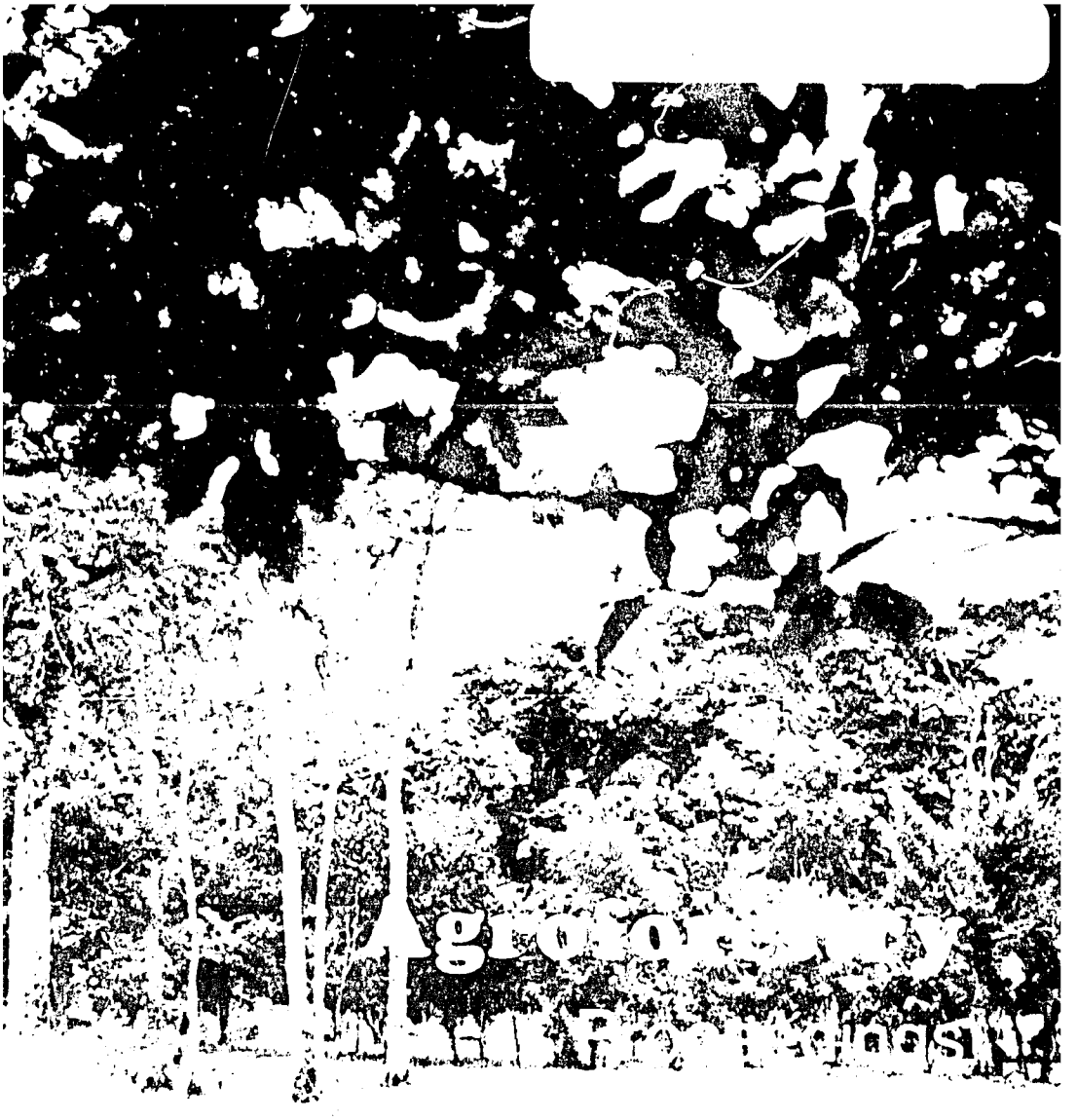

CATIE

gtz

DSE

CATIE is a civil, nonprofit, autonomous association, scientific and educational in nature. It carries out, promotes, and stimulates research, training and technical cooperation in agricultural, animal, and forestry production in order to offer alternatives to the needs of the American tropics, particularly in the countries of the Central American Isthmus and the Antilles. The Center was created in 1973 by the Government of Costa Rica and IICA. Accompanying Costa Rica as a founding member, Panama joined in 1975, Nicaragua in 1978; and Honduras and Guatemala in 1979.

The responsibility of the GTZ (German Foundation for Technical Cooperation) is to undertake technical planning and implementation of measures for technical cooperation with developing countries. The principal tasks of the GTZ are:

- Planning and implementation, control and monitoring of Technical Cooperation projects and programs with partners in developing countries;
- Advising other organizations likewise engaged in development schemes;
- Recruiting, selecting, preparing and assigning expert personnel and attending to their professional and personal affairs during their period of assigment;
- Planning the technical details of the material and equipment for the projects; also purchasing the equipment and dispatching it to the developing countries.

The DSE (German Foundation for International Development) is a civil rights foundation financed by the Federal Government and the State Government of the Federal Republic of Germany.

The DSE exists to:

- organize and implement training programs for specialists from the less developed countries in the RFA and the Third World;
- brief and debrief German specialists engaged in technical cooperation overseas;
- promote with other organizations the exchange of experience of international problems among the technicians from different countries.

Through these activities the DSE contributes to development policy of the Federal Republic of Germany.

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Agroforestry

Proceedings of a seminar held in CATIE, Turrialba, Costa Rica, 23 February-3 March, 1981

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Johannes Lagemann

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The editors

Foreword

The basic aim, development and results of the seminar were determined by the participants, which were experts from the fields of forestry, arable farming and pasture farming who are working in various tropical and subtropical regions as part of the GTZ program. The seminar took place against a background of common endeavour and the candid exchange of experience, with the will and the courage to tackle and develop new ideas. With this approach, the expectation expressed at the beginning of the seminar were, to a very large extent, fulfilled.

The introductory lectures and the discussions that followed each established suitable criteria for evaluation: whether agroforestry is more suited than other forms of land use in rural regions, and whether agroforestry holdings are superior, equal or inferior in competition with others. These have to be examined in each case from the point of view of the target group (rural population), the government, and technical cooperation.

From the viewpoint of development policy, the priorities for the Government of the Federal Republic of Germany are: development of rural regions; improvement of the energy supply; and protection of natural resources.

Efforts are concentrated in particular on combating absolute poverty and on the satisfaction of basic needs.

In the course of the seminar, it was established that agroforestry is in many cases suitable for fulfilling these objectives because it is so varied and adaptable, and that it makes an indispensible contribution to solving the priority problems in the rural regions with regard to food, energy, raw materials, environment/resources, and work/standards of living.

During the excursions, ideas and information were gained that are of immediate importance for practical application. In particular, it was impressive to see to what extent and with what degree of success farmers are already practicing agroforestry in some areas without being motivated or encouraged by aid and development programs. In addition to higher or more varied production, the reduction of risk is a crucial issue in the lives of the rural population and was always a prime consideration for the farmers. It became clear where and in what way forestry measures, arable farming, and pasturing profit from one another in integrated holdings and where the limits of combination have to be taken into account, to avoid possible disadvantages.

The group work followed a prescribed pattern that has proved its value both in practice and in research projects. The scheme dealt with the above priority problems of rural development in the following order: situation analysis, target definition, analysis of methods and evaluation of success. In the seminar, information was acquired which was both specific to a region and important for agroforestry in general. This resulted finally in suggestions and recommendations for practical application in the future for situating projects, preparation and planning, implementation and continued planning, evaluation of acceptance, project hand-over, follow-up phase, and evaluation of success.

The participants in the seminar came to the unanimous conclusion that agroforestry land use in the tropics and subtropics provides many opportunities to promote rural development and to achieve a lasting improvement of production while maintaining the productive power of the natural resources.

But in further practice, one should be careful not to arouse unjustifiably high expectations, since obviously, success or failure always depends on a multitude of specific conditions. In this respect, special emphasis was put on the importance of tropical and subtropical agricultural research and on the duty and responsibility of all those involved, not only to acquire knowledge, but also to apply it with the best possible multiplier effect, with the courage to make decisions and to promote new ideas. The excellent communication between all the participants from varied disciplines about the common objectives and possibilities must be seen as an encouraging example in this direction.

Definition and delineation of the term "Agroforestry"

Over the years there have been numerous definitions of agroforestry, some assuming very specific conditions, others assuming overlapping areas. Examples are:

1. ICRAF/Nairobi (1978): "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".

2. von Maydell (1978): "Agroforestry means, firstly and very generally, a combination of forestry and arable farming and/or pasturing measures on the same area. In view of the big differences between natural and farm locations and the socio-economic structures in the various regions, further, more precise definitions are naturally required from case to case. Basically, we should only refer to agroforestry when trees and shrubs, arable crops and/or pasture animals are kept together on a particular plot of land in such a way that they can be shown to influence each other ecologically. The result is that on the one hand, the plants and animals are in competition with one another, but on the other hand there is a certain ecological dependence on each other, or this dependence can be created, and that finally, various species supplement each other in terms of time and space".

During the discussion, the participants agreed that any interdisciplinary definition claiming universal validity would create unnecessary, scarcely solvable problems for the running of the seminar, and that it was more sensible and practical to communicate on a common basis and in terms of concrete examples. Therefore, the definition proposed by BUDOWSKI was accepted for the work of the seminar:

> *"By agroforestry we mean techniques of land use in which trees are combined with crops or pastures or with both. The combination can be simultaneous in terms of time and space or it can be phased. The objective is the sustained optimization of total production per unit of area".*

Introductory Paper

U. Vollmer

Agroforestry, which is the subject of the seminar starting today, epitomizes the concept of an integrated land use that combines elements of arable and animal production with special forms of forest use. There are numerous and varied systems of agro-silvo-pastoril land use according to the climatic, topographical and edaphic factors, and the socio-cultural conditions. Some of these systems are rooted in history and tradition. Our own history of the forest economy in Germany reminds us that it was common practice in various regions of our country to use the forests for food production or for livestock and to manage them accordingly. On the other hand, even today in extensive areas of the tropics the normal form of land use is the so-called shifting cultivation, with temporary use of the forest floor for agriculture after clearance by fire. Shifting cultivation is practiced particularly by those sections of the population living in remote regions outside the money economy.

But the results of the rapid growth of population and of the socio-economic developments in recent decades automatically influence the forms and systems of land use. This applies particularly to countries in the tropics. Under these conditions it is necessary to think about traditional as well as modern forms of land use. Where required, new land-use systems should be developed and introduced in keeping with the rising need for food, energy and raw materials, and with the ecological requirements.

What role can or should agroforestry play under these conditions of dynamic change? From the point of view of the development policy pursued by the German Government, we should first state that, within the general target of promoting the economic and social development of our partner countries, the fight against absolute poverty is regarded as priority. A central issue in creating development policy is the satisfaction of basic human needs as sufficient food, health care, and suitable living and educational facilities. The priority target groups in our cooperation with partner countries are those sections of the population that have not participated sufficiently in economic and social progress. This applies particularly to the peasant farmers and landless poor in the rural regions of the Third World.

The task that must be given the highest priority among the numerous problems of development policy awaiting solutions is the guaranteed supply of sufficient food. The 800 million people who suffer from hunger or malnutrition in the Third World demonstrate the seriousness of the existing state of affairs. Moreover, to feed those 2 billion people who, it is estimated, will be added to the world's population by the year 2000, increasing it to 6.5 billion, presupposes that, in addition to the production levels already achieved, approximately the whole of the world's food production of 1950 will need to be produced. With an average annual growth rate of somewhat less than 3o/o, food production in the Third World, as a whole, has in

* BMZ (Federal Ministry for Economic Cooperation) Bonn, Federal Republic of Germany.

the last 20 years been able to keep pace with population growth. But whereas in some areas, particularly Latin America and the majority of Asian countries, the per capita supply of food has improved, it has clearly declined in a considerable number of African countries.

In this context it should also be noted that the growing population and increasing requirements, together with the better supply of food, also mean a greater need for energy and raw materials. Thus, when we concern ourselves with the effects of the progressive exhaustion of fossil sources of energy that affects us all, we should not forget that a large majority of the rural population in the developing countries are dependent, today as in the past, on the availability of firewood and plant or animal waste for cooking and heating. The Sahel countries of Africa, where 60 to 90o/o of the total national energy consumption is derived from firewood and charcoal, are certainly extreme cases. But the data available on the structure of the energy consumption in other countries indicate that the situation in many rural areas of the Third World is not fundamentally different from the above examples.

Covering the food and energy requirements of a rapidly expanding population is an extremely difficult task, especially when we take into account the situation regarding natural resources and their development.

The experience of the past decades is worrying, and a change in land use as practiced in many regions must occur if a further depletion of natural resources, the basis of human existence, is to be avoided. Some figures and data will illustrate the processes and development trends already underway.

The growing shortage of land reserves caused by increasing population pressure is reflected in estimations that calculate the cultivable land area by the year 2000 will be below 10o/o of the current arable land area in the world in clear contrast to the assumed population growth of 50o/o over the same period. Whereas Latin American and some African countries still have considerable land reserves in the form of natural forests, in Asia the largest portion of cultivable land is already being used. Under these conditions it can be assumed that the additional food production necessary in the next two decades must be achieved mainly by intensifying land use in the existing cultivated areas, whereas extending arable land can only be of secondary importance.

On the other hand, if the current destruction of the forests in the tropics continues (the annual rate of loss of tropical forests is currently estimated to be about twice the total forested area of the Federal Republic of Germany) we can expect this to be reduced a further 40o/o by the end of our century.

Examples like Thailand, which lost 25o/o of its forest area in 10 years, or the Philippines, reported to have lost 15o/o of its forests in only 5 years, illustrate the speed at which forest destruction is occurring in regions with high population pressure.

Ecological damage caused by land-use practices incompatible with the support capacity of soils and natural resources can be seen in the following figures: about 20o/o of cultivated land worldwide is affected by erosion leading to a considerable decrease in crop yields. Year after year in the semi-arid and arid climatic zones, more than 5 million hectares of potentially productive lands are lost through desertification. Irrigated agricultural land, whose production capacity is badly impaired or threatened by salting, by becoming too alkaline, or by soil shifting, is estimated to be about 50o/o of the total agricultural area. Finally, I should also mention that growing pressures on natural resources, as well as types of land use practiced in many places, make it doubtful whether many of the natural fauna and

flora will survive. The *Global Study 2000* that U.S. ex-President Carter had done by an inter-disciplinary group of experts revealed that up to 20o/o of all plant and animal species, especially those in the tropical forest habitat, could be in danger of extinction by the end of the century.

Against the background of these facts and tendencies, the Government of the Federal Republic of Germany passed its *Principles of Development Policy* in July, 1980, in which it designated rural development, energy supply, and the protection of natural resources as the main areas of concentration in development cooperation with countries of the Third World.

In my opinion, agroforestry can make an important contribution to solving the land-use problems mentioned above.

Undoubtedly, the future food supply will depend mainly on intensive forms of agriculture and cattle-keeping where the right natural conditions allow. But agroforestry will have to adopt an increasingly important role to underpin the supply of food, energy, and raw materials, especially in regions with high population pressure and unstable environmental conditions. To achieve this objective, much research and experimental work will have to be done. The information and knowledge about agroforestry available in various parts of the tropics, moreover, needs to be systematically collected, evaluated, and incorporated in transferable models.

For all these reasons, the Federal Ministry for Economic Cooperation in Bonn is attributing great importance to this seminar that will deal with the different technical, economic, and social aspects of agroforestry. The practical emphasis of this conference is illustrated by the fact that it is jointly organized by the German Foundation for International Development (DSE - Deutsche Stiftung für Internationale Entwicklung), the German Agency for Technical Cooperation (GTZ - Deutsche Genellschaft für Technische Zusammenarbeit) and the Tropical Agricultural Research and Training Center (CATIE - Centro Agronómico Tropical de Investigación y Enseñanza). The seminar should, at the same time, be seen in the context of constructive cooperation as practiced in the past by CATIE and the German Institutions active in this field and also as envisaged for the future.

The composition of the specialist participants in the fields of plant and animal production and forestry is an indication that practical solutions to the problems to be discussed here can only be expected on the basis of an interdisciplinary examination of the system of agroforestry.

Agroforestry in Central America

G. Budowski*

General consideration

Agroforestry implies combining trees with crops or domestic animals, either simultaneously or in sequence. It is one of the curiosities of tropical forestry (and for that matter also in the agricultural sciences) that agroforestry has been rather blatantly ignored even though it has existed all the time and has played a most important role in the lives of rural inhabitants. With the exception of *taungya* which is now well over 100 years old, very little is known concerning most agroforestry systems, even if some of them appear to be extremely productive and rather sophisticated, and of course stable, possibly as a result of evolution over decades or centuries. At present much of the research in various countries amounts to the *discovery* and description of existing systems. It is interesting to speculate why this is so, and many arguments have been advanced: the avoidance by scientists of agroforestry systems because of their complexity and the great difficulty in setting up an experimental design, the present training of scientists in certain specialities of fields rather than in complex land use systems (how much do tropical foresters know about food plants and how do agronomists fare vice-versa?), the past reliance on cheap direct or indirect energy sources in agriculture, able to replace the beneficial effects of trees on crops (fertilizing, weeding, plowing, pest control, etc.) and perhaps more than anything else, the indiscriminate transference to the tropics of capital and technology-intensive methods which originated in temperate regions. Finally, the socio-cultural dimension of agro-forestry, so important in many countries, still adds another dimension that complicates a better understanding of the problems, at least from the researcher's viewpoint.

Moreover, there are a few mental blocks that must be overcome concerning agroforestry. Among them is the belief that agroforestry is mostly practiced by the rural poor or that it is restricted to *marginal* lands, (see, for instance, Table 1 below). This matter has been particularly stressed in a most stimulating publication that in a way led to the Foundation of ICRAF, the International Council for Research in Agroforestry *(Bene et al, 1979)* which pointed out that "...more than half of all land in the tropics, although too dry, too steep, too rocky to be classified as arable land, is suitable to the practice of agroforestry", and this statement in fact, was placed in a box for emphasis.

Actually, the more agroforestry is studied, the more it becomes clear that it has achieved productive and stable systems on all kinds of lands, on good and poor

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CATIE (Tropical Agricultural Research and Training Center) Turrialba, Costa Rica.

soils, with varying relief, climatic conditions and under different socio-economic conditions. Students who have taken agroforestry courses at CATIE report that they are now *discovering* agroforestry systems in areas they had repeatedly visited without noticing them.

A full discussion on agroforestry practices in Central America and elsewhere in Latin American can be found elsewhere (BUDOWSKI 1977, 1979 and 1980; CATIE, 1979; COMBE and BUDOWSKI, 1979). The present discussion will only attempt to emphasize some examples with a few speculations on social implications. A good introduction to the subject would be a comparison between agroforestry systems and monocultures resulting from lengthy discussions and exchange of experiences between researchers in Mexico and CATIE. The following table should be considered as tentative, and many of the statements found are clearly subjective. They represent mainly opinions or viewpoints by different people, not necessarily based on proven measurements and valid comparisons, aimed, above all, at stimulating discussions. It should be noticed that the second part of the table emphasizes socio-economic implications (Table 1).

Table 1. Comparison of advantages and disadvantages of some agroforestry systems (presence of trees within crop-lands or pastures) as compared with monocultures of these same crops or pastures.

Biological and physical aspects	
Advantages	**Disadvantages**
A better utilization of the vertical space and cropping period is achieved, and natural ecological models are simulated as to form and structure; solar energy is more efficiently captured.	Trees compete for light needed for crops or grass.
A larger biomass returns to the system (organic matter) and often is of better quality.	Trees may compete for nutrients.
There is more efficient recycling of nutrients including their *pumping* from the deeper soil layers.	Trees may compete for water (especially where there is a strong dry season).
Appropriate for marginal areas since there is likely to be a larger resistance to rainfall variability; it can also be practiced on steeper slopes.	There may be allelopathic influences.
The damaging action of rainfall and wind is reduced.	The harvesting of trees may cause damage to crops.
Fertilizer applied go *a longer stretch* since tree roots can *capture* nutrients that move beyond the area of crop or grass roots and recycle them.	There is no rest *period* (with a secondary forest stage) like in shifting cultivation.
Leguminous trees (and some from other families) fix and incorporate nitrogen.	Mechanization is impossible or made more difficult.
There is more mulch and lesser weed growth.	The greater air moisture can favour diseases (mostly fungi).
The soil structure is improved (more stable aggregates) and a hard pan is prevented.	Rain drops forming in the crown of trees can cause damage.
Diversity of species hampers insect proliferation.	A proliferation of noxious animals can be favoured.
There may be beneficial influences due to mutualism.	There could be excessive *export* of nutrients if trees are consistently harvested.
	The system is more complex and little understood. Any experimental design with statistical analysis is likely to be more complicated.
	In some cases yields of crops or grasses are smaller with less economic returns.
	In many ongoing economic structure, it is considered that the system is not *efficient*, because of the inherent complexity of operations needed to make it function effectively.

The farmer (particularly poorer ones) satisfies partly at least, his needs for firewood, poles, timber food, flower for honey, medicinal products, etc., and does not need to buy these.

Trees constitute a *standing capital*, an assurance against emergencies, when quick cash is needed.

Dependency on one single crop is avoided and traumas associated with irregular rainfall, market fluctuations, dependency on imported products (pesticides, fertilizers), outbreak of pests, are mitigated.

There is less need to import energy and/or to pay for products outside the area.

Investments to establish tree crops are reduced (such as in *taungya*).

Diversity and the interdisciplinary nature can be considered an asset for quality of life.

Social cohesion and team work can be promoted.

Trees serve to mark property boundaries and constitute a safeguard device against land usurpation.

Some schemes allow to gradually change from destructive land use practices towards more stable systems, without diminishing productivity.

There is more flexibility to distribute labour during the year.

Wildlife is favoured and in some instances can be a suitable source of protein.

There is obviously considerable scope to design "new" systems by associating the most desirable species.

Normally more labor is required

It is argued that some agroforestry practices do not stimulate farmers in moving out of their present socio-economic status (poverty or subsistence level).

Economic recuperation may take a longer time for people with low incomes (because of the time lag in cropping trees).

There may be opposition from some political and socio-economic structures towards agroforestry systems because of ignorance or false premises.

There is scarcity of trained personnel to improve and handle agro-forestry systems and install new ones.

There is lack of knowledge on the potentialities of agro-forestry systems among decision makers and this results in scarcity and lack of funds for research and extension programmes.

A few successful case studies on agroforestry

Alder in the highlands of Costa Rica

For at least 80 years, a local alder species *(Alnus acuminata)*, has been successfully planted at elevations between 1.300 and 2.500 meters with high rainfall (2000 - 3000 mm) and good soils in the dairy region in Costa Rica. The presence of alder trees is said by many to increase fodder production. This is an area where milk production is high, and many farmers are rather affluent. The trees are planted at wide spacings within pastures that are grazed *(Pennisetum clandestinum)* or cut *(Pennisetum purpureum* and *Axonopus scoparius)*. Most alder trees found in pastures are regularly pruned. The spacing of the alders can be any combination between 8 x 8 m to 15 x 15 m. Alder fix nitrogen through large nodules *(Frankia* sp. of the Actinomycetes). Some initial measurements indicate a mean annual diameter increment of 2-3 cm with harvesting after 15-20 years (CATIE, 1979).

The easily worked wood is used for multiple purposes where durability is not a requisite. The social implications have been partly studied by Poschen (1980) through questionaries distributed to dairy farmers which reveal a series of beliefs and assumptions among farmers that deserve more careful research. The practice of planting alder in pastures is presently increasing.

Coffee or cocoa with one or two strata of "useful" shade trees

Although the trees above coffee or cocoa are usually referred to as *shade trees*, their function and usefulness is clearly much greater than strictly for shade. Many of these advantages are outlined in Table 1. The system over coffee and cocoa have been evolving over the past years, and it is now frequent in various regions, particularly in coffee, to have a leguminous tree as an intermediate canopy (*Erythrina* spp. or *Inga* spp) overtopped by a tall and valuable timber tree with a narrow crown (*Cordia alliodora*). The leguminous nitrogen-fixing trees are severely pruned back in the case of coffee, usually twice a year. Several plots of *Cordia alliodora*, 15 to 17 years old, showed a mean annual diameter increment of 1.8 cm, an average height of 22-23 meters and a mean annual volume increment of 10-11 m^3/ha/year (COMBE and GEWALD, 1979). The practice is increasing, and several measurement show that coffee yields are high and compare favourably with neighbouring plots without *Cordia alliodora*.

Live fence posts that produce wood, food, feed, and more fence posts

Throughout tropical America, the practice of raising trees from large cuttings that root easily, to establish fences to keep cattle out, is extremely widespread. Fences can be grown by planting cuttings closely together, often mixed with low bushes or, more commonly, they serve as supports for barbed wire. The practice has received very little literature coverage and is currently being investigated as to its biological, social, and economic effects. The following summarized analysis again should only be considered as preliminary since it covers over 50 tree species in six Central American countries over a great diversity of conditions (Table 2).

Taungya as part of a strategy to change land use

Throughout Central America and the Caribbean the original forest has been cleared from large areas of steeply sloped land in order to establish low yielding pastures, many of which eventually revert to secondary bush. At present there appears to be great interest in converting such slopes into forest plantations for firewood, pulpwood or timber, or any possible combination. Taungya has a long history in the Central American and Caribbean region particularly in: Trinidad (as early as the twenties) with teak, and Caribbean pine; Belize (teak, Caribbean pine, *Gmelina*); Surinam; and at CATIE, Costa Rica, the latter with *Cordia alliodora*, *Gmelina arborea*, *Eucalyptus deglupta* and *Terminalia ivorensis* (COMBE and GEWALD, 1979). The latter four species and *Pinus caribaea* have shown particularly good adaptation in areas of high rainfall (2000 - 4000 mm) at elevations up to 1200 m. The associated crops have been maize and beans, cowpeas and string beans.

Table 2. Comparison between live fence posts and wooden fence posts (the latter either naturally durable or treated with preservatives). Both posts are being used to attach barbed wires and to prevent trespassing principally by cattle.

Factor	Live fence	Wooden (dead) fence
Choice of species	Depends of ecological conditions	Many possibilities depends
Cost	Relatively low or free	Relatively high
Handling of post before placing	Needs careful preparation, transport and storage	No special care require
Placing in soil	Needs care, adequate soils	Soil not limiting
Placing of barbed wire	Special techniques in some species	Some skills required
Initial maintenance	Necessary, requires protection against some animals	None, in some cases needs fire protection
Survival	Losses possible	100 %
When to place wire	Usually when well anchored	Inmediately
Increase of post density along fence	Easy and cheap	Easy but expensive
Durability	Usually very long	Variable, limited according to treatment and species
Organic matter production	Varies with species	None
N fixation	Possible in some species	None
Effect on soil fertility	Beneficial, especially when branches are pruned and some roots die off (aeration)	None
Erosion control	Can be effectively used as barrier	None
Competition for water	Does exist but varies according	None
Erosion control	Can be effectively used as barrier	None
Competition for water and nutrients and light with nearby crop	Does exist but varies according to system; organic matter production compensates	None
Protection of crops and/or animals against wind	Effective but varies according to species height, density	None

(Tabla 2. Cont.)...

Factor	Live fence	Wooden (dead) fence
"Horizontal" rain (fog drip) from moisture ladden winds	Possible	None
Toxic effects	Possible (allelopathy)	None, (except when some preservatives are used)
Toxic fauna	Can be sheltered	None (except termites in some cases)
Beneficial fauna	Provides shelter and food (e.g. birds, honey bees)	Little
Additional economic products	Many, such as food, feed, medicinal products; also firewood, posts and more live fence posts	None
In case removal is necessary	Difficult and costly	Relatively easy
Labour for management	Periodical pruning is necessary; skills required	Skills also required to place posts and wires and replace them
Acceptation by farmer	Very popular among poorer farmers	Depends on income. More affluent farmers tend to avoid live fence posts
Special limitations	Disliked by fumigation pilots	Firebreaks must be kept clean during fire season
Aesthetics appreciation	Depends on management and cultural background	Depends on investment possibilities and cultural background

A series of programmes are presently being visualized to convert large areas of degraded lands in all of the Central American countries as well as the Dominican Republic and Haiti into tree plantations. Thousands of farmers are expected to be involved in the programmes which allow them to combine field crops with seedlings of valuable trees for approximately two years and then has them participate in the tending and harvesting operations, therefore, changing gradually land use from extensive (and destructive) grazing to forestry. The rising prices of firewood, posts, timber, and pulp and the possibilities to eventually produce large and cheap sources of biomass on lands that do not compete with agricultural crops, have generated much interest from funding agencies.

In Costa Rica, the introduction of Caribbean pine 20 years ago, and the ready acceptance of local farmers to plant small plots, has led to the establishment of

pines and other species, and eventual grazing of these plantations under controlled conditions is presently being studied, the latter to keep the grass down, reduce weeding costs and produce additional income. There is already some experience on grazing pine plantations in Surinam and Jari (Brazil), and field trials are under way at CATIE, Costa Rica. The obvious interest in financing such schemes lies in a combination of factors: protecting degraded slopes from erosion and regulating run-off, providing wood for an industry that is willing to pay higher prices, for timber, firewood and charcoal (which are in great demand), and above all, proving thousands of farmers who have become impoverished from past misuse of land with a new source of income without drastically changing their way of life. Clearly, all these prospects need to be investigated in the light of land tenure problems, government incentives, long-term economic prospects, acceptance by the farmers, and careful planning of the relationship between wood-using industries and participating local farmers. There is an obvious role for governmental authorities to play, but misunderstandings and failures can easily happen.

Multiple use

The possibilities of promoting multiple use of forest land, particularly as a medium to improve the lives of people living near or within the forest, have not yet been well investigated in the region although this may not be so much a result of insufficient case studies as of ignoring the social factors.

A case in point is the Luquillo National Forest in East Puerto Rico covering an area of low and middle elevation mountain ranges with heavy rainfall. About forty years ago, the forested area, mostly secondary, was dedicated to silvicultural research (managing the natural forest and establishing plantations) as well as watershed protection, but increasingly over the years, it has become a focus of attraction for local and foreign tourists with recently over one million visitors per year. The effect on the local population has not been well studied, but it certainly has produced a powerful attraction for the Puerto Rican tourist industry with various favourable economic implications.

Another interesting development has been the creation in 1979, of the Río Plátano Biosphere Reserve in Northeastern Honduras, covering 180,000 hectares of rainforest (DIGEREMARE and CATIE, 1978). Besides the biological and archeological interest for science, a prominent reason for the establishment of the reserve has been the maintenance of the life style of the "Misquito" Indians with their peculiar agricultural, hunting, and fishing practices.

A better knowledge of the relation between multiple use and its influence on people living in the area where practiced is essential and there is a wide open field for research which would be of great use to planners and decision-makers.

Summary

Four broad categories of forest management in Central America and some countries of the Caribbean, namely for protection, wood production, a combination of agriculture and forestry (agro-forestry), and multiple use, are analyzed as to their present and potential impact on local populations living within or near the forest. Many problems resulting from past and present massive deforestation and

lack of management negatively affect local populations. In the light of experience from the region, it appears that large reforestation schemes on land that has been degraded would provide interesting opportunities for stable forest communities in the light of the shortage of forest products and the need to control erosion. Capitalizing on present widespread agroforestry practices appears to be particularly promising in some areas, but a better understanding of the biological and social characteristics of some of the present systems is required to launch successful improvement programmes. Some examples of multiple uses are also described, notably, the use of a national forest for recreation and the establishment of a Biosphere Reserve where the rights and customs of local populations are safeguarded.

Contributions from participants on the lecture

In the definition, the question of *optimization* is discussed. This does not necessarily refer only to an increase of yield. According to the target group, other aspects, *e.g.* optimizing yield reliability, can be more important.

With that definition in mind, the lower end of the scale of agroforestry is difficult to pinpoint. Fireclearence crops can, of course, be included as far as tree components are specifically used. However, it is not a question of making fireclearence acceptable, but of extracting from it any traditional, positive information that can be utilized. Stability criteria have to be considered at the same time.

Conversely, it must not be forgotten that in the Taungya system, for example, or in the case of pasturing, there are also destructive elements present.

In the definition of terms, it is much more difficult to state the conditions under which agroforestry takes place successfully. Among these are population density, pressure on land, land ownership conditions, etc.

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Criteria for planning and evaluation of agroforestry projects

H.J. von Maydell*

The development of land use in the tropics in recent decades has not often led to the anticipated success. The supply of agricultural products to the population has not been sufficiently improved; indeed, it has sometimes deteriorated, and the natural resources have been and are being destroyed to a frightening degree; unemployment and the drift from the land is increasing, etc. The recently introduced techniques of land use with plot separation, mechanization, high inputs of chemicals, monocrops, sales (export) oriented production, and similar features that have been mostly adopted from the industrialized countries in the temperate zone have only proved their worth in limited sectors of agriculture; in other sectors they have also led to structural damage. In any case, the problems of rural regions in the Third World have not been solved by these practices.

In the search for other ways, we came across agroforestry, a many-sided bundle of traditional land-use techniques that permits a careful but consistent further development of practices that have been traditionally adapted and that have grown organically. Because of insufficient expertise, and especially because of insufficient appreciation of interdependent factors in this kind of agroforestry land use, unjustifiably high expectations were initially aroused; indeed, agroforestry was regarded as a panacea, especially for marginal areas. The dangers are obvious: unrealistic hopes, disappointment, missed opportunities.

What in fact must be asked, bearing in mind the extensive and varied tasks of development policy under the quite specific conditions and requirements of a concrete case, is whether agroforestry is better suited than other forms of land use, whether agroforestry holdings are superior, equal, or inferior in competition with others. The people responsible for land use need to establish to what extent projects, holdings, or programs can produce or have already produced benefits in terms of satisfying the needs of particular individuals or communities. If the results of this type of investigation are positive, the reasons ought to be ascertained, and all the possibilities that present themselves should be consistently exploited. If, however, there are difficulties or disadvantages, their causes must be investigated to see whether they can be eliminated or modified or whether the projects in question should be abandoned. Working criteria must be established for the advance planning phase, for checking the success of the project as it progresses, and for the retrospective evaluation.

Needs (even *basic needs*) and *benefits* are largely subjective concepts. Therefore, the evaluation of success of an agroforestry project can only produce meanigful

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results if it is clear from what point of view the evaluation was undertaken and whom it should serve.

In the search for meaningful criteria for the planning and evaluation of agroforestry projects, it is often difficult in practice to find reliable criteria quickly and at reasonable costs because: Agroforestry projects represent complex systems with respect to their structure and objetives; also, there are different views among the participants (government offices, foreign donors, project workers, farmers, and people or groups interested in land use) as to what the objectives should be and what results (positive or negative) should be evaluated; and because problems arise in expressing the *value* in comparable units (e.g. units of currency) or in converting the value into these units.

In view of the difficulties, that can only be touched on here, to which should be added the problems associated with data collection, a simple scheme will be proposed that has proved its worth in theory and practice and that can be extended at will if the situation so requires. This scheme involves, first of all, posing the following questions: What is the state of affairs (analysis of development and situation trends)? ; what is the objective (definition of target and tasks)? ; how can it be achieved (analysis of procedure)? ; does it pay (evaluation)?

What is the state of affairs?

We cannot go into detail here regarding the data that must be collected and how this is to be done. Instead, we should simply emphasize that it is essential to have carefully collected information before the actual planning phase, if wrong decisions, losses and setbacks are to be avoided. The initial information should comprise, among other things, the natural location, but equally the economic location and therefore the socio-economic conditions.

The factor that must be decisive for a project in the context of rural development is what the people, who are supposed to benefit from the project (the target group), need, want, and can achieve. It is important to try and understand the causes and connections in traditional structures that, for an outsider, may appear inappropriate. The farmers' and shepherds' knowledge and experience of a particular region is usually infinitely greater than that of the *expert* coming to advise them. His first job, therefore, is to learn, so that he can then improve and change things by drawing on his expertise, his overview, his ability to evaluate, and the means at his disposal. This phase, *What is the state of affairs?* , is especially significant bearing in mind the often complicated structural interrelations within agroforestry systems and between them and their environment.

What is the objective?

A clear definition and delineation of the targets, a systematic ordering of those targets, and the creation of an order of priorities arising from them, should be a matter of course for all agricultural development projects. From these targets derive the problems to be solved by the project.

In agroforestry projects, the targets can be very complex; they can be competitive to a certain extent or even exclusive. In practice there is always the job of selecting the best option. There are, in addition, possible (and in practice, virtual-

ly daily) target conflicts between individual participants or related groups. For the work planned for this seminar, we shall differentiate in simplified form between the targets of the governments of the countries concerned, and their particular agencies; those of the target groups in the rural population: of the farmers, shepherds, and forest owners/users who are included in the project; and those of the organizations of technical and economic cooperation, *e.g.* GTZ, which make their contributions as partners of the government and of the personnel of these organizations.

An important task of the project work can be to achieve compromises wherever there are conflicting targets.. The other tasks arise from the delineation of the targets in terms of time, space, and materials.

How can it be achieved?

When it is a question of agroforestry as such, there can be no general quidelines. But the versatility and adaptability of agroforestry land-use techniques to the locational and socio-economic conditions and to the needs of the target group enable a frequently optimal input of resources to be made in the context of rural development. Just a few aspects will be mentioned here:

- The priority should be to do what is most urgently required, not what can be done easily (according to the sense of a Sanskrit saying: you should do not what you would like to do but what brings most benefit). This means in the case of tree plantations, for example, that the species to be used should not be those that grow with fewest problems but those whose specific production efficiency and protection value are most needed, (e.g. the conflict between growing, for example, eucalyptus and native species).
- Cropping and management techniques have to be adapted to the aims of the holding even when these aims appear unusual from the point of view of traditional agriculture and forestry. Thus, fodder trees or shrubs for goats and other grazing animals have to be treated differently from firewood and industrial timber plantations (e.g. arid hilly regions), stands for litter harvesting have to be treated differently from protective forest (e.g.: People's Republic of China), etc. This often requires rethinking and *interdisciplinary understanding*.
- Agroforestry land-use techniques often are suited also to marginal locations, but by no means just to these, as many examples of multi-storey and mixed intensive crops in the best locations (e.g. oases) prove. Particularly with respect to agroforestry in the small scale farming sector, in general no attempt should be made to operate on extensive land areas; instead it is preferable to start from small centers of need and the best conditions and to radiate outwards step by step. Examples are the domestic gardens in S.E. Asia, the *oasis principle* that has been developed for the agroforestry projects of GTZ in Senegal and Upper Voita, and last but not least, the general realization that, with limited resources, areas of special emphasis have to be created.
- The creation and maintenance of a particular optimal tension is a prerequisite for food performance, but too much tension can lead to breaking and collapse (as with a bow and arrow). This means, for the input of plants and animals in agroforestry, that the goal should be not a climax condition (that would be unproductive) but a sub-climax situation with optimal production. In saying this, we are

touching on that extremely problematic area between necessary production and maintenance of the natural resources.

- We have to warn against assuming that agroforestry is a land-use form that enables maximum outputs to be achieved with minimal inputs. There is no such form of land use, unless resources are ruthlessly exploited. Agroforestry indeed requires especially high inputs because it is, or can be, a question of intensive land use. But if taken to its limits, it can result in a substitution of plentiful and available investment goods for those in short supply, locally available goods for goods that have to be imported, etc. Examples: the input of human and animal power instead of machines, the use of existing energy sources instead of imported oil, the use of soil-improving plants and animal manure instead of artificial fertilizers.

Does it pay?

As we can see from the above, an evaluation of success is far from simple. Again we have to ask from whose viewpoint the success is to be measured. Input/output analyses, with all the usual reservations, are relatively simple. They become complicated because of the variety within the agroforestry systems and the necessity to make not only quantitative but also qualitative evaluations (e.g. not only whether more or less coffee was produced, but also whether its quality changed).

There are other important areas that cannot easily, if at all, be quantified in units of measurement, e.g. the change in ecological conditions, social structures (the number of nomads who have been settled can be ascertained, but the significance for development policy can hardly be quantified), the gain or loss of cultural values. Criteria like the reduction of drift from the land, humanizing the work place, reducing the risk to people's existence in the project area, have their own, often overriding importance. In any evaluation, they and the experience gained in the course of a (perhaps at first loss-making) project have to be represented as entities in their own right and weighed, and then given due consideration in the overall evaluation.

Conclusions

Interdisciplinary agroforestry projects, that can be very differently structured because of the particular conditions and targets, require a very high degree of expertise and appreciation of development policy both at the planning and implementation stage and during progress control and at the final evaluation. The vital criteria for planning and progress control can be ascertained from the concrete examples of different cases. Agroforestry projects usually require an interdisciplinary team, but in all cases close and frank cooperation with the farmers concerned, the forestry people/forest owners and the shepherds, and with all the responsible levels of government. These produce the relevant or decisive criteria that enable a determination of whether agroforestry is better suited than other forms of land use to solve the problems of an actual area. Because of its versatility and adaptability, agroforestry offers a very good possibility of achieving this cooperation.

Contributions from participants on the lecture

Regarding the developing countries, previous development policy (including forestry) has been overseas-oriented. The indigenous rural population was thereby neglected and subsistence agriculture criticized. In situations like these, agroforestry can offer alternative forms of land use.

Questions of land use are becoming increasingly the central problems in development policy. Due to growing (population) pressure, the conflicts are becoming more and more apparent, and the targets need to be more and more realistically and precisely designed at a time when the choice of possible solutions has decreased.

Several precisely formulated targets produce conflicts. A few flexible targets permit concentration on essentials, and the current development can be better incorporated into a project. In all cases a hierarchy of targets can be seen to emerge.

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The soil science basis of agroforestry production systems

G. De las Salas and H.W. Fassbender

Agroforestry is presented as a series of land-use procedures in which the combination of trees, arable crops, and pastures are interrelated in terms of time and space in order to ensure a lasting increase and optimization of production. Thus, agroforestry makes very high, integrating demands on many sciences such as forestry, agriculture, soil science, ecology, sociology, and economics, necessitating multi-disciplinary research to profound agroforestry production systems, to organize and steer them.

In agroforestry production systems, the soil plays an important role because it is crucial as the supplier of water, nutrients, air, and rootspace for tree and arable crop growth. The effect of the climate on agroforestry production systems is direct (temperature, ligh, relative humidity, wind, etc.) or indirect, via the soil. The demands of combined agroforestry production systems on the soil are high: the large number of crops arranged according to space or time require large amounts of nutrients and water. The interrelations between plants, climate, and soil are especially numerous in agroforestry production systems compared with monocrops, and in this comparison, they have a large number of advantages, such as:

- Vertical banding and gradations of temperature;
- Humidity and wind conditions whereby various growth space optima can be created;
- Increase in organic material (leaf litter);
- Improvement in soil structure and water absorption capacity of the soil, especially by deep rooted legumes;
- Separate use of nutrients and water at different soil depths by plants with different root systems;
- Improvement of erosion protection and weed control;
- Increase in desease resistance;
- Regulation of the life of the plantations and improvement in product quality.

However, the use of trees in combined production systems can also have negative effects:

- Competition for light, energy, nutrients, and water;
- Damage to crops when thinning and harvesting the trees;
- Mechanization of work processes being made more difficult.

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A recent publication by ICRAF (International Council for Research in Agroforestry) deals with various aspects of soil science in agroforestry (9). PRATT and LUNDGREN have dealt with details of soil science research projects and strategies in agroforestry. Attention is simply drawn to these works. This paper is an attempt to transfer eco-pedological points of view in the description of forest eco-systems to those of agroforestry production systems.

The cycle of water and nutrients in forest eco-systems

In describing the water and nutrient cycle in natural forest eco-systems, a principle of eco-system research has increasingly established itself in recent years. To record the cycle of water and nutrients, it is essential to record the various components of the eco-system and to investigate the transport and exchange processes of water and nutrients between the components. In addition to the many results from temperate areas, the results of surveys in Latin America by ODUM (11), GOLLEY et al (4), FOELSTER and FASSBENDER (3) and FASSBENDER and GRIMM (2) should be noted. Figure 1 shows the forest eco-system subdivided into various components, so that an inventory can be made, e.g. vegetation, layer of humus and mineral soil, or individual ingredients of these components. To record the organic substance in the vegetation, selective samples are taken by clearing plots or harvesting trees in selected areas.

Selective samples are subjected to chemical analysis to determine the nutrients. From the stock of nutrients and concentrations in these samples, the contents in the components can be calculated. To establish the organic substance in the humus layer, repeated samples are taken and weighed. The organic substance in mineral

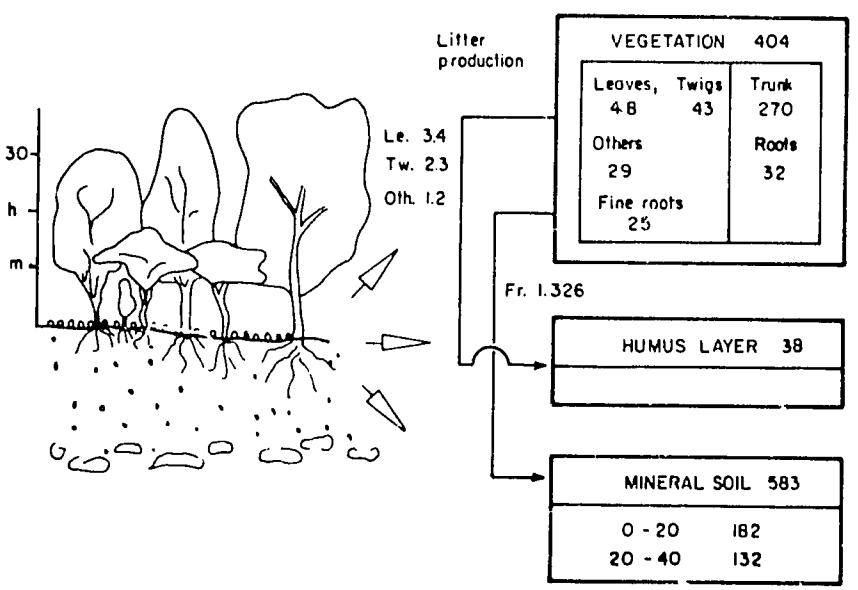

Figure 1: Cycle of organic matter in the forest eco-system of San Eusebio, Venezuela (stocks t/ha, transport t/ha per year).

soil is determined by the usual laboratory methods. By determining the content and soil weight, the total amount of organic material and nutrients are calculated.

To establish the dynamic processes, partial transport processes are investigated. The decomposition and release of nutrients in the soil can be determined from the plant remains in the leaf litter. With the help of chemical analyses of water samples from rainfall, run-off from trunks, surface run-off, percolation, and groundwater discharge, the transport rates in water are worked out.

Figures 1 and 2 show the models and results of the carbon and nitrogen cycle in a forest eco-system in the northeast Cordillieren of the Andes in Venezuela (2). This attempt enables us to show the reserve of organic material and nutrients in the various components of the eco-systems. Additionally, the areas between the components can be interpreted and the stability of the eco-systems described. Also we can deduce information about the interrelations of the individual components from the transport processes by water and in the leaf litter. The initial models achieve particular importance by allowing the simulation of the results and a time projection by which long-term changes in the eco-systems can be observed.

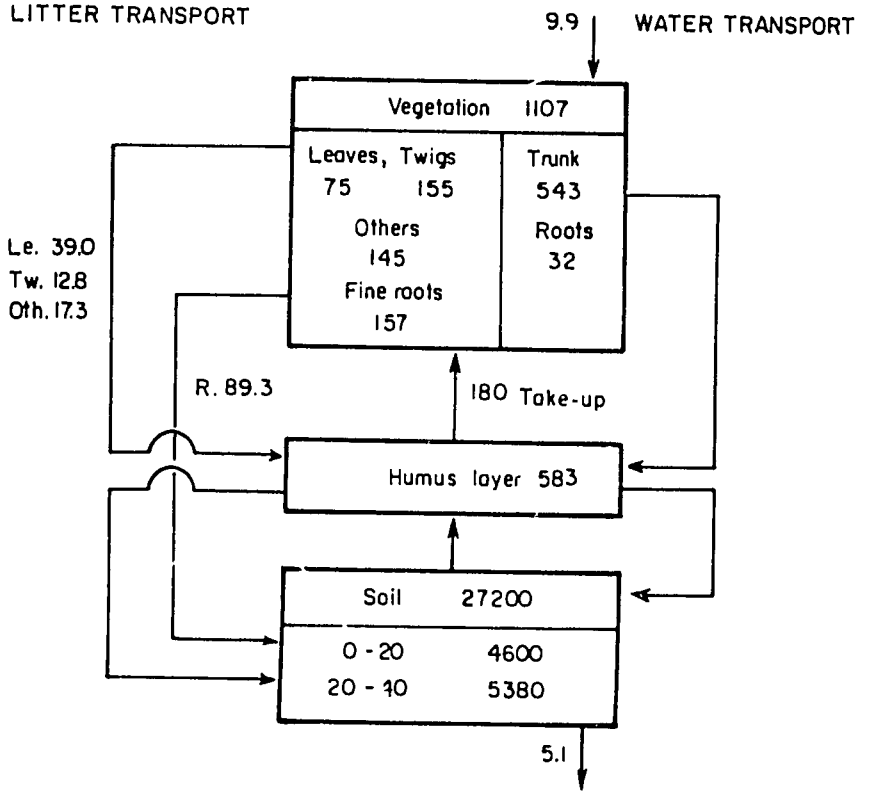

Figure 2: Cycle of N in the forest eco-system of San Eusebio, Venezuela (stocks kg/ha, transport kg/ha per year).

Cycle of organic material and nutrients

Figure 3 illustrates the basic ideas about recording and describing the cycle of organic material and nutrients in agroforestry production systems. In recording the stocks, the system is divided into the known components: vegetation, humus layer, and mineral soil, with the vegetation vertically subdivided into storeys. Figure 3 considers an agroforestry system consisting of *(Coffea* sp.), poró *(Erythrina* sp.) and laurel *(Cordia* sp.). These subcomponents of the vegetation are further divided according to wood-producing and litter-producing components (leaves, twigs, blossoms, fruits).

To establish the transport processes through the litter, the different components of the production system have to be regarded separately. The structure of the transport processes by water is very difficult to ascertain. The change in nutrient stocks can enable the up-take of nutrients to be established. For this the export of nutrients through the harvesting and cutting back of the coffee bushes, the pruning of the poro and the exploited laurel have to be considered in special investigations. In the model it should be noted that nutrients are added by fertilizing (up to 500 kg N-P-K per ha per year). As a special process in the N-circulation, the fixing by the nodule bacteria of the legumes (poro) in the production system should be investigated.

All agroforestry production systems can be examined and described according to this framework. The decisive factors are the establishment of the stocks in the various storeys of the vegetation and the conversion processes within the components.

In the literature there are scarce results from this attempt to describe agroforestry production systems. Results on stocks in the soils and in the vegetation of

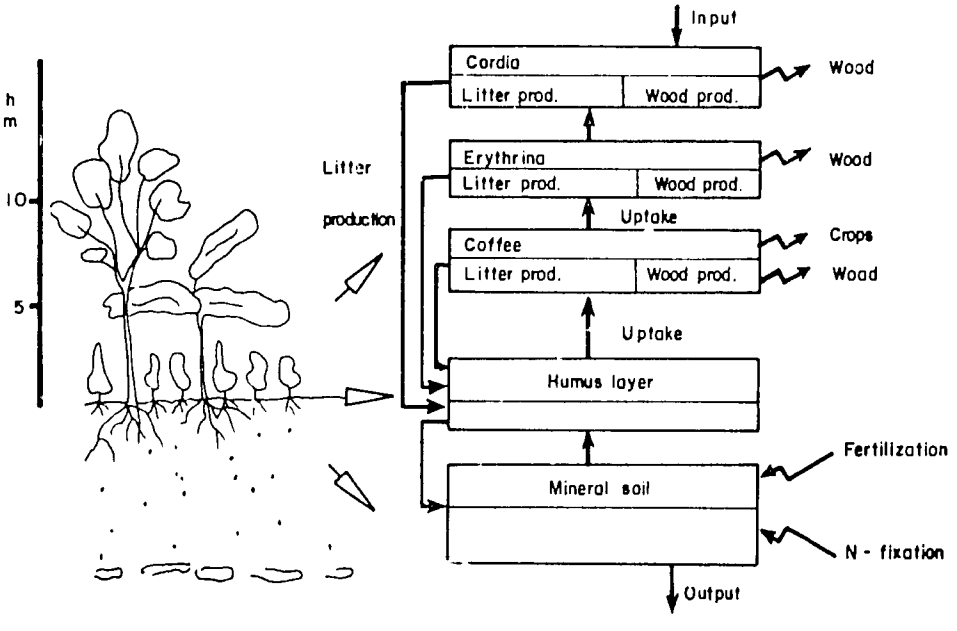

Figure 3: Basic representation of the cycle of organic matter and nutrients in agroforestry production systems.

a location are as yet unknown. With a coffee production of 2000 kg (freshweight coffee per ha), MALAVOLTA (8) gives a nutrient up-take of 30 kg/ha, 5 kg P 205/ha and 50 kg K 20/ha. As another example, according to HARDY /6), the annual production of 560 kg cacao fruit corresponds to 14 kg N, 7 kg P 205 and 11 kg K 20 per ha.

Table 1 shows the production of organic material through litter in four agroforestry production systems in Coatepec, Mexico, according to the data of JIMENEZ and MARTINEZ (7), with the annual amount of litter fluctuating between 6.0 and 10.2 t/ha. According to CHOKANNA (1), the annual litter rate of shade trees over coffee in India is 134 kg N/ha, 78 kg P 205 and 22 kg K 20. GRANADOS (5) gives an annual litter production of between 5.2 and 8.8 t/ha per year for an agroforestry production system of cacao with poro in Costa Rica.

Table 1. Annual litter production in various agroforestry production systems in Coatepec, Mexico (Kg/ha per year, according to Jiménez and Martínez, 1979).

	1	2	3	4
Ground flora	1	143	2600	3963
Coffea arabiga	1104	1380	1527	2079
Inga spec.	4918			
Inga unicuil		6857		
Inga leptoloba			8348	
Musa spec.				
TOTAL	10249	8380	9475	6042

Table 2 illustrates the production of agroforestry systems with coconut palms and different crops in Kasaragot, India (10). We can clearly see that different crop mixtures and subcrops can achieve different yields depending on coconut palm production, shade conditions, use of water, and microclimatic conditions.

Soil science investigations

Future soil science projects in agroforestry production systems should have the following targets:

- Description of the soil science basis;
- Selection and testing of experimental and working methods in short, medium, and long-term experiments;

Table 2. Yield from agroforestry production systems under coconut palms (t/ha) (Nair, 1977).

		Production	
		coconut	undercrop
Giant yam	*Amorphophallus companulatus*	13.46	16.82
Manioc	*Manihot utilisima*	14.82	16.78
Sweet potatoes	*Ipomea batata*	8.38	11.96
Large yam	*Dioscorea olata*	13.61	17.01
Yam	*Discorea esculenta*	9.26	11.57
Chinese potatoes	*Coleus barbatus*	7.32	11.26
Ginger	*Zingiber officinarium*	8.61	13.25
Large pumpkin	*Curcuma longa*	10.94	14.84

- Examination of micro-climatic and soil-science (water and nutrients) interrelations between the components;
- Development of methods to determine the production systems' nutrient requirements when agroforestry measures are introduced;
- Establishing and evaluating the traditional soil-management measures in smallscale agroforestry farming systems for developing new technologies in light of socio-economic and infrastructural conditions.

Contributions from participants on the lecture

Nutrients are derived primarily from the soil and are simply stored in the vegetation. According to the development history of the soil, there are in the tropics, therefore, locations where either the vegetation or the soil is extremely rich in nutrients. The example *San Eusebio* is typical of a soil rich in nutrients. This kind of inventory of nutrients is methodologically very interesting as an indication of whether a system is stable or not.

Among other things (shade, wind protection, etc.), trees and shrubs play an important role in the nutrient cycle of pastures and crops. Nitrogen fixation and release of minerals can occur even in poor soils. Where there is intensive agricultural use, the biological oil activity, for example, can be improved by a legume intercrop, and deep-rooted plants can still make optimal use of nutrients from lower soil levels.

The benefit of tree components is perhaps lost only under semi-arid conditions and with a very rapid crop rotation with different seasonal crops. Fertilizing (and irrigation) is then essential.

Before experimenting with largescale agroforestry, the intensive garden crops of the tropics should be closely studied. This includes the compost system, which is being examined by the University of Bayreuth.

Soil science analyses seem to be of fundamental importance for all decisions on land use and especially when preparing a project. But current analyses, like all, the results of very specialized sciences have to be treated with caution.

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Problems of agricultural production in the humid tropical lowlands

J. Lagemann*

The humid tropics are part of the most productive regions of the world. The gross production of biomass in the tropical rainforest is about 30 t/ha per year compared with about 10 t/ha per year in temperate zones (9). The high production potential results mainly from the very abundant supply of water and solar energy. In temperate climatic zones, each cm^2 receives between 80 and 120 Kcal of solar energy, whereas in the tropics the figures are 130-220 Kcal (8).

The figures for food production are in stark contrast to the high production potential. DUCKHAM, JONES, and ROBERTS (1) have estimated that the food production per cultivated hectare in the tropics is only half as great as the potential.

Can we conclude from this that the humid, tropical lowlands are under-exploited by the agricultural population, or are the cropping methods and the resulting production based on special limiting factors in this tropical zone?

I would like to pursue these questions with the help of three examples: first, an example of shifting cultivation in southeast Mexico, and then, two cases in East Nigeria of bush-field rotation and a permanent cropping system.

Shifting cultivation in southeast Mexico

General conditions

The region under investigation is located in the southern part of the Chiapas State on the border with Guatemala. Roughly half of the region is flat and crossed by many rivers. The sedimentary soils of the plains consist predominantly of loamy sand. The western and northern regions are dominated by mountain formations whose slopes are subject to severe erosion after fire clearance. The annual rainfall varies between 2000 and 4000 mm.

The region of Selva Lacandone was originally covered by uninterrupted rainforests (about 90o/o of the area). In the recent past shifting cultivation was introduced and intensified by immigration to the region. The result has been destruction of vegetation over a large area.

The fact that the question of land ownership has not been solved has also increased the destruction of the forest. The forests are regarded by the local population as common property and are accordingly laid claim to.

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Form of land use: The forest is currently being transformed to arable cropping by the use of fire clearance. After clearance, maize, beans, and occasionally manioc for household consumption and paprika as a cash crop *(Capsicum frutescens)* are cultivated. The cropping land is then usually taken over by cattlekeepers who sometimes sow the land and sometimes use it as natural pasture. The arable lands penetrate further into the forest, and the process begins again. The speed at which the forest is being destroyed is great, because with cattlekeepers waiting to move in, the arable farmers can cultivate each area of land only once (for two years).

Effects: In the tropical rainforest, most nutrients are held in the vegetative biomass, whereas the soil has a very low nutrient content (5). Shifting cultivation destroys the vegetation and affects soil fertility and its production:

- Almost all nitrogen and sulphur escape into the atmosphere when the forest is burned;
- Phosphorus, potassium, calcium, and magnesium are added to the soil via ash.

Although the nutrient content of the soil is higher after fertilization by the ash, the soil fertility and the yields decline so rapidly that after two or three harvests, the farmers have to move on to fresh land. The reasons are as follows (3):

- Because of the high temperatures and humidity, the physical and chemical processes in the soil take place much more rapidly than in temperate zones therefore reducing soil productivity;
- The soil is left uncovered for a period of time, resulting in erosion and nutrient loss by leaching;
- Weeds grow quickly in the rainy season, whereas in the forest they are kept down because of the lack of light.

Annual crops, not having extensive root growth, are not able to replace the leached nutrients from the lower levels of the soil. This appears to be true also in the case of pastures. They are degraded, increasing leaching and soil erosion, and only very extensive land use becomes possible.

Bush-field rotation and permanent cropping in Nigeria

General conditions

The area under investigation lies in the humid, tropical lowlands of East Nigeria. The average rainfall is 2000 mm, with a bimodal distribution. The cropping season begins in March and ends in November. As in large areas of the humid tropics in West Africa, acid, sandy soils predominate (ultisols). The fundamental factor differing with other regions of the humid, tropical lowland zones is the population density, which varies from 100 to 1000 persons per Km^2 and is, therefore, the highest in Africa south of the Sahara.

Bush-field rotation

Form of land use. Shifting cultivation disappeared some decades ago because of the intense population pressure. The people are sedentary and rotate fields and bush fallow within clearly defined borders. The length of the fallow is dependent on the population density and varies in East Nigeria between one and six years. During the dry season the bush is slashed and burned.

The soil is then tilled with a hoe, and the main crops grown are manioc, yams, maize, groundnuts, and melons.

As the length of the fallow decreases, the following changes occur:

- The number of crops and the plant density increase;
- The number of trees on the fields, mainly oilpalms, raffia palms, cola nut, and coconut, increases.

In this way the farmers try to adapt to the changing conditions. The vegetation density is increased by the smaller distance between plants, and the soil, which because of its structure could easily be eroded, is therefore covered more quickly and effectively.

Effects: As the fallow period decreases, soil fertility declines rapidly. The average soil fertility parameters confirm results from other locations (5) showing that the organic material, nitrogen, phosphorus, and the cation exchange capacity decline. The soils, on the whole, are very acidic, and the average potassium values are low (Table 1).

As we would assume from the results of soil analyses, the yields also sink rapidly as the fallow period is shortened. Figure 1 illustrates the relation between length of fallow and yield, expressed in kg dry-weight per ha.

The relation is best explained by a quadratic function. This shows that changes in length of fallow of 1 to 6 years cause marginal returns to increase. For example, the additional yield from a change of fallowing from 1 to 2 years is 240 kg, dryweight per ha, whereas it is 1680 kg when the fallow is increased from 5 to 6 years. It must be assumed that if the fallow is further increased, the curve is reversed, and sinking marginal returns occur. The empirical examination of about 250 fields shows that under the present location conditions, about 4 to 5 years of fallow are necessary before any *visible* regeneration effect of the fallow is apparent.

Permanent cropping

Form of land use. Because of the rapid decline in yields in the bush-field rotation system, the farmers developed a permanent cropping system on small plots in the immediate vicinity of the houses.

The cropping principle is that of storey agriculture, *i.e.* annual crops and trees of varying heights are cropped together on one plot. The species in the individual storeys are mainly the following:

Type of tree	height (in meters)
oilpalm, coconut palm	20-25
breadfruit, raffia palm	12-20

Table 1. Analysis of 242 soil samples (A-horizon) at 3 locations in East Nigeria, 1975.

	Population density and fallow period in years		
	low 5-6	average 3-4	high 1-2
Org. C. (o/o)	2.36	2.09	1.17
pH	4.53	4.71	4.42
N (o/o)	0.174	0.159	0.088
P (ppm, Bray)	17.62	9.10	9.81
K (mval/100)	0.09	0.06	0.10
Ca + Mg (mval/100)	1.28	1.73	1.18
C.E.C.* (mval/100)	4.10	3.91	2.86

* C.E.C. Cation exchange capacity; the analysis is derived from 68 soil samples of the same kind.

Source: Soil samples under direction of F. MOORMANN, Soil Scientist at IITA. The chemical analysis was carried out in the laboratory of IITA (Ibadan, Nigeria).

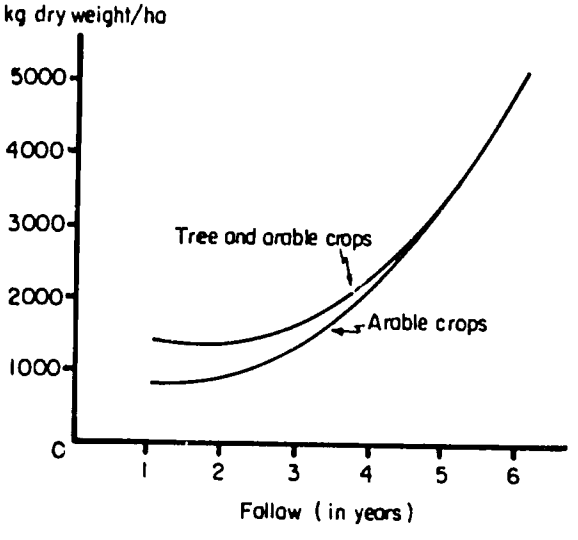

Figure 1: Relation between yield and fallow period in the tropical lowland of East Nigeria. Source: LAGEMAN, J.: Traditional African Farming Systems in Eastern Nigeria, (4).

cola nut, mango	8-15
citrus, papaya	5-10
banana, cooking banana	3-7

At the lowest level, in the shade of the trees, mainly cocoyam *(Xanthosoma)*, yams *(Dioscorea)*, Malagetta pepper *(Aframomum melegueta)*, okra *(Hibiscus esculentus)* and telferia *(Telfairia occidentalis)* are cropped. Maize and manioc are also grown at the edges of the fields where light conditions are better.

The vegetation density increases the nearer it is to the soil and therefore reduces soil erosion, reduces soil temperature, conserves moisture in the soil, and provides mulch that enriches the organic matter and finally returns nutrients to the soil. The variety of species (an average of over 40 per field) with their high density is similar to the conditions of the rainforest which represents a stable eco-system (6).

Permanent cropping is based on an intensive manuring system as well as on the above-mentioned combination of tree and arable crops. The export of nutrients is restricted to the edible parts of the crops. Large amounts of organic matter are added to the soil in the form of household waste, mulch from more distant fields, and the stall manure of goats.

Effects. The result of this cropping method is a considerable improvement of soil fertility even with permanent cropping: The figures for organic matter and nitrogen do not show any significant differences from the fields in the bushfield rotation system; on the other hand, the pH value rises to an average of 5.06; the figures for Ca and Mg are doubled; the potassium content rises to 0.16 me/100 g and the phosphorus figures rise to 2 to 3 times as high (Table 2).

The yields, again calculated in Kg dryweight per ha, average 4.800 Kg, and in one location as high as 6.000 Kg.

Table 2. Analysis of 88 soil samples (A-horizon) at two locations in Eastern Nigeria, 1975.

	Population density	
	Average	high
Org. C (o/o)	2.06	1.06
pH	5.06	5.06
N (o/o)	0.169	0.085
P (ppm, Bray)	36.18	19.18
K (mval/100)	0.14	0.17
Ca + Mg (mval/100)	3.50	2.77

Source: Soil samples taken under the direction of F. MOORMANN, Soil Scientist at IITA. The chemical analysis was carried out in the Laboratory of IITA (Ibadan, Nigeria).

This is more than double the yields produced at the same location in the bush-field rotation system with an average two-three year's fallow. With this cropping method, six years fallow are needed to produce 4.800 Kg dry weight of foodstuffs.

If the yields are converted to production per unit of area and year, it can be concluded that permanent cropping produces seven times as much as the fallow system.

Conclusions

The humid, tropical lowland zones are characterized by especially limiting factors regarding the production of arable crops. These factors are the result of the combination of easily erodable soils, paucity of nutrients, the impact energy of heavy rainfall[1]), and a high level of insolation.

The bush-field rotation system represents good adaptation to the ecological conditions of the humid tropics, but with increasing population density, it leads to impoverishment.

It appears that high food production from permanent cropping is only possible if agroforestry cropping forms are used, and this entails a high degree of complexity. This form of cropping has to be supplemented by intensive fertilizing.

Contributions from participants on the lecture

Crops with bush fallowing react to rising population pressure with declining yields. But with *multi-storey vegetation*, the reserve is true; as an intensifying measure more fruit trees are planted, at least on a part of the plot, for subsidiary income or as cash crops. Less intensively cultivated plots can, however, have declining yields.

The forms of land use referred to in the paper exist where there is a rainfall of 1800 - 2800 mm per year, and they can certainly be found side by side.

No mineral fertilization is carried out in either the bush fallow or the multi-storey vegetation, but the increasing weed infestation in the bush fallow (the decisive factor for the rotation of crops) does not occur in permanent cropping. Instead, a large amount of mulch is produced that contributes to soil improvement. A land-use system with forest plants allows the whole production of biomass of a location to be permanently raised and utilized more efficiently.

Other things being equal, the fallow system requires less labor input. In the example discussed in the paper, the yields after a fallow period of 5-6 years were approximately those of permanent cropping.

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Adventages and limitations of pasture management with agroforestry systems

J. Combe*

Which came first: the cattle or the forest? This thought-provoking question immediately occurs when we look more closely at agroforestry farming methods with cattle production.

The background to this issue in terms of development policy is well known: the food production of the world has to be raised by 3-5o/o per annum if worldwide famine is to be avoided. Since all agricultural production must ultimately strive to achieve the maximum possible utilization of sunlight, there seem to be many possibilities still open to the cattle economy to raise its production.

More than half, in some cases more than two-thirds, of the total cattle stock of the world is already concentrated in the developing countries (Table 1).

The developing countries have only a little more than half of all pasture land in the world, but they also have two-thirds of the still unutilized and/or unproductive land reserves.

Similarly, about two-thirds of all forest areas in the world are found in the developing countries where 50o/o, however, consist of open stands.

Finally, only 11o/o of tropical soils are flat enough to be used permanently for cropping. Cattle and forestry systems, if possible at all, are therefore the only sensible land-use alternatives on vast land areas.

But do the right conditions exist to increase cattle production in the tropics? In reality the identified land reserves can scarcely be used as pasture in the longer term without the ecological equilibrium being destroyed over large areas. Thus, pro duction increases must necessarily be achieved by intensification. Three procedures can be considered when trying to achieve this objective: increasing pure fodder production per unit of area; increasing the total production of the pastures by diversification; ensuring permanent pasture production by improving certain location factors.
bases for the cattle economy where the right long-term potential exists on already deforested land. It is not a question of clearing existing forest for the cattle economy.

In other words: the cattle came first; the forest should be introduced into the pasture system, as forest components improve benefits.

Silvo-pastoril combinations

Functions of the forestry component direct (material) and indirect functions of the forestry component are to be expected from silvo-pastoril systems as is the case

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Table 1. Distribution of animal stock and land in the world.

Animal stock in millions	World total	o/o	Developed countries	o/o	Developing countries	o/o
Horses, donkeys, mules	115.7	100	25.1	22	90.6	78
Cattle, buffaloes	1345.5		433.0	32	912.4	68
Sheep, goats	1491.0		530.5	36	960.5	64
Pigs	731.8		313.9	43	417.9	57
Fowl	6691.2		2975.4	44	3715.8	56
Land in millions of hectares						
Cultivated land	1462	100	671	46	791	54
Natural pastures	3058		1272	42	1786	58
Unproductive and unutilized land	4477		1708	38	2769	62
Forests	4077		1834	45	2243	55

Source: FAO Production Yearbook, 1978.
Developed countries: mainly North America, Europe, USSR and Oceania.
Developing countries: mainly Africa, Latin America, Asia (incl. China).

for all other agro-forestry combination forms. Forage trees represent an unusual situation since they fulfill the same function as the pasture they grow on.

Table 2 presents the most important functions. It is assumed, with one exception, that pasture management is the predominant and most important land use form. This exception is the so called *Forest Farming* or *Forest Grazing* system, where priorities are investigated: the long term utilization form is the forest (as secondary forest or plantation) and grazing only occurs during a certain development stage of the forest.

The understanding of agro-forestry systems in their totality requires either an interdisciplinary knowledge or the collaboration of several specialists. It is very difficult to quantify the mutual influences between single components. However, it is relatively simple to obtain economic values or dendronomic data by field measurements or from literature.

Some examples are given in the following section, on investigations carried out at CATIE during the last three years, mainly by John Beer.

1. Acacia albida (fodder tree). This interesting species of acacia keeps its leaves for the whole dry season, but stays bare in the rainy season. Since both the leaves

Table 2. Functions of forestry components in silvo-pastoril systems (selected examples).

Function	Performance	Tree species	Example No.
Production function (material benefit)	Fodder production for raising animals	*Acacia albida* *Bromisum alicastrum* *Diospyros conazotti, D. rosei, D. sonorae, etc.* *Leucaena leucocephala* *Parkia africana, P. biglandulosa, P. filicoidea,* *Pithecolobium saman, P. jiringa, P. lobatum, etc.* *Prosopis juliflora, P. chilensis, P. tamarugo*	1
		Psidium guajava	2
	Food production	*Cocos nucifera*	
	Firewood and construction timber production on pastures	*Cordia alliodora, Cedrela odorata* *Alnus acuminata* *Eucalyptus deglupt.* *Pinus caribaea*	3
		Psidium guajava	2
	Hedges (pastures and paddock limits)	*Gliricidia sepium* *Erythrina poeppigiana*	
	Forest grazing	*Pinus radiata, P. caribaea, P. oocarpa*	6
Protection function (indirect benefit)	Improvement of soil fertility, natural fertilising	*Alnus acuminata* *Erythrina poeppigiana* *Gliricidia sepium* *Leucaena leucocephala*	4 5
	Shade suppliers	*Pithecolobium saman* *Alnus acuminata*	

and the pods are eaten by cattle, it serves in many regions as an indispensable fodder reserve at the end of the dry season. The high nutrient value of the fodder is also retained when it is dry. The seeds contain up to 27o/o starch and are prepared, together with maize and groundnuts, for human consumption (4).

2. Psidium guajava (fruit tree, supply of firewood). On several peasant holdings in the vicinity of Turrialba, guava bushes are tolerated on pastures because they are beneficial to the small farmers in several ways at once. They produce fruit for men and animals, and also firewood with a relatively high heat value.

The guava fruit is used especially for fattening pigs, which explains the high density of trees per hectare which has been measured (in smallscale holdings up to 300 trees/ha and more) (1).

3. Cedrela odorata and Cordia alliodora (valuable wood). Both frequently occur as natural reforestation on the pastures of the Atlantic zone in Costa Rica. Both species are highly valued as timber and are correspondingly promoted by the farmers; but both are subject to certain limitations:

Cedrela odorata is very prone to infestation by the shoot-boring insect *Hypsipyla grandella*, and it cannot therefore be grown artificially in pure stands. However, together with other secondary forest species, this species thrives on pastures and achieves a high commercial value.

Cordia alliodora achieves the lowest growth rate in combination with pastures: far less than with sugarcane or coffee or cacao. It appears that this species, with its very shallow root system, reacts negatively to the compacting of soils that occurs with pasturing. Measurements have shown that this type of timber on pastures in lowland areas can produce a mean annual increment, at the age of approximately 30, of 13.7 m^3/gr. with a stand density of 150-190 trees/ha. In the region around Turrialba with less dense stands (67-114 trees/ha), the periodic increment of 15-20 year old *Cordia alliodora* is only 1.8 and 2.5 m^3 per year (6.1).

4. Alnus acuminata (timber and improvement of soils). As Table 2 illustrates, the alder on pastures produces two positive results: production of firewood and building timber; also improvement of soil fertility by nitrogen fixation and regulation of the water economy.

Only the value of the first function has so far been recorded, and the following data are based only on individual farms taken from the 54 farms examined. The growth measurements taken on eight different pasture-tree stands with *Alnus acuminata* mean annual increments showed between 4.75 and 15.0 m^3 per year. Since the alder in pure stands and on good soil can reach a mean annual increment of 27 m^3/ha per year in 25 years growths of 10 m^3/ha per year are certainly possible on the majority of pastures. In monetary value this is the equivalent of ₡ 3.120 or US$240/ha per year[1]). The net proceeds of a typical dairy farm in the region can therefore be increased by up to 20o/o.

Of the 54 farms investigated, 38 (70o/o) practiced alder cultivation on pastureland, but only 17 farms (32o/o) considered the regular pursuit of the method necessary. This applies particularly to smallscale holdings that have to aim for as wide a diversification of their production as possible (5).

5. Erythrina poeppigiana (soil improvement). One single farm in Santa Cruz of Turrialba (Costa Rica) has been planting the *Pennisetum clandestinum* pasture with *Erythrina poeppigiana* since 1930. This indigenous legume had no production value hitherto, not even as firewood. A way of utilizing it for cellulose has existed only since last year. However, the species has proved its worth in shading coffee plantations. The nitrogen fixation in the roots and the nitrogen content in the leaves (4.2 to 4.6o/o N) have induced the farmers, even without such benefits being measurable, to exploit these advantages for the pastureland also. However, it was established that the cattle like eating the bark and leaves of *Erythrina poeppigiana* and therefore, in addition, fodder production is possible (2).

6. Forest grazing. To ensure the supply of timber, large areas of pastureland in New Zealand and Australia have been reforested with *Pinus radiata*, but they

1) Exchange rate of February, 1981.

continue to be used for cattle production. According to the nature of the land and the soil quality, 800 to 1200 trees are planted (*e.g.* at distances of 1.8 m in rows at 7 m). For two years after planting the grass is harvested, after which the reforested land is grazed. The trees are pruned, and the stands periodically thinned out. In rotation times of 25 years, the timber production amounts to 637 m^3/ha. The recommended animal density of the stocked pastures is 12-25 sheep/ha. It has been established that the silvo-pastoril combination produced a significantly higher net return, especially on largescale farms with extensive cultivation. Smallscale farms with consequently intensive cattle-keeping were not able to profit from the combination (3.7).

At CATIE, about 7 ha spread over several plots have so far been set up on an experimental basis for grazing by horses, with 8-10 year trials involving pine (*Pinus caribaea* of various varieties, *Pinus oocarpa*).

The predominant Guinea grass (*Panicum maximum*) proved to be of low quality under the dense shade of the pine, so that the animal density (in horses per ha) had to be reduced from an initial 0.83 to 0.33. Even without calculating the return precisely, this is a promising result when one considers that, from the point of view of forestry, the fodder would be regarded as weeds, but manual weed control remains a necessity at least once yearly.

Comparative evaluation

To find out the total value of silvo-pastoril forms of farming, the positive and negative effects of the tree stand on the pasture economy have to be added to the production value of the forestry components. This presupposes that the relations between the cattle and the pasture, with or without trees, remain the same. This is probably not true in fact. The behaviour patterns of the animals do not just depend on the fodder but on the pasture as a total system. Thus, much more complex interactions ought to be taken into account than is the case in Table 3, which is intented to show the contrasting nature of the various hypotheses that relate to the protective role of the forestry components.

Interrelations which are especially informative are explained in the following. The specific problems of forest grazing or of grazing woodland as a whole is not discussed in this paper.

Production functions of forestry components

Compared with the indirect benefits of the forestry components, it seems simpler to estimate the production functions. As illustrated in Table 2, it is a question of: food production; fodder production; production of firewood and construction timber; and pure wood production (tree plantation).

The only objective is to establish the quality and value of these benefits. Nevertheless, a reduction in the value of the wood has to be frequently accepted, particularly in combination with pastures, because the tree-animal interactions can be to the trees' disadvantage; for example: shallow-rooting trees suffer from compacted soil and damages; the nutrient-rich bark of certain tree species is often stripped off, especially from young saplings, and the value of the exposed wood becomes reduced by insect or fungus infestation.

Table 3. Protection function of forest components: opposite effects of tree stands on the pasture economy (not a definitive list).

Factor influenced by the tree stand	Positive effect	Negative effect
Light	better quality fodder with light shade; shade for the animals	loss of yield of fodder; concentration of animals under the trees
Temperature	prevention of extremely high soil temperatures	low soil temperatures reduce biological activity
Wind	reduction of wind speed	increased irritation of animals by insects
Water	balancing of the water economy	competition during the dry season; waterlogging during the rainy season; run-off
Soil	better infiltration; erosion protection; improvement of soil fertility	soil compacting under the trees; therefore less infiltration; excessive local nitrogen fertilising; slow leaf decomposition
Vegetation	more species thanks to different micro-locations	introduction of useless weeds

Conclusions and predictions

The overall evaluation of silvo-pastoril systems must be based on a scheme that takes into account *all* the functions of the forestry components. The production functions are the simplest to assess (because they can be factually recorded). The non-material effects of the trees are, however, difficult to evaluate as to advantages or disadvantages.

It is not permissible to convert partial results into farming recommendations. Conclusions based on practical experience can only be drawn when the stocked pasture has been subjected to an overall evaluation that analyzes the system.

The evaluation always refers to a particular environment, and the criteria can therefore change with the passage of time. It is, for example, obvious that the natural nitrogen enrichment through stocking with legumes on extensively farmed pastures can have a positive effect, but on intensively fertilized plots no further useful effect can be achieved.

In order to involve long-term principles for the pasture economy in the tropics, it becomes necessary to look for utilization models that imitate the original natural vegetation in its structure and function.

Accordingly, the following should be examined for possible application: Appropriate selection of species of fodder grass, pasture trees and cattle breeds which complement each other as much as possible in a closed system. The combination of species used thus far has been largely random.

Use of suitable plant spacing that takes into account the differences in location

within a pasture; several small areas of pure reforestation on pastureland can be more effective than extremely varied combinations over large areas.

Removal of land from the forest-pasture economy should be undertaken on a large scale in order to ensure the most practical long-term exploitation of the production potential of the marginal pasture soils.

Contributions from participants on the lecture

The land-use conflict between forest and cattle economy is acute in many places; it is caused mostly by land shortages or a seasonal water problem. Under these conditions encroachment of forests is inevitable.

This leads, among other things, to the grazing of existing forests, a form of land use mentioned in the lecture. Forest grazing in pine reforestations seems to be still relatively easy to control. But it is difficult to find reliable data on the grazing of natural forest, because the forest vegetation is usually degraded very rapidly: *Forest grazing as preparation for or final act before fire clearance.*

In this context, grazing of dry forests by goats occupies a special position. To control this form of land use, deterrent measures against goats are being experimented with.

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Agroforestry from the forestry point of wiev

H.J. von Maydell

It was not long ago in forestry studies in Germany that it was taught that the connection between forestry and agriculture was, in the majority of cases, an operational one and usually unsatisfactory.

In the context of this seminar and the present increasing understanding of interdisciplinary cooperation in the question of land use, this is a provocative statement. Nevertheless, we have to consider whether it applies, when, and where, and if this is indeed the case, why it is so? At this point only an outline of important issues gives that question further explanation:

- Dominance of agriculture in decisions of agraria policy: farmers are strongly represented in decision-making levels of government; forestry is under-represented, and therefore, is at a disadvantage in many crucial areas.
- Agricultural holdings with small forest areas mostly do not have the necessary technical knowledge for well-regulated and successful forestry. Forest and pasture tree stands suffer accordingly.
- Forest often serves the holdings primarily as a money reserve (stopgap) for the agricultural sector. It is used irregularly; sometimes excessively and destructively.
- In extreme cases the forest is regarded as a cheap land reserve, or is even seen as a limitation to cropping from the point of view of arable land.
- The simultaneous use of land and forest on a given plot can have the effect of reducing efficiency (in all the sectors involved).

Much could be added to these outlines; they are intentionally presented as one-sided and incomplete in order to stimulate discussion later.

In a similar fashion a number of statements can be made as starting points for discussion.

1. The connection between agriculture and forestry exists in a vast number of cases regardles of whether the term agroforestry is used. This connection usually results in both advantages and disadvantages. The crucial factor is that mutual advantages should predominate. Such connections, are, for example:

- Cattle grazing or arable farming in forests in the most varied forms of combination.
- Use and care of wild (forest) trees and bushes on arable land, pasture, meadows, and in the vicinity of farming settlements.
- Administrative concentration of agriculture and forestry, *e.g.* in the same ministries. Joint (basic) training in many countries.

- Agriculture, pasturing, and forestry all serve to satisfy human needs. They are practiced with man and society in mind.
- Through land use in all three sectors, man influences his environment, which for him means living space.

2. Any combination of agriculture, cattle economy, and forestry has to solve 5 priority problems in the process of rural development in the Third World:

- Guaranteeing and improving the food supply for humans. In many development projects in regions with little forest, the gist of what we are asked is: "When can we eat your trees? ". Those who know the conditions know how serious and justified this question is. In agroforestry, trees and bushes contribute to the food supply in so far as parts of them are actually eaten (leaves, fruits, buds, shoots, blossoms). The quantitative and qualitative importance of this direct source of food (the tree) is in most cases, still inadequately known, and its potential even in world economic terms is inadequately exploited. The few tropical species that have hitherto supplied food and luxuries for the market could be supplemented by species trials and breeding selection and by specific cultivation on a significant scale. Attention should be drawn especially to the greater protection against risk of this type of production compared with annual crops (Figure 1).

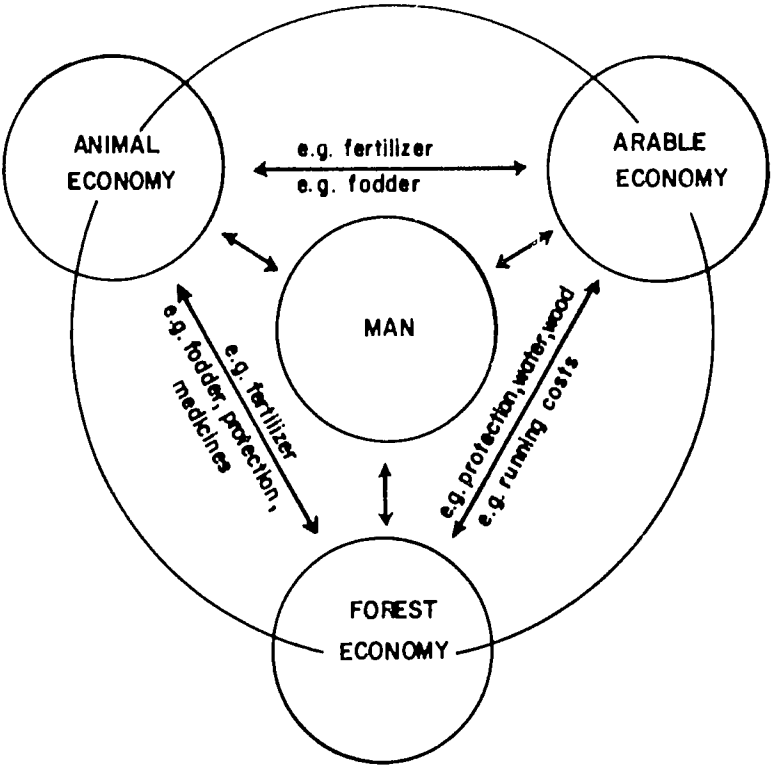

Figure 1: Agroforestry model.

Trees and bushes contribute indirectly to improvement of the food situation by supplying cattle fodder. For example, in the Sahel, according to Le HOUEROU (6), more than 20o/o of the fodder requirement is covered by trees and bushes, rising even as high as 45o/o towards the end of the dry season. Cattle-keeping would therefore not be possible without this fodder base. In other regions the dependence on trees and bushes varies, but in the dry mountain regions, it is especially pronounced.

It should be mentioned that trees and bushes can contribute to raising and improving food production in arable and garden cultivation by virtue of creating wind and erosion protection, shade, and nutrient enrichment in the upper soil layers. However, this contribution cannot yet be meaningfully quantified. But we must examine in the context of these positive achievements whether the forest also has negative effects on food production, and if so, why this should be and to what extent in occurs. This should be investigated in the way shown by BUDOWSKI (see above).

- Guaranteeing the energy supply. The importance of the energy supply for rural regions is generally recognized and undisputed. The most important supplier of energy is, in most cases, timber, either in its simplest form as firewood or as charcoal or wood gas. If firewood is in short supply, which is the case in many regions, the result can be extreme inconvenience for the population, either in the form of labor input *(e.g.* by women and children who have to fetch wood by carrying it up to 15 Km every day), money (up to one third of the income of a household must sometimes be spent on energy), or by consumption with negative effects, for example the vegetation is destroyed by excessive wood cutting or the yields are reduced by using cattle dung as fuel.

Quick-growing tree species on and around the farmer's pastures and arable plots contribute decisively to improving the energy supply, independently of the often limited production possibilities of the forest administrations on closed forest. In particular, examples from south-east Asia and parts of Central American show that, in agroforestry holdings, deriving their energy supply from their own firewood has long been just as much a natural part of subsistence agriculture as the supply of food. It should be noted in passing that the energy problem must not only be solved by more production but in various other ways. These include savings and rationalization methods that create lower consumption by avoiding unnecessary losses *(e.g.* cheap herd program, Upper Volta) and replacing dwindling energy supplies by new supplies that are available in abundance (biogas, solar and wind energy, etc.).

But the importance of energy in agroforestry projects goes far beyond cooking and heating and involves transport, the labor input for cultivation, care and harvesting of land, and the utilization of fertilizers, building material, etc., for whose production very different amounts and qualities of energy have to be employed.

Agroforestry offers many starting points for making peasant holdings more independent of outside energy supplies.

- Supply of raw materials. From the point of view of forestry, the main commodity is timber in its role as a versatile raw material and construction material. In most cases we can see without detailed studies the extent of the requirements and how difficult the supply is. Considerable quantities are needed as construction material, for household and agricultural implements, fences and transport, etc. As in the case of firewood, agroforestry holdings can cover a part or, in favorable cases, even the whole of their needs from their own production and can also

profit from the sale of timber if market conditions are favorable. This makes raising timber in peasant holdings an attractive proposition (example: *Cordia alliodora* in the coffee plantations and on pastureland in Costa Rica).

Trees and bushes can supply many other products in addition to wood. These products are partly for direct consumption, partly for selling and even for export. They include tanning agents and dyes, fiber, latex resins, gum arabic, insecticides, poisons, medicaments for human and veterinary medicine, types of bark (*e.g.* cork), salts, saponine, etc. They all supplement the supply of vegetable raw materials from the agricultural sector in a varied and effective way, and above all, they can help create cash income. Not least they have economic significance, especially as they help the country to become less dependent on many kinds of import. The diversification effect for the agricultural production of raw materials should be emphasized.

- Positive effect on the environment. The positive effect of trees and shrubs on the stabilization of agricultural eco-systems is obvious. Terms such as desertification, destruction of the rainforest's ecosystems (*e.g.* the Amazon region), and loss of land in mountain regions point to regional problems that can only be solved by the close and frank cooperation between agriculture and forestry. The same applies at the level of the single holding and individual project. In addition to the numerous protection functions (erosion, wind, excessive insulation), the improvement of the soil on arable and pastureland by leaf litter (nutrient pump), nitrogen enrichment (legumes), and root penetration (structural improvement) all play important roles.

Important tasks arise in the context of integrated land use ranging from spatial organization (from the *live fence* to the *avenue of trees*), via landscape formation to the maintenance of species and cultural values. Finally, we should not forget the desire of many country dwellers to grow decorative species of tree and shrub.

- Improvement of the socio-economic conditions. The four aspects mentioned above help to improve living conditions in rural areas. It would be going too far to treat the role of *the tree* in peasant agroforestry holdings in detail on this occasion. Its role ranges from provision of shade for the laborer exhausted by work in the fields, a communication function (meeting place, or a clump of trees in a market place, parks in the middle of settlements), the improvement of hygienic conditions and medical provision) remedies from trees and shrubs) to the improvement of domestic supplies and the creation of additional jobs (multiplier effect) and additional income, especially in a seasonal cycle. However, the function of trees and shrubs is of exceptional importance as regards reducing the risks of agricultural production (especially in so-called stress areas) as well as its balancing and *saving bank function* for a peasant holding when, for example, reserves have to be tapped on account of events in the family, harvest failure, of the exceptional need to invest. Without the forestry components, such reserves would otherwise not be available, and would result in frequent loss of property, debts, etc. We should draw attention to the cultural importance of tree plantations and their significance in terms of the pattern of ownership: with tree plantations come property rights, and a fairly long-term commitment to the plot occurs, and often only then is there finally a transition from exploitation to investment and therefore to land use with the future in mind.

3. One-sidedness involves the danger of wrong evaluation.

- The danger of a narrow viewpoint regarding rural development is becoming increasingly clear in nearly all parts of the tropics and subtropics. Programs and

campaigns that are implemented from the viewpoint of a particular sector can bring about serious damage. Examples are: the establishment of wells without supportive measures in dry regions, the construction of dams and roads without considering the locality, irrigation crops without considering the ecological and economic conditions, reforestation that leads to lowering of the watertable, etc. Rural development, indeed every project and every holding, has to be understood as a multi-dimensional system with many internal and external interrelations and interactions, which when looked at from a single viewpoint, must be less precise than when viewed from many angles, as can be insured by the proper cooperation of agriculture, cattle economy, and forestry.

4. Channelling all the available forces in one direction increases the effect.

- With generally limited resources, it is a question of employing them to best advantage, distributing them optimally (resource allocation), and directing them towards the common goals. This can often be better achieved in agroforestry holdings than in monocropping. Two adjacent projects in the Sahel serve as an example: in one, the forestry project, grass impeded the tree crops so that the grass had to be destroyed at relatively high cost; in the other project, involving pasture, trees impeded the growth of grass, so that they had to be felled and burned. With cooperation, it was possible to achieve the organized use of grass for feeding pasture cattle in the forest area and the protection function and timber production from the trees on the pastureland. Thus, the overall production in the catchment area rose, and supplies to the population were improved.

5. A combination of plants and animals on the same land at the same time, overlapping or immediately after each other, has mutual effects both ecologically and economically. They can be summarized as competition, supplementation, and dependence.

- Competition. Trees and shrubs, agricultural plants, and animals compete with one another for light, water, nutrients, space, labor input, land area, capital, etc. Even if no direct competition can be seen, it can become effective indirectly by, for example, certain plants being intermediate hosts for parasites of other plants, trees serving as nesting places for birds that decimate the grain harvest, etc. Desirable competition can, for example, reduce weed growth through the shade effect, etc. Much basic research is still needed in this area in the interest of extending agroforestry.
- Supplementation. This can be in terms of time, space, quality, etc. In terms of time, this can be accomplished by seasonal rotation or (in dry regions) the availability of foliage and fruit as cattle fodder during seasonal grass shortages (classic examples: *Acacia albida* in Africa). Spatial supplementation is achieved through a better exploitation of the cattle biotop, with production in two or several *storeys* at the same time. Qualitative supplementation derives from products of a different kind being provided, *e.g.* vegetable *and* animal protein.

- Dependence. This subject still needs a great deal of investigation. Many examples are known. Some fungi only grow under certain trees in pastures which are used by certain animals. In the case of the wild animal species in Africa. It is known that the system collapses without a balanced ratio of short -and long-grass eaters, and the short-grass eaters especially cannot get at their food, despite its being present in sufficient quantities. With the given complexity of agroforestry holdings, often what remains to be elucidated is: What really needs what, why, when, and how much?

> 6. *The majority of farmers and shepherds in the tropics and subtropics have always practised agroforestry. They are far more familiar with this from of land use than experts from technical aid organizations or governmental agencies for agriculture, cattle-keeping and forestry.*

This applies at least to land use. In most cases, however, there is a lack of opportunity, and often of the understanding to establish and manage systems combining trees, shrubs, agricultural plants and animals. In this area lie the main tasks of the Extension and Aid Services.

Conclusions

From the point of view of forestry, the integration of arable farming, cattle-keeping, and forestry in agroforestry systems can entail both advantages and disadvantages. These have to be carefully weighed against each other, whereby a balanced view, taking everyone's viewpoint into account, is the best guarantee of optimal solutions in the sense of the overall rural development that will evolve. From the forestry point of view, there exists already, especially in the tropics, a close and necessary integration of the three areas, with each one both giving and taking. Forestry has always borne in mind its service functions. Forestry is, in general, prepared to increase cooperation with arable and pasture farming, an attitude which has been expressed not least by the fact that the first impetus to develop *agroforestry* came from forestry.

Contributions from participants on the lecture

Many discoveries and the results of research from projects are set out in the publications of GTZ and BMZ (descriptions of wood types, the fodder value of forestal plants, alternative energy, forest raw materials for industry, etc.). In this respect project-related research plays a vital role.

In the reforestation projects around well sites in the Sahel, referred to in the lecture, it is *not* a matter of producing an absolute increase but of better utilizing the available resources. Since the project includes about 50-100 families around a well (with a total of six centers), it does not cover a large area, but it is long-term. The problem is the fossil water reserves, which will last for, as yet, an unknown limited number of years. By the time it runs out, all forms of land use in the Sahel must be self-sustaining.

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II EXCURSIONS

Central experiment at CATIE, Turrialba, Costa Rica: Comparison of several mixed crops

J. Combe

Many regions in the humid tropics do not permit the continual production of seasonal crops. On the other hand, they are relatively suited to perennial plants like pasture and fodder grass, cacao, coffee, trees, etc. In this experiment, the most common mixed crops in the region are compared with each other over an eight year observation period. The investigation began with all plants at the same time in August 1977, with certain seasonal crops being added during the first year, which were not later renewed.

Aims of the experiment

To compare several local crop systems that initially were mixed with seasonal crops.

To examine each individual system during the experimental period to establish its development and effects.

Species employed

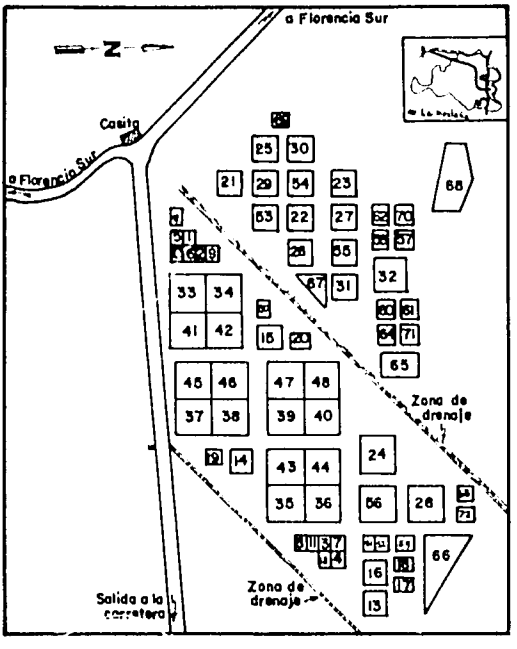
1. Garden Bean *(Phaseolus vulgaris)*, type *Turrialba-4*
2. Eye bean *cowpea (Vigna unguiculata)*, type V-5-Moh
3. Pigeon pea *(Cajanus cajan)*, local variety
4. Maize *(Zea mays)*, type Tuxpeno
5. Sweet potato *(Ipomoea batatas)*, type C-15
6. Manioc *(Manihot esculenta)*, type Valencia
7. Banana *(Musa* sp.), type *Pelipita*, cooking banana
8. Cacao *(Theobroma cacao)*, three different hybrids
9. Coffee *(Coffea arabica)*, type Hibrido de Timor
10. Laurel *(Cordia alliodora)* tree species of the local secondary forest
11. Poró gigante *(Erythrina poeppigiana)*, local tree species
12. Pasto Estrella *(Cynodon plectostachyus)*, fodder grass
13. Sugarcane *(Sacharum officinarum)*, type Pindar.

The first seven plant species represent the typical food base of the rural population in the region. Cacao and coffee are the traditional cash crops for the majority

of the small farmers. The two local species of trees are used primarily to shade cacao, coffee, and the plots of fodder grass. In the case of laurel, the production of timber is also measured; with poró, a legume, the nitrogen cycle and the stock of nutrients in the soil are examined.

Layout of the experiment

A total of 18 different combinations were planted (Table 1 - Figure 1), each with four repetitions. The size of the experimental plots varies between 8 x 10 m (annual crops) and 18 x 18 m (perennial crops).



Source:
Combe, J. y Gewald, N. eds. Guía de campo de los ensayos forestales del CATIE en Turrialba, Costa Rica. 1979. 378 p

Figure 1: Central experiment at CATIE. Comparison of several mixed crops. Layout of the experiment.

Table 1. Originally layout with annual crops, 1977.

No. of plots	First planting	Second planting (Nov.)
1, 2, 3, 4	maize	maize garden beans
5, 6, 7, 8	maize	garden beans sweet potatoes
9, 10, 11, 12	maize sweet potatoes	garden beans sweet potatoes
13, 14, 15, 16	cooking banana (manioc-maize)	garden beans sweet potatoes
17, 18, 19, 20	sugar cane	sugarcane maize
21, 22, 23, 24	fodder grass laurel	
25, 26, 27, 28	fodder grass ; poró	
29, 30, 31, 32	fodder grass	
33, 34, 35, 36	coffee laurel cooking banana (garden beans)	
37, 38, 39, 40	coffee poró garden beans	
41, 42, 43, 44	cacao laurel cooking banana (pigeon pea maize)	
45, 46, 47, 48	cacao poró cooking banana (pigeon pea maize)	
49, 50, 51, 52	manioc	manioc maize
53, 54, 55, 56	laurel maize garden beans	
57, 58, 59, 60	maize various	maize
61, 62, 63, 64	maize soil treatment	maize
65, 66, 67, 68	natural vegetation	
69, 70, 71, 72	maize	maize (soil cover with mulch)

Taungya reforestation at CATIE, Turrialba, Costa Rica: Terminalia ivorensis with annual crops and perennial crops

J. Combe

The Taungya System is a method of reforestation that combines forestry and agricultural production in the first few years. Under certain preconditions, Taungya reforestation develops better than pure reforestation because there is intermediate use of the land for agriculture where normally weeds would proliferate. Since 1868, significant areas in Asia and Africa have been reforested with the Taungya method. Wider application of this method has been hindered more by socio-economic problems than by technical difficulties.

Aims of the experiment

Comparison of rooting successes and the growth performance of the tree species with various Taungya combinations.

Economic evaluation of the Taungya combinations on the basis of the yields of the agricultural intermediate crops.

Investigation of certain location factors.

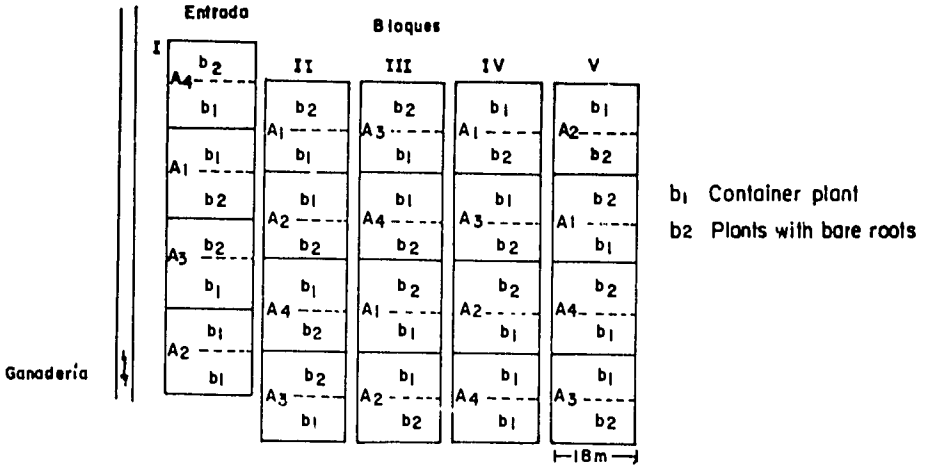
Species employed

Experiment period June 1978 - June 1979:

Terminalia ivorensis
Zea mays (maize)
Vigna unguiculata (cowpea, eye bean)
Phaseolus vulgaris (garden bean)

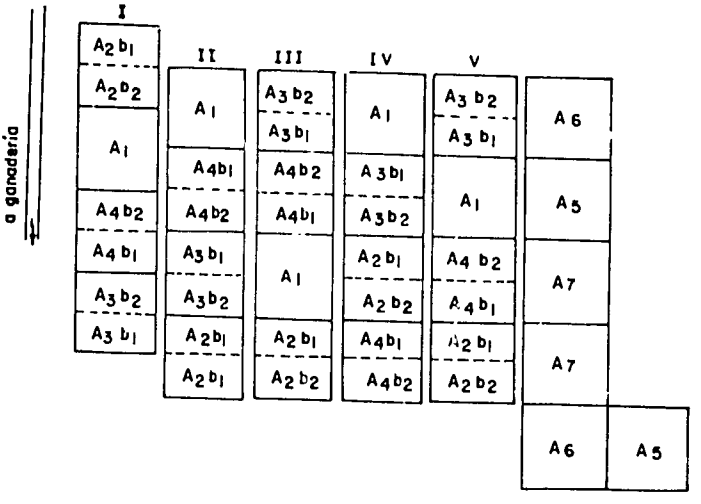
Experiment period September 1979 - September 1980:

Terminalia ivorensis
Coffea arabica (coffee)
Theobroma cacao (cacao)
Citrus sinensis (orange)
Phaseolus vulgaris (garden bean)
Phaseolus vulgaris var. Harvester
Vigna radiata (mung bean)
Vigna unguiculata (eye bean, cowpea)



Legend:
- A1 T. ivorensis pure forest plantation
- A2 T. ivorensis 6 months with maize, then 6 months with beans
- A3 T. ivorensis 6 months with eye beans, then 6 months with maize
- A4 T. ivorensis 6 months with maize and eye beans, then 6 months with maize and beans

Figure 1: Taungya experiment with *Terminalia ivorensis* with annual crops.



Legend:
- A1 T. ivorensis pure forest plantation
- A2 T. ivorensis 12 months with coffee
- A3 T. ivorensis 12 months with cocao
- A4 T. ivorensis 12 months with oranges
- A5 Coffee A6 Cocao A7 Oranges

b1 Garden bean (2 varieties)
b Mung beans - cowpea

Figure 2: Taungya experiment with *Terminalia ivorensis* with perennial crops.

Layout of the experiment

In the first period of the experiment, four Taungya combinations were compared with one another, with the young forest plants being planted either in pots (which enabled these *two planting techniques* to be compared). No fertilizing was carried out. In the second period of the experiment, four Taungya combinations were again compared with each other as well as with perennial plants. In addition, annual crops were planted, but they were not replaced at the end of the period of examination. The perennial plants were fertilized. At the moment, therefore, there are only 2 2/3 year old trees and 1 1/2 year old perennial plants on the experimental plot.

Results

First experiment period: the Taungya combinations with annual crops showed that:

- The nursery plants produced better rooting success (95o/o) than the plants in containers (57o/o);
- The height growth of *Terminalia ivorensis* in the first year with the Taungya system was up to 25o/o higher than the pure forest plantation;
- The planting costs were as much as 73o/o lower than for pure forest planting, because of the yields from intermediate agricultural use;
- On the other hand, a Taungya combination with two crops (maize + cowpea) produced lower yields on this location.

Second period of the experiment: Taungya combination with perennial crops showed that:

- The increase in height and diameter of *Terminalia ivorensis* in the Taungya plots was greater than in the purely forest plantations.
- The biggest increase in size of trees in combination occurred with cacao and orange trees.
- On the other land, the perennial plants achieved less growth than as monocrops.
- The yields of annual crops in the Taungya combinations were lower than the regional average, but they did produce a level of income that covered the cost of planting and achieved a net return (treatment A_3b1).

The farm"FATIMA": Example of an agro-silvo-pastoril agricultural holding

J. Combe

Location

Florencia near Turrialba, Province of Cartago, Costa Rica.

Population density:

15 persons/Km^2

Agricultural structure:

- Medium farm size in the canton: 31 ha
- Land use in the canton: pasture (62o/o); arable land (9o/o) and permanent crops (29o/o).
- Accessibility: very favorable; only 3 Km from Turrialba, but on a road requiring a four-wheel drive vehicle.
- Marketing: all agricultural products are sold in Turrialba.
- Size of the farm visited: 54 ha in 2 separate plots of 27 ha each: more than 80o/o of the land in used for dairying.

Height above sea level:

650 meters.

Climate and vegetation zone:

Average annual temperature: 22.2°C.
Annual rainfall: 2700 mm (data taken from the CATIE climatic station).
Vegetation zone according to HOLDRIDGE: *premontane wet forest.*

Soils

Latosol, deep and derived from volcanic material. The soils are very permeable but badly leached and have a low nutrient content; without fertilizers they have little agricultural potential.

Agroforestry forms of cultivation

Three basic forms can be differentiated:

- Trees in the coffee plantation: *Cordia alliodora* in the upper layer, *Erythrina poeppigiana* and *Musaceae* as shade trees above the coffee; *Eucalyptus deglupta* planted in 1970 in the upper layer, citrus trees and *Musaceae* as shade trees.
- Trees in the pastures, partly in groups: *Psidium guajava, Eucalyptus deglupta, Cordia alliodora, Pinus caribaea, Anthocephalus cadamba* in pastures that consist rainly of star grass *(Cynodon nlemfuensis,* Pasto Estrella).
- Hedges with *Gliricidia sepium;* there are about 3 Km of them on the farm. 6o/o of the land of the farm *Fátima* is stocked with forest, of which a part is secondary forest.

Treatment of the crops

The thinning of the 10 year old *Eucalyptus deglupta,* accounted for the harvesting of about one-fouth of all the trees. Apart from this, tending the stand is limited to the elimination of poorly shaped trees and regulating the light intensity in the coffee stands by regular pruning of the poró *(Erythrina poeppigiana).*

Results

The thinned out material of more than 25 m^3 *Eucalyptus deglupta* was sold locally (11 m^3 timber, 16 m^3 for fence posts). The harvesting costs were 27o/o of the selling price.

The following activities were not, however, quantifiable in monetary terms:

- Low maintenance costs for fences because of hedges of *Gliricidia sepium*
- Use of *Psidium guajava* fruit for fattening pigs;
- High growth of the exotic tree species that were indirectly fertilized as freestanding trees in the coffee plantation;
- Sufficient supply of firewood for the whole farm.

Problems

The slow decomposition of the pine needles seems to be a disadvantage on the pastures and the coffee plantation. The cows avoid, in particular the places where the needles are plentiful.

Remarks

The following data from the farm shows how extensively the forest sector on the farm can be cultivated:

Farm sector	o/o of farm land	o/o of labor input
Dairing	89o/o	65.0o/o
Pig breeding	0o/o	9.8o/o
Crops (annual and perennial)	2o/o	19.2o/o
Forest	6o/o	2.0o/o
Various	3o/o	4.0o/o

Sources

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Coffee plantation with alders: Coffea arabica-Alnus acuminata

J. Combe, L. Espinoza, R. Kastl and R. Vetter

San Antonio de Coronado, Costa Rica

Population density

47 persons/Km^2

Agricultural structure

- Average farm size in the region: 32 ha.
- Land use: pasture land 95o/o; arable land 3o/o; and permanent crops 2o/o.
- Size of the farm visited: 3.5 ha.
- Accessibility: the whole region is well developed.
- Marketing: all products are sold in San Jose.

Height above sea level

1 300 m

Climate and vegetation zone

Pronunced dry season from November to May, with strong winds and fine drizzle mainly between December and February. Average annual rainfall is 2100 - 2550 mm. Average annual temperature is 19°C. The vegetation zone is *premontane moist forest.*

Soils

Deep, fertile soils of volcanic origin, mainly sandy and moderately drained (type: dystrandepts of the range Heredia Ondulados).

Agroforestry forms of cultivation

Old coffee plantation consisting of a mixture of the types *Typica* and *Bourbon*

with *Caturra* planted later. Shade is provided by *Musaceae* and *Inga* spp. The fruit and part of the trunk of the *Musaceae* are solds as cattle fodder in the dry season. In May 1974, 100 alders were planted along the rows of coffee at 4 m distances. The young trees were produced at the nursery of the Ministerio de Agricultura y GanaderIA (Ministry of Agriculture and Livestock).

Treatment of the crops

The trees and coffee bushes were always tended at the same time and in the same way (weed control, plant protection, and fertilizing). During 1975 and 1977 the alders were also heavily pruned.

Results

Growth results (alder), (Tables 1 and 2). November 1980.

- Average DBH: 24.86 cm (14.33-31.37 cm)
- Average tree height: 16.56 m (May 1980)
- Annual height increase: 2.76 m

Table 1. Increase in diameter over 6 years.

Year	DBH	Current annual increase (cm)
1975	4.89	5.01
1976	9.20	
1977	14.32	4.42
1978	19.56	5.24
1979	23.70	4.14
1980	25.81	2.11

Table 2. Increase in diameter in 2 samples of 10 trees each with and without pruning.

Year	DBH (cm) with pruning	DBH (cm) without pruning
1975	4.34	4.67
1979	23.36	25.56
1980	24.86	31.36

The growth rate of the alder is very high compared to 19 exotic coniferous species in the same region (Table 1).

The pruned trees showed, in 1980, an average diameter increase of 1.5 cm; the non-pruned trees, however, showed an increase of 4.8 cm. The average height of the pruned trees was 16.9 m; that of the non-pruned trees 14.4 m (Table 2).

Remarks

Different trunk and treetop shapes and different increase in height and diameter underline the need for seed selection with the aim of making better use of the genetic potential of the species.

Sources

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2. ————. El cultivo del jaúl (Alnus jorullensis) en fincas de Café en Costa Rica. ACTAS, Taller Sistemas Agroforestales en América Latina, CATIE, Turrialba, March, 1979.

Alder on cattle pastures: Silvo-pastoril form of farming of the submontane level in Costa Rica

J. Combe

Location

Las Nubes de Coronado, Cantón Coronado, Costa Rica (Figure 1).

Population density

Canton Coronado:	47 persons/Km^2.
District of San Rafael:	138 persons/Km^2.

Agricultural structure

- Average farm size in the Canton Coronado: 32 ha*
- Land use in Canton Coronado (agricultural holdings): Pastureland 95o/o, arable land 3o/o; permanent crops 2o/o.
- Land use in the region (according to aerial photographs): Pastureland 55o/o; arable land 9o/o and forest 36o/o.
- Accessibility: Extremely good (valley transport of products). Practically all roads are paved.
- Marketing: all products are sold in the region around San Jose; the milk produced is fetched daily by lorry.

Height above sea level

1450 to 1700 m.

Climate and vegetation zone

Warm, temperature climate without any very pronounced dry season; rainfall spread over the whole year. Average annual temperature 12-18°C, according to height above the sea. Absolute maximum: 18-24°C. Absolute minimum: 8-13°C.

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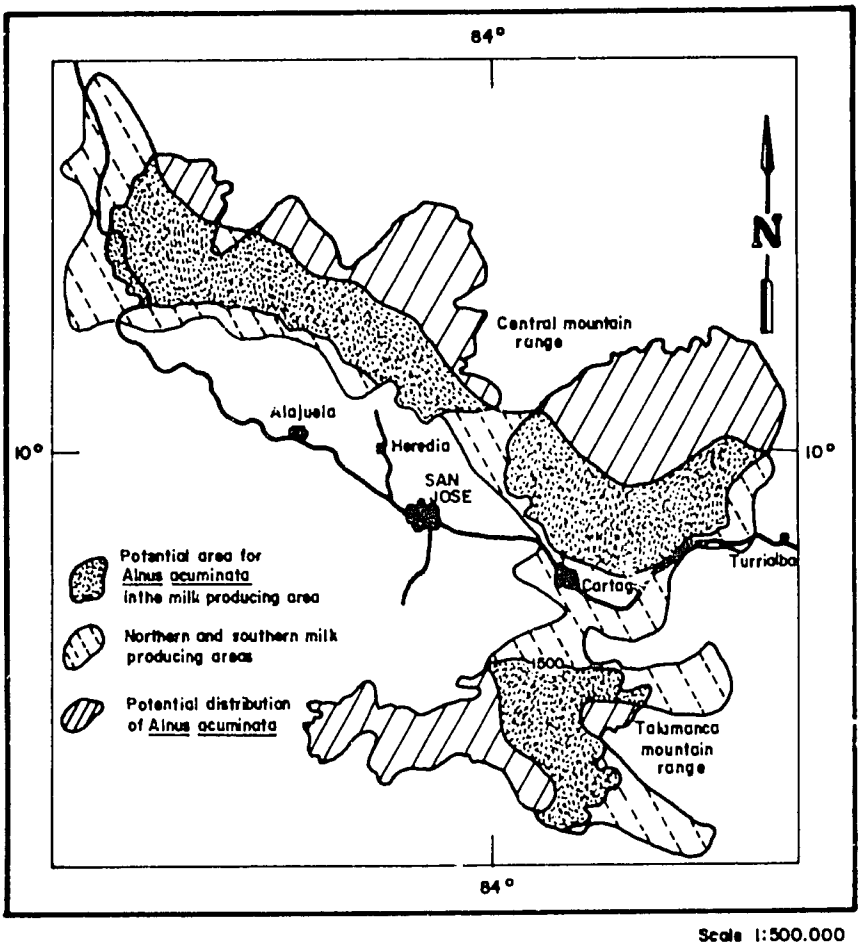
* Surveys have shown that dairy farms of less than 20 ha are now no longer profitable of increasing production costs.

Annual rainfall: 2000 mm on western slopes
3500 mm on eastern slopes

Frequent fog; permanent very high humidity. The farms visited are in the vegetation zone *lower montane wet forest* (HOLDRIDGE).



Scale 1:500.000

Source:

Peterson A. Regiones agrícolas de Costa Rica. Turrialba, Costa Rica. 1965

González, R. Relación entre el peso específico y algunas propiedades mecánicas de Alnus jorullensis H.B.K.. Tesis Maç. Sc. Turrialba, Costa Rica, IICA, 1970

Figure 1: Potential distribution of *Alnus acuminata* in the northern and southern regions of Costa Rica. Estimated area: 60.000 has. Elevation: 1200 - 2400 m.s.n.m.

Soils

Predominantly andosols (together with coarse soils, regosols), derived from volcanic ash and alluvial material. Generally flat, stony ground, sometimes sandy, very prone to erosion when the vegetation cover is destroyed. Nitrogen fertilizing is generally essential.

Agroforestry form of cultivation

For decades alders have been combined with cattle pasturing. The species used in combination are: alder *(Alnus acuminata)*, pastures and grass for cutting *(Pennisetum clandestinum, Pennisetum purpureum, Axonopus scoparious, e.g.)*.

Dairy cows (80o/o *Holstein*, 12o/o *Jersey* in the region).

The stand density in the cattle pastures varies between 625 trees/ha (4x4 m) and 35 trees/ha (17x17 m). Although a plant combination area of 10x10 m seems a good compromise between timber and grass production, on most farms less than 100 trees/ha are acceptable. The majority of farmers consider a plant combination area of 16x16 m and above essential to keep down yield losses of grass. The tree stand then develops, however, to the detriment of increased height.

Treatment of the crops

The shortest production period is 15 years. On the average, however, it is 20 years or more in this region: the final use is according to the needs of the holding (firewood) and is not determined, as a rule, by a target diameter or the lessening of the current growth increase. All trees are pruned to prevent too much shading of the grass rather than to improve the quality of the stem wood. All pastures are fertilized equally whether they are stocked or not. The amounts of fertilizer vary greatly between farms and are difficult to check. Example: farm *Yorusty:* 190 kg/ha urea fertilizer (33o/o N) twice a year.

Results

The increase in growth of alders on cattle pastures is, on a average, between 5 and 10 m^3 per year for stands with more or less 100 trees/ha and a rotation period of over 20 years. The farmers take their firewood primarily from the alder stands. 85o/o of all holdings depend on this energy source, and the annual consumption of alder as firewood in the region is estimated at 100.000 m^3 per year. The alder is also commonly used for construction timber, as it sells more cheaply than cypress from the same region. The potential of alder for production of construction wood has been calculated at 160.000 m^3/year for this region, which equals 13-14o/o of the annual wood demand of Costa Rica (Table 1).

With volume increases of this magnitude, the combination of alder and pasture (on dairy farms) creates an improvement in net returns of 20o/o or more. The following cannot be quantified, however:

- Enrichment of the soil with easily decomposed organic material.

Table 1. Data from the farms visited.

	Farm Yorusty (1.700 m)	Farm Don Rasgo Núñez (1.450 m)
Age (years)	13-16	7
Number of trees/ha (1980)	(9x13 m)	159 (7x9 m)
Average height (m) 1979	22.1	10 (estimate)
1980	22.9	12.4
Diameter (cm) 1979	44.6	17.0
1980	45.4	20.5
Increase in basal area (m^2/ha/year) 1979 - 1980	0.28	1.81
Stem volume (m^2/ha)	69	
Increase in stem volume March 1979 Nov. 1980 (m^2/ha)	3.22 (form factor for timber: 0.403)	

- The regulation of soil moisture on extremely permeable locations, which insures fodder production, especially in the months with little rainfall.
- Soil stabilization on locations prone to erosion.

Problems

Lower fodder production is certainly to be expected under the alders, among other things, because of the following:

- The shade.
- The competition of the very extensive shallow root system just below the surface of the soil.
- The low-hanging branches.
- The compacting of the soil and overfertilization due to cattle resting under the trees.
- Leaf litter from the trees.

Many interactions in this system remain to be explained if an optimal use of this silvo-pastoril form of cultivation is to be achieved.

Remarks

Because of the symbiosis of the roots with *Frankia alni*, an actinomycete (syn. *Actinomyces alni)*, nitrogen is fixed just below the surface of the soil. Young alder

plants contain in fact 355 times more nitrogen in their cell structure with symbiosis than without. The nitrogen content of *Alnus acuminata* leaves is 2.40-3.66o/o without fertilizers.

Sources

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2. POSCHEN, P. El jaúl con pasto: Anzatze eines sylvo-pastorilen systems auf Viehweiden der submontanen Stufe in Costa Rica. Thesis, University of Freiburg, Federal Republic of Germany, 1980.

Silvo-pastoril land use in the highlands of the Central Valley of Costa Rica, the farm "Las Esmeraldas"

J. Ccmbe, L. Espinoza, R. Kastl, R. Vetter

Location

The farm "Las Esmeraldas" is in the district of San José de la Montaña in Canton Barba of the Province of Heredia, 20 Km north-east of San José.

Population density

Of the San Jóse district: 63 persons/Km^2

Structure of agriculture

- Average farm size in Canton Barba: 9.5 ha.
- Land use in the Canton Barba: pastureland 61o/o; arable land 6o/o; and permanent crops 33o/o.
- Size of the farm visited: 270 ha.
- Land use in the farm visited: pastureland, 207 ha = 77o/o; wind protection strip, 34 ha = 16o/o; reforestation, 16.5 ha = 6o/o; and infrastructure, 3.5 ha = 1o/o.
- Accessibility: good (all transport along the valley).
- Marketing: in the vicinity of the capital San Jose.

Height above sea level

2000 m

Climate and vegetation zone (according to HOLDRIDGE)

Data from the meteriological station Barba (7 Km away), annual mean temperature: 18°C; rainfall: 2460 mm with a dry season from February to April (rainfall) less than 50 mm/month).

The region is subject to strong winds for practically the entire year. The farms is in the vegetation zone *lower montane wet forest.*

Soils

The deep, well-drained soils of the region (1.5-.!) have developed from volcanic ash. The pH value is 6.0. The relief is variable, with slopes of 5-50o/o and more.

Agroforestry forms of cultivation

From 1920 to 1930 the farm concentrated on dairy and arable farming (especially maize), but the yields decreased over time. Therefore, the subsequent owners established wind protection with lines of various trees: *Eucalyptus* spp., *Cedrela* sp., *Fraxinus* sp., *Cupressus lusitanica, Alnus jorullensis.*

Of these species *Cupressus* and *Alnus* were best suited as wind breaks. But because the cattle were fond of the alders, no more of these were planted. The wind break consisted of eight rows of trees that were laid according to the instructions of the Swedish Forestry Engineer Alfredo Anderson.

Treatment of the plantations

Until 1945, pruning was the only forestry technique used. From 1950 to 1974, no planting or pruning took place, so that the cypresses developed without any tending. Natural regeneration by the cypresses occurred on the neighboring open land. After 1974, plantations of alders and cypresses were created and the other trees thinned. At the time of tending the wind breaks, the nearby, formerly naturally regenerated plots were cleared (average age: 30 years; diameter in some cases more than 60 cm).

Results

At present the forestry sector produces one-third of the farm's income.

Problems

Root rot in some localized areas.

Remarks

Annual total increments of 38 m3/ha were calculated in 20 years old stands of *Cupressus lusitanica.*

Sources

1. GONZALEZ, M., MARTINEZ, H. and GEWALD, N. "El uso de Prácticas Silvopastoriles en las Partes Altas del Valle Central de Costa Rica; Finca Las Esmeraldas". ACTAS, Taller Sistemas Agroforestales en América Latina, CATIE, March 1979.

Characteristics of the region of Acosta-Puriscal, Costa Rica

J. Beer, L. Espinoza and J. Heuveldop

Geographical situation

North of Pacífico Central about 60 Km from San José.

Climate

Rainfall 2200 mm with bimodal distribution, rainy season from May to December; relative humidity 82o/o, average temperature 21°C.

Soils

Ferralitic (mainly ultisols and oxisols), pH 5-6; overall pronounced phosphorus deficiency; simularly pronounced sulphur deficiency in the sub-region Acosta; soils well provided with Ca and Mg.

Topography

Altitude varies between 500 and 1200 m, steep slopes.

Population density

90-100 persons/Km^2; 90o/o rural population.

Land use

About 80 to 90o/o of the land is used for agriculture (the average in Costa Rica is 40o/o). The forest has disappeared almost entirely; reforestation occurs sporadically, carried out in recent times by private owners and on land under public ownership (Table 1).

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* Compiled from information given by J. Lagemann, CATIE and M. Oviedo, Ministry of Agriculture, Forestry Division, San José, Costa Rica.

Table 1. Land use in the Sub-Regions.

	Acosta	Puriscal
Farm size (in ha)	7.2	13.3
Arable crops (maize, beans, tobacco)*	1.3	1.6
Sugarcane	0.2	0.2
Coffee, bananas, citrus	1.6	0.2
Pasture	3.8	10.2
Other land	0.3	0.1

* Tobacco only in the sub-region of Puriscal.

Table 2. Family structure, labor force and capital.

	Acosta	Puriscal
Persons per family	7.3	7.0
Family labor force	2-2.5	2-2.5
Capital		
a) Vehicles equipment		
Jeep or pick-up	14o/o	16o/o
Hand spraying equipment	43o/o	57o/o
Sugar mill	11o/o	11o/o
Power saws	7o/o	6o/o
b) Animals		
Cattle	5	7.5
Horses	1	1
Pigs	1	1
Hens	19	31

Cash crops

- Coffee, citrus fruit and tobacco (Puriscal).
- Maize and beans only in small quantities (between 20 and 30o/o of production).
- Eggs, especially in Puriscal from a few largescale producers.
- Similarly cattle, mainly in Puriscal.

Problems

- Erosion is becoming much worse as the density of the vegetation reduced and as dairying becomes more extensive in the direction of Puriscal.
- Very limited use of improved seeds (maize, beans) and plants (coffee, citrus).
- Cultivation techniques inadequate especially in the case of coffee.
- Low productivity of the natural pasture grasses.
- Increasing costs of inputs, especially fertilizer and transport.
- Rising costs of labor (especially for the coffee harvest).
- Currently low prices for coffee and oranges (10/100), with the latter subject to pronounced fluctuation.
- Because of the small amounts produced by each farmer for the market, there is no chance of influencing the prices.
- High cost of credit (between 18 and 24o/o per year). Special credit at 8o/o for small farmers is available to a very limited extent.
- Banks are unwilling to give credit to small farmers because of the risk factor involved.
- Extension services are inadequate because of insufficient personnel, vehicles, and money for petrol.

Characteristics and utilization of some tree species used for reforestation

The information presented here illustrates the utilization and characteristics of some tree species: (Table 3).

Pelotia macrantha: no data.

Bombacopsis quinatum: occurs in natural forest, very often in the dry Pacific region; can reach heights of 35 m; widely spreading top; strong branches. The trunk is irregular, covered with thorns; has tube-like roots. The wood is soft and easy to work, but difficult to dry (cannot be completely dried in humid, tropical climate zones). Does not warp when drying, is very durable, but protective treatment is recommended if in use for a long time. Is used as a live fence because of its quick growth. Used for cigar boxes, furniture, skirting boards, etc., in ship bulding.

Cupressus lusitanica: also develops on poor, eroded soils with 1000 - 4000 mm rainfall. Reaches a height of 40 m and a diameter of 100 cm, with up to 2 m height increment per year. Must be pruned. Has to be planted with bare roots for economic reasons. The wood is yellow-red with an orange grain. Has aromatic characteristics. Very durable when treated. The tree is used for: decorative purposes, wind protection, protective forest with dairy cattle, Christmas trees, live fences.
trees, live fences.

The wood can be used for house building, veneers, parquet floors, kitchen equipment, packaging, railway sleepers, masts.

Cybistax donnell-smithii: grows on chalky soils, volcanic ash, and well drained alluvial soils, in humid-to-dry tropical climates, can reach a height of 33 m and a diameter of 100 cm in 35 years. Shows no serious disease problems.

The wood is yellowish to shiny yellow with a light grain in older wood. Is used exclusively for interior decorating and furniture.

Table 3. Utilization and characteristics of some tree species.

	Age (months)	(mm) x Diameter	S x	H (dm) x	S x	G(m^2/ha)	Taking root o/o	N/unit of area m^2	Growth m/year	Growth m/year
Pelotia macrantha	54	115.02	38.19	96.26	32.29	22.07	77	62	.026	2.14
Bombacopsis quinatum	66	9.83	11.27	14.11	5.30	.36	81	66	.014	.19
Cupressus lusitanica	54	72.75	23.36	66.13	32.33	8.91	78	63	.016	.43
Cupressus lusitanica	90	105.40	32.85	100.94	26.71	20.68	86	70	.011	1.07
Cybistax donnell-smithii	66	184.19	29.85	167.00	21.80	10.52	32	26	.030	3.04
Diphysa robinoides	109	46.55	16.66	41.64	12.72	3.32	69	56	.005	.46
Diphysa robinoides	53	30.40	8.11	36.33	8.52	1.90	98	79	.070	.82
Eucalyptus deglupta	97	217.13	64.94	201.63	32.62	32.23	67	54	.027	2.49
Eucalyptus maculata	97	124.56	37.16	128.85	35.75	21.30	64	52	.015	1.59
Eugenia jambos	78	42.96	14.53	42.12	11.97	3.64	90	73	.020	.65
Juglans olanchana	104	152.95	66.04	95.89	19.66	12.90	50	40	.018	1.13
Leucaena leucocephala	3	5.68	1.71	1.81	.99	.06	93	75	.023	.72
Montana dumicola	6	15.59	5.24	9.73	3.50	.49	93	75	.031	1.95
Pinus caribaea	77	122.81	38.92	67.52	20.58	27.76	85	69	.019	1.09
Psedolmedia spuria	41	9.98	3.66	4.66	1.87	1.75	79	64	.003	.14

Diphysa robinoides: grows on soils with low nutrient content. Has to be pruned, especially in early years. Reaches a height of 16 m and a diameter of 40-45 cm.

The wood is light yellow, getting darker from the centre. Used in vehicle body-work, field and garden equipment, as ornamental and for fence posts.

Eucalyptus deglupta: grows on damp, well drained soils with a high content of nutrients. In tropical regions a diameter of 80 cm is reached in 30-40 years, 2-3 cm per year growth increase in young trees. Easily worked wood. Slow drying without defects. Underbark wood easy to preserve. Used for furniture, packaging, firewood, paper and cardboard, posts and masts.

Eucalyptus maculata: found all over the country and most productive at altitudes over 1000 m. Wood has medium density, used for plywood, construction, railway sleepers, posts and masts, sawn timber and charcoal.

Eugenia jambos: grows in the lowlands up to 1200 m, also on poor soils and steep slopes. It reaches a diameter of 20-25 cm; early growth is slow, presumably because of lack of light and nutrient elements. The wood is hard and heavy, beige coloured, and is used for posts and firewwod. The tree is used for decorative purposes, fruit production, protective forest and living fences.

Juglans olanchana: grows on deep well drained soils, reaches a height of 30 m and a diameter of 60 cm in 25 years, with a growth rate up to 3 m per year in the early years. Wood is various tones of grey. Easy to work. Used as posts and in carpentry.

Leucaena leucocephala: found on alkaline, well drained soils in lowlands, dry to humid climate. Rapid growth and has wood that is denser and heavier than that of other rapidly growing species. Used for construction, furniture, panels, paper, charcoal, small posts, shade, and soil improvement with coffee and cocoa crops.

Montanoa dumicola: no data.

Pinus caribaea: grows on red laterite soils, not on chalky soils or deep loams, has specific *mycorrhiza*, rapid growth (2 cm in diameter and 1 m increment in height per year). Good, light-coloured wood, used for flooring, construction wood, for pit props and railway sleepers when treated. Appears usable for pulp, produces high quality resin.

Pseudolmedia spuria: reaches a height of up to 32 m and 60 cm in diameter; straight trunks, occurs from sea level to 800 m. Wood is reddish-brown to pink, dense, strong, and heavy but not very durable in a humid climate. Used generally in construction and carpentry.

Growth of laurel in cocoa plantations and in pastures in the Atlantic zone of Costa Rica

J. Combe, L. Espinoza, R. Kastl, and R. Vetter

Location:

Madre de Dios and Cahuita, Limon Province, Costa Rica.

Population density:

Madre de Dios (Bataan District):	26 persons/Km^2
Cahuita (Cahuita District):	10 persons/Km^2

Agricultural structure

	Madre de Dios (Cantón Matina)	Cahuita (Talamanca)
• Average farm size in the canton	30 ha	26 ha
• Land use in the canton		
pastureland	34o/o	21o/o
arable land	21o/o	27o/o
permanent crops	45o/o	52o/o

• Accessibility: all cacao plantations are accessible, but only by dirt roads that are impassable in the rainy season. Transport (for large regions) in the Atlantic zone is by railway. The infrastructure is deficient and rail transport is, therefore, extremely unrealiable.

• Marketing: all agricultural products from the zone are marketed via Limon and/or Siquirres, also partly via agricultural cooperatives. Wood is sold directly to sawmills or their lorry drives.
Siquirres, also partly via agricultural cooperatives. Wood is sold directly to sawmills or their lorry drivers.

Height above sea level

Madre de Dios 100 m
Cahuita 10 m.

Climate and vegetation zone

Tropical rainy climate with high temperatures and high rainfall: average annual

temperature 25°C and above, minimum never below 18°C; annual rainfall 3000 mm.

Vegetation zone: *premontane wet and premontane moist forest* (HOLDRIDGE).

Soils

Madre de Dios: acidic alluvial soils with high loam content, therefore, frequent waterlogging and flooding for part of the year. Otherwise, generally high agricultural potential.

Caluita: poorly drained, clay soils, in parts mixed with sterile sands in the vicinity of the coast, flooded periodically. Difficult to work because either wet or very compacted.

Agroforestry form of cultivation

In the lowlands on the Atlantic zone, natural regeneration of laurel is frequently tended and encouraged both in the cocoa plantations and on the pastures. One of the reasons for the combined cultivation systems being widespread is that that the maximum growth of this wood-producing species of tree is obviously achieved in well drained locations, which are to be found on the coastal plains with their regular humidity (height above sea level: 0 - 300 m). These plains are also preferred for cropping *T. cacao.*

Teatment of the crops

Work in the stands is rectricted to removing unwanted trees and bushes once a year. The larger trees, whose growth is slowing, are usually harvested in combination with the pruning or complete reestablishment of the cocoa plantation. In this way damage to the cocoa plants is avoided.

Results

See Tables 1 and 2.

Problems

Many farmers are of the opinion that *Cordia alliodora* is not the most suitable shade tree for cocoa production because the root system is in competition with the crops grown in combination. But they, nevertheless, prefer *Cordia alliodora* because of the value of its wood, even though pure stands of this species are rare in *Theobroma cacao* plantations: a mixture of various shade trees with the predominance of *Cordia alliodora* is regarded as much more useful. Therefore, it is difficult to carry out an examination of the effect of *Cordia alliodora* on the yields of crops grown below it and to include other comparative parameters.

Table 1. Growth of *Cordia alliodora* in association *Theobroma cacao* and pasture.

	Density (trees/ha)			Diameter breast height			Heights "h" (m)		
	1977[3]	1979	1980	1977[3]	1979[2]	1980[2]	1977[3]	1979[2]	1980[3]
Madre de Dios (cacao)	180	167	160	34.5	36.0	36.6	35.6[4]	35.9	35.8
Patino (cacao)			76			39.6			32.0
Home Creek[3 5] (cacao)	120	100		41.1	43.1		34.0	35.2	16.0
Cahuita Plot 1 (pasture)		150	150		30.4	31.3		26.6	26.5
Cahuita Plot 2 (pasture)		208	208		36.7	37.5		33.0	33.8

	Basal area[1] (m^2/ha[G])			Commercial Volume V (m^3/ha)			(m^2/ha/yr)	(m^3/ha/yr)
	1977[3]	1979	1980	1977[3]	1979	1980	1979-80	1979-80
Madre de Dios (cacao)	17.6	17.8	17.7	160	168.5	168.7	0.6	5.8
Patino (cacao)			9.9			85.0		
Home Creek[3 5] (cacao)	16.0	14.6		141	134			
Cahuita Plot 1 (pasture)		11.4	12.1		81.9	86.1	0.65	4.23
Cahuita Plot 2 (pasture)		22.5	23.5		195.6	206.4	0.94	10.8

1. Values affected by exploitation and natural mortality.
2. Calculations based only on measurements of trees still standing in 1980.
3. ROSERO, P. y GEWALD, N. Growth of Laurel *(Cordia alliodora)* in coffee and cacao plantations, and pastures, in the Atlantic region of Costa Rica. *In* De las Salas, G., ed. Proceeding of the Workshop Agro-forestry Systems in Latin America. Turrialba, Costa Rica, CATIE. 1979. pp. 205-208.
4. Based on a diameter-height regression curve obtained from the 1979 measurements.
5. Remeasurements not taken as, after exploitation, only 6 *C. alliodora* remain in 1980.

Source: J. Beer. *Cordia alliodora* with *Theobroma cacao:* A traditional Agroforestry Combination in the Humid Tropics CATIE, Turrialba, 1981.
P. Rosero and N. Gewald: Crecimiento de Laurel *(Cordia alliodora)* en Cafetales, Cacaotales y Potreros en la Zona Atlántica de Costa Rica, ACTAS, Taller Sistemas agroforestales en América Latina CATIE, Turrialba, March 1979.

Table 2. Harvest and regeneration study of *Cordia alliodora* in *Theobroma cacao* plantations. Data from the farms of Srs. Mora y Buchanan, Cahuita[1].

A.	Average from range of the dimensions of the felled trees.		
	a)	Utilized undebark volume[2]	- 7.27 (315 - 1697) pulgadas ticas (p.t.) - 2.64 (1.12 - 6.06) m^3
	b)	Roadside value[2] (1 p.t. = C 1.1)	- C800 (347 - 1867)
	c)	Age[3] (assuming growth rings are annual)	- 25 (16-26) years.
	d)	D.B.H.[2] (Breast height diameter but above buttresses when necessary)	- 58 (42-84) cm
	e)	Total height[2] (ha)	- 36 (25-43) cm
	f)	Rates of growth[3] (assuming growth rings are annual)	- 2.2 cm/yr 1.3 m/yr 0.09 m^3/tree/yr
	g)	Commercial volume form factor[4]	- 0.255
	h	Commercial volume[2] (p.t.) = 55.48 d.a.p.[2] (cm^2) x h (m) - 16.61 (r^2 = 0.89)	
B.	Average and range of dimensions of the logs		
	a)	Log lengths - 3, 4, 5 or 6 varas (v) equivalent to 2.5, 3.3, 4.2 or 5 meters (m) (76o/o are 4v)	
	b)	Small end diameter - 47.3[4] (28.5 - 80) cm	
	c)	Utilized stem length - 13.9 (4.1 - 20.6) m (equivalent to 40o/o of total height)	
	d)	Stump height (includes where appropriate a disc which was rejected from the first log) - 1.4 (0.25 - 2.2) m	
	e)	Nose cones - 0.061 m^3 (8o/o of commercial volume)	
C.	Regeneration of *Cordia alliodora*		
	a)	Stumps which coppice[2] - 84o/o (Average height at 4 months is 1.25 m)	
	b)	Natural regeneration and immature trees in the cut over plots (0.75 ha; April 1980)	

Source: 1) BEER, J.W. and ESCALANTE, E. Unpublished data. 2) For 46 trees. 3) Derived from a study of 14 discs. 4) For 180 logs.

Remarks

It has to be accepted that in a cacao plantation of 400 trees/ha (5 x 5 m), eight cacao bushes will be destroyed as an average when a laurel tree is felled.

The recent occurrence of the fruit disease *Monilia rorerii* renders all future research into cocoa difficult in the Atlantic coastal region of Costa Rica.

Effective, economically feasible control techniques have still to be discovered. As the disease spread at a time when the cocoa prices had dropped almost by half, many farmers gave up their plantations, and the lack of income forced many to clear any trees that could be sold.

This sequence of events is a classic example of the importance of agricultural diversification and of the importance of agroforestry combinations in which wood ready-to-be-harvested represents an additional financial reserve.

The widespread clearance of *Cordia alliodora* in the stated regions has enabled the current timber yields and the gross income from timber to be established.

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La "Suiza": Traditional agroforestry forms of land use

J. Combe

Location:

La Suiza, 10 Km southeast of Turrialba, Costa Rica. In this case study, the catchment area of two small streams is investigated (the watershed "Danta" and the watershed "La Leona") with a total area of 830 ha north of the village of La Suiza, where the streams flow into the River Tuis.

Population density:

9 persons/Km^2

Agricultural structure:

- Average farm size in the catchment area: about 16 ha.
- Land use in the catchment area:

	(o/o) La Danta	(o/o) La Leona
Settlement	4.64	- -
Secondary forest	3.83	30.75
Coffee	38.47	6.88
Sugarcane	36.04	9.74
Pastureland	6.66	24.36
Bush vegetation	10.36	28.27

- Accessibility: the whole catchment area is crossed by only one dirt road. The land under cultivation in the catchment area is generally easily reached.
- Marketing: mainly through the cooperative *Coopesuiza* in La Suiza.

Height above sea level:

600 m (La Suiza village) to 1200 m.

Climate and vegetation zone

Largely corresponds to the conditions at CATIE: annual rainfall 2489 mm in La Suiza (average of last 6 years). Average annual temperature 22.3°C. Vegetation zone: predominantly *tropical premontane wet forest,* with the higher past becoming *tropical premontane rainforest* (Holdridge).

Soils

Of alluvial origin at the foot of slopes, partly with volcanic material. On the slopes litosols, not very deep, stony, little agricultural potential.

Agroforestry forms of cultivation

The region around La Suiza was selected for examination because a variety of traditional agroforestry combinations could be observed in a concentrated area:

- *Coffea arabica* variety caturra/*Erythrina poeppigiana*
- *Cordia alliodora (*)*
- *Paspadum spp/Psidium guajava (*)*
- *Saccharum officinarum/Cordia alliodora (*)*
- *Coffea arabica/Citrus* spp./*Cordia alliodora*
- *Paspalum* spp./*Cordia alliodora (*)*
- *Paspalum* spp./*Erythrina poeppigiana*

The land-use forms all arose spontaneously through the initiative of the farmers and were present when the investigations started in 1979. Since then, reforestation experiments have been undertaken with *Pinus oocarpa, P. caribaea* and *Cupressus lusitanica* on two degraded pastures. In the combinations marked with (*), measurements of yields of trees and crops have been made.

Treatment of the crops

Various

Results

Since the measurements have only been made for 2 years, no generally applicable conclusions can yet be drawn. The following provisional data show the wide distribution of measured yields for coffee in one farm (freshweight):

	Harves/ plant (g)	Density coffee bushes/ha	Harvest kg/ha	Gross income ₡/ha
Coffee *Erythrina poeppigiana*				
1979	2478	4101	10 162	34 957.00
1980	2895	4101	11 872	40 839.00
total			22 034	75 796.00
Coffee *Erythrina poeppigiana Cordia alliodora*				
1979	3648	3643	13 290	45 717.00
1980	2268	3643	8 262	28 421.00
total			21 552	74 128.00

Sources

1. BEER, J. W., CLARKIN, K., DE LAS SALAS, G., and GLOVER, N. A case study of traditional agro-forestry practices in a wet tropical zone; the "La Suiza" project. *In:* Simposio Internacional sobre las Ciencias Forestales y su Contribución al Desarrollo de la América Tropical. Ed. Manuel Chavarría, San José, Costa Rica, 1981, p. 191-209.

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Evaluation of results and discussions of the group work, with regard to important statements

Situation analysis

- There is frequently no suitable land-use/settlement policy, or it is difficult to implement. It is a precondition of rural development.

- There is a low level of wealth and little inclination on the part of small farmers and shepherds for long-term investment. Harvesting and exploitation are often primary objectives.

- Agroforestry is a particularly versatile and flexible form of land use; therefore it is adaptable.

- Understanding the system and thinking in terms of the system are essential for agroforestry. In agroforestry, plants, and animals are in competition; they supplement each other in terms of space and time and are to a certain extent dependent on each other.

- There are widespread conflicts between forestry, arable cultivation and pasturing. Special problem zones: in the humid tropical lowlands, the front along which the countryside is being opened up; in the tropical mountain regions; forest pasture in dry zones and arable cropping/protective forest in the humid region; in tropical dry areas; transition zones between nomadic pasture economy and settled arable cropping. Agroforestry can help to remove these conflicts.

- As prosperity increases and the danger to existence decreases: trend to crop separation, to specialization. As the pressure of population increases: threat to existence increases, trend to diversification and agroforestry forms of land use.

- Danger to eco-systems/natural resources through excessive and/or false, ultimately destructive land use Agroforestry is able, in most cases, to reduce the risk, avert the problem of damage, and prevent it by special measures.

Definition of objectives

- Possible conflicts of objectives between target group (rural population), government, and technical aid.
- Prevention of absolute poverty, satisfying basic needs.
- Long-term safeguarding of natural resources through optimal land use.
- Reducing risk by diversification, improvement to the infrastructure.
- Increased experience.
- Development of self-aid potential and greater independence from national and international aid programs.
- Improving and ensuring the food supply.
- Ensuring the energy supply.
- Ensuring raw materials, self-sufficiency.
- Creation of stable/secure ownership conditions for the smallscale farm sector.
- Conflict and/or supplement: subsistence agriculture and selling (export) economy.
- Job creation, creation of income, improving the quality of the workplace, prevention of rural depopulation.
- *Savings bank effect* by means of forestry components, liquidity, current supplies from arable and pasture agriculture.

Implementation/initial solutions

- Necessity of adaptation to the prerequisities of the natural and economic location, to the traditional systems and the development constraints.
- Concentration on particular areas (oasis principle) from which to work outwards with decreasing intensity.
- Often the compulsion to succeed rapidly.
- The target group must often first be motivated to see the necessity of stable eco-systems.
- Teamwork is important; interdepartmental cooperation by GTZ should be aimed for in the countries through cooperation of the services/organizations that are to participate.

- Priority solution to problems on marginal locations, where there is pressure of settlement, etc., special opportunities in favorable locations.

- Agroforestry can help to avoid a *build-up of negative factors.*

- Shortage of species in dry regions requires multiple-use species.

- Possible conflict: retention of labor mechanization.

Success evaluation

- Difficulty of evaluation of the complex total agroforestry system with the long-term economic and ecological aim.

- A socio-economic evaluation of success is not completely possible, *e.g.* because of the difficulty arising from the long-term nature of the forestry components.

- Follow-up phase and subsequent costs crucial for success.

- Advance, current, and retrospective evaluation of success are essential.

- The time factor is often decisive: periodicity in dry regions, instant aid in emergency areas, dependence of development stages on one another.

- Urgent need for applied research in the field of success evaluation, so that practical guidelines can be developed.

The results of the seminar from lectures, discussions, excursions and group work were discussed again in three study groups under the following headings: project location; preparation and planning phase; implementation and planning continuation phase; acceptance; handover of the project; follow-up phase; and evaluation of success.

The evaluation and discussion by all participants produced the following recommendations:

Project location

- A study group should be given the task of identifying the problems and the projects arising from them.
- Main task in area of regional development in those regions where past land use has failed or will probably fail in view of changing conditions. Priority should be given to those problem locations under ecological and economic stress.
- Detailed discussions are necessary with the various sponsoring organizations and departments responsible and with already existing projects.
- People must be made more aware of agroforestry and encouraged to understand it better. This usually means that agroforestry is in fact *discovered* for the first time.
- As early as the initial phase of project location, work must be done to harmonize the objectives, to settle conflicting objectives.
- Carefully avoid arousing too high expectations.

Preparation and planning phase

- Establishing basic data and its analysis require an interdisciplinary approach, best achieved by teamwork.
- The target group(s) should be involved to a significant extent right from the start. At can early stage it has to be established whether there are any research tasks and if so, what they are. *Zero plots* should be established as control plots to check changes occurring as a result of the later project.
- Backstopping provided by research institutes. Best of all would be participation by project-linked research.
- The technical preparation for agroforestry projects requires special care. The foreign partners should, as a rule, be trained on the job in the project or at least in the partner country.

Provided by Sida

- In the planning, including the time-scale, annual rhythm has to be taken into account (especially rainy and dry seasons). Preliminary projects to provide seed, to raise plant material, to erect building, etc., can be effective.
- Agroforestry projects that aim at optimizing land use in the long term usually require long-term involvement and long-term financing.

Implementation and planning continuation phase

- It may be appropriate to include the planners in the actual implementation.
- Importance of pilot projects.
- Rejection of maximizing production in fact of what is practicable on a low-input level.
- Evaluation throughout the project of the effects of agroforestry measures on ecological and socio-cultural changes.
- Involvement of the target group.
- Short-contract experts and project-linked research are especially important in so far as they can help to ensure the interdisciplinary character of the project without having a large team (permanently) operating.

Acceptance

- It is essential that there be no disparity between the short, medium and long-term objectives.
- Adapted technology: that can also be used later by the target group without help. Agroforestry enables farmers to have early and continuing returns compared with other, often longer (and less flexible) commitment of capital, land and diverse resources.
- Importance of humanizing working conditions. This applies especially in the case of women and children.
- Agroforestry provides the starting point for solving the conflict between the objectives of mechanization and the creation of more (acceptable) jobs.
- To evaluate acceptance, there must be constant survey and observation of the target group, the counterparts and the responsible government departments.
- Short-term, demostrable success can be important for the introduction of agroforestry land use. Therefore, at the beginning, risky sectors of operation should be avoided.
- The creation of landownership or ensuring long-term land-use rights are preconditions for the acceptance of agroforestry by the population.

Handover of the project

- The general criteria in the context of technical aid apply at this stage: close connection with follow-up phase.
- Special consideration has to be given to the subsequent costs both to the government and the rural population itself.

- The institutional integration can present difficulties (arable cultivation, forestry, pasturing). Higher institutional or governmental levels should be included.

Follow-up phase

- Ensuring continuation by national extension services that may have to be built up or extended.
- Implementation of refresher and continuation courses.
- Flanking measures by means of projects linked to the current project or measures taken from other continuing projects, *e.g.* plant protection marketing.

Evaluation of success

- In agroforestry projects there is the necessity (and therefore the problem) of taking a long-term view.
- Problems of data collection because of the varied components in agroforestry land use (character of the system).
- Measuring overall success by socio-cultural, economic, and ecological criteria.

Parameters make optimization measures necessary. Further research is necessary in this field to provide guidelines for practical application.

Suplementary recommendations

- From the viewpoint of the participants in the seminar, it would be desirable to create a superregional collaboration project to prepare and support the implementation and follow-up phase of agroforestry projects or partial projects.

- Support for international *(e.g.* ICRAF), regional *(e.g.* CATIE) or national institutes and organizations in developing countries should be intensified (reference to ISNAR).

- The development of further training programs for agroforestry should be encouraged. The teaching of agroforestry in developed and in the developing countries should be extended.

- There should be more publicity about agroforestry. Use should be made of the mass media. Educational films should be produced.

- A DSE/GTZ seminar in the near future on dry mountain regions and involving the participation of experts on arable farming, forestry and pasturing would be extremely desirable. Further counterpart seminars should be planned.

Forward view*

The seminar has provided the opportunity to extend and deepen our appreciation and consciousness of the potential and the limits of agroforestry; it has awakened the awareness of the participants. From this awareness grows the obligation to develop our knowledge further and to pass it on the others, especially in partner countries.

Apart from the many topic areas that have been dealt with in detail during the seminar, there are others that deserve special attention, for example:

The development of the organization and administration in the different countries as a basic prerequisite for policies of land use and a precondition for any activity in agroforestry. The agrarian reforms can play a special role in this.

A thorough knowledge of and appreciation of the relationship between people and trees in rural regions. The cultural importance of trees should be given special consideration, and care must be taken to prevent cultural values being destroyed by the measures required for technical progress. Anthropological studies should be carried out.

Agroforestry should benefit the city dweller as well as the rural population. The city population is particularly influential with regard to decision-making in most developing countries. Agroforestry in the catchment area of central (urban) settlements has an important function in many countries from an economic and social point of view. It leads to what is known as urban forestry.

With regard to acceptance, it is important to exert early and sufficient influence on the training of those people who will later be the decision-makers in their countries. These people too must be a target group for agroforestry development. Also, it is often easier to learn from the target group of the rural population (farmers, shepherds, forest owners), than to introduce something acceptable to them. Agroforestry requires, in this sense, much patience and a special continuity of effort. This is particularly necessary because poverty is often closely correlated with educational deficiency, and the poorest sector of the population is, the least receptive. A further factor is that it is more difficult to develop strategies for *stress regions* and to put them into practice than for more endowed regions.

In view of the general development, we can expect the tasks and problems in rural regions to increase in the future. It will be the job of research to work out possible solutions in time and to make them available for practical application. This requires close international cooperation and the continuous exchange of experience. Everyone with the knowledge and opportunity to promote rural development in the context of agroforestry has an obligation to apply his knowledge and expertise to serve mankind by creating a balance between the necessity of supplying resources to the population and the long-term exploitation of resources. The best prospects of success arise from the combined efforts of all participants which the structure of agroforestry demands.

In this sense, Dr. Lampe appealed to the members of GTZ to pursue their involvement and activity with courage: the courage to take risks, the courage to ask more questions, the courage to be unpopular, to be patient, to have a dialogue (over the whole subject range), the courage to look ahead to the next century, and the courage to take responsibility.

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* Summary of the papers presented by G. Budowski, K. Lampe and H.J. von Maydell at the end of the seminar.

APPENDIX I: LECTURES AND REPRESENTATIVES

Invited lecturers

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HEUVELDOP	Dr. Jochen Tropical Agricultural Research and Training Center (CATIE) Turrialba, Costa Rica
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APPENDIX III: LIST OF FURTHER READINGS

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APPENDIX IV: AGROFORESTRY DOCUMENTATION IN CATIE

As a service within the Forestry Department, the agroforestry documentation of CATIE is looked after and extended by INFORAT (Información y Documentación frestal para América Tropical).

In summary, what started with a document collection, developed into a bibliography and finally became a Documentation Center on Tropical Agroforestry, with the objective of making the documents available to all who require them.

Between 1977 and 1979 Mr. Jean Combe, a Swiss forestry expert assigned to CATIE by the Swiss Program of Cooperation for Development, DDA, began to

collect and classify approximately 380 bibliographical references, and most of the respective supporting documents, on tropical agroforestry

The collection of documents was initiated in July, 1977, and served as the basis for studies on classification and investigation on agroforestry techniques. Later, the collection was oriented toward the study of particular techniques, reports on successful applications, and a few reports on ongoing research. The acquired information permitted the design of various field experiments allowing the quantification of the most interesting techniques both on CATIE grounds and on small farms in the Turrialba region.

Publication on research methods on specific aspects were later introduced. Among these publications special notice should be made of *Expert Consultation on Soils Research in Agroforestry*, ICRAF.

Mr. Combe returned to Switzerland in March, 1980. His documentation work was continued by Mr. Humberto Jiménez Saa, M.S., a professional forester, in collaboration with Miss Claudia Monge, B.S., Miss Gerardina Araya, and Mr. Gilberto Gamboa, employeers of INFORAT, a project promoting forest information and documentation, sponsored by DDA.

The original collection continued growing: bibliographical references were composed, missing documents were obtained, key words were assigned to each of the documents, a Uniterm card system was introduced and the information was partially stored on discs to be processed by the computer center at CATIE. In 1981 a bibliography on Tropical Agroforestry was published comprising 680 references of technical documents. In regard to geographical distribution, emphasis was on Tropical America, but references on Africa, Asia, Australia and New Zealand are also included. There is no pretense to cover everything that has been published in the field of Agroforestry; on the contrary, in some cases only representative works have been included, with the hope that they will facilitate a detailed complementary search.

The present services of INFORAT cover four basic activities:

1. Locating technical and scientific information: INFORAT gives information about already existing sources, especially in the case of bibliographical journals, information about their publication, subscription conditions, synopses, etc.

INFORAT sends certain documents directly to interested parties if they have difficulty in contacting foreign sources of information. All publications available at CATIE are available at publication cost.

2. Publishing research results and distribution of publications: INFORAT is responsible for the publication and distribution of the results of work carried out by the Forestry Department at CATIE. INFORAT supports and advises those institutions that want to build up their own publication service, especially with respect to the staff required, the equipment and the costs.

3. Training: While performing the services for CATIE, INFORAT can also train staff for fairly short periods. This applies especially to the staff of new documentation centers and publication services.

4. Work documents and data banks: It is intended to extend the future range of activities of INFORAT and to investigate the most appropriate method of storing documents at CATIE.

Main parts taken from Presentation by G. Budowski in ***Bibliography on Tropical Agroforestry,*** CATIE, 1981.