Metodology and preliminary results of LANDCLIM application in mountainous mixed forests with coniferous and beech from northern Romania

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1. Introduction.

Forest modelling has become in the last 40 years an important tool to assess or to forecast the main features of forests (Mladenoff and Baker 1999). The appropriate use of modelling in forestry can bring significant: *i*) tangible benefits such as cost savings, higher revenues, improved operational efficiency, increased forest productivity, market share and profitability, and *ii*) *intangible benefits* such as better and increased knowledge about the resource, better planning, potentially better customer services and improved competitive advantages (Turland, 2007).

LANDCLIM is a spatially explicit, stochastic model designed to study forest dynamics determined by a set of driving forces including large-scale natural disturbances, land-use, climatic parameters, soil properties and topography (Schumacher, 2004; Schumacher *et al*., 2004; Schumacher and Bugmann, 2006; Schumacher *et al*., 2006). This model was created and tested for mountainous forest landscape in Swiss Alps. Swiss Alpine forests are very similar in terms of species composition, site conditions and geographical characteristics with the mountainous forests from Northern Romania. For this reason we decided to apply the model for two Romanian forests (Slătioara and Frasin) in order to test its applicability ant the possibility to extend it at a larger scale.

The main goal of this study is to simulate the long term forest response to different management and climate change scenarios using LANDCLIM application. The specific objectives of the study are:

- to calibrate the LANDCLIM model for Romanian conditions using a natural old-growth forest;
- to test the model for a larger area;
- to identify different forest management strategies in order to counteract the climate and human expected changes.

The present study set up the frame of the analysis and presents some preliminary results of the LANDCLIM model application.

2. Research method

2.1. Research location

The study area consists of two forests from the Northern Carpathian Mountains (Frasin and Slătioara – about 12800 ha) (Figure 1). Most of the forests (90%) are situated in mountain region. The main species are Norway spruce (*Picea abies*), Beech (*Fagus sylvatica*), Silver fir (*Abies alba*).The deciduous species represent 27%.

The main forest manager is Romsilva who manages the State forests and, on contractual basis, the forests belonging to other owners than State, i.e. municipalities, communes, churches, associations of individual private forest owners. Changes in ownership situation are expected as far as most forestland is claimed back by an association representing the ancient Orthodox Churches Communities (Fondul religionar Ortodox) from Bucovina. The issue is being clarified in the Courts.

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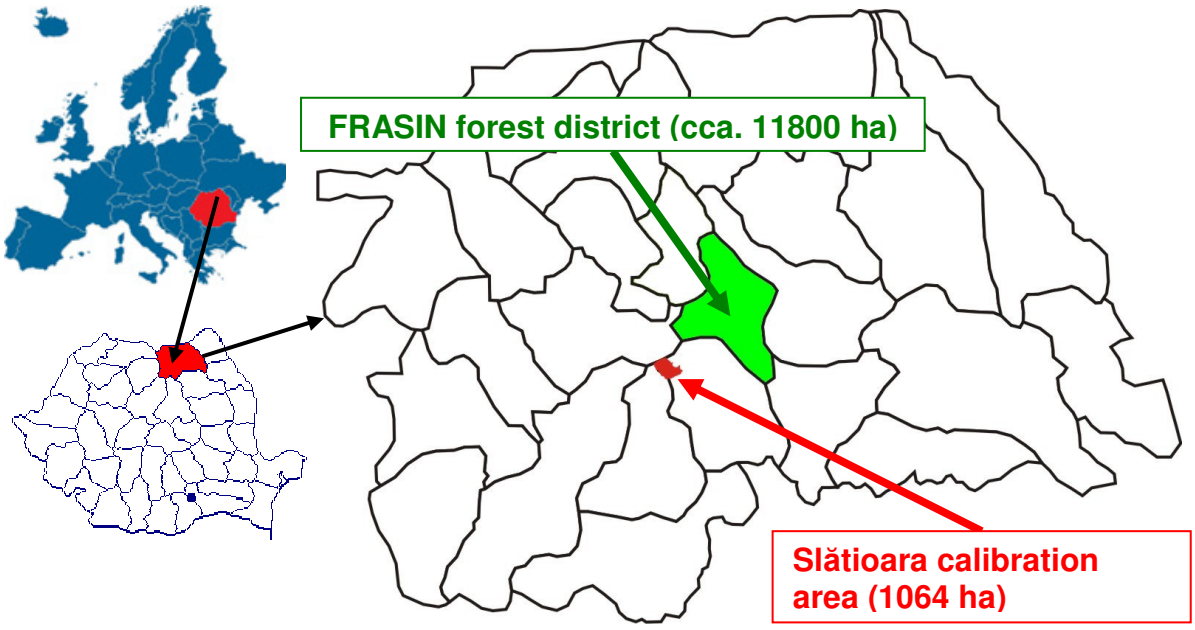

Figure 1. Location of Slătioara and Frasin Forests

Slătioara Old-growth Forest is a Natural Reserve selected for model calibration for two reasons. The first reason is its similarity with the larger study area Frasin in terms of forest and site characteristics. The second reason is the absence of human driving factors, and of several natural factors such windthrows and insect infection. Therefore the simulation in Slătioara forest involves a minimum set of modules in the model LANDCLIM. In order to calibrate LANDCLIM, six permanent plots of 0.5 hectares from five forests stands in Slătioara were fully inventoried.
Once the model was calibrated, it was applied on a larger scale for the mountainous forests of Frasin forest district. Also, to test the accuracy of the model, four 0.5 ha permanent plots were fully inventoried in Frasin forest and the results were compared with the model outputs.

2.2. Methodology

The landscape-level model LANDCLIM is used to simulate vegetation dynamic in mountainous environment. The modules developed over years enable to study the impact of the main drivers of concern in the Romanian case study. Adaptive management is explored using the harvest module by defining potential management scenarios for each management unit within the forest district studied following the silvicultural trends. The simulations are run on the forest district landscapes designed from a digital elevation model, stand and soil information, climate data and forest ownership maps. All these data were processed and used as input files, in the beginning for a 25x25 m grid and finally for a 100x100 m grid.
In this respect, the climate data were provided from the Rarău weather station for the period 1971-2003. Additionally, the CRU (Climate Research Unit) data were provided, compared and improved with data from the local station. These data were processed in order to be used as an input climate file in LANDCLIM application.
Digital elevation model (DEM) (elevation, slope, aspect), site (soil type) and stand (age, composition, basal are, etc.) data were available as a GIS layer for Frasin forest district.
The following main input files were created to run the model:

- *cell number*: each cell from the mentioned grids was numbered;
- *coordinates*: the coordinates were extracted from DEM for the centre of each cell and presented in World Geodetic System (WGS 1984);
- *climate data*: monthly temperatures and precipitations interpolated over the grid (either 50x50 in Slătioara or 100x100 m in Frasin site) based on DEM and CRU climate;
- *elevation*, *aspect* and *slope* were also extracted from DEM in respect with the centre of each cell;
- *soil available water capacity* (AWC) was simulated for each cell as a function of the elevation, aspect and slope in respect with the soil type (existing in a GIS layer). The texture detailed for each soil type was converted into water holding capacity. The depth of

the soil was considered to vary according to the elevation, resulting in a linear reduction of the AWC with elevation.

- *land type* file was created to distinguish between different cells in respect with the following land use categories: forest lands and lands without forests;
- *forest area mask* was created to make the differences between the following different types of forest land use: no forest, forests managed by Frasin forest district (FD), private forests (unmanaged or managed by other structures than Frasin FD, pasture lands, areas without forests managed by Frasin FD, unproductive lands, disputed lands);
- *management area* file, where the plot number of each cell is presented;
- *stands* file where the number of subplot (stand) is mentioned for each cell.

For Slătioara forest a GIS layer was not available so the elevation, slope and aspect data were obtained from a DEM but with low accuracy. In this calibration area, the AWC was estimated from field observations (Figure 2).

Figure 2. Field observations for determining the AWC in Slătioara forest

Field measurements were done at stand level for comparison with the model outputs. In this respect, some representative stands were selected and testing plots were installed (50x100m). For each tree from the selected plots the following features were determined: species, diameter, height, radial growth (cca. 10% of trees), and crown diameters. LANDCLIM outputs were then compared with the results of field measurements.
In addition, the personnel from the forest administration were interviewed to identify the key pressure and threats over the forest resource.

3. Preliminary results

3.1. Drivers of change identified

The data collected during the interviews with forest administration personnel was processed and the following human and natural drivers were distinguished:

- climate change (more drought expected to have increasing impacts within warming scenarios);
- insect damages (*Ips typographus*) and windthrows (more frequent events expected), especially in *Norway spruce* dominated stands. There are experiences in the region that insects appear in stands where are no harvesting operations;

- and the changes in land ownership with important changes in current forest management:
    - *Scenario 1*: a more dynamic management:
        - Rotation shortening;
        - Increase in intervention (thinning/sanitary cuttings) frequency;
        - Increase in intervention intensity.
    - Scenario 2: radical change:
        - Clear cuts on compartments to be restituted to private owners.

Additionally it was observed that the current management is a very conservative one. It may be very shortly described as: high growing stocks /stem density, high ages; high rotation length; low thinning intensity. Also, the problems induced as acknowledged by the management actors are the low quality of the resource, the high susceptibility to insect (*Ipidae sp.*) infection and spread, large amounts of annual windthrows, species shift.

3.2. Slătioara simulation results

To run the LANDCLIM application for Slătioara Forest 2504 cells were established for a 25x25 m grid. The main simulation outputs are presented in Figure 3.

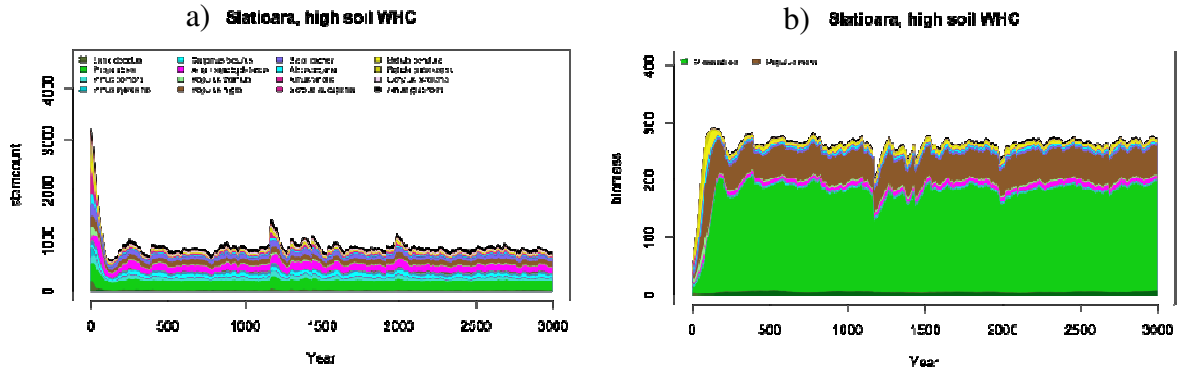

Figure 3. The outputs of LANDCLIM for Slătioara Forest in terms of stem count per hectare (a) and biomass per hectare (b)

LANDCLIM predicts *Picea abies* would develop and exclude the other species. Actual composition is: Norway spruce, silver fir and beech. The stem number per hectare (*N*) is in the normal range: *N* usually varies between 700 and 1500 depending on the development phase of stands (Figure 4). In terms of biomass/ha, field measurements indicate the growing stock varies between 380 and 760 cubic meters per hectare (Duduman, 2009).

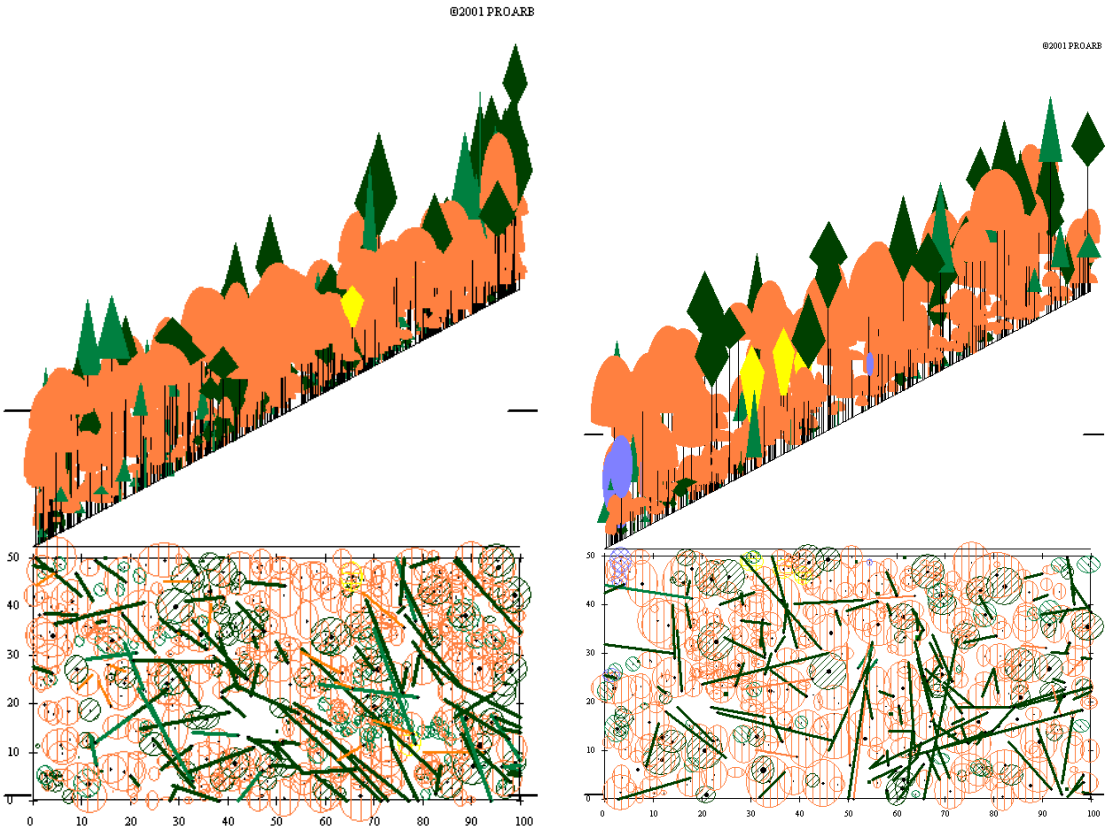

Figure 4. The vertical profile of forest stands in two permanent plots from Slătioara forest

3.3. Preliminary Results in Frasin area

From the beginning, it was decided to run the model only for the main forest types. The data at stand level for the whole forest district were processed and, in the first phase, the main forest types were selected: ***Norway spruce and silver fir stands***; ***Mixed Norway spruce, silver fir and beech stands*** (Table 1).

Table 1. General presentation of forests state from FRASIN forest district

Stand type		Area	
Code	Name	ha	%
0	Other land covers	310,4	2,6
11	Pure Norway spruce stands	115,9	1,0
12	**Mixed Norway spruce and silver fir stands**	**3180,5**	**27,1**
13	**Mixed Norway spruce, silver fir and beech stands**	**6714,5**	**57,2**
14	Mixed Norway spruce and beech stands	235,9	2,0
21	Pure silver fir stands	31,4	0,3
22	Mixed Silver fir and beech stands	114,8	1,0
41	Pure mountainous beech stands	1038,5	8,8
97	Aspen stands	0,6	0,0
Total general		11742,5	100,0

These forest types were then described with respect to the type of stand structure (Table 2). It was decided that only the even-aged stands are representative for the *mixed Norway spruce and silver fir forest type*, but for the *mixed Norway spruce, silver fir and beech stands* both, the even and the uneven-aged structures are representative for Frasin FD.

Table 2. Forest structure of the stands from the selected forest types

Stand type	%		
	Even-aged	Uneven-aged	Total
Mixed Norway spruce and silver fir stands	**77,1**	22,9	100,0
Mixed Norway spruce, silver fir and beech stands	**58,0**	**42,0**	100,0

For these selected forest types and stand structures, the site conditions were analysed (Table 3).

Table 3. Soil conditions for the selected forest types

Stand type	Stand structure	Soil type (%)						Total
		Luvisol	Eutric cambisol	**District cambisol**	Spodi -sol	Gley -sol	Techno -sol	
Norway spruce and silver fir stands	Even-aged	21,5	3,8	**72,2**	2,6	0,0	0,0	100,0
Mixed Norway spruce, silver fir and beech stands	Even-aged	14,0	7,5	**78,4**	0,0	0,0	0,1	100,0
	Uneven/aged	22,3	12,7	**64,9**	0,0	0,0	0,2	100,0

Due to the high percentage of district cambisols compared with the other soil types used by the two selected stand types, we considered it as the main soil type in Frasin forest district. So, for Frasin forest district LANDCLIM application was run using a single soil type: *district cambisol*. In terms of nutrients, and water content it might be described as it follows:

- Nutrients content and availability: *average*;
- Water holding capacity and availability: *high*.

Considering all these aspects and the main drivers of change identified for the Frasin forest district, some possible scenarios were defined and they are presented in Figure 5.

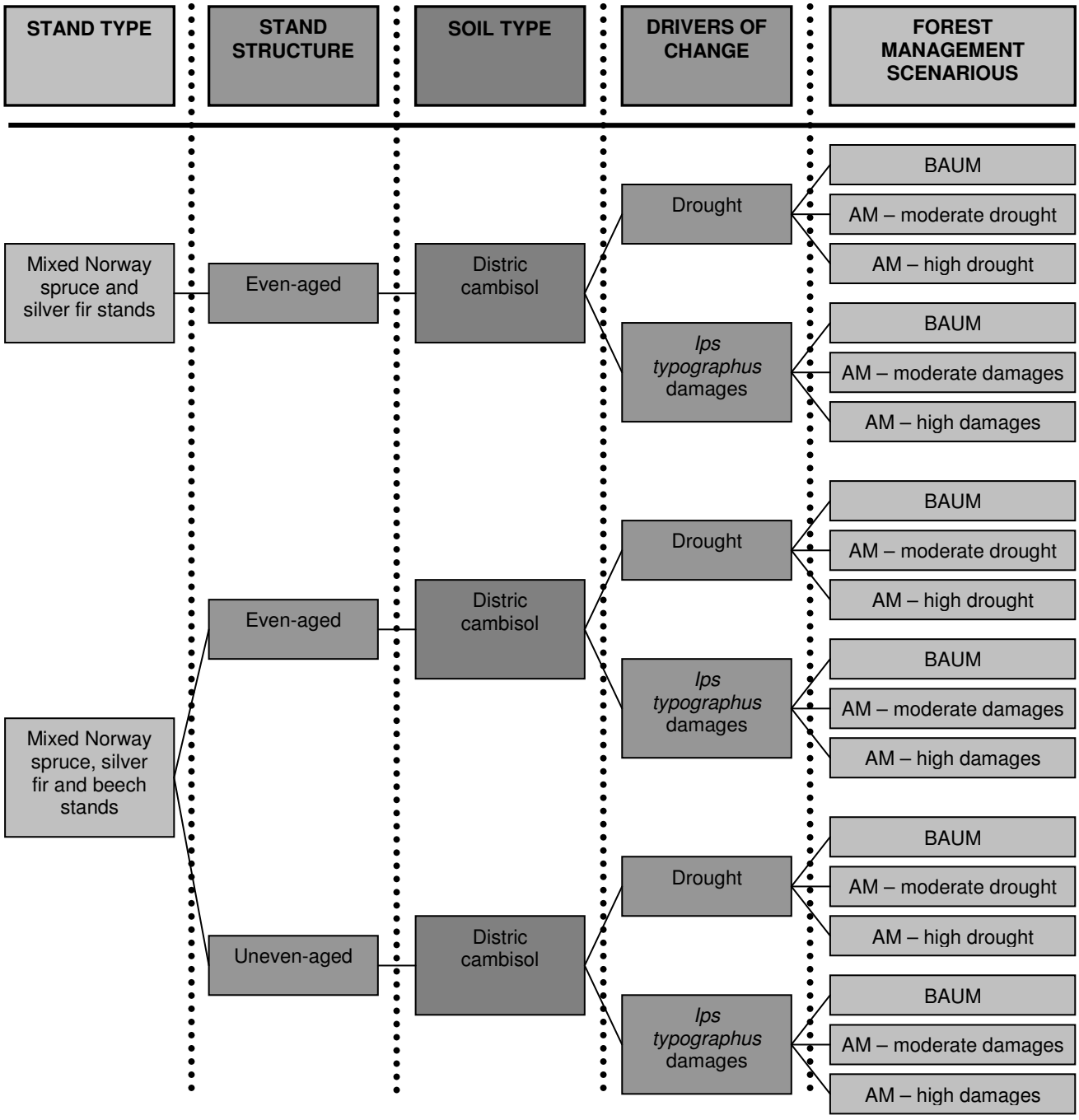

Fig. 5. Design of adaptive forest management scenarios in respect with the expected drivers of change

The first run of LANDCLIM application was very difficult due to the large number (more than 300 thousands) of 25x25 m cells. Field data from the four permanent plots were processed and some preliminary results are presented in Figure 6. These data will be compared with the outputs of LANDCLIM application after the rearrangement of data in the input files. At this stage it was decided to change the grid scale due to the difficulties that appeared in running the application appropriately.

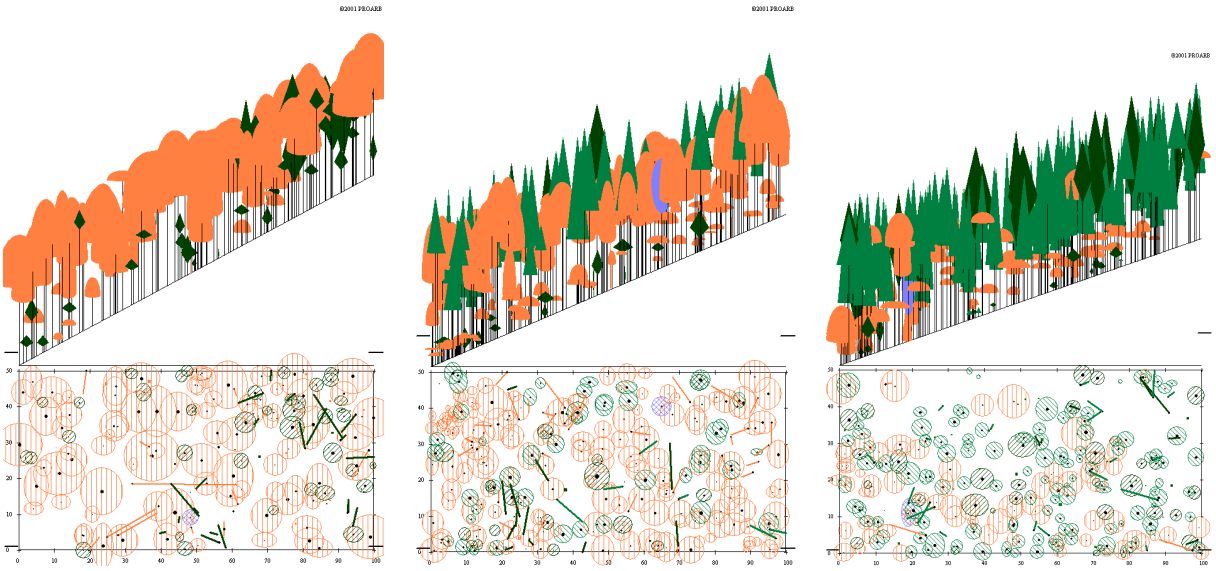

Figure 6. The vertical profile of forest stands in three permanent plots from Frasin forests

4. Preliminary discussion and conclusions

The first outputs of LANDCLIM for Slatioara calibration site are encouraging but some sensitive parameters need to be adjusted and/or improved (species parameters; site parameters etc.) in order improve the outputs of the model, which are compared against the field measurements of species composition, biomass variations along an altitudinal gradient.

After calibrating the LANDCLIM for Slatioara forest, and after defining the simulation scenarios, the model will be applied on the large study area Frasin using a larger cell size (100x100 m).

LANDCLIM will be then applied for the 18 proposed scenarios. The outputs of the model for Frasin area will allow us to define some future management strategies in accordance with different responses of the forests to the input data.

Complementary calibrations have to be done using the high-resolution tree-level data from the existing network of permanent plots. In addition the drought module will be tested against observed tree growth (dendrochronological data) and also, the elevation effects will be analysed due to the fact that the plots are set along an elevation gradient.

Another intended future research objective is to validate the growth module for Norway spruce in the investigation area and to define some management strategies to counteract the effects of human and natural change drivers.

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