Effects of forestry practices on the regeneration and biodiversity of woody plants in the northern forest ecosystems of Iran

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ABSTRACT
Undoubtedly, the regeneration and sustainability of forests are the most important aspects of sustainable forest management. The present study was conducted in Patam district, located in Kheyroud forest, Iran, and the regular regeneration of various plant species was evaluated in the region. The study of the regeneration was randomly regularly carried out by using a grid of 150 × 200 m and the sample plot with the area of 1.0 R (radius 1.8 m), provided by centre for sample plot. The highest rate of regeneration (seedlings) was observed in Carpinus betulus (50%), Acer insigne (23%), Fagus orientalis (10%), afforestation (6.2%), Acer cappadocicum (6%), Parrotia persica (2.8%), and Diospyros lotus (2%), respectively. In addition, 74 and 26% of the seedlings had height less than and more than 50 cm, respectively. Therefore, the studied region has proper conditions for regeneration in terms of the soil and mother trees. However, the number of the seedlings with height more than 50 cm is not above the normal range. In the studied region, regeneration coverage level, herbaceous species coverage level, and coverage level without sample plots were calculated to be 52, 41, and 7%, respectively. Considering the low rate of natural regeneration compared to similar forests and the habitat of the studied forest, the main causes in this regard could be the lack of mother trees, animal grazing, and the density of the forest floor vegetation. Therefore, the elimination of animal grazing and plantation operations are necessary for the improvement of regeneration.

1. Introduction
Northern forests of Iran are mainly located on the northern slopes of Alborz Mountains and extend from Astara in the west to Gildaghi in the east (Sefidi, Mohadjer, Etemad, & Copenheaver, 2011; Shatayi Goybari & Marvi Mohajer, 2002). Biodiversity (flora and fauna) is the most distinct feature of these forests, and existence of species such as Fagus orientalis, oak, Acer insigne, Alnus subcordata and glutinosa, Acer cappadocicum, Fraxinus excelsior, Cerasus avium, Sorbus torminalis, Parrotia persica, Ulmus carpinifolia, and Ulmus glabra in these areas are of particular importance (Delfan Abazari & Sagheb-Talebi, 2007). The preservation and management of forests require a thorough knowledge of these natural resources, which are based on the principle of constant use in order to achieve maximum economic returns (Tuffel et al., 2006).

One of the issues that sustains the continuity and sustainability of forests is natural forest regeneration (McNeely, 2002). In forestry plans, natural regeneration is driven by economic goals; in other words, with accurate markings and eliminating of poor stocks and improving the quality of the remaining masses, regeneration should be based on high-quality mother stocks (Demir, Makineci, & Yilmaz, 2007). Undoubtedly, forest regeneration is one of the most important aspects of sustainable forest management (Gould, Steiner, McDill, & Finley, 2006). Regeneration in forests is often synonymous with the natural regeneration by seeds (Atisri, 1995). It is notable that natural regeneration by coppice is possible as well, which most likely results from human interferences (Marvi-Mohajer, 2005). In general, it could be claimed that the forest masses created by natural regeneration are less likely to be lost in the future.

The regeneration of F. orientalis forests in the north of Iran has been natural for a significant period (Marvi-Mohajer, 2005). Several studies have focused on the
regeneration of these forests, such as the research by Doost Hosseini (1976), which examined the issues associated with regeneration in the Patam district. The obtained results of the mentioned study indicated that 3.4 seeds in the region are unhealthy; and in the late autumn, the number of seeds is higher compared to early autumn. Furthermore, it was reported that the number of perennial seedlings is significantly low, and the regeneration of *F. orientalis* on the northern slopes is greater, while regeneration has a reverse ratio with canopy.

Jalali (1980), in another study conducted to evaluate the regeneration of *F. orientalis* in Darebkolay region in Sari (Iran), it was observed that the number of *F. orientalis* seedlings in each square metre was 0–3, which is significantly lower compared to the average number of the *F. orientalis* seedlings in Germany (7–71). Therefore, it was concluded that the natural conditions in the studied area are unfavourable for regeneration. On the other hand, findings of the same study suggested that due to the presence of destructive factors in the area, the number of seedlings decreases with increasing age.

Narimani (1980), in an evaluation of *F. orientalis* regeneration in the Guilan province (Iran), the findings showed that 96% of the seedlings were aged one year, and only 4% were aged more than one year. After a five-year study of *F. orientalis* regeneration, it was identified that 85% of the seedlings were healthy, 11% were plugged, and 4% were broken. In the mentioned research, the best altitude for *F. orientalis* regeneration was estimated at 1150–850 m, and the rate of regeneration was reported to be higher in the northwest direction. Moreover, an adverse relationship was observed between the number of seedlings and density of the crown of the trees, grass cover, and litter thickness.

In this regard, Mir Badehyan (1989) studied two similar areas in Weiser and Asalem in order to determine the highest rate of *F. orientalis* yield, reporting that the regeneration in Weiser occurred easier than the Asalem district, while the density of the trees in the Weiser district was greater compared to Asalem. Other findings have indicated that the front seedlings in the Weiser area are approximately twice larger than those in Asalem. Evidence suggests that the rate of regeneration and growth of seedlings in the Weiser district is higher compared to the Asalem area, and livestock damages in both regions have been estimated to be 70%. Naturally, higher severity of cutting trees is associated with increased invasive species and livestock influx.

In a study of regeneration in the Patam district of Kheyroud forest in Iran, Hosni Abherian (1993) claimed that the average number of seedlings per hectare is 32,533, while it is 1.9–4.6 per square metre, which is significantly lower compared to the number of seedlings per square metre in Europe, which could be attributed to the unfavourable conditions of the soil (e.g., soil compaction and grazing). In addition, findings of the mentioned study showed that 92% of the seedlings in the area are aged one year, and 96% have a height of less than 20 cm. In the Patam district of Kheyroud forest, the average number of the native trees per hectare is 165–227 seedlings, and 77% of the mother stocks are of the *F. orientalis* and *Carpinus betulus* species. Moreover, the regeneration rate of *Acer pseudoplatanus*, *A. cappadocicum*, and *Ulmus glabra* has been determined to be 30.5% in this area, while *C. betulus*, *Acer pseudoplatanus*, *F. orientalis*, *A. cappadocicum*, and *Ulmus glabra* have a regeneration rate of 59.4, 26.5, 8, 2.9, and 1.3%, respectively.

The present study aimed to investigate the conditions of forest regeneration in order to evaluate the process of regeneration changes during the period of the study and verify the effects of implementing operation and conservation plans in the Patam district of Kheyroud forest, Iran, in the future.

### 2. Materials and methods

#### 2.1. Studied area

Kheyroud forest is located at 7.0 km from Nowshahr city, Iran, at 51°, 32′, and 30′ to 51° and 35′ of longitude and 36°, 37′, and 30′ of latitude (Figure 1). Patam district is 900 ha and its minimum altitude, which is adjacent to Najjardeh village, is 10 m above the sea level, with the maximum altitude of 930 m above the sea level.

According to the 22-year data of the meteorological station of the Research Institute for the Forests and Rangelands of Nowshahr (located at seven kilometres from Kheyroud Kenar region [2007]), the average annual rainfall is 986 mm per year, the average annual maximum temperature is 32.8 °C, the average annual minimum temperature is −3.7 °C, and the average annual temperature is 16.2 °C in the studied area. The climate is semi-humid with cold winters, and the highest rate of rainfall is in October. In addition, precipitation is 237.6 mm, and the driest month of the year is March with 47.5 mm of precipitation. Length of the growth season is 270 days, which is remarkably distinctive (Etemad, 1992). To date, two forestry plans have been implemented in the Patam district (Hosni Abherian, 1993).

#### 2.3. Research methodology

In the current research, we selected Patam district from Kheyroud Kenar forest. This area has 18 parcels and five supportive parcels (number 103, 104, 105, 106, and 107), and two of these parcels have suffered substantial human interference (number 101 and 102). Therefore, in the present study, we initially determined the forest conditions, and rounding of the forest was performed as well. Considering that the parcels with massive human interference were supportive, as well as the significant cost of census, parcels 108, 109, 110, 111, and 112 were
selected for further evaluation. In summer 2015, sampling was carried out at the parcel level, and selecting of the sample sections was performed via simple random sampling and based on the shape of the circular sample pieces (due to the number of smaller border trees), with a selected area of 10 R.

Grid dimensions were used in order to include the appropriate number of sample pieces, which were first applied as a random systematic technique in a calibre millimetre paper to obtain the initial point (i.e., the first piece of sample) and placed on the maps of each parcel. On each parcel map, a distinct point to represent a four-dimensional tree or a boulder was considered and assumed as the origin of reticulation. Afterwards, the selected point was meshed by rectangles, with the vertices of the rectangle showing the circles on the Earth’s surface (i.e., specimen) in a particular radius, which depend on the gradient of the area and must be fully measured to achieve the desired intensity census (Figures 2 and 3).

As mentioned earlier, a rectangular grid was initially plotted on the calcined paper with a specified dimension and randomly placed on the map, so that the grid width would be in the direction of the gradient. Following that, the sample piece was identified at a given distance from a specific point on the ground and on the map. Location of the sections was determined by calculating the angle and distance from the previous sample piece on the work map, and sampling at the centre of each sample plot was considered as the microplots with a radius of 1.8 m for the assessment of regeneration, while specification was obtained as well.

The studied area (with more than five parcels) is 220 ha. Considering the size of the area, diversity of the species, and objective of the regeneration assessment, 100 samples were counted from all the parcels in the

![Figure 1. The study area. Source: Map of Hirkani forests in northern Iran.](image)

![Figure 2. Percentage of seedling regeneration in terms of species.](image)
rate of regeneration by species, especially in breeding and marking operations that determine the amount of marking and harvesting of seedlings for cultivating operations. Results of the present study demonstrated that the number of *C. betulus* seedlings constituted 50% of the regeneration in the investigated area.

According to our findings, 83% of regeneration was reserved for *C. betulus*, maple, and *F. orientalis* species. For the most part, the regeneration of *C. betulus* and *F. orientalis* species is due to their relative abundance compared to the other species in the forest (Table 1). In terms of the studied parcels, 29% of *Alnus* and *A. cappadocicum* regeneration shows the ability of these trees and their winged seeds for proper regeneration, thereby resulting in the higher number of distributed seeds at farther distances compared to the mother stocks. It is also notable that the frequency of the seedlings per hectare has a more significant association with the *C. betulus* species.

According to the results, the highest number of seedlings per hectare belonged to *C. betulus*; therefore, the species should highly be taken into consideration while planning for forests. Acer species were observed to have a relatively favourable regeneration rate, and in forestry, species fit should be well preserved. On the other hand, the low regeneration of *F. orientalis* trees was attributed to the establishment of highly elevated mother stocks in the original habitat of this species. In order to evaluate the height of seedlings, the seedlings were classified into two classes, including class one (height of <50 cm) and class two (height of >50 cm) (Figure 4).

Results of the present study showed that 74% of the seedlings had a height of more than 50 cm, and only 26% had a height of more than 50 cm. Low height of seedlings is known to increase the risk of livestock grazing (Figure 5).

Investigations on the surface area of the sample pieces indicated that the coverage level of regeneration was 52%, grass covering was 41%, and blank sample surface
area was 7%. Moreover, the highest percentage of the surface coverage was related to regeneration.

4. Discussion and conclusion

Adequate data on regeneration status is the basis of sustainable forest management and the implementation of forestry projects. To date, only two forestry plans have been executed in the Patam district in Kheyroud forest, located in the north of Iran. Although these plans have provided the suitable conditions for regeneration, they have been shown to bear some limitations. Furthermore, other problems in these forests include livestock grazing, compacted soil, rocks, and shallow soil.

The average rate of total regeneration (seedlings) is estimated at 37,040 seedlings per hectare in Kheyroud forest, which is below the average number of seedlings per hectare in European countries (=172,000 seedlings per hectare) (Hosni Abherian, 1993). In other words, the number of seedlings per square metre is 3.4 trees on average, while it is 20 trees in European forests (Narimani, 1980).

According to the results of the present study, 74% of the seedlings had a height of less than 50 cm, and only 26% of the seedlings were able to reach a height of more than 50 cm, the number of which drastically reduced in the following years. Seedlings with a height of less than 50 cm were prone to livestock grazing, which decreased their quality as well. In terms of the type of forest (Table 1), most mother stocks were of the *C. betulus*, maple, and *F. orientalis* species. Regardless of the number of the mother stocks of *F. orientalis*, regeneration accounted for only 10% of the tree regeneration, which is mainly due to the elevated establishment of these mother stocks in the original habitat of this species. Despite the low number of the mother stocks of *F. orientalis*, *F. orientalis* regeneration accounted for only 10% of the tree regeneration, which is mainly due to the elevated establishment of these mother stocks in the original habitat of this species. Therefore, it is recommended that most of these species be used in forestry and trees with lower capacity be marked as well.

**Table 1. Average slope in studied parcels.**

| Altitude (m) | Slope (%) | Direction | Plant communities | Parcel (N) |
|-------------|-----------|-----------|-------------------|------------|
| 200–450     | 55        | North-South-West | Parrotia persica—Carpinus betulus and partly Alnus serrulata | 108        |
| 300–500     | 60        | East      | Parrotia persica—Carpinus betulus | 109        |
| 300–500     | 50        | North-West | Fagus orientalis—Carpinus betulus, and partly Alnus serrulata | 110        |
| 200–450     | 30        | North-East | Fagus orientalis—Carpinus betula, Parrotia persica—Carpinus betulus | 111        |
| 500–750     | 20        | North-South-West | Ruscus—Fagus orientalis and Parrotia persica—Fagus orientalis and Fagus orientalis—Carpinus betulus | 112        |
| 200–750     | 43        | North-East | Mixed Communities of Carpinus betulus, Fagus orientalis, Alnus suber data, and Parrotia persica | Total      |

**Figure 4.** Percentage of seedlings in terms of height.
5. Recommendations

Due to the lower rate of natural regeneration compared to European forests and forest capacity in the Patam district of Khayroud forest in the north of Iran, forestry with the bird seed and original species could be an effective approach. Furthermore, considering the severity of seedling removal due to increased age and inadequate height of seedlings in the area (Hosni Abherian, 1993), all degradation and seedling removal agents must be examined, identified, and eliminated as far as possible. One of the most significant influential factors in the degradation of seedling and their poor quality is excessive livestock grazing in the region, and the most effective solution in this regard should involve the prevention of animal grazing in the area or protecting the areas of forestry and natural regeneration. Other effective measures may include the existence of vacant surfaces (7%), low soil fertility, increasing the number of forests (especially with the plantation of the native species) in the region, and the continuous assessment of their compatibility and growth. Given the key role of regeneration in the survival of forests, regular studies must be performed focusing on regeneration, while effective strategies are needed to improve the quality and quantity of regeneration.

Disclosure statement

No potential conflict of interest was reported by the authors.

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