# AGROFORESTRY: CONCEPTS AND METHODOLOGIES FOR RESEARCH-DEVELOPMENT

**Dr. Denis DEPOMMIER**
French Institute of Pondicherry, december 1998

## 1. AGROFORESTRY, AGROFORESTRY SYSTEMS AND MPTS

### 1.1. Definition of agroforestry:

Agroforestry is a recent science for a very old practice. It is a collective name for land-use systems and technologies in which woody perennials (trees, shrubs, palms...) are deliberately combined, in space or time, with crops and/or livestock to obtain profitable ecological and economic interactions. (ICRAF, 1987). This makes agroforestry systems varied and complex. But agroforesty is not just a simple addition nor a juxtaposition of agriculture and forestry. It is a science where biology (ecology, forestry, agriculture, animal breeding...) and social sciences (anthropology, geography, economics...) interact, making agroforestry a multidisciplinary science.

### 1.2. Classification of agroforestry systems:

Agroforestry systems and their sub-systems can be classified according to the nature of the components (Nair, 1985; Table 1):

- agrisilviculture: associating crops with trees or shrubs, from improved fallows to complete multilayered homegardens;
- silvopastoralism: associating trees (fodder, live fences) with animals;
- agrosilvopastoralism: associating crops with trees and animals;
- others: aquaforestry (*e.g.*, in mangroves) or apiculture and trees.

This classification can be sub-divided based on the arrangement of the components, in time and space, and where trees, —the perrenial component of the systems— constitute the structure of the systems and sustain the combinations:

- in space: mixed (dense or scattered trees), linear (trees in lines, strips, boundaries)
- in time: trees and crops may be associated in a coincident, interpolated, overlapping or sequential manner.

Finally, agroforestry systems can be based on the primary function or role of woody perrenials:

- for production functions: food, fodder, fuelwood, medicine, crafts, mulch, etc., usually referring to quantifiable and economic values
- for protection and other service functions: windbreaks, living fences, countour strips, shelter belts, land delineation, land tenure, soil conservation, shade, etc., with ecological and socio-economic values that are more difficult to assess and quantify.

| System | Sub-systems and practices | Primary role of woody perennials | Arrangement of components in space(s) and time (s) | Type of interaction between components |
|---|---|---|---|---|
| AGRISILVICULTURAL | Hedgerow intercropping or alley cropping | Protective and productive | s: Zonal<br>t: Concomitant | Spatial |
| | Improved fallows | Protective and productive | t: Sequential | Temporal |
| | Homegardens | Productive | s: Mixed, dense<br>t: Interpolated | Spatial and temporal |
| | MPTS in parklands | Productive and protective | s: Mixed, sparse<br>t: Interpolated | Spatial |
| | Shade trees for cash crops | Protective and productive | s: Mixed, scattered<br>t: Coincident | Spatial and temporal |
| | Shelterbelts and windbreaks | Protective | s: Zonal<br>t: Interpolated | Spatial |
| SILVOPASTORAL | Fodder banks | Productive | s: Zonal<br>t: Interpolated | Temporal |
| | Living fences | Protective | s: Zonal<br>t: Concomitant | Spatial |
| | Trees in pastures | Productive and protective | s: Mixed, sparce<br>t: Coincident | Spatial |
| AGROSILVOPASTORAL | Hedgerows for fodder and soil conservation | Productive and protective | s: Zonal<br>t: Interpolated | Temporal and spatial |
| | Tree-crop-livestock mixed around homesteads | Productive and protective | s: Mixed<br>t: Intermittent | Spatial and temporal |
| | Fodder trees in parklands | Productive | s: Mixed<br>t: Overlapping | Temporal and spatial |

**TABLE 1: THE ROLE OF WOODY PERENNIALS, THEIR ARRANGEMENT AND INTERACTION WITH OTHER COMPONENTS IN SOME COMMON AGROFORESTRY SYSTEMS.**
(Adapted from: P.K.R. NAIR, ICRAF, 1985)

## 1.3. Multipurpose Trees and Shrubs (MPTS)

Multipurpose trees and shrubs are defined as "all woody perennials that are purposefully grown to provide more than one significant contribution to the production and/or service functions of a land-use system (Fig. 1). They are thus classified according to the attributes of plant species as well as the plant's functional role in the agroforestry technology under consideration (Wood and Burley, 1991). As observed by these authors, any woody perennial species can be 'multipurpose' in one situation and 'singlepurpose' in another. Most MPTS are indigenous species and refer to traditional knowledge and practices which have been neglected for a long time by Research and Development. Agroforestry systems are usually composed of multipurpose trees, but all MPTS do not make agroforestry systems (*e.g.*, pure stands of MPTS whose products and services have no relation to crops or livestock). MPTS certainly have high economic and social values but considering the shortage of fuelwood, timber, fodder, and other tree-based products or services which is common in many tropical areas, one cannot expect the 'multipurpose' potential of the MPTS to satisfy all the needs; agroforestry is not a panacea. Moreover, very little is known about them, especially their behaviour, management and breeding. This clearly shows the importance of research on MPTS.

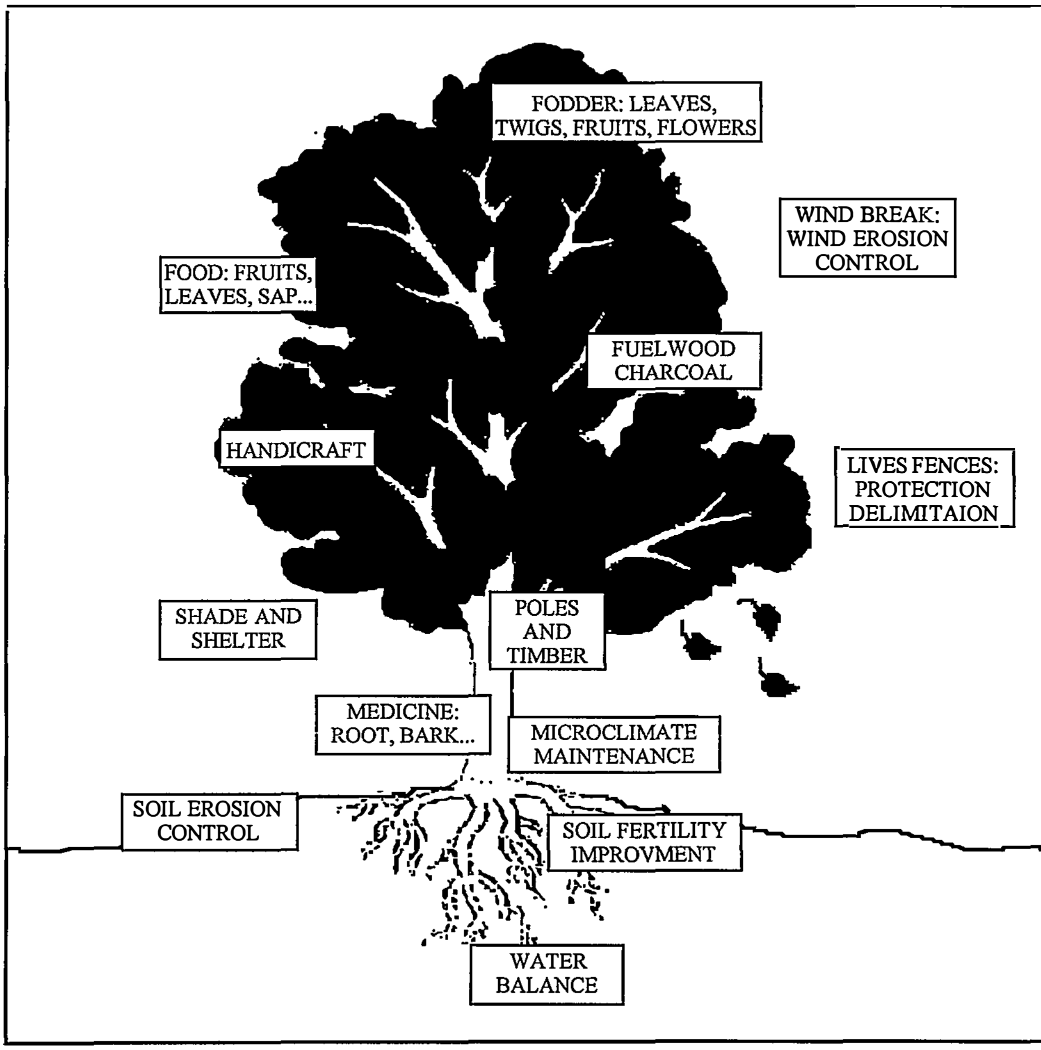


**FIGURE 1: MAIN PRODUCTS AND SERVICES FROM THE MULTIPURPOSE TREE (MPT)**

## 1.4 . Agroforestry systems and practices in India:

Agroforestry has been traditionally practiced in India since a very long time and multipurpose trees may be found throughout the country, from North to South:

- in Sikkim, large cardamom *(Amomum subulatum)*, a major cash crop, grows better under *Alnus nepalensis*, a nitrogen fixing tree which improves the fertility and moisture status of the soil and provides shade to the crop (Sharma *et al.*, 1994)

- in Himachal Pradesh, cereals and vegetables are grown on hill slopes, on terraces whose bunds are planted with *Grewia optiva* —the dominant species—, *Celtis australis, Bauhinia variegata, Albizzia chinensis, Morus serrata, Toona ciliata,* for fodder, timber, fuel and soil conservation (Parkash Toky *et al,* 1989);

- *Prosopis cineraria* (khejri) is sparsely associated with crops as parklands in Rajastan (Shankarnarayan *et al,* 1987). The tree is an important source of animal feed, fuel and timber, and also improves soil fertility, thus benefiting associated crops, in the same way as *Faidherbia albida* in Sahel, Africa. *Ziziphus nummularia* (bordi) is locally associated with the former and various fodder species (*Acacia tortilis, Ailanthus excelsa,* etc.)

- Fruit trees such as mango and jack fruit, and palms like coconut and arecanut are very popular among farmers in the humid and sub-humid regions of Karnataka, while tamarind, *Acacia arabica* and neem are the most common species in the drier regions (Rai and Shiv Shankar, 1994). In Kodagu district, the coffee-based system integrates two or three storeys of perrenials (Chaumette, 1997; de Pommery, 1996): *Erythrina sp.* which is pollarded, *Citrus sp.* and taller shade trees, including fast growing species such as *Grevillea robusta.* In Shimoga region, arecanut is commonly interplanted with banana, black pepper, cardamom, and locally with coffee and cocoa.

- *Borassus flabellifer* is dispersed among crops and also lines the bunds of paddy fields in Tamil Nadu, mainly for its sugary exudate ("nera"). In this state, according to Jambulingam and Fernandes (1986), *Ceiba pentendra* (kapok) is planted on field bunds or scattered on croplands like *Tamarindus indica,* commonly associated with cereals and pulses. Cuttings of *Delonix elata* are planted on bunds to provide green manure in rice fields. Simple or combined windbreaks of *Azadirachta indica, Prosopis juliflora, Euphorbia tirucalli,* all drought-tolerant species, have also been surveyed to protect associated crops in Tamil Nadu. Agrisilvopastoral or silvopastoral systems integrate *Acacia leucophlea* for its pods and to increase the yields of associated cereals, pulses and fodder grasses. They also include *Acacia nilotica,* a fodder species (pods, leaves) planted on bunds.

- in Kerala, coconut -based homegardens include many perrenials (Achutan Nair and Sreedharan, 1986): arecanut, cashew, cocoa, black pepper - with *Erythrina indica* as live stakes-, nutmeg, clove, cinnamon, fruit and shade trees (custard-apple, sapota, bread-fruit, jack-fruit, mango, tamarind), various crops (tubers, pulses, banana), spices (turmeric, ginger) and medicinal plants. Small livestock (poultry, goats, pigs) and grasses are often integrated with them. Windbreaks are found in some areas, composed of *Tectona grandis, Casuarina equisetifolia,* sometimes with fruit trees. Boundaries are often delimited with *Alstonia scholaris* and *Bombax ceiba.*

Although many researchers, managers and extension workers have pointed out the important role agroforestry could play in India, many agroforestry systems and practices are still ignored or poorly described and assessed in India. So inventories based on an appropriate approach for a better understanding of their functioning should be encouraged.

## 2. APPROACH AND METHODOLOGICAL TOOLS

### 2.1. ICRAF Diagnosis and Design methodology:

Agroforestry systems contribute significantly to satisfying the requirements of local populations in terms of energy, building materials, food, fodder and multiple ecological services.

They can be considered as a model of productive and protective value and developed by integrating more MPTS in fields and grazing lands in a sustainable manner. One of the most relevant issues is that the pressure on existing forests can be reduced through agroforestry approaches, of which the Diagnosis and Design methodology, developed by the International Council of Research in Agroforestry (ICRAF) in the 80's, is a very appropriate one.

As "diagnosis should precede treatment" the "D and D methodology" is a step-by-step methodology for diagnosing and designing agroforestry systems and technologies (ICRAF, 1987). It states that there is no substitute for good design and that a good agroforestry design should fulfill the following criteria:

- **productivity**, which can be achieved in many different ways through agroforestry : increasing the yields of trees and associated crops, reduction of cropping system inputs, diversification of production, better labour efficiency, etc.

- **sustainabilty**, in achieving conservation goals, notably through certain functions of trees (N fixing ability, mulch production...)

- **adoptability**, by the intended users, which proves the relevance of the designed technology.

The basic principles and chronological procedures are as follows:

**(a) Pre-diagnosis:**

Identification of the land-use system and site selection is done at the macro scale: delineation and comparative analysis of existing land use systems (resources, land users, existing technologies and strategies). The selected system is described.

**(b) Diagnosis:**

In depth assesment and the characterisation of the system functioning are done at a micro scale: analysis of constraints, sustainability problems, needs and potentials through interviews (farmers and all concerned "actors") and field observations.

**(c) Design:**

Proposed improvement of the system with specifications for solving problems. Interventions, “candidate technologies” and (non-agroforestry) alternatives are designed.

**(d) Planning:**

The planning phase refers to the organisation of development and dissemination of the proposed interventions. Project planning as well as research designing are based on Research-Development-Extension links and needs.

**(e) Implementation:**

As a final step, implementation has to adjust the project or technology to any new information channelled as a feed-back from on-farm and on-station trials. Rediagnosis and redesigning (adaptation of a technology) of the exercise is done as necessary following an iterative procedure.

Application of the "D and D methodology" or other similar approaches (*e.g.*, the "System approach" or the "Integrated R-D approach") is certainly an appropriate response to the difficulties and dead ends in communicating between Research and Development (Fig 2).

(a)

(b)

(c)

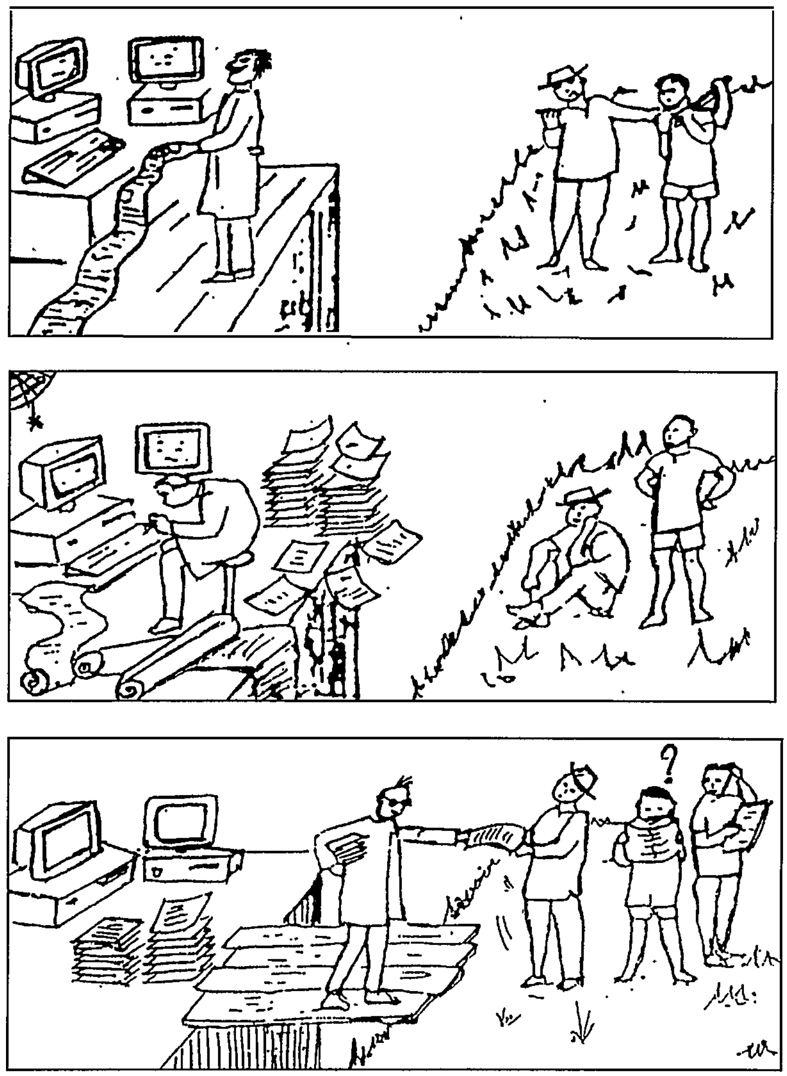

**FIGURE 2: DIFFICULTIES AND DEAD ENDS IN COMMUNICATING BETWEEN RESEARCH AND DEVELOPMENT**
The pitfall of speciality (a), anteriority (b) and linearity (c)

(a) Researchers on one hand, and extensionists and farmers on the other act separately as specialists. They have different approaches and expertise which they do not share (no communication);

(b) Research precedes Development: extension workers and farmers wait for results, often for very long periods (no application);

(c) Research-Development is based on hierarchical linearity: researchers are the sole designers. They build prototypes and technologies that extension workers and farmers have to understand and execute (no feed-back).

### 2.2. Tree-crop interface:

The tree-crop interface can be defined as the area where the tree (its roots and canopy) interacts with crops, directly or indirectly, with positive or negative effects, *viz.,* synergy or competition for light, water, nutrients (Fig. 3).

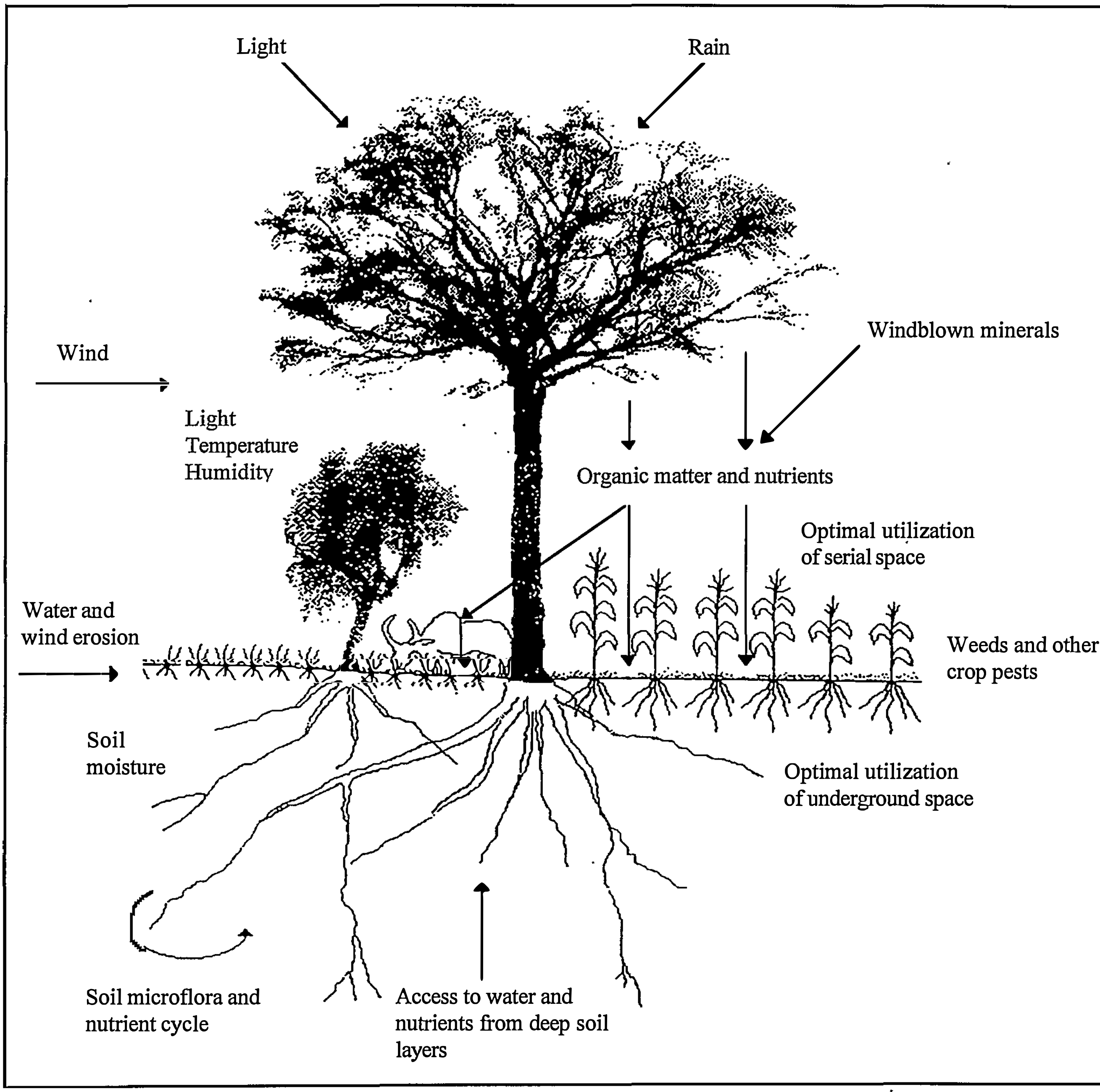


**FIGURE 3: MAIN AREAS OF ECOLOGICAL INTERACTIONS IN AGROFORESTRY**
(Source : TORQUEBIAU, 1990)

Interaction between components, whether ecological or economic, can be:

- complementary if the presence of one component increases the yield of the other,
- neutral if one has no effect on the other,
- competitive if the presence of one reduces the yield of the other;

As mentioned by Torquebiau (1990), the aim of agroforestry is to identify positive interactions and maximize them while trying to reduce negative interactions. In most agroforestry systems, trees have negative effects on associated crops but reduced crop production is compensated economically (woody and non-woody products). Additional benefits from the trees (erosion control, land delimination, etc.) may provide more than a compensation in terms of social and environmental value.

Different types or models may be considered when studying the tree-crop interface:

- mixed or azonal systems where trees are:
    . scattered: *e.g.*, parklands with very variable densities
    . dense: *e.g,* homegardens in plurispecific layers
- linear or zonal systems where the trees are usually planted in:
    . monolinear / monospecific rows: *e.g.* alley cropping, live fences
    . multilinear / plurispecific rows: *e.g.* windbreaks, shelterbelt

In Research on tree-crop interface, ecological effects of trees on soils and associated crops are commonly assessed (experimented, quantified and modelled in space and time):

- at different distances from the tree: beneath, around, beyond (where control plots can be set up) over several years or cycles;

- according to different combinations of trees and crops and management conditions (of soils, crops and trees);

- eventually translated into economic terms: (evaluation of certain products and services and taking stock of them is often a difficult enterprise);

- and can be compared with monoculture: *i.e.,* taking in to account the improved or reduced yield of a crop plus the expected gains from trees (products, services) over several years.

Finally, the objectives of studying tree-crop interface are:

- to optimize the positive interactions or to reduce observed negative effects depending on:
    . species, cultivars, origin (nature of components)
    . spatial or temporal arrangements (structure, combinations)
    . management (tree handling, various inputs and outputs in the system)

- to meet farmers' needs and productivity in a sustainable way, through a multidisciplinarity and system approach.

### 2.3. The ideotype concept:

Ideotype is a concept of breeders (ideal plants). In agroforestry, it is a model tree in morphological and physiological terms that will provide the best products and services in terms of quantity and quality.

An ideotype specifies the ideal attributes of a MPT for one or more particular purpose(s):

**(a) Biological aspects of trees:**

- adapted/unadapted germplasm to soil, climate, etc., (in terms of survival, growth, etc.)
- relevant/irrelevant, (*e.g.* spiny or not, nitrogen fixing or not).

**(b) Socio-economic attributes of the trees:**

- useful/useless,
- beneficial/harmful,
- "adoptable/not adoptable",

varying according to the function, land, labour requirement, market.

**(c) Taking into account the system specifications:**

- synergy or low competition with crops ("associative" ideotype that maximizes sharing of resources),
- ability to be handled (tree management, a set of key variables in agroforesty systems).

To give an example, the tree specifications for hedgerow intercropping by small farmers on Central Plateau in Burkina Faso are as follows (Fig. 4):

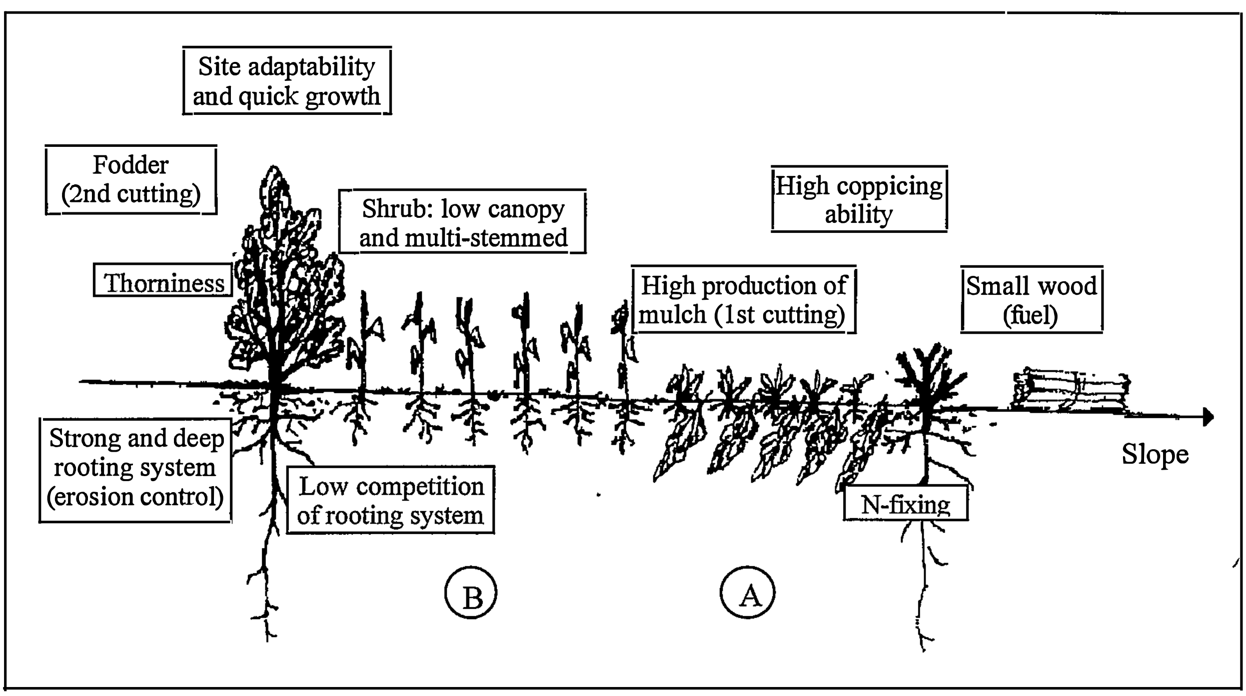


FIGURE 4: THE IDEAL TREE OR IDEOTYPE IN A HEDGEROW INTERCROPPING WHERE TREES ARE CUT BACK AND THE PRUNINGS ARE APPLIED TO THE CROPS IN BETWEEN AS MUCH
(A: during the growing period of the crop - B: at the harvesting period of the crop).

- compatibility with climatic and edaphic conditions (long dry season, shallow and poor soils),
- shrub or small tree (multi-stemmed, covering canopy),
- fast-growing (an important criterion for farmers who want quick proof of the benefits of the proposed species),

- easy to establish (propagation by direct seeding or cuttings may be appropriate to minimize costs and time),

- nitrogen fixing (and other nutrient cycling ability for the benefit of soils and associated crops),

- ability to coppice vigourously and to produce large quantities of herbaceous material following heavy pruning (green manure or mulch),

- thornless (easy handling),

- ability to provide by-products, such as fuelwood or fodder, under appropriate management.

## 2.4. Steps in experimentation:

Taking into account what has been said earlier in terms of methodology (diagnosis, MPT and technology specifications), step by step experiments can be developed as follows:

**(a) Study of MPTS behaviour:**

Behaviour of many multipurpose trees and shrubs is poorly documented. This may be tested:

- on-station, through elimination trials, provenances trials and complementary trials such as propagation of germplasm (*i.e.,* comparing cuttings, seedlings and direct seeding with a view to developing live fences),

- on-farm, where the MPTS are tested in existing agroforestry systems.

**(b) Study of MPTS management:**

Experimentation on MPTS management consists of on-farm and on-station experimentation where any trial involves direct or indirect handling of MPTS:

- spatial arrangement (*i.e.,* testing density, combination of species, in hedges or homegardens respectively),

- coppicing, pollarding to quantify the biomass, (*i.e.* wood and fodder production) and assess the response of the tree to the treatment, (*i.e.* coppicing ability and growth at various heights, frequencies and periods of the year).

At this stage the main factors usually studied are: species, space, time, tree handling (cutting, harvesting, combination).

**(c) Study of the tree-crop- (livestock) interface:**

Any experimentation on tree-crop (livestock) interface is necessarily based on a system approach, whether it is on-farm or on-station, with the aim of:

- comparing different associations of components (in existing or new systems),

- assessing competitive or synergic effects, in space and time,

- following the adoption, adaptability and extension of the proposed technology.

## 2.5. Research needs:

Because of its global nature, agroforestry is multidisciplinary, and agroforestry research which integrates at least the three basic disciplines, *i.e.,* forestry, agronomy and livestock breeding, is obviously more complex than research on monoculture or pure stands of trees. Accordingly, the system approach is a compulsory tool for studying agroforestry systems. As an integrated approach, it enables the analysis of the structure, functioning and dynamics of these systems, in space and time. However, agroforestry research is a fairly new discipline which needs to be consolidated especially in:

**(a) Methodologies:**

- The well established methodologies, D and D, integrated or participatory R-D, have to be refined and adapted to the wide variety of ecological and socio-economic conditions. In certain cases, simplified methodologies (*i.e.,* rapid appraisal) may be more appropriate.

- Interdisciplinarity is the basic feature of agroforestry, but it is more discussed than practised. Researchers still have to train and develop interdisciplinarity to make agroforestry successful.

- Institutionalization of agroforestry (through research development, training and education) has improved a lot during the last 10 years but in many cases its place —its institutional "niche"— is yet to be consolidated at the same level as other disciplines.

- Research-Development and Extension links should be strenghtened to make agroforestry efficient and practical; agroforestry management system in rural areas should be encouraged.

- Education and training facilities may play a fundamental role in boosting agroforestry and improving the research-development link.

**(b) Experimentation and research assessment:**

- In agroforestry research, applied and academic domains, like on-farm and on-station experiments, are too often separated when they should be linked and developed in tandem.

- Regarding the MPTS, many research domains have not been explored, especially germplasm, phenology, ecophysiology (very little is known about roots and water or nutrient uptake).

- Finally, assessment methodologies and indicators have to be developed to satisfy the objectives of research-development in agroforestry, taking into account the results of research, efficiency of the designed technologies (means, duration...), participatory, adaptability and their impact at different levels (farmer, rural community, watershed...).

These indicators should include:

. Changes in agricultural practices: adoptions, adaptations and diffusion of new technologies;

. Changes in farmers' attitude: information, familiarization, popularization;

. Social impact: vis-à-vis health, food, welfare, land, labour...;

Productivity and diversity of the studied system compared with others;

. Ecological impact: on soil, water, other resources;

. Economic impact: on household, local and others scales;

. Organizational impact: on communities, local structures and external partners.

## BIBLIOGRAPHY


ACHUTHAN NAIR, M. and SREEDHARAN, C., 1987. Agroforestry farming systems in the homesteads of Kerala, Southern India, Agroforestry Systems, 4, pp. 339-363.

CHAUMETTE, M., 1997. Composition et structure des ombrières des plantations de café dans le Coorg (Karnataka, Inde). Agroforesterie et conservation de la végétation naturelle. Mémoire de fin d'étude, 5ème promotion FIF-ENGREF.

DEPOMMIER, D., JANODET, E. and OLIVER, R., *Faidherbia albida* parks and their influence on soils and crops at Watinoma, Burkina Faso, Proceeding of the Workshop 'Faidherbia in the West African semi-arid tropics', Niamey, 22-26 April 1991, pp. 111-115.

DEPOMMIER, D., and MALLET, B., 1996. Trees in rural environments or the emergence of agroforestry, BFT, special issue, pp. 25-29.

DEPOMMIER, D., 1996. Structure, Dynamique et fonctionnement des parcs à *Faidherbia albida* (Del.) A. Chev. Caractérisation et incidence des facteurs biophysiques et anthropiques sur l'aménagement et le devenir des parcs de Dossi et de Watinoma, Burkina Faso, Thèse de biologie et écologie végétales tropicales, Paris VI, 2 vol., 519p. + annexes.

FRANZEL, S. JAENICKE, H. and JANSSEN, W., 1996. Choosing the Right Trees. Setting priorities for Multipurpose Tree Improvement, ISNAR, Reserch Report n°8, 87 p.

ICRAF, 1987. D and D User's Manual. An Introduction to Agroforestry Diagnosis and Design, edited by J.B. Raintree, ICRAF, 1987, 110 p.

JAMBULINGAM, R. and FERNANDES, E., 1986. Multipurpose trees and shrubs on farmlands in Tamil Nadu State (India), Agroforestry Systems, 4, pp. 17-32.

MARY, F. et BESSE, F., 1995. Guide d'aide à la décision en agroforesterie, CTA/GRET/Coop. Fse, 2 tomes avec fiches techniques, 301 p + 284 p.

NAIR, P.K., 1985. Classification of Agroforestry systems, Agroforestry, 3, pp. 97-128.

PARKASH TOKYO, KUMAR, P., and KUMAR KHOSLA, P., 1989. Structure and function of traditional agroforestry systems in the Western Himalaya. 1, Biomass and productivity, Agroforestry Systems, 9, pp 47-70.

De POMMERY, H., 1996. Etude de l'évolution des ombrières des caféières dans le district du Coorg (Karnataka, Inde) - Mémoire de fin d'étude, 4ème promotion FIF-ENGREF.

RAI, S.N. and SHIV SHANKAR, K., 1994. A survey on Agroforestry practices in Karnataka, KFD, 15 p.

SHANKARNARAYAN, K.A., HARSH, L.N.and KATHJU, S., 1987. Agroforestry in the Arid zones of India , Agroforestry Systems, 5, pp. 69-88.

SHARMA, R., SHARMA, E., and PUROHIT, A.N., 1994. Dry matter production and nutrient cycling in agroforestry systems of cardamom grown under Olnuits and natural forest, Agroforestry systems, 27, pp 293-306.

TORQUEBIAU, E., 1990. Introduction to the concepts of Agroforesterie, WP n°59, ICRAF, 121 p.

WOOD, P.J. and BURLEY, J., 1991. A tree for all reasons. The Introduction and Evaluation of Multipurpose Trees for Agroforestry, Science and Practice of Agroforestry n°5, ICRAF, 158 p.