The farmer with agroforestry practices might be the “next forester”?

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Summary

The main tropical Agro-Forestry Systems (AFS) are often complex, multi-stage and multi-species. Apart from home gardens intended for self-consumption, AFS are often based on a main crop with economic, or export value: rubber, coconut, cocoa, coffee, cloves, vanilla, damar, durian... with also local fruit trees, fast-growing fuelwood trees and timber trees for self-consumption or sale.

This diversification in AFS focused on industrial crops, often comes after a period of deforestation since the end of the 19th century during the period of the colonial empires. Wood can also come from species used for services such as providing shade for coffee or cocoa trees. Wood species are also common in the local forest (Indonesia/Thailand), reflecting farmers' strategy of conserving local resources. In other cases, native species have almost entirely disappeared (e.g. clove AFS on the East Coast of Madagascar) in favor of introduced species. Sometime, the main crop is also a timber specie such a rubber (used for furniture), Durian, Litchi… Now that most forests have almost disappeared in central plains with easy access in Southeast Asia (with potential commercial value), timber from AFS is becoming a real challenge that depends mainly on tree tenure and local regulation. Today, the current demand for tropical wood has decreased considerably since the golden age of deforestation (1980/2010) due to resource depletion and a global demand towards products from dedicated plantations from Europe or elsewhere. The market has changed from a massive use of tropical timber for multiple purposes to a limited use for specific purposes. In this context, timber in AFS, often produced at marginal cost, can be an alternative to produce valuable timber. We consider in this sense that the farmer in tropical regions with agroforestry practices might be the “forester of the future”. Beside, AFS with timber might significantly contribute to positive externalities and eco- systemic services for a better sustainability.

Key words: agroforestry, forester, timber, diversification.

1. Introduction

The last 20 years have been characterized by a high level of deforestation: timber harvesting, transformation from logged forest to plantations (oil palm rubber, cocoa, coffee…) and settlement from farmers in migration. If the tropical timber market was flowering from 1970's to the 2000's, most forest resources easily accessible in central plains have been largely depleted. Trees outside forest became important and in particular within agroforestry systems (AFS) as farmers do emerge as potential timber producers.

Most farmers integrate into their AFS more timber to fulfill their own requirement (housing for family) and provide the national/international timber market. Timber is becoming a serious challenge to improve and diversify farmers' income. We observe such trend in historically traditional fruit/timber AFS like the Durian/Surian system in Maninjau lake area in Sumatra (Michon et al, 1986), or "tembawang" in Kalimantan, Damar in Sumatra (Michon & al, 1991). Beside well known largely used species such as Mahogany or teak, the use of a greater number of lesser-known indigenous and exotic tree species is growing as recognized in the Philippines (Holding Anyonge, 2003). Fuel wood for local use as the main energy source for most families or specific use such as distillation (clove essential oil in Madagascar) is becoming a key element of AFS. Moreover, some trees have also a double use: timber and fuel wood.

Our aim is to show, through various examples taken from the entire tropical zone, the importance of wood produced in AFS. This statement leads us to believe that the farmers who manage these AFS are and will be more and more in the future foresters.

We do present several examples of current AFS including timber trees.

2. Methodology

This analysis rely mainly on bibliographic sources, previous research projects in Thailand, Indonesia, Ghana, Madagascar, from support mission (Brazil, Columbia, Sri Lanka ..) in order to provide of existing examples of "farmers as re-foresters".

3. Some examples of AFS with timber and fuelwood throughout the world

3.1 Introduction to complex AFS and timber/fuelwood production

Most AFS include a major crop (rubber, coconut, cocoa, coffee, clove, Damar, Durian/Surian...), with fruit trees, timber; fuelwood trees, trees providing "Non Timber Forest products (resins such a Gaharu, rattan etc) as well as annual foodcrops (Michon et al 1991). We present some examples of major AFS to illustrate that trend. Timber could be integrated into existing AFS to increase significantly timber production at low cost and low risk on a very deconcentrated manner. The future might belong to farmers to became the very next "forester" through developing more timber/fuelwood based AFS.

3.2 Rubber based AFS in Thailand and Indonesia with native species

3.2.1 Indonesia

Rubber is a very good candidate for AFS (Penot, Ollivier, 2009).Old traditional jungle rubber have a very large biodiversity (Lawrence 1996, De Foresta et al 1991, Gouyon 1995, Dove 1985…) with presence of *Magogany*, Teak, Keladan/sapwood/*Dryobalanops* spp., Belian/Bornéo Ironwood/*Eusideroxylon zwageri,* Meranti (Shorea spp.), Nyatoh (Palaquium spp), Sungkai (*Peronema canescens*), Petaling/*Ochanostachys amentacea*, kumpabok, Maraneh, Tamalun, Kawang (*Shorea macroptera, S.cristata, S.macrophylla, S.pilosa, S.pinanga and S.scaberrima*), Madang, Surian (*Toona sureni*) of very good commercial value (Diaz Novellon et al, 2002) (Tata et al, 2009). Due to forest depletion, Dayak people in Kalimantan want to integrate timber in AFS (Lawrence & al, 1995) such as in Modern RAS (Rubber Agroforestry Systems, SRAP and SRDP/Smallholder Rubber development Project) (Penot, 2001). In the 1990's, tree tenure was not favorable to farmers. Smallholders used mainly some trees emerging from the rubber interline managed as forest regrowth mainly Nyatoh and Keladan (Penot 1998) with a .density of 20/50 trees/ha. Tree tenure changed in the 2000's and now farmers can grow and sell freely timber. Best-bet combination alternative is Meranti with Durian. At the end of rubber lifespan (20 to 35 years depending on tapping quality), then RAS would become a *tembawang* (fruit/timber based AFS) with a lifespan of 50/60 years.

The Dayak community in the West Kutai District of East Kalimantan for instance has developed AFS with Meranti (*Shorea* sp.) and Kapur (*Dryobalanops aromatica*), with 400 trees/ha considered as easier to exploit economically. The maximum cycle was reached at the age of 40 years (Lahdji & al 2018).

3.2.2 Thailand

The current timber trees observed in rubber based AFS in southern Thailand are the following: Mahogany, Teak with a large local market, *Hopea odorata* (used for boat), *Shorea roxburgh,* phayom, *Dipterocarpus alatus*, Eagle wood/Agarwood for resin, perfume and carving), Bamboo (charcoal and house building), *Magnolia champaca /Michelia champaca* (Champak) (Warren Thomas & al, 2019). Our studies in 2010/2014/2016 in Phattallung area show clearly a new interest by farmers for timber as some rubber AFS do include timber only and not fruit trees. Timber trees are planted the first year with rubber, with shading from banana with more or less up to 280 trees/ha (Stroesser et al 2018, Simien & al, 2011). As timber species growth is largely inferior to that of rubber, the timber canopy is always below that of rubber at least for the first 30 years

3.3 Coffee Arabica based AFS in Nicaragua

Coffee Arabica is very often cropped with shading trees in Central America to improve potentially coffee quality and coffee lifespan with various level of intensification. (Vaast et al, 2005). Associated trees could be fruit trees, timber trees or specific shading tree such as *Erythema spp*. There is an experimental coffee business cluster with the EU/Breedcafs project in Nicaragua where high organoleptic quality and high productivity Arabica hybrid new varieties are grown with 80 timber trees for shading such as *Cedrella odorata, Khaya*

Senegalensis, Laurus nobilis, Juglans spp, Tectona grandis Erythrina spp, Pinus spp, cedar and local varieties traditionally used in AFS such as Inga, laurel and coyote (*Platinium spp*) (Bertrand et al , 2019). There is locally a good market for transformation and export (furniture factory in Managua) but tree tenure is limited as official authorization is required to cut and sell trees.

3.4 Very old coffee robusta based AFS in Eastern Guinea/Conakry with native species

There is approximately 165 000 ha of coffee in eastern Guinea around the area of Boussédou (DURAS project in the 2000's) in the forest area whith a large part of AFS with old coffee with a very low productivity (300 kg/ha/year) in association with banana, oil palm (red oil production), Raphia palm, Kola nut tree, coca, and other fruit trees (Avocado, citrus..) and fuelwood trees (old *Erythrema spp*..). The upper tree strata has many timber species from the original forest *Ceiba pentandra, Pycnanthus angolensis, Parkia bicore*, *Khaya ivorensis, Khaya anthoteca, Erythrina mildbraedii, Erythroxyllum mannii, Nauclea diderrichii, Distemonanthus bentamianum, Chrysophyllum, perpulchrome, Chlorophora excelsa, lovoa trichilioïdes et de Piptadeniastrum africanum.* (Penot, 2006). Timber is locally used for housing.

3.5 The case of cocoa and fruit based AFS in Brazil

The Bragantine zone is characterized by very innovative pepper and cocoa in AFS with Mahogany and coconut palm. In Marajo, farmers exploit some gallery forests with extraction that evoluate into AFS based with Acai (*Euterpe olearacea)*, Cupuaçu (*Theobroma grandiflorum*), Palmito/Pupunha (*bactrix gassipaes)* and Mahogany, teak, Andiroba (*Carapa spp*.) local "Pakati", a fast growing tree. The proximity of the city of Belem offers important outlets for fruit (Acai, Copoadzu and pineapple). In Uruara area in the Amazonian pioneer zone, pepper and cocoa AFS results from a strategy of accumulation and maximization of income by local cleaver farmers with large estates aware of the future timber value of certain species used for shading cocoa : Mahogany, cedars (*Cedrela odorata*/western *Thuia*) and Ipé. In Tomé acu, the 30-year-old cocoa trees are planted under magnificent local "brazilian chesnut tree" (or "castanheiro") of 50 to 60 years. Shading on cocoa can also be done with original trees from the forest such as butterfly pea tree /"palheteiras" (*Clitoria racemosa*) (Penot, 2005 comm pers).

The Amazonian zone has shown an impressive diversity of SAF systems. (Vosti et al, 1998. The main reasons for adopting timber/fuelwood species (Pickety et al 2005) are the following: i) quality wood at lower cost than extractivism from the remote forest, ii) a regular supply for local sawmills and booming local timber industry, iii) consolidation of land ownership, iv) a positive, "ecological" image of companies that promote AFS, v) the reduction of risks and synergy between species. Vi) better labor productivity for AFS compared to monoculture. Finally, the change in legislation in 2006 in Amazonia where 80% of the 100 hectares plot for immigrant must be maintained either in forest or in agroforest has largely favored the development of agroforestry practices. (SMITH ET AL., 1996). We ca similar trends in Amazonian Columbia with rubber based AFS (Penot & al, 2012).

3.6 Clove AFS in Madagascar: no place for native species.

The clove tree was introduced in the 19th century and promoted during the French colonial period as Madagascar became one of the main producers and exporters of cloves and clove oil (Danthu et al., 2014). Clove AFS in eastern cost in Madagascar may include some species such as Raphia palm (*Raphia farinifera*), E*ucalyptus spp*, G*revilea banksii* but almost no local timber species such as the famous rosewood (*Dalbergia* spp, *Diospyros spp*) that were exploited in the slash-and-burn operations that preceded the installation of AFS, This process has led to the disappearance of natural forest replaced by a mosaic of AFS (Mariel et al., 2021). Some fruit trees, litchi, bread tree, and mango, are also used for timber. Most current trees are introduced species. Clove is cropped in a diversity of cropping systems along the east coast of Madagascar ranging from parkland to complex agroforestry systems (Arimalala et al., 2019; Michel et al., 2020).. Today, clove cultivation is the basis of farmers' income with two products: i) the clove bud and ii) clove essential oil that required much fuelwood for distillation (Razafimamonjison et al. 2016; Danthu et al. 2020). Fuelwood requirement represents today a real threat to the environment with roughly 500,000 m3 of wood necessary to produce 6 000 tons of oil. This woody biomass is collected in and around AFS (bamboos, *Grevillea banksii*, and above all from the fruit trees pruned or felled: mango, lychee, breadfruit, old clove trees. Candidate species for planting are fast-growing exotic species such as *Eucalyptu*s or *Acacias* already introduced and planted in other regions of Madagascar. It is therefore conceivable that farmers on the East Coast of Madagascar will integrate wood energy (and service) production into their AFS alongside their cash crops (cloves, pepper, coffee, vanilla) or fruit (lychee, bread tree, jackfruit, trees, Citrus spp) for the international, local market or for self-consumption.

3.7 Cocoa AFS in RCI: timber tree tenure is not favorable to local farmers.

Ivory Coast is well known for its "full sun" cocoa systems (Assiri et al. 2009) with historical roots (migrants' strategy, short-term expectations, and monoculture oriented extension services (Ruf and Bini, 1998). The conversion of former agroforestry systems into monoculture was enhanced by a legal framework on "trees property" unfavorable to farmers allowing timber loggers to come into cocoa farms and to harvest valuable trees without giving any compensation to farmers (Ruf and Bini 2010) leading to no incentives for farmers to maintain valuable trees (Sanial 2018). However, during the last decades, we saw two major evolutions: i) most farmers are (re)introducing trees in their fields to face production difficulties due to climate change (Smith Dumont et al. 2014; Vroh, N'guessan, and Adou 2017; Sanial 2019) and ii) The second change is regarding the new forest law of 2014. According to this text, a tree situated in a cocoa farm cannot be logged down by a timber company without asking the farmer and without compensation. The new law is a great step forward to transform farmers into foresters. Indeed, in 137 plots covering 210 hectares from East to West of the country over the 163 identified species 44 have a commercial value but they represent less than 20% of trees. The most frequent are: *Ceiba Pentandra, Terminalia superba, Terminalia ivorensis, Milicia excelsa, Pycnanthus angolensis, Antiaris africana.*

3.8 The cocoa timber OK experience in Ghana in the 2000's

The Oda-Kotoamso Community Agroforestry Project (OCAP) was started in 1997 by Samartex (a big sawmill) in collaboration with various local stakeholders. in the village of Samreboi. The main objective of the project is to increase farmers' income and to create a stock of timber raw material for the sawmill "Samartex". The main timber species required by Samatex in AFS are: teak (on a 25 years cycle), *Cedrella odorata* (acajou amer), Ciber/Ofram (30 years), Wawa (35 years) or Mahoghany (35 to 60 years) (Basterrechea T. & Penot E. 2012).

4. The role and place of timber in AFS and importance of tree tenure

The role and place of timber in AFS depends of existing or emerging local/international market and local self-consumption. Historically for instance, timber from jungle rubber in Indonesia (3 million ha in the 1990's) was mainly used for self-consumption as most timber for export was produced from forest extraction. But now that most forests in central plains have disappeared, timber from AFS is becoming a real challenge. There is still some large forest areas in Southeast-Asia but they are very limited (Myanmar and Indonesian Papua province mainly). Timber production depends mainly on tree tenure: timber is controlled by farmers in Thailand, Indonesia (since the 2000's) and enable farmers to sell in good conditions. Tree tenure is not controlled by farmers in Nicaragua (governmental authorization to cut a tree) or in RCI where other actors can take up the tree and process it. In these cases, timber production is definitely not favored as mastering marketing is not fully controlled by farmers however there is a probable local demand for wood.

In other contexts, the introduction of wood-producing trees is a dynamic that remains to be promoted and that will become a necessity in the short term in order to respond to the shortage of combustible wood resources, the first signs of which are already perceptible.

5. The state of the current world offer/demand for tropical wood

The market has completely changed and move to a limited use of tropical timber for specific markets in Southeast Asia.

On the supply side, we note: i) the Increasing role of plantations in Asia, ii) the fragmented supply base and supply chain, iii) the development of regulations and emerging network effects and iv) synergies with forest certification. On the demand side, we note: i) domestic market typically at least 50% of volume consumption, ii) key role of China in international trade, iii) an overall slowdown in trade due to Covid-19,iv) regulations to exclude illegal wood in import trade and v) on-going substitution trends and the increased focus on carbon credentials of products. China has become an absolute major importer of tropical wood, draining nearly 50% of exports from the Congo Basin in recent years where forest products are still available.

Africa is at the heart of profound economic, social and environmental changes. Wood energy (charcoal) is one the main demand. 918 million people in sub-Saharan Africa will rely on biomass energy, one third of the total world population dependent on biomass energy, up

from 653 million people in 2009.[1] Given that demand for industrial wood will increase from 77 million m3 today to 300 million m3 in 2030, and supply will rise from 46 million m3 to 81 million m3 over the same period, forest plantations in Africa will only be able to satisfy less than 25% of industrial demand, compared to about 50% today. The GEF (Global Environment Fund) expects the supply gap to grow, and will have to be filled by wood imports if forestry and agroforestry in Africa does not develop.

Conclusion

The main challenge is to integrate more timber and fuelwood at low cost in various type of AFS in order to produce more at marginal cost. Timber do profit from maintenance of the main crop and other associated trees. Most valuable timber species requires shading provided by AFS.

In other words, it is far more easy to have 5 or 10 more timber trees in current existing AFS on millions ha (producing millions timber trees but deconcentrated) than creating new forest with valuable timber species with high investment and control for 40/50 years.

Beside, agroforesty systems with timber do produce forest ecological services (watershed protection, erosion control, habitat for wildlife, etc.) that are already included right from the beginning in farmers' strategies to provide more sustainability as there are generally considered by economists as externalities. Examples provided in this paper displays a large palette of knowledge and skills of local farmers to better strengthen these "forestry" roles.

The AFS farmer therefore might be the next timber producer: he is the best placed in terms or resources (low cost, low maintenance, good integration in AFS) to take the challenge. Governmental policies should take into account that opportunity and deliver favorable contexts and regulation to boost timber production.

Bibliography

Arimalala N, Penot E, Michels T, Rakotoarimanana V, Michel I, Ravaomanalina H, Roger E, Jahiel M, Leong Pock Tsy JM, Danthu P. (2019). Clove based cropping systems on the east coast of Madagascar: How history leaves its mark on the landscape. *AgroForestry Systems*, **93** (4): 1577-1592. https://doi.org/10.1007/s10457-018-0268-9.

Assiri, A.A., G.R. Yoro, O. Deheuvels, B.I Kebe, J.Z. Kelo, A. Adiko, and A. Assa. (2009). 'Les Caractéristiques Agronomiques Des Vergers de Cacaoyer (Theobroma Cacao L.) En Côte d'Ivoire'. *Journal of Animal and Plant Sciences* 2 (1): 55–66

Basterrechea T. & Penot E. (2012). Analyse et caractérisation avec le logiciel olympe des exploitations agricoles au « wassa-amenfi district» pour une meilleure gestion des ressources forestières. (Ghana). Book chapter in E Penot, Exploitations agricoles, stratégies paysannes et

[1] The possible sources of information are the following: ITTO : www.itto.int; GEF : www.globalenvironmentfund.com, FAO: www.fao.org/forestry and ATIBT : www.atibt.org.

politiques publiques. Les apports du modèle Olympe sous la direction de Éric Penot. Editions Quae, Versailles. Collection « Update Sciences & Technology. Janvier 2012.350 p

Bertrand B. Penot E. Baufumé S. Etienne H. Louafi S.Blangy L.Saletes S. (2019). Local value-chains dedicated to sustainable production (Coffee/Cocoa agroforestry business driven Clusters or CaFC): a new organizational model to foster social and environmental innovations. 4th World Agroforestry Congress (WAC 2019). Montpellier, May 2019.

Pascal Danthu, Eric Penot, Karen Mahafaka Ranoarison, Jean Chrysostôme Rakotondravelo, Isabelle Michel-Dounias, Marine Tiollier, Thierry Michels, Fréderic Normand, Gaylor Razafimamonjison, Fanja Fawbush, Michel Jahiel. (2014). The Clove tree of Madagascar a success story with an unpredictable future.Bois et forêts des tropiques. 2014. N° 320 (2).

http://publications.cirad.fr/une_notice.php?dk=574435

Danthu P, Simanjuntak R, Fawbush F, Leong Pock Tsy JM, Razafimamonjison G, Maoulida A, Penot E. (2020). Les produits du giroflier (clou, essence, eugénol) : un passé millénaire, un présent prospère, mais quel avenir ? Revue fruits, septembre 2020

De Foresta H and Michon G (1991) Complex agroforestry systems and the conservation of biological diversity (II). In: Proceedings of the International Conference on Tropical Biodiversity 'In Harmony with Nature', 12–16 June, 1990, Kuala Lumpur, Malaysia, pp 488–500. Malayan Nature Society

Diaz-Novelllon, S., Penot E., Arnaud M (2002). *Characterisation of biodiversity in improved rubber agroforests in West-Kalimantan, Indonesia. Real and Potential uses for spontaneous plants. Land-use, nature conservation and the stability of rainforest margins in Southeast Asia*. International Symposium, September 29- October 3, Bogor , Indonesia. IPB Bogor, University of Gottingen-University of Kassel (Germany).

Dove MR (1985) Swidden Agriculture in Indonesia. Mouton, Berlin

Gouyon A, De Foresta H and Levang P (1993) Does 'jungle rubber' deserve its name? An analysis of rubber agroforestry systems in southeast Sumatra. Agrofor Syst 22: 181–206

Holding Anyonge C and Roshetko JM. (2003). Farm-level timber production: orienting farmers towards the market. Unasylva 212, Vol. 54, 2003.

Lahjie AM, Lepong A, Simarangkir BDAS, Kristiningrum R, Ruslim Y. (2018). Financial analysis of dipterocarp log production and rubber production in the forest and land rehabilitation program of Sekolaq Muliaq, West Kutai District, Indonesia. Biodiversitas 19: 757-766.

Lawrence, D.C. Trade-offs between rubber production and maintenance of diversity: the structure of rubber gardens in West Kalimantan, Indonesia. 1996. *Agroforest Syst* 34, 83–100 (1996). https://doi.org/10.1007/BF00129634

Lawrence DC, Leighton M, and Peart DR (1995) Availability and extraction of forest products in managed and primary forest around a Dayak village in West Kalimantan, Indonesia. Conserv Biol 9: 76–88

Mariel, Juliette; Carrière, Stéphanie; Penot, Eric; Danthu, Pascal; Rafidison, Verohanitra ; Labeyrie, Vanesse, (2021). Exploring farmers' agrobiodiversity knowledge and management practices: a case study of clove-based agroforests on the north-east coast of Madagascar". People and Nature. Juillet 2021. https://besjournals.onlinelibrary.wiley.com/doi/full/10.1002/pan3.10238. https://doi.org/10.1002/pan3.10238

Michon, G, MARY F and BOMPARD J. (1986). Multistoried agroforestry garden system in West Sumatra, Indonesia . Agroforestry Systems 4: 31 5-338

Michon G (1991) The damar gardens: existing buffer zones at Pesisir area of Sumatra Selatan National Park, Lampung. Proceedings of the Symposium on Rain Forest Protection and National Park Buffer Zones, Manggala Wanabakti, Jakarta, Indonesia. Ministry of Forestry, Government of Indonesia

Michon G and De Foresta H (1991) Complex agroforestry systems and the conservation of biological diversity (I): Agroforests in Indonesia: the link between two worlds. In: Proceedings of the International Conference on Tropical Biodiversity 'In Harmony with Nature', 12–16 June, 1990, Kuala Lumpur, Malaysia, pp 457–473. Malayan Nature Society

Tata HL, van Noordwijk M, Harja D, JoshiL. (2009). Dipterocarp Trees in Rubber Agroforestry:Interplanting Strategies for High-valueTimber Production in Sumatra. The 2 World Congress of Agroforestry Nairobi, 24-28 August 2009

Marie-Gabrielle Piketty, Jonas Bastos da Veiga, Jean François Tourrand, Ailce Margarida Negreiros Alves,René Poccard-Chapuis, Marcelo Thales. (2005). Determinantes da expansão da pecuária na amazônia oriental:conseqüências para as políticas públicas. Cadernos de Ciência & Tecnologia, Brasília, v. 22, n. 1, p. 221-234, jan./abr. 2005

Penot E, Rivano F et Follin C. (2012). Stratégies de diversification et développement alternatif à la culture de la coca en Amazonie colombienne (Caqueta).Analyse du cas colombien dans la sous-région. Economie Rurale. n° 329/2012, p64-82. http://publications.cirad.fr/une_notice.php?dk=564192

Penot E. & Ollivier I.(2009). L'hévéa en association avec les cultures pérennes, fruitières ou forestières ; quelques exemples en Asie, Afrique et Amérique latine. Bois et Forêts des tropiques, dec 2009. http://revues.cirad.fr/index.php/BFT/article/view/20407.

Penot E. (1998). L'amélioration des agroforêts à hévéa en Indonésie. Published in CIRAD-CP PRD publication, Vol 5, n°2/98 April 1998, Montpellier, France.

https://www.researchgate.net/profile/Eric_Penot/publication/279840059_Communication_pour_le_15_symposium_international_de_l'Association_pour_la_Recherche_sur_les_Systemes_de_Production-Diffusion/links/559b8acd08ae21086d27a2f8.pdf

Penot, E. (2001). Stratégies paysannes et évolution des savoirs : l'hévéaculture agro-forestière indonésienne. Thèse de doctorat. Faculté des Sciences Economiques. Montpellier, Université Montpellier I.: 360p.

Penot Eric**.** (2006). Projet DURAS Appui méthodologique à la caractérisation et à la modélisation des exploitations agricoles : rapport de mission au Ghana et en Guinée, 12-26 novembre 2006. Montpellier : CIRAD-TERA, 43 p. N° de rapport : CIRAD-TERA N° 67/06

Gaylor Razafimamonjison, Renaud Boulanger, Michel Jahiel, Panja Ramanoelina, Fanja Fawbush, Marc Lebrun, Pascal Danthu. (2016). Variations in yield and composition of leaf essential oil from Syzygium aromaticum at various phases of development. International Journal of Basic and Applied Sciences, 5 (1) (2016) 90-94.

Ruf, François, and Serge Bini. (2010). 'Are Cocoa Farmers Ready for Timber? The Case of Jasikan, Ghana'. In .Ruf, François Olivier, and Honoré Zadi. 1998. 'Cocoa : From Deforestation to Reforestation'. In *Cocoa from Deforestation to Reforestation*. Panama City, Smithsonian Institute.

Sanial, Elsa. (2018). 'L'appropriation de l'arbre, Un Nouveau Front Pour La Cacaoculture Ivoirienne ? Contraintes Techniques, Environnementales et Foncières'. *Cahiers Agricultures* 27.
———. 2019. 'A La Recherche de l'ombre, Géographie Des Systèmes Agroforestiers Émergents En Cacaoculture Ivoirienne Post-Forestière'. Lyon: Jean Moulin Lyon 3.

Elsa Sanial. (2019). A la recherche de l'ombre, géographie des systèmes agroforestiers émergents en cacaoculture ivoirienne post-forestière. Thèse de doctorat en Geographie et aménagement. le 13-12-2019. École doctorale Sciences sociales (Lyon)/Université Jean Moulin (Lyon) et CIRAD/Montpellier

Smith Dumont, E., G.M. Gnahoua, L. Ohouo, F.L. Sinclair, and P. Vaast. (2014). 'Farmers in Côte d'Ivoire Value Integrating Tree Diversity in Cocoa for the Provision of Ecosystem Services'. *Agroforestry System* 88 (6): 1047–66. https://doi.org/10.1007/s10457-014-9679-4.

Smith, N. J. H., Falesi, C., Alvim P., Serrao E. A. (1996). "Agroforestry trajectories among smallholders in the Brazilian Amazon : innovations and resiliency in pionner and older settled areas." Ecological Economics n° 18: p 15-27.

Simien A. & Penot E (2011). Smallholding rubber-based farming systems in southern Thailand :diversification as a strategy against economic uncertainty. Journal of Sustainable Forestry. *Journal Sustainable Forestry*, 30:1–14, 2011. Copyright © Taylor & Francis Group, LLC.ISSN: 1054-9811

Stroesser L, Penot E, Michel I, Tongkaemkaew U and Chambon B. (2018). Income diversification for rubber farmers through agroforestry practices.How to overcome rubber

prices volatility in Phatthalung province, Thailand. Revue Internationale du Développement/Editions de la Sorbonne n° 235 (2018-3), https://dialnet.unirioja.es/servlet/articulo?codigo=6537375

Vaast Ph, Van Kanten R, Siles P, Dzib B, Franck N, Harmand J-M, Génard M. (2005). Shade: A key factor for coffee sustainability and quality. In : 20th International Conference on Coffee Science, 11-15 October 2004, Bangalore, India. ASIC, 887-896. ISBN 2-900212-19-7 Colloque Scientifique International sur le Café.

Vosti, S. A., Witcover, J., Oliveira, S. Faminow, M. (1998). "Policy issues in Agroforestry: technology adoption and regional integration in the Western Brazilian Amazon." Agroforestry systems n° 38: p 195-222. http://www.informaworld.com/smpp/content~content=a935253562~db=all?jumptype=alert&alerttype=ifirst_author_alert,email

Vroh, Bi Tra Aime, Kouakou Edouard N'guessan, and Yao Constant Yves Adou. (2017). 'Trees Species Diversity in Perennial Crops around Yapo Protected Forest, Côte DIvoire'. *Journal of Horticulture and Forestry* 9 (11): 98–108. https://doi.org/10.5897/JHF2017.0507.

Warren-Thomas E; Nelson L; Juthong W; Bumrungsri S; Brattström O; Stroesser L; Chambon B; Penot E; Tongkaemkaew U; Edwards P; Dolman PM. (2019). Rubber agroforestry in Thailand provides biodiversity benefits without reducing yields. Journal of Applied Ecology. 2019. here: https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13530