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Variability of light and soil physics indicators following gap formation in the Caspian forest, Iran

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ABSTRACT

To improve our understanding of the role of a canopy opening on the variability of light and soil physics indicators in a natural forest, a case study was undertaken in and around a gap in a natural beech - dominated (*Fagus orientalis* Lipsky) forest. This research carried out in twenty hectare areas of Experimental Forest Station of Tarbiat Modares University that is located in a temperate forest of Mazandaran province in the north of Iran. After field trip, twenty one canopy gaps with different areas were found in studied areas and classified as small (85.12 m^2), medium (325.21 m^2), large (512.11 m^2) and very large (723.85 m^2) gaps. Measurements of the light transmittance were collected with a ceptometer (LI 250 USA), at 1.00 m above the ground, with the instrument held horizontally. Soil samples were taken at 0 - 15, 15 - 30 and 30 - 45cm depths from gap center, gap edge and closed canopy using core soil sampler with 81cm^2 cross section. Bulk density, soil texture and moisture measured in the laboratory. With considering to analysis of variance, light transmittance amounts had ascending trend with increasing of canopy gaps areas. Also, this character showed significantly increasing from gap edge to center position. Bulk density had no significantly difference among canopy cover areas. But, the most amounts of this character devoted in 30 - 45cm depth, gap center and edge positions. The higher amounts of sand found in very large areas of canopy gaps, gap center and edge positions and also soil upper layers. Significant statistical difference weren't showed for silt character in different areas of canopy gaps, but the most were found in closed canopy and beneath depths. Medium areas of canopy gaps, closed canopy and 30 - 45cm soil depth had the higher amounts of clay. Greater values of soil moisture devoted in small areas of canopy cover and closed canopy, but significant differences weren't found in soil depths. These results further our understanding of the abiotic and consequent biotic responses to gaps in broadleaved deciduous forests created by natural treefalls, and provide a useful basis for evaluating the implications of forest management practices.

KEYWORDS

Closed canopy;
Light;
Bulk density;
Soil texture;
Moisture.

INTRODUCTION

Gap formation by wind is a characteristic disturbance event in temperate deciduous forests. Gap size varies greatly from the size of only a single crown to vast open fields with diameters of many tree lengths. The fall of canopy trees results in increased total incident light levels at the ground and in some cases also in increased nutrient and moisture availability. Gap microclimates may enhance seed germination and increase growth rates of herbs and woody species in comparison with rates in the forest understory. However, changes in abiotic and biotic conditions depend both on gap size and within - gap position[13,16,22]. In temperate forests, small - scale disturbances resulting in single or multiple tree fall gaps play an important role in driving stand dynamics. Since the 1980s, these canopy gaps have therefore been a major focus of forest ecologists, whose aim was to understand the functioning of forest ecosystems and to provide information useful for forest management[30]. One of the important characteristics of gaps that affects the establishment and growth of tree seedlings is environmental heterogeneity, such as variability in light regimes, within and around gaps. Microclimate also plays an important role in the ecological processes within forests that affect nutrient dynamics and decomposition[10,23,36].

In total, successful enrichment planting is based on knowledge of environmental conditions within gaps of different sizes and species - specific ecological requirements for seedling establishmentm[8]. One major limiting factor essential for both seedling growth and establishment in temperate forests understands different species' response to light availability and soil characters[29,26]. Increase in available light at the forest floor is typically formed by disturbances in the canopy, mostly by gap formation resulting from tree fall. Whilst light is considered to be a major limiting factor in the understory and small gaps, conditions in larger gaps may not be optimal for growth as excessive light stress, high temperature or drought may reduce growth[4,25]. Different frequency of formation and dimensions of canopy gaps form a mosaic of highly variable light and water conditions at the forest floor, resulting in a broad range of ecological niches for seedling establishment. Consequently, temperate species that differ strongly in their ecological requirements display different abundances and survival rates in those niches[21].

Gaps promote recruitment and growth of understory vegetation that may eventually become dominant trees by altering the availability of resources, including light, soil moisture, and nutrients. The availability of these resources, and consequently species survival and vegetative growth, is a function of gap characteristics, including area, orientation, and shape[2]. Due to the traditionally different scientific approach that was focused more on identifying and mapping of forest structures and developmental phases[41], there is a lack of more detailed knowledge about the disturbance regimes in the natural forests of Iran. The temperate forests were considered to underlie more the small - scale gap processes, but the recent findings emphasize a certain importance on the infrequent intermediate and large -scale disturbances as well[31,32]. The research dealing with the gap dynamics has been conducted mainly during the last decade, especially in the old - growth forest remnants in northern Iran[20]. The studies were concentrated on the investigation of basic features of disturbance regime, i.e. gap size distributions, gap formation and turnover time, characteristics of dead canopy trees that formed a gap (so-called gapmakers) etc.

Although it is recognized that gaps modify soil resources, few studies have focused on below - ground processes. Soil processes are controlled by a set of relatively independent state factors (climate, organisms, relief, parent material and time) and by a group of interactive controls (e.g., disturbance regime and human activities). Forest gaps are examples of natural interactive controls with direct impacts on state factors (e.g., climate and organisms). Forest gaps represent dramatic top - down trophic interactions between vegetation and the soil microbial - mediated processes[20]. Relatively few studies have addressed belowground effects of canopy gaps on soil properties. In Iran, there is still not enough knowledge about the effects of canopy gaps on soil characters and microclimate. Therefore, the research on the natural disturbance processes in the Iran forest ecosystems is needed. The objectives of this study were to examine the effects of small, medium, large and very large gaps on variability of light and soil physics indicators in beech - hornbeam stands in northern Iran.

Specifically, the following hypotheses were tested: is gap size an important factor in controlling light condition and also soil physics indicators? The study included investigation of light condition and soil physics characters about 4 years after gaps formation.

MATERIALS AND METHODS

Description of the study site

This research was conducted in Experimental Forest Station of Tarbiat Modares University located in a temperate forest of Mazandaran province in the north of Iran, between 36° 31 ' 56″ N and 36° 32 ó 11″ N latitudes and 51° 47' 49″ E and 51° 47' 56″ E longitudes. The maximum elevation is 1700m and the minimum is 100m. Minimum temperature in December (6.6°C) and the highest temperature in June (25°C) are recorded, respectively. Mean annual precipitation of the study area were from 280.4 to 37.4 mm at the Noushahr city metrological station, which is 10Km far from the study area. For performing this research, twenty hectare areas of reserve parcel (relatively undisturbed) considered that was covered by *Fagus orientalis* and *Carpinus betulus* dominant stands. This limitation had an inclination 60 - 70 percent with northeast exposure at 546 - 648 m a.s.l. Bedrock is limestone - dolomite with silty - clay - loam soil texture. Presence of logged and bare roots of trees is indicating rooting restrictions and soil heavy texture[3]. The current study is based on several windthrow events in the experimental forest station in during 2005 to 2006.

Selection of gaps

Twenty hectare areas of Experimental Forest Station of Tarbiat Modares University were considered for this research. Geoghraphical position all of canopy gaps were recorded by Geoghraphical Position System (GPS). Gaps required a minimum canopy opening of 30 m^2 and trees growing in the gap to be less than two thirds the height of the closed adjacent forest[38]. Canopy gaps areas were measured in the field according to[38] sampling protocol by locating and measuring two peripendicular lines in each gap: one along the longest line visible and one peripendicular to it at the widest section of the gap.

Measurement of light transmittance

Measurements of the light transmittance were collected with a ceptometer (LI 250 USA), at 1.00 m above the ground, with the instrument held horizontally. Four instantaneous readings were done at each sampling point, with reference to the cardinal directions. These measurements were carried out, during growing season, in bright sunny days, at 12.00 (local solar time). Measurements were taken: in the full open, in a large clearing near the experimental area inside the adjacent stands in correspondence of each subplot[1]. After measurement for each sampling point the PAR transmittance was calculated using the following formula:

% Light transmittance = (Light subplot / Light full open) × 100

Soil sampling and analysis

For this purpose, three positions were distinguished including gap center, gap edge and closed canopy. Soil samples were taken at 0 - 15, 15 - 30 and 30 - 45cm depths from all positions using core soil sampler with 81cm^2 cross section[35]. Large live plant material (root and shoots) and pebbles in each sample were separated by hand and discarded. The air - dried soil samples were sieved (aggregates were crushed to pass through a 2 mm sieve) to remove roots prior to analysis. Bulk density at air dried moisture content was measured by[34] method (clod method). Soil texture was determined by the Bouyoucos hydrometer method[6]. Soil moisture was measured by drying soil samples at 105° C for 24 hours[14].

Data analysis

Normality of the variables was checked by Kolmogrov - Smirnov test and Levene test was used to examine the equality of the variances. Light transmittance values were examined by two - way analysis (ANOVA) using the General Linear Model (GLM) procedure, with different areas (small, medium, large and very large) and positions (gap center, gep edge and closed canopy) as independent factor. Differences between gap different areas, gap positions and soil depths in soil characters were tested with three - way analysis (ANOVA) using the GLM procedure, with areas, positions and depth (0 - 15, 15 - 30 and 30 - 45 cm) as independent factor. Interactions between independent factors were tested also. Duncan test was used to separate the averages of the dependent variables which were significantly affected by treatment. Significant differences among treatment averages for different parameters were tested at Pd” 0.05. SPSS v. 11.5 software was used for all the statistical analysis.

RESULTS

Canopy gap and light transmittance

Twenty one canopy gaps with different areas were detected in study site. Gaps classified in four classes: four gaps in 40.11 - 130.30 m^2 area class (small gap with mean of 85.12 m^2 area), five gaps in 260.12 - 390.30 m^2 area class (medium class with mean of 325.21 m^2 area), eight gaps in 435.22 - 589.00 m^2 area class (large class with mean of 512.11 m^2 area) and four gaps in 626.12 - 821.58 m^2 area class (very large class with mean of 723.85 m^2 area). Result is indicating the most present gaps in study site have 300 - 500 m^2 area. With considering to analysis of variance, light transmittance amounts had ascending trend with increasing of canopy gaps areas. Also, this character showed significantly increasing from gap edge to center position (TABLE 1 and Figure1).

TABLE 1 : ANOVA for light transmittance in relation to canopy gap area and position

Variable source	Sum of square	Degree of freedom	Mean of square	F - value
Canopy gap area	2378.25	3	792.75	129.58**
Canopy gap position	7304.07	2	3652.03	596.96**
Interaction	1565.93	6	260.99	42.66**

** Different is significant at the 0.01 level.

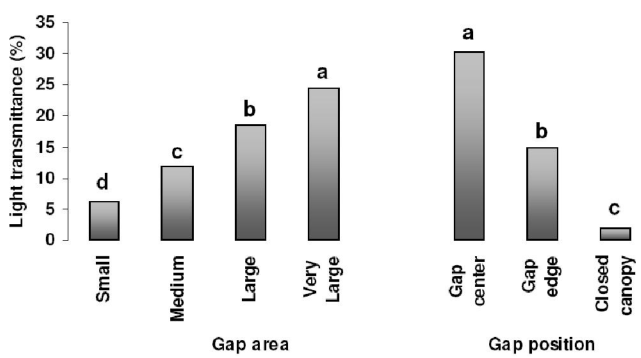

Figure 1 : Mean of light transmittance among canopy gap area and position

Soil characters

No significant differences ($P > 0.05$) were observed in bulk denisty between the canopy gap areas. Whereas, this character was significantly ($P < 0.01$) greater in canopy gap center, edge and 30 – 45cm depth (TABLE 2). Also, no significant differences ($P > 0.05$) were observed in soil texture between the canopy gap areas (TABLE 2). Sand was significantly higher in center and edge of canopy gaps ($P < 0.05$) and soil upper layers ($P < 0.01$) (TABLE 2). The greatest value of silt resulted in closed canopy position and beneath layers of soil. Significantly statistical differences ($P < 0.01$) were considered for this character (TABLE 2). Closed canopy position and 30 - 45cm depth had the greatest value ($P < 0.01$) of clay in comparison to the other position and depths (TABLE 2). As can be seen in TABLE 2, the soil moisture was significantly ($P < 0.01$) greater in small canopy gap and closed canopy position than in the other treatments. Whereas, no significant differences ($P > 0.05$) were observed for this character in different depths (TABLE 2).

DISCUSSION

The size and shape of created canopy gaps are related to the shape and size of falled trees. Trees crown havnt regular geometry form by reason of competition, natural events, social condition, etc. So, the treefall is effective on shape and size of created gaps. Sagheb Talebi and Schutz[39] pointed to lack of regular geometry shape in natural canopy gaps. In current research, the smallest gaps were similar to triangle form that is indicating delete of trees with low diameters, or small and irregular crown. It is expected that large canopy gaps includes geometry shapes near to circle or elliptical influenced by tree delete with expanded and symmetrical crown. Previous studies in temperate forests found that on the whole gap scale light quantity increases with opening size, whereas the pattern of soil moisture is less straightforward: it does not always increase in gaps, but it is generally more spatially variable than light[13]. Our results supported these findings, e.g. overall light levels were increased considerably in gaps. However, whilst relative light intensity values in small gaps could not reach those in large gaps. In general, the

TABLE 2 : Mean of soil characters in relation to canopy gap area, position and soil depth

Variable / soil character		Bulk density (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	Moisture (%)
Canopy gap area	Small	1.10 (0.00)	33.83 (0.30)	36.40 (0.15)	29.76 (0.15)	37.93 (0.71)a
	Medium	1.10 (0.00)	34.33 (0.74)	29.95 (0.15)	29.95 (0.15)	33.52 (1.07)b
	Large	1.10 (0.00)	33.51 (0.22)	29.63 (0.10)	29.63 (0.10)	28.25 (1.21)c
	Very large	1.10 (0.00)	35.55 (1.27)	29.71 (0.16)	29.71 (0.16)	28.35 (1.78)c
	F - value	0.21 ns	2.08 ns	0.40ns	2.37ns	384.65**
Canopy gap position	Center	1.11 (0.00)a	34.77 (0.20)a	35.90 (0.08)b	29.31 (0.13)c	24.16 (0.73)c
	Edge	1.11 (0.00)a	34.90 (0.71)a	36.22 (0.10)b	29.79 (0.11)b	27.16 (0.76)b
	Closed canopy	1.08 (0.00)b	32.80 (0.57)b	37.03 (0.20)a	30.13 (0.08)a	42.79 (0.37)a
	F - Value	101.23**	4.72**	17.75**	32.12**	2174.51**
Soil depth (cm)	0 - 15	1.09 (0.00)	35.52 (0.53)a	35.75 (0.10)b	29.31 (0.14)c	31.16 (1.34)
	15 - 30	1.10 (0.00)	34.28 (0.72)a	36.67 (0.15)a	29.75 (0.08)b	31.46 (1.17)
	30 - 45	1.10 (0.00)	32.67 (0.20)b	36.74 (0.15)a	30.18 (0.09)a	31.48 (1.10)
	F - value	48.95**	7.57**	14.76**	27.06**	0.77ns
Interactions F - value	Area ×position	0.14ns	0.32ns	0.21ns	3.55**	92.92**
	Area×soil depth	0.52ns	0.82ns	0.00ns	0.20ns	0.24ns
	Position×soil depth	2.75*	2.69**	1.57ns	29.96**	15.21**
	Area×position×soil depth	0.26ns	1.29ns	0.01ns	0.26ns	0.12ns

**** Different is significant at the 0.01 level. *Different is significant at the 0.05 level. (ns): Non significant differences ($P > 0.05$). Values are the means ±St. error of the mean (in parenthesis). Within the same column the means followed by different letters are statistically different ($P < 0.05$).**

light transmittance value is related to canopy opening intensity[11] that is observed in this research also. A lot of evidences show that the within - gap position isn't homogenous and changes are seen in different parts of it[23]. The solar regime of understory is affected by a lot of factors[16,22]. Our study result showed that light transmittance amounts had ascending trend with increasing of canopy gaps areas and from gap edge to center that was according to Kwit and Platt[22] and Galhidy, et al.[13] findings.

A greater amount of bulk density was found in within gap compared with closed canopy that can be related to sand content. Kooch[19] found that bulk density has a negative correlation with content of clay and positive correlation with sand, thus the bulk density tended to be less in clay soils compared with sandy soils. Soils are more compressed in deeper layers that are due to increasing of bulk densities[18]. By this interpretion, bulk density has a descending trend from upper soils to deeper that is visible in our resuls also. Moreover, in superficial layers of soil, bulk density amounts is less by reason of plant roots presence and more activity of organisms[19]. The components of soil texture are influenced by canopy gaps creation. With opening of canopy gaps rainfall will effect on these components as direct. Clays and silts with considering smaller size transferring to beneath layers whereas sands are stable in upper soil. This status can be regarded in this research also. Furthemore, Chen, et al.[9] reported that gap creation in forest ecosystems is due to decreasing of soil moisture and increasing temperature of superficial layers. In current study, opening of canopy cover was due to reduce of soil moisture as similar. Any way, the variability of soil moisture is different in forest ecosystems[12].

Beech (as dominant species in study area) twigs and leaves are need to longer times for decomposition than to hornbeam species. This character with old age of forest stands are due to increasing of litters volume in understory[17]. Thick humus layers creats appropriate positions for moisture preservation in forest lands. Spong character under closed canopy will increase water and moisture preservation capacities in comparison with positions without closed canopy. Disturbance and gap creation are due to decomposition of these layers and transmission to beneath horizons. Humour reduction within gaps can be related to solar radiation and increasing of microclimate temperature[33]. Gaps have more plant diversity than to closed canopy[40]. Settlement of diverse plant species and using soil different horizons are due to increasing of root respiration and following temperature increasing that can be effective on humour reduction. Constantly low soil moisture levels in the gaps and significant differences between gaps and closed forest found in this study were inconsistent with several other gap studies carried out in temperate hardwoods[24], beech - maple forests[17], longleaf pine (*Pinus palustris*) forests[7], temperate coniferous forest (Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) dominated)[43], or temperate deciduous forests (*Fagus sylvatica*)[5]. Gap diameters in these studies ranged from about 20 - 50m. Increased soil moisture content in gaps is often attributed to lower interception and higher precipitation. This is typically found in large gaps, e.g. in the study of Bauhus and Bartsch[5] with gaps of about 30m diameter in a temperate beech forest. In the smaller gaps, the amount of precipitation was similar in the gap and under closed canopy[36].

Soil moisture in gaps may also be influence by living roots[15]. Fine-root density has been found to be lower in gaps[7], even though differences might be small[42]. Lower root densities in below - ground gaps must reduce water uptake and transpiration via roots. Development of ground vegetation and regeneration will counteract this effect again. In Ritter and Vestrdal[37] research, the decline in soil moisture content in the gap along with growth of advanced regeneration supports this assumption. Further investigation of the root systems in this forest would be necessary to prove this hypothesis. If roots of the surrounding trees reach into a gap, water use by roots is also obvious along edges, but less pronounced than under closed canopy[5]. In present study, the most canopy gaps are surrounded by beech trees. With considering to superficial rooting system of beech, thus we are suspect to use of beech living roots from gap within moisture. Similar finding was also reported by Muth and Bazzaz[28] in a study of mixed hardwood forest. Galhidy, et al.[13] claimed that even centres of small gaps (radius <10 m) are beyond the reach of the root system of surrounding trees. Thus, less amounts of soil moisture were considered in within gap position. In general, Soil moisture and temperature patterns are also affected by local variations in soil depth and stoniness.

CONCLUSION

The scientific study for determining the influence of gaps on variability of light condition and soil characters having increased the knowledge of the future composition of the forest stand can be widely used in regulating the silviculture and forestry operations. The influence of gaps on the stand surface process is not in a linear relationship to the gap size. As a result, it seems that using small gaps will be considered as a better managing tool in controlling the value of understory light and the following interaction between regeneration and the variety of vegetation varieties. Play findings show that using various but small and medium gaps will provide better condition for the forest stands. Furthemore, the understanding of natural disturbance and stand development processes is necessary for their incorporating into the practice of any type of close-to-nature silviculture.

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