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Article

Logging or Conservation Concession: Exploring Conservation and Development Outcomes in Dzanga-Sangha, Central African Republic

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Abstract

The Dzanga-Sangha landscape consists of a national park surrounded by production forest. It is subject to an integrated conservation and development project (ICDP). In collaboration with the ICDP personnel, a participatory model was constructed to explore wildlife conservation and industrial logging scenarios for the landscape. Three management options for the landscape's production forest were modelled: (I) 'predatory logging', exploitation by a logging company characterised by a lack of long-term plans for staying in the landscape, (II) sustainable exploitation by a certified logging company, and (III) conservation concession with no commercial timber harvesting. The simulation outcomes indicate the extreme difficulties to achieve progress on either conservation or development scenarios. Both logging scenarios give best outcomes for development of the local population. However, the depletion of bushmeat under the predatory logging scenario negatively impacts the population, especially the BaAka pygmy minority who most strongly depend on hunting for their income. The model suggests that conservation and development outcomes are largely determined by the level of economic activity, both inside and outside the landscape. Large investments in the formal sector in the landscape without any measures for protecting wildlife (Scenario I) leads to some species going nearly extinct, while investments in the formal sector including conservation measures (Scenario II) gives best outcomes for maintaining wildlife populations. The conservation concession at simulated investment levels does not reduce poverty, defined here in terms of monetary income. Neither does it seem capable of maintaining wildlife populations since the landscape is already filled with settlers lacking economic opportunities as alternatives to poaching.

Keywords: Congo basin, integrated conservation and development project, participatory modelling, poaching, STELLA, Tri-National de la Sangha

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INTRODUCTION

The Congo basin forests constitute the second largest area of moist tropical forest in the world, after the Amazon, covering a total area of about two million sq. km (Congo Basin Forest Partnership 2006). About 12% of this area is under protection (Laporte *et al*. 2007) while 76% consists of production forest (Congo Basin Forest Partnership 2006). These production forests are often located in proximity to national parks, forming a buffer between the protected area and more intensively used agricultural areas. The Dzanga-Sangha landscape located in the south-western part of the Central African Republic (CAR) is typical of this situation. Clark *et al*. (2009) investigated the effect of logging on mammal populations in the proximity of this area and concluded that production forests, if managed appropriately, can extend the effective habitat of many of Central Africa's most threatened species.

Despite its high biological diversity, the Congo basin ranks economically amongst the poorest regions of the world (World Bank 2010). CAR has a gross national income of merely EUR 290 per capita and ranks amongst the lowest income countries (World Bank 2009). The forestry sector is of major importance to the CAR's economy; timber contributed 41% of the national export revenues in 2007, and the sector is, after the government, the most important provider of employment nationwide (de Wasseige *et al*. 2009). In remote rural areas, logging companies are by far the most important providers of salaried jobs (de Wasseige *et al*. 2009) and often take over the role of the state in providing services (e.g., electricity and hospitals) in the villages where they operate. For this reason, local people often see their arrival as an opportunity to advance local development. Logging concessions in the Congo basin thus have a dual function, buffering and extending protected areas while boosting the local economy. But the centres of development that are stimulated by forestry operations have also been linked to an upsurge in the use of wildlife for bushmeat (Bennett 2004). Not all of the vast production forest in the Congo basin is currently being logged; in 2007 only 36% was legally allocated as logging concessions. Africa's timber production is projected to increase substantially (FAO 2003); thus, an increase in the number of licenses and area exploited is expected. The arrival of logging companies in these remote forest areas will affect the local economy and wildlife populations.

Ever since the creation of the national park in 1990, an integrated conservation and development project (ICDP) has been operating in the Dzanga-Sangha landscape. Discussions on how to manage the production forest are on-going between the CAR government and proponents of the ICDP. The most likely scenario is that a license will be issued to a logging company for the extraction of timber under a rotation cycle. However, one conservation organisation leading the ICDP has advocated making the area a 'conservation concession'. The concept is defined as follows by Rice (2003: 1): "*Under a conservation concession agreement, national authorities or local resource users agree to protect natural ecosystems in exchange for a steady stream of structured compensation from conservationists or other investors*". With conservation and development experts from the ICDP, we constructed a systems dynamics model for the Dzanga-Sangha landscape to explore different management options for the production forest and their consequences for wildlife and the local economy.

METHODS

Conservation and development in the Dzanga-Sangha landscape

Situated in the extreme southwest of the CAR, the Dzanga-Sangha landscape covers a total area of 4,643 sq. km. Of this area, 27% is made up by the national park (Sangha and Ndoki sector), 4% is pre-park (a 2 km wide buffer zone around the parks), 55% is production forest (to be allocated to a logging concession), 13% is a communal hunting zone and 1% is reserved for agriculture (Figure 1). 70% of the production forest is also reserved for safari hunting, although no safari hunting companies currently operate in the area.

The forest of Dzanga-Sangha constitutes an integral part of the sites recognised as critical for the conservation of dense forests in the Afro-tropical region (de Monza 1996). It hosts approximately 105 terrestrial mammal species, out of which 16 are primates, 14 are ungulates and 14 are carnivores (Blom 2001). The region has a remarkably high density of forest elephants (*Loxodonta cyclotis*) with 0.2–0.3 individuals per sq. km and of western-lowland gorillas (*Gorilla gorilla gorilla*) with 1.05 individuals per sq. km (Blake 2005). The region is important for Bongo antelopes (*Tragelaphus euryceros*) with an estimated density of 0.3 individuals per sq. km (Klaus-Hügi 1998). Hunting pressure is high in the landscape resulting in rapidly declining populations of several wildlife species (Blake 2005). The worsening wildlife situation in Bayanga is illustrated by the withdrawal of the last active safari hunting company in 2007 (and it is unlikely that safari hunting will resume in the near future). The employment provided by the safari company at the time it was operational was rather limited (<10 permanent jobs) and safari tax revenues represented a tiny fraction of the forestry taxes (e.g., 0.25–1.5% of forestry taxes for the period 2000–2003). For this reason, safari hunting has not been included in the model.

In 2005, the Dzanga-Sangha landscape had a population of about 6,850 people (2 people/sq. km) living in 12 villages (Kamiss 2006; GTZ unpublished). Before the arrival of a logging company in 1972, Bayanga was a small fishing village (Kamiss 2006). The population at that time consisted of BaAka pygmies (mainly hunter-gatherers) and Sangha Sangha Bantu (mainly fishermen). These original people make up about one third of the present total population, the rest being Bantu migrants (Kamiss 2006). Principal income sources of the local population are agriculture, hunting, gathering and local sale of non-timber forest products (NTFPs) (like *Gnetum* spp.), fishing and employment in ecotourism and the ICDP project. Ecotourism is well developed in the landscape; tourists are offered various programmes (e.g., elephant spotting from the *mirador*, visit to a group of habituated gorillas and net-hunting with the BaAka), there is a relatively luxurious lodge, and there is an airstrip for small planes, attracting high-budget tourists. In 2007, about 580 well-spending tourists visited the area generating 72 million CFA francs (FCFA) (EUR 110,000) of local revenue. Of this, about 12% was directly captured by local people through salaries (Roth 2008 pers. comm.). Though this amount may seem substantial, the annual salary revenue generated by the logging company when it was operational was much higher at 270 million FCFA (EUR 411,600) (Czesnik 2007).

Bayanga—where the sawmill is located—is the largest village, home to 57% of the total population of the landscape. The sawmill was closed in 2004 and will resume operations only after a licence is auctioned to a new logging company. However, previous logging activities have attracted many migrants into the landscape comprising roughly two thirds of the current population (Kamiss 2006). Between 1972 and 2004, four different logging companies exploited the logging concession in the Dzanga-Sangha landscape. Most of the logging companies operated only for short periods, given that this is a remote area and the financial returns on logging are severely limited by the costs of extraction, transportation to ports and taxes. The departure of these logging companies was often abrupt, leaving its local employees unemployed with several months of unpaid salaries. The intervals during which the concession remained closed usually ranged between one and four years. The majority of the workforce remained in the village or in mining camps just north of the landscape, hoping to be paid for their past work and hoping to secure employment in a new logging company (Noss 1995). However, with each re-opening, only a fraction of the old workforce was usually re-employed and many new people arrived from outside the landscape (Kamiss 2007 pers. comm.). The 2004 sawmill closure resulted in an increase in households practicing agriculture from 39 to 76% (Kamiss 2006). Many laid-off employers turned to hunting (Doungoubé 1990). Logging by itself also augmented hunting pressure through increased access to markets and hunting by family members of sawmill employees (Bennett 2004). However, with its history of logging and the high number of migrants this attracted who settled in and around Bayanga, the hunting pressure is already high in absence of logging activities.

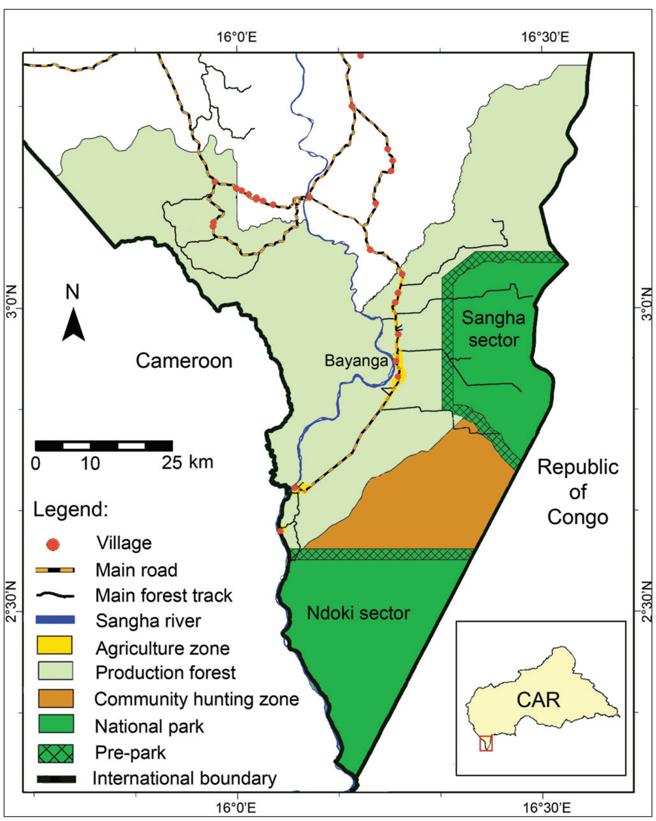

Figure 1
The Dzanga-Sangha landscape (modified from GTZ-GFA Unpublished)

Participatory modelling

Between 2004 and 2009, under the guidance of model experts, an exploratory landscape model was built by non-model expert conservation and development actors working in the Dzanga-Sangha landscape. The objectives of participatory modelling include stimulating the exchange of knowledge and visions between the actors, unravelling complex interactions, identifying drivers of change, understanding trade-offs between conservation and development outcomes, and exploring plausible future scenarios (Van den Belt 2004; Sandker *et al*. 2010). The model has been developed in the user-friendly modelling language STELLA 8.0 (High Performance Systems 1996). STELLA is a system dynamics modelling language whose basic components are *stocks* (such as forest area, elephant population and annual budgets), *flows* (e.g., change from forest to agriculture or birth and death of elephants) and *convertors* that moderate these flows (including laws, interventions and price variations). The scenarios to be simulated with the model were defined during workshops with conservation and development actors working in the Dzanga-Sangha landscape.

The model structure

The model reflects nature-society interactions. Model building was preceded by visioning exercises like historical trend analysis (Sayer *et al*. 2007) to identify trends of socio-economic and biological variables, as well as past responses to specific events. These exercises helped to select the main stocks and flows for the model. We did not attempt for the model to be all-inclusive, rather the stakeholders were urged to select only those variables and interactions they considered most important for the outcomes of concern to the ICDP. This resulted in a model existing consisting of 12 interconnected sectors (sub-models), containing a total of 260 variables. Figure 2 gives a schematic representation of some simplified relations between variables in the model determining per capita income. It demonstrates how many relations are ambiguous;

e.g., investment in logging provides an alternative to poaching through employment but at the same time attracts potential poachers through increased immigration. Many such relations are regulated through interventions either by the ICDP or by a certified logging company.

The model sectors with variables and their relations are given in Table 1, which also gives data sources. In the model, households get income from agriculture, fishing, hunting, NTFPs, employment and commerce. With the exception of NTFP and fishing, the income contributions per household are all dynamic. Households are simulated to turn to poaching and agriculture in the absence of formal employment (Figure 2). An increase in salaried jobs, on the other hand, results in agricultural products being sold at higher prices and commerce being stimulated. The model can be downloaded at: http://www.cifor.cgiar.org/conservation/_ref/research/research.2.5.htm.

The data entered in the model

Data from existing project monitoring, and extracted from scientific publications and ongoing studies underway in the reserve (e.g., recent data on duiker population), were used in the model (see Table 1). Additional information to fill some data gaps was gathered through 50 interviews held between April and June, 2006 with the head of household (*chef de ménage*); 20 interviews concern BaAka and 30 Bantu households. The interviewed households were randomly selected in three different villages (Bayanga, Bomandjokou and Mossapoula) characterised respectively as: a village with a sawmill (though closed at the time of the interview, but with a higher concentration of migrant households), a village with employment from ecotourism and a village without access to formal employment. The questions focused on income generating activities, and number and species of animals hunted. Income per activity was approximated from the respondent's estimate of the total production of the household, the share sold and the price per product. When respondents had difficulties using numbers in their replies, marbles were used to quantify importance of activities. Given the small sample size and the possible large error with estimated values, the interview results are of indicative value only and we deemed it necessary to discuss and validate the results with local experts (Table 1). Remaining data gaps were filled by informed estimates obtained through discussions with local experts working in the area. Thus, the simulation results of this study are based on the best available information to us. We recommend further profound and solid research to fill knowledge gaps.

Indicators of conservation and development outcomes in the landscape

The states of key attributes indicating the status of conservation and development in the landscape were selected and plotted on graphs to visualise the consequences of the different scenarios for conservation and development (simulation outcomes). Elephant and duiker populations were selected as proxies indicating the general state of conservation. Elephants have low reproduction rates and their hunting is prohibited; they are mainly poached with large calibre guns. Duikers have high reproduction rates and their hunting is legal under certain conditions; however, they are mainly captured with cable snares or hunted with small home-made guns, both of which are illegal. Duikers form the most important source of bushmeat; the 2006 household surveys revealed that of the small animals hunted, 9 out of 10 were duikers. Noss (1998) collected data on bushmeat hunting in Bayanga in 1994 and concluded at that time that hunting levels were likely to be unsustainable for duikers. When simulating the situation from 1994 to today, based on Noss's approximated hunting pressure for mid-range duiker densities and maximum reproduction rates, the results showed that there would be no duikers left outside the protected area. However, 16 years after Noss's study, bushmeat markets are still abundantly supplied with duikers, and the 2006–2008 mapping of hunting zones by the ICDP (Dzanga-Sangha Project unpublished) showed that hunting areas still exist in the proximity of the villages, providing little evidence of their depletion. Furthermore, the 2006 household questionnaires (Table 1) indicated that the number of duikers hunted per hunter is almost the same as the number found by Noss. This is why we have chosen rather high values for the possible range of duiker density and reproduction rate as given in Noss's study (Table 1).

Household cash income was used as a proxy indicating the state of local development. Though this only gives a rough approximation in a situation where subsistence income is of great importance, the actors building the model still thought this was the best indicator to approximate the development situation of local people. Since about half of the cash captured by BaAka comes from bushmeat (2006 household surveys, Table 1), monetary income does reflect their access to this important forest product.

The outcomes of the simulation often led to discussions among stakeholders and revisions of the model until consensus was reached on plausible future scenarios. Considering the process adopted for the elaboration and revision of the latter, the results presented in this article do not represent accurate predictions, but are indicative and should serve as a basis for reflection and discussion with regard to the future of the Dzanga-Sangha and similar landscapes.

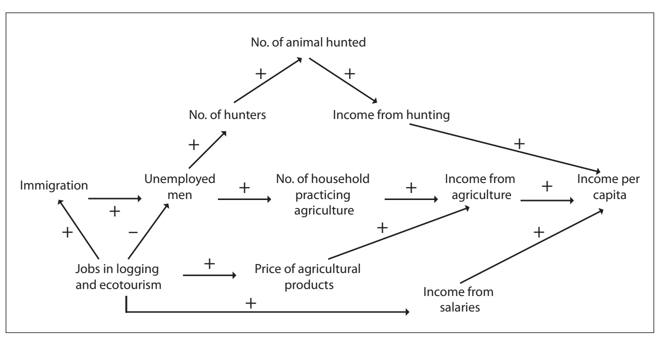

Figure 2
Schematic representation of relations between some variables in the model

Table 1

The model's assumptions and data inputs

Data	Source
Model sector: Human population	
Total population = 7,350 people in 2009 (2007 data projected to 2009 with an annual growth rate of 1.5%) of which 30% is BaAka, 70% is Bantu	GTZ unpublished
Natural growth rate = 1.5%	Mediated from United Nations (2009)
Immigration rate = 1–3%. We assume a 1% fixed immigration due to the bad socio-economic situation in CAR. An additional 0–2% immigration depends on total investments in salaried jobs, 0 being current investment, 2% being 5 times the current investment	Local expert approximation
One-off immigration due to opening logging concession = 2,000 Bantu. One-off outmigration due to closure logging concession (Scenario I only) = 500 Bantu	Local expert approximation based on historical trend; Kamiss 2007 pers. comm.
Model sector: Land-uses	
National park = 1,444 sq. km; Communal hunting zone = 587 sq. km; Logging concession = 2,571 sq. km; Agriculture zone = 40 sq. km (but agriculture is not modelled to be restricted to this zone)	2008 GIS measurements by Dzanga-Sangha project
Model sectors: BaAka and Bantu households	
Average BaAka household size = 6.8 Average annual BaAka household cash income = FCFA 300,000 (EUR 460) of which now 49% comes from hunting, 31% from NTFPs, 11% from fishing, 5% from agriculture and 4% from employment in ecotourism	Results from 20 BaAka household questionnaires from 2006
Average Bantu household size = 7.5 Average annual Bantu household income = FCFA 900,000 (EUR 1,370) of which now 46% comes from agriculture, 23% from employment by the ICDP project and ecotourism, 16% from fishing, 11% from hunting and 4% from commerce	Results from 30 Bantu household questionnaires from 2006
Cash per household from NTFPs and fishing remains constant	Local expert approximation
The price of agricultural products (and thus income from agriculture) increases with the employment rate (maximum increase 50%)	
Households practicing agriculture is positively related to the number of unemployed men	Kamiss 2006
Income hunting BaAka = duiker income * (100/Percentage duikers total bushmeat income BaAka) Income hunting Bantu = duiker income * (100/Percentage duikers total small bushmeat income Bantu) + elephant income Duiker income = (duikers hunted – wastage – auto-consumption) * average duiker price. For duikers hunted see hunting sector Elephant income = elephants hunted * price elephant (= FCFA 390,000). For elephants hunted see hunting sector	Local expert approximation
Wastage = 10% [wastage snare hunting = 27% (Noss 1998) but now more home-made gun hunting]	
Percentage duikers total bushmeat income BaAka = 80–85% Percentage duikers total small bushmeat income Bantu = 90%	
Average price duiker = FCFA 2,600 (weighted average of prices three duiker species; *C. monticola* = FCFA 1,300, *C. callipygus* = FCFA 4,400, *C. dorsalis* = FCFA 5,300)	2006 household questionnaires
Income from commerce = Percentage of total investment in salaries (now 60% of total commerce) + other cash to commerce (constant)	2006 questionnaire results mediated with expert approximation
Other cash to commerce = FCFA 14,600/household	
10% of the investment in salaries goes directly to commerce	Garreau 1994
Model sector: Logging concession	
Average annual log production rate = 0.11 cu. m/ha	Czesnik 2007
Number of logging concession employers = 430 at opening concession Average annual salary logging company without certification = FCFA 614,000 (EUR 936)	Pago 2007 pers. comm. (the ex-director of personal last active logging company)
Average salary certified logging company = FCFA 1,085,000 (EUR 1,654) 40% increase in production prospected in next 20 years for both certified and non-certified logging companies	Congolaise Industrielle des Bois (2006) management plan
Future projection of number of employers and taxes to be paid increases with log production	Local expert approximation
Total forestry taxes exist of logging tax (*taxe d'abattage*) which is 7% of the logged value and a reforestation tax (*taxe de reboisement*) which is 11% of the exported log value (article 36, finance law 2001). Logging tax = FCFA 137 million, Reforestation tax = FCFA 70 million (Average for the period 2000–2003)	Czesnik 2007
Model sector: Ecotourism	
At current ecotourism provides 13 fulltime jobs and some temporary activities (equivalent to another 2 fulltime jobs) Average annual ecotourism fulltime salary = FCFA 576,000 (EUR 878)	2008 Dzanga-Sangha project information
The number of ecotourists remains unchanged under Scenarios I and II and increases five times in the first 10 years of the simulation under Scenario III to remain fixed from year 10 to 20 Ecotourism starts to decrease when the number of elephants drops below 450 (45% of current elephant population)	Local expert approximation

Contd.....

Table 1
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Model sector: Employment	
Calculates the employment rate by dividing the number of formal jobs by the total labour force (number of unemployed adult men)	Calculated with model
Adult men = 12% of the total population	Noss 1998
Model sector: Local economy	
Sums up the total investment in the formal sector	Calculated with model
Model sector: Forest elephant populations	
Populations in and outside the park are simulated separately using a logistic equation, starting with 1,003 elephants (704 inside the park, 299 outside the park). Off-take by hunting is simulated in the 'hunting' sector	Blake (2005) densities, projected to 2009 by local expert approximation
Birth rate = 3%	Turkalo 2005
Natural death rate = 1% Carrying capacity (in and outside park) = 2.5 elephant/sq. km	Local expert approximation
Sustainable off-take rate = 0.0045 elephant/sq. km/year or 20 elephants for the entire area per year	Calculated with model
Model sector: Duiker populations	
Duiker refers to the species *Cephalophus monticola*, *C. callipygus* and *C. dorsalis*	
Populations in and outside the park are simulated separately using a logistic equation, starting with 196,420 duikers (86,050 inside the park, 110,370 outside the park). Off-take by hunting: 'hunting' sector Reproduction rate (birth rate – natural death rate) = 0.43% Carrying capacity = 110 duikers/sq. km [using maximum densities from Noss (1998) as reference point]	Data from Noss (1998) mediated with local expert judgement: mid-point data for Noss's density range is used, and maximum for Noss's reproduction rate
Sustainable off-take rate = 3.9 duikers/sq. km/year	Calculated with model
Model sector: Hunting	
Number of BaAka hunters = 97% of the adult male – adult males with a job	2006 household questionnaires
Number of Bantu hunters = 30% of the adult male unemployed population and 20% of the adult male population under Scenario II (hunting will be restricted under this scenario and is therefore expected to be a less attractive option)	Noss (1998) mediated with local expert judgement
Elephants hunted increases with number of immigrant hunters and number of large calibre guns and decreases with anti-poaching surveillances and when elephant density drops below 0.2/sq. km	Local expert approximation
Number of elephants hunted at the start of the simulation is 67/year	Estimation by Bokoto (2007 pers. comm.)
Duikers hunted increases with the number of hunters and decreases with snare removal and when the duiker density drops below 40/sq. km	Local expert approximation
Duiker hunting is calibrated with an approximate number of 115 duikers/hunter/year	Noss 1998
~67% of elephants hunted are captured inside the national park	Extrapolation of elephant poaching observations
~20% of duikers hunted are captured inside the national park	Local expert approximation
The number of large calibre guns increases with the increase of traffic, roads and salaries in the landscape and are controlled by the certified company (see interventions sector). At the start of the simulation there are 15 large calibre guns in the landscape.	Approximation by park director (*conservateur*) (2007 pers. comm.)
Model sector: Interventions	
Anti-poaching investment is FCFA 178/ha inside the park and FCFA 90/ha outside the park Currently 55 people are employed by the ICDP, projected to go up to 69, 71 and 84 in 20 years for Scenarios I, II and III respectively (ecoguard jobs increase with investment in ecotourism)	Local expert approximation
Anti-poaching surveillances and snare removal increase with ICDP budget (fixed in the simulation) plus the contribution of the certified logging company	Observation from neighbouring certified companies
The certified logging company controls the traffic of large calibre guns and bushmeat	

Scenario descriptions

Scenario I: 'Predatory logging' (Business as usual)

This scenario simulates logging companies characterised by a lack of long-term plans for staying in the landscape and minimal investments in local salaries, infrastructure and facilities. The continuous arrival and departure of logging companies simulate an extension of what the landscape has experienced since 1972. In our simulated model, the opening of the sawmill attracts many job seekers and their families (2,000 people), while the closure results in only some of them leaving (500 people). The simulation assumes opening of the sawmill in years 2 and 13, and closure in years 10 and 18.

Scenario II: Logging by certified company

This scenario simulates the re-opening of the sawmill by a company obtaining the Forest Stewardship Council (FSC) certification. We assume their sustainable exploitation practice to result in a long-term forestry enterprise, thus no closure is simulated. This feature was confirmed by Desmet (2009 pers. comm.) of the neighbouring logging company Congolaise Industrielle des Bois who claimed that without the FSC certificate the company would have most likely collapsed due to the financial crisis of 2008. The reason is that FSC certified products have a niche market which fluctuates less, and are sometimes subject to supply agreements, thus providing stable prices and a guaranteed timber off-take for the logging companies. Furthermore, the FSC certification requires the company to provide basic services in the villages located in the concession, pay higher salaries and invest resources in controlling poaching (Forest Stewardship Council 2007).

Scenario III: Conservation concession (No logging)

This scenario simulates the production forest in the Dzanga-Sangha landscape as a conservation concession. Following the earlier given definition of Rice (2003) of a conservation concession, we assume that the compensation the conservation investor pays to the state would be equivalent to the taxes and royalties paid by a traditional concessionaire, amounting on average to 207 million FCFA/year (EUR 316,000) for the period 2000–2003 (Czesnik 2007). We believe this would be the minimum investment of a conservation concession that would be approved by the government, since ideally a conservation concession should also compensate for the foregone salaries of logging company personnel. We assume ecotourism to develop under this scenario, with the number of eco-tourists increasing by five times the current number after 10 years.

RESULTS

Local economy and population dynamics

The cash investment in the formal sector is substantial under both logging scenarios (Figure 3). With each closure of the logging company under Scenario I (predatory logging), the investment drops below that of Scenario III (conservation concession); this difference is a result of the larger investment in ecotourism employment under Scenario III.

The human population increases substantially under all scenarios (Figure 4a). Due to the politically unstable and economically weak situation in the CAR, immigration into the landscape is expected to be high even in the absence of opportunities for paid labour. Under the conservation concession scenario, the annual population growth rate is 2.5%. Scenario II has the highest population growth attracted by the large cash investment in the formal sector (Figure 3). Though the cash investment under Scenario I is much lower than under Scenario II, population size is comparable due to the recurring cycle of opening and closing of the sawmill; with each opening (years 2 and 13) attracting more people than those leaving after each closure (years 10 and 18).

The number of hunters (Figure 4b) is calculated as a percentage of the unemployed male population in the landscape (Table 1). The number of hunters falls back when people are employed by the company after re-opening (years 2 and 13). However, the number of hunters increases substantially each time the predatory logging company shuts down (years 10 and 18) on account of laid-off workers turning to poaching.

The BaAka are poorer than the Bantu in monetary terms, capturing about one third of the cash the Bantu capture per capita (Table 1 and Figure 5). The BaAka cash income shows a downward trend that is mainly attributed to the declining duiker population. Their access to bushmeat diminishes, which currently contributes to 50% of their cash income (2006 household surveys; Table 1). Though the BaAka only capture 5–10% of the jobs in the logging concessions, their per capita cash income is quite dramatically affected since they are less in number and because their average per capita cash income is relatively low (Figure 5a). Since Figure 5a displays average values, it doesn't show the large income differentiation for BaAka under Scenario I with only some capturing the benefits (salaried jobs) but all suffering the costs (reduced access to bushmeat). The Bantu cash income also shows a downward trend; this is due to investments in the formal sector being divided over a larger number of people—since there is an increase in population, mainly due to immigration—thereby lowering the per capita cash capture (Figure 2). Even though the cash investment in the formal sector continuously increases under Scenario II (Figure 3), the migrant inflow exceeds the availability of new jobs at

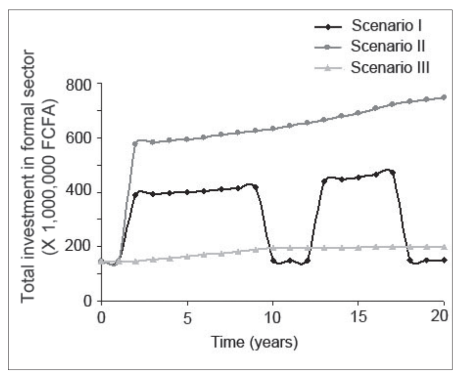

Figure 3
Investment in the formal sector (salaries from ecotourism, the ICDP and the logging concession) under the three scenarios explored (I: predatory logging, II: certified logging, III: conservation concession)

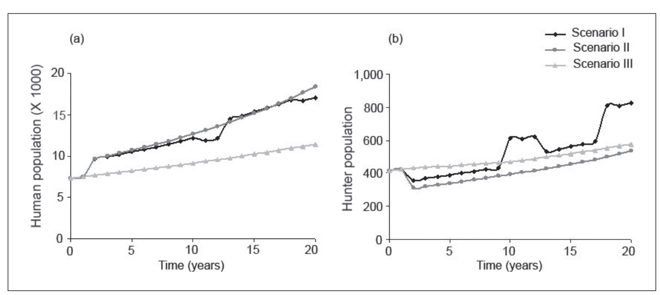

Figure 4
(a) Total human population and (b) number of hunters in the Dzanga-Sangha landscape under the three scenarios explored (I: predatory logging, II: certified logging, III: conservation concession)

the logging concession, resulting in the slight decrease in per capita cash income.

Wildlife populations

Under the predatory logging and conservation concession scenarios, the simulated elephant population declines by 85% and 50% respectively after 20 years (Figure 6a). Such dramatic losses have been seen in the past in the landscape when the elephant population decreased by 70% from 2,855 individuals in the 1980s (Carroll 1986) to 869 individuals in 2004 (Blake 2005). In year 7 of the simulation under Scenario I, and in year 8 under Scenario III, the elephant density inside the park drops below 0.2/sq. km, resulting in a decreasing hunting success from this moment onwards (Figure 6a). In year 10 under Scenario I, the elephant population declines faster due to the increase in poachers (Figure 4b) as a result of the closure of the logging company. The same feature is seen with the closure in year 18 under Scenario I, though the elephant population is already so weak that hunting elephants becomes quite difficult. Under Scenario III, the pressure on elephants increases steadily due to the increasing human population and the limited alternative income generating activities in the landscape. Although Scenario II provides the best option to conserve the elephant population, it still entails a 35% decline.

The duiker population (Figure 6b) is strongly related to the number of hunters (Figure 4b) under the three scenarios. For the first ten years of the simulation, the conservation concession gives the least favourable results for the duiker population because of the lack of alternative income generating activities for the local population, as a result of which a large share is dedicated to bushmeat hunting. The closure of the logging concession in years 10 and 18 (Scenario I) results in a sudden increase in duiker hunting and thus a sudden decrease in its population (Figure 6b) as people compensate forgone income from their lost jobs with bushmeat hunting. At the start of the simulation, the duiker population is already slightly below 40 animals/sq. km, so the hunting success diminishes linearly with the decrease in duiker density. Again, Scenario II provides the best outcomes for the duiker population, although duiker densities drop to less than half the current values.

The predatory logging scenario bares a more dramatic effect on elephants than duikers in comparison to the other scenarios. This scenario was modelled with an accompanying increase in import of large calibre guns used for elephant poaching through the opening of roads and increased traffic, and because the employers will have more money to purchase guns [in line with findings of Bennett (2004)]. With a certified logging company however, we expect the company to establish control points on the roads, limiting the transport of guns and bushmeat, and close logging roads that are no longer used. This is being done by neighbouring certified companies in Cameroon and Congo.

Sensitivity analyses

A sensitivity analysis showed that wildlife population outcomes are sensitive to levels of human migration, and duiker population outcomes are also sensitive to duiker density and reproduction rate. If, instead of the assumed 1–3% immigration rate, we assume an out-migration rate of 2%, e.g., as a result of economic opportunities in the town of Berberati or Bangui, the elephant population is 12–70% higher at the end of the simulation. Assuming this out-migration occurs under the scenario of a certified logging company, the elephant population becomes comparable to the current population size after 20 years. Using minimal duiker densities with maximum reproduction rates [as given by Noss (1998)] results in similar downward population trends when comparing the three scenarios; only they would go extinct under Scenarios I and III after 19 and 20 years respectively, while under Scenario II a small population of around 10,000 duikers would remain after 20 years. Assuming minimum densities and reproduction rates [as given by Noss (1998)] results in minimal differences between the scenarios, with duikers going extinct under all scenarios.

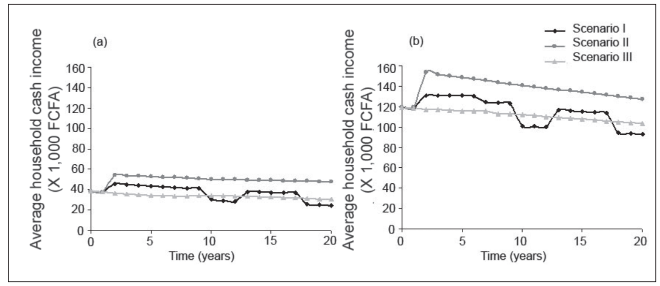

Figure 5
Average annual per capita cash income for (a) BaAka pygmies and (b) Bantu under the three scenarios explored (I: predatory logging, II: certified logging, III: conservation concession)

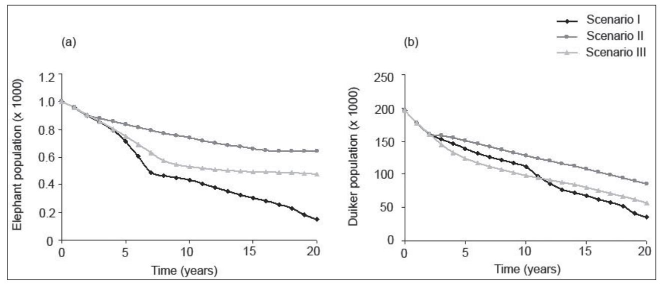

Figure 6
Total number of (a) forest elephants and (b) duikers in the Dzangha-Sangha reserve under the three scenarios explored (I: predatory logging, II: certified logging, III: conservation concession)

DISCUSSION

Local and national economy

Overall, peoples' incomes decline in the absence of a major entrepreneur/employer like a logging company, mainly because the landscape lacks the economic activities needed to support the increasing human population. Bushmeat hunting is unlikely to provide a sustainable cash flow for an increasing local population. Current modelled hunting levels are unsustainable (Figure 5b) and hunting pressure from outside the area might increase in the future as improved roads provide better access to the landscape. For a large proportion of the population, agricultural production is not likely to provide a feasible income alternative either. The Dzanga-Sangha landscape has mainly ferralitic soils which are rapidly impoverished by slash-and-burn when not altering cycles of cassava cultivation with other crops (Kokamy-Yambere *et al*. 2007) as is the current practice. This, together with the administrative restrictions placed on agricultural expansion, limits the potential of agriculture to become a major income source. We did not model soil fertility declines nor restrict agricultural expansion to remain within the small administrative agriculture zone. A separate modelling exercise showed that applying an agricultural rotation or agricultural expansion—as needed to keep agricultural production at current levels—will already be restricted by the limits of the agriculture zone within the next five years. If the boundaries of the agriculture zone are not revised and the current practice of continued mono-cropping continues, household incomes might decline more dramatically than suggested by the simulation results.

Investments in the area are not obvious. As the history of the Dzanga-Sangha landscape illustrates, with the repeated closure of the sawmill, logging companies are faced with the difficulty of having to bear high transportation costs, given the long distances to ports and generally worsening quality of the inland roads. In remote locations like those of Dzanga-Sangha, logging companies tend to export higher value timber in order to reduce the relative share of transportation costs (Ezzine-de Blas 2007). It is therefore in these locations especially that FSC certification increases the robustness of logging companies to withstand world market fluctuations, guaranteeing the feasibility of their continuance in the locality.

The sensitivity of the data to human migration levels in and out of the landscape illustrates the importance for rural areas of growth in the national economy (Frost *et al*. 2007), as this reduces pressure on natural resources. At the same time, national development also brings new conservation challenges for rural areas because of increased access through infrastructure development (Laurance *et al*. 2006).

If the socio-political turmoil in the country continues, without a significant surge in economic opportunities, the Dzanga-Sangha landscape will become a likely refuge for people who will make a living from some bushmeat hunting, agriculture and other activities. If, in such a situation, the flow of people coming to Dzanga-Sangha is even larger than the modelled 1–3% rate of immigration, it would result in very pessimistic outcomes for the landscapes' wildlife populations and impoverish the human population further.

Conservation concession

The current conservation concession scenario assumes a compensation of forgone forestry taxes of EUR 316,000/year or EUR 1.23 per ha/year (Table 1). The Cameroonian government has been unable to find investors ever since 2001 who would be willing to pay EUR 1.4 per ha for 830,000 ha of almost entirely intact forest bordering a national park as a conservation concession (The Economist 2008; Sandker 2009 pers. obs.). Likewise, the Peruvian government tried to auction off 800,000 ha of forest as a conservation concession but could not find investors willing to pay between EUR 0.7–2.8 per ha (Hardner & Rice 2002). The Dzanga-Sangha concession concerns largely logged-over forest so it might be overly optimistic to assume that investors will be found for the simulated EUR 1.2 per ha/year.

According to Karsenty (2007), opportunity costs of forgone wages for the Cameroonian 830,000 ha would be as much as EUR 6.4 million per year (EUR 7.8 per ha) in addition to the taxes and royalties paid. Even if investors are willing to pay the EUR 316,000 in the CAR, given the current situation of bad governance, direct payments to the government will do little for the local population.

One could argue that ecotourism will provide economic opportunities to the local population (although ecotourism could probably be developed under the certified logging scenario as well). Under our most optimistic scenario (assuming a 400% increase in tourists), ecotourism will contribute EUR 55,850 to the local economy, whereas the logging concession contributes between EUR 364,100 and EUR 885,200. A willingness-to-pay study in the Dzanga-Sangha landscape (Tieguhong 2009) revealed that tourists are willing to spend about 1.8 times more than they currently do, but even by doubling the revenue from ecotourism, it will still contribute less to the local economy than logging would. Furthermore, a large share of the population living far from the project area may have no access to income from ecotourism. Often, income from ecotourism cannot compete with income from more destructive activities (Oates 1999). Perhaps carbon payments can increase the investment in forest conservation, though research by World Growth (2009) found that the value of carbon credits at best brings in only a quarter of what can be secured from more effective economic use of forest land by developing countries.

Hunting

Logging activities might lead to a larger increase in hunting pressure than predicted by our model because of intensified commercial hunting through increased traffic and cash income in the villages and an increase in bushmeat demand from concession workers. This is likely to alter the difference between Scenarios I and II, but we do not expect this to change the overall trends under the three scenarios. Also, the scenarios don't envisage large scale mining to develop in the landscape. Recently, mining concessions have been on the increase in neighbouring landscapes in Cameroon and Congo, similar to that of Dzanga-Sangha. If mining concessions are given out in Dzanga-Sangha, hunting pressure is likely to be much higher than simulated in the current scenarios.

Elephants

One ecologist working in the landscape believed that the decrease in elephant population could be even more dramatic than the simulation results suggest (Turkalo 2010 pers. comm.). We assumed that elephant hunting will become less successful once elephant density drops to below 0.2 elephants per sq. km, but since elephants concentrate on forest clearings (*salines*), hunting success might start decreasing at a lower elephant density. Furthermore, the number of elephants might decrease more drastically than simulated in the three scenarios if the elephants migrate to neighbouring Congo or Cameroon, as elephants have been known to move out of dangerous areas (Blake 2005).

Duikers

Van Vliet & Nasi (2008) report how different methods to approximate duiker densities result in highly variable results. Noss (1998) compared his own findings based on line transect surveys and net hunt encounters with those of other studies using different methods to approximate duiker densities (i.e., radio-telemetry, pellet and track counts). He indicates that densities of *C. monticola* could vary in a range of 11–79 animals per sq. km in the community hunting zone of the Dzanga-Sangha landscape according to different methods used to approximate duiker density. The density range he gives for *C. callipygus* and *C. dorsalis* shows an even larger variation, with highest approximated densities being 25 to 30 times the most conservative estimates. As explained under the method section, based on the hunting off-take rates in combination with duikers apparently still being abundant, we have used a high reproduction rate and relatively high densities for duikers in the model (Table 1). When interpreting the results, one should consider the significant uncertainty concerning duiker density. This study therefore seeks to assess a realistic trend in duiker population. For an accurate prediction of duiker densities, we would recommend a more in-depth study on the population.

Given the large variation in possible duiker densities, Noss (1998) was not certain about whether hunt off-takes in 1994 of *C. monticola* and *C. dorsalis* were unsustainable. He did find hunting of *C. callipygus* to be at unsustainable levels even after assuming the most optimistic density and reproduction figures. When comparing Noss's (1998) data on snare-captured duiker species gathered in 1994 with the most hunted species according to the 50 household interviews in 2006, we observe that the capture of *C. monticola* has doubled in proportion to that of *C. callipygus*. Furthermore, the share of *C. dorsalis* (constituting 10% in weight of the duikers captured in 1994) has gone down by almost three times (3.6% in weight of the total hunted in 2006). A study carried out by Van Vliet *et al*. (2007) comparing duiker inventories in Gabon in the 1980s and 2006 demonstrated that *C. dorsalis* has become locally extinct as a result of hunting pressure. Thus, the relative decrease of *C. dorsalis* compared to the other duiker species in 2006 might reflect local depletion of this species due to over-hunting. We hypothesise that as a result of the depletion of one species of duiker, other species of duiker (notably *C. monticola* with its high reproduction rate) might increase as they have a higher carrying capacity and are exposed to less inter-species competition. These are, however, speculative findings since the data of Noss (1998) and the 2006 survey data were assessed in different ways and the standard hunting method for small animals has altered between 1994 and 2006 with small home-made guns gaining popularity. Further, the household hunting estimates from the 2006 questionnaires are thought to be too rough to allow drawing any solid conclusions. We recommend further research to be done to test the hypothesis we pose. All the same, if a resilient animal like the duiker shows a dramatic decline, it is quite likely that other less resilient bushmeat animals will locally disappear with high hunting pressure.

CONCLUSION

The simulation results oblige one to temper expectations on best outcomes for wildlife conservation and local development in the Dzanga-Sangha landscape. Even the most optimistic conservation scenario suggests dramatic wildlife losses over the 20 years to come, while the income situation for local people only improves a little. On a positive note, there does appear to be room for synergies, with Scenario II giving the best, or least bad, outcomes for both conservation and development.

Contrary to the suggestion of Niesten & Rice (2004), the simulation results suggest that at current investment levels, conservation concessions do not have the potential to provide economic development. In the situation of the Dzanga-Sangha landscape as well, the conservation concession is not capable of maintaining wildlife populations, since a majority of the settlers in the landscape already lack alternative income generating activities. Economic development outside the landscape, and economic investments in the landscape (notably logging or mining), have major consequences for wildlife densities as they determine the extent of human migration in and out of the landscape and determine the economic alternatives for the people living in the landscape. External economic investments have a higher impact on the size of wildlife populations than current conservation interventions. A key criticism of past integrated conservation and development initiatives has been their failure to recognise the importance of external forces whose impact dwarfs that of the on-site interventions of conservation agencies (McShane & Wells 2004). In situations like the Dzanga-Sangha landscape, the ICDP plays an important role in negotiating with the government and possibly other actors on the choice of logging company that gets to exploit the concession. The ICDP should inform the government about the consequences of their choices for wildlife and the social-economic situation. This choice will be the main determinant of conservation and development outcomes for the landscape.

The results of this study suggest that rather than seeking to expand the protected area networks in the Congo basin, both wildlife conservation and local development outcomes are better served by an appropriate balance between sustainable use and protection of the forest. This study therefore illustrates the importance of initiatives like Forest Law Enforcement, Governance and Trade (FLEGT), promoting timber certification and the allocation of Reducing Emissions from Deforestation and forest Degradation (REDD) funding for sustainable management as well as protection.

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