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Spatial pattern of tree diversity and evenness across forest types in Majella National Park, Italy

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Abstract

Background: Estimation of tree diversity at broader scale is important for conservation planning. Tree diversity should be measured and understood in terms of diversity and evenness, two integral components to describe the structure of a biological community. Variation of the tree diversity and evenness with elevation, topographic relief, aspect, terrain shape, slope, soil nutrient, solar radiation etc. are well documented.

Methods: Present study explores the variation of tree diversity (measured as Shannon diversity and evenness indices) of Majella National Park, Italy with five available forest types namely evergreen oak woods, deciduous oak woods, black/aleppo pine stands, hop-hornbeam forest and beech forest, using satellite, environmental and field data.

Results: Hop-hornbeam forest was found to be most diverse and even while evergreen Oak woods was the lowest diverse and even. Diversity and evenness of forest types were concurrent to each other i.e. forest type which was more diverse was also more even. As a broad pattern, majority portion of the study area belonged to medium diversity and high evenness class.

Conclusions: Satellite images and other GIS data proved useful tools in monitoring variation of tree diversity and evenness across various forest types. Present study findings may have implications in prioritizing conservation zones of high tree diversity at Majella.

Keywords: Tree diversity; Tree evenness; Forest type; Shannon diversity index; Shannon evenness index; Neural network; Kappa statistic

Background

Understanding relationship between environmental factors and plant diversity is a core research area in ecological studies (Zhang and Zhang 2011). Variations in the spatial patterns of plant diversity with various ecological factors e.g. elevation (Wallace 1878; Wang et al. 2003), topographic relief (Richerson and Lum 1980; O'Brien et al. 2000), terrain shape (Tivy 1993; Bolstad et al. 1998), aspect, slope and soil nutrients (Zhang and Zhang 2011), energy (Currie and Paquin 1987) solar radiation and potential evapotranspiration (Currie 1991; Pierce et al. 2005), etc. have been documented over centuries. However, studying the variations of the plant diversity with forest types is important for adopting appropriate management and conservation strategies. Majella national park in Italy is a protected area of high ecological importance. With more than 2000 floristic species, the Park hosts 65 % flora of Abruzzo region, 37 % of Italy and 22 % of the European species (Majella National Park 2011). Vegetation in Majella is divided into several distinct forest types. Each forest type has characteristic tree species composition and is named after the dominant tree species. Present study aimed to investigate pattern of variation of tree diversity across various forest types in Majella.

The concept of species compositional variation of plant communities (or 'diversity') should be expressed in two terms; diversity and evenness (Whittaker 1965; Gillespie et al. 2008), although numerous publications defined biodiversity in terms of species richness (number of species per unit area) only. There are two principal considerations/terms to understand in studying biological diversity which are a) number of different species in a community and b) number of individuals within each of these species in that community (Hamilton 2005). Species diversity is the number of different species in a particular area weighted by some measure of abundance such as number of individuals or biomass, while evenness is the relative abundances of individuals within each species. Both diversity and evenness are

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generally indicated by several indices e.g. Shannon index, Simpson index, Gini-Simpson index, Berger-parker index etc. However, Shannon indices (both diversity and evenness) (Shannon 1948) are the most commonly used and acceptable indicator of biodiversity (Kent and Coker 1992; Mouillot and Lepretre 1999) and have been used in this research to indicate the level of tree diversity.

At present, satellite data are potential source of information of tree diversity due to large scale complete spatial coverage at reasonable cost (Duro et al. 2007). Images are in many cases free to obtain (e.g. Landsat Thematic Mapper) and can be effectively used for studying tree diversity at broader scale with high accuracy for feasible spatial and spectral resolution. In this study, the tree diversity and evenness maps of Majella, produced by classifying Landsat Thematic Mapper (TM) image in an artificial neural network classifier were overlapped with five forest-type thematic maps available from the park office with an aim to explore the variation of diversity and evenness across forest types.

Methods

The study was conducted in the Morrone Region (42°4'30"–42°14'40" N; 13°49'55"–14°1'51" E) of Majella National Park located in central Italy. Morrone is the most forest-type rich area of the park at close proximity to each other (Fig. 1). Morrone mountain range (peak mount Morrone, 2061 m above mean sea level) passes through the western part of the park where this study site largely engulfs part of the range. Vegetation in Morrone grades with altitude. There are four distinct phytoclimatic belts located at various altitudinal range; Mediterranean (below 400/500 m), sub-Mediterranean (500–900/1000 m), temperate Montane (900–1600/1700 m) and subalpine (above 1700 m). Field data of present study were collected from the sub-Mediterranean and Montane zones. Sub-Mediterranean belt consist mainly of Pubescent Oak (*Quercus pubescens*), Turkey Oak (*Quercus cerris*), different Mapples (*Acer* spp.), Ash species (*Fraxinus* spp.), Hop-hornbeam (*Ostrya carpinifolia*), some conifers and farmlands (Fig. 2). Montane is deciduous, mesophilic forest where European Beech (*Fagus sylvatica*) is the most dominant species. Sub-Mediterranean belt possess warm, dry climate with frequent annual summer draught due to hot spell (July-August). Montane belt posses low temperature, harsh winter conditions, cooler summer and high evenly-distributed rainfall than contiguous lowlands. Tree vegetation of Morrone is broadly classified into five prominent forest types and named after the dominant species located sparsely or contiguously in different altitudinal levels. The forest types are evergreen oak woods (comprising 1 % of the area), deciduous oak woods (31 %), black/aleppo pine stands (26 %), hop-hornbeam forest (11 %) and beech forest (31 %).

For capturing field information regarding the tree diversity and evenness, 100 sample plots of 30 m square size were surveyed from 7th September to 30th October in 2009. Stratified adaptive sampling technique with strata based on forest type was adopted in the field. Tree species count in each sample plot was done by line transact method (detailed in Runkle 1982). Nomenclature of the trees was done following Conti (1998). Location of the sample plots was recorded using handheld iPAQ Global Positioning System (GPS).

For each of the plots, Shannon diversity and evenness indices were calculated using the following formula:

$$\text{Shannon diversity index(SDI)} = -\sum_{1}^{s} Pi\ln Pi$$

$$\text{Shannon evenness index (SEI)} = H / \log(S).$$

Here P_i is the proportion of total number of species made up of the ith species in the plot, and S refers to the total number of species or species richness (also called α diversity) of that particular plot (Whittaker 1972; Pielou 1975).

Calculated diversity and evenness indices values for 100 plots were then arranged in ascending order and divided into 5 equal-spaced discrete diversity and evenness classes namely very low, low, medium, high and very high (Table 1). Each diversity or evenness class thus contained values of 20 field plots. The lowest value of both SDI and SEI was 0 while the highest value was 1.818 for SDI and 0.985 for SEI (Table 1). Each of the 5 diversity and evenness classes however contained a range of diversity or evenness values (Table 1). Zero (0) value of SDI and SEI indicates there is only one species present in that plot, while the highest values of SDI and SEI indicate maximum number of species found in that particular plot.

A cloud and defect free Landsat TM image captured on 27 September 2003 and four ancillary GIS layers namely elevation, slope, aspect and solar radiation were used in a back-propagation artificial neural network (NN) classifier. NN is a promising non-parametric image classifier successfully used by some researchers in similar works (e.g. Skidmore et al. 1997; Mutanga and Kumar 2007). NN shows better performance in common landcover classification than some other methods e.g. maximum likelihood (Civco 1993). One big advantage of NN classifier is, image and other ancillary spatial data layers can be jointly put into the classifier to produce required number of discrete landcover classes. Thirty meter resolution ASTER Digital Elevation Model (DEM) of the study site was acquired from the archive of National Aeronautic and Space Administration (NASA) via ITC (Faculty of Geoinformation Science and Earth Observation, Univesity of Twente, The Netherlands). Slope, aspect and solar radiation data were created from DEM using surface analysis tool in ArcGIS 9.3. Field sampled data of all diversity and evenness classes were converted to

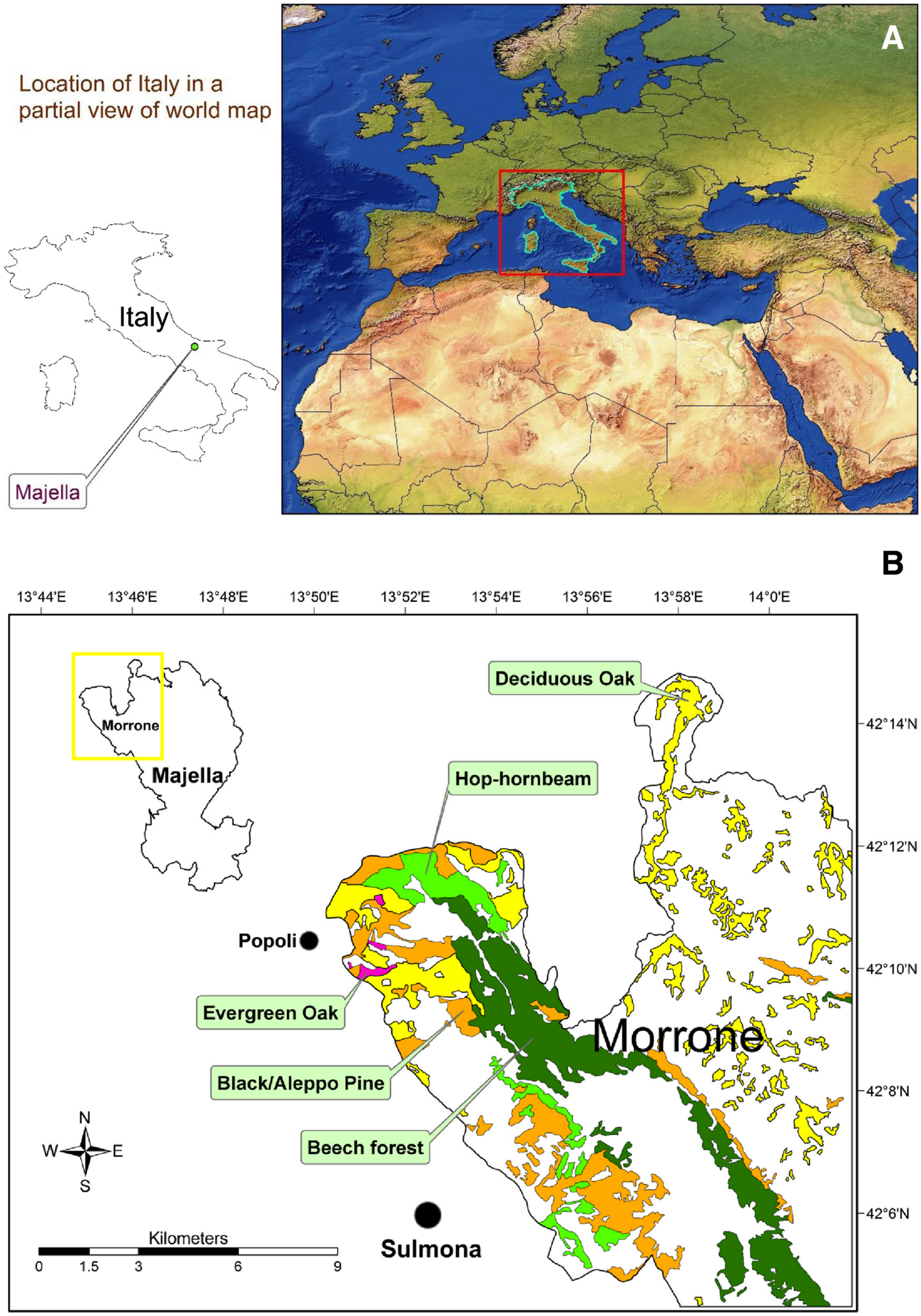

Fig. 1 Location of Italy in partial world map (**A**) and five forest types in Morrone Region of Majella National Park, Italy (**B**). Source of the park boundary shapefile: (Parco Nationale della Majella 1999)

Fig. 2 Glimpses of Majella National Park, Italy. Landscape view (**A**), mixed stand (**B**), pure stand of Beech (**C**) and Pine (**D**). Picture courtesy: Author

area of interest (AOI) point shape file in ENVI 4.3. Seventy percent of the field data were used for training the image and thirty percent for validation of classification result, which is a standard proportion (e.g. Mutanga and Rugege 2006). TM image and GIS layers were layer-stacked and fed to the NN classifier along with the training data set in ENVI 4.3. The outputs from the NN were diversity and evenness thematic maps of the study site with five classes in each. The NN classifier was run for the diversity and evenness maps independently. Map validation was done by generating error matrix using the training data set with overall accuracy and kappa statistic (Cohen 1960; Congalton and Green 1999). Kappa statistics is an index of inter-rater reliability that is commonly used to measure the level of agreement between two sets of dichotomous ratings or scores (Manel et al. 2001; Guisan et al. 2002). Kappa value of 1 indicates perfect agreement, >0.75 good classification, >0.80 excellent agreement and 0.50 a performance not better than chance. Forest type thematic map (shape file) of the study area was obtained from the park office. Diversity and evenness maps of Morrone produced using TM image and GIS layers were overlapped with forest type shape files separately using ArcGIS to explore the variation of diversity and evenness with forest types. Average value of Shannon diversity (SDI) and evenness (SEI) indices obtained from the field samples falling in each forest types was compared with the remotely sensed diversity and evenness levels/classes under each of forest type.

Table 1 Shannon diversity and evenness classes

Shannon diversity/ Evenness classes	Shannon Diversity Index (SDI)		Shannon Evenness Index (SEI)	
	Lower limit	Upper limit	Lower limit	Upper limit
Very Low	0	0.311	0	0.404
Low	0.325	0.637	0.428	0.660
Medium	0.643	0.939	0.663	0.754
High	0.960	1.136	0.755	0.868
Very High	1.170	1.818	0.869	0.985

For assessing the overall quantitative structure of the tree communities in all forest types, five parameters namely density (the numerical strength of a species per unit area), relative density (the proportion of a species in a stand as a whole), frequency (the degree of dispersion in terms of percentage occurrence), relative frequency (the dispersion of a species in relation to that of all the species) and abundance (the number of individuals of different species in the community per unit area) of individual trees were calculated using the following formula (Shukla and Chandel 2000).

$$\text{Density of a species per unit area} = \frac{\text{Total number of individuals of a species in all the sample plots}}{\text{Total number of sample plots studied}}$$

$$\text{Relative density of a species} = \frac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Frequency of a species} = \frac{\text{Total number of quadrates in which the species occured}}{\text{Total number of quadrates studied}} \times 100$$

$$\text{Relative frequency of a species} = \frac{\text{Frequency of the species}}{\text{Sum of the frequencies for all species}} \times 100$$

$$\text{Abundance of a species} = \frac{\text{Total number of individuals of a species in all plots}}{\text{Total number of plots in which the species occured}}$$

Results and Discussion

A total of 24 tree species belonging to ten families were recorded in all available forest types in Morrone region of Majella National Park. A list of such species along with structural information of tree communities namely density, relative density, frequency, relative frequency and abundance has been presented in Table 2. Majority of the trees found in Morrone belonged mainly to Fagaceae, Sapindaceae and Pinaceae families. Among the tree species, some were most frequently found in the sample plots while few others were rare. Most frequently found species were Mona Ash/Fraxinus (F 51, RF 15.64), Hophornbeam (F 49, RF 15.03), Black Pine (F 49, RF 15.03), Beech (F 30, RF 9.02), Pubescent Oak (F 25, RF 7.67), Maple (F 24, RF 7.36) and Aleppo Pine (F 16, RF 4.91). However in this case, the frequencies and relative frequencies of Mona Ash, Hophornbeam and Beech are nearly the same i.e. these species were equally frequent (Fig. 3, Table 2). Species like Wild Cherry (F 2, RF 0.61), Salix/White Willow (F 2, RF 0.61), Common Hazel (F 1, RF 0.31), Norway spruce (F 1, RF 0.31) and European Ash (F 1, RF 0.31) were equally infrequent or rare. Species with highest relative density (RD) include Beech (18.41), Black Pine (15.95), Hophornbeam (15.19), Mona Ash (9.60), Aleppo Pine (7.34) and Evergreen Oak (4.22). And species with lowest relative density include Common Hazel (0.03), European

Table 2 List of main tree species found in the forest types in the study site with several measures of their quantitative structure

No.	English name	Scientific name	Family	Density (D)	Relative density (RD %)	Frequency (F)	Relative frequency (RF %)	Abundance
1	Ailanthus	*Ailanthus altissima*	Simaroubaceae	0.11	0.37	4	1.23	2.75
2	Aleppo Pine	*Pinus alepensis*	Pinaceae	2.21	7.34	16	4.91	13.81
3	Beech	*Fagus sylvatica*	Fagaceae	5.54	18.41	30	9.20	18.47
4	Black Pine	*Pinusnigra*	Pinaceae	4.80	15.95	49	15.03	9.80
5	Common Hazel	*Corylu savellana*	Betulaceae	0.01	0.03	1	0.31	1.00
6	Common Laburnum	*Laburnum anagyroides*	Fabaceae	0.19	0.63	7	2.15	2.71
7	European Ash	*Fraxinus excelsior*	Oleaceae	0.01	0.03	1	0.31	1.00
8	Evergreen/White Oak	*Quercus spp*	Fagaceae	1.27	4.22	11	3.37	11.55
9	Hophornbeam	*Ostria carpinifolia*	Butalaceae	4.57	15.19	49	15.03	9.33
10	Italian Alder	*Alnus cordata*	Betulaceae	0.09	0.30	4	1.23	2.25
11	Maple	*Acer pseudoplatanus*	Sapindaceae	0.72	2.39	24	7.36	3.00
12	Mona Ash/Fraxinus	*Fraxinus ornus*	Oleaceae	2.89	9.60	51	15.64	5.67
13	Montpellier Maple	*Acer monspessulanum*	Sapindaceae	0.10	0.33	7	2.15	1.43
14	Norway Mapple	*Acer platanoides*	Sapindaceae	0.11	0.37	3	0.92	3.67
15	Norway spruce	*Picea abies*	Pinaceae	0.01	0.03	1	0.31	1.00
16	Port-Orford-Cedar	*Chamaecyparus cawsoniana*	Cupressaceae	0.22	0.73	5	1.53	4.40
17	Pubescent Oak	*Quercus pubescens*	Fagaceae	4.66	15.49	25	7.67	18.64
18	Robinia	*Robinia pseudoacacia*	Fabaceae	0.15	0.50	5	1.53	3.00
19	Salix/White Willow	*Salix alba*	Salicaceae	0.04	0.13	2	0.61	2.00
20	Small leaved Maple/Field Maple	*Acer campestre*	Sapindaceae	0.49	1.63	7	2.15	7.00
21	Stone/Holly Oak	*Quercus ilex*	Fagaceae	1.16	3.86	14	4.29	8.29
22	Tilia/Linden/Lime	*Tilia cordata*	Malvaceae	0.40	1.33	7	2.15	5.71
23	Turkey Oak	*Quercus cerris*	Fagaceae	0.19	0.63	2	0.61	9.50
24	Wild Cherry	*Prunus avium*	Rosaceae	0.17	0.56	2	0.61	8.50

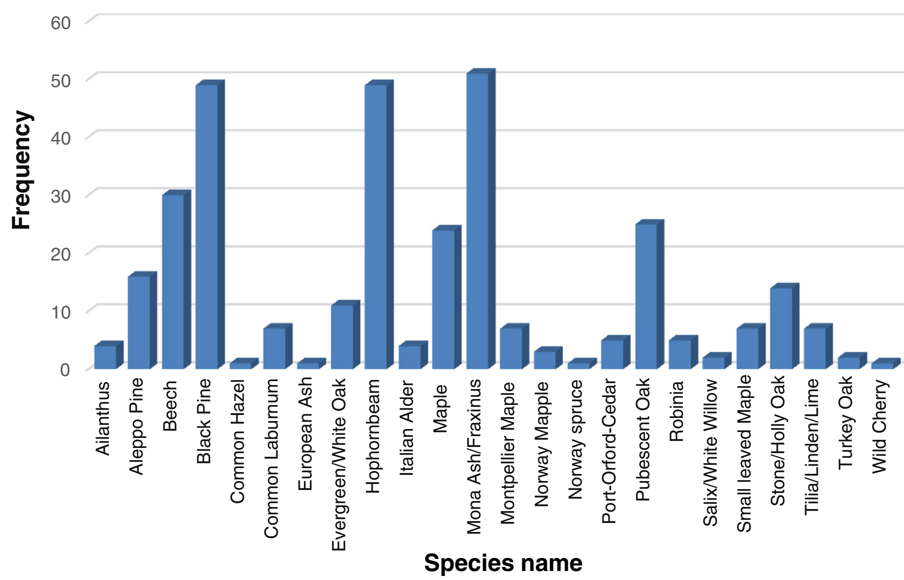

Fig. 3 Tree species found in Morrone region of Majella with frequency of occurrence

Ash (0.03), Norway spruce (0.03), Salix/White Willow (0.13) and Montpellier Maple (0.33).

The tree diversity and evenness maps of Morrone resulted from the classification of satellite image with other ancillary data in neural network with highest accuracies are given in Fig. 4. When only the image was used in NN, overall accuracies of the resulted tree diversity map was 53 % and tree evenness map was 57 %. Map accuracies significantly increased when ancillary data layers were jointly used with the satellite image in the NN classifier. In that case, the highest overall accuracy of the tree diversity map was 91 % (with kappa value 0.9) (Table 3) and the tree evenness map was 83 % (with kappa value 0.79) (Table 4). Obtained aaccuracies of the diversity and evenness maps were very high. Use of only image could not have produced such high accuracy maps unless other four ancillary environmental variables (elevation, aspect, slope and solar radiation) had been jointly used with the TM image in the NN classifier. As environmental variables have profound bearing on regulating plants' life, diversity and distribution, the use of such variables in NN classifier has increased classification accuracies significantly. The effect of ancillary data layers in increasing image classification accuracies in NN has been explained in details in other articles of this author (Redowan 2013; Redowan and Riadh 2013).

The diversity and evenness maps were overlapped with the forest type map and the results of overlapping with area (%) under each class are presented in Table 5 and Table 6 respectively.

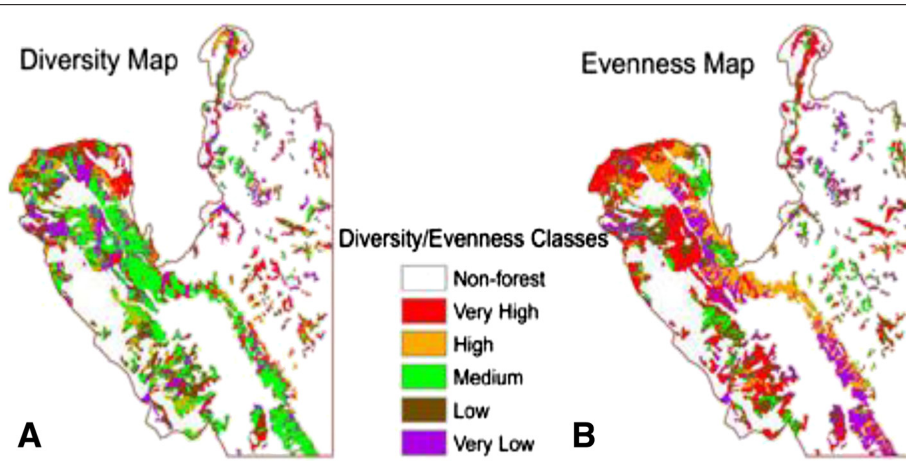

Fig. 4 Tree diversity (**A**) and evenness (**B**) maps resulted from classification of Landsat TM imagery

Table 3 Contingency table of accuracy assessment of tree diversity map with Kappa Statistic, Overall Accuracy, Producer's Accuracy (PA) and User's Accuracy (UA)

		Validation data							
		High	Low	Medium	Very high	Very low	Row total	UA%	PA%
Image data	High	5	0	0	0	0	5	100	83
	Low	0	5	0	0	0	5	100	83
	Medium	1	0	6	1	0	8	75	100
	Very high	0	1	0	5	0	6	83	83
	Very low	0	0	0	0	6	6	100	100
	Column total	6	6	6	6	6	30		

Overall accuracy 91 %, Kappa Statistic 0.90

Good agreement exists between average value of SDI and SEI in each forest type with the majority portion of that forest type belonging to the respective or contiguous diversity and evenness classes in the classified maps. As for example, average value of Shannon diversity index of ground survey in Beech forest is 0.65 which belongs to medium diversity category, while majority area of that forest type (34 %) belongs to medium diversity class as well, a good agreement between remotely sensed data with ground information (Table 5). Similar trend of diversity is noticed in other forest types as well.

For Shannon evenness index map, majority area of an evenness class corresponds to the respective ground information. As for example, majority area (36 %) of Black/Aleppo Pine forest belongs to medium evenness class of the map where average value of Shannon evenness index of the field samples is also of medium level (0.67). Similar trend is true for other forest types (Table 6).

Hop-hornbeam forest is the most diverse and even (average SDI 1.14 and SEI 0.82) followed by Black/Aleppo Pine forest, deciduous Oak woods, Beech forest and evergreen Oak woods (Fig. 5). Evergreen Oak woods is the least diverse and even (average SDI and SEI are 0.52 and 0.34 respectively). The diversity and evenness follow similar trend i.e. the forest type which is more diverse is also more even (Fig. 5).

As a broad pattern, 37 % of the study area belongs to medium diversity class, 16 % to low diversity class, 16 % to very high diversity classes, 18 % to very low diversity class and 12 % to high diversity class (Fig. 6). On the other hand, majority portion (27 %) of the study area belongs to high evenness class, nearly equal portion (21 % and 22 %) to low and very high evenness classes, 17 % to medium evenness class and 13 % to very low evenness classes (Fig. 6).

The study area is a mountainous landscape with mount Morrone (second highest peak of Majella) passing through the centre of it. Altitude is a principal regulatory factor governing the distribution and diversity of vegetation in the region (which is also documented in other studies e.g. Stanisci et al. 2005). Change in diversity is less prominent at lower altitude than at higher altitude. Vertical gradation of vegetation with altitude was very evident and noticed in the spatial extension and arrangement of typical forest types as a broad pattern; so were the species diversity and evenness (Table 5). As for example, beech forest was found confined to the specific phytoclimatic belt Montane (900/1000-1600/1700 m) with average SDI 0.65, belonging to *Medium* diversity class. Deciduous oak woods were mainly found below 900 m altitude in the sub-Mediterranean belt with average SDI 0.72, belonging to *High* diversity class. Diversity and evenness classes vary widely across the forest

Table 4 Contingency table of accuracy assessment of tree evenness map with Kappa Statistic, Overall Accuracy, Producer's Accuracy (PA) and User's Accuracy (UA)

		Validation data							
		High	Low	Medium	Very high	Very low	Row total	UA%	PA%
Image data	High	5	1	0	0	0	6	83	83
	Low	0	4	0	1	0	5	80	67
	Medium	1	0	5	0	0	6	83	83
	Very high	0	0	1	5	0	6	83	83
	Very low	0	1	0	0	6	7	86	100
	Column total	6	6	6	6	6	30		

Overall accuracy 83 %, Kappa Statistic 0.79

Table 5 Statistics of overlapping TM diversity map with forest types map along with average values of Shannon Diversity Index (SDI) in each forest type

Forest types	Total area (ha)	Area of each diversity class (%) that falls under a forest type					SDI* (avg)
		Very high	High	Medium	Low	Very low	
Beech	1842	20	26	**34**	11	9	0.65[M]
Black/Aleppo Pine	1507	8	22	**32**	29	9	0.82[M]
Evergreen Oak	42	27	9	4	**39**	21	0.52[L]
Hop-hornbeam	631	**32**	14	17	29	8	1.14[VH]
Deciduous Oak	1820	**35**	16	14	17	18	0.72[H]

Major diversity class in each forest type has been boldfaced
SEI* = Average value of Shannon Evenness Index in each forest types; Diversity classes: M = Medium; L = Low; H = High; VH = Very high

types due mainly to other associated species in each type beyond the dominant one along with altitude. As for example, highest average SDI (1.14) and SEI (0.82) were found in the hop-hornbeam forest situated at a wide altitudinal range (500–1200 m) while lowest average SDI (0.52) and SEI (0.34) were found in the evergreen oak woods situated in the lower altitude (up to 500 m). Of course it does not necessarily mean that tree diversity is high at the higher altitude and low at the lower altitude. Rather the opposite trend i.e. decreases of species diversity with altitude was observed. Indeed, generally the Mediterranean (<500 m) and sub-Mediterranean (500–900 m) phytoclimatic belts are the most species rich and even with assemblages of various species while Montane belt (900–1600 m) is the least species rich and even which is solely dominated by Beech (*Fagus sylvatica*). The forest types are basically broad categorization of the woody species assemblage of the park, each of them occupying a broad altitudinal ranges, and scale of that variation as 'forest stands' is wide too. For example "beech" is short for broad-leaved mesophilic deciduous forest mostly beech, but at lower altitudes (e.g. 800–1000 m) it is mixed with e.g. maples (*Acer* spp.), pubescent Oak (*Quercus pubescens*) and Linden/Lime (*Tilia cordata*). As the altitudinal range of occurrence of some of the forest type overlaps with each other, the variation in average SDI or SEI values of each of them does not narrowly attribute to altitude but very broadly. But variation of the diversity and evenness of trees across the forest types is distinct (Jiang et al. 2007). Of all forest types, hop-hornbeam forest is the most diverse and even while evergreen oak woods are the least diverse and even.

This study revealed a good agreement between the produced diversity and evenness maps when they were overlapped with the forest type map of Majella. Broadly, areas with high tree diversity also have high species evenness. This phenomenon is of course very usual. Plots or areas with more number of species will definitely count for higher diversity and evenness as diversity and evenness in most cases are concurrent to each other.

The level of diversity and evenness that is found in Majella is not high in comparison to some other similar studies. Jiang et al. (2007) reported average Shannon-Weiner index value as 2.03 in deciduous broadleaved forest and 1.90 in temperate evergreen coniferous and deciduous broadleaved mixed forest in northwestern China. Jing et al. (2004) documented SDI ranging from 0.92–1.96 and SEI from 0.15–0.46 at different altitudinal belts (1100–1700 m) in a coniferous forest at Changbai mountainous landscape. Marsden and Pilgrim (2003) studied tree diversity of two lowland rainforest sites on New Britain in Papua New Guinea and reported SDI value at different habitats ranging from 1.63 to 2.38. In comparison to these study areas, it can be opined that diversity in Morrone is comparatively neither high nor low, rather of intermediate level.

Table 6 Statistics of overlapping TM evenness map with forest types map with forest type map along with average values of Shannon Evenness Index (SEI) in each forest types

Forest types	Total area (ha)	Area of each diversity class (%) that falls under a forest type					SEI* (avg)
		Very high	High	Medium	Low	Very low	
Beech	1842	23	31	3	7	**37**	0.40[VL]
Black/Aleppo Pine	1507	22	20	**36**	16	7	0.67[M]
Evergreen Oak	42	17	11	12	12	**48**	0.34[VL]
Hop-hornbeam	631	24	**35**	16	16	9	0.82[H]
Deciduous Oak	1820	**32**	12	25	15	18	0.76[H]

Major evenness class in each forest type has been boldfaced
SEI* = Average value of Shannon Evenness Index in each forest types; Diversity classes: M = Medium; L = Low; H = High; VH = Very high

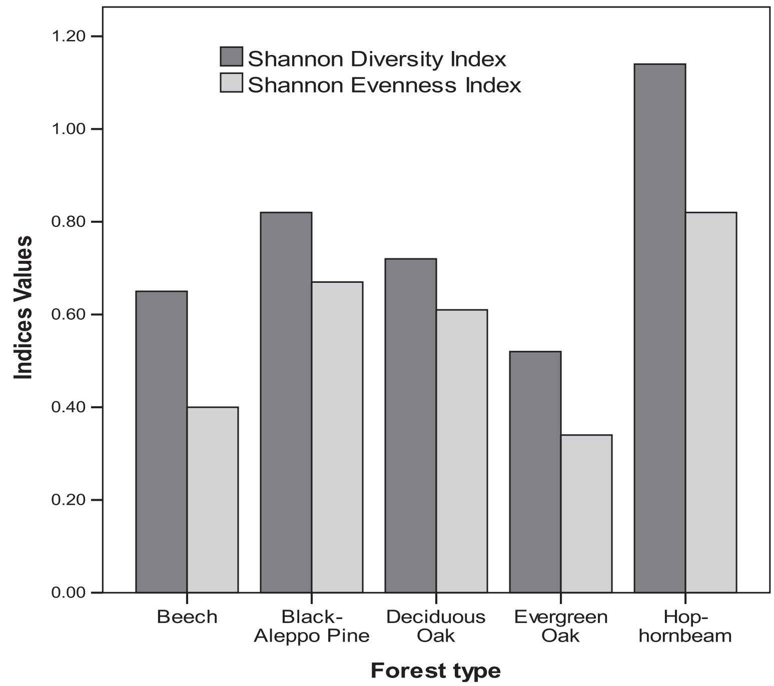

Fig. 5 Average value of diversity and evenness in each forest type

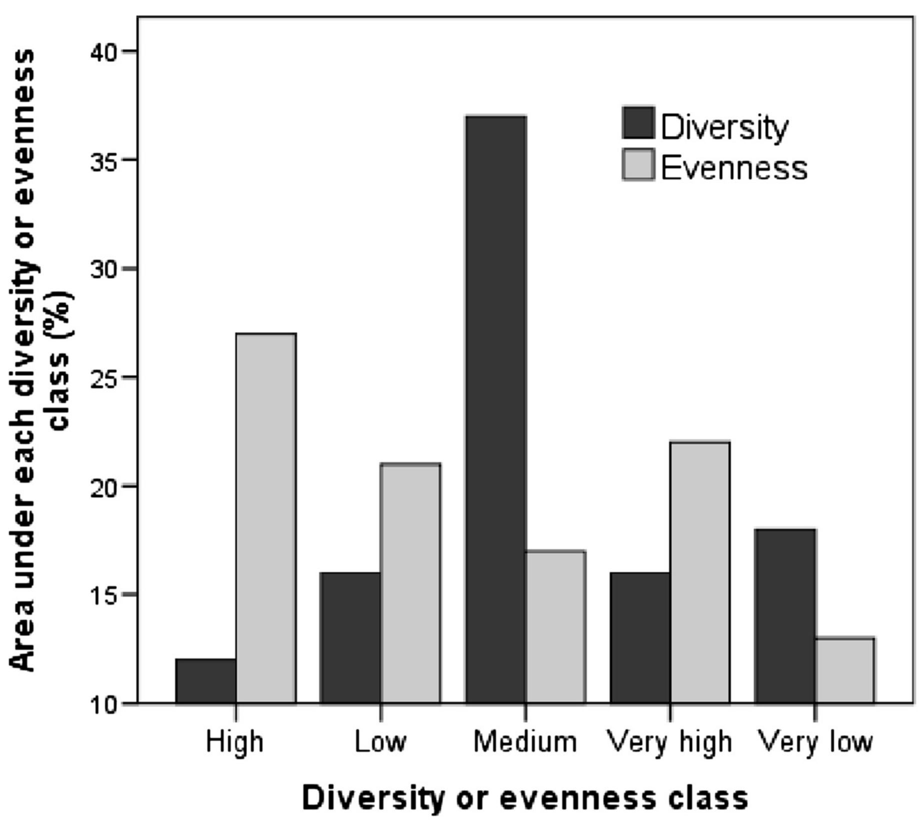

Fig. 6 Area falling under a particular diversity or evenness classes

Conclusion

Diversity and evenness are two integral components to describe, measure and compare biological diversity of forest communities. This study demonstrated how tree diversity and evenness of an Italian forest site varied with forest types and could be mapped and compared against each other using a combination of satellite image, GIS and ground survey data. The diversity and evenness went parallel to each other i.e. the forest type which was more diverse was also more even. As a broad pattern, majority portion of the study area belonged to medium diversity but high evenness classes. In comparison to the other similar studies, diversity and evenness of Morrone were of medium level. Findings of the present study might have significant implications in prioritizing biodiversity conservation areas of different forest types/ecoregions, undertaking silvicultural operations and selecting sites or enrichment planting. Further research can investigate the variation in mapping accuracy of diversity and evenness using high-resolution image and with less number of field samples in other areas of the park.

Competing interests

The author declares that he has no competing interests.

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