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Spatial variability of coniferous species radial growth in Moldovita River Basin

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Abstract. Ecological distribution study of forest species has a major importance for a better understanding of the relationship between forest vegetation and the climate`s complex actions. This study highlights spatial segregation of coniferous species diameter increment situated in the area of Moldovita River Basin. A network of dendrochronological series was accomplished, composed of 4 silver fir (*Abies alba*) series, 3 Norway spruce (*Picea abies*) series, 2 Scots pine (*Pinus sylvestris*) series and 2 European larch (*Larix decidua*) series. There have been taken 480 samples of radial growth from 240 trees. All individual radial growth series were standardized using the 67% spline function. Four patterns of radial growth were pointed out, as well as 4 types of dendroclimatological response appropriate to the 4 coniferous species from Moldovita River Basin. The analysis of the 4 types of dendroclimatological response will bring new information in the field of climatology, of the trees growth processes, as well as of the knowledge of climatic changes impact on forest ecosystems.
Key Words: coniferous trees, radial increment, climate, correlation.

Rezumat. Studiul zonării ecologice a speciilor forestiere are o importanță deosebită pentru o înţelegere mai profundă a relaţiei dintre vegetaţia forestieră şi acţiunile complexe ale climei. Acest studiu scoate în evidenţă segregarea spaţială a creşterii în diametru a arborilor de răşinoase localizaţi în zona bazinului râului Moldoviţa. A fost realizată o reţea de serii dendrocronologice constituită din 4 serii de brad, 3 serii de molid, 2 serii de pin silvestru şi 2 serii de larice. Au fost prelevate 480 probe de creştere radială de la un număr total de 240 de arbori. Toate seriile de creştere individuale au fost standardizate folosindu-se funcţia spline cu o frecvenţă de 67%. Au fost evidenţiate 4 modele de creştere radială, precum şi 4 tipuri de răspuns dendroclimatic corespunzătoare celor 4 specii de răşinoase din bazinul râului Moldoviţa. Analiza celor 4 tipuri de răspuns dendroclimatic va aduce informaţii noi în domeniul climatologiei, a proceselor de creştere a arborilor, precum şi a cunoaşterii impactului modificărilor climatice asupra ecosistemelor forestiere.
Cuvinte cheie: specii de răşinoase, creştere în diametru, climă, corelaţie.

Introduction. In mild areas, the annual interchange of the seasons has climatic effects, strong enough to cause a regular inactivity in trees growth (Schweingruber 1996).

The annual variation of limitative environment conditions for trees growth, both during and before annual rings formation, is incised like an annual variation of trees annual rings structure. The annual growth of trees' annual rings is easy to be measured and it inclines to reflect general environment conditions for a tree (Cook & Kairiukstis 1990).

The tree writes in a distinctive language its own history. It marks on the blaze, not only the years, but also time's condition. It says that the tree is a dedicated historian of times gone by (Giurgiu 1977).

The network of dendrochronological series represent the base of climate's space-time variability analysis, offering fundamental information concerning climatic changes (Schweingruber 1985).

Dendrochronology, both through dendrochronological series and particularly through spatial spread response functions to climatic factors, offers conclusive instruments in ecological zoning of forest vegetation (Schweingruber 1996).

The main purpose of this study is spatial spread analysis of radial growth of coniferous species (silver fir - *Abies alba*, Norway spruce - *Picea abies*, Scots pine - *Pinus sylvestris*, and European larch - *Larix decidua*) from Moldovita River Basin.

Material and Method. The study site is represented by forest ecosystems of silver fir, Norway spruce, Scots pine and European larch from Moldovita River Basin (Figure 1). Researches have been done in 2 experimental areas for both Scots pine and European larch, in 4 experimental areas for silver fir and in 3 experimental areas for Norway spruce, spread relatively equally along Moldovita River Basin (Table 1 and Figure 1).

Table 1

Geographical characteristics of experimental sample areas

No	*Code series*	*Forest unit*	*Forestry district*	*Species*	*Altitude (m)-exposition*	*Latitude*	*Longitude*
1	SF1	17 c	Vama	CF	735-980	47°39'	25°33'
2	SF2	91 a	Vama	CF	980-1120	47°38'	25°29'
3	SF3	205 a	Moldoviţa	CF	990-1235	47°34'	25°34'
4	SF4	41 b	Vama	CF	880-1150	47°44'	25°20'
5	NS1	205 a	Moldoviţa	NS	990-1235	47°34'	25°34'
6	NS2	41 b	Vama	NS	880-1150	47°44'	25°20'
7	NS3	301 f	Moldoviţa	NS	875-1100	47°44'	25°34'
8	SP1	143 b	Moldoviţa	SP	1200-1350	47°41'	25°22'
9	SP2	401	Moldoviţa	SP	820-900	47°44'	25°36'
10	EL1	216 c	Moldoviţa	EL	1050-1180	47°46'	25°21'
11	EL2	41 b	Vama	EL	1000-1150	47°35'	25°30'

CF - Silver fir; NS - Norway spruce; SP – Scots pine; EL - European larch.

There were chosen in each experimental area, according to dendrochronological criteria (Fritts 1976; Cook & Kairiukstis 1990; Popa 2004), 20-25 trees and from each of them two increment samples at 1.30 meters were taken. The increment cores were taken using Pressler drill. These cores were carried and preserved in special paper tubes, so that they would dry slowly. After drying, increment samples were fixed on special wood holders. The measuring of annual rings width was done with CooRecorder 7.4 software. The increment series were interdated using TsapWin software and COFECHA software (Holmes 1983; Cook et al 1997).

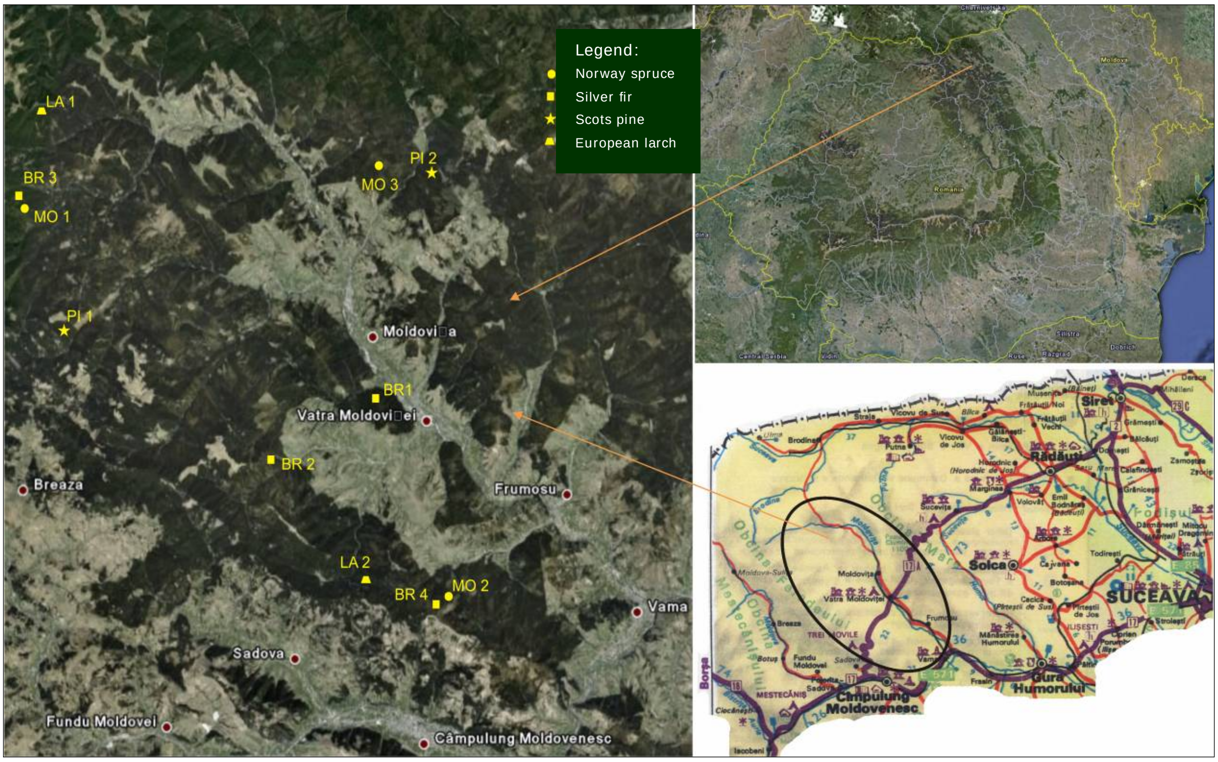

Figure 1. The study sites (http://www.google.com/earth/).

All individual radial growth series were standardized to eliminate non-climatic influence and to obtain the maximum of climatic information from dendrochronological series. For that 67% spline function was used (Sidor 2011). It was used ARSTANwin software (Cook & Krusic 2006). The residual dendrochronological series were used due to the fact that autocorrelation is cut out from the obtained index series.

To analyze spatial variability of dendrochronological series, a complex statistic instrument was used, respectively the analysis of principal components. The evaluations were done with Statistic 8 software. The analysis of principal components is a statistic method to reduce the variables to a number of coefficients that explains most of variability, being able to mark out the type of stratum of dendrochronological series related with the response to climatic parameters transformation (Sidor 2011). Using this method to analyze dendrochronological series, an elaborated statistic analysis to highlight the potential differences between dendrochronological series was possible. Also, to obtain statistic the degree of similarity between the analyzed increment series, Pearson correlation coefficient was calculated and insetted into the analysis. The correlation coefficient measures the relative version which is common to the two sets of data (Giurgiu 1972). Regarding the analyzed period, it was studied the 1901-2011 period, which is common to all analyzed series.

Results and Discussion. The analysis in the first two principal components and of correlation coefficient was accomplished at regional level, all elaborated radial growth series being introduced in the statistic evaluation. The series distribution at areal line is given in Figure 2.

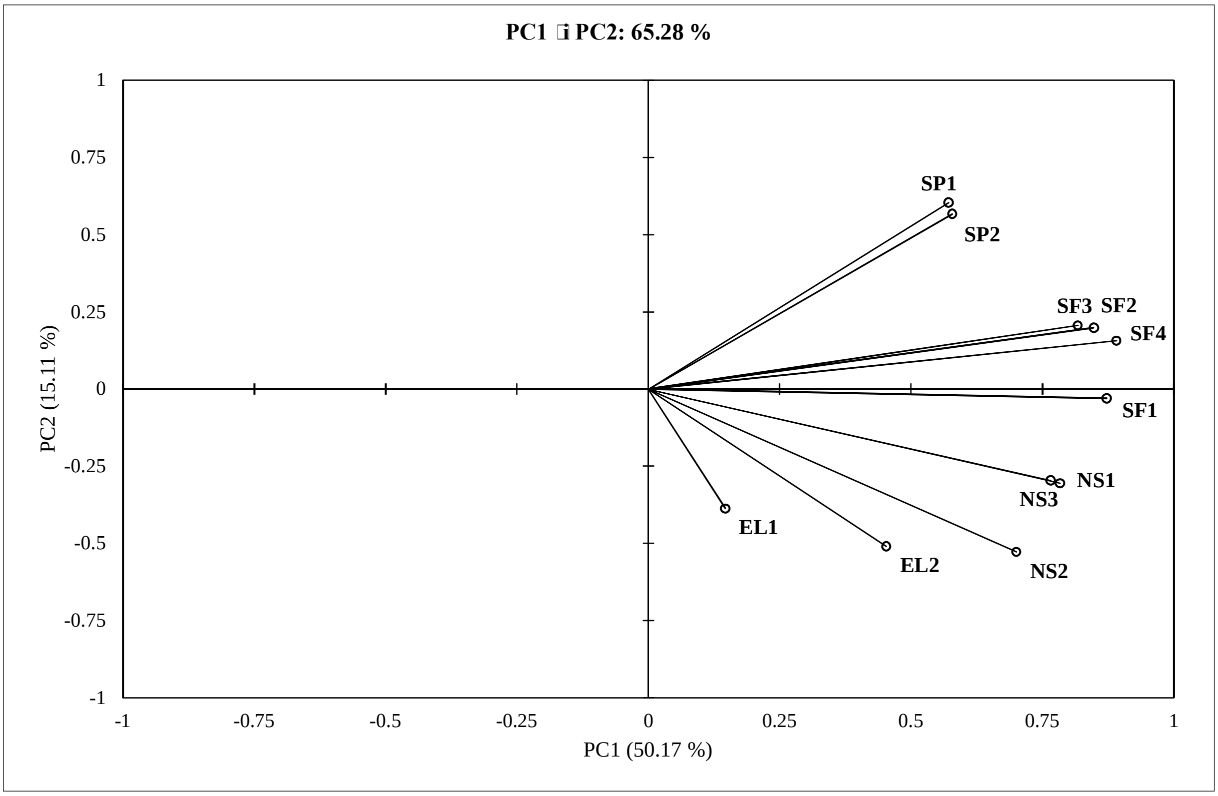

Figure 2. The analysis in the first two principal components of diameter increment series from Moldovita River Basin.

Analyzing Figure 2, definite spatial segregation of diameter increment series according to species can be noticed. The first principal component explains 50.17% of variability, and the second 15.11%. The first principal component represents the climatic response common to all increment indices series, and the second one achieves the interspecific specialization. The existence of 4 models of radial growth according to each species can be noticed. For the same study area 4 types of dendroclimatic response according to the

4 coniferous species were highlighted (Plaiu 2013). Considering the uniformity of the 4 highlighted types of radial growth, there were elaborated regional series for each and every species. Thus, the areal curves of mean radial growth which were elaborated are presented in Figure 3 and the regional series of radial growth indices in Figure 4.

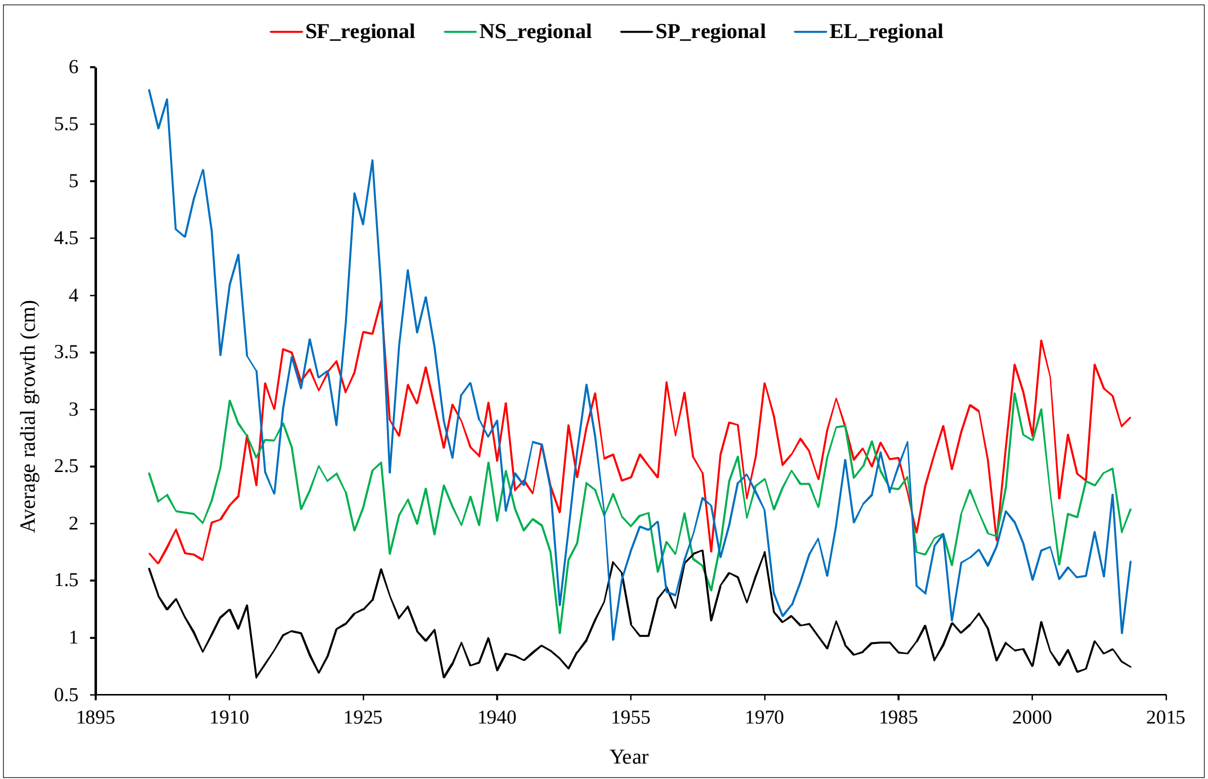

Figure 3. The regional curves of mean radial growth.

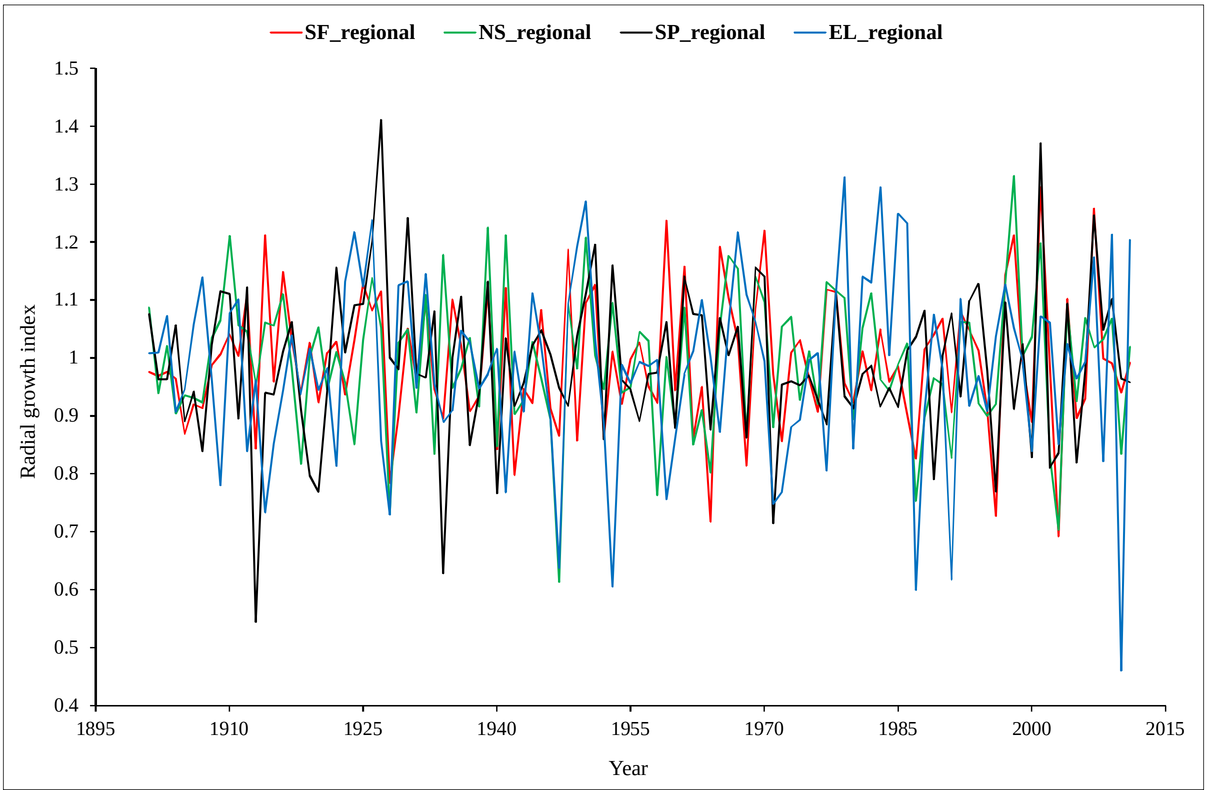

Figure 4. The regional series of radial growth indices.

In order to completely highlight the differences between radial growth at species level, there were analyzed Pearson correlation coefficients among all analyzed series (Figure 5), the analysis in the first two principal components of regional series (Figure 6) and the chart of Pearson correlation coefficients among regional series (Figure 7) were pointed out.

The tendency of silver fir radial growth is the closest to the one of Norway spruce and to Scots pine, the correlation coefficient between regional series of silver fir and the one of Norway spruce and Scots pine, having significant and high values, respectively 0.632 and 0.535.

The highest correlation is between silver fir first series with Norway spruce third series (0.656) and Norway spruce second series (0.603). A high correlation can be noticed also between Norway spruce first series and all silver fir series (the values of correlation coefficients are beyond 0.500 in all cases). The same acknowledgment is also valid between silver fir fourth series and all Norway spruce series.

Regarding the correlation between silver fir series with the ones of Scots pine, the highest correlation is between silver fir third series and Scots pine first series (0.545). The Scots pine series have values of correlation coefficient beyond 0.450 with all silver fir series, except for the silver fir first series.

The radial growth pattern of Norway spruce is the closest to the one of the silver fir while between Scots pine and European larch, the tendency of diameter increment is closer to the one of the European larch. The highest correlation is between the second series Norway spruce and European larch (0.435).

Mentionable is also the fact that European larch second series presents values of correlation coefficients beyond 0.300 with all Norway spruce series.

Concerning the correlation between Norway spruce and Scots pine, the highest correlation is between Scots pine second series and Norway spruce first series (0.337). Otherwise, a high correlation is also between Scots pine first series and the first and third Norway spruce series (with values of correlation coefficient close to 0.300).

In regard to the comparison between radial growth of European larch and the one of Scots pine, the analysis of correlation coefficient and of the first two principal components relieves the fact that they present significant distinctions, the correlation coefficient, both between series and at regional level, being insignificant, with low values, close to 0.

Variables	SF1	SF2	SF3	SF4	NS1	NS2	NS3	SP1	SP2	EL1	EL2
SF1	1	0.792	0.638	0.835	0.571	0.603	0.656	0.36	0.418	-0.006	0.411
SF2	0.792	1	0.743	0.861	0.512	0.442	0.517	0.479	0.452	-0.013	0.277
SF3	0.638	0.743	1	0.774	0.578	0.404	0.476	0.545	0.472	0.136	0.249
SF4	0.835	0.861	0.774	1	0.541	0.54	0.531	0.512	0.483	0.015	0.336
NS1	0.571	0.512	0.578	0.541	1	0.729	0.748	0.314	0.337	0.197	0.37
NS2	0.603	0.442	0.404	0.54	0.729	1	0.702	0.053	0.163	0.153	0.435
NS3	0.656	0.517	0.476	0.531	0.748	0.702	1	0.292	0.311	0.137	0.316
SP1	0.36	0.479	0.545	0.512	0.314	0.053	0.292	1	0.712	0.111	0.056
SP2	0.418	0.452	0.472	0.483	0.337	0.163	0.311	0.712	1	-0.025	0.065
EL1	-0.006	-0.013	0.136	0.015	0.197	0.153	0.137	0.111	-0.025	1	0.305
EL2	0.411	0.277	0.249	0.336	0.37	0.435	0.316	0.056	0.065	0.305	1

0.3 0.5 0.7 0.9 1.0

Figure 5. Pearson correlation coefficients between series of radial growth residual indices.

Variables	SF_regional	NS_regional	SP_regional	EL_regional
SF_regional	1	0.632	0.535	0.142
NS_regional	0.632	1	0.283	0.324
SP_regional	0.535	0.283	1	0.071
EL_regional	0.142	0.324	0.071	1

0.3 0.5 0.7 0.9 1.0

Figure 6. Pearson correlation coefficients between regional series of growth indices.

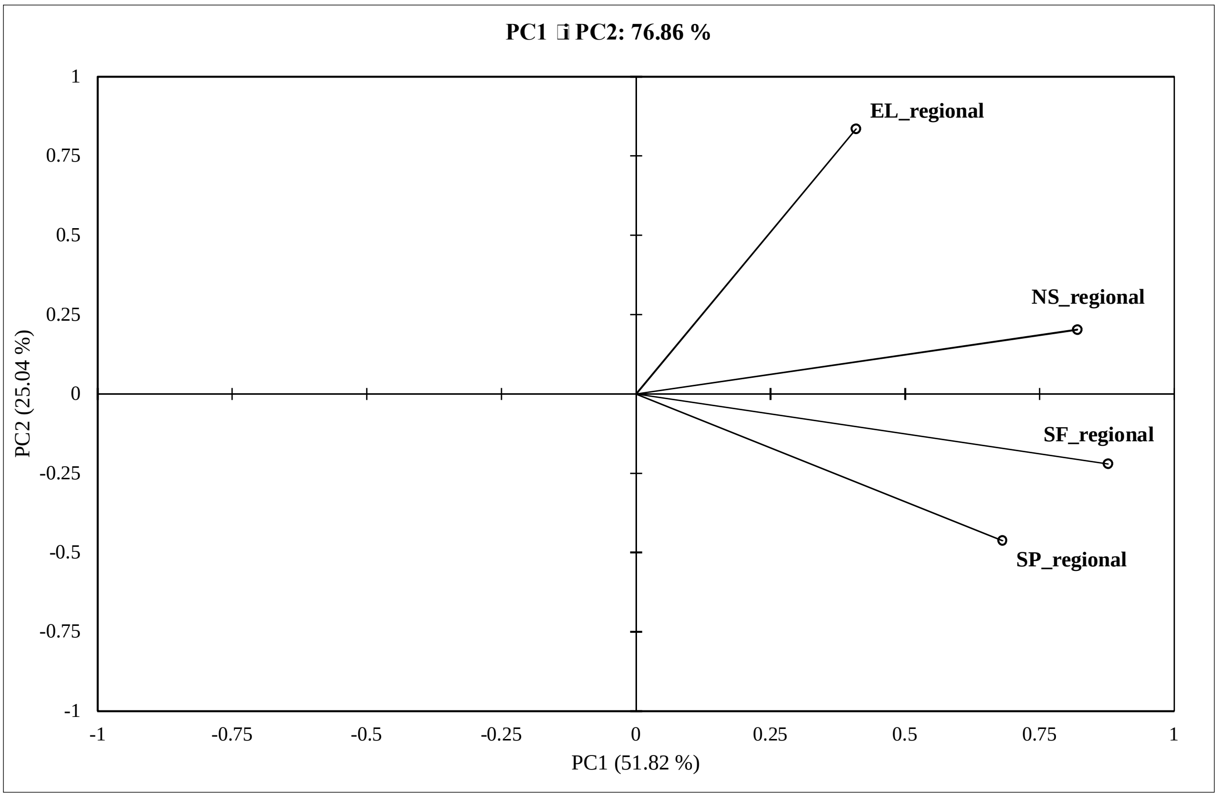

Figure 7. The analysis in the first two principal components of diameter increment regional series from Moldovita River Basin.

Conclusions. The analysis made at regional level highlighted 4 models of radial growth, as well as 4 types of dendroclimatic response according to the 4 coniferous species from Moldovita River Basin. Furthermore, there were also pointed out comparatively the similarities between radial growth of the four coniferous species. The analysis of the four types of dendroclimatic response will bring new information in the field of climatology, of the trees growth processes, as well as of the knowledge of climatic changes impact on forest ecosystems.

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