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Tree improvement research for agroforestry: a note of caution

Tree improvement is increasingly considered as an important research direction for the development of more productive agroforestry systems. In these systems trees have multiple economic uses and ecological functions that should be taken into account in tree improvement programmes in order for these programmes to ensure that the improved species, the end-result of their research, is adapted to agroforestry. The key issue here may be for tree improvement specialists involved in agroforestry programmes to be able to differentiate, from the range of characters that could be selected for improvement of a given species, characters that are absolutely necessary to improve whatever agroecosystem the tree may be grown in - the primary targets - and characters for which improvement would only be appropriate for particular agroecosystems - the secondary targets.

Selection results in plants that are well fitted to monoculture, but that have lost most of their ability to grow in complex multi-species associations

In agroforestry, careful examination of the multiple functions of trees is a prerequisite in the choice of plant characters that are targeted for improvement

Written by forest ecologists who have been involved for years in research on agroforest systems, this article represents a reminder to tree improvement specialists that tree improvement for agroforestry systems is *not* tree improvement *as usual*.

While tree improvement is increasingly considered as an important research direction for the development of more productive agroforestry systems, it should be noted that modern plant improvement research has usually led to monoculture, as reported by Guy Lund at the International Conference on Domestication and Commercialization of Non Timber Forest Products in Agroforestry Systems (ICRAF, Nairobi, February 1996). Consciously or unconsciously, most plant improvement research programmes adhere to the pure plantation model - the dominant model in agricultural and silvicultural research, and selection results in plants that are well fitted to monoculture, but that have lost most of their ability to grow in complex multi-species associations.

While this in itself is not necessarily undesirable, it is argued here that where combinations of various plant species are involved, as in agroforestry, careful examination of the multiple functions of trees is a prerequisite in the choice of plant characters that are targeted for improvement.

In order to clarify the consequences of different choices in the set of plant characters selected for improvement, we refer to two production models that are each at one extreme end of the existing range of cultivation systems, the pure plantation model and the agroforest model (Box 1). While differences in the consequences are deliberately magnified here through the choice of these opposite models, the conclusions drawn are of general value, reflecting differences in the perception of trees between agroforestry systems on the one hand (multiple production and ecological functions of trees) and pure plantations on the other hand (trees reduced to their main economic product).

As a theoretical example, we consider a high canopy tree species with edible fruits of interesting commercial value and a large potential market, growing wild in tropical rainforests of a given region. In most such species, individual trees are encountered in the wild at low densities that make fruit harvesting and marketing economically inefficient. Such a species might have been selected for improvement by researchers, with the objective of transferring the improved species to small farmers for cultivation, in order to help raise their income.

In the wild, the species bears fruits at irregular times and the production varies considerably from one tree to another, in terms of fruit taste, individual amounts of edible fruit and fruit quantity. For the potential market of the species to be tapped, there are thus obvious improvement needs for these characters, *whatever the system in which the tree would be cultivated*. Homogenization of fruit quality and regularization of fruit production are here considered as primary targets of plant improvement research.

Box 1. A non-conventional definition of agroforests

The word 'agroforest' is sometimes understood as the end-result of all agroforestry systems, whatever their structure and composition. For us 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 line systems, represents a language abuse that only leads to confusion.
The word 'agroforest' is thus used in this article, as in our previous publications, in a more restrictive but also more appropriate meaning. We define agroforests as forest structures planted and managed by farmers for the production of various forest and agricultural products on the same piece of land. Established through a complex succession of development and production stages involving the planting of crops as well as of various commercial and useful tree species, 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. 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. Numerous examples of such agroforests have been described from South-East Asia, and especially from Indonesia. In Sumatra alone, an estimated area of about 4 million ha is covered with damar (*Shorea javanica*) agroforests, rubber agroforests and fruit/timber/spice agroforests (Michon and de Foresta, 1995). It describes systems that exhibit a close link between the forest world and the agriculture world on the same piece of land.

However, in a classic bid towards efficiency, researchers would most probably add other characters as targets for improvement: for instance, lowering the tree canopy would be seen as beneficial in facilitating the harvest, and reducing the time period before fruiting would be considered beneficial in reducing the unproductive phase. These characters (here canopy height and time before sexual maturity) are what we consider as secondary targets of plant improvement research.

The selection of such secondary targets would be a quite obvious and relevant choice for most plant improvement researchers, even those involved in agroforestry. However, this choice would bear important consequences regarding both the potential for multiple products from the tree as well as for its multiple functions.

Reducing the time period before sexual maturity most often entails a correlative reduction of the lifespan: earlier production is accompanied by shorter production life, and for a given species, plantation regeneration is more frequently needed with early producing trees than with late producing trees, a point that is rarely taken into account in calculating profitability. When mature, high canopy trees offer space underneath their crowns for lower canopy species to develop and are, therefore, appropriate for higher canopy layers in multistrata agroforestry systems.

In addition, whatever their primary economic production, large tree species are also potential timber producers, a feature that can only gain in economic importance while rainforest areas, the traditional source of supply for timber in tropical countries, are vanishing (de Foresta and Michon, 1992). Lowering the canopy height in the improved tree species would thus reduce both the capability of producing timber at the end of its life-time and the ability to sustain a multistrata production system.

In the above example, the selection of the secondary target characters results from a focus on fruit production as the only valuable function of this species - a very common trend well embedded in the tree improvement *as usual*, reductionist approach, where the tree is considered as a kind of producing machine, in this case a fruit producing machine. Deeply linked with the domination of the pure plantation model in both agriculture and forestry, this approach leads for the improved species to a pre-adaptation to the pure plantation model and to a corresponding non-adaptation to the agroforest model. Choosing these secondary characters as targets for the improvement programme may be seen as a trivial technical decision. However, consequences of this decision are not trivial at all (Box 2) as the choice amounts to favouring the pure plantation model over the agroforest model, with all the ecological, economic and socio-political implications it entails (Michon and de Foresta, 1996).

Once again, favouring the pure plantation model is not necessarily inappropriate in itself, and the issue is not whether one model is better than the other. Each model has its benefits and constraints, each has a certain domain of application in which it is more efficient - in a very general meaning - than the other.

Reducing the time period before sexual maturity most often entails a correlative reduction of the lifespan: plantation regeneration is more frequently needed with early producing trees than with late producing trees, a point that is rarely taken into account in calculating profitability

Tall tree species are potential timber producers; they are also appropriate for high canopy layers in agroforests, a vital component as there can be no agroforests without high canopy trees. Lowering the canopy height of such species for facilitating the harvest thus entails a reduction in their capability to produce timber and prevents their use as the backbone of multistrata systems

Box 2. The pure plantation model and the agroforest model: selected characteristics at various levels

	Pure plantation model	Agroforest model
species level	one product / one function	multiple products / multiple functions
ecosystem level	one product / one function	reproduce the multiple economic uses and ecological functions of a forest ecosystem, from the establishment stage to maturity
	one resource only	various resources in a diverse forest ecosystem
	very low agro- and bio-diversity	high agro- and bio-diversity
	high ecological risks	low ecological risks
	reduction of the range of potentialities for further development	preservation of a high range of potentialities
	highly specialized technical knowledge segregated	indigenous knowledge well shared
economic level	high cash benefits	low to high cash benefits, depending on species composition
	high capital needs	low capital needs
	high economic risks	low economic risks
	high labour/cash inputs	low labour/cash inputs
socio-political level	often leads to land appropriation by better-off farmers or estates	leads to reappropriation of forest land and resources by local people

But what needs to be underlined here is that it is of critical importance, for tree improvement researchers involved in agroforestry, to be conscious of the consequences of their choice in the set of characters they select for improvement in a given tree species. During the process leading to that selection, particular attention should be given to the identification of what we called the primary and the secondary targets. In tree improvement research for agroforestry, secondary targets should be carefully assessed, keeping in mind the multiple functions of trees, in order not to decrease the improved species' ecological combining ability with other species with which it may be associated (Sinclair *et al.*, 1994) below a certain threshold that would make the species unsuitable to grow within agroforestry systems.

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