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The effect of forest management on the frequency of dangerous trees in the Northern forests of Iran

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Abstract: A study of work accidents in forests has shown that dangerous trees play an important role in forest accidents. Despite the importance of safe working environments for forestry operations, the definition of these areas in natural forests is still unclear. Dangerous trees are considered those snagged with broken branches and a canopy or ones with dead trunks and stumps that have a hazard potential to the forest workers. This study investigates the frequency of these trees in the managed and unmanaged forests in the Caspian forests of Iran. In order to do the study, 15 circular plots with a total area of 1,000 square metres in two studied parcels were selected and the trees, according to their dangerous characteristics, were evaluated. The final results indicated that 66 and 50 trees per hectare had signs of being dangerous trees in the managed and unmanaged stand, respectively. A comparison of the average number of dangerous trees in the two studied parcels using the Mann-Whitney test indicated a significant difference so that the average number of dangerous trees in the managed parcel was more than the unmanaged parcel. Trees with broken branches had the highest frequency in the managed stand, while trees with a dead trunk or stump, a broken branch and canopy in the unmanaged forest were more than the other classes. Considering the relative frequency of the dangerous trees in the two study areas, identifying them could be one of the main attempts in logging safety. The existence of hazardous trees with different risk classes in each of the forest stands requires the development of specific safety instructions to deal with the risks of each tree.

Keywords: forest harvesting; managed forests; unmanaged forests; work accident

Identifying common dangers in the wood harvesting industry requires safety guidelines. One of these guidelines could be the specific requirements for working around dangerous trees and the use of safe techniques for felling these kinds of trees. Dangerous trees are a kind of trees with due to their specific conditions, including physical damage and rotten roots, trunk, stems, branches, incline and direction have the potential for creating a hazard to the workers (EGAN 1995). Although there is no specific degree of damage in this definition, the US Occupational Safety and Health Administration (OSHA 2000) has considered the management of dangerous trees as the following

“Any dangerous tree that threatens a forest worker has to be cut off and transported to a safe place before the worker can begin to work on it, otherwise it is advisable to consider a drop zone around the tree as twice the height of the tree unless the worker is sure that a shorter distance does not endanger him” (ILO 1994). Because of the dangerous intrinsic nature of logging operations, safety in this industry is a major concern and discussing the responsibility about the dangerous conditions prior to cutting and logging should be essential for owners, managers and contractors (EGAN 1996; AGROW 1995; MYERS, FOSBROKE 1994). However, the presence of dangerous trees in any forest stand

will create problems for the operational safety and the related costs.

Regarding the manual felling with a chainsaw in the Caspian forests of Iran and the risk of dangerous trees for the felling group, the identification of the dangerous trees and introducing methods to deal with these kinds of trees could be useful for reducing the accidents for the felling crew, logging workers and other forest labour. The aim of this study was to compare the number of dangerous trees in managed and unmanaged forest stands and the classification of the trees based on their characteristics. The result of this study provides the basic data for assessing the potential risk in forest operations. The study of forestry operation accidents in the Caspian forests of Iran has shown that the most common recorded accidents occurred during the felling operations (NIKOOUY et al. 2012). The study of forest harvesting accidents in the Caspian forest revealed that 24% of the recorded incidents occurred during the felling component (NIKOOUY et al. 2012). An exact evaluation of these accidents has shown that injury or death due to the dangerous trees with widowmakers were the most common accidents in the cutting operation. Although the role of decayed, rotten, and dead trees should not be diminished in the incidents (ASHBY et al. 2002; BELL, HELMKAMP 2003), lodged trees are also a variety of dangerous trees that can hurt the felling workers. The severity of the injuries in such a context is such that, despite the use of safety devices, it may result in the death of the worker. A closer look at operational accidents in the different areas shows that felling with a chainsaw is a dangerous activity and most of the incidents in the forest have occurred during the work with this device. 53% of accidents in the United States, 34% in Canada, 28% in Greece and 43% in Nigeria were due to the manual felling with a chainsaw (JINADU 1989; BELL et al. 1994; HELMKAMP 2003; LINDROOS, BUSTROM 2010). Moreover, felling workers are injured by objects such as branches, parts of the trunk, the dead crown, etc. Commonly, about two-thirds of these events in the United States have resulted in the death of the worker (MYERS, FOSBROKE 1994). Poor cutting techniques were the reason in 15% of these incidents (PETERS 1991). The high mortality rate in forest operations and its relationship to the felling operation is not related to a particular country, but some countries have taken important steps by adopting specific measures such as increasing

the forest mechanisation and worker training programmes. A review of studies conducted in Canada (SALISBURY et al. 1994), New Zealand (KAWACHI et al. 1994) and Australia (DRISCOLL 1994), shows that the trends and causes of work accidents in the Caspian forests of Iran are the same as in other countries. For instance, a study by NIKOOUY et al. (2012) in a 24 year period in the Caspian forests of Iran indicated that the mean frequency of incidents in the study area was 17 events per year. Milburn (1998) has calculated this amount for nearly 30 incidents in South American forests in 1996 to 1997. POTOČNIK et al. (2009) estimated this number to be 20 for a period of 15 years (1990–2005) in the forests of Slovenia and the number calculated by BENTLEY et al. (2005) in New Zealand in 2003 was about 20 incidents. Overall, the studies have shown that tree felling is one of the most dangerous activities in the forest, and the presence of dangerous trees in the forestry environment increases the risk of felling. The main problem is: who is legally responsible for the unsafe conditions in a forest operation? Operators, contractors, foresters and forest owners are faced with workers on one side and the costs of work accidents and legal problems on the other side. The main focus of the complainants is that the operating companies do not provide safe environmental conditions according to work safety standards. According to Occupational Safety and Health Administration (OSHA) standards, dangerous trees must be felled and extracted from the stump area before starting any specific operations around the remarked trees. OSHA standards stipulate that if such trees should be mechanically or manually felled, it must be performed in such a way that it minimises the risk for the workers. The main objective of this study was to compare the frequency of hazardous trees in managed and unmanaged populations.

MATERIAL AND METHODS

This study was carried out in the Nav district of watershed number 7 of the Caspian forest in the Guilan province. The study area is located between longitude 48°44'36" to 48°49'55" and latitude 37°42'31" to 37°37'23". In this study, parcel 32 (24 ha) was selected as an un managed parcel and parcel 34 (44 ha) was selected as a managed one (Table 1). The mean annual rainfall ranged from 920 to 1,100 mm,

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Table 1. General description of the two study parcels

Study area	Parcel number	
	32 (unmanaged)	34 (managed)
Area (ha)	24	44
Elevation range (m)	850–1,100	900–1,050
Aspect	West	West, North west
Area of parcel in each slope class (ha)	0–30 (1.5), 31–60 (8.5), 61–80 (8), 81–100 (4.5), > 100 (1.5)	0–30 (4), 31–60 (29), 61–80 (8.5), 81–100 (2), > 100 (0.5)
Forest type	Beech-hornbeam	Beech-hornbeam
Tree density ($d_{1.30} \geq 10$ cm) ($m^3 \cdot ha^{-1}$)	255.71	264.29
Standing volume ($m^3 \cdot ha^{-1}$)	318.41	306.21
Species (number percentage)	<i>F. orientalis</i> (65), <i>C. betulus</i> (10), <i>A. subcordata</i> (6), others (19)	<i>F. orientalis</i> (42), <i>C. betulus</i> (21), <i>A. subcordata</i> (4), others (33)

with most of the precipitation occurring in the fall and winter. The mean daily temperature varies from $-3^{\circ}C$ in December, January and February and up to $+25^{\circ}C$ during the summer. The area is characterised by uneven-aged mixed forests dominated by *Fagus orientalis* Lipsky and *Carpinus betulus* L., and accompanied by *Alnus subcordata* C.A. May, *Acer cappadocicum* Gled species. The forests of the area are characterised by mixed and uneven-aged high forest stands, managed with single and group selective cutting methods. The soil in the study area is a brown forest (Alfisol) soil with appropriate drainage, and the soil texture is loamy to clay loam. The Nav district is one of the oldest forestry districts in Iran, and, so far, it has completed three harvesting periods. During the forest management, various forestry activities are carried out in the harvesting area such as a regeneration method and a silvicultural system selection, tree marking, felling and transportation, forest plantation and conservation. The most common silvicultural regimes and harvesting method in the Caspian forest are close to nature and single tree selection. According to this method, the marked trees were felled by chainsaw and transported by a rubber-tyred skidder in the harvested area. The sanitary cut is the most widely used method of tree felling in these forests, and through this method, the trees with dangerous indicators are selected and harvested. The selection of the trees was undertaken by the supervisor of the forestry plans in the marking season and the selected trees were cut during in the winter.

In each of the two studied parcels, 15 circular plots with an area of 1,000 square metres were systemati-

cally randomly identified. The trees with a diameter of more than 10 cm in each plot were identified according to the characteristics of the dangerous trees so the diameter at breast height (DBH) was measured by a calliper and the name of the species was recorded. The dangerous features including the rotten stump, the damaged trunk, the broken branch and canopy and widowmaker branches were measured by observation and the necessary information was recorded. The trees were classified based on the hazard characteristics in the four main classes and four subclasses as follows (EGAN, ALERICH 1998) (Fig. 1):

- (1) Standing trees with broken branches
- (2) Standing dead and rotten trees
- (3) The trunk of the rotten trees
- (4) The stump of the rotten trees
- (13) Standing trunks of the rotten trees with broken branches
- (14) Standing stumps of the rotten trees with broken branches
- (34) The trunks and stumps of the rotten trees
- (134) The trunks and stumps of the rotten trees with broken branches

The correlation between the tree diameter and the frequency of the dangerous trees was calculated by Pearson's correlation coefficient. In order to compare the average frequency of the dangerous trees in the managed and unmanaged parcels, the Mann-Whitney U test was employed. Due to the difficulty of studying the root rot and its role in the risk of felling the trees, in this study, the study of such trees was not possible.



Fig. 1. Images of the dangerous trees in the study area

RESULTS

The study of dangerous trees in the study area showed that among the 1,000 trees in the two parcels, about 75 trees in the managed parcel and 99 trees in the unmanaged parcel had at least one of

Table 2. The frequency and percentage of the dangerous tree species in the studied parcels

Species	Unmanaged parcel		Managed parcel	
	frequency	percentage	frequency	percentage
<i>Fagus</i>	53	53.5	28	37.3
<i>Acer</i>	21	21.2	23	30.6
<i>Alnus</i>	14	14.1	11	14.6
<i>Carpinus</i>	10	10.1	11	14.6
Other species	1	1	2	2.6
Total	99	19.8	75	15

Table 3. The Mann-Whitney *U* test statistic for this study

Statistic	Danger of trees
Mann-Whitney <i>U</i>	46
Wilcoxon <i>W</i>	166
<i>Z</i>	-2.85
Level of significance	0.004

the different specifications of the dangerous trees. The trees were classified in eight different classes of danger as mentioned in the method of study. The greater share of *F. orientalis* species in both parcels has caused more of this species to have the characteristics of being a dangerous tree. In terms of the relative average percentage, 19.8% of the trees in the unmanaged parcel and 15% of the trees in the managed one belonged to one of the dangerous classes (Table 2).

In the managed parcel, danger class 1 had the highest frequency with 42.6%, while in the unmanaged parcel, the highest percentage of dangerous trees belonged to danger class 134 (26.2%), but the share of dangerous trees of danger class 1 (21.2%) was remarkable too (Fig. 2).

The comparison of the mean frequency of the trees in the two parcels by the Mann-Whitney *U* test revealed that there is a significant difference

Table 4. The ranking of the studied variables in the Mann-Whitney *U* test

Variable	Number	Ratings	
		average	total
Unmanaged stand	15	19.93	299
Managed stand	15	11.07	166
Total	30		

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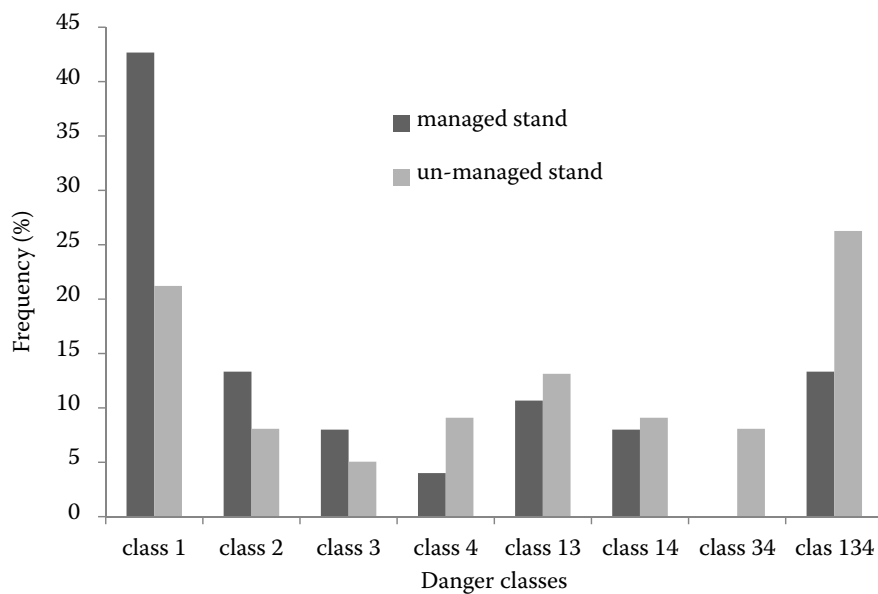


Fig. 2. The percentage of the dangerous trees in each class of danger in the two study areas

Table 5. The frequency of the dangerous trees in the diameter classes in the two studied parcels

Diameter classes	Unmanaged parcel	Managed parcel
25	2	1
30	2	2
35	2	4
40	3	3
45	4	5
50	3	4
55	8	5
60	4	4
65	6	5
70	8	3
75	5	3
80	6	4
85	7	4
90	7	2
95	8	5
100	8	5
105	2	4
110	4	3
120	2	2
125	2	2
130	2	1
135	2	1
140	2	3

between the average frequencies of the hazardous trees in the two study areas (Table 3). The average ratings of the dangerous trees in the managed and unmanaged area were 19.93 and 11.07, respectively (Table 4).

Table 5 shows the frequency of the dangerous trees in the different DBH classes. The highest frequency of the dangerous trees was observed in the middle DBH classes.

Figures 3 and 4 show the correlation between the DBH of the trees and the frequency of the dangerous trees. Despite the difference in the number of dangerous trees in the two populations, the tree’s distribution process in the diameter classes is a quadratic curve.

DISCUSSION

Our study showed that 66 and 50 trees per hectare in the managed and unmanaged area were classified as dangerous trees, respectively. In the managed area, the most dangerous trees were in the first danger class (42.6%), while in the unmanaged area, the highest percentage of dangerous trees were in the first, third and fourth danger classes (26.2%). Competition between the trees for receiving light alongside natural pruning were the main reasons for the broken off limbs. Trees with a rotting trunk and cavities were the first trees that were selected for the re-marking operations, therefore their frequency were fewer in the managed area than the

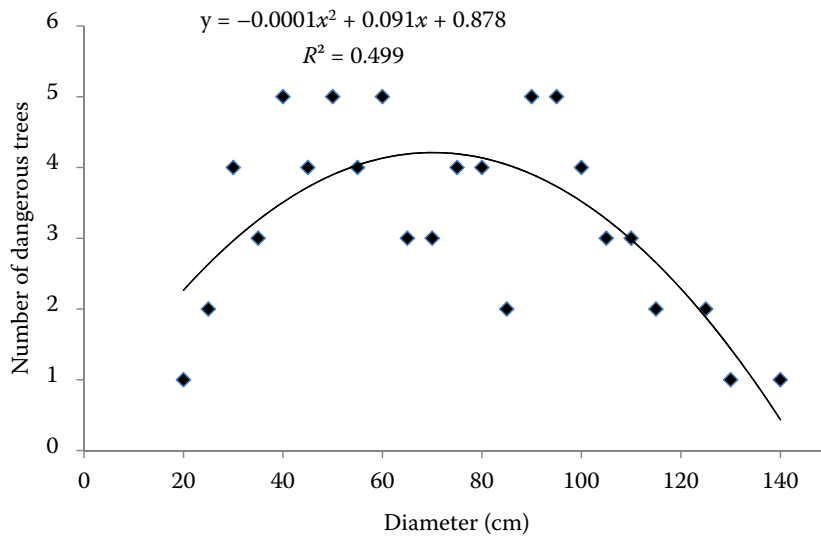


Fig. 3. The correlation between the number of the dangerous trees and the diameter of the trees in the managed parcel

unmanaged one. The implementation of the sanitary cut in the managed area is one of the most important reasons for decreasing the frequency of the hazardous trees in these areas compared to the unmanaged areas. According to the forestry plan and predicted harvested volume in the managed stands, the majority of the dangerous trees are harvested by the sanitary cut. Since such a cut does not occur in the unmanaged stand, the frequency of the dangerous trees in these stands was more than in the managed stands. EGAN and ALERICH (1998) in their study of American forests found that the number of dangerous trees per hectare was 20 in their study area. Considering the frequency

of the dangerous trees in both stands, the role of the felling worker's training in relation to the dangerous trees and the methods of their felling are very important. The trees frequency trend in the diameter classes, in both of the studied areas, was a quadratic curve. In the small diameter classes, the frequency of the dangerous trees was low. The low number of branches, the light crown, and the young age are the most important reasons for decreasing the frequency of the dangerous trees in this diameter class. By increasing the diameter of the trees along with increasing their frequency, the dangerous risk of these trees also increases. The bigger the crown, the older the trees and reaching

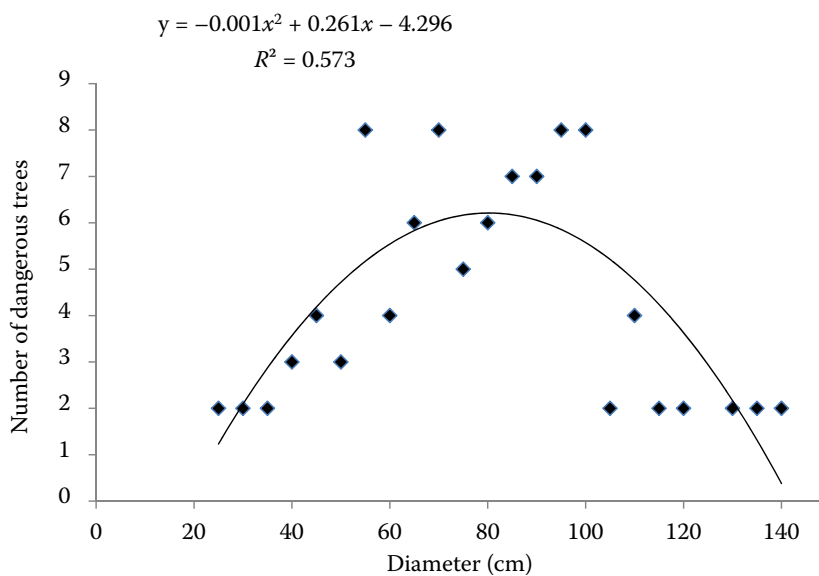


Fig. 4. The correlation between the number of the dangerous trees and the diameter of the trees in the unmanaged parcel

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the mortality age are the main causes of increasing the frequency of the dangerous trees in the higher diameter classes.

Thicker trees in the unmanaged stand fall or are uprooted on the ground for some reasons like wind, snow, etc. While these trees were marked and cut off in the managed stand during the sanitary cutting. For this reason, the frequency of the dangerous trees decreases in the high-diameter classes. However, the frequency of the total trees in the high-diameter classes is generally lower than other classes also.

CONCLUSIONS

Working in a safe area is the right of each worker and it is a subject that should be considered by forestry contractors especially in tree cutting operations.

The purpose of this study was to introduce the dangerous trees and the related risks in the managed and unmanaged stands. The workforce in the forests requires workers who, along with the training on hazardous trees and safety procedures, are equipped with the necessary safety equipment. Although the definition of a safe working environment is still unclear, this study described the dangerous trees. Some of these conditions such as the root system of dangerous trees could not be evaluated in this survey but other conditions were assessed objectively and practically. The study of accidents in different parts of world has shown that many of these events are caused by dangerous trees; therefore, it is essential to take the necessary measures in relation to these types of trees. It could be better to identify and mark the dangerous trees in the forest before cutting them down. However, cutting and transporting these trees requires a lot of time and costs and the revenues from the sale of the wood is not significant. Dangerous tree felling and extraction from the harvested area provides safer conditions for the activity of the forest working groups. However, due to negative effects of cutting these kind of trees on the wildlife, further considerations are needed (HUNTER 1990; FRANKLIN et al. 1997). The cutting of dangerous trees to create safe conditions for working in a forest area is not inconsistent with the maintenance of the same trees for environmental concepts. The next solution according to OSHA is that when facing dangerous trees, a drop zone surrounding the tree of

twice the height of the dangerous tree should be taken into account unless the worker is sure that a shorter distance does not endanger him. This is also problematic because a circle covering a tree radius, for example, of 30 meters in height covers an area of 2826 square meters, which it is not possible to indicate such a range in a forest. This problem seems to be solved by the ability to recognise how to differentiate the dangerous conditions of the trees. Although the advice of OSHA on establishing an area around the dangerous trees as twice the tree height is not absolute to make a safe condition, it is unclear how the worker can detect a shorter distance. The hazard potential associated with dangerous trees must be neutralised and eliminated before the cutting operations causing injury and or danger to the workers especially the hazards that occur during routine operations (such as dropping branches and canopy). Protecting wildlife nests by leaving some dangerous trees in the forest needs professional operators and foresters. This problem can be resolved by allocating such trees to high steep areas and other areas where tree marking for harvesting is not performed.

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