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Interactive Simulations with a Stylized Scale Model to Codesign with Villagers an Agent-Based Model of Bushmeat Hunting in the Periphery of Korup National Park (Cameroon)

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Abstract

An agent-based model (ABM) representing snare trapping of blue duikers (*Cephalophus monticola*) was co-designed and used with local populations to raise their awareness about the sustainability of bushmeat hunting activities in the region of the Korup National Park (South-West Cameroon). Village meetings based on interactive simulations with a stylized scale model were structured in three successive steps. During the first step, an abstract representation of a village surrounded by a portion of forest was co-designed by directly manipulating the computer interface displaying a spatial grid. Then, knowledge about the live-cycle traits and the behavior of blue duikers was shared through the demonstration of the individual-based population dynamics module of the ABM. The objective of the second step, introducing the hunting module of the ABM, was to elicit snare trapping practices through interactive simulation and to calibrate the hunting module by setting a value for the probability of a blue duiker to be caught by a snare trap. In a third step, a more realistic version of the ABM was introduced. The seven villages included in the process were located in the GIS-based spatial representation, and the number of 'Hunter' agents for each village in the ABM was set according to the results of a survey. The demonstration of this realistic version triggered discussion about possible management scenarios, whose results obtained with the finalized version of the ABM will be discussed during next round of village meetings. We present the pros and cons of the method consisting in using at an early stage of the process interactive simulations with stylized scale models to specify empirically-based agent-based models.

Keywords:

Bushmeat Hunting, Participatory Simulation, Community-Based Wildlife Management, Companion Modelling, Qualitative Data



Introduction

- 1.1 Computational models of socio-ecosystems often use concepts that are unlikely to be meaningful to the local stakeholders whose behavior is being modeled. For command-and-control approaches based on predictive models meant to support decision makers to select the "best", "optimal" management option, this may not be an issue. Yet this conventional approach to natural resource management is increasingly challenged by environmental problems that are embedded in highly complex systems with profound uncertainties (Schlüter et al. 2012). In some situations, no amount of technical expertise is likely to solve such "wicked" problems that defy classification (Ludwig 2001). Each solution will entail costs and lead to unexpected consequences, and may even worsen the problem.
- 1.2 Simulation models are more and more used to raise the awareness of stakeholders about the true nature of the problem they face. Oriented toward social learning, these models do not pledge for prediction anymore, but rather aim at fostering critical thinking, sparking creativity, identifying and clarifying the impacts of potential solutions to a given problem (Brugnach 2010). From a methodological point of view, the involvement of stakeholders in the modeling process can take place at any stage from conceptual design; implementation; use; and simulation outcome analysis. Moreover, models commonly used to support participatory modeling processes are from various types (System Dynamics, Bayesian Networks, ABMs, etc.), leading to a diversity of approaches (Voinov & Bousquet 2010; Kelly et al. 2013).

- 1.3 One of these approaches, companion modeling, combines quantitative tools (empirically-based agent-based models) and qualitative research methods (role-playing games, surveys and interviews) to engage stakeholders in adaptive processes, with models evolving to address the questions and priorities that emerge from stakeholder engagement (Barreteau et al. 2003; Etienne 2011). The companion modeling approach aims at making a "matter of concern" emerge from a group of participants through the process of co-designing and using a model whose purpose is to support the multi-stakeholders platform.
- 1.4 An ongoing companion modeling process related to the sustainability of bushmeat hunting in the Southwest Province of Cameroon is presented in this paper. To integrate qualitative data into the ABM, we used in an interactive way a stylized scale model enabling to co-design the ABM with the villagers. First, the context of the case study is presented, and then the methodology used to conduct the participatory simulation workshops organized in three villages is detailed. These methodological aspects are put into perspective in a general discussion.



A companion modeling process on bushmeat hunting in the Southwest Province of Cameroon

- 2.1 Bushmeat hunting is an essential survival mean for rural populations living in Africa (Brashares et al. 2004). At the same time, bushmeat hunting impacts biodiversity directly by threatening the viability of all the wildlife species catchable by snares, the most common hunting technique that is quite unselective (Wilkie 1999). For many years, global population dynamics models have been used to determine sustainable hunting pressures. Yet with a same global level of hunting pressure, the system "hunter-animal-hunting territory" can be sustainable or not depending on the spatial and temporal distribution of hunting and of hunted individuals (Van Vliet & Nasi 2008). This evidence encourages adopting spatially-explicit individual-based models to investigate the sustainability of bushmeat hunting (for previous examples of such ABMs developed in Cameroon, see for instance Bousquet et al. 2001; Van Vliet et al. 2010).
- 2.2 Moreover, translating scientific recommendations into sound hunting practices well accepted by the local populations has repeatedly proved to be challenging. It is often difficult to establish the legitimacy of the institution in charge of defining, monitoring and enforcing the rules when this is putting in question traditional hunting practices. In Africa, this difficulty is exacerbated by the lack of sufficient means for the basic functionality of the institution, for being able to provide compensation for loss of earnings arising due to restriction or prohibition.
- 2.3 Put together, these methodological and institutional considerations have prompted the scientific team working for 10 years on wildlife in the periphery of Korup National Park (South West region of Cameroon, see Figure 1) to engage in a companion modeling process. The objective in designing and using an ABM with the local villagers was to turn the question of bushmeat hunting sustainability into a matter of common concern at a sub-regional scale (group of 7 villages), and to stimulate villagers to engage in community-based hunting management.

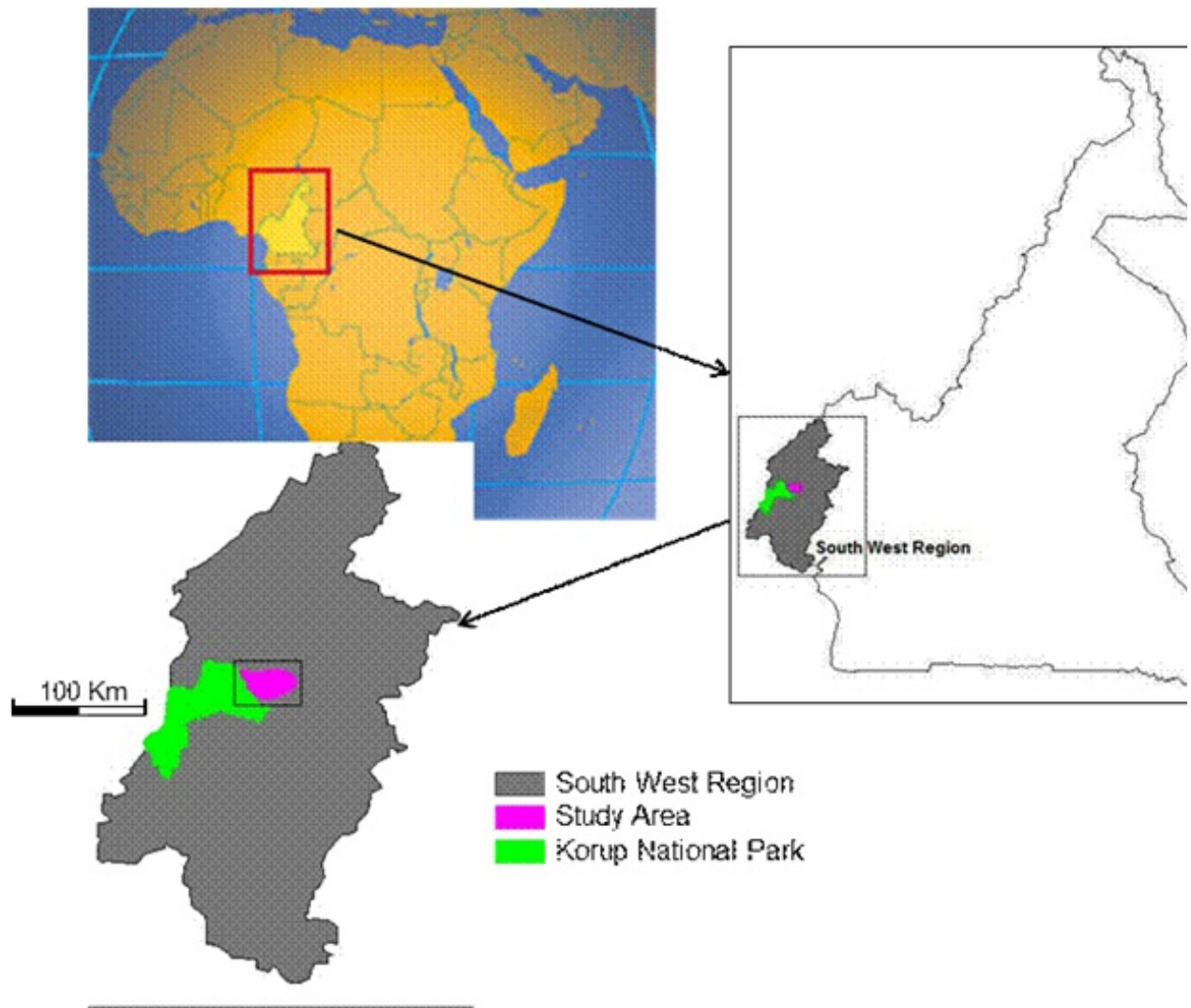


Figure 1. Study site location

- 2.4 The blue duiker (*Cephalophus monticola*), a very common game in African tropical forests, is considered as a good bioindicator species. Biological data on blue duikers and socio-economic data related to bushmeat hunting and to the contribution of bushmeat to household livelihood were collected in the study area from May to November 2009 and 2010, and from January to May 2011 (Bobo & Kamgaing 2011).
- 2.5 187 hunters were identified in the study area and 65 (35%) of them were monitored. While farming remains the main activity, hunting is performed by male villagers (from 15 to 60 years old) mainly during the wet season (mid-March to mid-November) through intensive snare trapping: in average, a trapper sets around 100 snares. The trapping productivity was about 0.66 kg of bushmeat/hunter/day. Around 60% of the harvested bushmeat was meant for sale, representing 12.6% of the average household revenue (Bobo & Kamgaing 2011).
- 2.6 An ABM was designed to assess the impact of this hunting activity on the population of blue duikers. The CORMAS platform (Bousquet et al. 1998; Le Page et al. 2012) was used to implement the model called "Frotembo" from the local name of the blue duiker. The computer code and the full documentation (including ODD) are available from the CoMSES Net Computational Model Library.
- 2.7 The modeling process started with a first version of the model being just a spatially-explicit individual-based population biology module based on the blue duiker lifehistory characteristics. Our idea was to showcase this first version to the villagers and to progressively engage them in the collaborative and interactive design of the hunting module. The specific objective of these participatory simulation workshops was to allow sharing of information on the following aspects:
- the biology and behavior of blue duikers in a non-hunted habitat;
 - the potential impact of snare trap hunting on the blue duiker population;
 - the elicitation and specification of hunting practices through collective discussions during the presentation of the computer simulation model;
 - the feasibility and potential impact of different hunting management rules in this context.
- 2.8 Three workshops were organized from the 29th through the 31st of July 2012 in three project villages: Abat, Mgbegati and Bakut.

Four other project villages were also involved: villagers from Bajoh and Bayib-ossing attended the first workshop in Abat; participants from Basu joined the second workshop organized in Mgbegati; people from Osselle came to Bakut for the last workshop. The three groups were made to minimize the travelling of participants while ensuring an effective participation of the population. As any villager interested in attending the workshop was welcome, the audiences were important (between 60 and 80 people) and heterogeneous (male hunters but also women, children and the elderly). The three workshops all started in early afternoon and lasted over three hours. Just before and just after the interactive demonstration of the ABM, a total of 42 participants (most of them belonging to the group of 65 hunters whose activity was previously monitored) were asked a short list of questions in order to assess the effects of attending the workshops (Ngahane 2013).



A step by step interactive design of the ABM

- 3.1 This section provides details about the 3-step process that was carried out in order to facilitate the comprehension of the computer model by the participants. The main characteristics of the 3 successive versions of the "Frotembo" ABM are given in Table 1.

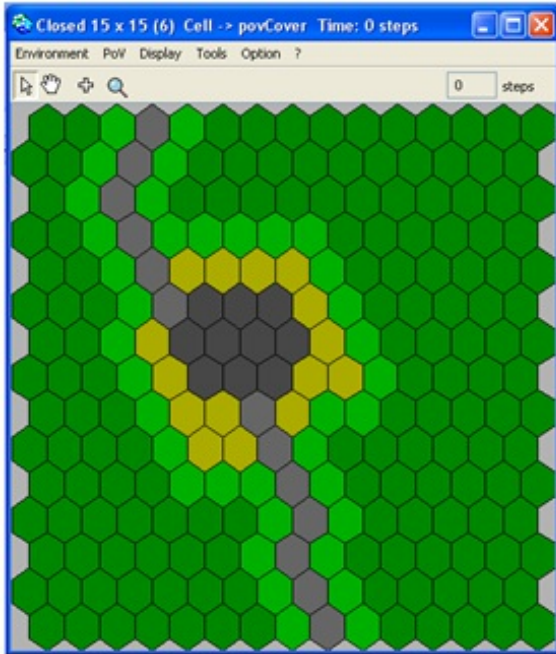
Table 1: Steps of the interactive design of the "Frotembo" ABM

	Spatial representation	Spatial extent	Hunting
Step 1	Abstract/Co-designed	1 village 2.25 km ² (15x15 cells)	None
Step 2	Abstract	2 villages 25 km ² (50x50 cells)	Interactive simulation, then 10 hunter agents
Step 3	Realistic/ GIS-based	7 villages 288 km ² (160x180 cells)	146 hunter agents

- 3.2 The first step was meant to introduce the abstract representation of a village in the forest and the blue duiker individual-based population module. The different types of land cover and the notion of cell as a 1-ha portion of space were presented, as well as the various stages of individual blue duikers. In a second step, hunting with snares was interactively introduced in a wider portion of forest (two villages linked by a road, a stylized map still without any realism). The last step was built on the elements previously introduced but was based on an explicit representation of the 7 villages and the Northern periphery of the Korup National Park. The spatial resolution of the model (the dimension of the smallest observable detail) was the same in the 3 steps: a cell always represents 1 ha. The whole portion of space represented in the model was gradually expanded: 1.5 km * 1.5 km in the first step; 5 km * 5 km in the second step; 16 km * 18 km in the last step (see Table 1). This process of zooming out allowed starting focusing on the biology and the behavior of the blue duiker. The objective was to communicate and to discuss the related parameters and the underlying assumptions for the participants to not consider the model as a black box and to become familiar with it. In the final step of the workshops, the more realistic representation of the region in the model allowed making the final discussions more concrete.
- 3.3 More details about each step are now provided.

First step: introducing an abstract representation of a village in the forest and the blue duiker individual-based population biology module

- 3.4 A piece of pristine forest was depicted as a regular grid made of 15*15 hexagonal cells, with a cell having a surface area of 1ha. The spatial extent of this small portion of forest was thus 1.5 km * 1.5 km. The primary forest land cover was represented by the dark green background color of the cells. To help them to understand the degree of simplification and stylization of the computer model, participants were requested to change this initial cover to indicate the presence of human beings. One participant was then called up to show where he/she thinks a village (dark grey background color, see Figure 2) could be established on this artificial landscape representing a virgin forest. Another participant was requested to locate the farmland (light brown background color), another one the roads (light grey background color), the secondary forest (light green background color) and the streams (blue background color). The results obtained in the three workshops are shown in Figure 2.



a. Abat



b. Mgbegati

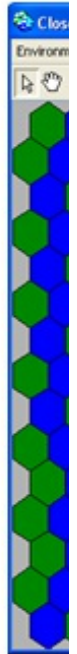


Figure 2. Spatial settings drawn by the participants

3.5 In the model, duikers grow, move, mate, reproduce, and die on a weekly time-step. Only the growth is similar for all duikers (they all get older by 1 week each time-step). The other functions depend on their age and sex. The details of each function are given in a description based on the ODD protocol, which is available from the openABM website. To communicate these details to the participants of the village workshops, we used the tools provided by the Cormas simulation platform to interactively create and manipulate blue duiker agents from the spatial grid (see Figure 3). An adult blue duiker was first introduced on the artificial landscape (in the forest) and figured as a colored diamond (blue for male, red for female). Its age was also indicated as a number of weeks.



a



b



d



e

Figure 3. a) a single 190-week old adult female; b) 4 adult females and 2 adult males; c) 5 weeks later, a 1st territory has been established; d) a newborn duiker appears; e) at t=177, the 7 different stages co-exist

- 3.6 After having shown that this lone adult duiker just moved and got older when time was running out (Figure 3a), 5 additional adult duikers were interactively introduced in the surrounding (Figure 3b). When a free adult male and a free adult female are able to detect each other and to find a suitable space (3 ha of unoccupied forest), they mate and establish a territory that they will occupy until the death of one of them. To highlight this concept, the corresponding aggregates of 3 cells were displayed in very light grey (see Figure 3c). After fecundation, the pregnancy of the female lasts for 30 weeks and then a newborn duiker (small white diamond in Figure 3d) is delivered. As the weeks go by (see Figure 3e), the baby duiker grows older and becomes a juvenile (represented in yellow) and later either a sub adult male (represented in light blue) or female (represented in orange).
- 3.7 We ran the simulation step by step, and each time something new happened on the screen, we took some time to build, from the reactions of the audience, a shared understanding of its meaning, and then to introduce and to discuss the corresponding lifehistory parameter. These feedbacks allowed checking the consistency of the scientific knowledge with the direct observations and/or beliefs of the participants. In other words, the values of the biological parameters, defined prior the workshops to calibrate the model, were acknowledged as realistic by the participants. The questionnaires used just before and just after the workshops enabled also us to identify some traits -like the longevity of the blue duikers- they knew little about, evidencing the effects of attending the workshops on individual learning (see next section).

Second step: interactive introduction of the hunting activity

- 3.8 In a second step, the representation of a bigger population of blue duikers in a wider portion of forest (5 km × 5 km) was introduced (see Figure 4).

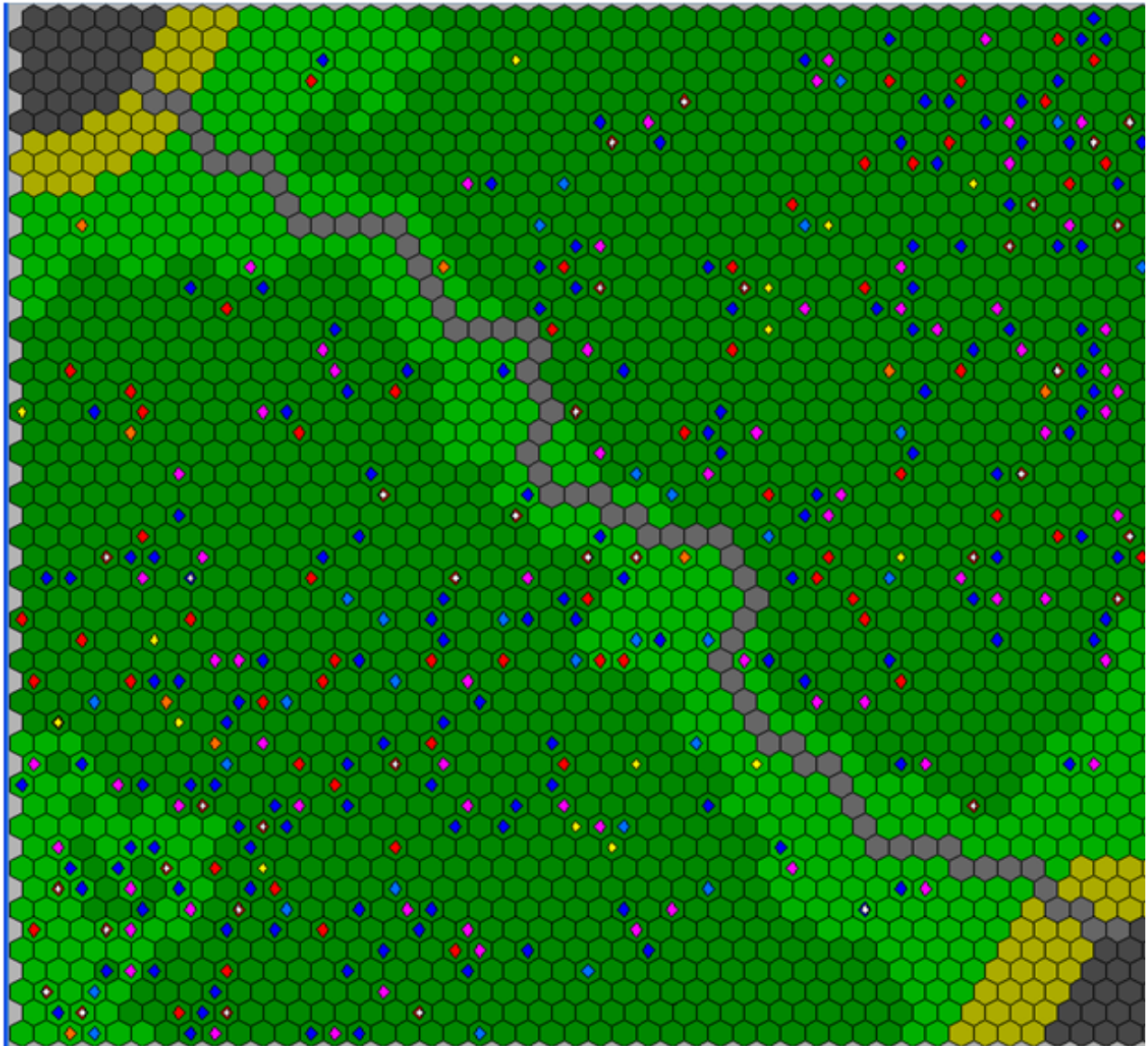


Figure 4. Stylized portion (5 km * 5 km) of forest with 2 villages in opposite corners connected by a road and a structured population of blue duikers

- 3.9 This second version of the model is still a stylized scale version of the "frotembo" ABM, but it represents a step further towards realism. First, the spatial resolution remains unchanged (1 cell = 1 ha), the distance between the two neighboring villages connected by a road is around 7 km, which is comparable to the actual distances observed in the study site. Because villagers are used to walk from one village to another, this relative distance helped them to get a better sense of the spatial extent of the model. Second, the initial population of blue duikers was set as an aged-structured population. When the model is run long enough, the saturation of space in terms of reproduction territories leads to a convergence of the population density toward an equilibrium. At equilibrium, the simulated population is structured due to the effect of the age-dependent natural mortality rates. 535 individual blue duikers were created as a sample of this structured population to realistically populate the artificial landscape shown in Figure 4. These individuals were randomly located over the spatial grid, with fewer animals located close to both villages. The corresponding average blue duiker population density (around 20 individuals per km²) is still a high estimate of actual densities for hunted blue duiker populations. Nevertheless, this value was selected as the initial situation in this second step because when running the simulation for 10 years (520 time-steps) without hunting, the population remains stable (see blue curve in Figure 5), which represents a convenient baseline scenario to be used as a reference when comparing with hunting scenarios.

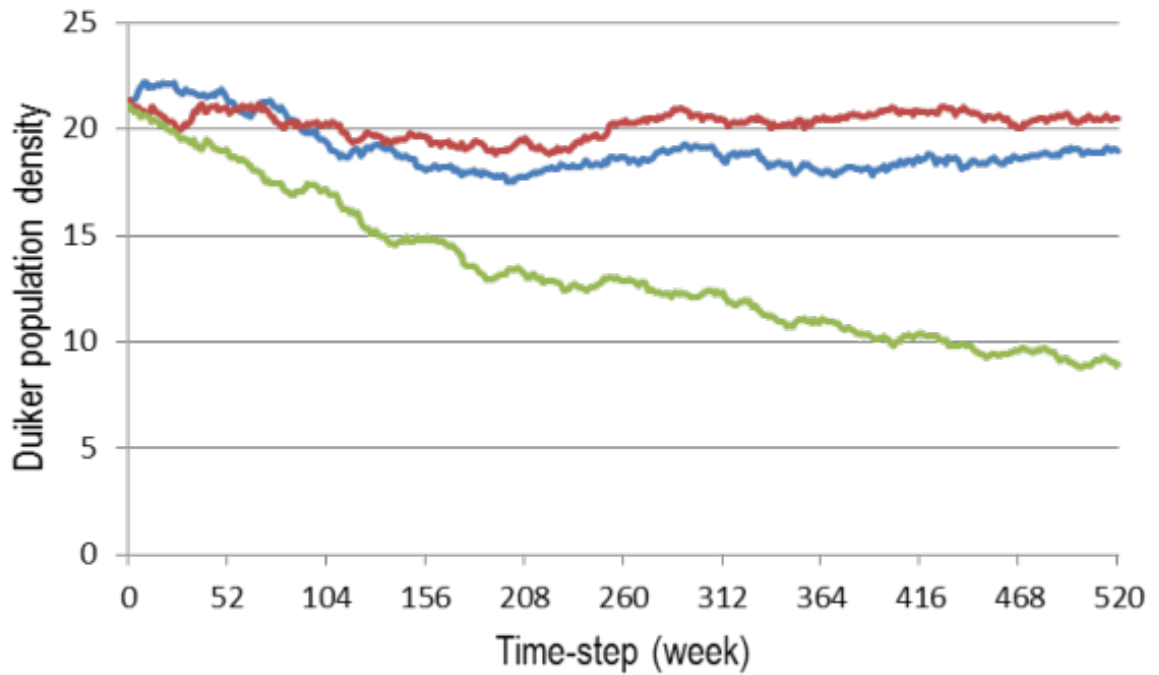


Figure 5. Evolution of the simulated duiker population density over 520 time-steps without hunting as in Figure 4 (in blue); with 1 trap line (50 traps) set as in figure 6b during the wet seasons (in red); with 10 trap lines (total of 475 traps) set as in Figure 7 during the wet seasons (in green); with 146 trap lines set along trails as in Figure 8 during the wet seasons (in orange)

3.10 To introduce the snare trap hunting module of the "Frotembo" ABM, a participant was called up to come and show directly on the projected map where he would locate his snares on the virtual landscape (see Figure 6a). His trap line was interactively displayed with black dots representing snare traps (see Figure 6b). The facilitator requested him to express the rationales directing his choices by explicating the decision-making criteria.



A

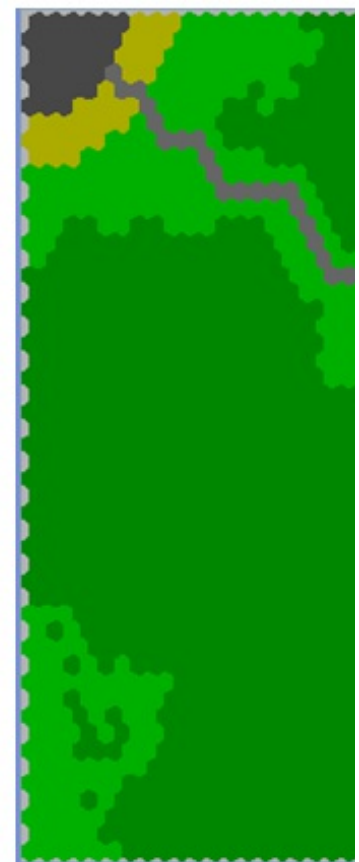


Figure 6. a) a participant indicating his traps setting on the virtual landscape; **b)** 50 black dots representing the snares

- 3.11 For instance, the participant shown in Figure 6a, who was asked to consider that his home was located in the bottom-right village, explained he would walk on the road for a while to go a bit far from the village before entering the forest and starting to set traps. He then mentioned he would set around 50 traps along a trail that would retrace his steps back to the road. Other participants discussed the realism of this practice, specifically regarding the total number of traps they found too small, which was consistent with the results obtained from the surveys (average number of snares per hunter was equal to 107).
- 3.12 After discussing the spatial aspects and the total number of snares, the discussion focused on the temporality of using the snares. It was agreed that the snares should be permanently set during the wet season from mid-March to mid-November. During that period, all the snares have to be checked every week to collect caught animals and to be reset (reactivate) the snares. The snares should then be removed during the dry season from mid-November to mid-March.
- 3.13 The catchability of the snares was then discussed by observing on the spatial interface the blue duikers passing by cells with snares and disappearing from time to time, according to a probability set to 0.01 for an active snare to catch an individual duiker located there for a period of one week. The participants mentioned that newborns were not concerned. They established a linkage between this parameter and the resulting bag size (defined as the total number of animals caught by a trap line in one wet season). For instance during the first workshop, after running the 35 time-steps corresponding to a first wet season, the trap line interactively set as shown in Figure 6b had caught a total of 9 blue duikers. This simulated value seemed reasonable to the participants.
- 3.14 To investigate the effects of hunting on the mid-term (10 years), it was decided to repeat 10 times the yearly scheme. We proposed to run the 10 years by relocating the 50 traps at the exact same locations that were interactively indicated for the first wet season. Whereas the participants acknowledged that the interactive mode would be too time-consuming and understood that this "trick" enabled us to speed-up the simulation, they clearly mentioned that this was unrealistic: from one year to another, hunting tracks are changed. For the research team, this meant that the formalization of an algorithm accounting for the locations of the snares lines would request additional work, but at least we collected useful elements to implement a first version of the hunting module to serve as a reference situation for hunting, and this also enabled us to make explicit all the underlying assumptions.
- 3.15 The results of the 10-year long simulation (red curve in Figure 5) show that the impact on the duiker population of such minimal hunting cannot be detected: it is very similar to the scenario without hunting (blue curve in Figure 5).
- 3.16 To represent a more intensive hunting pressure on the same virtual landscape, 10 predefined trap lines (5 from each village) were then presented. Each individual trap line was made of around 50 snares (see Figure 7).



Figure 7. 10 predefined trap lines made of a total of 475 snares (black dots)

- 3.17 The same periodical scheme was applied for 10 years: the 475 traps were repeatedly set exactly at the same location in the beginning of the 8-month long wet seasons and then these snares were all removed during the 4 months of the dry seasons. The green curve in Figure 5 clearly illustrates the impact of such a hunting pressure on the duiker population: after 10 years, the abundance was halved. This result triggered a discussion about the risk of extinction of the blue duiker population due to overhunting. The cumulated catches per year aggregated for the 10 hunters also reflected this impact by exhibiting a clear

decreasing trend (see Figure 8).

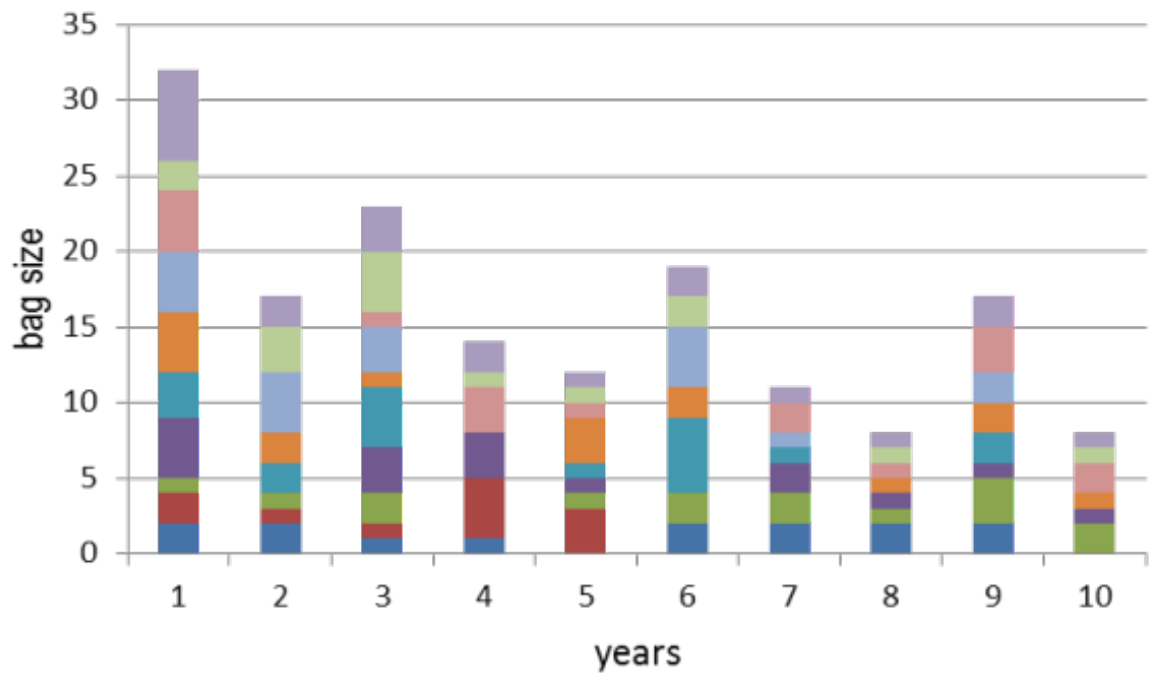


Figure 8. Cumulated catches per year by 10 trap lines permanently set during wet seasons (see figure 7)

Third step: introduction of the realistic version of the ABM

- 3.18 In a third step, we introduced the representation of space in the ABM based on the relative positioning of the 7 villages of the study site and also provided the delineation of the river marking the Eastern border of the Korup National Park (see Figure 9).

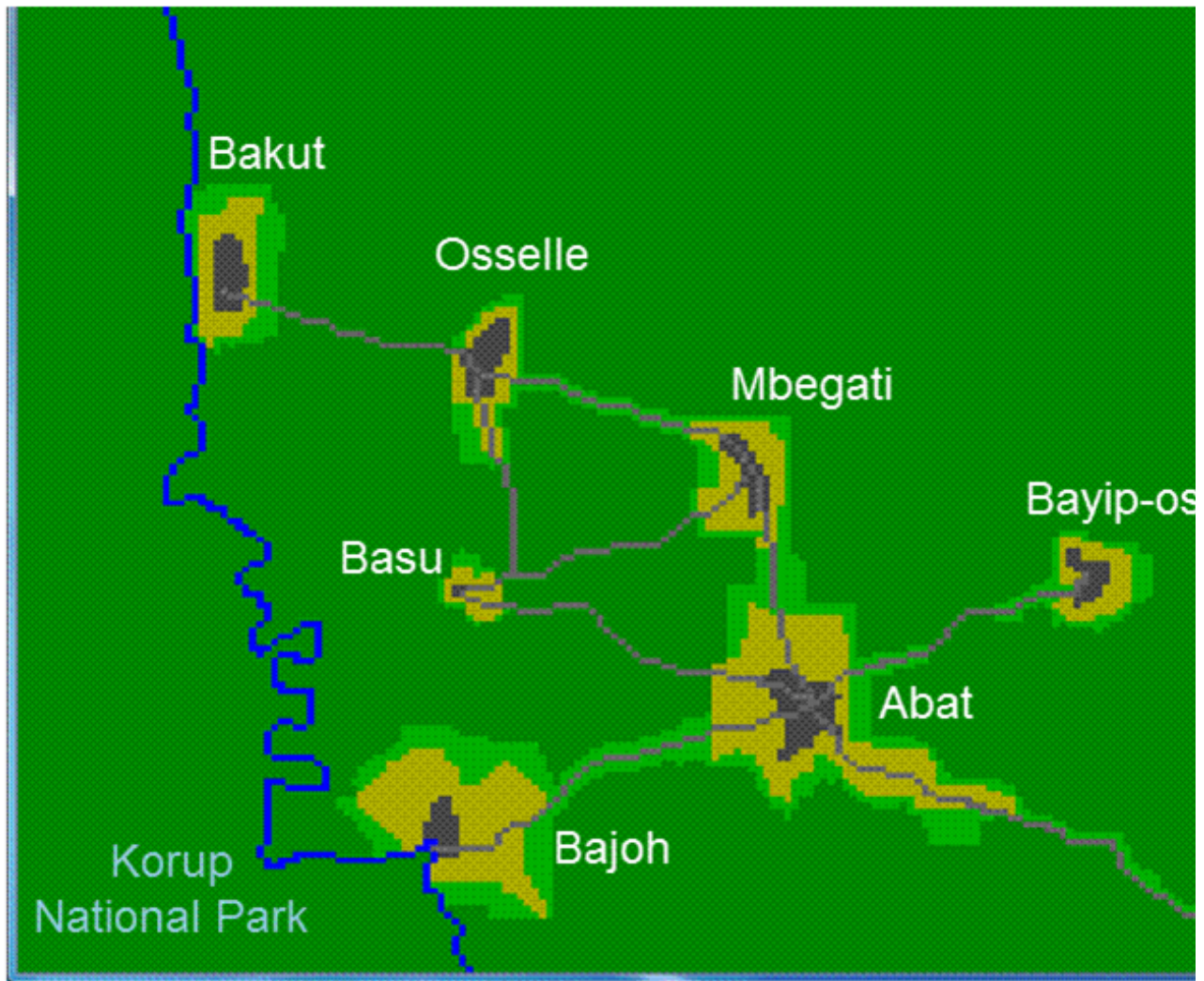


Figure 9. Study site area represented in the spatial grid (16 × 18 km) of the "Frotembo" ABM

- 3.19 The names of the 7 villages were not disclosed at first. We wanted to check if the participants would easily situate themselves in this virtual landscape. It was not straightforward and some of them got confused, but finally the right picture emerged from a collective and persuasive effort.
- 3.20 To conclude the workshops, we explained to the participants that the model could be run on this realistic configuration, by explicitly representing the 146 households from the 7 villages that were identified as practicing snares hunting during the past survey. The objective of this second phase would be to promote non-judgmental, non-directive public discussion and reflection and to collectively envision possible management options for the sustainability of blue duikers hunting.



Effects on the participants

- 4.1 In the three workshops, the participants reacted positively: 37 out of the 42 interviewed participants volunteered to be involved in the next stage of the process (Ngahane 2013). By the ends of the first workshops, the participants already started to discuss about the possible scenarios to be tested with the ABM. Three main management options were mentioned:
- foreign hunters should be totally restricted from going into the forest around the villages;
 - the number of snares per hunter should be reduced;
 - a reserve zone should be created in the forest.
- 4.2 The reality and the magnitude of the overhunting problem were acknowledged by a large majority of participants. Before the workshops, 20 out of the 42 interviewed participants expressed skepticism about the risk of extinction of the blue duiker population in the region. After the workshops, this number fell to 9 (Ngahane 2013). Education and raising awareness were stressed by some other participants as being crucial. They argued that the population should be sensitized on the long term dangers of overhunting and that the youths should better educated in agriculture, forest sciences and biodiversity conservation.
- 4.3 Learning about the biology and the ethology of the blue duiker also occurred during the workshops. The expressions of good understanding increased mainly for the longevity (1 before up to 16 after) and the territoriality (7 before up to 18 after) of the species (Ngahane 2013).

- 4.4 About the ABM itself, 37 out of the 42 interviewed participants declared to have enjoyed its demonstration, only 3 found it difficult to follow and understand, and 36 felt that it was a fair representation of the reality (Nghahane 2013).



Discussion

- 5.1 Agar (2005) opposes *emic* models that represent how stakeholders attached to a given socio-ecological system think things are, to *etic* models that are built on an outsider's view of the people and the world being modeled. There are two main approaches to develop emic models.
- 5.2 The mainstream one consists in using ethnographic data and to find ways to distill the essence of the insiders' perspective into the model (Yang & Gilbert 2008). The use of social surveys to empirically ground agent-based models is nowadays recognized as essential, but at the same time, the quest for generalization beyond case studies remains very challenging (Rounsevell et al. 2012).
- 5.3 To translate narratives into functions or algorithms required to implement an ABM, several techniques have been developed. For instance, Becu and his colleagues (2005) used knowledge engineering techniques to formalize -from the transcripts of individual representations acquired through ethnographic surveys- diagrams made of elements and relations. In a last step of the methodological sequence, the diagrams are validated by the stakeholders themselves through playable stories.
- 5.4 Another one relates strongly on the involvement of the local stakeholders into the process of designing the model (Voinov & Bousquet 2010). To involve local stakeholders in the co-design of ABMS, role-playing games, enabling to represent a context-specific situation in a particular community, are the basis of one recognized empirical approach in agent-based modeling (Janssen & Ostrom 2006). Usually, a participant to a gaming session plays the role corresponding to its main activity in real life. The information to be used to develop ABMs is derived from the gaming session (Bousquet et al. 2002; Barreteau 2003). In Kenya, Washington-Ottombre and her colleagues (2010) extracted narrative and spatially explicit drivers of land-use decisions from a role-playing game on land adjudication. In Northern Thailand, the behavioral rules related to land/water use and migration that were integrated in an ABM were designed with local farmers during several role-playing game sessions (Naivinit et al. 2010; Le Page et al. 2014).
- 5.5 The post-game debriefing of a role-playing game session is essential for co-learning to occur. On the one hand, the results are evaluated by the stakeholders -the players themselves-, who can debate how the game is different from reality. Taking into account requests to adjust the game represents opportunities to follow stakeholders' perspectives. On the other hand, the game organizers can refer to the behaviors exhibited during the game and the decisions made by the players to specify rules-based methods for the computerized agents (d'Aquino et al. 2003).
- 5.6 Yet, there is still a gap from the post-game debriefing discussions to the formulation of decision-making algorithms. The level of abstraction required by explaining generalities is high for participants who tend to focus on their peculiar situation. As an individual, it may be difficult to think in terms of behaviors representative of a group of individuals. The approach described in this paper advocates for the early and interactive use of a stylized scale model as an intermediate object to facilitate this activity with local stakeholders.



Conclusion

- 6.1 Whereas it is commonly acknowledged that participatory agent-based simulation promotes learning, the knowledge engendered during the model design process goes largely unnoticed (Johnston et al. 2007). As illustrated by the famous Confucius say "*I hear and I forget, I see and I remember, I do and I understand*", the learning during the design stage of a participatory modeling process could well be more intense than during the simulation stage.
- 6.2 Following De Kraker and van der Wal (2012), we do believe that more efficient feedbacks between model outcomes and stakeholder choices through interactive visualization or user-friendly scanning tools would facilitate the integration of stakeholder perspectives into models and ultimately enhance social learning. Moreover, more interactive simulation interfaces would also greatly benefit to the all the more delicate phase of ABM checking.



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