Agroforestry systems : some definitions and contribution to forests dynamics.

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Summary

Agroforestry is probably one of the most controversial word for the definition of a combination, or integration of trees (forestry components) and crops or fodder (agricultural components) into various types of cropping systems. Agroforestry systems varies from the most simple (SAF), a crop associated with a tree, to the most complex in terms of structure, the CAF (complex agroforestry systems) with multi-strata components, a large biodiversity in terms of species and frequencies, where several perennial crops and trees are associated. After describing rapidly the concept of agroforestry, we will focus on a particular typology and provide two examples of simple agroforest (SAF), parkland in Africa, and complex agroforests (CAF) in Indonesia. SAF are considered as a "regreening factor" when CAF in humid tropics can be considered as a reforestation factor. CAF in humid tropics are developed by farmers, whose structure and dynamic are close those of secondary forests. Such CAF may replace natural forests in areas where forests may have completely disappeared. There is therefore a clear dynamic from forests to agroforests, from natural vegetation to real man-made forest-like cropping systems based on trees.

1 Introduction : the concept of agroforestry and agroforestry systems.

The objective of agroforestry (AF) is can be defined as the reconcilation of 2 types of land exploitation that have deeply affected during the last centuries countrysides of both tropical and temperate countries : agriculture and forestry The main feature which caracterize agroforestry is the combination, or association of several plants, annual and perennial, on the same field.
Agroforestry systems are a kind of "cropping systems". It means that the field is homogeneously managed , through a particular technical pathway (or a "technological pattern") within a certain plants succession. We better talk about "agroforestry systems" (AFS) as cropping systems, possibly based on one main specie. ...The systemic approach is highly relevant to define systems where labour, inputs, land use and know-how are managed under a particular strategy.. The agroforestry strategies can be defined mainly through 3 main features : the minimization of risk (crop failure), the optimization of labour efficiency, different levels of intensification depending on the type of systems and the possible use of improved planting material and inputs, according to a strategy taking into account land tenure and occupation.At the field level, combinations between crops, planted or emerging from the natural regeneration, lead to interactions between plants : competition and sometimes complementarity.

2 Some definitions of Agroforestry Systems (AF)

In rural areas, AFS are as old as monoculture systems and even, sometimes...were developed before monocultures. Officially, AF is recognized by scientists through the creation of ICRAF in 1974, first a council and later, a CG center[1].

The traditional definition of ICRAF is the following:
"a collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit".
Agroforestry is generally practised with the intention of developing a more sustainable form of land use that can improve farm productivity and the welfare of the rural community (leakey , 1996).

The general definition of SOMARIBA E. 1992 seems to us to be the less "reducing" definition :
"Agroforestry are diverses technical practices that have in common the following :
- *there is at least 2 different plants in biological interaction.*
- *one of these 2 plants is a perennial*
- *one of these 2 plants is a forage, a foodcrop or a tree crop."*

The definition has been revisited by Leakey R, in 1996
"Agroforestry should be considered as a dynamic, ecologically based, natural resource management system that, through the integration of trees in farm and rangeland, diversifies and sustain smallholder production for increased social, economic and environmental benefits".

.Another definition has been suggested by the "Laboratoire de Botanique Tropicale" of Montpellier:
Agroforestry is a land use system, controlled by local population where perennial trees are associated to agriculture and/or stock farming on the same piece of land in such a way that the consequent ecosystem tend to mimic the natural forest ecosystem according to aerial and soil biomass, vegetation structure and specific richness.
That definition paves the way to Complex AgroForestry (CAF).

3 Definition of an " agroforest " by de Foresta H and Michon G.

Agroforests are particular kind of agroforestry land use. but, "tthe word "agroforest" is sometimes understood as the end-result of all agroforestry systems, whatever their structure and composition. For us[2] as for many scientists and laymen, using the word "agroforest" to describe structures that have no forest features, like alley-cropping or trees on contour lines systems, represents a language abuse that only leads to confusion" (H de Foresta, G Michon, 1996). A typology is therefore necessary to classify agroforestry systems. Many typologies have been defined (King, 1979, Huxley, 1883, Nair, 1985, Macdicken, 1990, Somarriba 2, 1992, Mary & Besse , 1996, Torquebiau , 1998) that are generally based on their components (crops, trees and stock) and their combination in space and time.

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[1] The CG center are International Research Centers in Agriculture under the consultative group (CGIAR).
[2] This group represent the "Montpellier group/ Laboratoire de Botanique Tropicale with F hallé, JM Bombard, F Mary, G Michon, H de Foresta, E Torquebiau... and other CIRAD/ICRAF researchers (E Penot, F Besse...)..

We propose an other classification, with two components : simple agroforestry systems and complex agroforestry systems (H de Foresta, Michon1989/99),

4 A typology of agroforestry systems that fits our vision[3].

As H de Foresta and G Michon (1999) recall :
"Simple agroforestry systems" (SAF) refers to associations involving a small number of components arranged with obvious, usually well-ordered patterns: one or a couple of tree species, either as a continuous canopy, in equally distant lines or in edges, and some annual species for ground cover. The tree component can be of major economic importance –coconut, rubber, clove, teak...–, or have a more qualitative role –Erythrina, Leucaena, Calliandra planted for fodder as well as for soil fertility–, whereas the annual species is usually always important economically –paddy, maize, vegetables, forage herbs–; this ground species can also be a semi-perennial, like banana, cocoa, or coffee These simple agroforestry associations represent the classical agroforestry model as it is the most favoured in research and development programme of most institutions dealing with agroforestry (Steppler et Nair 1987; Nair 1989). Most agroforestry experimentation and extension projects until now have also concentrated on simple tree/crops associations, and simple systems are important as improved technologies like alley-cropping, hedgerows, improved fallows. They are also practiced in plantation agriculture -coffee under Erythrina, coconut and cocoa, rubber and rattan...- , as well as in traditional agricultures: in Indonesia, most dry fields include trees either as true components -coconut with maize- or as borders -teaks, mahogany, rosewood, in East and Central Java-. Trees are also commonly associated with irrigated ricefields, which sometimes reflects natural constraints, such as the association between coconuts and rice-fields in the swamp areas of Sumatra East Coast, or characterize areas of high population densities, such as kapok trees cultivated for centuries on the dikes of Javanese rice-fields or the recent trials of introduction of clove and lime trees on mounds in the middle of Sundanese rice-fields.

These SAF do not have the structure and functioning similar to that of a "forest structure" and are not relevant for an analysis in humid tropics. However, many SAF are present in "dry tropics". Parklands in Africa will be taken as an example of a "regreening factor" in $ 4.

Complex agroforestry systems are tree-based systems with a forest-like configuration. They associate a high number of components, among which trees as well as tree-lets, lianas, herbs. Agroforests mimic natural forest structures, with a complex multistrata structure and a closed or almost closed canopy that is usually dominated by a few tree species (H de Foresta, G Michon, 1997[4]). Therefore the word "complex agroforestry systems" (CAF) is far more appropriate for systems developed under this definition.

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[3] Paragraphs in italics are directly imported from previous publications from H. de Foresta en G Michon.
[4] Definition in: van Noordwijk, M., Tomich, T.P., de Foresta, H. and G. Michon (1997). To segregate – or to integrate? The question of balance between production and biodiversity conservation in complex agroforestry systems. Agroforestry Today, vol 9, n°1: 6-9.

The agroforest/CAF concept also implies a relative continuity in time and space. Even if it consists of a mosaic of different management units, often exhibiting different silvigenetic units, an agroforest constitutes a large and easily recognizable forest block in agricultural landscapes. Forest biodiversity in agroforests is usually quite important, as farmers do not systematically eliminate unused species, thus allowing the regeneration of numerous forest species -those that are perceived as having no detrimental impact on system productivity

Their physiognomy and functioning are close to those observed for natural ecosystems. Complex systems are encountered most exclusively in peasant agricultures of the humid tropical world. Except for home-garden systems, a particular form of complex agroforestry association that has been rather well documented all over the world, complex systems, though common components of indigenous farming systems, are being much ignored and poorly investigated.
This striking physiognomic, physiological and functional reference to a natural forest ecosystem –the "forest preference" in agroforestry– is one of the main features separating "complex" from "simple" agroforestry systems. It is also the main determinant of their diverging ecological as well as economic functions.

CAF are far more relevant for the forest dynamic analysis as their ecological structure and physiological functioning in mature period is very similar to that of a forest. However, as perennial cropping systems, CAF are more close to plantations than forest in terms of investment, management, economic strategies and outputs. However, CAF are representative of the situation in humid tropics.

The dimension of the concepts of simple and complex agroforestry systems goes far beyond this physiognomic description or its intrinsic implications for the respective qualities of both systems. Simple and complex agroforestry systems relate to two different, though potentially complementary, conceptions of land development. One refers to field management: simple agroforestry systems address the integration of trees in agricultural lands. The other refers to resource management: complex agroforestry systems address the integration between forests and agriculture. This difference does not only involve important ecological aspects but has also essential socio-political implications, especially concerning the global role and interest of smallholder farmers in the management of forest lands and resources (H de Foresta, G Michon)

Therefore , for the purpose of this book, and referring to "forest dynamic", we think that according to this typology, the use of agroforests should be restricted to CAF which contribute significantly to this dynamic in the humid tropics, firstly as a deforestation factor at establishment and last as a reforestation factor later on. CAF do contribute to this dynamic as their structure and physical functioning in mature period are similar to that of a forest. We suggest that SAF can be considered as "agroforestry systems", not "agroforests", as a "regreening factor", compared to CAF that can be considered as an effective "reforestation factor".

Therefore 2 examples of SAF and CAF will be presented in $5 and $6 in order to contribute to show the current dynamics.

5 The traditional Parklands in African dry regions : an example of SAF[5]

5.1 Introduction

The traditional agroforestry parklands are widely spread in the Sudanian and Sahelo Sudanian regions of West and Central Africa. These parklands are constituted with planted or naturally originated trees integrated into agricultural fields, with a relatively low density of trees per hectare (Baumer, 1994).
If ACF mimic "secondary forest", we can also consider that parklands do mimic "savannah vegetation", associating grasses, bushes and trees. Of course such association is less dense than in a tropic humid forest but it does reflect the natural vegetation association similar to that encountered in dry tropics.
These trees are kept by peasants because of direct interest for rural population, such as edible fruits or leaves production, fodder or oil production, gums production, as well as for soil fertility improvement, and, of course, potential wood production (Depommier, 1996; Boffa, 1995). In Mali, for example, more than 3.5 million hectares are covered with parklands dominated with *Vittelaria paradoxa*, with a planting density varying from 20 to 50 trees/ha.

Those parklands are constituted with local species, the most important at socioeconomic and geographical level beeing *Vitellaria paradoxa* (shea butter and oil production), *Parkia biglobosa* (fruits and fodder for cattle feeding), *Faidherbia albida* (fodder production and soil fertility improvement), and *Adansonia digitata* (leaves for human consumption).
Other species such as *Acacia senegal* and *Sterculia setigera* (for gum production), *Prosopis africana* (wood production), *Tamarindus indica* (fruits production), ... are of economic importance for the rural populations in some regions. In many cases, different tree species can be mixed in the parkland, one specie possibly being more abundant.
The trees can be associated with agricultural crops such as food crops (mil, millet, sorghum, ...) or with cash crops (cotton, peanuts, ...). Parklands are also a place for local or migrant livestock divagation and feeding.

5.2 From forest to Parklands ...

Even if their total canopy cover is higher than 10%, those parklands are not taken into account in forest inventories, and are mostly referred as agricultural areas. Nevertheless, those parklands are derived from natural forests degraded by slash and burn activities, most of the natural trees being burnt or logged in order to develop agricultural activities.
The case of Vittelaria Parklands is interesting, as this species is naturally present in the dry forests or in the woody savannah of Sudano Sahelian African region, and is protected when the originated forest if cleared for land preparation for crop productions. Parklands with little tree specific diversity, and even mono-specific Parklands, are then derived from a multi-specific natural forest ecosystem. Intermediate situation between forests and parklands can be seen, indicating that there are continuum between forests, woody savannah and parklands.
Studies (Bernard, 1999) have shown that in the savannah region of Côte d'Ivoire, land tenure status, land and trees traditional owner objectives, gender issues

[5] This particular chapter has been written by B. Mallet.

(women are the main users of *Vitellaria* fruits; men are involved in agricultural productions), are important factors for the planting and the future of such parklands.
In Mali, in relation with roads and access to the market, *Vittelaria* can also become of interest for fuel wood or charcoal production, with direct effects on *Vittelaria* Parklands evolution (Bazile, 1998).

5.3 And from Parklands to fields ...
In many regions, the intensification of agriculture (the use of fertilizers decreases the interest of keeping trees for fertility maintenance) and the development of crops using cattle ploughing, such as cotton have result with a decreasing interest for parklands.
In the case of *Prosopis africana* and *Faidherbia albida* Parklands in the Northern part of Cameroon, it has been showed that the recent evolutions of both cultural and religious practices, in relation to agricultural activities, were the main factors for Parklands dynamics (Seignobos, 1996).

5.4 But also from Parklands to forests ...
In different parts of the Sudano-Sahelian regions of Africa, it has been observed that there were evolutions from fields to parklands, and in some cases, from fields to mixed parklands and woody fallow, with an evolution on a long term towards the reconstitution of woody savannah or dry forests, depending of the region.

Such examples have been showed in Burkina Faso (Boffa, 1996; Depommier, 1996), and in Northern parts of Cameroon (Harmand, 1996), where *Faidherbia* Parklands were builded by peasants by selecting resproutings of natural *Faidherbia* trees.
In the northern part of Côte d'Ivoire, indications were given that the *Faidherbia* parkland studied in Lataha (Bernard, 1999) where this species is out of its natural area, was related to the invasion of this part of the country by ethnies coming from regions were this species was traditionally used in parklands.

In other situations, it has been shown that the evolution of agricultural lands could evolve on a long term (more than 30 years) from parklands or fallow, towards woody savannah or dry forests, depending of the soil status and the natural forest proximity (Louppe, 1995; Bonnetti, 1998).

5.5The traditional agroforestry parklands, a reversible system between fields and forests ...and a good indicator of socio-economic dynamics.
Most of the studies have shown that the main factors involved in the evolution from forests to parklands and to fields, and from fields to parklands and to forests were related to socio-economics, the agro-ecological factors having an effect on the speed of the dynamic.

The rural populations adapt their agro-ecosystems in relation with their short term and long term objectives, and the dynamics of the parklands is a good signal of those objectives.
Detailed studies of the structure and composition of the agroforestry parklands in relation with their surrounding agronomic system could gave very interesting

information on the socio-economic dynamics of the rural populations (Mallet et Depommier, 1997).

6 The example of Complex Agroforestry Systems (CAF) in Indonesia

6.1 CAF are cropping systems

Being based on the association of various plants, annual and perennial, at different stages, or periods, on different strata (multistrata systems), a permanent component of CAF is the interactions between plants. Competition on light, soil (nutrients) and water is always present. If competition is very often negative for each individual plants, the global output of CAF is positive, both in terms of total production as well as externalities such as biodiversity maintaining and soil and water conservation. CAF should be analyzed as systems. CAF are, most of time, based on a particular association, or on a particular set of plants, where plants do not significantly suffer from this competition (rubbber in jungle rubber, Shorea javanica in the Damar forest, the Illipe-nut tree in the Tembawang in Indonesia..).
The most important in CAF is the spatial and temporal management of the system, creating a real long term management and strategy.

6.2 CAF do provide services and products.

Products are various from fruits, foodstuffs, timber, NTFP (Non-Timber Forest products) such as resins, medicines, handicraft materials.... The "services" defined the ecological sustainability of CAF and are generally positive externalities : "forest like" environment, long term soil regeneration, water catchment, maintenance of a certain level of both vegetal and animal biodiversity, protection against fires. It is clear that most of time these externalities are not included in the economic calculation of systems productivity. As the "social cost" of desertification in temperate countries can be calculated and now taken into account in regional policies, CAF positive externalities on the environment should also be considered for what there are : the do conserve the original positive externalities of forests. And it seems that everybody agree on the necessity of maintaining forest in landscapes , whatever.
This explain why "forest dynamics" is preferred to the "cycle deforestation/reforestation" as CAF can be an important part of the landscape, in particular in countries like Indonesia or Sri Lanka.

6.3 Forest Biodiversity and Agroforests

This agroforest model is at the extreme 'forest' end of the wide spectrum of agroforestry systems and is almost unique in how it conserves forest species of both animals and plants (Michon and de Foresta, 1995). In no way can these features be extended to –or expected of- all agroforestry systems, such as alley cropping, trees scattered in or bordering on fields of crops, simple associations involving a single crop and 1-2 species of shrubs or trees and contour hedgerow systems. These agroforestry systems are no better at conserving forest biodiversity than monoculture. Therefore , they cannot consider as reforestation factor, or , at least, on a very limited area as a re-greening factor. Reforestation, defined as the re-establishment of a "forest-like" structure, should be therefore restricted to CAF in

humid tropics. CAF do maintain a certain level of biodiversity, close to that of a forest at the same age

6.4 Examples of CAF in Indonesia

Numerous examples of such agroforests have been described from South-East Asia, and especially from Indonesia. An estimated area of about 5 million ha is covered with various systems in Indonesia such as damar (*Shorea javanica*) agroforests, tembawang, (dayak fruit/timber based agroforests in Kalimantan), rubber agroforests (around 3 millions ha) and fruit/timber/spice agroforests (Michon and de Foresta, 1995). These examples describe systems that exhibit a close link between the forest world and the agriculture world on the same piece of land. In Indonesia, farmers do describe CAF as "kebun" which is generally not properly defined as "gardens". "Kebuns" are tree-crop based systems, negerally after a first phase of slash and burn agriculture based on foodcrops.

7 Conclusion

In drylands in Africa, other simple agroforestry systems reintroduce, or maintain, at least some trees in the cropped fields as a regreening factor as shown in the case of parklands.

In humid tropics, CAF are man-made productive "forest like" cropping systems that provide a regular income to hundred thousands of farmers in Sumatra and Kalimantan in Indonesia, as well as in some other part of the humid tropics. CAF have been proven ecologically sustainable. On the economic point of view, some CAF need to be improved in order to maintain a sufficient income, such as jungle rubber for instance, in particular when new competitive crop opportunities appear such as oil palm. CAF improvement is possible in some conditions. CAF may be adaptive to new economic conditions. Damar forests have disappeared in West Kalimantan but are still exploited in the Pesisir (Sumatra). Jungle rubber is partly replaced by clonal ruber monoculture but re-introduction of agroforestry practices is quite common in a second phase.
But CAF need a particular environment. CAF can be established only after a forest of an old CAF. Traditional CAF such as jungle rubber cannot be established on an *Imperata* grassland as , in that case , the stock of seeds has disappeared.

CAF have largely contributed to the forest dynamic and reforestation in humid tropic areas where forests have almost entirely disappeared. CAF are the expression of man willing to combine both productivity and sustainability in the long term.

In both cases, the reforestation , or regreening, level is depending on both the type of SAF/CAF and the local definition of the forests that are different according to the ecological environment. Integration of trees in SAF and CAF do contribute to a forest dynamic through its structure , by also through its sustainability.

References

Baumer (M.), 1994 - Forêts parcs ou parcs arborés ? Bois et Forêts des Tropiques 240: 53-66

Bernard (C), 1999 - Structure, dynamique et fonctionnement des parcs agroforestiers traditionnels, Thèse de doctorat de l'université de Paris 1, 1999

Boffa (J-M), 1995 - Productivity and management of agroforestry parklands in the sudan zone of Burkina Faso. Thesis Doctor of Philosophy, Purdue University, 1995

de Foresta, H. and G. Michon (1996). Tree improvement research for agroforestry: a note of caution. Agroforestry Forum, vol. 7, n°4: 8-10.

Depommier (D), 1996 - Structure, fonctionnement et dynamique des parcs a Faidherbia albida (Del.) A. CHEV. Au Burkina Faso. Thèse de Doctorat de lUniversité Pierre et Marie Curie, Paris VI, 1996.

Hallé F. Laboratoire de Botanique Tropicale of Montpellier.

Huxley P.A. 1983. Comments on agroforestry classification with special references to plant aspects. in Plant research and agroforestry, Ed P.A Husley, ICRAF, Nairobi, Kenya, pp161-172.

King, KFS. 1979. Concepts of agroforestry. In international cooperation in agroforestry, eds T Chandlern T&D Spurgeon, ICRAF, Nairobi, Kenya, pp1-13.

Leakey R. Definition of agroforestry revisited.In Agroforestry today, Jan-March 1996, vol8 n°1.

Louppe (D), Ouattara (N.), Coulibaly (A.), 1995 - Effets des feux de brousse sur la végétation, Bois et Forêts des Tropiques, 245.

Macdicken K.G& Vergara N.T. 1990. Agroforestry : classification and management. Wiley, New York.

Mallet (B), Depommier (D), 1997 - Agroforesterie et gestion de l'arbre rural, Bois et Forêts des Tropiques, 248.

Mary F & Besse F. Guide d'aide à l'Agroforesterie.

Michon G and de Foresta H.. 1995. The Indonesian agroforest model. Forest resource management and biodiversity conservation. In P. Halladay and D.A. Gilmour Eds, "Conserving Biodiversity Outside Protected Areas. The role of traditional agro-ecosystems" . IUCN: p. 90 – 106

Michon G and de Foresta H., 1999 (?) Agro-forests: Incorporating a forest vision in agroforestry. In Buck, Fernandez and Lassoie. Book on Agroforestry Final title not known, in press...

Nair P.K.R. 1985. classification of agroforestry systems. Agroforestry Systems, 3, pp97-128.

Nair P.K.R,1989. Agroforestry systems in the tropics. Kluwer Dordrecht, Netherlands and ICRAF, Nairobi, Kenya.

Noordwijk, M. van, Tomich, T.P., de Foresta, H. and G. Michon 1997. To segregate –or to integrate? The question of balance between production and biodiversity conservation in complex agroforestry systems. Agroforestry Today, vol 9, n°1: 6-9.

Seignobos (C.), 1996 - Faidherbia albida, élément decripteur d'agrosystèmes, l'exemple du Nord-Cameroun. Cahiers scientifiques, CIRAD Forêt.

SOMARIBA E. 1992. Revisiting the past, an essay on agroforestry definition. Agroforestry systems, 19, 232-240.

Steppler et Nair 1987 .Agroforestry a decade in development. ICRAF, Nairobi, Kenya. 335p.

Torquebiau E. 1998. An agricultural system approach to agroforestry. ICRA Montpellier, France.