Evaluation of Using Systematic Random Sampling along with Forest Cruising Method in Caspian Forests-(Iran)  
(Case Study: Kheyrood-Kenar, Naushahr)  

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Abstract: In this study, in order to develop an appropriate sampling method for inventory in un-even aged and mixed forest, a systematic random sampling (SRS) along with forest cruising method was suggested in which basal area and distribution of trees number in diametric classes have no significant difference with full callipering (at 95% level). Real type and amount of rare and thick trees was also suggested to be measured.  For this study three parcels (312,313,319) of GORAZBON district in Kheyrood-Kenar, NAUSHAHR-(IRAN) were selected. And In order to compare and investigate SRS along with forest cruising method, SRS method (currently used in un-even aged and mixed Forests) and full callipering (the comparison base for other methods) were selected. Results of Kolmogoroff-Smirnoff (K.S) and paired t-tests for comparing number and basal area of trees per hectare in diametric classes that obtained from full callipering and sampling methods showed that there is no significant difference (at 95% level) between mentioned factors. Calculated confidence interval includes real population mean too and in both sampling methods, sampling error was acceptable (less than 10%). The numeral values of E (square of sampling error) × T (total inventory time) were used to evaluate and compare these two methods. Results of this study showed that the SRS along with forest cruising method is preferred for inventory of un-even aged and mixed forests.

Key words: Systematic random sampling along with forest cruising method • Un - even aged and Mixed forest  
Systematic random sampling • Full callipering • Caspian Forest  

INTRODUCTION  

Based on statistic data, forests of Iran with an area about 12.4 million hectares comprise 7.4% of the whole country area. While the forest cover of Iran is considered poor as compared with other countries, it is a unique country regarding plant diversity and genetic reserves. Considering this limited forest coverage, logical management and planning seem to be necessary. For this natural resources, an optimal management involves enough and accurate information that is obtained through forest inventory, is neccessary.  

Forest inventory can be done in different ways. We can measure the whole area for information gathering (full callipering) or after selecting some pieces of forest (sample plot), measure these pieces separately. But the point is that, at what cost can we get the considered accuracy or in what area or with what accuracy should the inventory results be responsible?  

On the other hand, with common inventory methods, we can not have an accurate estimation of the number and real type of rare and thick species [1]. So, according to the importance of these rare and thick species in silvicultural planning, biodiversity, sustainable development and etc, a complementary method, along with common inventory method in un-even aged and mixed forests (SRS with circular sample plots) is necessary for accurate measuring of rare and thick trees so that with a determined cost, an accuracy near to full callipering with clear assurance can be attainable.  

The aim of this study is offering an inventory method in which the basal area diagram and tree distribution in diametric classes have no significant difference with full
callipermeing and the type and amount of rare and thick trees can be measured.

Some studies, focusing on comparison between inventory methods related to this research, have been accomplished. In 1981, SAFE analyzed the different inventory methods in Kheyrood - Kenar forest [2]. In 1996 Akhavan compared the SRS method with stratification method in sense of cost and accuracy in northern forests of Iran by the mean of aerial photographs [3]. In 1996 Namiranian inspected the way of selecting the grid dimensions and sample plot in forest stands inventory [4]. In 2000 Nimvari compared SRS (with circular sample plots) with transect method focusing on accuracy and cost in western oak forests of Iran [5].

MATERIALS AND METHODS

Area of Study: The related study has been done over Gorazbon district located in Kheyrood-Kenar, Naushahr-Iran. This area has been composed of 27 parcels with spaces variable from 20.5 to 80 hectares. As the forest area with high diversity of species and un-even aged trees was needed for this study, tree parcels (312, 313 and 319) were selected by forest cruising.

The Way of Study and Information Gathering: Initially, in order to obtain the real statistic parameters, the full callipermeing method was exercised in the area of study. Then SRS method (which is common in un-even aged and mixed forest) and SRS along with forest cruising method (a suggested method) were come into practice.

Full Callipermeing: Via this method all trees of the forest stand that are too much to be counted, are measured [6]. The measuring limit is 7.5 cm in this study. The average number and basal area per hectare were calculated and the diagram of basal area and tree distribution in diametric classes per hectare were designed.

SRS: In SRS method, the sampling unit is selected at an equal interval over space. The advantage of SRS is the convenience of obtaining the sample and the uniform spread of the sampled observations over the entire population [7]. In this method each composition of (n) sample plots that have been organized in systematic network, has the equal chance of being selected. In this method, designing of network dimensions and deciding the shape and space of sample plots are in high importance [8].

In this survey, the shape and area of sample plot were decided respectively circular and 10 Ar. The motivation for using a circular plot is that they are easily established and the ratio of the circumference to the area is enclosed. This means that the number of accidentally included or excluded trees is minimized. Considering the aim and the space of area of study and also in order to have enough sample plot in area of study, it was decided, via forest cruising and inspection of forest, to put one sample plot per hectare. Accordingly the 100 × 100 network was selected to be used.

In this method, Diameter Breast Height (DBH) of all trees that were beyond counting, were measured in the sample plot. The point of measuring the diameter was determined in the above of slope and the trees with diameters above 7.5 cm were measured and finally the results of measuring were recorded in special forms. After calculating the average number and basal area in each sample plot, they were calculated then in hectare and standard deviation, standard error and finally inventory accuracy were calculated at 95% level for both attributes of number and basal area of trees. The diagram of basal area and distribution of trees number per hectare were designed as well.

SRS along with Forest Cruising: This method is similar to SRS in view of administration. The only difference is that, measuring the rare and thick trees will be done accurately through forest cruising. For accurate measuring of rare and thick trees, first some directions, with intervals of 50 m, were designed in a zigzag manner on the topographic map of area of study. Then the azimuths of these stripes were measured on the map and finally were prepared to be established in reality. In this study, according to the performed surveys, the species with diameters above 100 cm were identified as thick species and coliseum maple (Acer cappadocium), mountain elm (Ulmus glabra), basswood (Tilia begonifolia), cherry (Cerasus avium) and ash (Fraxinus excelsior) species were identified as rare species.

In this forest cruising, the inventory team was composed of two personnel. A leader who pointed the direction by the mean of a compass and a measurer who measured the rare and thick trees. Meanwhile, the leader, along with supervising the measurer work, helped to find these kinds of trees in their direction as well. Finally the results of the measurements were recorded in special forms.
After SRS via Excel software, the trees with diameter above 100 cm and also rare trees were eliminated in the mentioned sampling and the real number of these trees, obtained through forest cruising, were put in sampling. The average number and basal area per hectare were calculated as follow:

- Attribute of number of trees per hectare

Average of trees number in sample plot ignoring rare and thick species

\[
\bar{n} = \frac{\sum_{i=1}^{n} n_i}{n}
\]

Average of trees number per hectare

\[
\bar{N} = (\pi \times 10) + \frac{n_r}{p_r} \quad (n_r = \text{number of rare and thick trees, } p_r = \text{parcel area})
\]

- Attribute of basal area per hectare

Average of trees basal area in sample plot ignoring rare and thick species

\[
\bar{ba} = \frac{\sum_{i=1}^{n} ba_i}{n}
\]

Average of trees basal area per hectare

\[
\bar{BA} = (\bar{ba} \times 10) + \frac{ba_r}{p_r} \quad (ba_r = \text{basal area of rare and thick trees})
\]

After calculating the average number and basal area per hectare, standard deviation, standard error and inventory accuracy were obtained at level 95% and the diagrams of tree distribution and basal area per hectare in diametric classes were designed.

### RESULTS AND DISCUSSION

#### Results of Full Calliper:
As it is clear from Table 1 the being studied forest stand has been mainly composed of beech (Fagus orientalis) and hornbeam (Carpinus betulus) species and less than 15% has been dedicated to other species (oak (Quercus castaneifolia), maple (Acer spp), alder (Alnus spp) and …). Accordingly the diagram of basal area and tree distribution in diametric classes were drawn respectively for beech (Fagus orientalis) and hornbeam (Carpinus betulus) species (Figure 1) and all species (Figure 2).

After designing the diagram of number and basal area per hectare in diametric classes, the statistic parameters of average number and basal area per hectare, were calculated. The Table 2 shows the values of statistic parameters obtained from full callipering.

#### The Results of SRS:
According to Table 3 it is clear that more than 80% of the related forest stand has been composed of beech (Fagus orientalis) and hornbeam (Carpinus betulus) species and less than 20% has been composed of other species (oak (Quercus castaneifolia), maple (Acer spp), alder (Alnus spp) and …). Accordingly the diagram of basal area and tree distribution in diametric classes were drawn respectively for beech (Fagus orientalis) and hornbeam (Carpinus betulus) species (Figure 3) and all species (Figure 4).

After designing the diagram of number and basal area per hectare in diametric classes, the statistic parameters of number and basal area per hectare, were calculated. Table 4 shows the values of statistic parameters obtained from SRS.

At level 95%, the real average number per hectare in the area of study through the SRS is located between 209.8 ~ 251.6. Regarding that the real average number
Table 1: Average of basal area and number of trees per hectare resulted from full callipering

<table>
<thead>
<tr>
<th>Species</th>
<th>Basal area per hectare (%)</th>
<th>Average of basal area per hectare (m²)</th>
<th>Frequency (number of tree)</th>
<th>Frequency percent</th>
<th>Average of number per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fagus orientalis</td>
<td>62</td>
<td>21</td>
<td>12172</td>
<td>40</td>
<td>98.1</td>
</tr>
<tr>
<td>Carpinus betulus</td>
<td>22</td>
<td>7.5</td>
<td>13922</td>
<td>47</td>
<td>112.2</td>
</tr>
<tr>
<td>Other species</td>
<td>16</td>
<td>5.4</td>
<td>3979</td>
<td>13</td>
<td>32.1</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>33.9</td>
<td>30073</td>
<td>100</td>
<td>242.4</td>
</tr>
</tbody>
</table>

Table 2: Amounts of statistic parameters resulted from full callipering

<table>
<thead>
<tr>
<th>Area of study per hectare</th>
<th>Average of number of tree per hectare</th>
<th>Average of Basal area per hectare (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>124.08</td>
<td>242.4</td>
<td>33.9</td>
</tr>
</tbody>
</table>

Table 3: Average of basal area and number of trees per hectare resulted from SRS.

<table>
<thead>
<tr>
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<th>Average of basal area per hectare (m²)</th>
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<th>Average of number per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fagus orientalis</td>
<td>61</td>
<td>22.1</td>
<td>1067</td>
<td>40</td>
<td>92.8</td>
</tr>
<tr>
<td>Carpinus betulus</td>
<td>24</td>
<td>8.5</td>
<td>1269</td>
<td>48</td>
<td>110.3</td>
</tr>
<tr>
<td>Other species</td>
<td>15</td>
<td>5.5</td>
<td>317</td>
<td>12</td>
<td>27.6</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>36.1</td>
<td>2653</td>
<td>100</td>
<td>230.7</td>
</tr>
</tbody>
</table>

Table 4: Values of statistic parameters number and basal area of trees resulted from SRS

<table>
<thead>
<tr>
<th>Statistic parameter</th>
<th>Number of trees per hectare (n)</th>
<th>Basal area of trees per hectare (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{x}$</td>
<td>230.7</td>
<td>36.1</td>
</tr>
<tr>
<td>$s^2$</td>
<td>10.49</td>
<td>1.12</td>
</tr>
<tr>
<td>$%s^2$</td>
<td>4.55</td>
<td>3.12</td>
</tr>
<tr>
<td>E</td>
<td>20.87</td>
<td>2.24</td>
</tr>
<tr>
<td>%E</td>
<td>9.05</td>
<td>6.2</td>
</tr>
<tr>
<td>$\bar{x} \pm E$</td>
<td>209.8 - 251.6</td>
<td>33.86 - 38.34</td>
</tr>
</tbody>
</table>

Fig. 1: Diagram of number of trees per hectare in diametric classes of *Fagus orientalis*, *Carpinus betulus* and other species resulted from full callipering

Fig. 2: Diagram of basal area per hectare in diametric classes of *Fagus orientalis*, *Carpinus betulus* and other species resulted from full callipering
It is clear from table 5 that more than 80% of the related forest stand has been composed of beech (Fagus orientalis) and hornbeam (Carpinus betulus) species and less than 20% has been composed of other species (oak (Quercus castaneifolia), maple (Acer spp), alder (Alnus spp) and …).

Accordingly the diagram of basal area and tree distribution in diametric classes were drawn respectively for beech (Fagus orientalis) and hornbeam (Carpinus betulus) species (Figure 5) and all species (Figure 6).

At level 95%, the real average basal area per hectare in community equals to $\mu = 33.9$, it is observed that the real average is located between two confidences intervals resulted from SRS.

Fig. 3: Diagram of number of trees per hectare in diametric classes of Fagus orientalis, Carpinus betulus and other species resulted from SRS

Fig. 4: Diagram of basal area per hectare in diametric classes of Fagus orientalis, Carpinus betulus and other species resulted from SRS.
Fig. 5: Diagram of number of trees per hectare in diametric classes of *Fagus orientalis*, *Carpinus betulus* and other species resulted from SRS along with forest cruising.

Fig. 6: Diagram of basal area per hectare in diametric classes of *Fagus orientalis*, *Carpinus betulus* and other species resulted from SRS along with forest cruising.

to $\mu_s = 242.4$, it is observed that the real average is located between two confidences intervals obtained from SRS along with forest cruising.

At level 95%, the real basal area average per hectare in the area of study through the SRS along with forest cruising is located between 32.5 ~ 35.96. Regarding that the real basal area average per hectare in community equals to $\mu_{BA} = 33.9$, it is observed that the real average is located between two confidences intervals obtained from SRS along with forest cruising.

The Results of Measuring the Rare and Thick Species: The recognition and knowledge of existence or lack of rare and thick species in natural stands can be useful for forestry and silvicultural planning. We can not have an accurate estimation of real type and number of rare and thick species through SRS method, due to the shortage of these species in natural stands. Most of the time, we can’t have such an estimation or if there is any, it is a value more or less than the real one. According to figures 7 & 8 it is observed that for species such as coliseum maple (*Acer cappadocicum*), mountain elm (*Ulmus glabra*), cherry (*Cerasus avium*), maple tree (*Acer velutinum*) and basswood (*Tilia begonifolia*), the SRS method has underestimated and has overestimated for species such as oak (*Quercus* sp), hornbeam (*Carpinus* sp), alder (*Alnus* sp) and ash (*Fraxinus excelsior*) in both number and basal area per hectare. This is while, the SRS along with forest cruising has got a real estimations for this species. The little difference of basal area per hectare of some species in SRS method with full calliperling is due to this fact that the diametric classes of this species have been low in the area. The number and basal area per hectare obtained from different inventory methods have been illustrated respectively in figures 7 & 8 for different species.

The Results of Time Studies: After time studying and measuring the needed time for establishing each sample plot, the needed time for moving from one sample plot to another and also the needed time for full calliperling and forest cruising, the related results were summarized in Table 7 for different inventory methods separately.

Since the inventory team of full calliperling and SRS had been composed of 3 personnel and forest cruising of measuring rare and thick trees had been composed of 2 personnel, the whole needed time for different inventory methods was calculated in man-minute unite.

The Results of Statistic Tests: In order to compare the real number and basal area per hectare in diametric classes with the estimated number and basal area per hectare through the inventory methods, it seems to be very necessary how to select a desired statistic test among others. We used Kolmogoroff-Smirnoff (K-S) test for comparing the tree number distributions in diametric classes obtained from different inventory methods. The reason is that, through this test, we are able to compare the real distributions with the expected ones. This test focuses on the difference between the real distributions with the expected one whether it is significant or not [6]. For comparing basal area per hectare in different diametric classes obtained from different inventory method, paired

Table 7: Results of time studies for different inventory methods per man-minute

<table>
<thead>
<tr>
<th></th>
<th>Total time for full callipering</th>
<th>Total time for SRS</th>
<th>Total time for SRS along with forest cruising</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18720</td>
<td>6786</td>
<td>7986</td>
</tr>
</tbody>
</table>

359
Fig. 7: Number of tree average of different species resulted from inventory methods

Fig. 8: Basal area average of different species resulted from inventory methods

T test was used. For, this test is usable only when we have two sampling from the same statistic community and the data is the results of paired differences [6].

Via MINITAB software, paired T test was put into practice for basal area per hectare in diametric classes in both sampling method with full callipering. The results of this test showed that in all cases (at level 95%) the difference between basal area per hectare in diametric classes obtained from SRS and SRS along with forest cruising and basal area per hectare in diametric classes obtained from full callipering method, is not significant and this difference is random. However at level 5% this concluding may be incorrect.

Through the K-S test the differences between the distribution numbers of trees per hectare in different sampling methods separately and full calliper have been inspected to show whether this differences are significant or not. The results of this test showed that in all cases (at level 95%); the above mentioned differences are not significant but random. However at level 5% this concluding may be incorrect.

CONCLUSION

In order to evaluate and compare two inventory methods (SRS and SRS along with forest cruising) in
Table 8: Value of $(E\%)^2 \times T$ for each of being surveyed attributes in different inventory methods

<table>
<thead>
<tr>
<th>Attribute</th>
<th>SRS method</th>
<th>SRS along with forest cruising method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trees per hectare</td>
<td>555790.36</td>
<td>536978.64</td>
</tr>
<tr>
<td>Basal area per hectare</td>
<td>260853.84</td>
<td>221486.52</td>
</tr>
</tbody>
</table>

It should be considered that the smaller this index is, the more suitable the related method is, considering the compositive effect of the inventory error percent together with the total time of inventory. Accordingly, it is observed that in SRS along with forest cruising, $(E\%)^2 \times T$ for both attributes is a smaller value, comparing with SRS. So for estimating the basal area and number of trees per hectare, SRS along with forest cruising seems to be the best method. Furthermore SRS along with forest cruising is more acceptable for accurate estimation of number of rare and thick species because through this method real type and number of rare and thick species are measured, this is while that the importance of this rare and thick species can not be ignored in biodiversity, forest management, silvicultural studies and planning, sustainable development and … finally, considering that the needed time spent on this method is 40% of the total time of full callipering and the inventory error is in an acceptable rate, the SRS along with forest cruising method was preferred as the best method for inventory of uneven-aged and mixed forest.

REFERENCES

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