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USING MODELS FOR PREDICTING RECOVERY AND ASSESS TREE SPECIES VULNERABILITY IN LOGGED TROPICAL FORESTS

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Introduction

Matrix models of forest dynamics allow a time-projection of diameter-class distributions, useful to estimate the time needed, after logging, to recover a given part of the stock of valuable trees above the diameter cutting limit (DCL) and assess felling cycles (Mengin-Lecreulx, 1990, Vanclay, 1994, Favrichon, 1998, Debroux, 1998, Alder et al., 2002, Sist et al., 2003). Once calibrated on permanent sample plots, those models can easily be used by managers as they only require, as input parameters, the diameter structure of the population(s) under scope, generally available from classical forest inventories (Durrieu de Madron et Forni, 1997, Alder et al., 2002). However, such models must be used with caution (Vanclay, 1994, Alder et al., 2002). Easy to build, they are limited by the quantity of data available, especially when working on a species basis: (i) a lot of species have very few individuals and must be grouped with others in order to be described; (ii) in most cases, only trees ≥ 10 cm dbh are surveyed on permanent sample plots. This has two major drawbacks for modelling the recruitment of new trees: recruitment over 10 cm dbh is a rare event and it can hardly be linked to the presence of mother trees (too much time elapsed since seed dispersal). This causes matrix models to become highly questionable when used to predict the behaviour of the species after two or three felling cycles, when the feeding of upper classes becomes highly dependent on the way the feeding of the first class has been modelled.

In this article we compare long-term simulation results provided by StoMat, a non-regulated matrix model, and Selva, a single-tree distance dependent model. These models were designed for different purposes and independently calibrated, resp. on a limited data set and an extended one, derived from the 12 permanent sample plots of the Paracou site in French Guiana. We focus on the major timber species *Dicorynia guianensis* Amshoff (Caesalpiniaceae), logged with a DCL of 60 cm dbh, under 40 years felling cycles.

Methodology

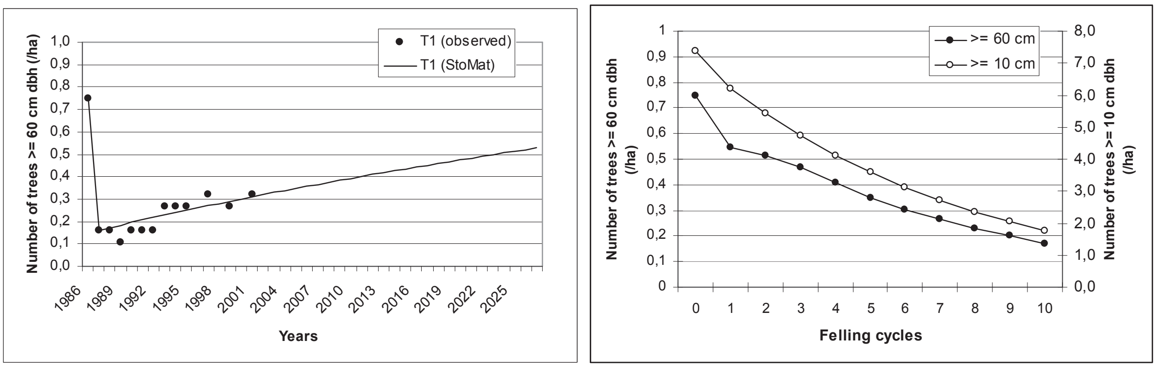
StoMat is a non-regulated matrix model, designed to be calibrated with limited data sets in order to help managers predict the recovery of the valuable stock of trees after felling. For *Dicorynia guianensis*, trees were broken down into 6 diameter classes (from 10 cm dbh to ≥ 60 cm dbh). The parameters of the 6×6 transition matrix were obtained by sampling inside diameter increment distributions in each diameter class, and inside variation intervals observed for mortality rates (Gourlet-Fleury et al., 2004). Recruitment rate was taken as a fixed proportion of mature trees.

Selva is a single-tree distance dependent model (Gourlet-Fleury et al., 2004), built and calibrated for research purposes, in particular the study of the long-term spatial behaviour of species, and gene flows at the local scale. In Selva, the fate of each tree (growth, mortality and recruitment) is predicted, depending on its local neighborhood. For *Dicorynia guianensis*, the model benefited from 4 years of intensive field work on regeneration processes and the complete life cycle was implemented, including fruiting, dispersal, early stages survival till 1 cm dbh, individual survival and growth above 1 cm dbh.

First, we assessed the individual performance of the two models, regarding the purpose for which they were built. Then, we simulated on a 36-ha area the effect of repeated logging with a felling cycle of 40 years. We compared the outputs of the two models for two main variables: total number of trees ≥ 10 cm dbh and total number of trees ≥ 60 cm dbh.

Results

As illustrated on Fig.1(a), StoMat predicted well the evolution of the number of *D. guianensis* trees >= DCL in the stands where logging took place in 1987. According to the model, repeated logging of exploitable trees every 40 years would be unsustainable: more than 50% of the population would disappear within 200 years (Fig.1(b)).

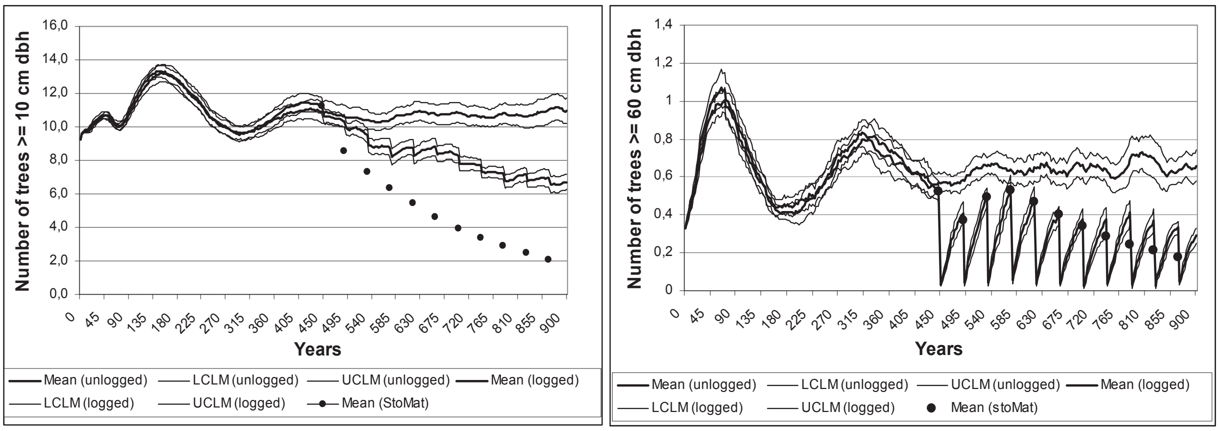


(a) (b)

Fig.1. Evolution of the population of *Dicorynia guianensis* after felling, as simulated by StoMat. (a) number of trees ≥ 60 cm dbh, comparison with data observed in exploited stands. (b) Number of trees resp. ≥ 10 cm dbh and ≥ 60 cm dbh when logging is repeated according to 40 years felling cycles.

Selva reproduced the global characteristics of the population in terms of demography and structure (total number of trees ≥ 60 cm dbh, total number ≥ 10 cm dbh, number of juveniles, basal area) and spatial pattern (strongly aggregated). However, it generated a turnover above 10 cm dbh about tenfold higher than that observed in real stands. As a consequence, small size trees (10-15 cm) tended to be over-represented, and medium-size trees (25-50 cm) under-represented.

To compare the two models, we started from an initial state generated by Selva after a first 450 years period of stabilization, on the 36 ha area where the regeneration studies took place. Repeated logging operations were then simulated for ten 40 years felling cycles. The compared evolution of the two variables of interest is illustrated on Fig.2(a) and (b).



(a) (b)

Fig.2. Compared evolution of the population of Dicorynia guianensis when repeated felling is performed under a 40 years felling cycle. The behaviour of the undisturbed population is shown for comparison. LCLM and UCLM

are the 95% lower and upper confidence limits of the mean of 20 repetitions performed with Selva. (a) Trees ≥ 10 cm dbh). (b) Trees ≥60 cm dbh.

Selva predicted the decline of the population, as did StoMat, but with twice a slower pace than the matrix model. For the trees ≥ 60 cm dbh, the predictions were very similar till the 6^{th} felling cycle when the decrease in total number generated by StoMat began to strongly affect the feeding of the classes above the DCL.

Discussion

While the two models were very differently built, calibrated using only partially common data sets, and performed inequally, they give partly convergent information on the possible behaviour of *D. guianensis* under a repeated felling regime, enlightening, in addition, their respective limitations.

When long-term simulations are performed, StoMat logically proves to be very sensitive to the recruitment rate. Here, the rate was taken as the observed ratio between recruitment above 10 cm dbh and the number of trees ≥ 40 cm dbh in undisturbed plots, and kept constant: we checked that, with Selva, the same ratio only slightly increases between undisturbed and disturbed simulations. This behaviour is due to the buffer effect of the young stages: those stages attenuate, over time, the impact of the systematic elimination of seed-trees ≥ DCL upon the population of trees ≥ 10 cm dbh. This also explains the differences observed between Selva and StoMat for the simulated evolution of the total number of trees ≥ 10 cm dbh (Fig.2(a)): the logging impact is very strong, in the second case, due to the direct link that was established between the largest trees and the recruitment rate.

Those results simply illustrates the necessity to take into account, in matrix models, as small diameter classes as possible in order to reproduce the buffer effect of young stages. But they also help to relativize this conclusion: StoMat was able to predict, on a 240 years period, the same evolution of the number of trees ≥ DCL than the complex and heavy-parameterised Selva model.

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