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Forest vegetation in the upper Iara basin. Considerations on plants diversity

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Abstract. Forests cover important areas in Romania, but are poorly investigated from a biological point of view. Forestry studies are focused on economic productivity, while biological studies have focused on phytosociological descriptions. Biodiversity measures have been rarely used in Romania to describe forest environments. This study is an attempt to link classical biologic forest studies with more modern statistical methods of investigation. The diversity of 65 forest relevées from the upper Iara basin is measured using the Shannon index. The values are plotted on a map, in order to assess the spatial distribution of forest diversity. The average of Ellenberg indicator values is calculated for each relevée and used to describe the spatial distribution of each forest association in a CCA plot. Finally, an optimized regression is made between Shannon diversity and the environmental variables (Ellenberg values, altitude, exposition, slope). The results of this analysis may help us understand which physical locations harbor the highest diversity, and are more important to protect from deforestation. The floristic analysis reveals that all forest types are important, even those with low Shannon diversity, as they may be the habitat for certain valuable species.

Key Words: Iara basin, spruce forests, mixed forests, biodiversity, Shannon index, regression.

Rezumat. Pădurile se întind pe suprafețe importante în Romania, dar sunt destul de puțin investigate de către biologi. Studiile silvice sunt axate pe productivitatea economică, în timp ce studiile de biologie s-au focalizat pe descrierea asociațiilor identificate. Măsurători ale biodiversității pădurilor sunt rare în literatura din România. Acest studiu reprezintă o încercare de a folosi baza studiilor clasice în analize statistice moderne. Diversitatea a 65 de relevee din păduri aflate în bazinul superior al Ierii este măsurată folosind indicele Shannon. Valorile sunt dispuse pe hartă, pentru a analiza distribuția spațială a diversității acestor păduri. Pentru fiecare releveu a fost calculată o medie a indicilor Ellenberg, folositoare pentru a descrie nișa diferitelor asociații de păduri într-un grafic CCA. În final, s-a executat o regresie optimizată între diversitatea Shannon și variabilele de mediu (valorile Ellenberg, altitudinea, expoziția, panta). Rezultatele acestor analize ne pot ajuta să identificăm locațiile de interes din punct de vedere al diversității, care sunt mai important de protejat împotriva defrișărilor. Analiza floristică dovedește că toate tipurile de pădure sunt importante, chiar și cele cu diversitate Shannon redusă, deoarece pot reprezenta habitate pentru diferite specii de interes.

Cuvinte cheie: bazinul Ierii, păduri de molid, păduri de amestec, biodiversitate, indicele Shannon, regresie.

Introduction. As noted by Newton (2007), forests are very important for economical exploitation, reason for which they are subject to specific laws and regulations, in a very different manner compared to other types of vegetation. Access inside large forests which lack tourist trails is difficult, and largely relies on forestry personnel, which are not trained to identify plant species, and do not use phytosociological instruments to describe their findings. Thus, large areas covered with forest vegetation in Romania are not investigated yet by biologists or ecologists.

The upper Iara basin is one of these areas. There are only a couple of papers on forest investigations near the Iara basin. The first phytosociological investigation near the study area was conducted by Csürös Kaptalan & Csürös. In their paper from 1968, they published two relevées located in the upper Iara basin, namely in the spruce forests from the eastern and southern slopes of the Buscat peak (1676 m). The main focus of their study was the description of vegetation near the chalet from Mt. Băișorii (1350 m), and the article has mostly data on the spruce and beech forests in that area. Nearby, at the lower altitudes of the Gilău Mountains, there is another study regarding forests, by Hodișan & Pop (1970), focusing on the Someșul Rece Valley. Some floristic investigations were also carried out in the Iara basin by Al. Marcu, with contributions to the Herbarium in Cluj. Marcu focused his research on the middle and lower Iara basin, with rare investigations in the upper basin, and unfortunately did not publish any of his findings.

Even more problematic is the general lack of literature data on plant diversity and species richness. The notion of biodiversity is considered to be important for more than two decades, and represents a key concept in nature conservation. However, its spread - from species diversity to ecosystem and genetic diversity - is so vast that there is a risk that it may loose meaning – as Hurlbert stated as early as 1971-, and become a synonym with the concept of life itself (Perlman & Adelson 1997). Lack of precise measurements for biodiversity in ecology papers contributes to this predicament. In this context, even if diversity indices have been criticized for being an expression of entropy rather than diversity (Jost 2006), they are still valuable to use, more valuable than simple richness counts, as they take into consideration both species richness and dominance (Cristea et al 2004). Very few articles in Romanian literature have used the Shannon index to describe diversity (Coldea & Cristea 1998).

Material and Method. The studied forest vegetation is located in the upper Iara basin ($46^0$14′ – $46^0$29′ lat. N / $23^0$11′ – $23^0$17′ long. E), between 850 – 1700 m (a.s.l.). Iara springs in multiple locations under the ridge between the Buscat peak (1676 m) and Muntele Mare peak (1824 m), its main course flowing towards the North-East.

The geological substrate in the upper basin is acid, with volcanic rocks near the Muntele Mare peak and crystalline schists in the valley. Soils also lack variety, and most of them are brown acid or lithosoils.

The study area is about 70 km^2, approximately two thirds of it being covered by forests. In the period 2006-2010, 113 relevées were executed in the woody vegetation, using the method described by Braun-Blanquet, with Alexandru Borza's additions for the Romanian landscape. The size of each relevée is constant, 400 m^2, allowing diversity comparisons to be made (Cristea et al 2004).

The objective of the study was to describe the flora and vegetation of the study area, as we have seen that literature data was scarce, and also to investigate diversity (using indices described in the literature), the relation between diversity and environmental variables, as well as to compare the mathematical and floristic aspect of diversity.

65 Forest relevées for which there was no doubt on their phytosociological classification were selected for further investigations. They totalized 185 species (using the taxonomical system described by Ciocârlan 2009), and were attributed to 6 associations, 3 alliances, 2 orders and 2 classes of vegetation (Coldea 1991).

Diversity was calculated replacing the coverage notes of the Braun-Blanquet scale (+, 1, 2, 3, 4, 5) with the mean value of the corresponding percentage class (0.5, 5.5, 17.5, 37.5, 62.5, 87.5), followed by a computation of Shannon's diversity (Shannon 1948) with the help of Past software (Hammer et al 2001). Shannon index was used as Jost (2006, p. 364) still recommends its use, with the exception of inference of statistically significant differences between groups. In the latter situation, Jost recommends that the Shannon index be transformed using the formula $e^{Shannon}$. The transformed values correlate strongly with the simple Shannon values (r^2=0.93), the advantage in their use being limited to the inference of statistically significant difference, as stated above. As this analysis was not considered in this paper, we considered simple Shannon index values to be sufficient.

The spatial distribution of Shannon diversity was investigated by plotting the Shannon index values on a map (Figure 3), using Google Earth software (Google Inc., 2009) and the free plug-in GE-Graph 2.2.

Floristic value was assessed using the existing red lists (LR1 - Boșcaiu et al 1994; LR2 - Ciocârlan 1999; LR3 - Dihoru & Dihoru 1994; LR4 - Moldovan et al 1984; LR5 - Oltean et al 1994), as well as Flora Europaea data on taxa distribution.

Environmental variables were deduced for each relevée using the Ellenberg indicator values (Ellenberg 1992). An average of Ellenberg values was calculated for each relevée. Not all 185 species have Ellenberg indicator values described in the literature, but the analysis was considered to be useful, as dominant species are more important and their Ellenberg indicator values are known. Ellenberg indices were proved by literature to be quite reliable (Schaffers & Sykora 2000). A CCA analysis was performed using these values, as well as values on diversity, altitude, exposition and slope, and as a result, the relevées were plotted in a multi-dimensional space, useful for highlighting the environmental preferences of the forest associations in the study area, in a similar way to the method exposed by Coldea et al (2008). Exposition values were transformed into semiquantitative values (values in the interval 0-2) using the formula:

(COS(RADIANS(45))*COS(RADIANS(exp)))+(SIN(RADIANS(45))*SIN(RADIANS(exp)))+ 1, where "exp" is the exposition of each relevee (from 0 to 360 degrees).

The CCA analysis was performed using R software (R Development Core Team, 2005), the package "vegan".

A multiple regression was also executed in R (vegan package) to determine which of the variables mentioned above explain more of the variation in Shannon diversity. In order to investigate non-linear relations each environmental variable was considered also in a squared form. The regression model was then optimized by stepwise regression (in both directions), and as a result the number of variables taken into consideration was reduced.

Results and Discussion. The forest associations found in the study area are: *Hieracio rotundati-Piceetum*, *Leucanthemo waldsteinii-Piceetum*, *Soldanello-Piceetum* from the alliance *Piceion abietis*; *Pulmonario rubrae-Fagetum*, *Leucanthemo waldsteinii-Fagetum* from the alliance *Symphyto-Fagion* and the association *Telekio speciosae-Alnetum incanae* from the alliance *Alno-Ulmion*.

Spruce forests (alliance *Piceion abietis*):

A) Forests from the association *Soldanello-Piceetum* are pure spruce forests from high altitudes characterized by the presence of *Soldanella major* (syn. *S. oreodoxa*). These forests are located on the large shoulders of the ridges in the studied area. Their position on the altitudinal gradient can be observed in the CCA plot (Figure 1). In general, these forests have fewer species, and a reduced Shannon index value (Table 1).

B) The low diversity and number of species is also a characteristic of the association *Hieracio rotundati-Piceetum*. These forests cover the largest part of the upper Iara basin, dominating the middle of the slopes in the lower part, and the entire slope in the upper part, except for the ridges – occupied by *Soldanello-Piceetum* forests. They are located in the CCA plot based on their preference for inclined slopes (average slope 28.16 ± 7.3 degrees, as can be seen in Table 1).

C) Norway spruce forests from the association *Leucanthemo waldsteinii – Piceetum* appear sporadically on the tributary rivulets or on the main valley, in humid conditions. They are characterized by the presence of species from the order *Adenostyletalia* (e.g.: *Chaerophyllum hirsutum, Doronicum austriacum, Stellaria nemorum, Veratrum album*). These forests have more species and an increased diversity, as seen by their location in the CCA plot between the high humidity and diversity vectors.

Mixed forests (alliance *Symphyto-Fagion*):

D) Mixed forests from the association *Pulmonario rubrae – Fagetum* appear between 850 and 1200 m a.s.l., mostly in the inferior part of the slopes, up to the middle of the study area (near Bundureasa lake). The distribution of these forests is limited by altitude, as beech is abundant only in relatively warm conditions. As altitude increases, beech is more and more scarce, while in the floristic structure of the forest, species from the order *Fagetalia* are replaced by species from the alliance *Soldanello-Piceion*. In the CCA plot these mixed forests are characterized by the steep slopes they inhabit, and also by the less acidic reaction of their soils (probably due to the litter layer formed by beech leafs).

E) Mixed forests from the association *Leucanthemo waldsteinii-Fagetum* have been identified in only a few locations from the lower part of the study area, between 850 and 1100 m a.s.l. They are located on the steep valleys of various tributaries, and are characterized by the presence of beech and spruce in the woody layer and *Leucanthemum waldsteinii* and other *Adenostyletalia* species in the herbaceous layer.

Mixed forests with spruce and beech from both associations mentioned above have higher average number of species per relevée, and higher diversity (Table 2).

Table 1

Eigenvalues & proportion explained by the CCA axes

	CCA1	CCA2	CCA3	CCA4	CCA5	CCA6	CCA7
Eigenvalue	0.408	0.347	0.162	0.1332	0.1219	0.0985	0.088
Proportion Explained	0.266	0.226	0.106	0.0868	0.0794	0.0642	0.0573
Cumulative Proportion	0.266	0.491	0.597	0.6837	0.7631	0.8273	0.8846

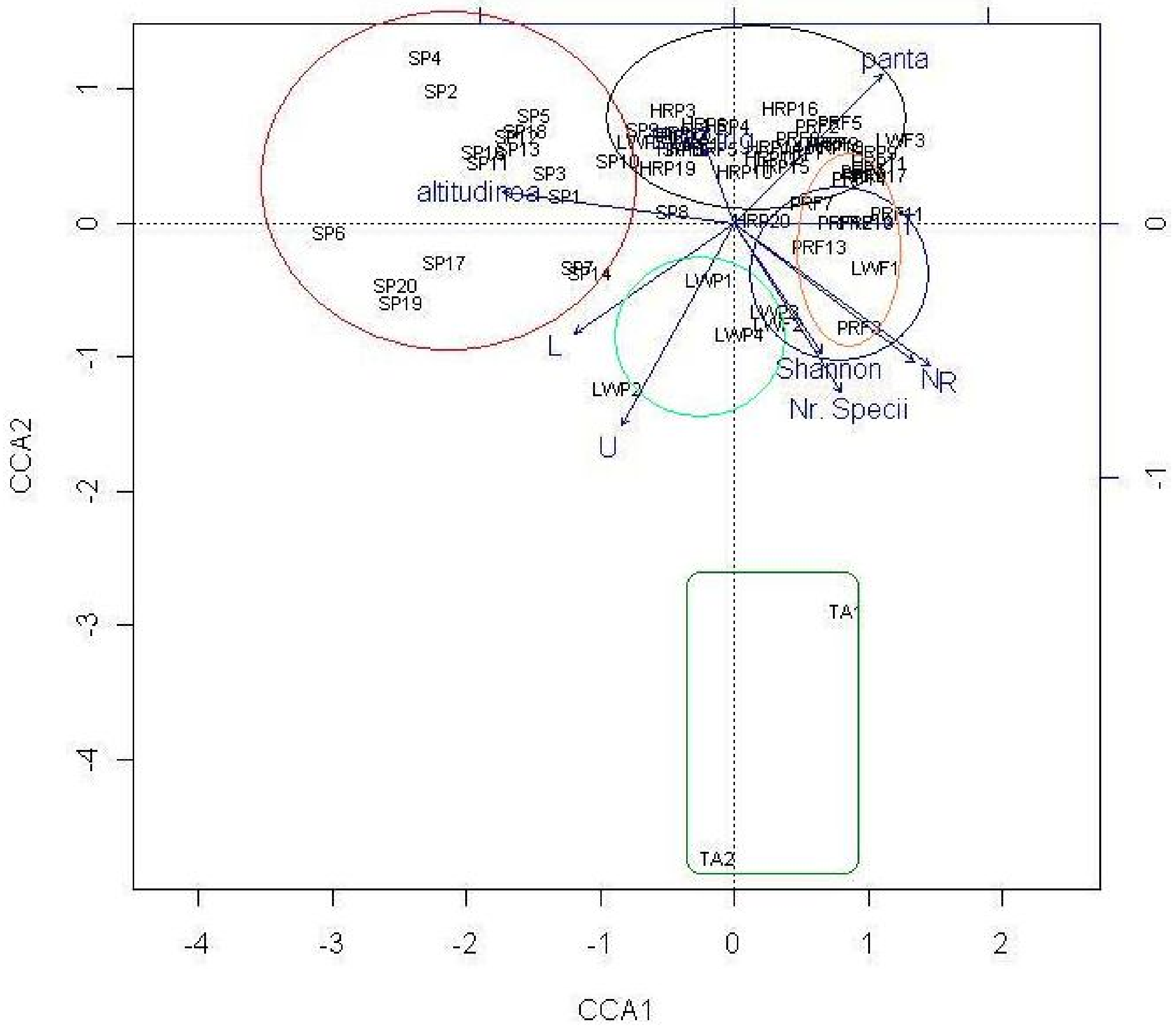

Figure 1. Ordinogram of the 65 relevées in the space determined by the first two CCA axes, according to the variables taken into consideration (the average values of Ellenberg indicators for light (L), humidity (U), temperature (T), soil reaction (R) and preference to nitrogen in the soil (N), as well as exposition (exp), altitude (altitudinea), no. of species (Nr. Specii), slope (panta) and Shannon index; SP – *Soldanello-Piceetum*, HP – *Hieracio*

rotundati-Piceetum, LWP – *Leucanthemo waldsteinii-Piceetum*, PRF – *Pulmonario rubrae-Fagetum*, LWF – *Leucanthemo waldsteinii-Fagetum*, TA – *Telekio-Alnetum*)

Table 2

Comparison between the main characteristics of the forest associations in the upper Iara basin

No.	Association	No. Rel.	Average altitude (m)	Average slope (degrees)	Total No. of sp.	Average sp./ relevée	Average Shannon Index	No. of valuable sp.
1	*Soldanello-Piceetum*	20	1540 (± 98.8)	14.25 (±6.74)	81	17.9 (±5.22)	1.58 (±0.3)	7
2	*Hieracio rotundatii-Piceetum*	20	1168 (±136)	28.16 (±7.3)	90	22.57 (±5.26)	1.58 (±0.24)	6
3	*Leucanthemo waldsteinii-Piceetum*	6	1288 (±169.3)	17.50 (±5.24)	70	32 (±9.19)	1.90 (±0.33)	4
4	*Pulmonario rubrae-Fagetum*	14	1011 (±93.84)	30 (±6.79)	95	27.35 (±5.71)	1.92 (±0.34)	5
5	*Leucanthemo waldsteinii-Fagetum*	3	964 (±89.29)	35 (±5)	73	37 (±6.24)	2.12 (±0.19)	6
6	*Telekio-Alnetum*	2	1000 (±141.2)	0	62	38 (±9.89)	2.13 (±0.37)	6
	TOTAL	65	1245 (±245.9)	23.05 (10.71)	185	24.2 (±8.16)	1.72 (±0.34)	

Table 3

Species considered to be valuable (floristic analysis); R- rare, V-vulnerable; LR1 - Boșcaiu et al 1994; LR2 - Ciocârlan 1999; LR3 - Dihoru & Dihoru 1994; LR4 - Moldovan et al 1984; LR5 - Oltean et al 1994

No.	Taxa	Red List	Status	Endemic sp.	Other status
1	*Campanula abietina*				Conv. Berna
2	*Pedicularis limnogena*	LR 3/4/5	R/R/V		
3	*Listera cordata*	LR 1/5	R/R		
4	*Arnica montana*	LR 5	V		
5	*Campanula serrata*			END	
6	*Dentaria glandulosa*			END	
7	*Pulmonaria rubra*			END	
8	*Symphytum cordatum*			END	
9	*Aconitum toxicum*				Carp.-balc.
10	*Ranunculus montanus subsp. psuedomontanus*				Carp.-balc.
11	*Hieracium transsylvanicum*				Carp.-balc.
12	*Telekia speciosa*				Carp.-balc.-cauc.- anat.
13	*Leucanthemum waldsteinii*				Carp. et ex-Iugoslavia
14	*Bruckenthalia spiculifolia*				Carp.-balc.

Alder forests (alliance *Alno-Ulmion*):

F) Along the valley, *Alnus incana* appears sporadically, forming compact phytocoenosis in two locations, where the valley is larger and the soils are more profound. The higher location is at about 1100 m a.s.l., just above the Bundureasa lake, while the lower one is very near to the lowest point of 850 m. a.s.l.. In the CCA plot they are located in a humid niche, characterized also by the highest average number of species per relevée (and highest diversity, as can be seen in Table 2).

Spatial distribution of forest diversity - Figure 2 suggests that there may be a negative correlation between altitude and diversity, as well as a positive one between humidity and diversity.

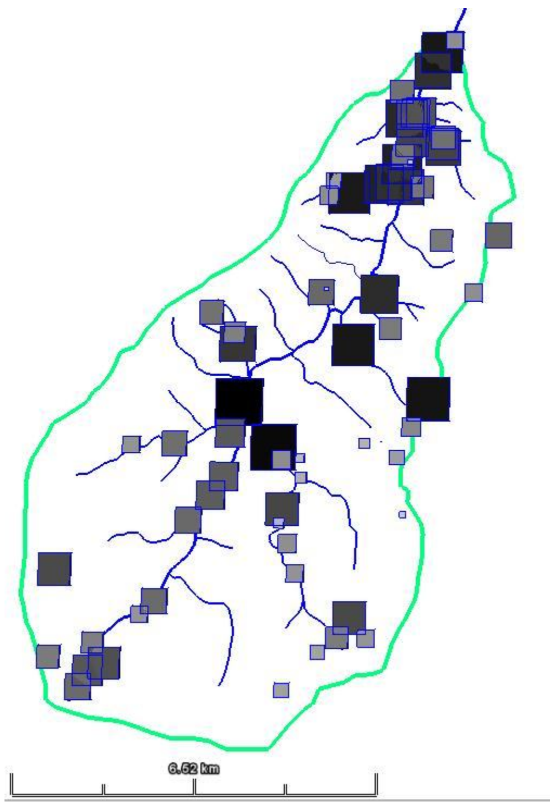

Figure 2. Shannon diversity of forests in the upper Iara basin (more diverse relevées are represented by larger, darker squares; less diverse relevées are represented by smaller, whiter squares)

Multiple regression – the optimized model using stepwise regression in both directions (based on AIC) reveals humidity ($p<0.02$) and slope ($p<0.007$) to be variables that can explain some of the variation in Shannon diversity, but even more, soil reaction ($p<0.0003$).

It is interesting to notice that altitude as a predictor of biodiversity is not considered to be relevant by the regression model, in contrast to the observations based on figure 2. The effect of altitude on forest diversity is probably hidden by that of other variables. The variance of soil reaction in the study area can be quantified in relation to altitude: forests at higher altitudes have more acid substrates, with litter composed only from coniferous needles, while forests at lower altitudes have less acid substrates, with litter made also from deciduous leafs. Another variable, humidity, is also related to altitude: it is more pronounced deep in the valleys, it varies on the slopes (may be high on the tributaries), and is usually reduced on the high ridges (except the bogs near the Muntele Mare peak, which are only in a very small part covered by forests). These two variables (soil reaction and humidity) may explain some of the altitudinal variation observed in the spatial distribution of forest diversity in the upper Iara basin (Figure 2). But not all diverse forests lay in the humid valleys on less acidic substrate, and because of this there isn’t a simple, linear regression between these factors and Shannon diversity.

Slope is another factor to explain the variation in Shannon diversity, but also not in a linear way. Forests have high diversity on flat surfaces (on the bottom of the valley – alder forests, humid spruce forests with *Leucanthemum waldsteinii*), but also on slopes which are quite steep (such is usually the case of mixed forests, with *Leucanthemum waldsteinii* or *Pulmonaria rubra* – Table 2).

On the contrary, pure spruce forests with *Hieracium rotundatum*, also found on steep slopes, have smaller Shannon diversity values, probably due to their more acidic, shallower substrate. Spruce forests with *Soldanella oreodoxa* found on the gently inclined ridges are also poor in species and have reduced diversity (due to soil reaction), in contrast to the diverse forests on flat ground in the bottom of the valley.

The non linear variance of this slope-diversity relation is reflected in the optimized model.

Floristic considerations: Analyzing the number of valuable species from Table 3, we can see why diversity analysis based on the Shannon index or any other diversity index need to be doubled by floristic analysis. Environmental variables that determine Shannon diversity may help us determine which physical locations are more important to be safeguarded from deforestation, in order to protect more species. However, forests with reduced diversity are also important for protection, as they may represent the habitat for certain species of interest not found inside the richer forests. In this regard (Table 3), there is no clear difference between the various forest associations. The less diverse forest associations harbor just as many species of interest.

Conclusions. It would be useful to implement these findings into forestry practices from the study area. Forests from humid locations, and those on tributary valleys should be harvested more carefully, and impact caused by nearby exploitations should be limited. Also, it is useful to keep intact patches from all types of forests, at varied altitudes, as they may provide shelter for valuable species.

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