AGROFORESTRY AS AN APPROPRIATE LAND USE SYSTEM IN THE AMERICAN TROPICS[1]

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ABSTRACT

The improper use of land is resulting in the rapid deforestation of the American tropics, with a concomitant degradation of land and water resources. Agroforestry is a land management system of a conceptual design involving multiple use and sustained yield, which could provide — depending on its adaptation to local environmental and socio-cultural characteristics — appropriate alternatives to these destructive land uses.

FORETHOUGHT

"The growing of trees and crops intermixed on the same piece of land is an old and indigenous practice followed by farmers in many ecological zones in many countries of the world. Agroforestry — the elegant term for the practice — is being increasingly recognized as a land-use/food production system which has a high potential for stabilizing food production, for providing many 'tree' products, while at the same time, exerting a stabilizing influence on the environment".

(*H. Steppler as quoted in Nair, 1980*).

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INTRODUCTION

The land uses currently practiced by agriculturists in the American tropics are a result of a complexity of local and regional social, cultural, environmental, economic and political factors. Distinct cultural patterns provided the basis for early man/land relationships.[3] Inherent environmental factors such as topography and climate influence methods and crops employed and the sites selected for settlement. Plucknett (1976) for example explains that, one reason that people have occupied hill lands in the tropics is to escape the adverse conditions of the lowlands of excessive heat, diseases and insects. Population rates in the region are soaring to more than 3 percent in some countries, causing an ever-increasing hunger for land from which to obtain basic needs of food, shelter and energy. Improper or in effective land tenure laws, which make it nearly impossible for the poor agriculturist (also known as "small farmer") to acquire property, contribute to the perpetuation of shifting agriculture. In Honduras, for example 54 percent of a sample of small farmers surveyed did not own any property (Jones, 1982).

Governments have failed to respond to the general needs of the small farmer because of economics, politics, or because of badly placed priorities. The near non-existence of agricultural extension services tends to lock the small farmer in a closed cycle of subsistence based on primitive and inappropriate methods of cultivation, bad seed, and a lack of diversity of crops. In many cases, the illiteracy of the people exacerbate any such extension efforts. Because of the relative inactivity in other related sectors of the local economies, there are few or no alternative employment opportunities. Finally, the economies of the countries in the American

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[3] Heckadon (1981) for example, describes the initial populating of Panama and the early settlers' regard of the forest as an obstacle to agricultural subsistence which constantly had to be "slashed and burned" in order to cultivate underlying soils.

tropics are very closely aligned with commodity prices. A reduction in prices brings economic chaos and inflation, while price rises improve trade balances. Both situations, however, encourage the expansion of agricultural lands in order to produce more (volume) to earn more; whether because of need when prices are depressed, or because of greed when prices are high.

The factors described above, in combination with weak national legislation dealing with land management and land-use controls (or their enforcement), are the principle causes for the most serious of environmental problems in the American tropics — that of deforestation.

DEFORESTATION

The most alarming characteristic of deforestation in the American tropics is perhaps its voraciousness. The process is so rapid that no monitoring system has yet been devised that is capable of keeping up with its extent and magnitude. Although a combination of the interpretation of Landsat imagery and aerial photographs has long been suggested as a practical method of monitoring the advance of deforestation (depending on the quality of images), efforts to date include only spotty attempts in a few countries in the region.[4]

FAO, through its Global Environmental Monitoring System, is the foremost organization in the accounting of forest resources throughout the world. In table 1, data collected by FAO (1981) illustrate the seriousness of deforestation in the American tropics. Some countries (Haití, El Salvador) are practically devoid of forest resources. Deforestation rates shown do not fully reflect the amount of real deforestation. These rates only account for

[4] Among these are a project completed in Guatemala (Instituto Geográfico Nacional, 1976) and a project currently under development in Costa Rica (Personal Communication. Instituto Geográfico Nacional. San José, Costa Rica. April 13, 1982).

TABLE I

FOREST COVER AND DEFORESTATION RATES FOR SELECTED COUNTRIES IN THE AMERICAN TROPICS (1980)

Country	Dense and Commercial Forest Cover (% total land area)	All Forest-Type Cover* (% total land area)	Annual Deforest. Rate (% total land area)	Annual Deforest. Rate (% dense forest area)
Belize	58.9	87.8	0.4	0.7
Costa Rica	32.2	40.0	1.3	4.0
El Salvador	6.7	21.7	0.2	3.2
Guatemala	40.8	58.8	0.8	2.0
Honduras	33.9	52.6	0.8	2.4
Nicaragua	32.3	43.6	1.0	2.7
Panamá	54.0	55.6	0.5	0.9
Jamaica	5.9	39.7	0.2	3.0
Cuba	12.7	21.5	0.02	0.1
Haití	1.7	5.2	0.06	3.7
Dominican Republic	13.0	19.6	0.08	0.6
Suriname	90.6	97.6	0.01	0.02
Brazil	42.0	79.5	0.17	0.41
Perú	54.2	61.7	0.21	0.39

*Includes dense broadleaf and commercial pine forests, open forests, secondary forests, wooded savanna, and woody scrub.

Source: FAO, 1981

the rate of the disappearance of dense and commercial forest cover. Just as serious, in relation to land and water resources, is the increasing cutting of secondary forests and lower forest forms such as wooded savannas and woody scrub because of reduction in the length of the fallow period in the rotative cycle of shifting agriculture. This practice leads to the degradation of the forest (reduction in species diversity and production of biomass), and to the degradation of the site (impoverished soils, lack of water, etc.).

The lion's share of deforestation is attributed to the expansion of agriculture — especially pasturelands. Since 1950 for example, man-established pasture or grazing lands and the number of cattle have more than doubled in Central America, almost entirely at the expense of natural forests (Myers, 1979). Most of the output of increased production is exported to expanding "fast food" markets in the United States. Costa Rica is a prime example: 40 percent of the forest cover in the country has been lost between 1950 and 1977, primarily due to the expansion of pasturelands (Perez, 1978).

IMPACTS OF DEFORESTATION

The relationship between tropical forests and land and water resources is only recently being studied and understood in scientific circles. What is understood (simply) is that if the forest cover is removed, the underlying soils are more directly subject to the effects of rainfall, sunshine, winds, and more importantly, the impacts of their cultivation.

Removal of the vegetative cover for instance, decreases in magnitudes the protection of the soil from rainsplash erosion.[5] Depending on the land

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[5]Hudson (1974) showed that soil losses from bare soil was 126.6 tons/hectare/year, but under a protective canopy the rate was reduced to 0.9 tons.

use, vegetation offers a range of protection from rainsplash, sheetwash, and gully erosion. Referring to table 2, it can be seen that protection from soil losses under forests and woodland can be much greater than under other types.

TABLE 2

EROSION RATES UNDER CERTAIN LAND USES
(Dunne and Leopold, 1978)

Land Use (cover type)	Soil Loss (tons/hectare/year)
Primeval Forest	0.04
Woodland (burned annually)	0.16
Tropical Perennial Grasses	.54
Grass and Scrub	.80
Maize	4.72
Hill Rice	4.21
Dry Woodland and Rangeland (heavily cut and grazed)	6-34
Bare Fallow	45
Road Cuts	35-106

In Honduras, accelerated erosion rates as high as 500 metric tons/hectare/year have been reported for extremely steep denuded sites (Secretaría de Recursos Naturales, 1977). The loss of soil decreases on-site productivity, resulting in nutrient loss and decreased crop yields, and causing small farmers to shift to other more productive sites (under cleared forest). Eroded sediments end up in stream courses where they reduce the normal carrying capacity of channels, there by increasing the potential for flooding.

Increased runoff and peak flows are another cause of unnatural flooding. Again, land-use exerts a great influence over the characteristics of runoff from a site. Forested sites tend to be much better receptors of precipitation, transmitting the moisture to the soil and water table through infiltration. Conversely, as the character of vegetative cover varies away from these of forests (forest to open woodland to grassland to agriculture to bare soil), runoff usually increases and infiltration decreases. The following table of runoff data collected at different sites in tropical Africa illustrates this point:

TABLE 3

RUNOFF OBSERVATIONS UNDER VARIOUS COVER TYPES (Nair, 1982)
(% of total precipitation)

Location	Avg. Annual Rainfall (MM)	Cover Type		
		Forest	Agriculture	Bare Soil
Upper Volta	850	2.5	2-32	40-60
Senegal	1300	1.0	21.2	39.5
Ivory Coast	1200	0.3	0.1-26	15-30
Ivory Coast	2100	0.1	0.5-20	38

Wouters (1980) reported on runoff plot observations in Honduras where a cover of overgrazed pasture/scrub converted as much as 25 percent of precipitation to runoff, where as agriculture resulted in 20 percent and forest cover transmitted only 6 to 11 percent of total precipitation as runoff. Figure 1 illustrates the importance of vegetative cover in its influence of runoff and erosion rates. A definite trend is perceived as land use changes from forest to agriculture to grazing.

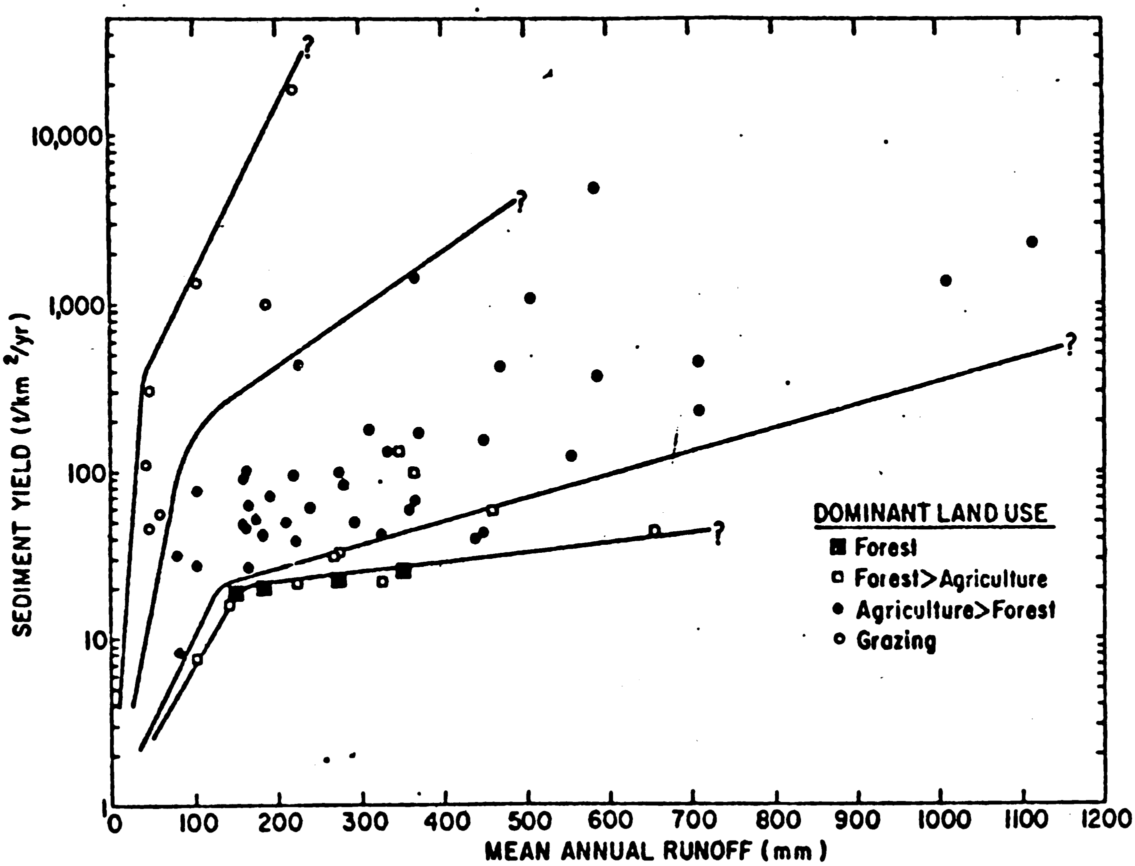

Figure 1. The influence of land use on runoff and erosion for watersheds in Kenya over a 20-year period (Kunkle, 1978-citing T. Dunne, personal communication).

Other possible adverse impacts of the continued deforestation in the American tropics, although less understood, are the elimination of species and the loss of diversity in forest environments, and climatic changes. Myers (1978) predicts that if present patterns of exploitation of tropical moist forests continue, it could mean the loss of hundreds of thousands of species of plants and animals — the impact of which would dramatically alter the ecological make-up of the tropics. Conversion of forests to other uses causes a release of carbon dioxide (CO_2) resulting in an annual upward trend of CO_2 in the atmosphere (Woodwell, 1978). It is postulated that should the CO_2 content continue to rise, a warming trend of the atmosphere would occur with related changes (perhaps detrimental) to climates.

The small farmer is the victim of deforestation as well as the agent. Land begins to degenerate because of excessive cultivation in the absence of conservation measures. Soils are leached of nutrients, are badly eroded, and weeds begin to invade the sites. Unable to produce food on degraded sites, the small farmer looks for new ones — usually cutting down immature secondary growth or converting forests to simple plots of basic grains. At the some time, the same small farmers must procure fuel (fuelwood) with which to cook these food grains and building materials for shelter from these same forests. As the forests disappear, so then does their source of these basic needs. This paradox of inappropriate land use must be changed if the small farmer is ever to escape his cycle of poverty; and the forests of the American tropics are to endure.

REVERSING THE TREND

It is doubtful that the small farmer is going to appreciate the "abstract" conservation benefits of appropriate land-use techniques such as downstream flood protection, soil erosion control, increased infiltration of water, and the maintenance of water supplies (Kunkle, 1978b). In a situation of marginal lands or those requiring specific management practices in order to achieve continued economic returns, the farmer can make the decision to utilize conservation techniques which would maintain crop yields (and income) at a prescribed level over the medium and long term; or the farmer may adapt resource-depleting practices (e.g. slash and burn, short fallow) that require a minimum of capital and/or labor inputs. The latter would initially produce greater economic return due to the intensity of land use, with a minimum input of labor and capital; but economic output would decrease over the short to medium term due to soils degradation, weed invasion, desertification, etc. These conservation aspects must be incorporated in current land-use systems if they are to provide the small farmers' needs while, at the same time, be available (non-preemptive) for future generations. The concept of "multiple-use management" is perhaps the best approach for accomplishing this task:

1. the deliberate and carefully planned integration of various uses so as to supplement each other as much as possible, and to interfere with each other as little as possible.

2. the skillful adjustment of land resources and uses into a pattern of harmonious action to achieve overall objectives for the area being managed, and

3. the coordination of existing and potential uses and activities with a resultant benefit to people that is greater than the sum of the individual uses if they were not coordinated.[6]

The overall objective of multiple-use management is the more efficient utilization of land in order to achieve a sustained yield of products or services while maintaining productivity without impairing the site. Application at the field level would involve the incorporation of soil and water conservation practices, reforestation of degraded or denuded lands, extension and education programs and shifts in land use systems to intensify use on suitable lands while reducing the intensity of utilization of marginal land (i.e. hill lands).

Reversing the trend of inappropriate land use and deforestation will require changes in land tenure and land-use legislation. The small farmer will have to be given more access to owning property in order to

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[6]Multiple Use and Sustained Yield Act of 1960. Public Law 86-517. United States 86th. Congress, H.R. 10572. June 12, 1960.

stabilize his agriculture.[7] A land classification system should be developed in each country, being specifically adapted to local socio-economic needs and natural conditions. Lands would be classified according to their capability to support certain uses (i.e. based on limiting physical factors of soil depth, slope, climate, etc.) and by their suitability for use, based on local socio-economic conditions (i.e. land might be capable of supporting a higher use, such as a corn crop, but local socio-economic conditions dictate a greater need for fuelwood, so trees are grown instead). This classification system would then be used as the principal basis for land-use decisions that adhere to the multiple-use, sustained-yield concept.

Although there is an urgent need to bring about legal and institutional changes necessary to promote the appropriate use of land, the responsibility is enormous in scope when considering the complex and diverse legal/political systems of the various countries in the American tropics; and (although ongoing in many cases) would require years to carry out. What is actually needed is a program that can bridge the gap between the land use currently practiced by the small farmer and those more appropriate practices which would ideally be brought about by legislative change. Such a program would consider actual land-use techniques, yet promote concepts of multiple use and sustained yield through complementary technology.

AGROFORESTRY: AN APPROPRIATE ALTERNATIVE?

Agroforestry, with its flexibility in application and multiple-use

[7]Banks in the region do not as a rule extend credit to farmers who do not have clear title to lands. Without credit it is nearly impossible to make the improvements necessary to stabilize agriculture (e.g. fencing, improved seed, fertilizers,tools, etc.)

orientation is a promising land-use system for the American tropics. Study of these systems throughout the tropics worldwide has shown that agroforestry has resulted in stable and productive management systems on all kinds of land, of varying soil, topographic, and climatic conditions; and under differing socio-economic conditions (Budowski, 1981a). As stated by Lundgren (1979): "Agroforestry as a form of land use, is primarily considered as a desirable replacement or improvement of land-use systems that are degrading under the pressure of increased population densities in areas with low inherent potential for intensive agriculture". Much of the area in the American tropics fits into this category.

A review of the following definitions of agroforestry reveals themes common to that of multiple-use management: the integration of various uses, sustained yield, the compatibility of the system with existing socio-economic and environmental conditions, and a maximization of benefits for people.

> "Agroforestry has been defined as a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially, on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population"
>
> (King and Chandler, 1978).

> " The art, and eventually, the science of combining herbaceous crops and/or animals with trees on the same unit of land in order to optimize multi-purpose production and put it on a sustained yield footing"
>
> (Raintree, J. in ICRAF, 1982).

> "Agroforestry develops the concept of using trees as a component of the overall management of land resources to meet the needs of the people for food, fuel, shelter and income. The systems used need to be socially, culturally and economically acceptable, to maximize total output at given input levels and the minimize damage to the total environmental"
>
> (Constant, R. in ICRAF, 1982).

Alluding to agroforestry, Nair (1980) finds essential the development of a system that would facilitate the utilization of lands unsuitable for "profitable production systems "(monocultures) for the production of food and/or animals ensuring "that the protective cover of the forests in the tropics is maintained and/or restored". It is important here to reiterate that the basic needs of the small farmer (food, water, shelter, energy) must be met by any such system.

Generally a land use technique is selected relevant to desired results —— e.g. cultivation of certain crops for subsistence or profit; pasture for cattle production; or the maintenance of natural forests for water production, recreation, or wildlife preservation. What should be considered, depending on the techniques chosen, are the multiple-use and conservation-oriented applications of those techniques. Table 4 presents a list of agroforestry techniques with various advantages or functions available with each. Although a technique might be chosen for a specific function —— e.g. shade for crops or animals —— additional advantages of fuelwood, foods and fruits, flowers for honey, forage and fodder, fenceposts, furniture wood, fertilizer, fixing of nitrogen, firebreaks, forest protection, and financial stability can be obtained.

Alternatives must be developed that offer the small farmer economic advantages over currently practiced techniques (whether in terms of simple subsistence or more sophisticated "profit motives"). Such advantages

TABLE 4

ADVANTAGES/FUNCTIONS OF AGROFORESTRY TECHNIQUES IN MULTIPLE-USE MANAGEMENT OF LAND

Agroforestry Technique	Advantage/Function*
Taungya	• Wood production (fuelwood, timber) • Soil rehabilitation/improvement of fertility • Watershed rehabilitation
Shade Trees with Crops	• Manipulation of flowering and maturing process • Maintenance of moisture (microclimate) • Weed and soil moisture control (mulch) • Soil rehabilitation/improvement (organic material, fertilizer) • Slope stability, erosion control • Economic diversity (multi-source income) • Forage/fodder
Fruit Trees with Crops or Pasture	• Nutrition (foods) • Economic diversity (multi-source income) • Flowers for honey production • Slope stability, erosion control • Building materials • Precious woods (furniture) • Forage/fodder • Shade for livestock or light sensitive crops
Living Fence Posts	• Low-cost durable fencing and corrals • Fuelwood • Timber (small construction) • Shelterbreaks • Forage/fodder • Shade for livestock and roads • Economic diversity (multi-source income)
Shelterbreaks Windbreaks	• Eolic erosion control • Crop and animal protection • Fuelwood • Building materials • Precious woods • Flowers for honey production • Forage/fodder
Trees and Pasture Forest Plantations and Pasture Pasture and Secondary Forests Fodder-Producing Trees Vegetative Barriers in Pastures	• Shade for livestock • Soil/forage • Slope stability, erosion control • Fuelwood • Flowers for honey production • Building materials • Precious woods • Shelterbreaks • Economic diversity (multi-source income) • Wildlife refuge (indirect consequence) • Maintenance of moisture (microclimate) • Weed control in pasture
Vegetative Barrier with Crops	• Erosion control on hills • Green manure for crops • Fodder • Soil rehabilitation/improvement • Fuelwood

*Advantages/functions depend directly on the species selected as arboreal component and on site conditions.

are seen as increased crop yields or generated or increased income, compared to the amount of labor and/or capital invested. A review of the literature yields some examples of the economic viability of agroforestry. Grinnell (1977) showed that an agroforestry model produced a 22-percent higher net income than a farming system incorporating shifting agricultural methods (disregarding labor investments which were greater in the agroforestry model). Profitability can be up to two-times as high under silvipastoral combinations than under pure pasture (Bishop, 1979; Tustin, 1976). Combining coffee with leguminous shade trees (Erythrina poeppigiana) and a locally valuable timber species (Cordia alliodora) in Costa Rica was found to be more economical to the farmer, based on coffee and timber yields, than only combining coffee and shade (Glover, 1981). The employment of the Taungya system (King, 1968) has been shown to reduce the costs of reforestation by as much as 85 percent in Belize and Ugande, 67 percent in Thailand and the Ivory Coast, and by as much as 40 percent in Senegal and Dahomey. Certain species of trees (e.g. Guazuma ulmiflora, Pithecolobium saman) which are intentionally left in pastures in Nicaragua produce fruits which are consumed by cattle during the critical dry season when other forage is absent. These same trees also provide shade for the cattle, and a source of fuelwood and building materials for the rancher (Personal observation of author, Las Maderas, Nicaragua, 1981).

In an FAO/Host Country integrated watershed management project carried out in Honduras from 1976 to 1981, it was found that "agroforestry modules" (including integrated works of social promotion, soil conservation, reforestation and forest protection, and agricultural extension) represent an economically efficient alternative to migratory agriculture (Dongelmans, 1980; Michaelsen, 1981). A similar United Nations-supported project in Indonesia promotes the planting of fodder crops with trees on slopes of greater than 50 percent. The combination results in mutiple benefits both on-site and downstream: (1) Pinus merkussi to provide permanent slope protection and by products of resin and wood, (2) Albizzia falcata to improve soil quality and provide fuelwood, and (3) an underplanting of perennial grasses for fodder (Kunkle, 1978a).

Besides the benefits mentioned above, the following may also be obtained through agroforestry practices:

- Provide economically attractive alternatives to current shifting agricultural practices.
- Provide medium to long-term economic advantages as opposed to only short term
- Stimulate self-sufficiency on the small farm through a diverse agricultural base
- Stabilization of agriculture
- Provision of basic human needs of food, shelter, and energy.
- Conservation of soil and water resources, especially on hill lands.
- Reduction of pressure on remaining forests.
- Provide a biologically and ecologically diverse land-use system that reduces the chances of complete losses due to drought, pestilence, etc.

Of course agroforestry is by no means the "panacea" of land-use systems. Just as any other system, it has limitations in its application, and under some conditions may not be appropriate at all. Some of these limitations and disadvantages are stipulated by Budowski (1981a; 1981c):

- Competition of trees and plants for light, water and nutrients
- Difficulty of mechanization of agriculture with the presence of trees
- Allelopathic effects on some crops by certain trees
- Increased need of labor and maintenance
- Income advantages are realized in medium to long term when farmer desires short-term returns
- Some techniques are too complex in design for the farmer and therefore inappropriate.

In these and related cases, other land use techniques (i.e. monocultures) may be more appropriate.

PUTTING THE SERMON TO PRACTICE

Cautions have been sounded as to the dangers of promoting agroforestry programs as alternatives to current land-use practices (Budowski, 1981c; Nair, 1980; Lundgren, 1979). Because of the lack of quantitative research information with which to make comparisons with other land-management systems, there is a hesitation to encourage agroforestry in the field. The land resource base, however, might not be there when the results are in. Available scientific information and the results of observations of existing practices can be combined by the "best brains" in order to develop agroforestry pilot projects; then effectively disseminate the information (Mongi, 1979).

Nair (1980) provides a simplified approach to refining agroforestry techniques for their dissemination (figure 2) which involves the observation and analysis of existing systems to arrive at refined systems. The further refinement to improve systems through research, though ideal, is time consuming and expensive. There is an immediate need to get agroforestry into practice at a moderate development scale in all countries. Obviously, mistakes will be made, but the potential for acquiring valuable feedback and solutions to land-use problems is greater in the field than in the petri dish. This is not to disassociate research from agroforestry, rather research can run concurrently with field application and as improvements come from research they can readily be incorporated in the field. Eventhough agriculture and forestry are still evolving in the laboratory, they are practiced in the field.

It is the responsibility of local land managers and land-use planners, multi- and bi-lateral assistance organizations, and project officers to promote the incorporation of agroforestry techniques into current land-use systems in the field. The proper approach would be to promote agroforestry as part of integrated development projects/programs which would include aspects of:

- Design of program objectives with orientation to socio-economic level and needs of "target sector"

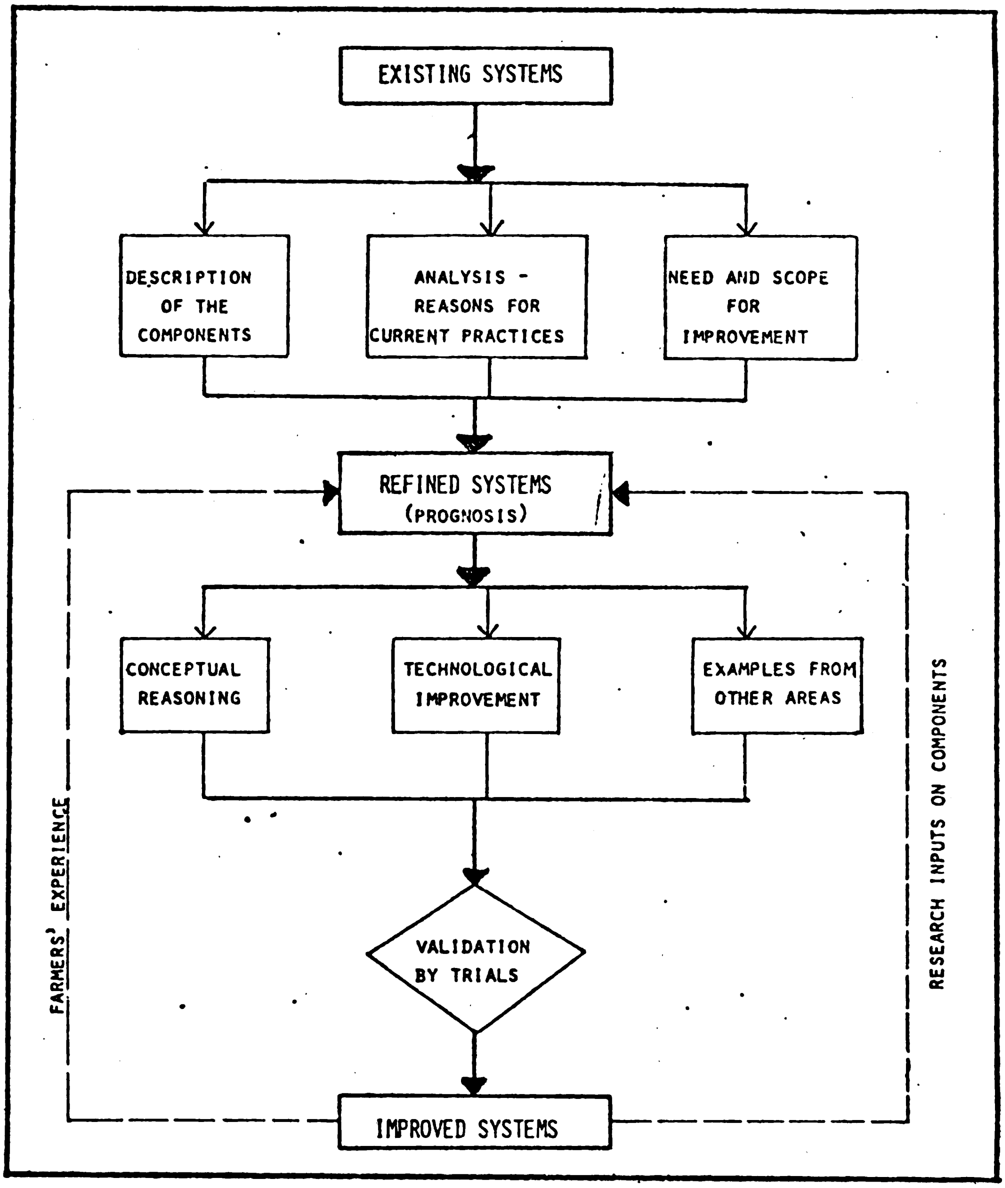

Figure 2: A simplified approach to refine agroforestry techniques (Nair, 1980)

- Organization of "target sector" into semi-autonomous action groups
- Education/consciousness-raising in environmental and agro-economic aspects
- A strong extension program in agriculture, cottage industry, nutrition, credit, etc.
- Infrastructure improvements as dictated by socio-economic needs
- Special legislation dealing with land tenure, land-use controls, contracts or charters, etc.

In the case of the small farmer at the subsistence level, the most important aspect of any such system would be food production; hence, program design would emphasize this aspect.

In retrospect, it is realized that no land-use system, regardless of its ratio of benefits obtained for effort expended, will succeed in the near future in the countries of the American tropics without informed decision making by policy makers and proper legislative support. As Eckholm appropriately states (Losing Ground, 1976):

> " *The mounting destruction of the earth's life-supporting capacity is not the product of a preordained, inescapable human predicament, nor does a reversal of the downward slide depend upon magical scientific breakthroughs.*
>
> *Political and economic factors, not scientific research, will determine whether or not the wisdom accumulating in our libraries will be put into practice*".

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