SilvaWorld
http://silvaworld.org
e-ISSN: 2822-6127
PRENSIP
https://prensip.gen.tr

RESEARCH ARTICLE

# Comparison of Basal Area and Trees Abundance for Estimating Tree Diversity in Beech Forests (Case Study: Guilan, Masal, Northern Iran)

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## ARTICLE INFO

**Article History**
Received: 08.08.2022
Accepted: 31.08.2022
First Published: 14.09.2022

**Keywords**
Diversity indices
Error percentage
Evenness indices
Masal

## ABSTRACT

Measuring tree species diversity is necessary to manage forest resources sustainably and to better understand the economic consequences to changes in species diversity due to management. This research aimed at comparing the basal area and trees abundance for evaluating tree species diversity in oriental beech (*Fagus orientalis* Lipsky) forests (Guilan, Masal, Northern Iran). For this study, compartment 515 was selected, and then data were collected through the random-systematic method with a grid dimension of 150×150 m in an area of 50 ha, and lozenge shape with the sizes of 400; 800; 1,000; 1,200; 1,600; 2,000; 2,500; and 5,000 $m^2$ was established. In total, 160 sampling plots were taken. In each plot, the diameter at breast height (DBH≥7.5 cm) of all trees was measured. Diversity and evenness indices were estimated applying different variables (the basal area and the trees abundance) separately. The results elucidated that the error percentage of Mac Arthur's $N_1$, Hill's $N_2$ indices, and Simpson's evenness, was lower using basal area compare to the trees abundance. The result of Camargo, Nee, and Smith-Wilson evenness indices revealed that the error percentage by using the trees abundance was lower than the amount of basal area. We recommend using the basal area for estimating tree species diversity.

**Please cite this paper as follows:**

Mirzazadeh, A., Pourbabaei, H., Daryaei, M. G., & Bonyad, A. (2022). Comparison of basal area and trees abundance for estimating tree diversity in beech forests (case study: Guilan, Masal, Northern Iran). *SilvaWorld*, *1*(1), 16-22. https://doi.org/10.29329/silva.2022.462.02

## Introduction

Investigation of the relationship between natural resource development and environmental degradation can aid to manage the ecological implications (Ahmed et al., 2020). Protection of biodiversity is one of the most critical issues in natural resources on Earth (Mirzaei et al., 2019). Measuring of woody species diversity facilitates to estimation of the economical results in biodiversity. Trees are an influential factor on other components in forests. Therefore, increasing the tree species diversity can reduce the effects of drought, and is crucial to access precise information about tree species and plant communities (Grossiord, 2018). Oriental beech (*Fagus orientalis* Lipsky) is one of the commercial species in the north of Iran, which is used in different woody crop industries (Alavi et al., 2020). The most important point of environmental protection is keeping the local species in an area that can be accomplished through the acknowledgment of biodiversity, and estimation strategies (Nesper et al., 2017). Mirzaei et al. (2019) studied the effects of inventory grids on tree species diversity in semi-arid area of Iran, which indicated that based on using criteria $E\%^2 \times T$, with a grid dimension of 200×100m (25 plots)

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was selected as the most appropriate one for measuring the tree species diversity. Etemad et al. (2014) utilized quadrat plots sizes of 100, 225, 400, and 1,600 $m^2$ for studying the tree species diversity in Zagros forests in Iran; and these authors revealed that the quadrat plots 1,600 $m^2$ and 400 $m^2$ were the most appropriate sizes for determining the tree species diversity. On the other hand, estimating the woody diversity by using a software provided the possibility for quickly evaluating with a reasonable error and efficiency. The usual way for assessing the diversity is applying of the basal area, the trees abundance, and the cover percentage, which are used for trees, shrubs, and herbaceous plants, respectively. Moreover, characteristics such as the volume of trees and basal area have been used to estimate different parameters. In another research by using 26 sample plots of 1,000 $m^2$ were used to evaluate and compare the characteristics of frequency, the basal area, and the volume of trees in estimating of tree species diversity. The results indicated that the quantity of diversity and evenness indices using the trees abundance is higher than utilizing the volume or basal area to estimate the indices (Mirzaei et al., 2016). In another research, in Kalaleh region of Golestan province (Iran), the characteristics of standing volume and tree density (trees abundance per hectare) were estimated with sample plots of 200, 600, 800, and 1,000 $m^2$, circle and square shapes, and full inventory. The results revealed that the size of 400 $m^2$ with circular and square shapes had the lower percentage of sampling error (Ghiasi et al., 2020).

Zohrevandi et al. (2016) in order to select the optimal sample plot size by studying of woody species diversity in Zagros forests (Iran), sizes of 1,000; 1,500; and 2,000 $m^2$ were utilized. The results showed that the size of 1,000 $m^2$ had the lowest error percentage of the forest inventory. Neumann and Starlinger (2001) concluded that the Shannon-Wiener diversity index is the most appropriate index to evaluate the tree species diversity. The main aim of this study was to compare the accuracy of the tree species diversity and its evenness by applying basal area, and the trees abundance in different areas of the sample plot in order to determine the best characteristic and the optimal sample plot size in the beech forest of the Hyrcanian regions in northern Iran.

## Materials and Methods

### *Study Area*

This study was carried out in the northern forests of Iran that are known as Hyrcanian regions. The total of the study area was 50 hectares, and located between 48°55′19″ to 49°02′00″ longitude and 37°14′00″ to 37°19′20″ N latitude. Elevation ranges between 300 to 200 m above sea level and the study area has a mean slope of 35%, and an East aspect. The mean annual precipitation is 1,530 mm and the mean annual temperature is 16.5 ºC. The bedrock is limestone, shale, and acidic sandstone, and pH is approximately 5.5-6.5. The forests in the study area consist of deciduous broad-leaved trees of different ages that vary in composition from pure beech to mixtures of oriental beech with other hardwood species. These forests were previously impacted by disturbances from overgrazing, harvesting by forest dwellers, and illegal logging for supplying logs and firewood, all of which have influenced the quantity and quality of forests. Conversely, the study area has been strictly protected for 16 years (Anonymous, 2016).

### *Method*

Initially, a map of the study area was utilized to establish an inventory grid of 150×150 m, in a 50 ha area of the compartment. Eight concentric lozenge sampling plots with sizes 400; 800; 1,000; 1,200; 1,600; 2,000; 2,500; and 5,000 $m^2$ were established for each sampling point. In total, 160 sampling plots were measured. In each plot, species, number of species, trees abundance, and diameter at breast height (DBH≥7.5 cm) were measured and recorded. For study of tree species diversity, the eight diversity, and evenness indices were utilized with the formulas (Table 1).

### *Data analysis*

The total basal area of each tree in each sample plot size was calculated using MS Excel software. To calculate the diversity, the data related to the basal area, and the trees abundance in each plot was measured separately, and entered into the Ecological Methodology software. In this software, Shannon-Wiener, Simpson, McArthur $N_1$, and Hill $N_2$ diversity indices, as well as Camargo, Simpson, Nee, and Smith-Wilson evenness indices were calculated (Table 1). The standard deviation, standard error, and error percentage related to each of the diversity, and evenness indices were calculated for basal area, and the trees abundance. In this research, the error percentage was estimated in each of the two parameters (variables), which used as a criterion for choosing the best parameters for evaluating the tree species diversity.

## Results

In this research, three species were identified, which included *Fagus orientalis*, *Carpinus betulus* L., and *Alnus subcordata* C. A. Mey. *F. orientalis* in 8 different areas of the sample plot size showed that the highest, and the lowest percentage of the abundance in the size of 2,000 and 5,000 $m^2$, with the amount of 91.8 and 83.2%, respectively, in comparison with *C. betulus* and *A. subcordata*. The percentage of abundance of the *C. betulus* in all the sample plots was higher than the *A. subcordata*, and its lowest and highest values were 6.4 and 13.7%, respectively, in the sample plots of 1,200 and 5,000 $m^2$. The lowest and highest percentages of *A. subcordata* in all sample plots were 2.4, and 4.6% in the size of 1,000 and 400 $m^2$ (Table 2)

**Table 1.** Diversity and evenness indices with equations

| Index | Equation |
|---|---|
| Simpson (1-D) | $1 - D = 1 - \sum_{i=1}^{s}\left[\frac{n_i(n_i-1)}{N(N-1)}\right]$ |
| Shannon-Wiener (H´) | $H' = \sum_{i=1}^{s}(P_i)\,(log_2 P_i)$ |
| Hill ($N_2$) | $\frac{1}{D} = \frac{1}{\sum p_i^2}$ |
| Mc Arthur ($N_1$) | $N_1 = e^{H'}$ |
| Camargo (E') | $E' = 1..0 - \left(\sum_{i=1}^{s}\sum_{j=i+1}^{s}\left[\left\|P_i - P_j\right\|/S\right]\right)$ |
| Smith-Wilson ($E_{var}$) | $E_{var} = 1 - \left(\frac{2}{\pi}\right)\left[arctan\left\{\frac{\sum\left(log_e(n_i) - \sum log_e(n_j)/s\right)^2}{s}\right\}\right]$ |
| Simpson ($\mathbf{E_{1/\hat{D}}}$) | $E_{1/\hat{D}} = \frac{1/\hat{D}}{S}$ |
| Nee ($E_Q$) | $E_Q = \frac{-2}{\pi\ \arctan(b)}$ |

D is dominance index, $n_i$ = the number of individuals of the i^th^ species, N = total number of all individuals, H' = Shanon-Wiener, $P_i$ = the relative frequency of the $i^{th}$ species, $P_j$ = the relative frequency of the $j^{th}$ species, $N_1$ = an equal number of common species that create diversity similar to the H', E' = Camargo, S = the total number of species, b = the gradient of dominance - diversity curves, e = 2.71828.

**Table 2.** The trees density based on sample plot size, and species

| Abundant Percentage of the Total Species (%) | | | The Number of Species | | | |
|---|---|---|---|---|---|---|
| ***F. orientalis*** | ***C. betulus*** | ***A. subcordata*** | ***F. orientalis*** | ***C. betulus*** | ***A. subcordata*** | **Plot size ($m^2$)** |
| 87.2 | 8.0 | 4.6 | 412 | 38 | 22 | 400 |
| 89.8 | 7.0 | 3.0 | 788 | 62 | 27 | 800 |
| 90.8 | 6.5 | 2.5 | 1,048 | 76 | 30 | 1,000 |
| 91.1 | 6.4 | 2.4 | 1,375 | 97 | 37 | 1,200 |
| 90.60 | 6.7 | 2.6 | 1,781 | 133 | 52 | 1,600 |
| 91.8 | 7.4 | 2.6 | 2,154 | 179 | 63 | 2,000 |
| 88.9 | 8.4 | 2.6 | 2,543 | 242 | 75 | 2,500 |
| 83.2 | 13.7 | 2.9 | 3,438 | 570 | 123 | 5,000 |

Results with Shannon-Wiener Diversity Index error revealed that the lowest error percentage by using the basal area compared to the trees abundance was related to size of 2,000 and 1,000 $m^2$, with 5.5 and 25.8%, respectively. In another side, both of the plot sizes had the lowest error percentage by applying the error percentage of the trees abundance (Table 3). The sizes of 400; 800; 1,200; 2,500; and 5,000 $m^2$ had the lowest error percentage by utilizing the trees abundance. Totally, the size of 2,000 $m^2$ by using the basal area had the lowest error percentage of Shannon-Wiener index. The results of Simpson diversity Index elucidated that the lowest error percentage in size of 5,000; 2,000; and 1,000 $m^2$ was measured by using the basal area, which was 12.2, 18.9, and 32.1%, respectively. The lowest error percentage by applying the sizes of 400; 800; 1,200; 1,600; and 2,500 related to the use of the trees abundance variable. Totally, the size 5,000 $m^2$ had a reasonable error percentage by utilizing Simpson diversity index. The lowest error percentage of Mc Artor's $N_1$ index was related to size of 2,000; 5,000; 1,000; and 800 $m^2$, respectively, with 0.5, 6.6, 7.6 and 7.8%, respectively, which calculated using basal area, respectively, and the least percentage of error in other sizes was using the trees abundance. Totally, the plot size 2,000 $m^2$ had the lowest error percentage by applying Mc Artor's $N_1$ index. The results of the Hill $N_2$ index indicated that the lowest error percentage by size of 2,000; 5,000; and 1,000 $m^2$, with the amount of 3.8, 5.4 and 6.7%, respectively, which was calculated using basal area. In addition, the plot size of 400; 800; 1,200; 1,600; and 2,500 $m^2$ had the reasonable amount of error percentage by utilizing of the trees abundance. Totally, the size of 2,000 $m^2$ elucidated the lowest error percentage by applying the basal area (Table 3).

**Table 3.** Inventory error (E%) of diversity indices in different plot sizes

| Diversity Indices | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Hill ($N_2$) | | Mc-Arthur ($N_1$) | | Simpson | | Shannon-Wiener | | |
| Basal area | Trees abundance | Basal area | Trees abundance | Basal area | Trees abundance | Basal area | Trees abundance | Plot size ($m^2$) |
| 18.6 | 18.0 | 18.3 | 17.9 | 36.7 | 33.1 | 30.7 | 28.1 | 400 |
| 7.3 | 7.2 | 7.8 | 8.2 | 32.5 | 30.9 | 25.6 | 24.7 | 800 |
| 6.7 | 6.9 | 7.6 | 8.4 | 32.1 | 32.2 | 25.8 | 27.0 | 1,000 |
| 6.4 | 5.9 | 7.6 | 7.4 | 30.4 | 28.4 | 24.7 | 23.7 | 1,200 |
| 6.5 | 5.2 | 6.9 | 6.5 | 25.8 | 23.5 | 20.7 | 18.7 | 1,600 |
| 3.8 | 5.3 | 5.0 | 6.7 | 18.9 | 23.8 | 5.5 | 18.7 | 2,000 |
| 5.8 | 5.3 | 6.9 | 6.3 | 25.9 | 22.2 | 21.6 | 17.2 | 2,500 |
| 5.4 | 6.7 | 6.6 | 7.0 | 18.2 | 19.1 | 15.7 | 15.2 | 5,000 |

The right and left columns are the error percentage using the basal area, and the trees abundance in different plot size.

The results of the Camargo evenness index showed that the lowest percentage in all sample plot sizes related to the size of 5,000 $m^2$, which was obtained by using the trees abundance, and the amount was 1.5%. Moreover, the lowest error percentage in all of the sample plot sizes was measured by using the basal area in size of 2,500 $m^2$ with an amount of 7.5%, and in the other seven sample plot sizes, the lowest error percentage was related to the applying of the trees abundance (Table 4). The lowest error percentage of Simpson's evenness index in the size of 2,500 and 5,000 $m^2$ was 7.7 and 5.3%, respectively, which was related to the use of the basal area in the estimation of Simpson's evenness index. In summary, the lowest error percentage in the other sample plot sizes was calculated using the trees abundance. Totally, the size of 5,000 $m^2$ utilizing the basal area had the lowest error percentage in all of the sample plot sizes by using this index, and comparing the basal area with the trees abundance. The results with Nee's evenness index elucidated that the lowest error percentage using the basal area with size of 2,500 $m^2$ was 10.4%. On the other hand, the lowest error percentage in different plot sizes was calculated using the trees abundance. The reasonable error percentage in all of the sample plot sizes was also related to the calculation with the trees abundance, which was 7.5%. The lowest error percentage of the Smith-Wilson evenness index, like the Nee's evenness index, was related to the basal area in size of 2,500 $m^2$, which was 20.0%. Meanwhile, in the other plot size applying the trees abundance has the lower error percentage. The size of 2,000 $m^2$ using the trees abundance showed that the lowest error percentage in all of sample plots sizes and comparison the basal area with the trees abundance (Table 4).

**Table 4.** Inventory error (E%) of evenness indices in different plot sizes

| Evenness Indices | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Smith-Wilson | | Simpson | | Nee | | Camargo | | |
| Basal area | Trees abundance | Basal area | Trees abundance | Basal area | Trees abundance | Basal area | Trees abundance | Plot size ($m^2$) |
| 30.9 | 29.6 | 37.2 | 27.1 | 18.6 | 18.0 | 18.0 | 17.6 | 400 |
| 33.3 | 25.7 | 24.6 | 19.5 | 9.9 | 9.3 | 9.0 | 8.2 | 800 |
| 32.8 | 16.9 | 12.6 | 10.1 | 6.3 | 5.8 | 6.1 | 5.5 | 1,000 |
| 25.9 | 17.0 | 13.4 | 8.7 | 8.7 | 7.8 | 8.3 | 7.3 | 1,200 |
| 21.8 | 15.2 | 11.4 | 8.0 | 8.7 | 8.5 | 8.3 | 7.9 | 1,600 |
| 24.8 | 13.9 | 12.7 | 7.5 | 8.8 | 7.7 | 8.4 | 7.2 | 2,000 |
| 20.0 | 20.7 | 10.4 | 10.7 | 7.8 | 8.8 | 7.5 | 8.1 | 2,500 |
| 23.1 | 14.4 | 12.3 | 8.6 | 5.3 | 6.3 | 5.2 | 5.1 | 5,000 |

The right and left columns are the error percentage using the basal area, and the trees abundance in different plot size.

## Discussion

In this research, the amount of the tree species diversity was estimated by applying the basal area and the trees abundance variable. The edaphic and climatic conditions were suitable for the growth of other species. However, the Oriental beech have the maximum crown and its shade-tolerance abilities and mechanisms which prevents the growth of other species, especially light-demanding species. According to, the results (Table 2), the lowest frequency percentage of oriental beech compared to other tree species with amount of 83.24% was related to the size of 5,000 $m^2$. However, the highest frequency of beech with a value of 91.8% is related to the plot size of 2,000 $m^2$. Subsequently, more than 80% of the species composition was related to oriental beech in all of 8 plot sizes. Hence, the investigated area was a pure stand of oriental beech.

In this research, the criteria for comparing the basal area, and the trees abundance was the statistical error percentage of each diversity and evenness indices.

According to the results of Shannon-Wiener diversity index, the plot size of 2,000 $m^2$ applying the basal area with an acceptable error percentage was more suitable than the evaluating based on the trees abundance. The plot size of 2,000 $m^2$ was reasonable, and also no difference with the error percentage in size of 5000 $m^2$ based on amount. In estimating the Simpson's diversity index based on both variables (the basal area and trees abundance) the size of 5,000 was the most suitable plot size with the lowest percentage. Conversely, the amount evaluated with the basal area had a lower error percent compared to the trees abundance. Comparison of both ways to calculate Simpson's diversity index error, the results of the basal area in all of the sample plot sizes elucidated that the size of 1,000 and 2,000 $m^2$ had the lowest error percentage compared to the same size by using the trees abundance.

However, the size of 400; 800; 1,200; and 1,600 $m^2$ had the lowest error percentage by utilizing the trees abundance. In the calculation of MacArthur's $N_1$ diversity index, the plot size of 2,000 and 2,500 $m^2$ were measured with the basal area and the trees abundance as the most reasonable error percentage respectively. On the other hand, the size of 2,000 $m^2$ with the lower error percentage and the area is smaller that affects the time and cost of forest inventory which seems more appropriate.

In addition, the calculations revealed that among the eight investigated plot sizes, the numbers of sample plots with a lower error percentage using the basal area and the trees abundance are equal. In calculating Hill's $N_2$ index, the plot size 2,000 $m^2$ had a lesser error percentage was more suitable in comparison with the size of 1,600 $m^2$ by applying of the trees abundance.

The results of Zohrevandi et al. (2016) in Zagros forests in Iran was different from the results of the present research the reason can be attributed to the lower density of trees and shrubs in Zagro forests compared to the northern forests of Iran. In addition, by size of 1,000; 2,000; and 5,000 $m^2$, the statistical error percentage with the basal area is lesser than the same sample plot sizes using the trees abundance variable. The results of four diversity indicators showed that the lowest error percentage was related to the estimation of the basal area.

Moreover, Hill's $N_2$ index had the lowest error percentage among the diversity indices evaluated in this research. However, our result is inconsistent with the conclusion of Neumann and Starlinger (2001), who utilized the Shannon-Wiener index as the best way to measure diversity. Hill's $N_2$ index is derived from Simpson's diversity index. Likewise, Simpson's index gives the highest return to species with more abundant, and is more sensitive with the presence of these species (Daly et al., 2018; Zohrevandi et al., 2016).

In the studied area, oriental beech was more abundant than other species in all plot sizes. This factor effects on the results of the error percentage of $N_2$ index. The results of Mirzaei et al. (2016) also had the same conclusion similar to our results, and showed that using the basal area is more appropriate for investigating the trees diversity. The results of Kapos (2005) also revealed that the applying the basal area is reasonable and more accurate to evaluate the tree stand diversity that is economical and commercial or the tree species that need preservation. On the other hand, the aforementioned results indicated that the basal area is able to be suitable to study the structure of the stand. Our study area was also a protected forest and consisted of oriental beech that has economical and commercial scope. Totally, the results revealed that utilizing the basal area in estimating of diversity indices had a lower error percentage, and in the calculation with the evenness indicators using the trees abundance had a more appropriate accuracy, and a lower error percentage. Conversely, considering that the diversity indicators simultaneously richness, and evenness are used in the measurement. The basal area is also used to calculate the evenness indices. Therefore, it can be concluded that the basal area is applicable to simultaneously study the indicators of diversity and evenness.

The results of Table 4 show that size of 5,000 $m^2$ using the Camargo evenness index with both variables (basal area and trees abundance) had the lowest error percentage, but the same plot size related to the calculation with the trees abundance had a lower and total error percentage; therefore, in analysis of this index can use the trees abundance. On the other side, the estimation of the evenness value with this index indicated that only the size of 2,500 $m^2$ had a lesser error percentage compared to the same sample plot size using the basal area. In the other seven plots sizes, the lower error percentage was related to the calculation with the trees abundance, was revealed that the error percentage with this sample size and Camargo evenness index in most of the sample plots is lower and acceptable based on the criteria of this research. Conversely, it should be considered that to measure diversity indices, the combination of richness, and evenness is used simultaneously, and the value of trees can be based on the biomass of each tree and the effect of biomass in the stand, calculated (Yuan et al., 2018). In other words, in the evaluating with diversity indices, the results are not impacted by the evenness factor, and the richness or the trees abundance had greatly impacted on the conclusion (Darcha et al., 2015; Mekonenet al., 2015; Guisande et al., 2017; Sintayehu et al., 2020).

The plot size of 1,000 and 5,000 $m^2$ had the lowest error percentage of Simpson's evenness index by applying the trees abundance and basal area, respectively. The size of 1,000 $m^2$ with a smaller area and less time had an acceptable error percentage in comparison with the size of 5,000 m$^2$, and considering due to its effect of both factors on reducing or increasing the statistical cost and time, this sample plot size is reasonable by utilizing the trees abundance to calculate Simpson's evenness index. The results of the comparison of similar sample plot sizes in using variables showed that the size of 5,000 and 2,500 m$^2$ had the lowest error percentage in the estimating with the basal area, and in different plot sizes, the lower error percentage is related to the calculation with the trees abundance. The results with Nee and Smith-Wilson's evenness indices elucidated that the size of 2,000 and 2,500 m$^2$ had the lowest error percentage in the measurement with the trees abundance and basal area, respectively.

In addition, the trees abundance variable showed lower error percentage in comparison to the total error percentage; therefore, in calculating both evenness indices, it is more appropriate to use the trees abundance on these results. The comparison of similar sample plot sizes using both variables showed that in calculation of Nee, and Smith-Wilson evenness indices, the error percentage in size of 2,500 m$^2$ by applying the basal area had a reasonable percentage in evaluating the trees abundance. Furthermore, using the basal area the size of 2,500 m$^2$ had the lowest error percentage in all of the plot sizes. The reason can be the effect of the biomass of trees on the calculation with the basal area that the value of each tree is considered proportional to its impact in the stand, that the error percentage of the evenness indices is affected by the small diameter trees and the impact of measurement in stand forest with a similar value (Ali et al., 2016; Zhang et al., 2017; Ali & Yan, 2017).

Similar research conducted on the evenness of plant species indicated that evenness is strongly influenced by the type of variable or measurement characteristic, so the distribution of trees in diameter classes has the most significant effect on the calculation of evenness indices (Orwin et al., 2014; Ribas et al., 2015).

## Conflict of Interest

The authors declare that they have no conflict of interest.

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