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AN ENVELOPE MODEL ANALYSIS OF CLIMATE CHANGE IMPACTS ON FOREST TREE SPECIES IN ROMANIA

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Abstract: *The paper deals with possible impacts of climate changes, as described in the most recent Intergovernmental Panel on Climate Change Reports, on the most important forest tree species native to Romania. The study uses the simplest version of bioclimatic envelope, with two basic parameters (mean temperatures and mean rainfall amounts) and a rectangular shape, based on values describing species requirements. There were considered seven tree species, for which were selected 17 populations, located in various ecological regions of the country. The changes of the two main bioclimatic parameters in the selected locations, were calculated and evaluated for a total of 12 scenario-period combinations.*

Key words: *climate change scenarios, tree species, climate envelopes.*

1. Introduction

The global environmental modifications, in particular the climate changes, represent major threats facing the contemporary society. Nowadays, a significant majority of us is convinced that various human activities (generating pollution, especially high greenhouse gases emissions, land surface properties and land use changes etc.) are threatening our future, by affecting irreversibly the planetary climate. This process is already in progress, as revealed by the World Meteorological Organisation (WMO) observations, documenting the increase of the global mean air temperature over the last century, by satellite images showing the significant reductions of ice cover in the Arctic region etc. [4].

In the past, over Earth geological history, numerous tree species have reacted to climate changes by adjusting their distribution ranges, or failed and are presently known only through deep rocks strata investigations. In the same way, most probably, in the future, the projected climate changes are very likely to cause changes in habitats, with local abundance adjustments and even species extinctions, range shifts etc. [5]. Increased tree mortality, in relation to higher temperatures and drought, has been already reported in Europe and many other world regions, with consequences from carbon storage to biodiversity and water quality issues [5], [10]. Recent studies showed that biodiversity and species' ranges have been already affected and these impacts are expected to increase in the future decades [1], [15], [19].

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Among the most vulnerable forest areas in Romania one could mention the border regions, located at the lower range margin, near the steppe zone and the upper limit, in the mountains. As regards the mountain forests, there are two important climate change related issues: the mountain climate variability (interacting with the global and regional trends) and the vital environmental services provided by those woodlands.

This paper aims at analysing the impacts of the climate changes, as described by the most recent scenarios produced by the IPCC (Intergovernmental Panel on Climate Change) [4], [11], on tree species representative for Romanian forests.

2. Material and methods

Basic climate envelope models were used in this study. The method is simple, enabling not only a very easy replication in other studies but also providing a useful tool for practitioners, who want to "translate" the IPCC projections to the local level, where their forests grow, to analyse how the climate conditions will evolve with respect to the bioclimatic envelope of certain tree species.

Envelope modelling approach consists in determining the '*bioclimatic envelope'* that describes the limits of a species spatial range. These models are also referred to as ecological "niche" models, but for some scholars this could be confusing, because in modern ecology this concept is used in the upgraded version (proposed by Elton, in 1927), meaning the role of the population in the ecosystem instead of its initial definition (given by Grinell, in 1917), synonymous to the environmental envelope, in more recent terminology [2].

Bioclimatic envelope models have certain advantages in studies of climate changes possible impacts on plant and animal species, enabling a simple analysis that outlines the basic relationships between species and the environmental factors subject to modifications. Thus the range adjustments and other responses of individual populations to various environmental stressors could be easily inferred.

The most common techniques are based on correlative analysis focusing the current species distributions and various sets of climate variables [16]. An alternative to this approach, used in this study, is to take into consideration the simplest version of a bi-dimensional climatic envelope, with two basic parameters (mean temperatures and mean rainfall amounts) and a rectangular shape derived from the intervals of values describing tree species requirements, as resulting from expert panels or are published in textbooks [17], [18].

There were considered 7 representative Romanian forest tree species [3], for which were selected 17 populations, located in various regions of the country, presented in Table 1, where there are also noted the basic characteristics of the present climate (mean annual temperature and precipitation amount). The position of the corresponding local sites is depicted in Figure 1.

As regards the climate change scenarios, the main focus was on those presented in the fifth IPCC Assessment Report (AR5), issued this year [4], [5], with four brand new scenarios, called Representative Concentration Pathways: RCP 2.6, RCP 4.5, RCP 6.0, RCP 8.5, where the figures in the name indicate the total associated radiative forcing (in W/m^2).

For enabling comparisons it was also considered the best known emission scenario, from the SRES set, used in previous reports, and the associated AR4 predictions [11], for periods spanning over the current and next century.

The changes of the two main bioclimatic parameters in the 17 locations were calculated for a total of 12 scenario-period combinations, with the results illustrated in the charts (Figures 2, 3). Some examples of the predicted modifications are also noted in Table 1, next to the present climate data.

The study locations and the main bioclimatic parameters Table 1

Tree species	Location	Bioclimatic parameters T-mean annual temperature [^{o}C], P – mean annual rainfall amount [mm]									
		Present Climate		AR4-A1B (SRES)				AR5-RCP 4.5			
				2046-2065		2080-2099		2046-2065		2081-2100	
		T	P	T	P	T	P	T	P	T	P
Norway spruce (*Picea abies*)	Rarau	2.0	926	3.75	972.3	4.65	1018.6	3.4	964.9	3.8	976.0
	Parang	3.5	951	5.25	998.6	6.15	1046.1	4.9	990.9	5.3	1002.4
	Paltinis	4.5	910	6.25	955.5	7.15	1001.0	5.9	948.2	6.3	959.1
	Gheorghieni	5.6	603	7.35	633.2	8.25	663.3	7.0	628.3	7.4	635.6
Silver fir (*Abies alba*)	Predeal	4.9	945	6.65	992.3	7.55	1039.5	6.3	984.7	6.7	996.0
	Sinaia	6.1	808	7.85	848.4	8.75	888.8	7.5	841.9	7.9	851.6
European beech (*Fagus sylvatica*)	Rucar	7.2	819	8.95	860.0	9.85	900.9	8.6	853.4	9.0	863.2
	C.Muscel	8.1	738	9.85	701.1	10.75	664.2	9.5	768.9	9.9	777.8
Sessile oak (*Quercus petraea*)	Tg.Neamt	8.2	672	9.95	638.4	10.85	604.8	9.6	700.2	10.0	708.3
	Ocna Sugatag	8.0	742	9.75	779.1	10.65	816.2	9.4	773.2	9.8	782.1
	Rm.Valcea	10.2	707	11.95	671.7	12.85	636.3	11.6	736.7	12.0	745.2
	Strehaia	10.0	574	11.75	545.3	12.65	516.6	11.4	598.1	11.8	604.9
Pedunculate oak (*Quercus robur*)	Gaesti	10.1	617	11.85	586.2	12.75	555.3	11.5	642.9	11.9	650.3
	Baneasa	10.3	555	12.05	527.3	12.95	499.5	11.7	578.3	11.7	578.3
Gray oak (*Quercus pedunculiflora*)	Tamadau	10.3	500	12.05	475.0	12.95	450.0	11.7	521.0	12.1	527.0
Pubescent oak (*Quercus pubescens)*	Isaccea	11.1	445	12.85	422.8	13.75	400.5	12.5	463.7	12.9	469.0
	Babadag	10.7	418	12.45	397.1	13.35	376.2	12.1	435.6	12.5	440.6

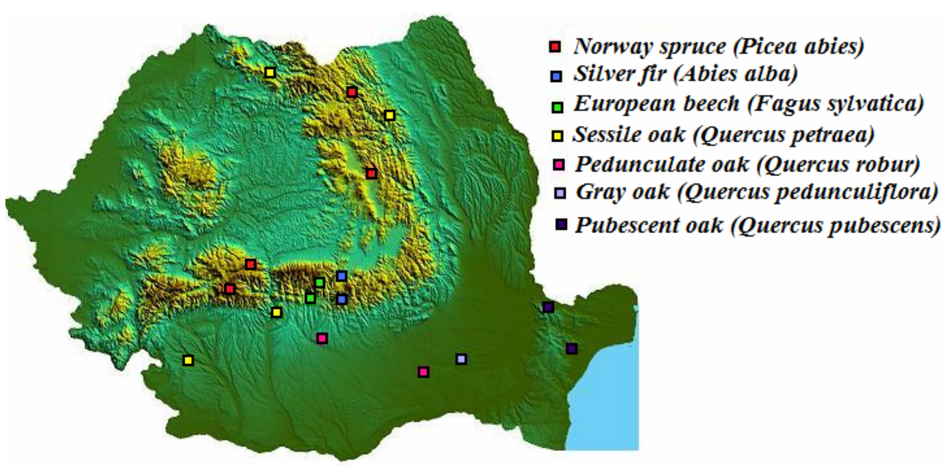

Fig. 1. *The position of study locations for several forest tree species*

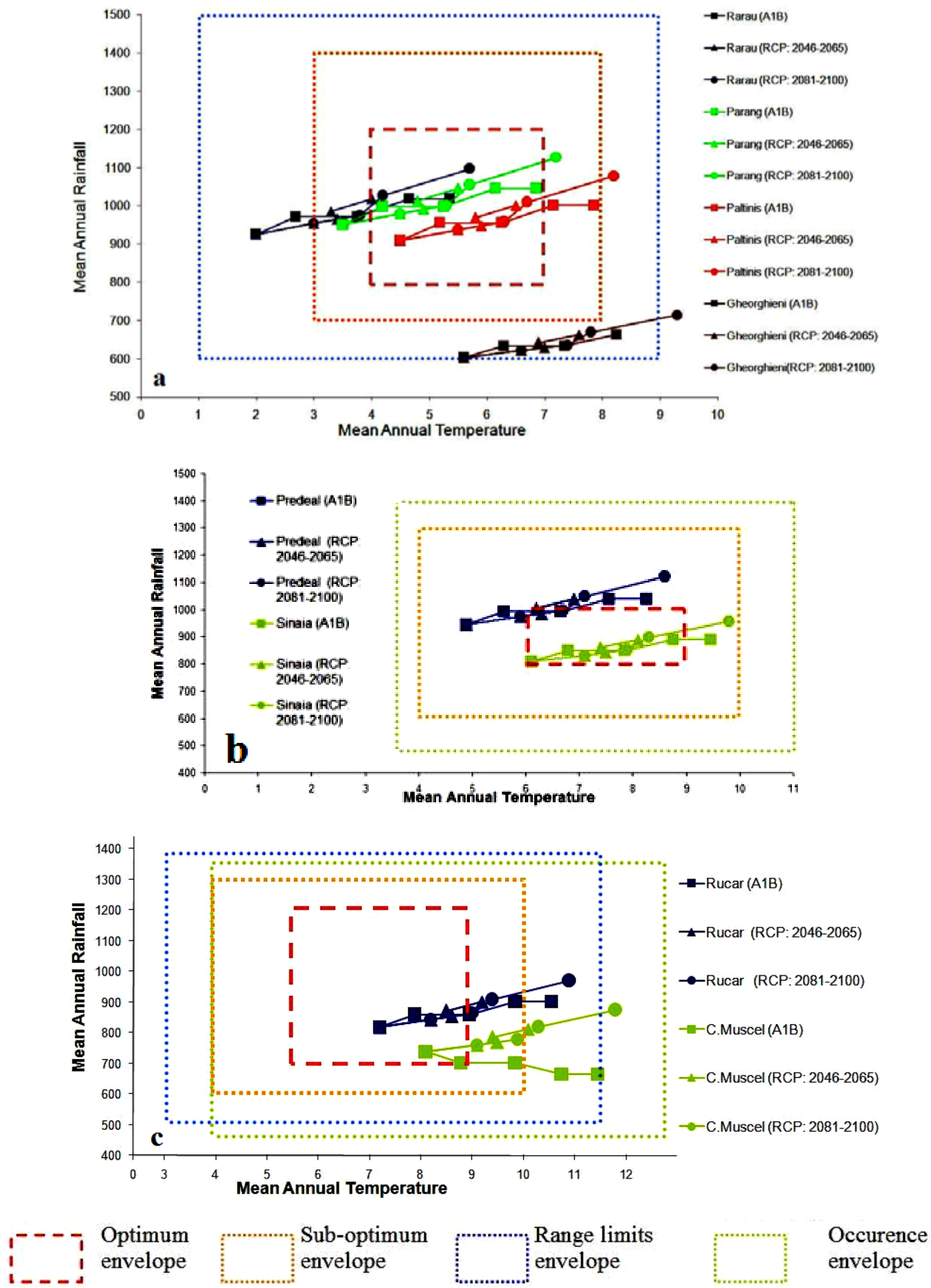

Fig. 2. *Tree species simple bioclimatic envelopes and lines of climate possible evolution in different locations for various IPCC scenarios and periods (AR4-A1B: 2011-2030, 2046-2065, 2080-2099, 2180-2199; AR5:RCP 2.6, RCP 4.5, RCP 6.0, RCP 8.5). Charts: a- Norway spruce, b-Silver fir, c- European beech.*
For the A1B lines, each marker indicates a period. The RCP lines, for two periods (2046-2065 and 2081-2100), are marked for scenario type.

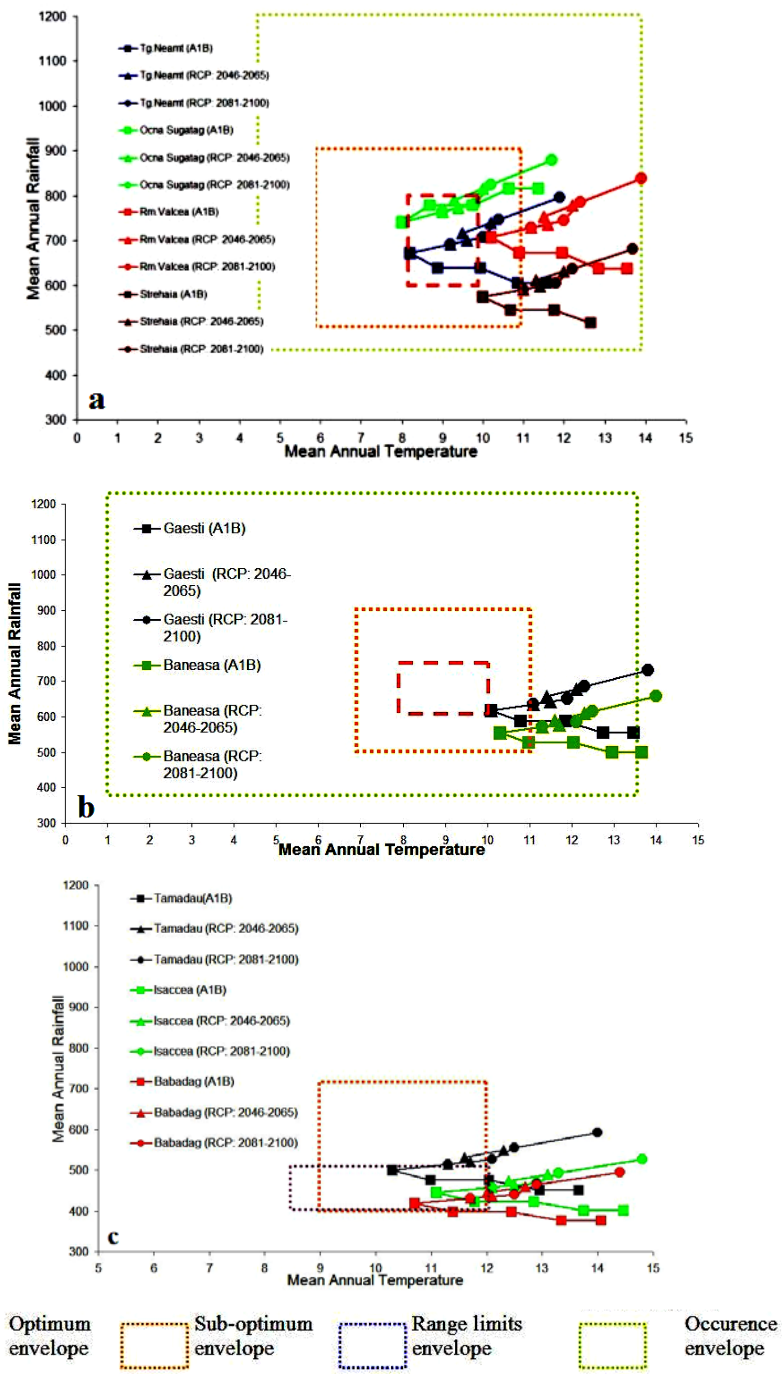

Fig. 3. *Simple bioclimatic envelopes and lines of climate possible modifications for oak species in different locations (see Figure 2). Charts: a-Sessile oak, b- Pedunculate oak and c: Xerophilous oaks (Gray and Pubescent oak).*

3. Results and Discussions

The changes in temperature were extracted straight forward from the mentioned reports. No attempts were made for downscaling the values to regional and local levels [13], [14], in order to keep the approach as simple as possible. The precipitation changes are much more difficult to predict with acceptable accuracy and consequently the predictions in the reports are more qualitative than quantitative statements, such as ‘wet-get-wetter’ and ‘dry-get-drier’ [4], generally low confidence predictions of changes lesser than natural variability.

In this study, for the A1B scenario, there were considered changes in the average annual amount of 5% for the first two periods and 10% for the following two, with different signs over the country, accepting the hypothesis of an increase in Transylvania and the mountain regions and a decrease in low areas situated south and east of the Carpathians, as suggested by the regional predictions of the fourth IPCC report [11].

For the RCP scenarios, an elegant but not certainly accurate alternative was adopted, based on the results indicating a relationship between temperature and precipitation changes [8], [9]. Thus, an increase in rainfall amounts of 3%/1^{o}C was adopted for RCP2.6 and RCP4.5 respectively 5%/1^{o}C for RCP6.0 and RCP 8.5.

In the charts of Figure 2 and Figure 3, there are represented optimum, suboptimum and range limits envelopes for the most important species, derived from the literature survey [17], [18], which were confirmed by field observations and thus widely accepted by foresters. For comparison and validation, these envelopes were confronted with results from classical envelope modelling researches. Some examples were included in the figures, namely the ‘occurrence envelopes’ for fir, beech, sessile and pedunculate oaks, established in researches undertaken in Bavaria [6], [7]. Obviously, for consistency, these envelopes were also represented in the form of rectangles, encompassing the original ones with irregular shapes (the extension of the envelopes in one dimension -temperature or rainfall- is naturally variable).

By analysing the charts, it is possible to observe the position of a certain location in the present climate and in various future periods, affected by climate changes. For spruce (Figure 2 a), the Păltiniş site could downgrade from the optimum status at the end of the century, while those from upper areas (Rarău and Parâng) are “waiting” for those optimum climate conditions. The Gheorghieni area, presently at the lower precipitation range limit, could end over the upper temperature sill etc. The silver fir stands, from Prahova Valley, taken into study (Figure 2 b), would remain within the suboptimum envelope, with the Predeal climate conditions closer to the optimum ones at the middle of this century (for A1B and RCP 4.0 scenarios) and the Sinaia site “leaving” the optimum envelope (in the 2180-2199 period for A1B and in 2081-2100 for RCP 8.5). As regards the European beech stands, considered as examples in this study (Figure 2 c), these are presently situated in optimum climate conditions, but their environmental conditions would be considerably altered if having the IPCC climate changes predictions confirmed, with the mountain Rucăr site outside the suboptimum envelope, and the C. Muscel one, located at lower altitude, at the southern bottom of the Carpathian Mountains, in conditions beyond the range limits niche.

Various oak species (Figure 3), in lower areas, show a higher vulnerability but those and especially the xerophilous oaks (Figure 3 c), namely pubescent oak (*Quercus pubescens*) and gray oak (*Quercus* *pedunculiflora*) represent a valuable resource, in the context of the drying trend, already reported in many regions where also a future enhancement of this phenomenon is expected. The locations of the sessile oak populations considered (Figure 3 a) are presently within the optimum envelope (Ocna Şugatag and Rm. Vâlcea) or very close to it (Tg. Neamt and Strehaia) but in the end, these would be outside the suboptimum niche and even close to the occurrence envelope border (Rm. Vâlcea, at the end of next century for A1B and even in 2100 for RCP 8.6 when also Strehaia will be in a similar situation). The IPCC scenarios projections are even more threatening for the studied pedunculate oak forests (Figure 3 b), nowadays in the suboptimum range (even at the optimum threshold, at Găeşti) and predicted to go outside the occurrence envelope etc.

4. Conclusions

This paper presents a very simple approach, useful for those interested in a quick analysis of the climate change impacts on a particular site, especially for passionate foresters worried for the future of the stands they are looking after. The advanced researches on these extremely complex topics require much more effort and time for an increased accuracy in envelope modelling.

In addition to range shifts, the expected impacts of climate changes on forest ecosystems are also concerning trees and stands growth (in a warmer and dryer climate, productivity is expected to increase in the mountains and near the upper limit of a certain species range, and to decrease in lower sites, respectively), phenology, abiotic (windthrows, fires) and biotic hazards (pests, diseases) etc.

For studying the impacts of climate changes on forests, detailed scenarios, at regional or local scales, are required and these could be obtained, from the large scale datasets, provided by the global climate models (GCM), by using various downscaling techniques [13]. Furthermore, the forest management decision making process requires data for the stand level and consequently, the local climate conditions (modified on the mountain and hill slopes by aspect, inclination, shading etc.) have to be considered [12], [14].

References

1. Berry P.M., Dawson T.P., Harrison P.A., Pearson R.G., 2002. Modelling potential impacts of climate change on the bioclimatic envelope of species in Britain and Ireland. Global Ecology and Biogeography, No.11, p.453–462.
2. Huntley B., Green R.E. et al., 2004 The performance of models relating species geographical distributions to climate is independent of trophic level. Ecology Letters, No.7, p.417–426.
3. Chiriță C. (ed.), 1981. Romania's Forests (in Romanian). Editura Academiei, Bucureşti.
4. Stocker T. F., et al (eds.), 2013. IPCC: Climate Change 2013: The Physical Science Basis. Cambridge University Press, Cambridge, UK and New York, USA, pp. 1535.
5. Field C.B., et al (eds.), 2014. IPCC: Climate Change 2014: Summary for policymakers. Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge and New York, p. 1-32.
6. Kölling C., Bachmann M., Falk W., Grünert S., Schaller R., Tretter S., Wilhelm G., 2009. Klima-Risikokarten für heute und morgen. Der klimagerechte Waldumbau bekommt vorläufige Planungsunterlagen. AFZ/ Der Wald, No.64, p.806 – 810.

7. Kölling C., Dietz E., Falk W., Mellert K.-H., 2009. Provisorische Klima-Risikokarten als Planungshilfe für den klimagerechten Waldumbau in Bayern. Forst und Holz, 64 H. 7/8 64, p. 40–47.
8. Lambert F. H., Webb M. J., 2008. Dependency of global mean precipitation on surface temperature. Geophysical Research Letters, p.35, L23803.
9. Lu J., Cai M., 2009. Stabilization of the atmospheric boundary layer and the muted global hydrological cycle response to global warming. J. Hydrometeor, No.10, p.347-352.
10. Lucht W., Schaphoff S., et al., 2006. Terrestrial vegetation redistribution and carbon balance under climate change. Carbon Balance Management, No.1, p.1-6.
11. Meehl G.A., et al., 2007. Global Climate Projections. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.
12. Păcurar V.D., Nicolescu N.V., Crişan V.E., 2009. Air Temperature Spatial Variation Modelling-A Prerequisite for Modern Mountain Forestry in a Changing Environment. Revista Pădurilor, No.6, p.17-21.
13. Păcurar V.D., 2008. Climate Change Local Scenarios for Braşov Area Established by Statistical Downscaling. Bulletin of the Transilvania University, Braşov, vol.15(50), p.25-28.
14. Păcurar V.D., 2010. Spatial Distribution of Some Climate Parameters in Brasov Mountains for Different Climate Change Scenarios. Bulletin of the Transilvania University, Braşov, vol.3. (52), p.79-82.
15. Parmesan C., Yohe G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature, No.421, p.37–42.
16. Pearson R.G., Dawson T.P., Berry P.M., Harrison P.A., 2002. SPECIES: a spatial evaluation threats to plant diversity in Europe. Ecological Modelling, No. 154, p.289–300.
17. Stănescu V., Şofletea N., Popescu O., 1997. Romania's Woody Forest Flora (in Romanian). Editura Ceres, Bucuresti.
18. Şofletea N., Curtu L.A., 2007. Dendrology (in Romanian). Transilvania University Publishing House, Braşov.
19. Thuiller W., Lavorel S. et al., 2005. Climate change threats to plant diversity in Europe. Proceedings of the National Academy of Sciences, No. 102, p.8245–8250.