11 Código Florestal Amazon – Ecologically sustainable models to adjust the Brazilian Forest code in rural properties of Amazonas State (Model CF Amazon)

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The Brazilian Forest Code (Código Florestal) aims at reducing ecosystem degradation and to contribute to a more sustainable development in Amazônia. Any successful move towards that direction automatically meets the international standards that Brazil signed in the COP 21 agreement on greenhouse gas reduction. Within the project EcoRespira-Amazon, this part on CF Amazon was performed in parallel to the activities in "Forest ecosystem respiration – a key to sustainable land-use management". Research results of EcoRespira-Amazon help in defining more sustainable models in respect to the most appropriate soil management.

The structure of native forest is associated to the distribution of forest species in multiple vertical and horizontal spatial arrangements. Based on this conceptual model, the structure of post-forest systems should include fast and medium-growth forest species. An important challenge for Amazonian forest research is to find ways to reintroduce degraded areas into the productive process, using a greater number of native species and identifying among these species, which are the ones that best fit the specific environments (Full sun, under shade, flooded areas, compacted, among others).

Planting forests, like any intensive activity, generates impacts. Such impacts can be minimized, when negative and maximized, when positive.

Positive impacts will be reflected in productivity and quality of products from the planted systems, including their biotechnological potential together with management practices. Environmental services will be made available, such as the protection and strengthening of biodiversity; Recovery of degraded areas; Maintenance of soil fertility; Protection of water resources and mitigation of the greenhouse effect. The inclusion of small and medium producers in the forest/agroforestry business must be ensured. Short-term income generation through trade of seeds and seedlings and, in the medium and long term, the commercialization of timber and fruit can be a structural factor to keep people in the countryside, avoiding their exodus to the capital cities.

Possible negative impacts from the implementation of post-forest systems may result in the export of excessive amounts of nutrients from the soil, which may compromise the productivity of future land use. Alternative solutions provide for effective implementation of good management practices and implementation of agro-forestry interventions at the appropriate time. Choosing the right species at specific sites, according to their soil and climate requirements. as well as mixed and mixed cropping systems, will help to alleviate the deleterious effects of excessive export of nutrients.

To establish post-forest models in the Amazon region, several native forest species are considered that are promising or show potential for various purposes (Marques et al. 2008). *Bertholletia excelsa* (Brazil nut), *Dyterix odorata* (Cumarú), *Aniba rosaedora* (rosewood), *Jacaranda copaia* (para-para), *Sclerolobium paniculatum*, *Schizolobium amazonicum* (paricá), *Ceiba pentandra* (sumaúma, Kapok), *Aspidosperma oblongum* (araracanga) and *Simaruba amara* (marupá) appear useful for planting under full sunshine conditions. Due to their sensitivity towards attacks of the terminal shoot borer, Meliaceae such as *Cedrela spp.* (Cedar), *Carapa guianensis* (andiroba, mahogany) and *Swietenia macrophylla* (mahogany) should be used in association with natural regeneration or in the form of mixed plantations.

For plantations under partial shade, the species *Cordia goeldiana* (freijó, cordia), *Vochysia maxima* (true quaruba), *Didymopanax morototani* (morototó) and *Bagassa guianensis* (tatajuba) are indicated. Many models and species have been experimentally tested in Amazônia. We describe some possible options in Table 28.

The preliminary results of EcoRespira-Amazon in the areas studied show the following trend based on soil respiration flux data:

Environment: Forests > SAF's > Mixed systems > Monocultures

And from the point of view of producers for income generation:

Economic: Monocultures (Pastureland, Açaí, Oranges) > SAF's > Mixed systems > Forests

The challenge facing the scientific community is to find models that satisfactorily combine the environmental and economic component.

New models must be tested and/or validated in the different conditions of the Amazonas State ecosystem in order to know the extent to which it is possible to simplify its structure from a more complex model such as natural forests; And that such a system can fulfill its environmental functions with an acceptable level of income. Such models must permeate between mixed systems and SAF's.

Amazon producers are already making a major contribution to maintaining the planet's climate by sacrificing income on 80% of their property. Models that contribute to the sustainable economic use of these forest areas would be a great contribution so that producers do not have the need to advance in their legal reserve area.

Any list of species proposed to define a model will never be sufficient to cover all variations of climate, soil and personal taste of the producers.

The results of the EcoRespira-Amazon and CF Amazon projects indicate that from the point of view of soil respiration the most complex systems such as forests, SAF's and mixed systems with forest species such as *Bertholetia excelsa* appear to be the most promising. However, considering the economic need of producers, it has been found that the adoption of monoculture systems is still desired.

In a next phase of the project, the models should be tested/validated with these two biases: environmental and economic.



f.l.t.r.: Ednilson Alves Figueiredo in a Brazil nut plantation with guaraná (loc. 06); Gilvan Coimbra Martins in a rubber tree plantation (loc. 03); Sophie von Fromm and Laura Medeiros Braga at a agroforestry research site near Manaus

Table 28. *Conceptual models with details*

Model	History	Conditions (soils and relief)	Model-proposed plantation techniques	Objective for model/strategy implementation	Species	Floristic structure*	Testing Area
[1]Planted forests in ILPF* system	Livestock and agriculture	Terra firme areas with smooth slopes and clayey soils	Seedling in pits	Economic exploitation (timber, non-timber, SAF, forest grazing, other ...)	*Khaya ivorensis* (African Mahogany), *Bertholletia excelsa* (Brazil nut) and *Dipteryx odorata* (Cumaru, Sarapia) in the ILPF* system; annual cultures and fodder	Horiz = 4 Vertic = 3	UAS*
[2]Management of social bees	Livestock and agriculture	Terra firme areas with smooth slopes and sandy soils	Ecosystem maintenance through manipulation of social bee colonies	Economic exploitation (timber, non-timber, SAF, forest grazing, etc.); Environmental restoration	n.d	n.d.	APP*, ARL*
[3]Multilevel agroforestry system	Young fallow forest	Clayey soils, smooth slopes	Seeds and seedlings in pits	Economic exploitation (timber, non-timber, SAF, forest grazing, etc.)	*B. excelas; C. papaya; T. grandiflorum; E. stipitata; G. americana L.; M. emarginata; P. edulis; T. grandis; I. edulis; S. macrophylla; G. sepium; P. cupana; Oryza sativa; Mucuna aterrima; Manihot esculenta*	Horiz=3-5 Vertic=6-7	UAS*
[4]Secondary forest development (capoeira)	n.d.	Small areas, max. 1 ha with flat to lightly undulating terrain	Seeds/seedlings in pits with planting of species, that grew naturally from the system, such as mulatto wood		Banana (*Musa sp*) x açaí (Euterpe *oleracea*) x wood; açaí x fruit x wood; açaí x fruit; and fruit x wood	Horiz=3-5 Vertic=3-5	APP*
[5]Planting of forest species and fruit on pastureland	Area previously cultivated with coffee, then pasture	Soil type of the area is a yellow latosol	Seedlings in pits		*Bertholetia excelsa; Paullinea cupana; Hevea brasiliensis; Brachiaria brizantha*	Horiz: 4 Vertic: 3	UAS*

[1] Personal information: Arystides Resende Silva – Embrapa Amazônia Oriental

[2, 4, 5] Almeida EN, Sabogal C, Brienza Junior S (2006) Iniciativas Produtivas Agroflorestal e Silvicultural em Áreas Alteradas na Amazônia Brasileira. CIFOR - EMBRAPA (Divulgação em CD ROM).

[3] *Personal information: Eliza Wandelli; Silas Garcia Aquino de Souza – Embrapa Amazônia Ocidental.*

** ILPF system = Integração-Lavoura-Pecuaria-Floresta (https://www.embrapa.br/tema-integracao-lavoura-pecuaria-floresta-ilpf)*
** Floristic structure = Horizontal: # species per unit area; Vertical: # plant levels*

** Type of area = APP: Área de Proteção Permanente (permanently protected area); ARL: Área de Reserva Legal (area of legal reserves; UAS: Uso Alternativo do Solo (alternative land use area)*

A more comprehensive list of experience and models can be found at the site: https://www.embrapa.br/codigo-florestal/solucoes-tecnologicas

Illegal wood transport along the BR-230 (Transamazônica between Humaitá and Apuí)