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ORIGINAL ARTICLE

Marked Trees as Indicators of Forest Sustainability- Case Study: Kheyrud Hyrcanian Forest

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ABSTRACT
Conditional monitoring is central to sustainable forest management (SFM). In order to evaluate the SFM, many indicators have been proposed. Wood harvesting has important direct effects in forests and these effects must be detected for assessing status and condition of forests. Monitoring of marked trees can be a useful indicator of the conidtion of forests under harvest. This study aims at monitoring forest sustainability with marked trees indicator. Two districts of Kheyrud Forest (Patom and Namkhane) as part of the Hyrcanian Forests of Iran was chosen and marked trees data were collected for the two last management periods (1984-1999 and 2000-2009 in Patom and 1982–1995 and 1996–2012 in Namkhane). Statistical analysis was performed using t-test and one-way ANOSIM to determine variation of number, volume and species composition of marked trees. Results showed significant reduction in the total number and volume of marked trees during the two last management periods. ANOSIM revealed significant differences in dbh (diameter at breast height), class composition and the volume of the trees during the two periods. The findings showed that the number and volume of the remained trees were reduced as a result of forest harvest. Accordingly, results imply unsustainability in management leading to forest degradation. Hence, longer rotation period of forest management plans and lower amount of harvest are recommended. This study shows marked trees indicator is a simple and appropriate tool for monitoring forest sustainability and using this indicator is suggested for other forested areas with similar ecological condition.
Keywords; *Sustainable forest management (SFM), Sustainability Indicator, Marked trees, Tree communities*

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INTRODUCTION

Sustainable forest management (SFM) is defined as a practice that prevents the ecological negative impacts of forestry in the long-term while maintaining forest benefits to the society. This approach has been emerged in the early 1990s as a remedy to anthropogenic forest degradation [1].

In order to evaluate the sustainability of forest management, many indicators have been proposed that span from forest stands to forest management units [2,3]. Many organizations such as FAO, ITTO, IUCN, IUFRO, UNDP and UNEP, as well as non-governmental organizations, communities and the private sectors have supported work on the development and field testing of national and sub-national level indicators [4].

In forestry, monitoring and information reporting of indicators are central to SFM [5], and both of them are necessary to promote learning, understanding and the application of management strategies [6]. Indicators are tools to help identify trends in the forest sector and the effects of forest management interventions over time, and to facilitate decision making in forest policy processes. Forest managers

must have a way of tracking changes in the status and condition of forests over time, extrapolating backward to historic and forward to a range of potential future conditions [7]. Changes occurred in the indicators between management periods indicate whether a forest is moving towards or away from sustainability [8]. Therefore demand for an assessment of the current forest management, which generally involves indicators at all levels, from local to national, has increased in the last decade [9].
The conservation of biological diversity, tree species composition and stand structural complexity are among the most valuable indicators of SFM [10,11]. Predictably, as forest ecosystems decline, so do the species associated with them [7].
As Kahl and Bauhus [12] mentioned, to assess the influence of past forest management on current ecosystem properties, management intensity must be quantified. Moreover, it is important to know whether an annual harvest of selected trees is more or less intense in terms of timber extraction than a management scheme in an age class forest [13].
Trees marked for harvest influence on tree species composition and stand structural complexity, hence these trees provide information on production rate and management strategies trend. Therefore, trees marked for harvest are important indicators for SFM.
Harvesting compared with annual increment and timber production and future availability are some UK indicators of sustainable forestry [14]. Harvest volume of forest products is one of the indicators at the national level [8]. Mean and range of tree ages within defined seral stages across landscape and diversity of tree ages or diameters in stand are important indicators for SFM [7].
Following the increasing awareness of the ecological negative effects of wood harvesting on condition, composition and structure of forest plant communities all over the world, researches have been carried out about these impacts on forests. Some of these researches include selective logging [15,16], illegal logging [17], clear-cut logging [18], logging operations on forest stand [19], and some researchers have tried to develop models for simulating stand development to achieve a sustainable yield [20]. Bennett and Adams [21] reviewed harvesting effects on some response variables such as tree regeneration. Nolet et al., [22] reported that sustainability is achievable by application of a wide range of alternative tree marking regimes. Tavankar and Bonyad [23] showed density of trees in the protected stand was higher than in the harvested stand and species composition was different.
Kia-Daliri et al. [24] investigated marking of trees for harvest during selection cutting and its impact on stand structure in a mixed Beech stands in Hyrcanian forest.
Pourmajidian and Rahmani [25] compared stand structure after 12 years in a Beech stand. They reported the stand volume was not significantly changed, but density of trees significantly increased after 12 years.
Villela et al. [26] investigated the effect of logging on stand structure in Brazil forests. They reported that there were no difference in tree density in logged and unlogged stands, but unlogged stands had more density of large diameter trees.
Nolet et al. [22] used a method that integrates stand growth simulation and tree marking regime optimization. The optimization parameters that were applied in their study aimed to identify possible tree marking regimes under 10-year rotation partial cutting, which would ensure that the basal area of high-quality trees was maintained for 40 years.
In some studies researchers have tried to quantify harvesting effect using indices [12,28,28].
Goushegir et al. [29] developed indicators for monitoring sustainability of Hyrcanian forest functions. They reported that harvesting amount, the balance between harvesting and growth increment, and marking of trees based on 'close to nature approach' are some of the more important indicators.
Generally, there is a considerable knowledge gap regarding long-term impacts of earlier tree harvests on the following harvests in district level. Yet, use of marked trees data in the context of harvest trend in these circumstances has not fully been studied. Therefore, a case study has been implemented by applying marked trees as sustainability indicator for monitoring stand status at Kheyrud forest as part of the Hyrcanian forests.
Kheyrud Forest in Nowshahr has been under harvest for over 50 years. The management prescription for this forest aimed for a mixed species, un-even aged, and the production of different kinds of wood with different native species of excellent quality with regards to conservation of a healthy and resistant ecosystem [30]. Timber harvesting is a major industry in this area which consists of tall trees with both single and group selective cutting regimes [31]. Therefore, it is necessary to use existing data regarding marked trees as sustainability indicator in order to investigate the changes in the number and volume of trees in different management periods. With this information, we can measure how successful forest management has been in attaining some of its important goals such as sustainable yield.

MATERIALS AND METHODS

Study area

Hyrcanian forest is a productive region along the southern coast of the Caspian Sea. Most of Hyrcania is located in Iran and Azerbaijan.Unlike the arid and semiarid areas throughout most of the central and southern Iran, this region is one of the remnants of natural deciduous forests [32]. The Hyrcanian Forests are mostly uneven-aged and broad-leaved. The stands are often spatially heterogeneous with large variations in the tree sizes [33].

Forest management plans commenced in 1957 in Iran and have been applied in Reyhanabad (Sari city) and Golband (Nowshahr city) [34]. Prior to this time, forest wood harvesting was being conducted through selective cutting. Despite the existence of management plans for harvesting, the quality and quantity of Hyrcanian plant community have decreased within the last decade [33]. Intensive human settlement in the lower elevations as early as AD 1100 has left large portions of the lowlands deforested. Later, these areas have been converted to agricultural, residential, and industrial use [35].

This study was carried out in Kheyrud, an 80 km2 area, located 7 km east of Nowshahr in Mazandran Province, Iran (51°32 31″- 51°35′38″ N, 36°37′25″- 36°34′30″ E). The lowest side of the forest in the northern border is 10 m above sea level and for the highest it goes up to 2,200 m above sea level in the south. The average rainfall ranges from 1,420–1,530 mm· a–1 with the heaviest precipitation during summer and fall seasons. The forest consists of 80 tree species and 50 shrub species. The soils are characterized by karst topography and the most common soil type is calsisols. The most common forest types are hardwoods, dominated by Fagus orientalis and C. betulus, and other tree species such as A. velutinum, Parrotia persica and Quercus castaneifolia. Although timber harvesting is a major industry in this forest, hunting, and tourism can also be accommodated with consideration of forest ecology and conservation.

Allocated to educational purposes, with strict adherence to scientific principles, this forest was consigned to the College of Natural Resources at University of Tehran through a contract with the Forestry administration in 1964 in order to carry out research and use the area for educational purposes. The forest has been divided into seven districts, called Patom, Namkhane, Gozarbon, Chelir, Baharbon, Manyasng, and Darno. The whole study area is a watershed and almost all these districts are sub-basins. Forest management plans have been outlined for three districts of the forest: Patom, Namkhane and Gorazbon.

The first part of the forest (the Patom), was being exploited during three management periods (1973-1983, 1984-1999, 2000-2009). Each management period is 10 years long, but due to financial problems was renewed for longer periods. Management of the Namkhane district was completed in two periods (1982–1995, 1996–2012).Only the Gorazbon district was exploited just during the first period [36,37,38,39,30,31]. Forest management plans have not been prepared for the other parts and they are left to remain as natural forest for future studies.

Primarily, forest compartmenting helps planning, stock accounting, soil investigation, exploitation, and transportation. Indeed, compartments are single program units in districts. Borders of compartments are determined with regard to the construction of future road network and considering the natural features (i.e valleys and ridges) in the district [30].

Data collection

Data collection was performed according to tree marking documents obtained from University of Tehran-Department of Forestry and Forest Economic, and forestry action plans [36,37,38,30,39,40]. In order to investigate the differences between the management periods (almost 10 years long) we needed data at least from two periods, therefore Gorazbon district with one management period was removed from consideration. Because data from the first period of Patom was not available, we chose only the last two periods (1984- 1999 and 2000- 2009 in Patom and 1982–1995 and 1996–2012 in Namkhane). The Data included total number and volume (m3) of trees in each class of dbh and for each individual species.

Tree marking documents consist of a list of each kind of marked tree species with its dbh. We used volume functions [20] to calculate volume from dbh for Fagus orientalis Lipsky.,C. betulus L., and other species. The diameters of all trees with minimum dbh of 7.5 cm were considered.

Other species mostly included Tilia platyphyllos scop., A. velutinum Boiss., Alnus subcordata C.A.Mey., Quercus castaneifolia C.A.Mey., Ulmus glabra Hudson., Acer cappadocicum Gled, and Parrotia persica C.A.Mey. These species were low in numbers in document lists and therefore we summed them up together and named them “other species”. In addition, there was no function to calculate their volume separately.

Dbh of each marked tree was measured at 5-cm intervals. After plotting trees according to abundance, diameter was reclassified into <30 (7.5 to 32.5 cm), 35– 50 (32.5 to 52.5 cm), 55–80 (52.5 to 82.5) and 85< (dbh more than 82.5 cm).

Twenty one compartments in Namkhane district and thirteen compartments in Patom district were exploitable and others were non-exploitable compartments. Totally, 13 compartments from the exploitable compartments were harvested during the last two management periods consecutively. Among these, six compartments were randomly selected and their data was extracted from the mentioned documents for research (Table 1).

Table 1 – Characteristics of the selected compartments

Parcel	Area (ha)	Height Max	Height Min	Average Slop (%)	Direction
212	54.8	627	477	40	NW
114	38.4	790	610	35	NW
115	34.7	780	700	20	S
117	70.5	780	600	40	W
219	49.5	1080	860	30	W, SW
225	55.8	1190	1100	30	NW

(Department of Forestry and Forest Economics, 1995 a and b)

DATA ANALYSES

A paired t-test was used for total number and volume differences of trees over time in the two periods. Normality of data was checked by the Shapiro-Wilk test prior to the t-test. The result showed that some factors were skewed. However, all data on the tree volume were transformed using logarithmic and squared root-transformations was performed on tree number to reduce skewness, outliers, and approximate normality.

One-way analysis of similarity (ANOSIM) was derived from Bray–Curtis dissimilarity matrix based on square root and logarithmic transformation of marked tree number and volume, respectively, to test the significance of differences in marked tree assemblages with respect to tree number and volume between the two periods.

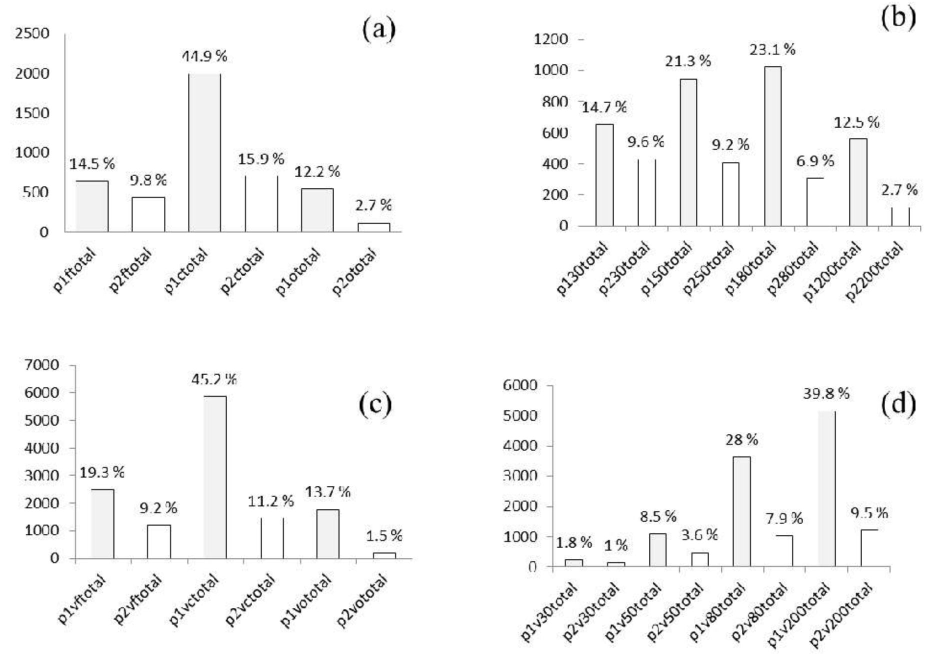
Afterwards, compartment state trends in volume, density and species composition were obtained from existing documents in different years. They are helpful data for comparison of harvesting effects on the trees in different years.

RESULTS

Figure 1 shows the percentage of total marked tree number and volume with breakdown of each species (a and c) and dbh classes (b and d) in two periods. In the first period, the number of trees with medium diameter was more than others and in the second period, based on marked tree volume, thicker trees were more marked than in the first period (b and d).

In terms of volume, trees with dbh 35–50 and 55–80 cm were more targeted and marked in the first period, but trees with smaller dbh were marked (b and d) in the second period. Accordingly, both number and volume of the marked trees in the first period are considerable and the highest harvest was performed on C. betulus.

The results of paired t-test are shown in Tables 2 and 3, respectively, for number and volume of marked trees. As results in Table 2 show, there are significant differences in total number of marked trees, total C. betulus, and total of other species ($P \leq 0.01$).A significant difference was also detected for total number of marked trees at three dbh classes 35–50, 85< ($P \leq 0.05$) and 55–80 ($P \leq 0.01$) in the two periods. Dbh class 55–80 for C. betulus and other species ($P \leq 0.01$) and both 33–50 and 85< dbh class ($P \leq 0.05$) showed significant differences in the two periods.



p1= period 1, p2= period 2, total= total markrt trees, f= *Fagus orientalis*, c= *Carpinus betulus*, o= other speises, 30= the total marked trees in dbh class 0-30, 50= the total marked trees in dbh class 35-50, 80= the total marked trees in dbh class 55-80, 200= the total marked trees in dbh class 85<

Fig. 1. Percentage of total marked trees number in two periods with separation of species (a) and dbh classes (b), and percentage of total marked trees volume in two periods with separation of species (c) and dbh classes (d)

Table 2 –Summary of paired t-test for number of marked trees

The pair comparison	Df	T	Sig. (2-tailed)
p1total - p2total	5	4.552 **	.006
p1ftotal - p2ftotal	5	.785 ns	.468
p1ctotal - p2ctotal	5	4.474 **	.007
p1ototal - p2ototal	5	4.106 **	.009
p130total - p230total	5	.181 ns	.864
p150total - p250total	5	3.719 *	.014
p180total - p280total	5	8.854 **	.000
p1200total - p2200total	5	3.554*	.016
p1f30 - p2f30	5	-1.606 ns	.169
p1f50 - p2f50	5	1.124 ns	.312
p1f80 - p2f80	5	1.512 ns	.191
p1f200 - p2f200	5	1.361 ns	.232
p1c30 - p2c30	5	-.459 ns	.666
p1c50 - p2c50	5	3.146 *	.025
p1c80 - p2c80	5	7.116 **	.001
p1c200 - p2c200	5	3.233 *	.023
p1o30 - p2o30	5	2.024 ns	.099
p1o50 - p2o50	5	1.595 ns	.172
p1o80 - p2o80	5	5.485 **	.003
p1o200 - p2o200	5	1.037 ns	.347

p1= period 1, p2=period 2, total= total marked trees, f= Fagus orientalis, c= C. betulus, o= other species, 30= the total marked trees in dbh class 0–30, 50= the total marked trees in dbh class 35–50, 80= the total marked trees in dbh class 55–80, 200= the total marked trees in dbh class 85<, ns= not significant; *= significant ($P \leq 0.05$) and **= significant ($P \leq 0.01$).

Table 3 – Summary of paired t-test for volume of marked trees

The pair comparison	df	T	Sig. (2-tailed)
p1vtotal - p2vtotal	5	6.765 **	.001
p1vftotal - p2vftotal	5	1.47 ns	.201
p1vctotal - p2vctotal	5	6.933 **	.001
p1vototal - p2vototal	5	3.241 *	.023
p1v30total - p2v30total	5	.235 ns	.824
p1v50total - p2v50total	5	5.049 **	.004
p1v80total - p2v80total	5	12.387 **	.000
p1v200total - p2v200total	5	3.688 *	.014
p1vf30 - p2f30	5	-8.255 **	.000
p1vf50 - p2f50	5	-2.895 *	.034
p1vf80 - p2vf80	5	1.868 ns	.121
p1vf200 - p2vf200	5	.974 ns	.375
p1vc30 - p2vc30	5	-.135 ns	.898
p1vc50 - p2vc50	5	3.563 *	.016
p1vc80 - p2vc80	5	7.571 **	.001
p1vc200 - p2vc200	5	3.606 *	.015
p1vo30 - p2vo30	5	1.828 ns	.127
p1vo50 - p2vo50	5	2.821 *	.037
p1vo80 - p2vo80	5	6.559 **	.001
p1vo200 - p2vo200	5	.955 ns	.383

v= volume, others is similar to tab.2

On the basis of marked tree volume, significant differences were found in total marked trees, total C. betulus ($P \leq 0.01$), other species ($P \leq 0.05$), and marked trees at dbh classes 35– 50, and 55–80 ($P \leq 0.01$) 85< ($P \leq 0.05$) in the two periods. Dbh class of Fagus orientalis had no significant difference in number between the two periods but there were some significant differences in volume; dbh classes 30> ($P \leq 0.01$) and 35–50 ($P \leq 0.05$). Significant difference for volume of C. betulus in dbh class was similar to the number data. Other species in dbh classes 35–50 ($P \leq 0.05$) and 55–80 ($P \leq .01$) had significant differences.

The result of one-way ANOSIM (Tables 4 and 5) showed significant differences in dbh class composition for tree number ($P \leq .01$) in the two periods and volume ($P \leq 0.05$). Other species had significant differences in both market tree number and volume ($P \leq 0.05$). Also, there are nearly significant differences in dbh class composition of C. betulus as marked tree number and in species composition as marked tree volume.

Table 4 –Result of ANOSIM for number of marked trees data

Comparison	Global R	P-value
Species composition	0.154 ns	0.082
Dbh class composition	0.506 **	0.009
Dbh class composition of Fagus orientalis	0.042 ns	0.206
Dbh class composition of Carpinus betulus	0.226 ns	0.052
Dbh class composition of other species	0.333 *	0.011

Table 5 –Result of ANOSIM for volume of marked trees data

Comparison	Global R	P-value
Species composition	0.156 ns	0.058
Dbh class composition	0.307 *	0.030
Dbh class composition of Fagus orientalis	0.009	0.350
Dbh class composition of Carpinus betulus	0.163 ns	0.095
Dbh class composition of other species	0.320 *	0.011

Table 6 shows state trend of compartments (volume and number of trees per ha, and species composition) in different years. According to this, there is a decreasing trend in both number and volume in almost all compartments. In terms of species composition, a high change is observed so that species composition changed before the start and after the last harvesting.

Table 6- Compartments state trend in different years

Date	Compartment	Number per ha	Volume per ha (m3)	F (%)	C (%)	O (%)
1969		-	297.50	-	-	-
1984	114	270.00	327.68	-	-	-
1995		231.00	208.96	-	-	-
1969		-	238.00	-	-	-
1984	115	154.00	255.85	-	-	-
1995		176.62	211.85	-	-	-
1969		-	-	-	-	-
1984	117	226.00	248.97	-	-	-
1995		232.78	335.79	-	-	-
1980		278.00	322.15	50.00	30.00	20.00
1995	212	215.45	320.18	20.00	70.00	10.00
2013		192.00	367.20	39.15	55.11	5.75
1980		350.00	431.00	65.00	30.00	5.00
1995	219	162.00	369.71	86.00	10.00	4.00
2013		213.00	441.15	83.56	12.91	3.53
1980		349.00	513.00	42.50	45.00	12.50
1995	225	122.58	255.91	34.00	49.00	17.00
2013		189.00	345.95	44.01	36.21	19.78

DISCUSSION

In this research, monitoring of harvested tree communities (marked trees) with respect to the remained tree communities was performed in two management periods (1984- 1999 and 2000- 2009 in Patom and 1982–1995 and 1996–2012 in Namkhane), whereas most studies [23,26] had investigated harvesting effect (harvested stands) in comparison with non-harvested stands. Despite the emphasis made by Goushegir et al. [29], for the area, there has been little research on change detection of harvested amount and there is a particular lack of quantitative approach into exploring the harvest rate changes and checking how marked trees communities might have altered in time. We examined these changes based on marked trees indictor. In this case, pressure variable is harvesting (marked trees), state is condition of remained trees, and response is change in the pressures and state over time that indicates trend of management.

CHANGES IN MARKED AND REMAINED TREES

In this study, the number and volume of marked trees showed significant reductions in the two management periods for some species and dbh classes (table 2 and 3). Therefore, studied forest must be harvested into long rotation periods with less tree yields. According to comparison of number and volume in Table 6, it is obvious that volume became higher in almost all of compartments in the last year especially in Namkhane district. It is demonstrated that the forest is being pushed to become old with low amount of trees and high volume.

Tavankar and Bonyad [23] reported that tree density in harvested stand is lower than non- harvested stands after 10- 30 years. However these studies are performed along space not time, but they demonstrated harvesting affect tree density that is same to results of this study (tree density before the first harvesting in comparison with tree density after the last harvesting (tab. 6)). Reduction of harvesting amount also showed that total tree stocks were reduced. Investigation that was performed by Pourmajidian and Rahmani [25] before and after harvesting showed tree density and tree diameter per hectare were more after 12 years since harvesting that this condition was same to the last management periods of this study (in Namkhane district). It is obvious that although number and volume of trees were increased after the last harvesting (2012 in Namkhane district), but it was not achieved to the number and volume of trees (per ha) before the first harvesting (1980 in Namkhane district).

Harvest reduction due to over exploitation of wood during the early management periods and poor regeneration due to grazing by livestock [41], and also climate change, drought[42], and reduced springs and river water have caused more sensibility and vulnerability of Kheyrud Forest.

The balance between amount of cutting and increment is necessary for achieving SFM. In the past forest management plans of Kheyrud Forest permits for the total area of a forest were similar. They were issued regardless of the sloped surfaces, open areas between the stands such as livestock place, gaps, roads and other open spaces, but recently these unsuitable areas are not imputed. This is another factor for reduction in harvesting.

CHANGES IN THE TREES COMMUNITY

The results of this study indicated significant differences in the dbh class composition in both number and volume and showed harvested assemblages as dbh classes were not similar in the two management periods considered (Table 4 and 5). In the first period, middle dbh classes and in the second period the lowest thickness class were more than other classes marked in terms of number (Table 4). The highest volume of marked trees in dbh classes during the first period belonged to 85< class and during the second period the two classes 55–80 and 85< had the highest marked tree volume.

The reason for these differences may be related to harvesting old growth forest stands. In these stands with the harvesting of old trees in the first period, trees with smaller dbh remained for the second period.

A survey of other marked species also showed that in all classes the first period was taken more uniformly, while smaller dbh classes in the second period occurred. As the total operations in this forest were carried out with a goal to improve forest quality, it seems that thicker species remained after operation. In terms of the number of dbh class composition of C. betulus, which was fairly significantly different in the two management periods, the dbh class of 55–80 in the first period and the dbh class of 35–50 was more harvested. In terms of harvested volume, although yields of C. betulus in the two management periods were higher than other species, the percentage of harvested amount in the related period was nearly constant (58% of the harvest in the first period and 51% in the second period).

Fagus orientalis was harvested at a rate of 25% in the first period which reached 42% in the second period and other species were initially extracted 17% and reduced to 7%. Therefore, the volume of harvested species assemblages was significantly different.

Table 6 demonstrates that the remained trees community was changed in terms of species composition in Namkhane. With respect to the goals of forest management (mixed species and un-even aged), it seems that management detracted away from these goals, although with more extraction of C. betulus, this harvest was implemented to support more economic species such as *F. orientalis*. Management goals did not allow new species composition in the area. For example, other species in the compartment 212 declined from 20 % in the year 1983 to 6 % in 2013. Also, in compartment 225 other species increased from 12 % to 20 %. This condition is almost coincident with appearance of early successional species like Diospyros lotus that demonstrated disturbance as result of human actions and environmental stress.

Tavankar and Bonyad [23] reported that forest management leads to changes in structure and species composition of stands that is similar to this study results. However, many researches agree with change of species composition due to harvesting.

Marked trees is recognized as straightforward indicator for SFM in local scale and can be used as indicator of the past management practices in forested areas and a guideline for future forest management.

Limited effort has gone into exploring how marked tree communities might have been altered in time. Since the objective of forest management is to improve the quality and quantity of forest stands, harvesting has been accordingly done in this regard to prevent forest damage. So species harvest is an indication of the quality and quantity of forest stands and can be important for forest managers. Tree marking and harvesting should be below the allowable quota, to improve forest stands, in the studied forests where the forest management plans are going to be performed, however this is not enough, so, area wise logging distribution is also an important factor. This paper focuses on how marked trees indicator helps assess progress in SFM. However, a significant reduction in yields is concerned with factors such as livestock grazing and drought. Also, more accurate measurement of the annual growth of the forest and subtraction of less productive trees can help in this regard. The findings of this study highlighted that the rotation period of forest management plans should be longer and amount of harvest should be lower. Also, it is important to pay attention to harvested and remained species composition in order to achieve management goals.

In conclusion, marked trees indicator is a good tool for SFM and has many good indicator properties such that it can detect changes in forest management over time; is efficient in time and costs; and can easily be applied by non-scientists [43]. It shows pressure variable regarding remained trees condition as state variable and can obviously indicate the management trend.

Finally, we emphasize that quantifying some indicators like marked trees should contribute to more robust assessments of the effects of forest management on state of the forest. They show the orientation of management and the state of stand in long-term and should be applied in further policy implications. Marked trees indicator is helpful for local-level monitoring and sustainable management of forests.

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REFERENCES

1. Auld, G., Gulbrandsen, L. H. & McDermott, C. L. (2008). Certification schemes and the impacts on forests and forestry. Annual Review of Environment and Resources., 33: 187- 211.
2. Wolfslehner, B., Vacik, H. & Lexer, M.J. (2005). Application of the analytic network process in multi-criteria analysis of sustainable forest management. Forest Ecology and Management., 207: 157–170.
3. Makelaa, A., Riob, M.D., Hynynenc, J., Hawkinsd, M. j., Reyere, C., Soaresf, P., Oijeng, M. & Tomef, M. (2012). Using stand-scale forest models for estimating indicators of sustainable forest management. Forest Ecology and Management., 285: 164-178.
4. Stupak, I., Lattimore, B., Titus, B.D. & Smith ,C.T. (2011). Criteria and indicators for sustainable forest fuel production and harvesting: A review of current standards for sustainable forest management. biomass and bioenergy., 35: 3287-3308.
5. Hickey, G.M. (2004). Regulatory approaches to monitoring sustainable forest management. International Forestry Review., 6 (2): 89- 98.
6. Hickey, G.M., Innes, J. L., Kozak, R. A., Bull, G.Q. & Vertinsky, I. (2006). Monitoring and information reporting for sustainable forest management: An inter-jurisdictional comparison of soft law standards. Forest Policy and Economics., 9: 297- 315.
7. Noss, R.F. (1999). Assessing and monitoring forest biodiversity: A suggested framework and indicators. Forest Ecology and Management., 115: 135-146.
8. Food and Agriculture Organization (FAO). (2001). Use of Criteria and Indicators for Monitoring, Assessment and Reporting on Progress toward Sustainable Forest Management in the United Nations Forum on Forests. In: The International Expert Meeting on Monitoring, Assessment and Reporting on Progress toward Sustainable Forest Management, 2001, Yokohama, Japan.
9. Jalilova, G., Khadka, C. & Vacik, H. (2012). Developing criteria and indicators for evaluating sustainable forest management: A case study in Kyrgyzstan. Forest Policy and Economics., 21: 32- 43.
10. Parviainen, J., Bozzano, M., Estregui, C., Koskela, J., Lier, M., Vogt, P. & Ostapowicz, K. (2007). Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems. (Eds. Kohl, M. and Rametsteiner, E) State of Europe's forests 2007-MCPFE report on sustainable forest management in Europe, MCPFE Liaison Unit, Warsaw: 45- 72.
11. Lindenmayer, D.B., Margules C.R. & Botkin, D.B. (2000). Indicator of biodiversity for ecologically sustainable forest management. Conserv Biol., 14 (4): 941-950.
12. Kahl, T. & Bauhus, J. (2014). An index of forest management intensity based on ssessment of harvested tree volume, tree species composition and dead wood origin. Nature Conservation., 7: 15-27.
13. Mund, M. & Schulze, E.D. (2006). Impacts of forest management on the carbon budget of European beech Fagus sylvatica forests. Allgemeine Forst- und Jagdzeitung., 177: 47-63.
14. UK Forestry Commission. (2002). UK Indicators of Sustainable Forestry. Forestry Commission, Edinburgh, p 106.
15. Hirschmugl, M., Steinegger, M., Gallaun, H. & Schardt, M. (2014). Mapping Forest Degradation due to Selective Logging by Means of Time Series Analysis: Case Studies in Central Africa. Remote Sensing., 6 (1): 756-775.
16. Shakeri. Z., Marvie Mohadjer, M.R., Simberloff, D., Etemad, V., Assadi, M., Donath, T.W., Otte, A. & Eckstein, R.L. (2012). Plant community composition and disturbance in Caspian Fagus orientalis forests: which are the main driving factors?. Phytocoenologia., 41(4): 247-263.
17. Allnutt, T.F., Asner, G.P., Golden, C.D. & Powell, G.V.N. (2013). Mapping recent deforestation and forest disturbance in northeastern Madagascar Tropical. Conservation Science., 6 (1): 1-15.
18. Cohen, W.B., Spies, T.A., Alig, R.J., Oetter, D.R., Maiersperger, T.K. & Fiorella, M. (2002). Characterizing 23 Years (1972–95) of Stand Replacement Disturbance in Western Oregon Forests with Landsat Imagery. Ecosystems., 5: 122-137.
19. Jourgholami, M. & Majnounian, B. (2013). Traditional mule logging method in Hyrcanian Forest: a study of the impact on forest stand and soil. Journal of Forestry Research., 24 (4): 755-758.
20. Bayat, M., Pukkala, T., Namiranian, M. & Zobeiri, M. (2013). Productivity and optimal management of the uneven-aged hardwood forests of Hyrcania. Eur J Forest Res., 132 (5-6): 851- 864.
21. Bennett, L.T. & Adams, M.A. (2004). Assessment of ecological effects due to forest harvesting: approaches and statistical issues. Journal of Applied Ecology., 41: 585- 598.
22. Nolet, P., Doyon, F. & Messier, C. (2014). A new silvicultural approach to the management of uneven-aged Northern hardwoods: frequent low-intensity harvesting. Forestry., 87 (1) 39-48.
23. Tavankar, F. & Bonyad, A.E. (2015). Effects of timber harvest on structural diversity and species composition in hardwood forests. Biodiversity., 16 (1): 1-9.
24. Kia-Daliri, H., Akhavan, R. & Anisi, I. (2011). Timber marking and its impact on forest stand (Case study: Shourab district of Golband region). Iran J For., 3 (1): 49-59.
25. Pourmajidian, M.R. & Rahmani, A. (2009). The influence of single-tree selection cutting on silvicultural properties of a northern hardwood forest in Iran. American-Eurasian J Agric Environ Sci., 5 (4): 526-532.

26. Villela, D.M., Nascimento, M.T., De Aragao, L.E.OC. & Da Gama, D.M. (2006). Effect of selective logging on forest structure and nutrient cycling in a seasonally dry Brazilian Atlantic forest. J Biogeogr., 33: 506-516.
27. Schall, P. & Ammer, C. (2013). How to quantify forest management intensity in Central European forests. European Journal of Forest Research., 132(2): 379-396.
28. Furukawa, T., Kayo, C., Kadoya, T., Kastner, T., Hondo, H., Matsuda, H. & Kaneko, N. (2015). Forest harvest index: Accounting for global gross forest cover loss of wood production and an application of trade analysis. Global Ecology and Conservation., 4: 150-159.
29. Goushegir, S.Z., Feghhi, J., Marvi Mohajer, M.R., Makhdoum, M. & Rosset, C. (2015). Development of appropriate performance indicators for monitoring sustainability of Hyrcanian forest functions, north of Iran (case study: Kheyrud forest). Natural Environment, Iranian Journal Of Natural Resources., 68 (2): 267- 276.
30. Department of Forestry and Forest Economics. (1995). Second revision of forest management project of Patom section of education and research faculty forest (Kheyruk kenar). University of Tehran, Tehran, Iran, p. 296.
31. Department of Forestry and Forest Economics. (2009). Forest management project of Gorazbon section. University of Tehran's Kheyrud Experimental Forest in northern Iran. University of Tehran, Tehran, Iran, p. 513.
32. Naqinezhad, A., Hamzeh'ee, B. & Attar, F. (2008). Vegetation-environment relationships in the alder wood communities of Caspian lowlands N Iran (toward an ecological classification). Flora., 203: 567- 577.
33. Marvie-Mohadjer, M.R. (2012). Silviculture. University of Tehran Press, Tehran, Iran. p. 380.
34. Javanshir, K. (1999). History of Natural Resources Sciences. Tehran Donald West press, Tehran, Iran.
35. Sefidi. K., Marvie Mohadjer, M.R., Mosandl, R. & Copenheaver, C.A. (2011). Canopy gaps and regeneration in old-growth Oriental beech (Fagus orientalis Lipsky) stands northern Iran. Forest Ecology and Management., 262 (6):1094-1099.
36. Asli, A. & Eter, H. (1969). Forest management project of College Experimental Forest at Noshahr. Publishing and Printing Institute, Vol 16, Tehran, Iran, p. 120.
37. Department of Forestry and Forest Economics. (1982). Forest management project of Namkhane section of education and research faculty forest (Kheyruk kenar). University of Tehran, Tehran, Iran, p. 205.
38. Department of Forestry and Forest Economics. (1984). first revision of forest management project of Patom section of education and research faculty forest (Kheyruk kenar). University of Tehran, Tehran, Iran, p. 165.
39. Department of Forestry and Forest Economics. (1995). First revision of forest management project of Namkhane section of education and research faculty forest (Kheyruk kenar). University of Tehran, Tehran, Iran, p. 205.
40. Department of Forestry and Forest Economics. (2013). Second revision of forest management project of Namkhane section of education and research faculty forest (Kheyruk kenar). University of Tehran, Tehran, Iran, p. 496.
41. Javanmiripour, M., Marvi Mohdjer, M.R., Etenad, V. & Zobeiri, M. (2013). The Effects of Grazing on Change and Diversity of Natural Regeneration (A Case Study: Patom District Kheyroud Forest. Journal of Forest and Wood Product (Iranian Journal of Natural Resources)., 66 (4): 401-426.
42. Tirandaz, M. & Eslami, A. (2012). Zoning droughts and wetness trends in north of Iran: a case study of Guilan province. African Journal of Agricultural Research., 7(15): 2320-2327.
43. Maes, W.H., Fontaine, M., Rongeb, K., Hermy, M. & Muys, B. (2011). A quantitative indicator framework for stand level evaluation and monitoring of environmentally sustainable forest management. Ecological Indicators., 11: 468-479.