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Soil Loss Under Different Release Cutting Intensities in an Artificial Oriental Beech (*Fagus orientalis* Lipsky.) Stand

Bodenerosion unter verschiedenen Läuterung Intensitäten in einem künstlichen Bestand von Orientalischer Buche (*Fagus orientalis* Lipsky)

Zafer Yücesan[1], Sezgin Hacısalihoglu[2], Ercan Oktan[1] and Sevilay Özçelik[3]

Key words: Oriental beech, thicket, release cutting, soil loss amount, USLE

Schlüsselwörter: Orientalische Buche, Dickung, Läuterung, Bodenerosion, USLE

Abstract

The main goals of this research were (1) to assess the impact of different release operations on soil loss amounts and (2) to determine the relationship between soil loss amounts and release cutting intensities in Oriental beech. Study area is an afforestation area which was constructed in 1991. Actual age of the stand was 22. To maximize spatial variation in the dataset, stratified random sampling was used to layout transects. 24 sample plots were determined which reflects the average characteristics of the actual stand structure. 8 sample plots were selected from non-released stands, 8 sample plots were selected from the parts of the stand where light release

Corresponding Author: Asst. Prof. Dr. Zafer YÜCESAN, yucesan@ktu.edu.tr
1Karadeniz Technical University, Faculty of Forestry, Silviculture Department, Trabzon/TURKEY
2 Karadeniz Technical University,Faculty of Forestry, Watershed Management Department, Trabzon/TURKEY
3 General Directorate of Combating to Desertification and Erosion Control, Ankara/TURKEY

cutting operations were done and 8 sample plots were selected from the parts of the stand where high release cutting operations were done. Obtained results showed that canopy density has negative correlation with soil loss amounts and tolerance. According to the obtained results if the surface stoniness is less, soil depth is shallow and the slope gradient is high, intensity of the release cuttings should be regulated which can be fewer than 40% of the total basal area of standing trees. By the way site factors can be controlled more efficiently.

Zusammenfassung

Die Hauptziele dieser Forschung waren die Auswirkungen der verschiedenen Läuterung arbeiten auf den Bodenerosion und die Beziehungen durch den Läuterung des Bestandes zwischen dem Bodenerosion und Kronenschlussgrad. Untersuchungsgebiet ist eine Aufforstung die im Jahre 1991 errichtet wurde. Das tatsächliche Alter des Standes ist 22. Um räumliche Variation in der Datenmenge zu maximieren, wurde geschichtete Zufallsstichprobe verwendet. 24 Probeflächen wurden ermittelt die den durchschnittlichen Eigenschaften der tatsächlichen Stand-Struktur geben. 8 Probeflächen wurden ermittelt in dem keine Läuterung durchgeführt wurde, 8 Probeflächen mit dem geringem Läuterung Intensität und 8 Probeflächen mit hoher Läuterung Intensität. Die erhaltenen Ergebnisse zeigten, dass Kronenschlussgrad habe negative Korrelationen mit dem Bodenerosion und Toleranz. Laut der erhaltenen Ergebnisse, wenn die Oberflächen Steifigkeit gering, Bodentiefe flach ist und die Hangneigung hoch ist, sollte die Intensität der Läuterung geregelt und weniger als 40% der gesamten Grundfläche von stehenden Bäumen umfassen. Auch die Standortfaktoren müssen effizienter gesteuert und geregelt werden.

1. Introduction

The Oriental beech (*Fagus orientalis* Lipsky) forests in Turkey cover 1.8 million ha (Figure 1) of 21.2 million ha forest areas in total and it is the fourth widely spreading tree species of Turkey (Huss and Kahveci 2009). The oriental beech is also the second common broadleaved tree species of Turkish forests after oak species. Beech grows on cool, mesic northern mountain slopes of the Black Sea Region (Saatcioglu 1957; Atalay 1992; Colak 1997; Esen et al. 2004) and it is one of the most important component of old-growth forests (Kurdoglu and Çokçalıskan 2011). Oriental beech forests form optimum stand structures between 700-1200 meters from the sea level in East Blacksea region and it can arise up to 1800-1900 meters (Suner 1978). Beech stands are generally found in steep slopes (%18-58) in Turkey (Atay 1982). Because of its wood quality and neighbouring to the settlement and agricultural areas anthropogenic effects are usually seen on beech forests. Moreover, over than 80% of the country area is open to the erosion risk deal with the topographic conditions in Turkey (Huss and Kahveci 2009) and oriental beech stands are one of the most important components of this subject.

After new growths and young crops form stand canopy, competition between trees begin. In thicket stage, natural selection through competition cannot guarantee that the management goals will be met. So, artificial selection is also needed in order to constitute the new stand. In this sense, selection of the individuals removed is important. The common idea in managing beech forests which have a great ability of wide-spreading crown is to grow them as dense as possible when the stand is in thicket stage. Hence, it is important to give better conditions for commercially and biologically important trees (Nyland 1996, Stredanský 1994, Smith et al. 1997). In the release of most young stands main goal of the objective is to give the trees that are released enough light and growing space for qualified growing and developing into trees of the main canopy. On the other hand, intensity of the release cutting depends on all characteristics of the ecotope (Stredanský 1994). Release cuttings are mostly envisioned as freeing the crowns of present popular trees. However there are several additional considerations. If the crowns of the trees are released more than their ideal form for giving more growing space, their growth may be prevented because of the competition for moisture and nutrients with the root systems of neighbouring trees (Smith et al. 1997) and increasing soil erosion trend.

Soil erosion is a very considerable event which is affected by incorrect land-use forms and human activities (Karagül 1999; Hacısalihoglu et al. 2006; Hacısalihoglu et al. 2010; Wu et al. 2001; Turner 1989; Burel et al. 1993; Fu et al. 1994). Soil erosion has considerably increased in all the existing word agricultural systems as well as in forests (Stredanský 1994; Brown et al. 1984). Silvicultural operations cause soil erosion.as well. Canopy dynamics, site preparation, harvesting and logging are all deal with silviculture and reduce infiltration rates, increase surface runoff hence increase the potential for soil erosion and nutrient export by disturbing the protective surface layers of the forest floor (Moehring and Rawls 1970; Hewlett and Troendle 1975; Douglass 1975; Blackburn et al. 1986; Laffan et al. 2001; Marshall 2000; Gümüs and Acar 2010) and thus influence the development and growth of forests (Pritchett and Fisher 1987; Oliver and Larson 1990; Smith 1992; Smith et al. 1997; Esen et al. 2004). Consequently soil conservation is one of the most dominant environmental functions of the forests and in all silvicultural treatments soil erosion and properties should be taken into consideration.

The main goals of this research was to assess the impact of three different crown release options on soil loss amounts and consider the suitable intensity of release cutting operation for creating positive effects on soil loss amounts.

2. Material

2.1 Description of the study area

The study area was located in Trabzon City, Düzköy County, Sögütlü Basin in North East of Turkey (40085' N- 39045' E) (Figure 1). Study area is an afforestation area which was constructed in 1991. While construction of the stand 1+0 years old *Fagus orientalis* Lipsky saplings were used. Study area is approximately 3 hectares in size and takes place between 1320-1430 meters from the sea level. The main aspect is west and according to the management plans site productivity is high in the study area (Table 1). Most of the individuals in the sampled stands were in thicket stage and the silvicultural objective was release cutting in update management plans.

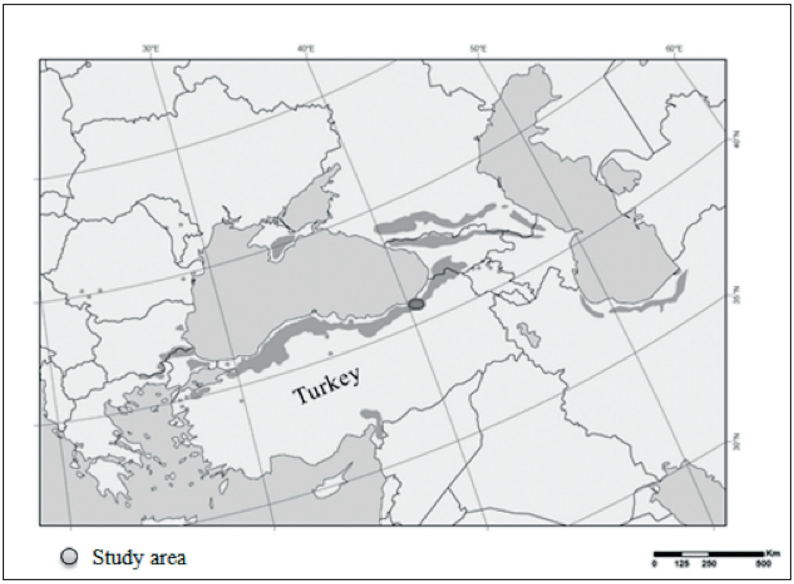

Figure 1: Location of the research area on the distribution area of Fagus orientalis (map obtained from the website http://www.euforgen.org/distribution_maps.html)

Abbildung 1: Untersuchung und der Verbreitung Gebiet des Orientalische Buche (benommen von den Webseite http://www.euforgen.org/distribution_maps.html)

According to the data obtained from nearest meteorology station in Düzköy (850m) average annual temperature is 8.6 oC, average annual precipitation is 853.7 mm. When climate diagram was drawn (Thornwaite 1948) according to these data drought is seen in July (Karagül 1999). However average altitude of the research area is 1350 meters. So when temperature and precipitation values were interpolated no drought is seen in the watershed upper 850 meters (Karagül 1999) from the sea level.

Table 1: General characteristics of sample plots

Tabelle 1: Einige Eigenschaften des Untersuchungsgebiets

Sample plot	Altitude (m)	Aspect (Degree)	Slope Gradient (%)	Canopy density (%)	Coordinate (UTM)	Crown Release Option
1	1330	3150	30	70	538574-4523450	Non-released
2	1326	3420	28	80	538519-4523401	Non-released
3	1350	3100	34	90	538630-4523391	Non-released
4	1365	3300	34	100	538610-4523367	Non-released
5	1390	3300	32	90	538669-4523280	Non-released
6	1400	3150	30	100	538747-4523335	Non-released
7	1430	3260	33	60	538791-4523286	Non-released
8	1425	3150	40	80	538753-4523219	Non-released
9	1320	3300	41	60	538652-4523491	Heavy
10	1355	3260	43	80	538727-4523461	Heavy
11	1375	3150	44	70	538741-4523427	Heavy
12	1425	3150	43	50	538784-4523382	Heavy
13	1385	3200	45	50	538799-4523443	Heavy
14	1360	3150	46	80	538755-4523479	Heavy
15	1320	3150	55	80	538698-4523514	Heavy
16	1330	3150	43	90	538732-4523577	Heavy
17	1330	3000	41	80	538712-4523626	Light
18	1330	3000	40	60	538712-4523640	Light
19	1380	2750	42	90	538780-4523634	Light
20	1380	2750	40	80	538780-4523648	Light
21	1330	2750	65	70	538751-4523687	Light
22	1380	2900	66	80	538777-4523574	Light
23	1390	2750	62	80	538821-4523689	Light
24	1330	2750	71	70	538752-4523723	Light

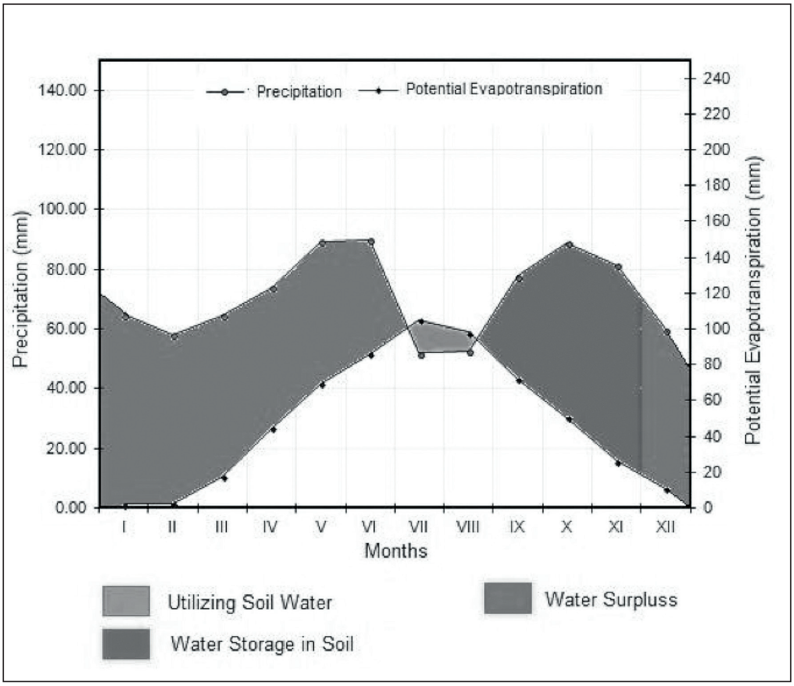

Figure 2: Climate Diagram

Abbildung 2: Klima Diagramm

2.2 Data collection

To maximize spatial variation in the dataset, stratified random sampling was used to layout transects. 24 sample plots were determined which reflects the average characteristics of the actual stand structures. 8 sample plots were selected from non-released stands, 8 sample plots were selected from the parts of the stand where light release cutting operations were done and 8 sample plots were selected from the parts of the stand where heavy release cutting operations were done (Table 2). Light release cutting operations were done in 2008 and heavy release cutting operations were done in 2009 by the local directorate of forest enterprise.

Each sampling plots were sampled in 10 m wide and 20 meters long at intervals at least 50 meters. Soil samples (0-20 cm depth) were taken randomly from two locations within each plot. 16 of soil samples are in where no crown release were done, 16 of samples are in where light release cutting operations were done and 16 of samples are in where heavy release cutting operations were done.

Table 2: Some of the dendrometric parameters in treated sample plots

Tabelle 2: Einige dendrometrische Parameter in den Untersuchungsgebieten

Crown release option	Available tree numbers (n/ha)	Available total basal area (m^2/ha)	Harvested tree numbers (n/ha)	Harvested basal area (m^2/ha)	Total basal area before harvesting (m^2/ha)	Treatment ratio (%)
Non-released	4325	19.288	0	0	19.288	0
Light Release Cutting	3319	16.927	1425	4.063	20.991	19
Heavy Release Cutting	2056	12.089	2594	8.0786	20.168	40

Each plot was mapped using a GPS. Altitude above sea level (asl) was assessed with an altimeter and slope gradients were measured with clinometer. Aggregate classes and surface stoniness were determined according to Boden Kartieranlietung (BK 1994), permeability was determined according to Saxton's simulation method (Saxton et al., 1986). Soil depth was measured at 2 random places in every plot and the values were averaged. For further laboratory analysis, soil samples were being dried, than the soil samples were grounded to pass a 2 mm sieve and stored in sealed polyethylene bags. Soil textures were determined according to the Bouyoucos hydrometer method (Bouyoucos 1962) and organic matter contents were determined according to the Walkley-Black wet oxidation method (Allison 1965) in the laboratory.

The stand profiles were determined and painted with using the "ARGUS Forstplanung" simulation program (Staupendahl, 2003). Vertical stand profiles were used to determine the canopy density in each sample plot.

3. Methods

3.1 Soil loss predicting with the universal soil loss equation (USLE)

The international version (where the values are turned in to metric system and adapted to the European conditions) of the simulation model USLE was used to determine the soil loss amounts according to Schwertmann et al. (1990) in this study. Most of the erosion assessments performed in North America during the past two decades have used the USLE. This model was derived empirically from approximately 10,000 plot-years of data (Wischmeier and Smith 1978) and may be used to calculate erosion at any point in a watershed that experiences net erosion. The expected soil loss potential (erosion hazard) expressed as t/ha/year for the study area was determined using the USLE model. The factor controls of soil erosion, namely: climate, soils, vegetation cover, topography and management are combined in the empirical USLE (Equation 1) in the form:

$$A = R.K.L.S.C.P \quad (1)$$

where *A* is the average annual soil loss (t/ha/year), R the rainfall erosivity factor, K the soil erodibility factor, L the slope length factor, S the slope steepness factor, C the cover management factor and P is the supporting practice factor. Climate erosivity is represented by R and can be estimated from the rainfall intensity and amounts data which were taken from Dogan and Guçer (1976) in this study. The soil erodibility nomograph can be used to predict the K value (Schwertmann et al. 1990). The topography and hydrology effects on soil loss are characterized by the L and S factors. For direct USLE applications, a combined LS factor was evaluated for each land cell as Wischmeier and Smith (1978). Land use and management are represented by P and can, with some difficulty, be inferred using remote sensing combined with ground-trusting.

3.2 Determining soil loss tolerance

"T" is the soil loss tolerance factor. It is defined as the maximum amount of erosion at which the quality of a soil as a medium for plant growth can be maintained. This includes maintaining (1) the surface soil as a seedbed for plants, (2) the interface between the air and the soil that allows the entry of air and water into the soil and still protect the underlying soil from wind and water erosion, and (3) the total soil volume as a reservoir for water and plant nutrients, which is preserved by minimizing soil loss. Erosion losses are estimated by the USLE and the Revised Universal Soil Loss Equation (RUSLE). The T factor is assigned to soils without respect to land use or cover. T factors are assigned to compare soils and do not directly relate to vegetation response. However, many of the factors used to define a T factor are important to vegetation response, but the T factor itself is not. The classes of T factor are 1 (0 -1 ton/ha/year), 2 (1-2 ton/ha/year), 3 (2 - 3 ton/ha/year), 4 (3 – 4 ton/ha/year), and 5 (4 - 5 ton/ha/year). The five classes range from 1 ton per acre per year for very shallow soil to 5 tons per acre per year for very deep soil that can more easily sustain productivity (NRCS, 1999). T factor class 6 indicates that the soil loss amount is more than 5 ton per acre per year.

4. Results and Discussion

Average canopy density was about 84% in non-released sample plots, 76% in light released sample plots and 70% in heavy released sample plots. The study results showed that average soil loss amount according to simulation model USLE was about 0.9727 (t/ha/year) in non-released sample plots. Same values were 1.6688 (t/ha/year) in the sample plots where light release cutting operations were done and 2.1050 (t/ha/year) in the sample plots where heavy release cutting operations were done (Table 3). According to obtained results, the average soil loss tolerance class was about 1 in non-released sample plots (0 to 1 t/ha/year), the value was in class 2 (1 to 2 t/ha/year) in sample plots that light release cutting operations were done and in class 3 (2 to 3 t/ha/year) in sample plots that heavy release cutting operations were done (Table 3). This indicates that soil loss tolerance was exceeded in different amounts in almost all of the sample plots. Negative correlation was found between soil loss amount, soil loss tolerance and canopy density (Table 4). So, it should be thought that, how soil loss amount can be controlled by the canopy density. It is known that for anti-erosion purposes it is necessary to know the characteristics of the soil's vegetation cover. Vegetation has positive effects on water regime and water balance (Üçler et al. 2011). Vegetation cover, in other words, is canopy control interception capacity, absorption of the kinetic energy of water, roughness of the soil surface, soil texture, permeability, and some other characteristics (Stredanský 1994). These characteristics protect the top soil against the destructive effects of the rain drops and wind. Thus, researchers now recognize the forest canopy as a part of the forest ecosystem (Parker and Brown, 2000). Forest canopies have structural and functional characteristics. Compared to the outside of a forest, inside of the forest is dark, moist, quiet and still. The structural complexity of canopies forms micro environments for the biota (Nadkarni et al. 2004). Canopies modify average values of temperature, relative humidity, wind speed, light. These values can be changed by the canopy. Canopy biotas enhance watershed integrity, nutrient cycling, erosion control, carbon sequestering, and climate stability (Blair and Ballard, 1996). However changing intervals of these factors are very important for the ecological and evolutionary environment of organisms (Parker 1995). According to Spies (1998) measuring forest canopy structure is a key to understand many aspects of forest ecology. Consequently, it is certain that development of the forest canopy structure is key factor for sustainable forestry. Many timber harvesting practices deal with the silvicultural treatments aggressively disrupt the microhabitats and resource use in the canopy (Davis and Sutton 1998). Sustainability is important in silvicultural treatments and in order to sustain tree communities and other vegetation, sustaining the site factors are also important. The main idea of the sustaining site factors by silvicultural treatments is to sustain the soil conserving effects. The soil conserving effects of vegetation include its favourable influence on soil properties and the soil protection effect of the plant cover. Vegetation modifies the effects of radiation, light, temperature, humidity, evaporation and etc. By changing the influence of these factors, vegetation may influence the water regime of the soil, the circulation of nutrients, the life of organisms in the soil and other environmental features (Stredanský 1994).

Table 3: Annual average predicted soil loss amounts and soil loss tolerance

Tabelle 3: Jährliche durchschnittliche Bodenverluste und Bodenverlusttoleranz

Crown release option	Average slope gradient (%)	Average canopy density (%)	Predicted soil loss (t/ha/yr)	Soil loss tolerance class
Non-released	33	84	0.9727	1
Light Release Cutting	54	76	1.6688	2
Heavy Release Cutting	45	70	2.1050	3

According to the study results the average slope gradients were 32% (minimum 28% and maximum 40%) in non-released sample plots, 54% (minimum 41% and maximum 72%) in sample plots that light release cutting operations were done and 45% (minimum 41% and maximum 55%) in sample plots that heavy release cutting operations were done (Table 3). It is well known that a positive and strong correlation between the topographic characteristics and soil loss exists including gradient, length, shape and exposure of the slope (Wischmeier and Smith 1978; Stredanský 1994; Liu et al. 1994; Hacisalihoglu 2004; Hacısalihoglu et al. 2010). Correlation results (Table 4) support this general knowledge. According to obtained results there is a positive significant ($p<0.01$) correlation between soil loss amount and slope gradient. Even though obtained slope gradient values were between larger intervals in sample plots that light release cutting operations were done (Table 3), soil loss amounts are much more in sample plots where heavy release cutting operations were done and those sample plot's slope gradients were changed in a smaller interval as well. So, it can be said that by constructing the suitable canopy density with release cutting operations according to the slope gradients, site factors can be sustained more efficiently.

Table 4: Correlation data sheet between soil loss amounts and the other variables

Tabelle 4: Korrelation zwischen Bodenerosion und andere Daten

		Slope gradient (%)	Canopy density (%)	Predicted soil loss (t/ha/yr)	Soil loss tolerance
Slope gradient (%)	Pearson Correlation	1	-0.198	0.398(**)	0.222
	Sig. (2-tailed)		0.176	.005	0.130
	N	48	48	48	48
Canopy density (%)	Pearson Correlation	-0.198	1	-0.761(**)	-0.773(**)
	Sig. (2-tailed)	0.176		0.000	0.000
	N	48	48	48	48
Predicted soil loss (t/ha/yr)	Pearson Correlation	0.398(**)	-0.761(**)	1	0.924(**)
	Sig. (2-tailed)	0.005	0.000		0.000
	N	48	48	48	48
Soil loss tolerance class	Pearson Correlation	0.222	-0.773(**)	0.924(**)	1
	Sig. (2-tailed)	0.130	0.000	0.000	
	N	48	48	48	48

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

According to the data of General Directorate of Turkish Forestry the number of the future crop trees must be 80-150 n/ha in pure beech stands. In Turkish forestry applications silviculture practisers are thought that if you give larger developing areas to the individuals in stands that the main tree species are in high shade tolerant and have a great ability of spreading its canopy like beech trees, growth characteristics may be better and by the way you don’t need to repeat release cutting treatment frequently (e.g., every 5-6 years). Obtained results show that negativity can be seen on this idea. In the cited literature in tending of thickets it was suggested that treatment must be repeated frequently (e.g., every 2-4 years) (Stredanský 1994). High interventionist silviculture aims to reduce competition between the hyper dominant trees because of favouring value increment. When considering thinning one should determine the amount of growing space being made available to the residual trees, how quickly will their crowns be able to utilize that released space, and how long the trees will have additional space available. These determinations have two important consequences. If the crowns take a very long time to utilize the released space because of previous conditions, the thinning may not provide the benefit required (Siemon et al. 1980; Oliver and Murray 1983; Oliver et al. 1986; O'Hara 1989). As a result of the study, while giving larger development areas to the future crop trees you can destroy the soil characteristics which are also important for plant's growth and site quality as well. During the thicket stage it is not possible to select future crop trees which are the main bearers of stand quality and quantity. So positive selection must be limited and more often treatments have to be carried out by negative selection. Negative selection becomes intense on less dominant trees, co-dominant trees, diseased, damaged or poorly shaped trees (Stredanský 1994). The socially leading trees have crown grade of about 40% to 50%, which is sufficient for good stability (Schütz 2006). However it should not be forgotten that, less dominant and co-dominant trees support the development of future crop trees. On the other hand less and co-dominant trees are the most important components of multi-storeyed stand structures. It is necessary to form or carry out the multi-storeyed stand structure with tending treatments especially in stands which are in thicket stage and especially where the main tree species are in shade tolerant as beech.

5. Conclusion

Topographic factors can be changed in a very short distances in Eastern Blacksea Region. Studied area is a small stand in size. Although sampled plots were under the same climate conditions, having the same soil depth, the same altitude class and aspect, canopy and slope gradients were changed. Obtained results showed that canopy degrees have a negative correlation and slope gradients have positive correlation with soil loss amounts and tolerance. According to the study results if the soil depth is shallow and the slope gradient is high, light release cutting have to be preferred in oriental beech stands. In other words, mild cleaning should be better especially for the first release cutting intervention in oriental beech. Heavy release cutting for the first intervention of the release cutting nay cause destruction on the canopy structure and thus affect the soil loss amount. Vertical and horizontal canopy density is very important in beech stands and especially in thicket stage canopy density should be around 80% after treatments. According to the obtained results, to protect the soil loss, the release cutting intensity have to be fewer than 40% of the total basal area for the first treatment during the thicket stage. The stand must remain a thicket after the treatment. By the way future development of stand structures can be more effective, soil humidity and erosion ability can be controlled more efficiently and so soil properties can be sustained for the further stand stages.

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