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Determination of appropriate grid dimension and sampling plot size for assessment of woody species diversity in Zagros Forest, Iran

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Abstract.*Zohrevandi AA, Pourbabaei H, Akhavan R, Bonyad AE. 2015. Determination of appropriate grid dimension and sampling plot size for assessment of woody species diversity in Zagros Forest, Iran. Biodiversitas 17: 24-30.* This research was conducted to determine the most suitable grid (dimensions for sampling) and sampling plot size for assessment of woody species diversity in protected Zagros forests, west of Iran. Sampling was carried out using circular sample plots with areas of 1000 m^2, 1500 m^2 and 2000 m^2 for 9 grid sizes in 200ha forest area. Importance-value curve which fitted by a Lognormal Distribution Model was plotted using Species Importance Value index (SIV). After determining the diversity indices such as Hills (N_0, N_1, N_2) and Alatalo's evenness (E_5) in each plot and assigning each sampling time, $E\%^2$x T criterion was calculated in order to compare the methods. Results of hundred percent inventory and sampling in forests showed that the accuracy of sampling in 1000m^2plot size is higher than 2000 m^2 ones. According to the Importance-value curve, accuracy and $E\%^2$x T criterion, the 150 m x 400 m grid size and sampling plot size with an area of 1000 m^2 was proposed as the most appropriate one to estimate woody species diversity in Iranian Zagros Forests.

Key words: Importance-value curve, inventory grid, sampling plot size, woody species diversity, Zagros forests

INTRODUCTION

Zagros forests in west of Iran are severely degraded and consequently their basic structure and complexity in identifying forest communities have changed (Khanlari 2006). This issue leads to poor soil condition and loss of woody species diversity in forests. Diversity is a prerequisite for understanding the patterns and processes of forest ecosystems which described well the forest structure in quantitative terms (Aguirre et al. 2003). Diversity indices are important input variables for restructuring of forest (Hasenauer and Pommerening 2006; Pommerening and Stoyan 2008). With increase human population and demands for resources and habitats, destructive human pressure on nature will increase and which is the beginning of the destruction of biodiversity (Lund et al. 2004). Measuring woody species diversity helps us to calculate the economic consequences of diversity destruction (Buongiorno et al. 1994; Kant 2002). Biodiversity increases the reproductive capacity and ability of adaptation to changes in forest ecosystems (Macneely 2002). Studying the patterns of species diversity helps us to understand the mechanisms that create diversity in a society (Wang et al. 2008). In a study in New Zealand by means of species level curve, it showed that sampling in 500 m^2 plot size is the most appropriate area for studying diversity of plant species (Neldner 2008). Alijanpour et al. (2009) in their study for comparison of woody plants diversity in protected and non-protected areas of Arasbaran forests used an inventory grid with 300 m x 150 m. They concluded that protection-based management increase woody species diversity in forest biomasses of Arasbaran forests. Recent studies about diversity patterns focused on tropical forests that have too much plant species (He et al. 1996; Hubbell et al. 1999; de Oliveira and Mori 1999; Condit et al. 2006).For example, in a 52-hectareplot area in Borneo and a 25-hectareplot area in Ecuador, there were 1175 and 1104 species, respectively (Wright 2002). In contrast, the 4.2 x 10^6 km^2 of temperate forests in Europe, north of America and Asia support only 1166 tree species (Latham and Ricklefs 1993).

In other words, the diversity of a small area in tropical forests is comparable to the diversity of tree species in the North Temperate Zone. Although ecologist studies rely on a better understanding of species diversity in moderate temperature forests, few studies focus on the spatial distribution of species diversity and the extent in which these patterns are influenced by environmental and spatial factors (Legendre and Fortin 1989; Legendre 1993). In general, number of species and their distribution (Two components which form species diversity), are estimated based on sampling of population at an extended level. Obviously, a large sample size need high cost and time, and small sample size leads to lack of accuracy of estimations. It is always tried to select the best possible sample size in the existing information framework with respect to the time, cost, and accuracy (Amidi 2006). Accuracy of estimation increases with extending the sample size (Nilsson 2002). The plot size also is a crucial factor in determining the species diversity of studied area. In inventory discussions, clarity of goals and application of results in accordance with the goal or other predefined and predetermined purposes are the basic principles in sampling (Zobeiry 2002). Hence, inventory methods are precisely selected with regard to the goal of inventory, forest structure, and available facilities. Wang et al. (2008) studied 25 hectares of Chang-bye forests in China and used plot size of 10 m x 10 m. Then, the areas of samples were doubled until, were covered the whole of 25hectares. In this research, the estimation of species richness, abundance of species, and Shannon diversity index were used to assess the patterns of species diversity.

The aim of current study is determining the appropriate network and sampling plot size for estimating the shrub and tree species diversity in the protected Zagros Forests in west of Iran (Zagros oak forests). Eventually with the highest accuracy and lowest cost of sampling (an acceptable combination of accuracy and cost) the diversity of woody species was studied in Zagros forests.

MATERIALS AND METHODS

The study area

The study area is a part of Ghalajeh forests located in the southwestern part of Kermanshah province, west of Iran (33°99´ N, 46°3´E) (Figure 1).The altitude ranges from 1450 to 1950 m asl., stretched at the geographical direction of northeast to southwest. Annual average of precipitation and temperature are 516.7 mm and 12.8°C, respectively. According to the Emberger climatic, Ghalajeh forest has mountainous sub-humid cold climate (Zohrevandi 2012). Stone types include limestone and marl which belong to the tertiary (Oligo-Miocene) period. The depth of soil is medium and its texture is heavy.

Data collection

According to a Digital Elevation Model (DEM), 9 inventory grids with dimensions of 100 m x 200 m, 150 m x 200 m, 200 m x 200 m, 100 m x 400 m, 150 m x 400 m, 400 m x 200 m, 100 m x 600 m, 150 m x 600 m, and 200 m x 600 m were designed. Sampling procedure was the systematic random method. Data was collected in circular sample plots with areas of 1000 m^2, 1500 m^2 and 2000 m^2.

In each plot, the type of woody species (trees and shrubs) were identified, counted and the two perpendicular diameters of canopy of each tree and shrub were calculated and recorded along with the coordinates of the plot center.

Data analysis

Species abundance distribution

Importance-value curve is plotted using Species Importance Value index (SIV).

Species Importance Value

Species importance value (SIV) was calculated for all species using relative frequency, relative density and dominance values for woody species. The following formulas were used for each calculation (Maingi and Marsh 2006; Adam et al. 2007):

Relative frequency = Number of plots that contain a species x 100 / Number of all plots

Relative density = Individuals number of a species in all plots x 100 / Total individuals number of species in all plots

Relative dominance = Total basal area of a species in all plots x 100 / Total basal area of all species in all plots

Diversity indices

The following indices are used to determine the variety of woody species in the study area. Hill (1973) has introduced a series of indices that are known as Hill numbers. The Hill numbers provide a better ecological interpretation than other indices. These numbers measure the effective number of species in the sample.

$$H' = \sum_{i=1}^{s} (p_i)(Log_2 p_i)$$

where:

H´= Information content of sample (bits/individual) or index of species diversity

S = Number of species

p_i = Proportion of total sample belonging to i^{th} species

Figure 1. The geographical location of the study area in Ghalajeh forest, Province of Kermanshah, Iran

The Shannon-Wiener index may be expressed in another form (MacArthur 1965) in units of numbers of species as

$N_1 = e^{H'}$

Where:
e = 2.71828 (base of natural logs)
H´ = Shannon-Wiener function (calculated with base e logs)
N_1= Number of equally common species which would produce the same diversity as H´

$D = \sum p_i^2$

Where:
D = Simpson's index
p_i = Proportion of species i in the community

$$\frac{1}{D} = \frac{1}{\sum p_i^2}$$

Where:
1/D = Simpson's reciprocal index (= Hill's N_2)
p_i = Proportion of species i in the community

Hill (1973) called this reciprocal N_2.

Evenness

$$E_5 = \frac{N_2 - 1}{N_1 - 1}$$

E_5: This index is known as the modified index of Hill which is known as Alatalo index. Alatalo (1981) showed that when a species becomes very dominant, E_5 closes to zero. This index is not affected by species richness.

Inventory time cost

The necessary time for measuring every plot includes the time of measuring the intended features of the trees of every sample as well as time of movement from one plot to the next one. The total time is calculated by $T_i = (n_i \times ta_i) + (n_i \times tb_i)$, where T_i is the total time of inventory of i method, $n_i$is the number of plot of *i* method, ta_i is the average time taken for measuring the trees of each plot in i method and tb_i is the average time taken for movement from one plot to the next (adjacent) plot in i method (Heidari et al. 2007). It should be pointed that since the routes of all samples were equal, the average time of moving from one plot to another was considered the same. As a result, the time of going from one plot to the other one was removed from time estimation. Accordingly, the relation $Ti = (n_i \text{ x } ta_i)$ was used to calculate time in every sampling method.

Selection criterion

Following formula is used to calculate the precision of inventory.

$$E\% = \pm t x S_x \%$$

Where:
E% =Precision of inventory or the percentage of inventory error
t =Statistic of t-student table
S =Percentage of standard error

The best sampling grid was determined by$E\%^2$ x T criterion, where T is the total time of sampling in each method (Heidari et al. 2007).

Hundred percent inventories

Firstly to assess the data accuracy, hundred percent inventories was done in 40ha of the forest then N_0, N_1, N_2andE_5 diversity indices were determined 4.55, 2.28, 1.86, 0.59, respectively. Data analysis was done using GIS, SPSS, Past and Excel software.

RESULTS AND DISCUSSION

Trees and shrubs species

In current study the following species of trees and shrubs were studied: *Quercus brantii* Linddl., *Acer cinerascens* Boiss., *Pistacia atlantica* Desf., *Crataegus azarolus* L., *Cornus australis* C.A.Mey., *Lonicera persica* Jauh. & Spach., *Cerasus microcarpa* (C.A.Mey.) Boiss., *Amygdalus orientalis* Duh., and *Pyru scommunis* L.

Species abundance distribution

Importance-value curve was plotted using Species Importance Value index (Figure 2). Means and standard error was determined for diversity indices through 27 different sampling methods (Tables 1and 2).Table 1 shows that estimating the richness index N_0 and diversity indices N_1,and N_2 using different sampling grids and different surfaces of plot size, have no significant differences. Table 2 shows that the standard error for estimating the richness index N_0 and diversity indices N_1, and N_2 in different sampling grids, have no significant differences, but increasing of grid dimension (Lowering the number of plot), leads to increase standard error. ANOVA was performed to measure the estimation mean of diversity indices in grid dimension and sampling plot size(Table 3).

The variance analysis ofE_5 index in different sampling methods showed that there is a significant difference (95% level) between 1000 m^2 and 2000 m^2 plot size.

Comparing different methods of sampling

Different grid dimension and plot size were compared for estimation of woody species diversity using $E\%^2$x T criterion.

Regarding Table 5, is the least value of $E\%^2$x T criterion belongs to sampling grid of 150 m x 400 m with 1000 m^2 plot size.

Table 1. The estimated mean of diversity indices (N_0, N_1, N_2, and E_5) for 9 grid dimensions (Left-hand column) and 3 plot sizes (1000 m^2, 1500 m^2, and 2000 m^2)

Statistical parameters					**Mean**							
Plot size (m^2)	**1000**				**1500**				**2000**			
Diversity indices	N_0	N_1	N_2	E_5	N_0	N_1	N_2	E_5	N_0	N_1	N_2	E_5
Network(m)												
100 x 200	4.4	2.2	1.8	0.58	4.5	2.3	1.9	0.59	4.6	2.4	1.9	0.63
150 x 200	4.5	2.3	1.9	0.59	4.6	2.4	1.9	0.65	4.8	2.5	2	0.67
200 x 200	4.7	2.3	1.9	0.55	4.8	2.4	1.9	0.62	4.9	2.5	2	0.64
100 x 400	4.5	2.2	1.8	0.60	4.6	2.3	1.9	0.59	4.7	2.4	1.9	0.61
150 x 400	4.5	2.2	1.8	0.59	4.6	2.3	1.9	0.60	4.8	2.4	2	0.62
200 x 400	5	2.4	1.9	0.57	5	2.5	2	0.60	5.1	2.5	2	0.62
100 x 600	4.3	2.2	1.8	0.58	4.4	2.3	1.9	0.57	4.5	2.4	2	0.65
150 x 600	4.5	2.4	1.9	0.61	4.6	2.5	2	0.70	4.7	2.6	2.1	0.72
200 x 600	4.5	2.4	1.9	0.54	4.5	2.5	2	0.67	4.6	2.5	2	0.69

Table 2. The standard error of estimating of diversity indices (N_0, N_1, N_2, and E_5) for 9 grid dimensions (Left-hand column) and 3 plot sizes (1000 m^2, 1500 m^2, and 2000 m^2)

Statistical parameters							**Standard error ($S_{\bar{x}}$)**								
Plot size (m^2)	**1000**					**1500**					**2000**				
Diversity Indices	N_0	N_1	N_2	E_5	**Mean**	N_0	N_1	N_2	E_5	**Mean**	N_0	N_1	N_2	E_5	**Mean**
Network (m)															
100 x 200	0.15	0.09	0.08	0.02	0.08	0.14	0.09	0.07	0.02	0.08	0.13	0.09	0.07	0.02	0.08
150 x 200	0.19	0.10	0.08	0.03	0.10	0.17	0.11	0.09	0.03	0.10	0.17	0.11	0.09	0.03	0.10
200 x 200	0.20	0.14	0.11	0.03	0.12	0.20	0.13	0.11	0.03	0.12	0.20	0.13	0.11	0.03	0.12
100 x 400	0.21	0.13	0.10	0.04	0.12	0.19	0.12	0.10	0.02	0.11	0.18	0.12	0.10	0.02	0.10
150 x 400	0.25	0.14	0.11	0.03	0.13	0.24	0.14	0.11	0.03	0.13	0.20	0.14	0.12	0.03	0.12
200 x 400	0.28	0.19	0.15	0.03	0.16	0.26	0.18	0.14	0.03	0.15	0.23	0.18	0.15	0.03	0.15
100 x 600	0.28	0.16	0.13	0.05	0.15	0.26	0.16	0.13	0.04	0.15	0.25	0.16	0.13	0.05	0.15
150 x 600	0.32	0.15	0.11	0.04	0.15	0.31	0.16	0.12	0.06	0.16	0.30	0.16	0.12	0.06	0.16
200 x 600	0.40	0.24	0.19	0.04	0.22	0.40	0.25	0.20	0.08	0.23	0.38	0.24	0.19	0.08	0.22

Table 3.ANOVA for comparing the estimated mean diversity indices in 27 sampling methods

Indices	**Source of variation**	**df**	**Sum of squares**	**Mean square**	**F**	**Sig.**
N_0	Net	8	2.180	0.272	0.293	0.965^{ns}
	Size	2	0.783	0.392	0.421	0.659^{ns}
	Net x Size	16	0.078	0.005	0.005	1^{ns}
N_1	Net	8	0.554	0.069	0.117	0.998^{ns}
	Size	2	0.444	0.222	0.374	0.689^{ns}
	Net x Size	16	0.007	0	0.001	1^{ns}
N_2	Net	8	0.310	0.039	0.108	0.999
	Size	2	0.305	0.153	0.424	0.656
	Net x Size	16	0.007	0	0.001	1
E_5	Net	8	0.087	0.011	0.624	0.754^{ns}
	Size	2	0.111	0.056	3.190	0.049^{*}
	Net x Size	16	0.072	0.004	0.258	0.998

Note: ns: not significantly different*: significantly different

Table 5. $E\%^2$x T criterion for comparing different modes of samplingfor the estimation of woody species diversity

Parameters		**The time taken for each plot(minute)**			**T=Nxt (Minute)**			**$E\%^2xT$**		
Plot size (m^2)		**1000**	**1500**	**2000**	**1000**	**1500**	**2000**	**1000**	**1500**	**2000**
Network (m)	**N**	**t**	**t**	**t**						
100 x 200	90	25	36	47	2250	3240	4230	$(7.95)^2$ x 2250 = 142206	$(7)^2$ x 3240 = 158760	$(6.95)^2$ x 4230 = 204319
150 x 200	60	25	36	47	1500	2160	2820	$(8.85)^2$ x 1500 = 117484	$(8.65)^2$ x 2160 = 161617	$(8.32)^2$ x 2820 = 195207
200 x 200	50	25	36	47	1250	1800	2350	$(10.67)^2$ x 1250 = 142311	$(10.37)^2$ x 1800 = 193566	$(10.25)^2$ x 2350 = 246897
100 x 400	45	25	36	47	1125	1620	2115	$(11.57)^2$ x 1125 = 150598	$(9.5)^2$ x 1620 = 146205	$(8.67)^2$ x 2115 = 158982
150 x 400	30	25	36	47	750	1080	1410	$(11.75)^2$ x 750 = 103547	$(11.12)^2$ x 1080 = 133547	$(10.45)^2$ x 1410 = 153975
200 x 400	25	25	36	47	625	900	1175	$(14)^2$ x 625 = 122500	$(12.25)^2$ x 900 = 135056	$(11.87)^2$ x 1175 = 165554
100 x 600	36	25	36	47	900	1296	1692	$(14.75)^2$ x 900 = 195806	$(13.25)^2$ x 1296 = 227529	$(12.75)^2$ x 1692 = 275056
150 x 600	24	25	36	47	600	864	1128	$(13.25)^2$ x 600 = 105337	$(14.25)^2$ x 864 = 175446	$(13.75)^2$ x 1128 = 213262
200 x 600	20	25	36	47	500	720	940	$(20)^2$ x 500 = 200000	$(21.25)^2$ x 720 = 325125	$(19.75)^2$ x 940 = 366659

Note: ta_i: The average needed time for measuring the trees of every plot in i method; $T_i = n_i \times ta_i$; $E\% = \pm t x S_{\bar{x}}\%$; $E\%^2$ x T: criterion for comparing different modes of sampling

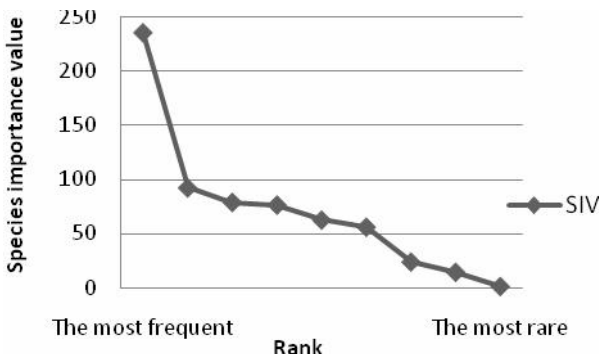

Figure 2. Rank-abundance curve

Table 4. Duncan test for 3 plot sizes (for evenness index)

Size	N	Subset	
		1	2
1000 m^2	27	0.56	-
1500 m^2	27	0.62	0.62
2000 m^2	27	-	0.64

Discussion

The first Part of species abundance distribution curve indicates that the large areas of the Zagros forests was dominated by *Q. brantii* that are the main species of this area forests which cover around 72% of total canopy of trees and shrubs. Destructive human pressure on nature has led to poor soil condition and loss of woody species diversity in forests. Zagros forests in west of Iran are severely degraded and consequently their basic structure and complexity in identifying forest communities have been changed. This issue leads to poor soil condition and loss of woody species diversity in forests (Khanlari 2006). The second part of the curve has a low slope that shows diversity and higher evenness. These areas include valleys and stone walls that are less subject to degradation. The third part of the curve shows that there are three rare species in the habitats. This species due to environmental features have been deployed in specific areas of habitat.

Results of hundred percent inventory and samplings in the forest showed that the accuracy of sampling with 1000 m^2 plot size is higher than sampling with 2000 m^2 plot size. Variance analysis ofN_0 index showed that there is no significant difference between variable sampling grids and areas of plot.

Species abundance distribution curve shows that 5woody species gather in more suitable areas which may be the result of group behavior, heterogeneous environment, restoring methods (Pourbabaei 2010). The forests with this distribution pattern of tree species have lower sampling accuracy and higher costs. In such cases, increase the number of plots (reducing the grid dimension) is effective in increasing the accuracy of the sampling. The number of plot for sampling depends on the homogeneity and heterogeneity of under studied stands (Zobeiry 2002).

He et al. (1996) studied 50 hectares of rain forests of Malaysia and investigated different areas of sampling for estimation Shannon diversity index and illustration of species-area curve. They found that sampling design is effective on the estimation and illustration of diversity curves especially species-area. Wang et al. (2008) studied species diversity models in a part of moderate-temperature forests in China. They estimated Shannon diversity index, species richness and species abundance using geostatistics and the diversity curves. They concluded that sampling design is effective on studying the diversity pattern of study area.

In sampling the transparency of purpose and using the results of such purpose is a key rule (Zobeiry 2002).So the sampling method should be selected based on the target of sampling, forest structure and available tools. If our aim is the comparison of plant diversity in two different areas, diversity estimation will suffice with equal sampling methods and don't need to more accurate sampling methods and spending higher costs. Etemad et al. (2014) used sampling plots at the dimensions of 10 m x 10 m, 15 m x 15 m, 20 m x 20 m, and 40 m x 40 m for estimation of trees diversity in northern Zagros forests. They compared the diversity indices with hundred percent inventory data using $E\%^2$x T criterion, and concluded that square methods with dimension of 40 m x 40 m, and 20 m x 20 m were the best sizes for determining the density and canopy cover diversity of trees. Saber (1993) used the grid dimensions of150 mx400 m and circular sample plots with an area of 1000m^2 for estimating the canopy trees of Zagros Forest.

In conclusion, according to the Importance-value curve, accuracy and $E\%^2$xT criterion, the 150 m x 400 m grid size and sampling plot size with an area of 1000 m^2 was proposed as the most appropriate one to estimate woody species diversity in Iranian Zagros Forests.

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