Agroforests: pre-domestication of forest trees or true domestication of forest ecosystems?

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Abstract

Domestication of forest resources and artificialization of forest ecosystems in tropical forest areas are often encompassed in a linear way: from wild resources to genetically improved trees, from complex ecosystems to controlled tree plantations.

This linear evolution might be true for professional forestry or horticulture. However, it does not embrace the complexity of smallholder farmers practices for forest resources utilization. Incorporating forest resources in production systems is not a new practice in the tropics, it even constitute the very basis of a whole facet of indigenous agricultures. But this agroforestry practice is not usually considered as a full domestication process. And, in spite of an increasing amount of academic interest for indigenous forest-like plantation models, agroforestry research is not yet fully considering the prospects of these models as far as forest species are concerned.

The paper focuses on the discussion of Indonesian examples of ecosystem manipulation and plant domestication. Complex agroforestry systems have been developed by local people for the management of resources ranging from locally consumed forest fruits to highly valuable industrial products such as resins and latexes. This indigenous agroforestry is presented as an elaborate process of total transfer, not only of selected forest resources, but also of true forest structures, from the sphere of 'nature' to that of 'agriculture'. This process is analyzed as a particular domestication strategy which integrates conventional species domestication techniques to an original attempt of ecosystem domestication. Prospects for further developing this 'agroforest strategy' for the domestication of forest species are then discussed.

Keywords: forest resources, indigenous agroforestry, plant domestication, ecosystem artificialization, Indonesia

Introduction

Plant domestication refers to two inter-related aspects: one concerns the plant itself and targets the modification of morphological or production patterns of the wild species (species 'domestication' s.s.), the other aims for the design of the ecosystem in which this plant is to be included (ecosystem 'domestication'). Plant modification and ecosystem design are usually encompassed in a rather linear way: from genetically diverse resources in the wild to morphologically and genetically specialized cultivars, from complex and diverse ecosystems to simplified, homogeneous plantations. Modern domestication science has, in fact, mainly evolved through the development of material, techniques and models for food cropping in temperate regions, somehow neglecting the immense variety of timber as well as non-timber resources of the tropics. By doing so, it has implicitly assumed that this temperate model was the only efficient one for plant domestication and explicitly ignored the variety of models developed by local people for the cultivation and domestication of tropical forests. Most of the tree species planted by smallholders in the tropics are still considered as 'wild' by conventional plant breeders. Most of the tree gardens are confused with natural forests by either agronomists, horticulturists or even foresters. This historical imperialism reflects the antagonism between two main traditional trends in plant domestication (Barrau, 1967; Geertz, 1966): the 'grain model' developed for cereal domestication through 'agriculture', and the 'garden model' developed for multiple purposes through 'horticulture'. The most significant differences between these two models involve patterns of plant manipulation and ecosystems design for cultivation (Michon & De Foresta, 1997). Whereas the grain model focuses on the adaptation of wild plants to artificially simplified openfields, the garden model retains the complexity of the natural ecosystem, trying to replicate its structure to accommodate the exigencies of the cultivated plant. Domestication in the garden model benefited more from farmers trials and experiments than from true scientific research and 'gardens' are still a major component of indigenous agricultures in the tropics. On the contrary, domestication through the grain model, which benefited from decades of scientific research, proved highly successful in sustaining the development of modern agriculture. As it has achieved incredible results in raising food production all over the world, it tends to be considered as the only valuable model for efficient (agri)cultural development. Though it was initially devised for annual crops, the grain model has deeply influenced modern horticulture and silviculture in the tropics: forest plantations and plantation agriculture based on tropical forest trees such as acacia, eucalyptus, rubber, oil palm or cocoa replicate the biological model and the technical options of a corn field.

The fact that domestication science did develop along the same lines for temperate annuals or tropical perennials has never be really criticized. But doesn't the domestication of wild forest species evolved in a highly diverse and structurally complex environment deserve its own original scientific way? When switching from annual crops to trees and from temperate fields to tropical forests, some of the reductionist interpretations of domestication and ecosystem manipulation issued from the open-field preference should be re-examined. Is it true that 'domestication' unavoidably comes down to the adaptation of a wild species to massal treatment in an industrial plantation? Should agroecosystem design always emphasize 'artificialization', in its narrow sense: the negation of natural structures and processes? Why are diversified structures considered detrimental to production?

These questions are not only academic ones. Domestication of tropical forest species is an urgent matter for forestry as well as for agriculture, for intensifying production as well as for improving conservation. Domestication models developed for tropical tree crops upon the openfield model have proved efficient in terms of gross production and immediate productivity. However, their actual ecological and social costs might just invalidate this economic success. Aren't there other models, other strategies better suited to ecological conditions prevailing in tropical humid areas or to technico-economic and social conditions of smallholder production?

The present paper proposes to analyze options offered through indigenous systems that obviously propose interesting alternative models for forest domestication. These systems have efficiently and sustainably incorporated timber as well as the so-called 'minor' forest resources into farm lands. The domestication strategies developed in these systems usually do not conceive crop management in highly specialized stands that are quite far from the original conditions in which the wild species have evolved. They do not go through a deep modification of the typical, 'forest' structural and biological features of the tree species. Instead of considering these systems as intermediate stages in linear domestication and artificialization processes, we propose to examine how they can inspire alternative pathways towards the design of fully domesticated agro-forests that integrate and develop the potentials offered by forest crops in an agricultural perspective. We will then discuss how these indigenous examples could generate 'new' models for the accommodation of forest domesticates that could help reducing the present movement of segregation between forest and agricultural development.

Indonesian examples of plant domestication and ecosystem manipulation

Forest culture is a common practice in rural Indonesia. Its originality lies in the fact that it is not managed as a specialized 'silviculture' distinct from common agricultural activities, but happens through the integration of forest gardens into farm lands. These 'cultivated forests', established after total removal of the original vegetation, are usually closely associated with shifting cultivation. They often complement subsistence food cropping in annual fields, and constitute complex, tree-based agroforestry systems, that fully deserve the name of 'agro-forests' (De Foresta & Michon, 1993; Michon & Bompard, 1987). They are a universal tradition indeed, but a rather modern tradition in the sense that they fully developed with the increase in demand for certain forest products that happened between one and two centuries ago.

The interest of the Indonesian examples for domestication lies in their very conception: a replicate of forest structures and features in agriculture. Some of these indigenous systems, like the fruit forests of East Kalimantan (Sardjono, 1992) or the Dipterocarp agroforests of Sumatra and Kalimantan (De Jong, 1994; Michon & Bompard, 1987; Momberg, 1993), hold structural as well as functional characteristics typical of a primary forest ecosystem, with predominance of big trees, a high species richness, a high ecological complexity, and a closed nutrient cycling. Others, like rattan gardens (Fried, 1995; Weinstock, 1983) or rubber agroforests (Dove, 1993; Gouyon et al., 1993) that cover the lowlands of Sumatra and Kalimantan, are close to secondary forests, with dense stands of smaller trees and a rapid turnover of species.

Genesis of an agroforest: domestication and ecosystem design

Establishing an agroforest is conceived by farmers as a specialized tree plantation process aimed at controlling and concentrating a selected forest resource taken out of the former extractive systems. The domestication strategy exhibited in these indonesian examples partly relies on conventional plant domestication techniques – selection, reproduction, plantation –. However, the design of the ecosystem in which the domesticated species is to be included is not at all conventional, and influences retro-actively the whole domestication strategy. Besides the active manipulation of plants and vegetation structures, farmers heavily rely on the natural evolution of the established tree population. This combination between voluntary and natural processes creates a chain of action and reaction between farmers and the created environment that efficiently establishes domesticated structures while restoring diversified forest structure.

This double process can be illustrated by the establishment of damar or rubber agroforests in Sumatra (De Foresta & Michon, 1993; Michon & Bompard, 1987). The plantation starts with a drastic transformation of the natural ecosystem, through common artificialization processes in agriculture: destruction, selection and plantation. The seedlings, usually raised in nurseries, are introduced in an already planted openfield which can be a rice swidden, as in the case of rubber seedlings, or a young coffee or pepper plantation, as for damar. This early agro-forestry association, that lasts up to 8 years in the case of a damar plantation, allows seedlings to establish in the best possible conditions in terms of micro-environment and concurrence. However, the parallel with more conventional tree plantations does not go further, and the consecutive phases are more conceived in a logic of connivance with the forest ecosystem than of environmental confrontation: once the crop phase is abandoned, the planted trees develop along with the subsequent successional vegetation. During this period of relative abandonment, the young plantation gradually acquires a typical secondary forest facies through natural processes of plant dispersion and niche colonization. The structure and the composition of this successional forest complexifies over years following natural silvigenetic mechanisms. In this natural enrichment process, man merely selects among the possible options given by the ecological processes – selecting and/or introducing economic trees and protecting their development – thus favouring resources, but non-resources are establishing and reproducing as well as they are not considered as 'weeds'. This 'minimalist' management that gives the major role to natural processes in the evolution and shaping of the cultivated ecosystem does not fundamentally change when the agroforest starts producing. In the mature plantation, the balanced combination between natural dynamics and appropriate management of individual trees allows further diversification. In the case of permanent agroforests, this leads to the establishment of more climactic forest species among the cultivated stand: plant species carried from the neighboring forests establish while forest animals find shelter and feed. Mature damar or rubber agroforests shelter several tens of commonly managed tree species, but also several hundreds additional species, spontaneously established and often used (Michon & Bompard, 1987; Michon & De Foresta, 1995). This balance between free functioning and integrated management also helps maintain a system which produces and reproduces without disruption either in structural or in functional patterns. Once established, agroforests are usually maintained without reversing to a phase of massive regeneration, as decaying trees are replaced whenever needed. Unlike plantations, that evolve through plantation/total harvest cycles, agroforests remain permanent.

From a socio-economic point of view, the mature agroforest is not fundamentally different from any highly specialized commercial plantation: it provides the majority of household income, constitutes an important complement to ricefields in the farming system and represents the main component of the family patrimony (Levang, 1992; Mary, 1987). However, from a biological point of view, the mature phase of the agroforest finally resembles more the forest it replaced than a conventional tree plantation, with its high canopy, a dense undergrowth, high levels of biodiversity, and perennial structures.

Agroforests: back to Nature or an original journey on the path of domestication and artificialization?

Rubber or damar culture constitute true domestication and artificialization efforts: they do involve selection and plantation of economic species, as well as modification of the natural environment to allow for the establishment of a cultivated system. But considering the result – a forest in its own rights –, one can question the artificialization process: is not this more like a 'dis-artificialization' process? Or one of these attempts of intensive cultivation by smallholders that soon revert to nature through progressive abandonment of the cultivation efforts?

This question could be answered by re-analyzing the how and the why of the technical choices. In developing the agroforests in the place of pre-existing natural forests, the farmers objectives are to protect and control several important forest resources, as well as to intensify naturally poor production of forest commodities. This is a common starting point in plant domestication. The technical steps taken for this domestication have to integrate several constraints, the major one being the availability of labour and cultivation techniques: to minimize labour input and given the limited range of available cultural techniques, farmers have to maximize the use of natural processes. But the ecological consequence of this technical choice is the re-establishment of a forest. Indigenous tree gardens do result from a management choice – switch from collection to production through cultivation with domestication and artificialization – but their ultimate 'forest' version is no more than the (eco)logical consequence of the artificialization process.

But the question could also be answered by looking beyond the technics themselves or their immediate consequences. What is the ultimate result, the present finality of the agroforest establishment process? Is it only controlling the production of an economic forest resource? Or is it, finally, the appropriation of the forest resource as a whole?

If the restitution of forest characteristics did not result from an initial will to restore a forest environment, it did imply important choices for the farmer: should this diversity be kept or combatted? Should it be considered as adverse to the main production, or, rather, as an ally of this production? Does it present other immediate advantages? The restoration of forest features did allow the restoration of ecological processes that are essential for the maintenance of the system as a whole. But of more immediate significance for the farmer is the restoration of a whole range of economic products and functions originally offered by the forest. For farmers, agroforests act as a rather integral forest resource, which is, for institutional and political reasons, much more significant than natural forests. Starting as a plantation, agroforests often arise as an original strategy for forest re-appropriation by indigenous farmers (Michon *et al.*, 1995; 1996).

Domestication and artificialization in tropical forests: linear processes or multiple ways?

The potentials of these examples for forest domestication have remained largely underestimated. Indigenous agroforestry systems in the tropics are invariably presented as intermediary stages in the continuum that leads from resource harvesting to modern production through intensive cultivation. If on top of it all they look too much like a forest, they are not even considered as true production units: most of the above mentioned agroforests, though evolved from active plantation of trees in cleared plots, are barely considered as examples of 'integrated forest management' or 'managed forests'. Why are those obvious efforts of local people to tame natural forests and wild species systematically denied?

Domestication and cultivation have long been considered as the prerogative of agriculture, whereas forests remained perceived, at least by plant breeders and agronomists, as the domain of gathering. When rationalization of forest production was felt necessary, at the beginning the industrial era, the openfield preference stood as a postulate in domestication strategies. Techniques devised by domestication research for forest trees started following the rules of specialization, homogenization and intensification which had proven efficient for grain crops, developing genetically homogeneous, fast-growing and highly productive tree cultivars. Scientific forest culture simplified the structure and the function of the cultivated 'forest' to the extreme: oil palm or rubber plantations are not referred to as 'forests' anymore, and timber estates are barely specialized fields of trees. This process of domestication and cultivation induced a true movement of dissociation between domesticated forest resources and forest ecosystems. Due to its high technicity and productivity per unit of land, it is considered as the only 'scientifically correct' standard for forest domestication.

Local farmers developed a large diversity of forest cultivars, but their criteria for variability selection remained quite different from those sought out by plant breeders: fruit cultivars produce fruits of great taste but of poor appearance for western horticulturists; whereas fruit domestication has consistently tried to produce low branching trees, local varieties remain tall forest trees (that therefore perfectly integrate in the complex structure of the gardens). For scientific plant breeders, agroforests might synthesize centuries of interdependence between forest people and forest species, but they do not represent centuries of true domestication trials and experiments, and agroforesters are never estimated as skilled plant breeders or forest cultivators. It is true that farmers, even though mastering vegetative reproduction, even though selecting the best producing individuals for reproduction, do not make full use of the genetic potentials of the economic species upon which they rely and cannot capture the genetic variation of these local cultivars as efficiently and reliably as plant breeders do. As a consequence, agroforest varieties of the wild forest species are still considered in the scientific literature as 'semi-domesticates', if not as as wild forest resources. But is that reason enough to consider agroforests as early evolutionary stages on an imaginary line that leads from forest gathering to agri- (or silvi-) culture.

This question leads to another one: is that evolution towards improved production a linear one? Is there only one modern, efficient, desirable model for domestication and production, especially for forest commodities? The well established debate opposing intensive or maximum production to optimum or sustainable production tends to prove the contrary: agriculture and silviculture urgently need other models. In that respect, the Indonesian examples could well be considered as the starting point for alternative evolutionary lines towards improved resource management through production. Beyond a physiognomic, functional or technical model for tree/crop association, they allow to set the bases of original alliances between agriculture and forestry, involving integration of agricultural and forestry logics and strategies. As far as domestication research is concerned, they bring an original 'ecosystem perspective' into the debate.

The 'forest preference': a new perspective for ecosystem domestication?

In humid tropical environments, the openfield model implies a total partition with the climax formation: the evergreen rainforest. The agroforest on the contrary, is fundamentally close to it. The question should not be to decide which strategy expresses the greatest achievements in terms of domestication, but which appears as the most adapted to present ecological as well as socio-economic constraints of agriculture in the tropics.

In modern agriculture, domestication intentionally dissociates resources from their natural habitat. Transfer of the candidate species to an artificially prepared milieu is conceived as an essential step that allows to induce and efficiently select useful genetic variations. The design of the artificialized agroecosystem aims at replacing natural ecological processes by a more or less total mastering of the environment in order to increase human control over the plant as well as over all the factors of production. This increased human control implies high energetic input and an elaborate technical knowledge. In the agroforest model, artificialization refers to the induced reconstitution of a true forest-like ecosystem that simulates the basic principles of natural silvigenetic succession, and allows the selected species to establish, grow and reproduce as in their original habitat. The mimicry of natural structures –

the 'forest preference' – allows to use internal ecological dynamics as the main instrument of production and reproduction, which reduces labour costs but implies a good ecological knowledge. If 'mastering' is the key word in modern agriculture, 'taming' is more appropriate for the agroforest strategy.

Agroforests constitute, more than sophisticated examples of plant domestication, an original attempt of 'ecosystem domestication' (Michon & De Foresta, 1997) which proved quite efficient in acclimating true forest tree species in cleared lands. For example, forest farmers in Sumatra and Kalimantan have succeeded in what remains a dream for most foresters: establishing, maintaining and reproducing, at low costs and on huge areas, a healthy Dipterocarp plantation. This is a unique example in the whole forestry world. These dipterocarp agroforests rely on selected forest trees planted at high density, combine good productivity and good ecological sustainability, have low establishment costs and regenerate easyly over years, which is quite uncommon in conventional plantation forestry.

The domestication process exhibited in the agroforest model, as it does not focus on the selection of single-purpose genotypes, allows to maintain diversity of the tree qualities: the multipurpose dimension of wild species is not lost through domestication, as it most often happens in conventional processes. Low canopy varieties of durian, rambutan or rubber selected by plant breeders produce nothing else but fruits or latex, but damar or illipe nut trees domesticated for resin or oil production by local farmers in Sumatra and Kalimantan are still good timber producers. This multipurpose dimension is also maintained at the ecosystem level. In the conventional plantation model, what is not the crop is a weed. In the agroforest, self-established species are integrated as economic resources – or kept as potentially useful ones –.

But the most interesting point of the agroforest strategy, which constitutes not only its originality but also its fundaments, is how the re-establishment of natural biodiversity is utilized to support the domestication process. Restoring biodiversity is essential as it contributes to the restoration of agents and processes which are determining in the functioning and the reproduction of the agroforest: as an example, wild tree species that might be of no use for the farmer help supporting populations of birds, squirrels and bats, which are essential natural pollinators of economic species, thus helping not only production, but also breeding. In the agroforest genesis, these natural agents and processes schematically replace the high technicity and energy costs that sustain forest plantations, first speeding up and securing the integration of slow-growing trees in the cultivated system, then helping maintain a continuous balance between 'obsolescence' and regeneration. Through this 'forest preference', the agroforest domestication strategy does not only achieve a simple transfer of forest resources and structures, it also guaranties the renewability of these resources and structures, thus assimilating the long-term aspect linked the management of forest species.

The 'agroforest' strategy therefore raises several fundamental questions that go even beyond domestication and cultivation: does artificialization, that is usually perceived as the ultimate, less reversible step of an anthropization process, necessarily imply a fundamental difference between the cultivated and the original ecosystems? Should the artificial ecosystem escape natural ecological laws through intensive human control (Michon & Bouamrane, 1997)? The basic question here can be stated in terms of continuity versus divorce between the cultivated and the initial, 'natural' state, in terms of confrontation versus connivance with Nature (Henry, 1987). Confrontation has proven its success for immediate development, but its long term consequences are presently dramatically obvious. Connivance seems promising for a development that remains sustainable in the long term, but its practical ways are still to investigate. Existing models, such as the agroforest, could be used as starting points to build more advanced systems. Unfortunately, because of the historico-political advent of confrontation models, indigenous examples build on connivance are getting scarce, as official development programmes eradicate them to make place for more politically correct systems: rubber agroforests are being replaced by monocrop plantations under national 'rubber improvement' programmes, fruit or damar agroforests, after being logged-over, are converted to oil palm plantations, rattan gardens have to give room to industrial forest estates... .

Perspectives and conclusions: domestication as a multipurpose strategy

It may seem obvious that an 'ecosystem' perspective in domestication of forest species might change the angle under which domestication is encompassed and lead to changes in techniques and processes. But it is essential to understand that the importance of an ecosystem approach in domestication goes far beyond biological or technical considerations.

Existing agroforest examples can easily be criticized for the relatively low levels of production of the main economic species: rubber yields of an hectare of rubber agroforest are 4 times lower than those obtained in intensive plantations. But the answer is that they did not benefit, as plantations did, of scientific domestication research: what plant breeders did in terms of genetic improvement of forest species remained out of the reach of agroforest farmers. Rubber research consistently assessed – though it never proved it – that high yielding rubber clones would not survive in the indigenous rubber gardens, and in order to benefit from rubber improvement programmes, farmers had to abandon their 'traditional' way of managing rubber and to switch to conventional models of homogeneous and capital intensive plantation. Here, technical explanations clearly allowed to justify a choice that had important economic, social and political fallouts. This clearly illustrates that domestication is more than a set of technics: it is, primarily, the expression of a strategy for development (Michon & Bouamrane, 1997). The transfer of wild resources to cultivated lands, from the sphere of 'nature' to that of 'agriculture', is an essential process, for example to capture natural genetic variations or select useful characteristics, to increase population density, stimulate cross breading, or escape from natural competitors and pests. But it always bears major economic and socio-political consequences as well as important policy implications. The common preference of governing elites and scientists for the plantation model in the domestication of commercial forest resources in the tropics did not only change the face of forest landscapes and national economies. It also deeply affected forest communities and their socio-economic life.

This indirect link between the choice of a particular domestication strategy and the fate of local populations is also essential to analyze in the context of forest domestication: domestication has to be understood as a part of a resource appropriation process. And resource appropriation by a powerful fraction of the active population might lead to dispossession of the other weaker fraction (Michon & De Foresta, 1997).

As a domestication strategy based on forest resources, agroforest development represents an interesting alternative to the two common options devised for forest products management: harvesting from natural stocks or domestication for specialized plantations. But they obviously need improvement. Dealing with forest resources domestication in agroforests will first require new types of experimentations allowing to accomodate this 'forest preference'. A first option would be to test existing, high yielding varieties of forest plants already improved through genetic research in the agroforest technical and environmental conditions. This type of experimental research is presently being carried-out by ICRAF in Sumatra and Kalimantan with the testing of highly productive rubber clones in the technical and environmental conditions of the 'jungle rubber' agroforests (Penot & Wibawa, 1996). A second option would be the development of improved plant material specially designed for a complex, forest-like environment, rather than for conventional plantation conditions. Instead of trying to adapt wild species to homogenous openfield conditions, plant selection could try to take benefit of the 'forest' characteristic of the species for both ecological and economic benefits. A particular aspect to keep in mind is the importance, for farmers as well as for the ecosystem itself, of 'multipurposeness', as this quality helps, in spite of actual specialization, to avoid irreversibility in future economic and ecological choice for smallholders. As an example agroforest timber is conceived as a derived production from fruit or resin trees, but it could easily become a strategic commodity for farmers in a next future, with potential benefits that might be much higher than those provided by the product for which the species are actually cultivated. In that perspective, it would be a pity if domestication options and agroecosystem design negatively influence, as they did in the course of modern rubber or fruit domestication, the capacity of the candidate forest species to produce quality timber. The forest preference also implies the adaptation of existing selection and breeding techniques to forest-like ecological conditions and as well as to farmers technical standards. Transforming undergrowth forest species into light-demanding cultivars, as this happened for coffee or cocoa, is not the best way to allow the integration of the species into a domesticated forest ecosystem. Relying on sophisticated and expensive hybridization techniques is not the best way to empower local farmers in the domestication process.

Beside adapting domestication techniques to forest exigencies, the forest preference requires that new bases for conceptualization are established, specially in the framework of agroforestry. This conceptualization extends far beyond the classical concept of association between agricultural crops and forest trees. It directly addresses the integration into agriculture not only of forest resources, as conventional domestication in silviculture did, but also of forest structures and of forestry logics, the fusion between a long term perspective of forest ecology and development, and short term imperatives of production in agricultural systems. Elaborating on this original association between forests and agriculture might allow to devise alternative strategies for forest domestication and culture.

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