the conditions necessary for successful introduction of taungya as follows: 1) a low level of income or standard of living, 2) land hunger among the farming population, and 3) unemployment or underemployment. "These factors constitute important elements of the so-called cycle of poverty and may, to some degree, be attributed to the practice of shifting cultivation" (Enabor 1974). The same author sums up the classical forester's view of taungya as an "excellent opportunity for the maximum ultilization of land resources, while at the same time effecting the desired control of traditional shifting cultivation."

Basically, then, classical taungya is a way of reducing the labour costs of plantation establishment or, in other words, of maintaining a supply of cheap, unskilled labour by perpetuating the "cycle of poverty" it pretends to address. It depends for its limited appeal to farmers or effective restriction of uncontrolled access to forest land. Boserup (1965) notes that in feudal Europe restriction of forest clearance, thus forcing the farmers to work in the landlord's fields, was an expedient in times of labour scarcity for the landlord. I have argued elsewhere (Raintree 1984) that conventional forestry is limited less by land scarcity than by a scarcity of skilled and committed labour. Farmers vastly outnumber foresters and as long as farmers are viewed as at worst "encroachers" and at best "cheap labour," the traditional antagonism between the two will continue, to the ultimate detriment of sustainable forest production.

No doubt some accomodation between farmers and foresters is needed in land pressured areas where forestry agencies have the responsibility of producing timber and other forest products to meet national needs, but it is unlikely that unmodified forms of classical taungya will provide the answer. A more promising land use alternative would be one that allows farmers to become more equal partners in the opportunities and responsibilities of a more integrated land use system. An example of such an approach is the Thai "Forest Village" scheme discussed in the final section of this paper.

Expansion of dryland farming into grazing lands

Traditional dryland farming in the developing countries is at best an ecologically precarious existence. Plagued by crop failure due to drought or unpredicable rains, exhaustion of fragile soils, dry season feed shortages for draught animals, and difficulties in maintaining a sustained supply of fuelwood due to the slow regenerative capacity of natural woody vegetation, the system is nevertheless expanding rapidly as population expands into agriculturally marginal lands.

This expansion is associated with at least two distinct types of tenure conflict: 1) conflict between farmers and non-farming pastoralists over the loss of grazing land and, from the other side, crop damage by herd animals; the former is particularly significant to pastoralists, since at the frontier of agricultural expansion it is usually the best grazing lands (often the critical dry season grazing reserves) that are the first choice of the farmers, while the latter is an important constraint on tree planting; 2) conflict within the mixed farming community itself over the loss of grazing land for domestic animals and, as population density increases, the restriction of traditional gathering rights to fuelwood and other natural products.

Under pressure from the advancing agricultural frontier, pastoralists have be the focus of programmes aimed at increasing the security of their tenure over pastoral lands. But the magnitude of the social learning process necessary to institutionalize the land use changes implicit in these schemes is easily underestimated. The Masai Group Ranch Scheme in Kenya is an interesting case in point. Although the establishement of legal boundaries around the group ranches has succeeded in giving the Masai a measure of freedom from land grabbing farmers and speculators, after more than a decade it is now fairly clear that the group ranches have not been able to successfully replace the traditional pastoral strategy with the social institutions necessary for common property management within boundaries of the ranches. There is now a vigorous movement in the group ranches toward subdivision and individualization, which may have the ultimate effect of exposing individual ranchers, once again, to the risk of losing their land.

Table 5. Agropastoral interactions in semi-arid regions of Africa. After McGown et al.(1979).

TYPES OF LINKAGE	COMMENTS
Between Different Management Units	
1. No linkage	Pastoralists and farmers opperate as independent units; e.g. traditional relations between Masai and Kikuyu in Kenya (now changed to exchange and competition linkage).
2. Ecological linkage	Crop residues manure (may become exchange linkage).
3. Exchange linkage	Exchange of agricultural and livestock food products; crop residue manure exchange with payment (direction of payment depends on relative scarcity).
4. Competition linkage	Competition for land between farmers and pastoralists (greatest during the dry season); land taken for cultivation usually the best grazing land; crop damage by livestock incursions; crop residue manure linkage may mitigate the conflict somewhat.
Within the Same Management Unit	
1. Investment linkage	Livestock investments generally give higher returns than farming investments (most typical form of integration of livestock with farming in Africa); for capital development and emergency savings.
2. Food linkage	Cattle or more commonly smallstock kept for daily milk and occassional meat consumption.
3. Manure linkage	Critical to permanent cultivation systems; where field types of different intensity exist, manure usually concentrated on intensive near fields.
4. Draught linkage	Critical component of dryland mixed farming systems (constrained by low nutritional status of draught animals at beginning of rains).
5. Fodder linkage	Crop residues and fodder crops as supplementary dry season feed; in high density areas households with small number of domestic animals may practice cut-and-carry pen feeding (constrainted by low quality of herbaceous feeds in dry season).

Table 5 gives a summary overview of agropastoral interactions in semi-arid areas of Africa, which might also have relevance to other regions.

Expansion of farming onto sloping lands

Hill farming is nothing new in the tropics, but steeper and steeper slopes are now coming into cultivation under pressure of population growth. The main farming hazard, of course, is that the topsoil under cultivation will be washed away. The problem is most severe in systems of continuous cropping, but is also quite sigificant with shifting cultivation, particularly under conditions of shortening fallow period.

In hill areas of high population density the establishment of more ecologically approprtate and sustainable perennial crop based systems is often hampered by small farm sizes, since with barely sufficient land for subsistence food production most smallholders cannot afford to forego immediate production in order to make the transition to the higher yielding and more sustainable tree crop systems. In many areas the severity of land scarcity is artificial, being associated with highly unequal landholdings.

The "minifundia-latifundia" disparity in Latin America is, perhaps, the classic case in point, but similar problems are found wherever stratified communities exist, often in association with commercialized plantation agriculture. As demonstrated by a recent case study in the Philippines (Torres and Raintree 1983), the situation may present difficult technological challenges. In one part of the study area under traditional tenure, a highly productive and sustainable coconut-based multistorey tree crop system was expanding by means of "hacienda taungya" using tenants as the labour force for plantation establishment. In another part of the area coming under a government land reform programme, tenant farmers were being given the opportunity to obtain title to the fields they had cultivated as tenants. The small size (usually under 2 ha) of these holdings, however, prevented these farmers from participating in the tree crop system for the previously mentioned reasons.

The only alternative known to the local smallholders was to continue the destructive plough cultivation technology which had been diagnosed as the main cause of erosion and gradually declining yields. Confronted with the paradox of "sustainability without equity" vs. "equity without sustainability," the agroforestry design team which conducted the study proposed an "alley cropping" system for research and development which, by combining aspects of the tree crop system with the traditional field practice, appeared to offer a sustainable solution to the land use problem of the newly formed group of freeholders. This case illustrates the need for technological innovations in support of social reforms.

Agricultural intensification

The history of farming in the humid, and to a lesser extent the subhumid, tropics is bye and large the history of agricultural intensification from shifting cultivation to permanent arable farming. The basic outline of this evolutionary process is summarized in Table 6.

Increase in the frequency of land use

In Stages 1 and 2, as population density increases, the intensification of shifting cultivation (swidden) takes the form initially of an increase in the frequency with which a given plot is cultivated, with an accompanying decrease in the fallow period. According to Boserup's (1965) analysis, this process is generally accompanied by a shift in traditional land tenure from common "tribal rights" to the gradual recognition of increasingly exclusive "family rights" to reuse of fallow land. (Note: "family" in the sense used here is differently defined in different societies.) At the forest fallow stage, every family enjoys common rights of access to swidden land by virtue of its membership in the tribe or other territorial unit. In some systems kingroup heads or local chiefs may play a redistributive role, allocating land to household production units from the common pool. Since good land is not scarce, fallow land reverts to the common pool and the right to recultivate a given plot is generally only a matter of "courtesy" in eqalitarian societies or a discretionary privilege in systems in redistributive systems. As land use intensifies, however, family rights to the plot tend to become more fixed and exclusive, by dint of previous use and labour invested in clearing, although these rights may lapse through non-reuse.

Table 6. The 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).

Stage 1	Stage 2	Stage 3	Stage 4
Simple shifting cultivation	Recurrent cultivation	Recurrent cultivation with continuously cultivated plots	Continuous cultivation
	long term		
	medium		
		short	
(Greenland 1974)		Shifting cultivation with permanent tree or other cash crops	
Forest fallow	Bush fallow	Short fallow	Annual cropping
			Multicropping
----------------------	population density	----------------------	---------------------->
very sparse 0-4/km^2	sparse 4-16/km^2	medium 16-64/km^2	dense 64-256/km^2 to very dense 256+/km^2
(Boserup 1981)			

At the bush fallow stage, when the better cultivation sites are becoming scarce, there is greater interest in recultivating a given plot and family tenure tends to become more exclusive. When the attachment to a given plot becomes permanent, the custom of "pledging" may emerge which involves the transfer of cultivation rights in a given plot to another family, subject to being returned on request or after a contractually specified period.

> Thus, the attachment of individual families to particular plots becomes more and more important with the gradual shorting of the period of fallow and the reduction of the part of the territory which is not used in the rotation. By the same token, the general right for the members of the tribe to clear a new plot becomes less valuable, because the land which is not reserved fallow land for some family is now likely to be of inferior quality or very difficult to clear (Boserup 1965).

It is quite probable that in the history of any given area, it is precisely this "inferior" land which becomes the object of common grazing and gathering rights which become so important in the later stages of intensification. In this connection it may be interesting to inquire whether any land use innovations could be introduced at an early stage which would embody a preadaptive solution to the "tragedy of the commons" which so often accompanies the later stages of intensification. At the earlier stages the land in question is likely to still be under the stewardship of the local chief or relevant kingroup head. Perhaps this is the right person to approach with preadaptive land uses in mind.

Technological intensification of land use

When, in the course of swidden intensification, the fallow period becomes too short to allow adequate restoration of soil fertility and control of weeds, the swidden "degradation syndrome" sets in, driven by declining yields and the need to clear and plant larger fields to achieve a given production target, which in turn results in shorter fallows, further decline in yields, and so on. In the absence of opportunities to relieve population pressure by migration, the only way out of the degradation cycle is to adopt technological changes in farming practice which result in higher yields per unit of cultivated land. Such changes in technology have generally been accompanied in pre-industrial (i.e. non-fossil fuel dependent) agriculture by declining returns to labour (Boserup 1965, 1981).

Thus, the development sequence depicted in Table 6 may be characterized as a "reluctant evolution," since farmers will quite rationally avoid the adoption of intensive technological innovations as long as extensive, less labour-requiring alternatives are still capable of satisfying their production objectives. Whether there are alternatives to arable crop intensification which offer higher returns to both land and labour is one of the central questions in agroforestry. Preliminary indications are quite promising (Raintree and Warner 1985).

In Stage 3 fallows continue to shorten, but the length of the cropping period may remain the same, or even lengthen through the adoption of crop rotations (Okigbo 1984). Field patterns have usually shifted by Stage 3 from the previous situation in which nearly all of the fields were fallowed to a mixed mosaic of permanently or semi-permanently cultivated fields on the best land with recurrently cultivated fields on the less fertile land (Greenland 1974). Plough agriculture and manuring make their entry at this stage on the permanently or semi-permanently cultivated fields, as ways of increasing the productivity of cultivated land in the absence of adequate fallow. Farmers may also begin to exhibit a willingness to use commercial fertilizers, pesticides, weed controling chemicals and other productivity increasing or labour saving inputs, if they are available and offer favourable returns on the investment and if cash savings or credit are available. The willingness and/or ability to adopt these technological innovations is often closely associated with cash cropping enterprises.

The differentiation of field types and cropping systems at varying levels of technolgy, the rise of cash cropping and the differential use of commercial inputs, along with the general trend with increasing population density toward more diversified economies based on specialization of production roles, opens up greater possibilities for economic stratification based on differential access to land of variable quality and/or differential adoption rates and opportunities for new cash crops or productivity increasing technologies. Such changes become more permanent when they are combined with supportive changes in land tenure.

One of the most significant ways in which increased socioeconomic disparity is expressed is in the differentiation of male and female production opportunities and responsibilities. (See the background paper by Rocheleau.)

Stage 4, when all the land is in permanent cultivation, marks the end of shifting cultivation, although it is a natural outcome of swidden intensification. Fields are now used for at least one crop per year and with multicropping may be used continuously. In the absence of fallow to restore fertility and control weeds, industrial inputs such as fertilizer and herbicides, or alternately, highly labour intensive practices are needed to sustain productivity. Under conditions of continued population increase, in the absence of sufficient industrial inputs to support very high levels of crop offtake, it is problematic how much further the intensification of annual crop husbandry can be pushed.

Landlessness or near-landlessness is an inevitable result of unchecked population growth. Wage labor, land rent and tenancy become common, along with outmigration in search of alternative employment opportunities. If the rural areas are to be more than just subsistence havens for the retired and semi-dependent women and children and, indeed, if they are to rise to the challenge of supporting substantially higher expected rural population densities at adequate levels of maintenance, significant technological transformations of land use will have to occur and these imply a host of far reaching changes in tenure relations.

4. AGROFORESTRY POTENTIALS AND TENURE ISSUES

To clarify the concept and scope of agroforestry it may be useful to review the definition used by ICRAF:

> 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).

From a project standpoint there are basically two ways of arriving at agroforestry: integrating trees into farming systems and farmers into forests. The range and diversity of traditional agroforestry systems is suggested by Table 7.

Appropriately selected woody components may contribute to both the productivity and sustainability of farming systems on marginal land by enhancing organic matter production, maintaining soil fertility, reducing erosion, conserving water and creating a more favorable microclimate for associated crops and livestock. These "service roles" of trees in agricultural systems are above and beyond the direct "production roles" they might also play vis-a-vis food, fodder, fuelwood, building materials, and a variety of raw materials for rural industry. Traditional land use practices also indicate the importance of agroforestry in maximizing and diversifying the productivity of even highly productive 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 unfavorable

Table 7. Some examples of prominent agroforestry systems and practices in developing countries. Source: Nair (forthcoming). (See also Nair 1985).

S Y S T E M S		E X A M P L E S F R O M D I F F E R E N T G E O G R A P H I C R E G I O N S*						
Major Systems	Sub-Systems/Practices	Pacific	Southeast Asia	South Asia	Middle East and Mediterranean	East and Central Africa	West Africa	American Tropics
AGROSILVICULTURAL SYSTEMS	Improved "Fallow" (in shifting cultivation areas)		Forest villages of Thailand; Various fruit trees & plantation crops used as "fallow" species in Indonesia	Improvements to Shifting Cultivation; several approaches e.g. in the north-eastern parts of India		Improvements to Shifting Cultivation e.g. gum gardens of the Sudan	*Acioa barteri*, *Anthonotha macrophylla*, *Gliricidia sepium*, etc. tried as "fallow" species	Several forms
	The Taungya System	(e.g. Taro with *Cedrella* and *Anthocephalus* trees)	Widely practised; Forest villages of Thailand is an improved form	Several forms, several names		The "Shamba" System	Several Forms	Several forms
	Tree Gardens	Involving fruit trees	Dominated by fruit trees	In all ecological regions	The Dehesa system; "Parc arboref"			e.g. "Paraiso Woodlot" of Paraguay
	Hedgerow Intercropping (Alley Cropping)		Extensive use of *Sesbania grandiflora*, *Leucaena leucocephala* and *Calliandra calothyrsus*	Several experimental approaches e.g. Conservation Farming in Sri Lanka		The Corridor System of Zaire	Experimental systems on alley cropping with *Leucaena* and others	
	Multipurpose Trees and Shrubs on Farmlands	Mainly fruit or nut trees (e.g. *Canarium*, *Pometia*, *Barringtonia*, *Pandanus*, *Artocarpus altilis*)	Dominated by fruit trees; also *Acacia mearnsii* - cropping system, Indonesia	Several forms both in lowlands and highlands e.g. Hill Farming in Nepal; "Khejri" - based system in the dry parts of India	The Oasis system; Crop combinations with the Carob tree; The Dehesa system; Irrigated systems; Olive trees + cereals	Various forms; The Chagga system of Tanzanian highlands; The Nyabisindu system of Rwanda	*Acacia albida*-based food production systems in dry areas; *Butyrospermum* + *Parkia* systems; "Parc arbored"	Various forms in all ecological regions
	Crop Combination with Plantation Crops	Plant. crops and other multipurpose trees: e.g. *Casuarina* and coffee in the highlands of PNG; also *Gliricidia* and *Leucaena* with cacao	Plant. crops + fruit trees; smallholder systems of crop combinations with plantation crops; plantation crops with spice trees	Integrated production systems in smallholdings; shade trees in plantations; other crop mixtures including various spices	Irrigated systems; Olive trees + cereals	Integrated production; shade trees in commercial plantations; mixed systems in the highlands	Plantation crop mixtures; smallholder production systems	Plantation crop mixtures; shade trees in commercial plantations; mixed systems in smallholdings; spice trees
	AF Fuelwood Production	Multipurpose fuelwood trees around settlements	Several examples in different ecological regions	Various forms		Various forms	Common in the dry regions	Several forms in the dry regions
	Shelterbelts, Windbreaks, Soil Conservation Hedges	*Casuarina oligodon* in the highlands as shelterbelts and soil improver	Terrace stabilization in steep slopes	Use of *Casuarina* spp. as shelterbelts; several windbreaks	Tree spices for erosion control	The Nyabisindu system of Rwanda	Various forms	Live fences, windbreaks especially in highlands
SILVOPASTORAL SYSTEMS	Protein Bank (Cut-and-carry Fodder Production)		Very common, especially in highlands	Multipurpose fodder trees on or around farmlands especially in highlands		Very common	Very common	Very common
	Living Fence of Fodder Trees and Hedges		*Leucaena*, *Calliandra*, etc. used extensively	*Sesbania*, *Euphorbia*, *Syzigium* etc. common		Very common in all ecological regions		Very common in the highlands
	Trees and Shrubs on Pastures	Cattle under coconuts, pines and *Eucalyptus deglupta*	Grazing under coconuts and other plantations	Several tree species being used very widely	Very common in the dry regions; the Dehesa system	The *Acacia* dominated system in the arid parts of Kenya, Somalia and Ethiopia	Cattle under oil palm; Cattle and sheep under coconut	Common in humid as well as dry regions; e.g. Grazing under plantation crops in Brazil
AGROSILVOPASTORAL SYSTEMS	Woody Hedges for Browse, Mulch, Green Manure, Soil Conservation, etc.	Various forms: *Casuarina oligodon* widely used to provide mulch and compost	Various forms	Various forms especially in lowlands			Very common	
	Home Gardens (involving a large number of herbaceous and woody plants with or without animals)		Very common; Java Home Gardens often quoted as good examples	Common in all ecological regions	The Oasis system	Various forms (The Chagga homegardens; the Nyabisindu system)	Compound farms of humid lowlands	Very common in the thickly populated areas
OTHER SYSTEMS	Agro-Silvo-Fishery ("Aquaforestry")		Silviculture in mangrove areas; trees on the bunds of fish-breeding ponds					
	Various forms of Shifting Cultivation	Common	e.g. Swidden Farming	Very common; various names		Very common	Very common in the lowlands	Very common in all ecological regions
	Apiculture with Trees	Common	Common		Common	Common	Common	

political economy make it imperative for risk-reducing smallholders to try to satistfy 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 (see Nair 1984), although such systems 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 of how many and what 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: 1) a functional role within the land use system, 2) a place within the landscape, and 3) a time within the cycle of land use or the stages of development of a particular 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 mangement 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 which 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).

Let us now consider some of the ways in which agroforestry might be used to address the problems and opportunities identified in the previous sections of this paper.

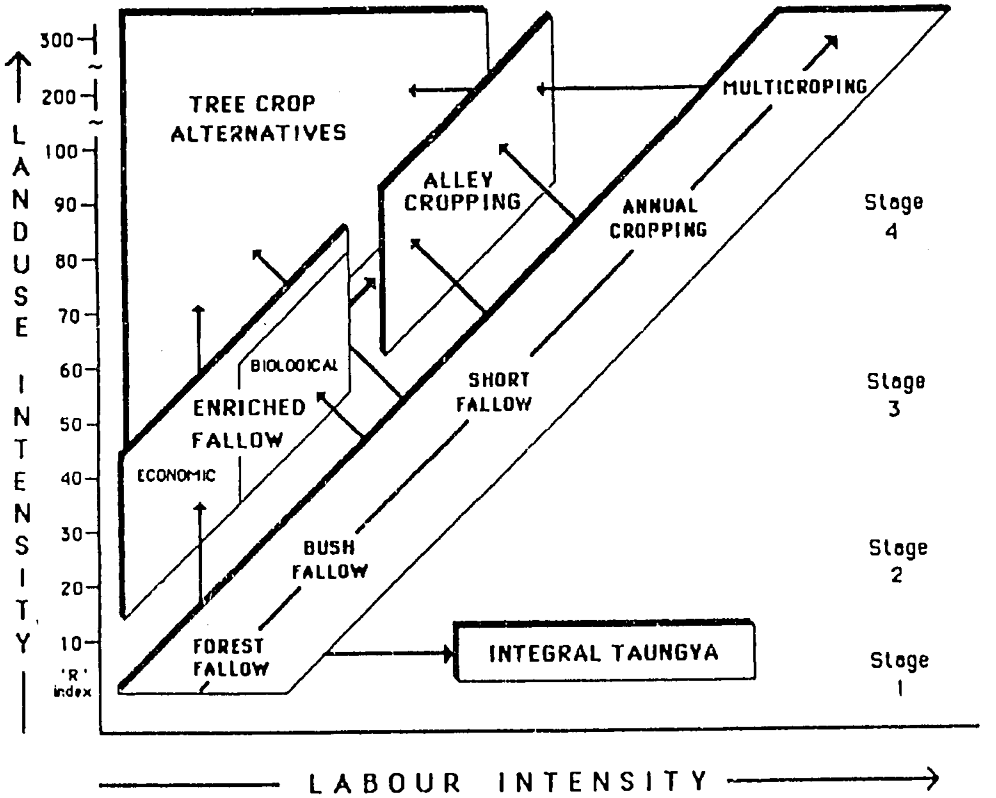

Figure 6. Agroforestry pathways for agricultural intensification in the tropics, with particular reference to the humid and subhumid zones. The R index (Joosten 1962) shown on the left gives an approximate indication of the land use intensity corresponding to the stages shown on the right. R = (C/C+F) x 100, where: C = cropping period, F = fallow period. The R index is also equivalent to the percentage of land in cultivation, as read from aerial photos. Boserup's (1981) treatment as a "frequency of cropping" index allows the interpretation to be extended to multicropping. For R > 100, R corresponds to the number of crops taken per year x 100. Source: Raintree and Warner (1985).

From shifting to permanent cultivation

Different agroforestry options and development pathways open up from different stages in the intensification sequence outlined in Table 6. Figure 6 on the preceeding page summarizes what appear to be the most promising agroforestry approaches. Table 8 outlines in somewhat greater detail, the suggested matching of agroforestry technologies to specific stages.

Table 8. Stages in the intensification of shifting cultivation and matching agroforestry options. Primary (**X**) and secondary (x) feasbilities indicated. Source: Raintree and Warner (1985).

	Stages of Intensification			
	1	2	3	4
Improved Fallows				
"Integral taungya"	**X**	x		
Economically enriched fallows	**X**	**X**		
Biologically enriched fallows		**X**	x	
"Alley cropping"			**X**	**X**
Tree Crop Alternatives				
Tree cash crops	**X**	**X**	x	x
Home gardens		x	**X**	**X**
Interstitial plantings		x	**X**	**X**

<u>Integral Taungya</u>

In the classification of swidden systems, the 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 which 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 for labour, 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, but perhaps the "Forest Village" schemes in Thailand come closest to the ideals of this concept. In some variants of this approach, to make participation in the foresty effort more attractive to traditional shifting cultivators the Thai foresters not only encourage the participants to grow long term perennial cash crops by widening the between-row spacing of the commercial forest species, but also allocate permanent agricultural plots to the farmers for use as they see fit. In addition, they pay decent wages for a variety of work opportunities in the forestry sector of the village economy and provide a range of extension and community development inputs such as housing assistance, clinics, schools, and places of worship (Boonkird et al. 1984). Far from an "exploitative" practice, this Thai variant of the taungya system shows promise of becoming a model example of what is meant by "integral taungya," although it is nowhere adequately documented in the literature.

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

Enriched Fallows

The 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), become interesting to farmers somewhere around Stages 1-2 and 2-3, respectively, in the intensification sequence. Long fallow forest shifting cultivators are not likely to be interested in techniques to cope with 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 successfully marry the two types of production the phase lengths must match. Hence, the entry point of primary feasability for integral taungya would seem to be in Stage 1 when fallow lengths are of the sáme order of magnitude as tne growing period for commercial forest trees. It could possibly be introduced at Stage 2, however, providing that short rotation (< 10 years) forest species are selected, or that agricultural practice can be technologically intensified to a degree which could accomodate 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 10 to 100 years for some trees). Indeed, the planting of fruit or other valuable, long duration, continuously productive trees 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 for satisfying the production requirement of preferred field crops) is signficantly more rewarding than the continuation of conventional swidden practice.

The basic feasability of the economic enrichment approach is demonstrated by such indigenous examples as the fallow enrichment planting of rattan by the Luangan Dayaks of Borneo (Weinstock 1983), of cedar and bamboo by the Lingnan Yao of China (Lebar et al. 1964), of casuarina by the Siane of New Guinea (Salisbury 1962), of gum arabic in the Sahel (Maydell 1980) and of multipurpose fallow "woodlots," whose species diversity exceeds that of the natural forest; by the Ifugao terrace builders of the Philippines (Conklin 1980). The latter agroforestry practice exemplifies not only a very rich, long duration fallow system but also the role which such systems can play in meeting requirements for ecologically sound upper watershed management. It should be noted, however, that the system seems to be breaking down in some localies because of accelerated cutting of wood for the tourist woodcarving industry, increased fuelwood pressure and a complex set of social changes associated with the loss of customary regulatory controls formerly exercised by the wealthier and more influential farmers whose influence is waning under the more equalitarian ethos of modern times (Eder 1982). In some parts of Ifugao, notably in the vicinity of the main tourist center, "disintensification"(Brookfield 1972) of traditional agriculture seems to be occuring as a result increased opportunities for non-farm employment and other modernizing influences.

Biologically enriched fallow practices using Acioa barteri, Anthonotha macrophylla, Alchornea cordifolia, Gliricidia sepium and Leucaena leucocephala have been reported by Benneh (1972), Okigbo and Lal (1979), Getahun (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 which undertakes the labour investment of the fallow improvement. Without secure rights of this type, it is unlikely that the benefits would be worth the effort. Any yet the potential benefits of the approach would seem to justify efforts to bring about supportive tenure tenure changes, with the caveat always in mind, however, that the system could be abused by individuals as a strategy for grabbing land.

Alley cropping and other intercropping systems

If the preceeding discussion stretches the conventional concept of "fallow" beyond its normal usage, the extension of the approach into the "continuous fallow" processes (G.F.Wilson, personal communication) of "alley cropping" goes even further toward 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 (Huxley 1980, Huxley and Raintree 1983) to agroforestry, in which field crops are planted in the alleys between hedgerows of nutrient-cycling trees or shrubs, which are kept pruned throughout the cropping season to control shading and below ground competition while providing 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 fulfill a "service function" (Torres 1983) 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), Verinumbe et al. (1984), Hoekstra (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 1982, NAS 1983), where the yields of crops grown in proximity to the tree are typically double those of crops grown outside the tree's sphere of influence. Nitrogen fixation, microclimatic benefits and the peculiar "reverse phenology" of the tree (which leafs out in the dry season and drops its leaves at the beginning of the rainy season, thus nicely accomodating itself to the requirements of crop cultivation) account for part of the yield increase, but an important tenure-related effect is the concentration of manure in the vicinity of the trees as a result of the livestock which gather under the shade of the trees during the dry season to consume the nutritious pods produced at this time. Presumably, the benefits to the arable crops would be reduced if tradititional grazing rights were to be restricted.

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 of adoptability. This does not necessarily mean that the benefits of multipurpose trees chosen for the purpose (see FAO 1984:32 for selection criteria) could not conceivably be shared by claimants with different land and tree utilization rights (see the background paper by Fortmann), but it is obviously the case that the incentives for adoption of these more-or-less permanent improvements would be more effectively concentrated if exclusive use rights were vested with the innovating management unit, although (as discussed below) it might be advantages to allow controlled grazing by livestock (which may be owned by pastoralists or other farmers) during the dry season. Insofar 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. This latter point was brought home to me in the course of conducting farm trials of alley cropping systems in Nigeria, where some of the participants had to drop out when the kingroup steward of the land "borrowed" for the trials learned that trees were to be planted and withdrew the usufruct rights.

For these reasons, and for reasons 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, when ecological demands and tenure adjustments make it necessary and possible. Again, providing the system is not abused as a way of grabbing excessive amounts of land, supportive tenure adjustments would seem justified.

One way of effecting a smooth adjustment of agroecological and tenure factors associated with alley cropping would be to take a phased approach to the adoption of the system, based on the concept of an "optimal pathway of intensification" (Raintree 1980, 1983, FAO 1984, Raintree and Warner 1985). Starting with a fallow enrichment approach at Stage 2, tree species could be introduced which have both economic and biological fallow improving properties. By planting the selected trees in hedgerows at appropriate between-row spacing (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. As a final measure of intensification, undertaken under conditions of very high population pressure by the children or grandchildren of the original shifting cultivators, the installed "green manure factories" could be maintained in place and a variety of economically valuable upperstorey trees could be added to the system. 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 population-pressured necessity. Of course, this may result in accelerated emergence of income disparities, but this would be true of virtually any productivity enhancing innovation and should not be used as an argument to squelch the innovation, although projects could take measures to insure equality in the distribution of opportunity to adopt the system (which, in itself, may involve land reforms).

Tree Crop Alternatives

Even with the aforementioned improvements as an efficiency enhancing adjunct to the use of fertilizers and other modern agricultural inputs, there is a limit to what can reasonably be expected from the intensification of tropical field crop systems.

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 agriculturalists and land use planners.

> 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 are indicated by the widespread practice of "home gardens" in areas of high population density, where conditions are such as to favor the most efficient land use systems. In his study of Ibo farming practices in Nigeria, where population densities may reach 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 5 to 10 times greater in monetary terms than from the outfield plots and the returns to labour are 4 to 8 times higher. In Java, where various tree garden types exist in a mosaic with wet rice paddies and rainfed arable crops (Penny and Singarimbun 191973, 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 Roti and Savu islands (Fox 1977) and the domestication of Shorea javanica in southern Sumatra (Torgueblau 1984), a species which silviculturalists 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 the drinking water may be provided by a tree (i.e. the coconut palm). In this connection, the underexploited potential of the palms is so striking as to deserve special mention (see Johnson 1983).

Horticultural tree crops for cash purposes are extensively planted by smallholders 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 et al. 1982), and the coconut, rubber, oil palm, cacao and coffee plantations of smallholders in Southeast Asia (Pelzer 1978, Nair 1979, Liyanage et al. 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 for social activities 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 and 4, however, the transition to tree crops is less easily achieved, due to the commitment of land to other uses and the relatively long lag time between planting and first harvest, although "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, after Stage 1 extensive plantings must usually be accompanied by some form of field crop intensification.

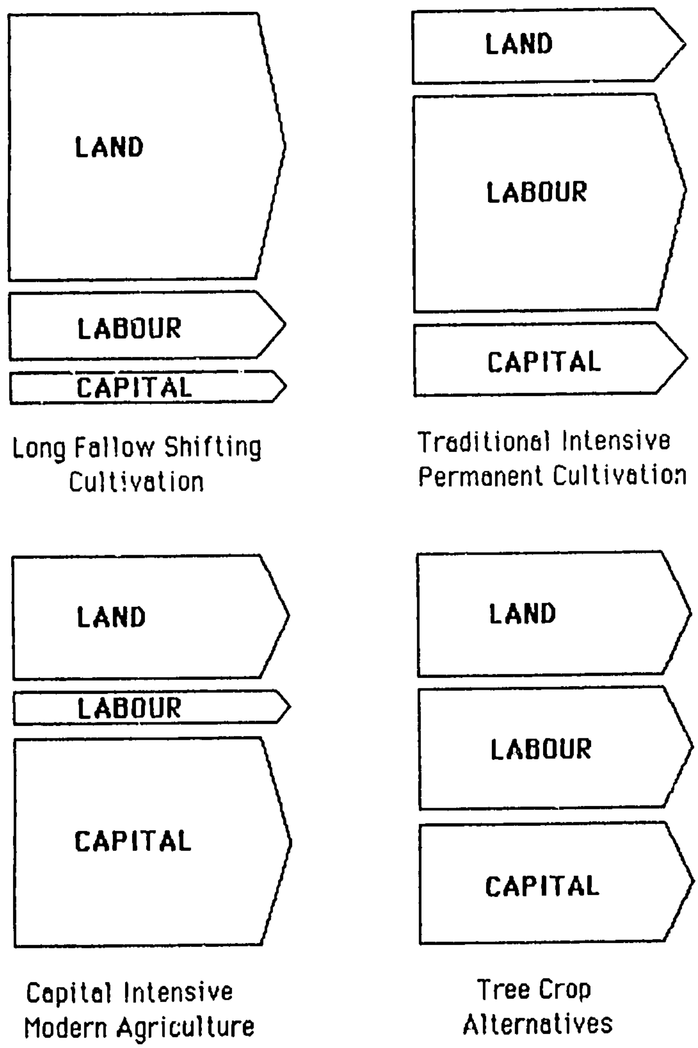

Figure 7. Relative factor proportions of different tropical land use systems. One of the potential advantages of trees as a productive form of capital for the self-reliant smallholder is their partial substitution for labour and less accessible capital inputs thus making it possible to aspire to a more balanced mix of production factors.

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 is often found 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 land holder, once the critical tree establishment phase is passed.

Interstitial tree planting

It has been repeatedly suggested throughout this paper that tree planting need not always be in competition with field crops for land. The planting of fertility enhancing trees is one case in which the crops may actually benefit from association with the 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 the trees and other crops have negligible or neutral interaction, can also be cited. Even when there is a "competive" 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 production of a diversity of products (Arnold 1983, Raintree 1983, Hoekstra 1985,).

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 opportunty for supplementary production, since plantings at these locations (almost regardless of the biological competitiveness of the trees) may often be undertaken with little or no opportunity cost to other land uses. For example, a recent aerial photo analysis of a watershed in a fairly densely settled farming commity 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 30 percent of the fuelwood and 40 percent of the fodder requirements of the households in the area could be supplied by these hedgerows, with very little competiton with existing agricultural land uses (Rocheleau and Hoek 1984).

Can it be assumed that the tenure issues arising in connection with interstitial plantings will be as benign or readily solvable as the technological problems? Possibly not, since in the case of boundary plantings the boundaries per se might be the source of dispute, and trees planted on degraded or "underutilized" lands in the general landscape may arouse the concerns of those currently enjoying gathering or grazing rights in the commons. Perhaps a some kind of common property approach to multiple use of these lands may be feasible. The opportunities for the satisfaction of diverse interests might be enhanced in such cases by the use of appropriately selected multipurpose trees. One social organizational approach which might be worth exploring is the partitioning of planting responsibilities and exclusive harvest rights among individual members of an inter-household working group, organized on a neighborhood basis and operating at a larger-than-farm scale (Rocheleau 1984).

As regards boundary disputes per se, it is an important consideration that trees often take on legal meaning as boundary markers. In Kakamega District in Western Kenya, for example, it doesn't matter where you might locate your barbed wire fence, the boundaries of the 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 neighbors. There are, perhaps, two approaches to the the resolution or avoidance of such conflicts. One is to plant only valuable fruit or fodder trees and allow the neighbors to take the share of the produce which extends into or falls on their property. The other approach is to choose trees which 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 be taken to the point that only useless trees can be planted, as in the case of the comparatively useless Euphorbia tirucali hedges of Kakamega (apologists will argue that the tree can be used as an emergency fuel, but there are many better 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 in Kakamega District.

Where land use patterns and tenure rules are undergoing changes in adaptation to population pressures or other factors, the boundary marking role of trees can have either postive 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. On the one hand, trees can be used to consolidate tenure aspects of ecologically necessary and beneficial changes, while on the other hand they might be used for out and out land grabbing.

The planting of trees at interstitial locations within farms might seem to be a wholly positive development, since this is one relatively painless way to increase the supply of tree products for household consumption, sale or savings on land which is under the direct control of the household. Unfortunately, this is where many of the gender-related tenure problems arise. It all depends on what <u>kind</u> 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 the 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 are beginning to be openly questioned, but the Kakamega case is illustrative of how it is possible to have a landscape full of trees (mostly eucaplypus and cypress) and yet the women must rely on eucalyptus leaves and twigs for much of the domestic energy supply.

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: 1) aridity itself, which increases the risks and the costs associated with successful tree establishment, usually requiring the labourious planting of individual seedlings; whereas, in the humid tropics direct seeding often suffices), and 2) 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 the 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.

The role of trees in mixed farming systems

The expansion of farming into fragile dryland environments poses special problems for crop husbandry: 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 main keys to successfully coping with the first three of these problems is the maintenance of adequate soil organic matter and nitrogen (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 for return to the soil and by the competition with food crops for water, land and labour. Likewise, the usefulness of herbaceous fodder crops as a source of supplemental feed for the critical dry season fodder gap is limited by their low protein quality at this time of year and, again, by the competition for water, land and labour with food crops.

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: 1) they are generally more drought tolerant than herbaceous plants, 2) they have higher feed value during the dry season (particularly the pod producing species) and are thus better able to insure the strength of draught animals at the beginning of the rains, 3) they can be grown at interstitial locations on the farm or in association with crops without replacing them, 4) appropriately selected and arranged with respect to the crops, they can offer microclimatic benefits associated with windbreak effects and reduced evaporation, 5) they can produce food, fuelwood, building materials, and other directly useful by-products while performing their service roles on the farm, and 6) as a form of standing capital, they can serve as a source of convertable savings for emergency needs, including "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 agro-pastoral tenure problems, the path to these ends must be cleared by social means.

The role of trees in pastoral systems

While trees may have a role in bringing about an accomodation 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 feat 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 (Maydell 1980, NAS 1983) and the "Land Management Near Wells" project in Niger (Weber and Hoskins 1983) have been exploring various technical and social models for mitigating the ecological effects of herd concentrations around boreholes.

Another common situation is overgrazing around around pastoral home areas and the problems associated with the provision of feed to young and sick animals that are kept in in these areas. The Masai "olopololi" is a dry season grazing reserve maintained jointly by several households for such animals in the vicinity of their residential bomas which, since it is protected from grazing during the rainy season, might 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. This also would be a natural site for the growing of supplemental fodder trees to meet dry season feed requirements (Nambombe 1984, Mhungu 1984). It would be especially useful to use such fodder to feed smallstock and weaning calves, since the expected production would be roughly commensurate with the volume requirements of the smaller herd animals and, in the latter case, the milk savings effected by substitution of tree fodder would directly benefit the household, which is normally in competition with the calves for milk (B.E. Grandin, personal communication).

These are the kinds of modest agroforestry proposals that it might be worth exploring with pastoralists and, insofar as they are oriented toward the development of small areas under control of one or a small group of households, 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, insofar as it would involve common grazing lands. However, to cite the Masai example again, such pod producing legumes as Acacia tortillis occur naturally on the open range in Masailand and in some cases their exploitation is controled by the local group (nowadays the group ranches).

According to the accounts given by Masai informants to an ICRAF research trainee (V. Nambornbe, personal communication) the "courtesy" rights accorded by one group ranch to members of a neighboring ranch to utilize the nutritious Acacia tortilis pods underwent an interesting change during the recent drought. Normally they were allowed to shake the tree, thus 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 which fell to the ground naturally. If, in fact, the Masai are exercising this kind of regulatory control over the use of the pods of such trees, might they not then be encouraged to undertake steps toward the domestication and artificial propagation of this valued range resource?

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 encourage greater investment in the commons might be to identify the least cost method of investment. Now, 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 Rajastan 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 supplying such pods in quantity to pastoralists to feed to their herds and see what happens. No doubt the establishment percentage would be low, but so would the herder's investment, and the result, probably long after the project has come and gone, might be quite significant. We don't know whether this would work because we don't know any project that has 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 to the problem of identifying the right multipurpose trees. Why not choose an energy tree from among several outstanding desert biomass producers which happen also to produce copious quantities of high quality dry season pods. Again, Prosopis would seem to exemplify the appropriate ideotype (Felker and Bandurski 1978, 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, that it could make a big difference in the dry season carrying capacity of the range, and that such a choice might make all the difference in the world to the survial rate of the trees in pastoral areas. In this connection it is interesting to note that present day energy experts are coming to the conclusion that for biomass energy sources 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 around solution to the related developing country problems of biomass energy supply, decentralization of rural industry, and participation of pastoralists in national development?

Perhaps it is well to end this paper on an imaginative note and with a question, since the purpose of the paper has been to provide some images to serve as a background to our consideration of tenure questions in agroforestry.

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