CoForTips Set

Newsletter n°6 - 2016

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The future of the forests of the Congo Basin is conditioned by two processes: climate change and land use change - crop development, infrastructure and logging. The CoForTips/Set project has identified ecological transitions between different forest formations, enabling better anticipation of the environmental impacts of human activities. We have described the practices and standards that men and women develop in response to environmental change. We have finally built models that couple these drivers of ecological and social change. These models, which can take the form of games, are privileged tools for identifying and building new strategies, and inventing new forms of collective action.

Used in a commune, they develop social capital and trust between stakeholders. Used at the regional level in the framework of existing platforms, they serve as a support for negotiations on the major reform proposals to come: ecological compensation, certification, Forest Landscapes Intact. These tools that we have developed allow better decision-making and concerted management of the Congo Basin forests.

WP 1 - Building Resilience Landscapes

Raphaël Pélissier, Sylvie Gourlet-Fleury, Maxime Réjou-Méchain, Jean-François Bastin, Valéry Gond, Johan Oszwald

WP1 aims at increasing our understanding of the dynamics of forest biodiversity in the central African region including the role and impact of forest degradation on the structure, diversity and resilience of the main tree communities. To achieve this, WP1 combines (i) a regional remote sensing-based forest typology; (ii) an advanced statistical modeling of large-scale commercial forest inventory data and; (iii) the sharing of expert ecological knowledge from a network of field-oriented scientists. We finally produced a map of the resilience of biodiversity in the central African forests on which the other WPs rely to elaborate future change scenarios.

A regional map of forest types has been produced based on a classification of the seasonal profiles of photosynthetic activity (measured by EVI, Enhanced Vegetation Index) as derived from a 13-y time series (2000-2012) of MODIS (Moderate Resolution Imaging Spectro-radiometer) satellite data. Ten terra firme forest classes were identified and interpreted in terms of deciduousness and structure based on 37,898 0.5-ha ground truth plots gathered from 19 forest companies. Radar and Lidar data were also used to discriminate the swamp forests. The resulting product (Fig. 1) was presented at the annual World Bank Conference on Land and Poverty in March 2015 [1].

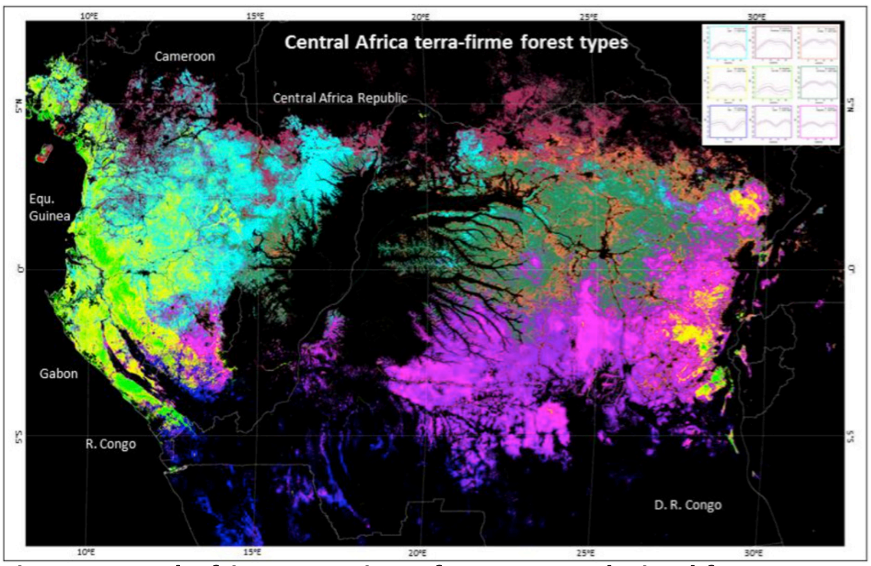


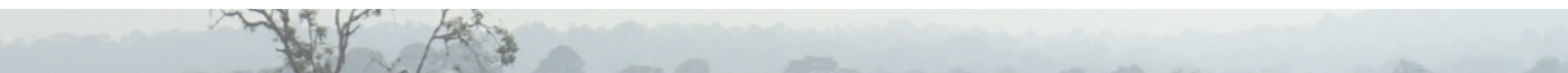
Fig. 1. Central Africa Terra Firme forest types derived from MODIS time-series. Source [1].

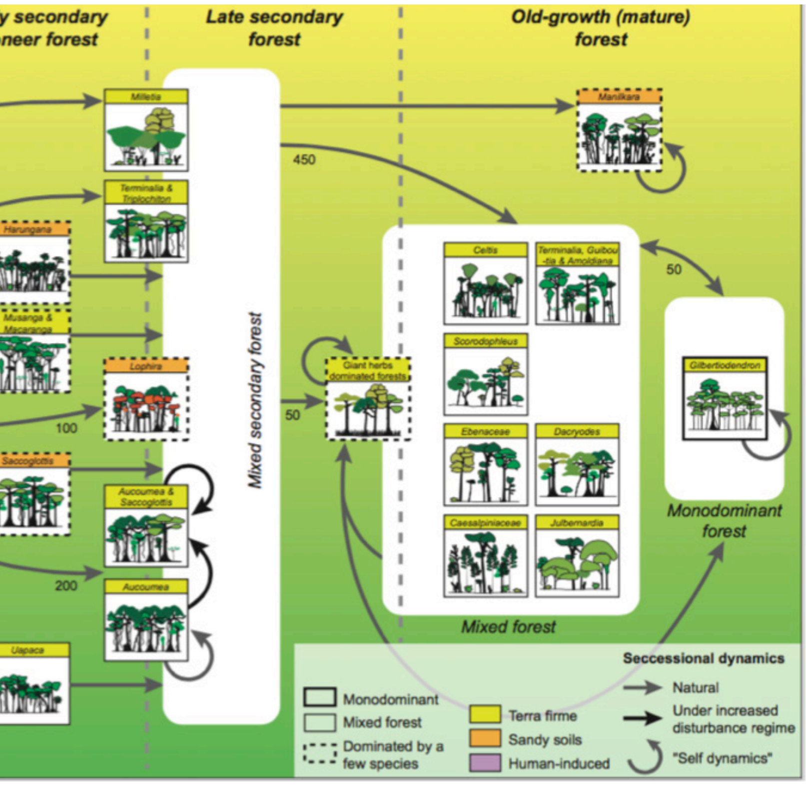
We synthetized the field experience of a network of experienced botanists involved in the project, into a conceptual scheme of the potential natural pathways of the secondary forest successions in central Africa (Fig. 2). This work was publicly released at the 53nd annual meeting of the ATBC (Association for Tropical Biology and Conservation) in June 2015 and a call for contributions was also made in order to gather insights from the full community of the expert botanists with expertise in the region [2].

Fig. 2. Conceptual mode firme forests. Source [2].

A local-scale remote sensing analysis of the land use changes was conducted based on a diachronic analysis of Proba-V images available for about 3 decades in 3 different village territories experiencing various intensities of anthropogenic pressure in the region (Makokou in Gabon, Bokito and Mindourou in Cameroun) [3]. It allowed us to document the forest transition pathway and tipping points of forested landscapes under anthropogenic pressure (Fig. 3).

Finally, the forest inventory data of 140,000 plots spread over 4 countries in central Africa were used to define the principal floristic and functional forest types in the region and to model their environmental and anthropogenic determinants using advance statistical methods. Thanks to the development of a dedicated index of anthropogenic pressure independent from the vegetation, we were able to show that while genus distributions are hardly predictable by environmental variables, forest community composition are well predicted [5]. This demonstrates that ignoring interspecific interactions effects could lead to unstable predictions of the expected forest response to global environmental changes.





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Similarly, we have shown that multiple functional shifts can be expected in the Congo basin forests under the combined effect of an increasing climate dryness and anthropogenic pressure when considering the deciduous and pioneer character of genus [5]. These results will now be combined to provide a biodiversity resilience landscape of the central African forests.

[1] Gond V., Betbeder J., Fayolle A., Viennois G., Cornu G., Réjou-Méchain M., Baghdadi N., Benedet F., Doumenge C., Gourlet-Fleury S., 2015. New insights in tropical forest diversity mapping in Central Africa using low resolution remote sensing. Annual World Bank Conference on Land and Poverty 2015: Linking Land Tenure and Use for Shared Prosperity. Washington, DC, 23-27 Mars 2015.

[2] Garcia, C., Bastin, J.-F., Réjou-Méchain, M., Chamagne, J., Dauby, G., Viennois, G., Droissart, V., Dessard, H., Stévart, T., Hardy, O., Gillet, P., Vermeulen, C., Gond, V., Fayolle, A., Bretagnolle, F., Oszwald, J., Doucet, J.-L., Gourlet-Fleury, S. & Pélissier, R. 2016. Gateway to the Forests of Central Africa: a first step towards a unified collaborative model of forest dynamics in the region. 53rd ATBC Annual Meeting “Tropical Ecology and Society: reconciling conservation and sustainable use of biodiversity”, 19-23 Juin 2016, Montpellier, France.

[3] Oszwald, J., Gond, V., Tchiengué, B., Nzigou Boucka, F., Dallery, D. & Garcia, C. 2015. Description des éléments paysagers des classifications d’occupation des sols, projet CoForTips (Cameroun), rapport technique, 40 pages.

[4] Réjou-Méchain, M., Mortier, F., Barbier, N., Bastin, J.-F., Bénédet, F., Bry, X., Chave, J., Cornu, G., Dauby, G., Doucet, J.-L., Fayolle, A., Gourlet-Fleury, S., Pélissier, R. & Trottier, C. 2016. Can we predict forest composition across space and time in Central Africa? 53rd ATBC Annual Meeting “Tropical Ecology and Society: reconciling conservation and sustainable use of biodiversity”, 19-23 Juin 2016, Montpellier, France.

[5] Bastin, J.-F., Mortier, F., Réjou-Méchain, M., Bénédet, F., Cornu, G., Doucet, J.-L., Fayolle, A., Tadesse, M., Gourlet-Fleury, S. & Pélissier, R. 2016. Functional shifts within Central African rainforests. 53rd ATBC Annual Meeting “Tropical Ecology and Society: reconciling conservation and sustainable use of biodiversity”, 19-23 Juin 2016, Montpellier, France.

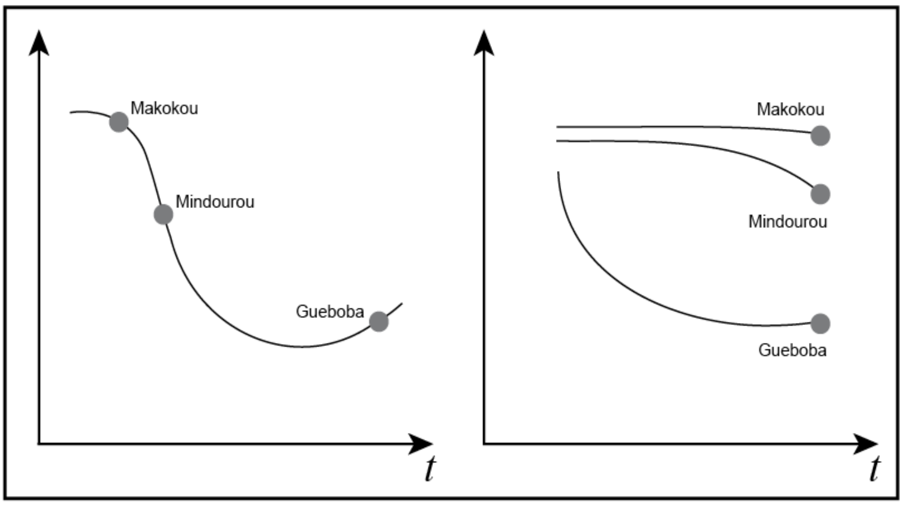


Fig. 3. Position of the three study sites along the forest transition curve (y axis: forest cover). The left diagram represents our initial hypothesis. The right one our current understanding of the landscape trajectories of the social and ecological systems.

WP 2 - Identifying drivers of change

Laurène Feintrenie, Pauline Gillet, Hélène Dessard, Laurence Boutinot, Philippe Karpe, Cédric Vermeulen

Based on in-depth investigative work and participatory observation, we analyzed in three sites considered as 3 stages of evolution of a socio-ecosystem (SES) following the forest transition: (i) the contribution of biodiversity to the well-being of human communities; (ii) changes in practices in the management and use of ecosystem goods and services and land use; and (iii) drivers and impediments to these changes.

We explored the links between biodiversity and well-being through the analysis of hunting and fishing practices, collection of non-timber forest products (NWFPs) and agriculture. We assessed the contribution of these different elements to food security and household income. Changes in practices were observed using a synchronous approach applied to the three sites. Finally, we analyzed drivers and barriers to change at the local, national and regional levels.

Influence of industrial sectors

Africa contains 30% of the world's mineral reserves, of which at least 60% would be in the Congo Basin forest subsoil[1]. Implemented on all identified world-class deposits, mining would contribute to significant forest degradation. Few industrial mining projects began in 2015 for financial, and administrative reasons and because of ore price volatility.

Industrial agriculture is dominated by European, Asian and domestic investment, and mainly concerns palm oil, natural rubber, banana and cane sugar. Most of the plantations date from 1910 to 1960, and have contributed little to deforestation after their establishment. The attribution of new concessions in forest areas could reverse this trend.

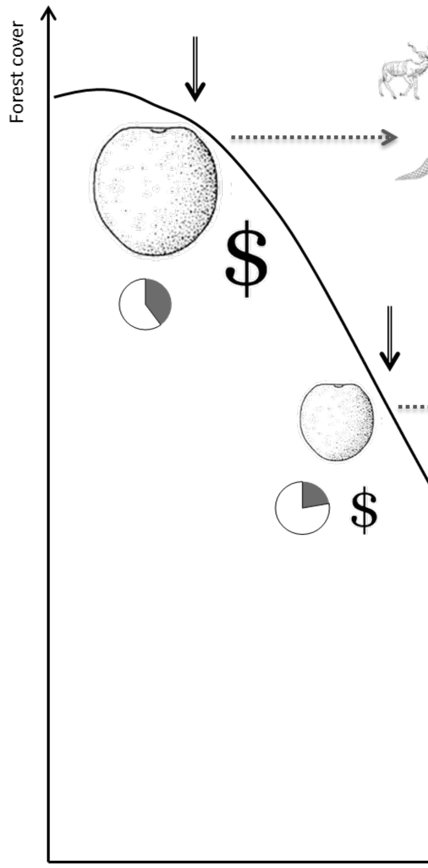


Figure 1. Illustration of local c

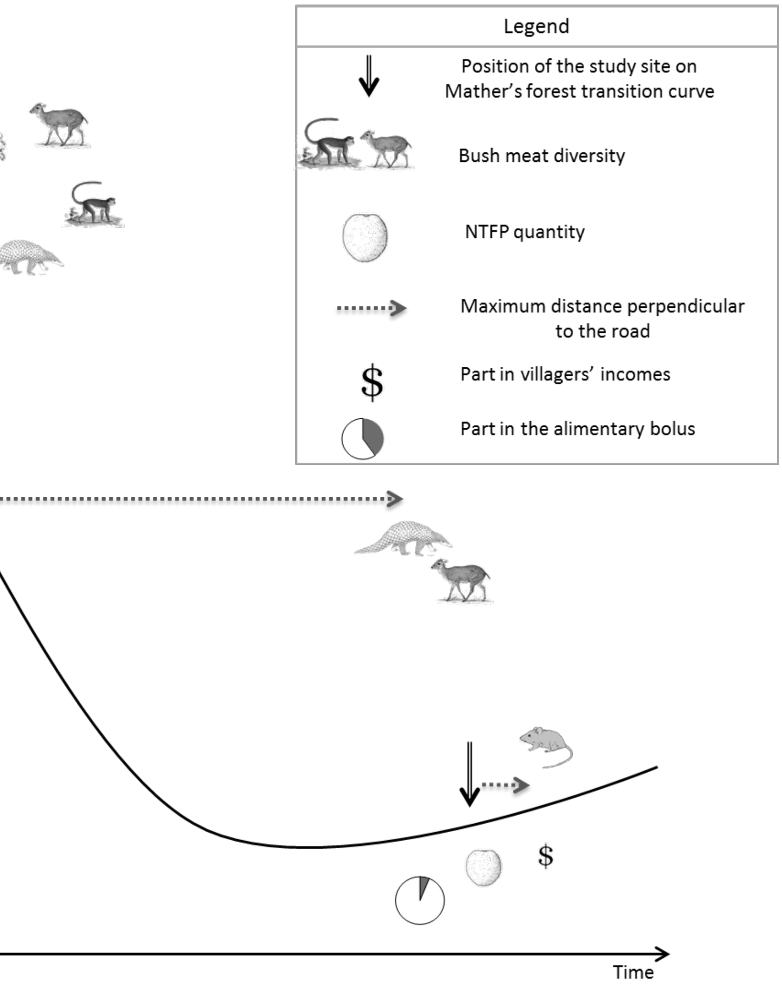
Logging is carried out by companies licensed to operate. Only certain species of high commercial value are harvested on rotations of 25 to 30 years, according to management plans that guarantee a sustainable management of the resource.

If the direct impacts (deforestation, pollution) of these different modes of industrial exploitation can be controlled and reduced, the indirect impacts (increase in population, access opening) are difficult to control and can be significant.

Figure 2: Cocoa cultivation can drive forest cover increase in the later phases of the forest transition curve. But with the proper set of incentives, it can also mark a state transition where forests are converted directly to agroforestry systems without losing forest cover. The question of biodiversity conservation in production landscapes is then paramount.

Forest transition at the local level

The main difference between Makokou and Mindourou is the presence of a logging company in the latter locality, which resulted in improved infrastructure, job creation, the arrival of migrants, and the development of the



changes during forest transition [2].

local market. The sites of Makokou and Bokito illustrate comparatively stable states while Mindourou is undergoing a profound change. Changes, driven mainly by external pressures, are rapid, with intensive use of forest resources.

During the forest transition (Fig.1):

- The share of forest resources (bushmeat, fish and NTFP) in the food supply of the households decreases in favor of agricultural products and livestock. The cost of meals increases.
- Game diversity decreases and the size of the preys shrink. Similarly, the diversity of NTFPs and their importance in the livelihood and income of villagers decreases.
- Agricultural activities increase and become the majority in the allocation of work effort, in the food supply and in the generation of income.
- Land ownership evolves. Forest areas that once had undifferentiated access become restricted and exclusive; the number of individual agricultural plots increases.

Land tenure and social justice

The problem of land tenure does not arise in terms of conflicts of rights or present or future conflicts of use, but rather in the relevance of political and legal action in the service of social justice. Communities or common interest groups can be identified in the villages we analyzed (Fig. 6). However, land tenure security, a constituent of social justice, does not seem to be occur through the rule of law, despite reforms and restructuration. The concept of the commons could serve as a basis for a conceptual and structural revolution. The challenge is to guarantee to all populations dependent on this space a shared and balanced management. Some of these populations claim a vital right with this space, a life link that legitimizes their claims on it and presented as a superior to that of the state. This "Law of the Commons" remains to be defined.

[1] Edwards D., Tobias J.A., Sheil D., Meijaard E., Laurance W.F. 2014. Maintaining ecosystem function and services in logged tropical forests. TREE: 1846

[2] Gillet P. 2016 (forthcoming). L'Afrique Centrale : entre traditions et transitions, la mutation des socio-écosystèmes. Doctorat en sciences agronomiques et ingénierie biologique de l'Université de Liège-Gembloux.

Figure 3: Baka Pygmies form a group distinct from that of the Bantus, sharing space and resources with them, but with considerable power asymmetries. Their integration in the landscape governance is a question of social justice.

WP 3 - Creating an integrative platform for building scenarios

Stephan Pietsch, Aline Mosnier, Michael Obersteiner, Frédéric Mortier

The objective of the WP 3 was to incorporate biophysical, ecological and socio-economic drivers and processes to predict land allocation at both local and national scales.

For this purpose, we have further developed the GLOBIOM model for the Congo Basin region to project future deforestation and other land use changes for each decade, from 2010 to 2030 (Fig. 1). GLOBIOM is an economic model which includes the sectors that are drivers of change, i.e. agriculture, forestry and bioenergy. It has a global coverage where countries qre aggregated into 29 regions. The model defines 18 crops but for the Congo Basin, we restricted that to cassava, maize, and groundnuts, the most widespread. The productivity of each crop varies across the territory with climate, topography and soil type.

For oil palm, we have created a new suitability map for both smallholders and industrial plantations to better take into account future opportunities and constraints for expansion. The production is determined for each grid cell level by the area allocated to a crop (in hectares) times the productivity of the land in this cell (in tons per hectare). This production is consumed in the same cell, in another region of the country (e.g. big cities) or exported to other countries. This means that future landuse change in the Congo Basin can also be driven by what happens in the other regions through imports and exports.

Input from WP2 has been used to better understand underlying mechanisms of deforestation and more particularly to improve the representation of shifting agriculture, still the dominant production system. We have added an additional land class agricultural fallow, which is not used for production but where vegetation grows after abandonment. The total land demand for agriculture is thus significantly increased in the model compared to previous setting since typically the cultivation of a parcel does not exceed three years while fallow can last more than 10 years. The length of the fallow is a dynamic process: in the Congo Basin a reduction of fallow length in observed in many areas. In the model, we assume that this is related to increase in population density. Observations from WP2 tend to support this assumption. We also assume that a reduction in fallow length will reduce crop yields if no fertilizers are used. Alternative production systems – with fallow lower than 2 years and fertilizers use- are also observed in some parts of the region and possible alternative for intensification in the model but they are costlier. The population is expected to strongly increase in the region, with population density increasing especially in the Western and Central parts of Cameroon, around the capitals, and in most of DRC. In all these areas the length of fallow is expected to reduce. The length of the fallow time will also affect the carbon stock on the fallow.

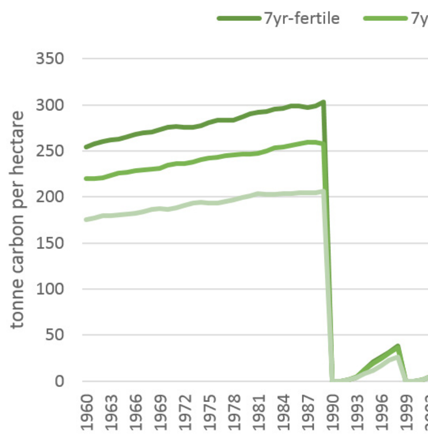


Fig. 2: Aboveground and belowgr ing cultivation (7-yr fallow 3 differ

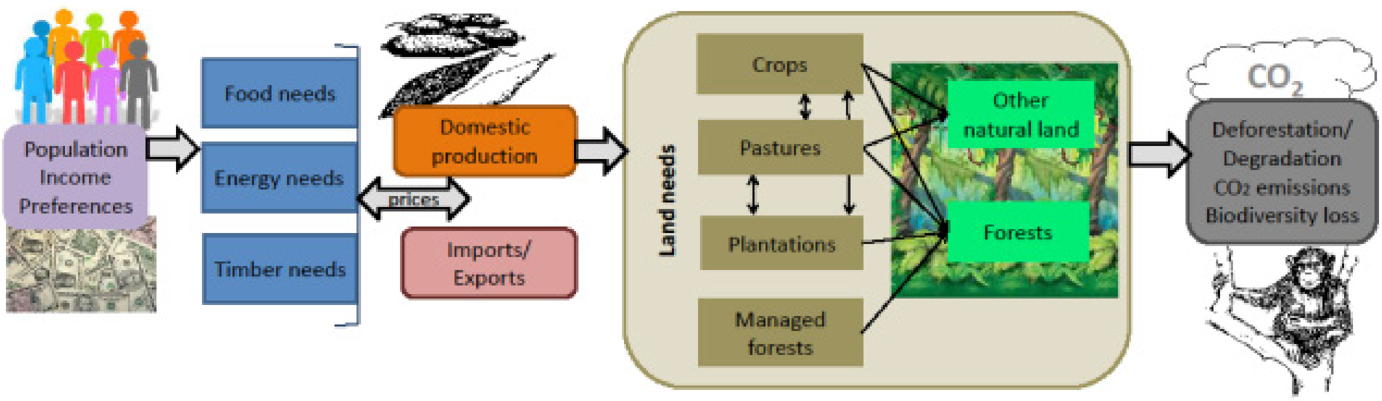
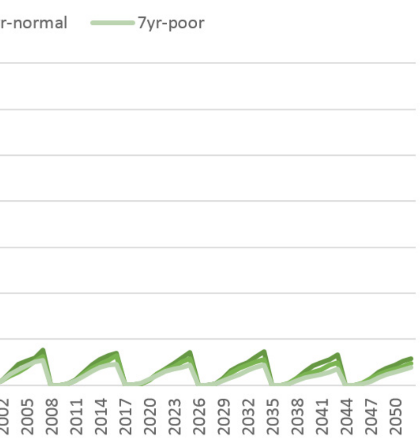


Fig 1: Overview of the GLOBIOM model



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The BioGeoChemistry Management (BGCMAN) model is used to simulate the dynamics of carbon on fallows depending on the length of fallow (4, 7 or 10 years) and the soil type (fertile, normal or poor). In BGC, daily weather data and site information are needed to calculate the cycles of carbon, nitrogen, water and energy within a given ecosystem. The estimates are done over the period 1960-2050 by assuming that humid dense forest is cleared from 1990 for shifting agriculture. The results are then used to estimate carbon sequestration on fallow land. Until now, emissions from deforestation were computed assuming zero carbon stock on cropland. According to the estimates of the BGC-MAN model (Fig. 2), carbon sequestration on fallow over 30 years would be between 50 tC and 127 tC per hectare of land under shifting cultivation in the Congo Basin which represents approximately between 25% and almost 50% of the initial carbon stock of the forest. The average carbon sequestration rate reduces over the number of cultivation cycles. A reduction of the fallow from 10 years to 7 years reduce the average carbon sequestration between 13 and 21% and from 7 years to 4 years between 23 and 29%. From our results, cassava, groundnuts and maize are the main crops responsible for cropland expansion and oil palm area also doubles between 2010 and 2030.

Coastal Forests and Center parts of Cameroon and in the Bandundu and Eastern regions of DRC are projected to be under especially high pressure in the next decades (Fig 9, left). The estimated total deforestation varies between 28 and 43 million hectares over 2011-2030 in the Congo Basin (Fig. 9, right). This corresponds to at least a 55% and at most 140% increase of average annual deforestation compared to historical period 2001-2010 (Hansen et al., 2013). The factors which reduce the most the future deforested area are the increase in yield productivity per hectare (RDMT+) and a slowing down of population and economic growth (MACRO-, GDP- and POP-). Expansion of protected areas and the deterioration of transportation infrastructures could also lower future deforestation. The factors that will increase the risk of deforestation in the region are a strong population and economic growth (MACRO+, POP+, GDP+) and ambitious targets of oil palm development combined with retrocession of forest concessions or non-enforcement of protected areas (PALM+_FC_NON, PALM+_AP_NON). In terms of emissions, this represents between 66 and 105 Gt CO2 emitted over 2010-2030. The fact, however, that carbon sequestration on fallow land is not taking into account in many models leads to significant error in emissions for the Congo Basin. It also tends to overestimate the negative environmental impacts of shifting agriculture, especially when fallow is long.

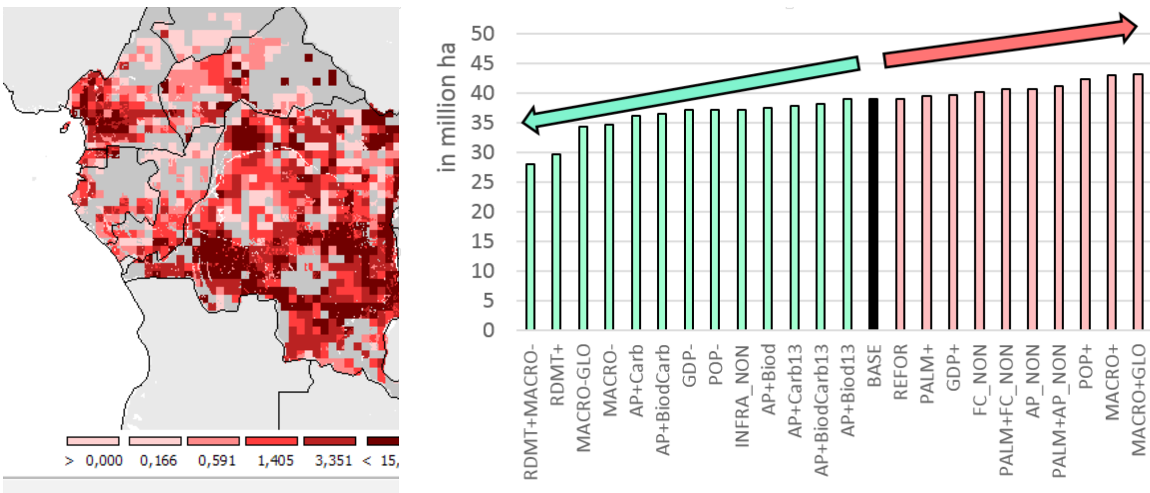


Fig. 3: Projected deforestation over 2011-2030 in the Congo Basin with the GLOBIOM model in the base scenario. Values in 1000 ha (left) and for each scenario in million ha (right).

WP 4 - Participatory design and analysis of scenarios

Claude Garcia, Eglantine Fauvelle, Jean-Pierre Müller, Juliette Chamagne

In this WP, we (1) constructed a land use model at the village scale; (2) outlined scenarios of biodiversity and governance and (3) explored these scenarios with the skateholders at the local level.

The first task was to downscale the models outlined by WP3. We integrated the ecological processes identified in WP1, data on the agricultural practices, social composition and livelihood strategies at the village level coming from WP2 and using the Companion Modeling (www.commod.org) approach, developed AgriForEst. AgriForest is a role-playing game describing the patterns of land use and land cover change at the village level in the forested landscape of Eastern Cameroun. Players engaged in this game act as households needing to manage natural resources (land, wildlife and non-timber forest products) and their human (workforce) and social capital (the interactions with the other players) to derive their livelihood, and invest in several dimensions of Quality of Life (QoL) locally relevant: Food; Housing; Petrol; Soap; School; Rest; Safety deposit.

The scenario we outlined associated several drivers of change into one single storyline. We confronted players to the arrival of a logging company that had secured the rights to the adjacent forest concession.

Fig. 2: AgriForEst in action: the villagers have transformed the gamescape replacing forest with their fields, and negotiated access to forest, land, bush meat and non-timber forest products to invest in different dimensions of the wellbeing of the household they control.

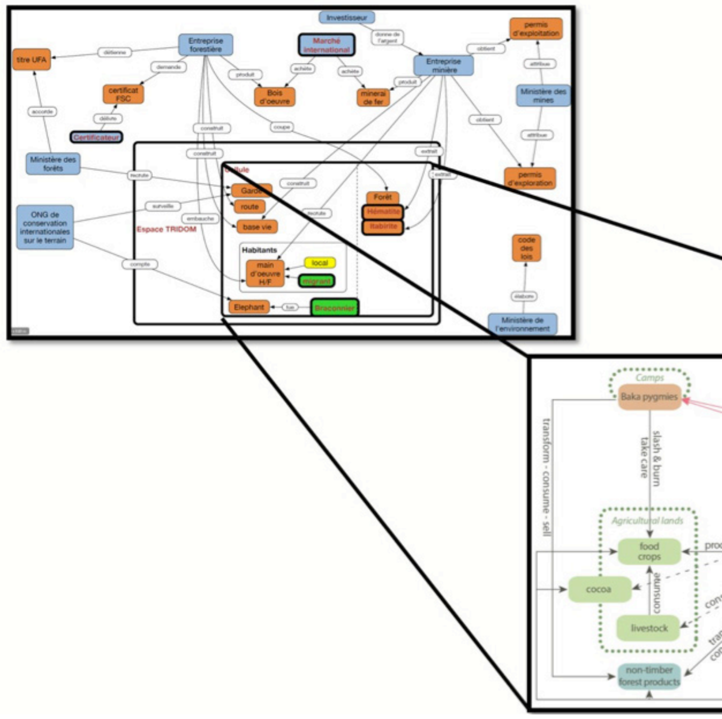
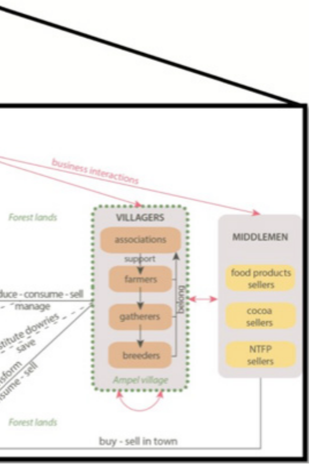


Fig. 1: Overview of the nest conceptual models of Agrifores Set (CoForSet).

The company brings with it staff and their families, effectively doubling the population of the village. These newcomers have access to cash through salary paid by the company, but need to negotiate access to the resources with the locals. Finally, the company develops the road infrastructure, creating a dramatic change in the access to market and therefore opening the way for villagers to diversify their livelihoods. This scenario is based on the most likely development pathway for the region – and one that had already been witnessed in Mindourou, the study area located on the downward slope of the forest transition curve (see fig. 3b page 3).

The model and the scenarios were tested and validated with the partners from the various WP in two workshops organized in 2015 (Montpellier and Vienna). They were taken to the field to explore the response of local communities to the scenario of infrastructure development outlined previously. In the Bokito study area, the scenario and model was adapted to explore the complementarity and competition between food and cash crops (cocoa) in the later phases of the forest transition. The game sessions raised issues of governance, market access, soil fertility maintenance and restoration, and power asymmetries between Bantu and Baka pygmies, between migrant and locals.



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AgriForEst sheds light on the underlying process that underpin collective action in a typical forest village of the Congo Basin where local communities progressively move from hunting/gathering and shifting cultivation to more market integrated livelihood strategies. While the forest dynamic, wildlife reproduction and agronomic sub-components are based on actual research results, none of the rules regarding governance, land tenure nor conflict resolution are defined in the model. This gives complete freedom to the players to either mimic existing arrangements and institutions or invent new ones. Developed jointly with stakeholders, decision makers and academics across disciplines, the models serve as boundary objects, highlighting the forces driving change and the pitfalls and bottlenecks that must be overcome to avoid negative impacts of external interventions. The work in its different stages of development has been presented at the GtoE 2015, ICCB 2015 and ScenNet 2016 Conferences [1, 2], and detailed in the reports of the students involved in the development [3-6].

To counterbalance the high costs of running participatory workshop, we transformed AgriForest into CoForSim, a fully autonomous multi-agent model. CoforSim has the same entities than AgriForest, spatial units, households, and markets. Natural succession is identical in both models. Human decision trees have been established using null hypothesis (uniform probabilities along the decision trees) and can be adapted later if better assessments emerge from the analysis of the game sessions. Here also we predefine scenarios, based on market capacity and price stability, the efficiency of enforcement, and demographic pressure. The model delivers outputs to monitor the evolution of land cover, wildlife population, household assets, and the extent of informal activities. This model is now functional and is linked to the regional forest model developed in the CoForSet projet.

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[2] Garcia C (2015) Scenarios, Biodiversity and Offsetting Mechanisms in the forests of central Africa. International Congress for Conservation Biology.

[3] Fauvelle E (2014) Analyse comparée des moteurs de changement et des enjeux d'adaptation d'un socio-écosystème de forêt tropicale. Systèmes agraires tropicaux et gestion du développement (Institut des Régions Chaudes de Montpellier SupAgro Montpellier).

[4] Gaingne Kamto M (2015) Dynamique d'évolution du socio-écosystème forestier de l'arrondissement du Dja à l'Est Cameroun : acteurs, interactions et perspectives d'évolution. (Université de Dschang, Cameroon).

[5] Rouxel C (2014) Territoires villageois de projets, Interface agriculture-forêts et Problème épineux des éléphants dans la localité de Makokou (Gabon). (Université de Rennes).

[6] Somwag G (2014) Modélisation participative de la paysannerie agricole sur le territoire de Guéfigué et Guéboba. (Université de Paul Sabatier de Toulouse).

Fig. 3: Villagers from Ampel (Mindourou, Cameroun) after the first game session of AgriForest. The smiles of the participants are a testimony of their engagement through the workshop.

The products of the CoForTips project

To this day:

13 publications in peer-reveiewed journals, including publications in:

Nature, Journal of Ecology, Remote Sensing and Environment, Global Ecology and Biogeography

7 publications in proceedings

17 reports: masters qnd PhD thesese, expertise reports etc

13 communications in conferences:

9 talks in 6 conferences

4 posters in 4 conferences

6 newsletters

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