FPS COST Action FP1202

Strengthening conservation:
a key issue for adaptation of marginal/peripheral populations
of forest trees to climate change in Europe (MaP-FGR)

SHORT TERM SCIENTIFIC MISSION REPORT

Survival probabilities of Norway spruce and silver fir in Bosnia and Herzegovina

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Abstract

This STSM included the analyses of managed and unmanaged forests composed of European beech (*Fagus sylvatica* L.), silver fir (*Abies alba* Mill.) and Norway spruce (*Picea abies* (L.) H. Karst) on Bosnian mountains. The focus was placed on tree species replacement patterns. We hypothesized that managed forests (MF) have less demographic stability than old-growth forests (OGF). The other assumptions were: a) if a tree species has greater productivity, then it is better adapted to climate extremes and it will have more abundant regeneration; b) OGF have smaller gap fraction than MF, and consequently lower share of shade-intolerant species in medium and upper stand layer; c) there is significant difference in disturbance regime and overall flora diversity between OGF and MF; and d) compared to beech, peripheral populations of spruce and fir in Bosnia have lower reproductive capacity and lower transition probabilities to become dominant species in the future.

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1. Introduction

After disastrous consequences that followed the application of clear cuttings all across Europe, many forest scientists shifted their work toward the research of alternative management systems. The answer to previous mistakes was selection (plenter) system as it allows for demographic sustainability on a very small scale, namely on a stand level (Schütz, 2001). Following the Rio summit in 1992, the sustained yield approach has been widely replaced by concern over sustainability of the entire ecological system (Kimmins *et al*., 2007). For that reason, it is nowadays of vital importance to get the insight into the structure and dynamics of natural forests.

Naturalness can be genuinely studied in virgin (old-growth) forests as they serve as references for structure complexity, species diversity and system resilience. They are also reliable indicators of climate change since they were not directly influenced by human activities. Unfortunately, there are only few such remnants left untouched in Europe, and consequently, studies on virgin forest ecology in high mountains have been more rarity than rule.

Given the fact that several authors from different European countries indicated progression of beech and decline of conifers in beech-fir(-spruce) old-growth forests (Bolte *et al*., 2010; Nagel *et al*., 2010; Diaci *et al*., 2011; Boncina *et al*., 2014), our intention in this STSM was to investigate the replacement patterns in Bosnian forest reserves and managed forests.

2. The purpose of STSM

The purpose of this STSM was to develop scientific cooperation between the Faculty of Forestry in Krakow (Poland) and the Faculty of Forestry in Banja Luka (Bosnia-Herzegovina) in the field of ecology of mountainous old-growth and managed forests. The goal of our analyses during the STSM was to compare the structure (managed *vs.* unmanaged forests), but also to analyze if there have occurred significant changes in terms of tree species composition in the last six decades.

3. Links with COST Action FP1202 MaP FGR

Since COST Action FP1202 Map-FGR is dealing with marginal forest populations, the links of this STSM with the objectives of the Action are entailed in the fact that in Bosnia-Herzegovina tree species such as Norway spruce (*Picea abies* (L.) H. Karst) and silver fir (*Abies alba* Mill.) are close to the limit of their natural range. Therefore, we were interested to investigate how these coniferous tree species interact with European beech (*Fagus sylvatica* L.) in managed forests, but also in unmanaged mixed old-growth forests. Thereby, important to notice is that beech is not at the margin of its natural range, so it might not be affected by climate change as much as spruce and fir. This was the subject of our investigation in

unmanaged old-growth forests in Bosnia-Herzegovina which have not been directly affected by humans, so the regeneration and growth process in the study area are as natural as possible.

4. Materials and methods

This STSM included two virgin forests (Janj and Lom) and ten neighboring managed stands on Bosnian Dinaric Mountains. These forests are located between 1200-1400 m a.s.l. and they are composed of European beech, silver fir and Norway spruce. From Janj and Lom old-growth forests 80 sample plots and from adjacent managed forests 120 sample plots were analyzed regarding following characteristics: occurrence of 1-year old seedlings, forest structure (stand density, basal area, etc.), tree species composition, regeneration patterns, ground flora diversity, gap fraction (canopy openness) and disturbance regime. For the analyses of long-term structural changes, old-growth forest Perucica was taken into account along with Janj and Lom. Based on collected data, the following hypotheses were tested:
1) Climate change in 20th century triggered progression of European beech and decline of Norway spruce and silver fir on high Bosnian mountains (modeling past events).
2) Managed forests (MF) have less demographic stability than old-growth forests (OGF).
3) If a tree species has greater productivity, then it is better adapted to climate extremes, it will have larger presence of seedlings and young trees than a tree species that has lower productivity.
4) OGF have smaller gap fraction than MF, and consequently lower share of shade-intolerant species in medium and upper stand layer.
5) There is significant difference in disturbance regime and overall flora diversity between OGF and MF.
6) When compared to beech, peripheral populations of spruce and fir in Bosnia have lower reproductive capacity and lower transition probabilities to become dominant species in the future (modeling future events).

Time schedule of activities carried out during the STSM:
a) In the first week together we prepared and organized data sets for statistical analyses.
b) In the second week stand densities, regeneration patterns and growth dynamics were modeled. In this week we also tested the above-mentioned hypotheses labeled under (1), (2) and (3).
c) In the third week the hypotheses (4), (5) and (6) were analyzed. All tests and indices for biodiversity and stand structure were calculated in the statistical program SPSS.
d) During the last week we finished the first draft of scientific paper. Some time was used for literature review, so we added relevant citations within the draft.

5. Results

Long term analysis of tree species composition

The results from older inventory which was conducted in 1952 (published in 1956 by Drinic) were compared with our newer results. Climate change in 20th century, especially drought spells in the second half of that century, triggered several bark beetle outbreaks which consequently contributed to decline of conifers and progression of beech on high Bosnian mountains. Consequently, first hypothesis was confirmed (Fig. 1).

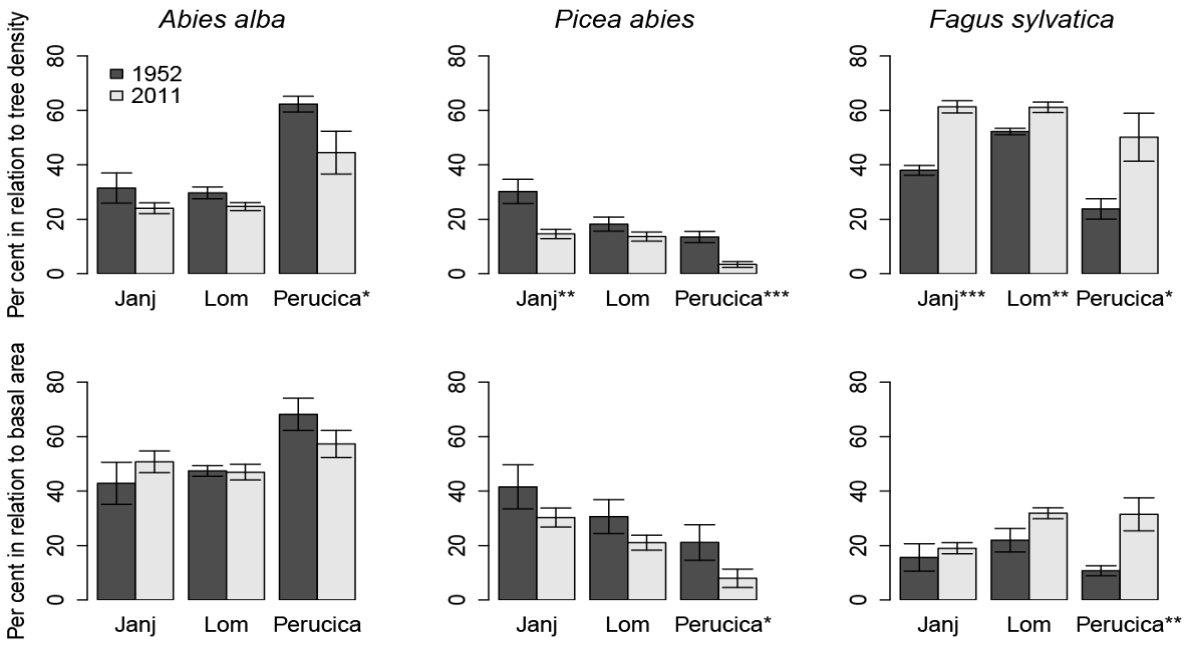

Figure 1. Change in tree species composition according to tree density (above) and basal area (below) in last six decades. One, two and three star denote significance code of $p < 0.001$, $p < 0.01$ and $p < 0.05$, respectively.

Current diameter distribution shapes in OG forests and managed forests

Managed forests and OG forests had rather similar shapes of diameter distributions, however, they universally differed in a way that smallest dbh class contained more trees in managed forests, whereas the presence of trees with dbh above 50 cm was clearly greater in OG forests. In the Table 1 the results concerning diameter distributions are calculated according to the procedure described in Janowiak *et al*. 2008.

Table 1. Best-fitting models for multiple regressions between the base 10 logarithm of trees per hectare and all possible combinations of dbh, dbh^2 and dbh^3 for OG forests Janj and Lom and adjacent managed forests.

	MF Janj				**OGF Janj**			
	Fir	Spruce	Beech	Total	Fir	Spruce	Beech	Total
Shape	RS	IQ	RS	RS	UNI	UNI	RS	RS
	MF Lom				**OGF Lom**			
Shape	NE	UNI	CO	IQ	IQ	IQ	RS	NE

RMSE - root mean square error, UNI – convex or unimodal shape, RS - rotated sigmoid shape,
IQ – increasing-*q*, CO – concave (sensu Janowiak *et al*., 2008)

Tree species composition in three successive DBH groups

Species diversity in the ground layer (woody and herbaceous plants) and site conditions were more heterogeneous in managed than in OG forests due to larger range of Shannon index values on sample plots. Sycamore maple above dbh 7.5 cm had low but constant share in composition of managed forests, while in OG forests it was virtually absent in the middle- and upper-story despite its constant presence in regeneration layer (Figure 2).

Based on presented results, we cannot state that selection managed forests had lower demographic stability regarding tree species composition in social layers (or dbh classes) than old-growth forests.

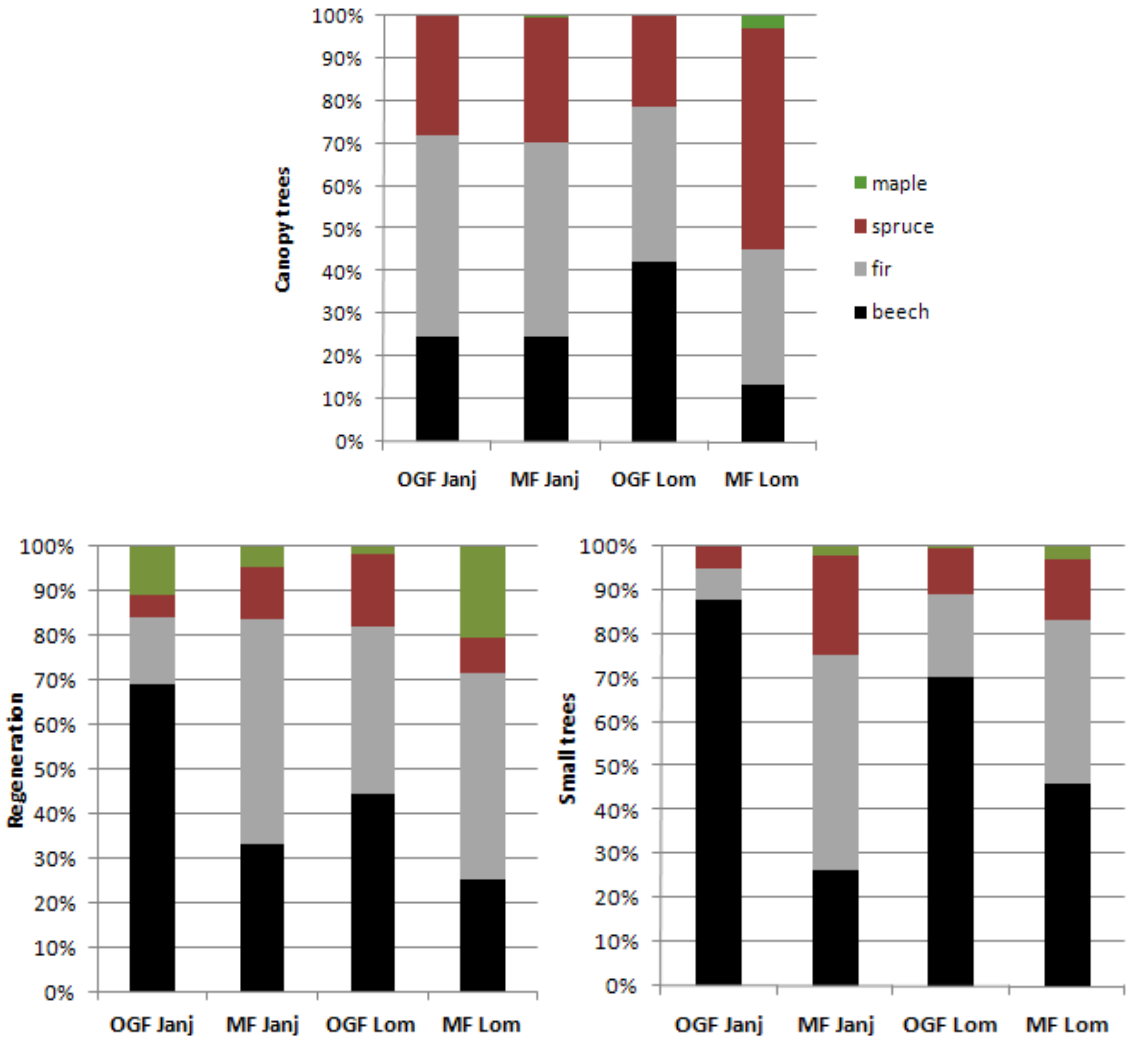

Figure 2. Tree species composition in different social layers. Regeneration represents youngest trees up to 7.5 cm dbh, small trees have between 7.5 and 27.5 cm dbh, while canopy trees have dbh more than 27.5 cm.

Further, we found that increased wood productivity does not mean increased species adaptation capacity and capability to occupy certain area. Namely, beech in OG forests had smaller absolute increase of basal area in last six decades than conifers but much more successful regeneration and ingrowth of young trees.

As regards canopy openness or gap fraction, the frequencies of gaps (openness) reveal the fairly uniform distributions in both OGF and MF (Figure 3).

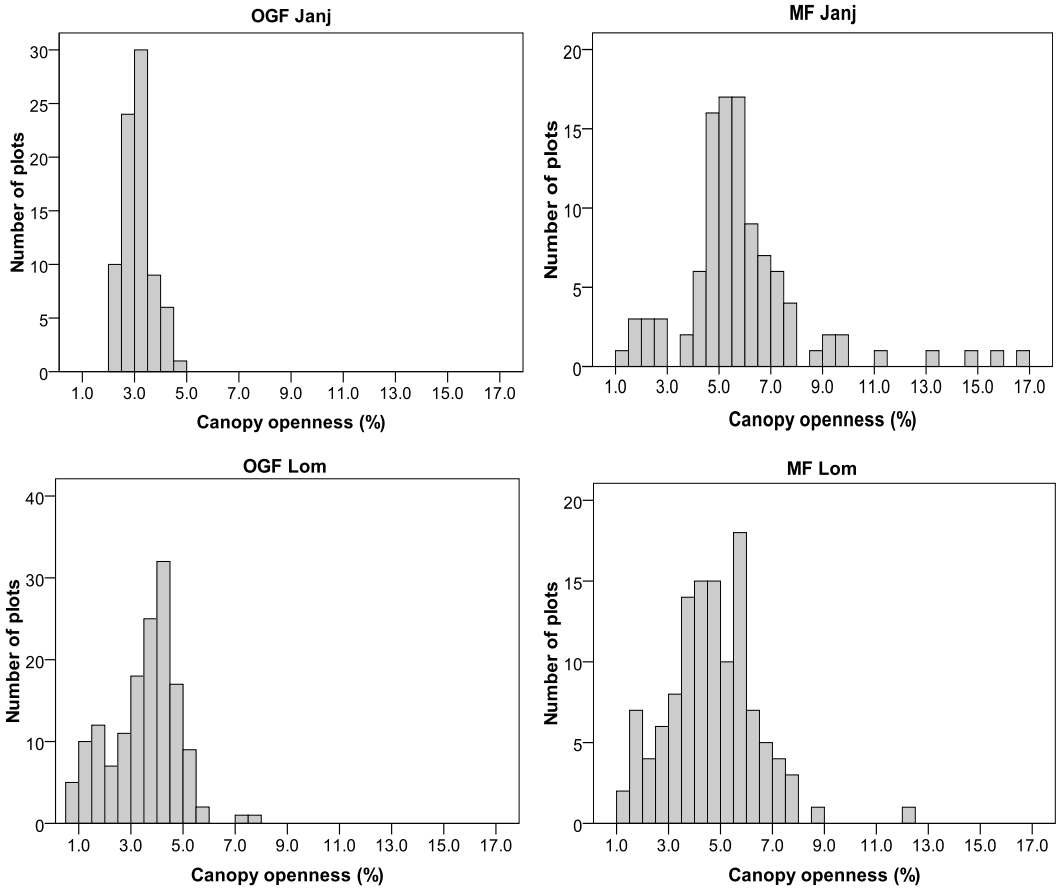

Figure 3. Frequency distributions of canopy openness (%) in studied forests.

As all other site conditions were equal, due to smaller gap fraction of OGF compared to MF, a lower share of shade-intolerant species in medium and upper stand layer occurred in OGF (Fig. 2 and 3).

Ground vegetation and disturbance regime

Cover of ground vegetation (without tree species and up to 1 m above ground) was greater in managed forests than in OG forests. Average coverage of ground by non-tree vegetation was: in OGF Janj 22.9 %, MF Janj 23.9 %, OGF Lom 9.8 % and MF Lom 27.4 %. Overall species diversity and site conditions were most heterogeneous in MF Janj due to largest range (2.57) of Shannon index values on sample plots. Plots in OGF Janj had range of Shannon indexes 1.65, which made this forest more homogeneous than others in terms of species diversity and site conditions. In this sense, range in MF Lom was greater (2.07) compared to OGF Lom (1.76).

Disturbance regime was assessed based on the number and basal area of stumps compared to those characteristics of living trees in MF and OGF. Presence of stumps was significantly lower in OG forests, which indirectly implied lower disturbance intensities of their canopies compared to managed forests (Table 2).

Table 2. Disturbance ratios based on number and BA of stumps.

		Mean	Median	Min.	Max.	Std. error
OGF Janj	N stumps/N living trees	0.10	0.09	0.00	0.35	0.01
	BA stumps/BA living trees	0.19	0.15	0.00	1.16	0.03
MF Janj	N stumps/N living trees	0.21	0.21	0.06	0.40	0.01
	BA stumps/BA living trees	1.26	1.15	0.37	3.13	0.07
OGF Lom	N stumps/N living trees	0.15	0.14	0.00	0.45	0.01
	BA stumps/BA living trees	0.31	0.25	0.00	0.76	0.03
MF Lom	N stumps/N living trees	0.40	0.36	0.13	0.83	0.03
	BA stumps/BA living trees	1.26	1.09	0.24	3.68	0.08

Transition probabilities

For modeling future events, that is, future tree species composition we calculated transition probabilities considering regeneration frequency occurrence of certain species under canopy (mature) trees of the same or some other species. From the Table 3 we can draw the inference that beech regeneration has greatest probabilities to occupy the upper-storey in the close future in all studied forests. The only exception were transition probabilities for silver fir regeneration in OGF Lom as they were slightly higher than those calculated for beech regeneration in this forest.

Table 3. Transition probabilities for regeneration

OGF Janj		Regeneration (10 cm height–7.5 cm dbh)			
		Beech	Fir	Spruce	Maple
Upperstory Trees	Beech	0.73	0.14	0.07	0.06
	Fir	0.69	0.11	0.09	0.11
	Spruce	0.68	0.20	0.05	0.06
MF Janj		Regeneration (10 cm height–7.5 cm dbh)			
		Beech	Fir	Spruce	Maple
Upperstory trees	Beech	0.53	0.23	0.11	0.13
	Fir	0.47	0.33	0.14	0.05
	Spruce	0.50	0.31	0.15	0.05
OGF Lom		Regeneration (10 cm height–7.5 cm dbh)			
		Beech	Fir	Spruce	Maple
Upperstory trees	Beech	0.36	0.39	0.24	0.02
	Fir	0.38	0.41	0.20	0.02
	Spruce	0.29	0.54	0.16	0.01
MF Lom		Regeneration (10 cm height–7.5 cm dbh)			
		Beech	Fir	Spruce	Maple
Upperstory trees	Beech	0.50	0.26	0.07	0.17
	Fir	0.47	0.25	0.09	0.20
	Spruce	0.48	0.23	0.06	0.24

6. Discussion

In this STSM the greatest attention was given to the analysis of replacement patterns and competition between Norway spruce, European beech, silver fir and Sycamore maple in the study area. Analysis was based on our relatively new data and compared with data from older inventories (Drinic, 1956). Results from Bosnian virgin forests could be important to forest managers in the Balkan Peninsula, but also to scientists and managers in other European countries, assuming that global warming will continue. Namely, Bosnia (and whole Balkan Peninsula) has similar tree species like Central and Northern Europe, however, due to its geographic position it has higher temperatures. If the temperatures will be increasing in the upcoming period, then certain parallels can be expected between current species composition in the Balkans and future species composition in Central and Northern Europe. In addition, Norway spruce and silver fir are close to the edge of their natural range in Bosnia.

Based on the outcomes of research results and tested hypotheses, we can state that climate change in 20th century triggered progression of European beech and decline of Norway spruce and silver fir on high Bosnian mountains in last six decades. Similar pattern was found in some other European studies (Bolte *et al*., 2010; Nagel *et al*., 2010; Diaci *et al*., 2011; Boncina *et al*., 2014). Studied managed forests in Bosnia did not show lower demographic stability than old-growth forests. The tree species that have greater wood productivity are not necessarily better adapted to climate extremes, as the number of their seedlings can be smaller than that of tree species which exhibits smaller growth rates. However, the results on this hypothesis were not unanimous across studied forests. Further, OGF had smaller gap fraction than MF, and consequently lower share of shade-intolerant species in medium and upper stand layer since all other site conditions were virtually equal. Significant difference in number of stumps was obvious between MF and OGF, however, disturbance regime has to be studied further as it can be assessed also by using the other components of dead wood, such as the number of standing dead trees. Flora diversity was slightly greater in MF, which is in unison with European studies (e.g., Boncina, 2000), however, opposite to the findings in the USA (Angers *et al*., 2005).

7. Conclusions

This STSM was meant to contribute to better understanding of the ecology and coexistence of beech, fir, spruce and sycamore maple based on the analysis of large data sets from the upper montane zone of Bosnian mountains. Sycamore maple was able to reach the upper story only in managed stands due to somewhat greater canopy openness. When compared to beech, peripheral populations of spruce and fir in Bosnia proved to have lower reproductive capacity and lower transition probabilities to become dominant species in the future. However, some other studies have indicated that compositional stability of mixed beech-fir-spruce old-growth forests may remain stable under climate change. Therefore, further analyses and monitoring is necessary both in old-growth forests and managed forests in order to confirm or reject this

statement with more certainty, so that we are sure that indicated species shift is not accidental temporal shift between tree species but really driven by climate changes.

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