African Journal of Agricultural Research Vol. 5(16), pp. 2200-2214, 18 August, 2010
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.613
ISSN 1991-637X ©2010 Academic Journals

Full Length Research Paper

Predicting soil erosion in oriental spruce (*Picea orientalis* (L.) Link.) stands in Eastern black sea region of Turkey

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Accepted 12 August, 2010

Human induced pressures on the natural resources are still in progress and the conservation efforts, too. The need for sufficient knowledge and data for the decision makers is obvious. This study is aimed to contribute this absence. The study area Çamlıhemsin district Kito mountain is situated in the Eastern Black Sea Region of Turkey and characterized by a humid climate covered with natural growth oriental spruce stands. The canopy closures of the Oriental spruce (*Picea orientalis* (L.) Link.) stands (Treeline, Timberline, Regular forest) varies between 0 to 90% in the study area, including Kito mountain occupied forest and pasture lands. Universal Soil Loss Equation (USLE) simulation model was used to predict the soil loss amounts in the study area. The results show that the predicted average soil loss amount is 29.79 (ton/ha/year). The average soil depth is about 26 cm and the soil loss tolerance limit is widely exceeded especially in the pasture lands, control plots, tree line zone and timberline zone in the study area.

Key words: Soil loss, tolerance tree line, timberline, subalpine zone.

INTRODUCTION

Oriental spruce *Picea orientalis* (L.) Link. is one of the most important woody species for Turkey due to being the semi monopoly tree with respect to its distribution. Distribution area of oriental spruce ranges between 550 to 2400 m in Turkey and covers total area of 146300 ha on the North Eastern Black sea Mountains. Different habitat conditions such as altitude and stand structure cause functional grouping in oriental spruce forests. In the past, wood production was the most important function. However, all these forests were also intensively subjected to overgrazing and individual selection. Recently, oriental spruce forests have been gained more importance in Turkish forestry applications because of their landscape, recreation and nature conservation functions as well as the wood production function (Ucler et al., 2007).

Mountain forests are generally found on steep slopes and they live under very extreme climatic conditions and in a very thin soil layer. The trees in these habitats are mostly under the threats of avalanches, rock falls, land slides, torrents and violent winds (Kienholz and Price, 2000). One of the most important functions of mountain forests is to protect the environment from these natural hazards (Schonenberger, 1998). The natural progress of soil erosion can be increased horrendously by human activities, such as over-cultivating depleted soils until the protective ground covers are gone and accelerated erosion takes place. Soil erosion, for whatever cause, destroys man-made structures, fills reservoirs, lakes and rivers with washed soil sediment, and badly damages the land. Whether it is called mud, silt or sediment, it is all soil material that should have been kept in place, on top of the land where it can support plant growth and plants can, in turn, stabilize the soil. Erosion sediment is the richest part of the soil, the nutritive topsoil containing most of the organic matter. The cost of dredging the several billion tons of sediment from rivers and harbors each year is about 15 times more than that of holding the soil on the land from which it eroded (Miller and Donahue, 1990). Since thousands of years, the Anatolian region has been the theatre of nonstop human activity, embracing a

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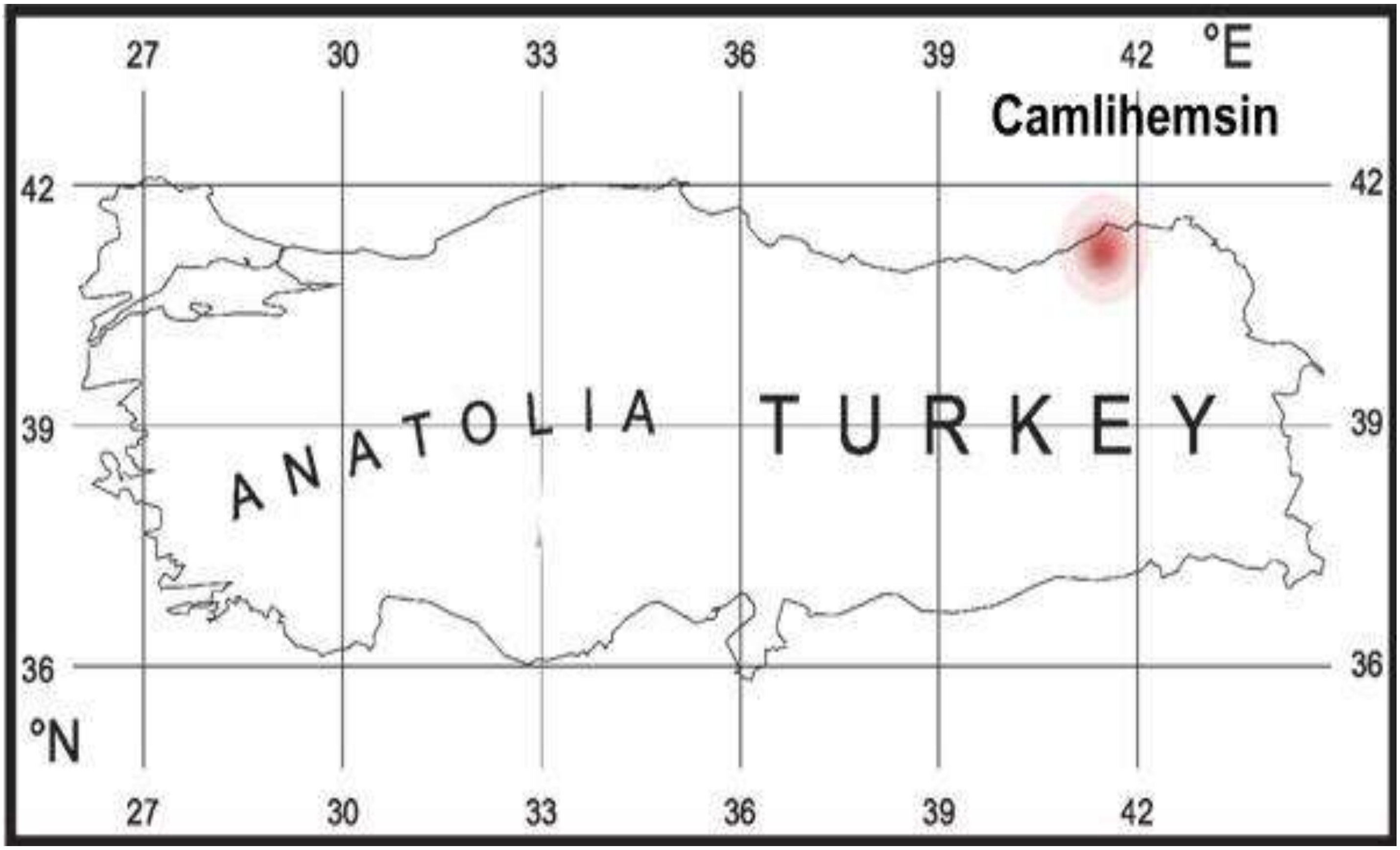


Figure 1. The study district (the Kito mountain) in Turkey.

continuous quest for fuel wood and timber going hand in hand with an ever expanding grazing area. This uninterrupted and long lasting human disturbance has lead to an important decrease in forest area (Boydak, 2003; Özkan, 2009; Özkan et al., 2009).

According to International Soil Reference and Information Centre (ISRIS), very high water or wind erosion takes place in Turkey (Oldemann et al., 1991). Although, the extents of soil loss and runoff rates in different regions and areas of Turkey have not been studied extensively (Sariyildiz and Gemci, 2004), very few studies have investigated to determine the effects (social, economical, cultural etc.) of different land-use types and slope classes on soil loss and runoff (Hacisalihoglu et al., 2010).

The aim of the present study was to determine the soil erosion amounts in a humid climatic conditions using the most popular soil erosion predicting model Universal Soil Loss Equation (USLE) in a mountainous alpine to subalpine zone (Kito mountain) with oriental spruce (*P.orientalis* (L.) Link.) stands (Tree line, Timberline, Regular forest, Pasture and control points) covered and highly sloped (partly > 50%) study area (Çamlıhemsin, Turkey).

MATERIALS AND METHODS

Study area

The study area is situated in Rize city, Çamlıhemşin county, Fırtına valley, Kito mountain (41° 08' N - 41° 01' E, elevation: between 1800 and 2200 m asl (altitude above sea level)) in Eastern Black Sea Region of Turkey, located 30 km SE of the Ardeşen county (Figure 1). It is a mountainous, alpine to sub alpine zoned, in most points different canopy closured (stand closure) natural oriental spruce (*P. orientalis* (L.) Link.) forest area (Yucesan, 2006). The pasture lands and the sample plots in the pasture lands are placed in the alpine zone (above 2100 m).

Eastern black sea region was comprised from a volcanic arc. Volcanisma which comprised this formation had shown an important activity in upper Kratese and covered widespread area. In the arc of upper Kratese from Trabzon to Hopa dacite, basalt and sedimentary units was seen as a geological cross-section (Tuysuz and Akcay, 2000). Dominant bedrocks are granite and granodiorite in the high mountains they are in one and more hundred meters thick (MTA, 1998). In the study site two different soil types as brown forest soil without lime and high mountain grass soil had been formed by bedrock and climate (KHGM, 1988).

Region is rainy in every season. At coast section winter is warm and summer is hot. Most of rain happens in autumn and winter months. In July and August heavy rain storms are seen. In Turkish climate classification those characteristics are defined as "East Black sea Climate" (Atalay et al., 1985). Regional climate

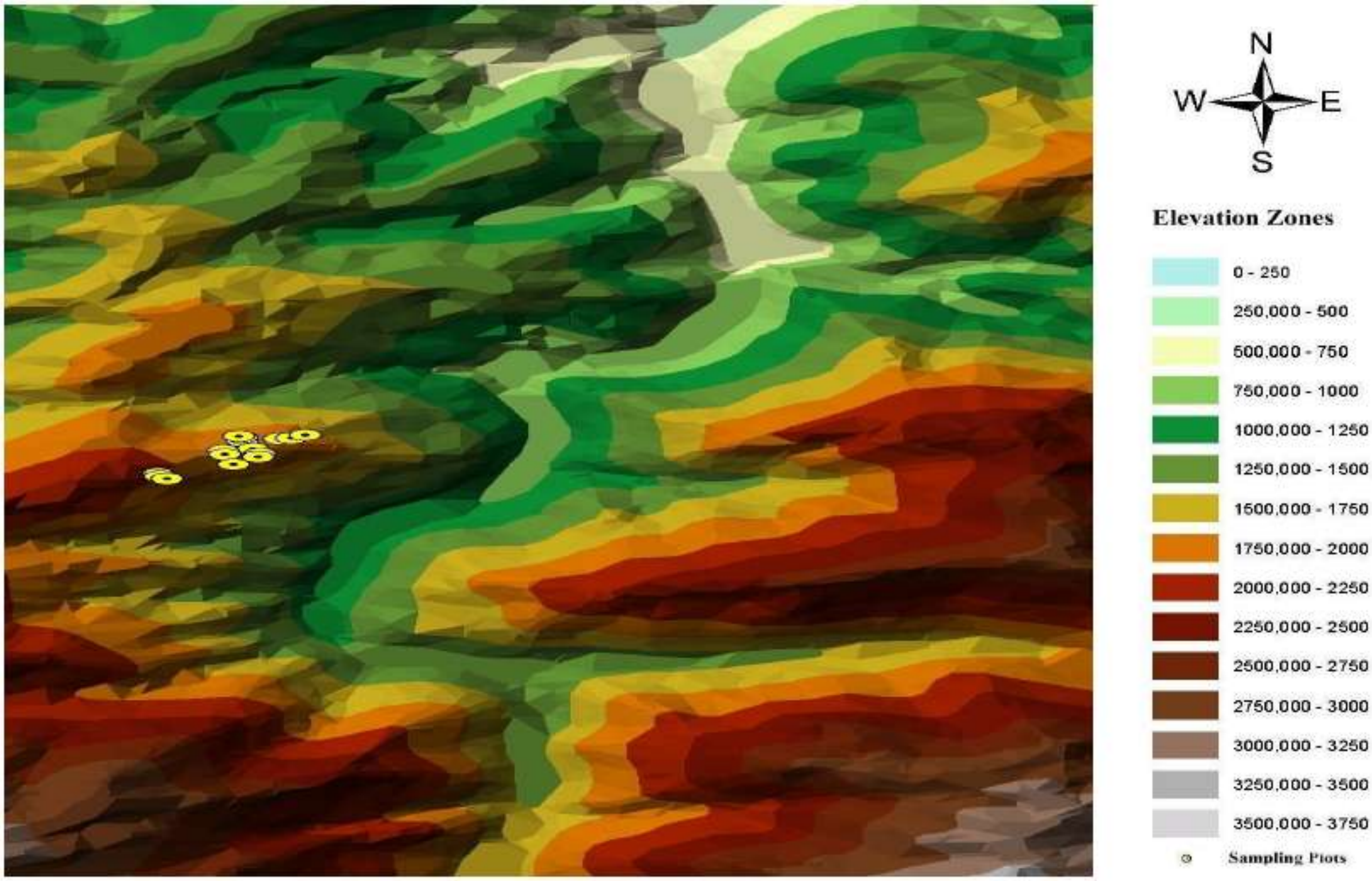


Figure 2. Sample plots taken from different elevation zones in the study area.

characteristics could be shown micro climatic characteristics in some parts of research area. According to datum obtained in Ayder (1277 m) annual mean temperature is 7°C (DSİ, 1997). Region and especially suburb is the most rainy part of Turkey. Annual mean total precipitation amount is 1373.1 mm in Çamlihemşin (MIGM, 1994) In general precipitations are happening in rain form and seasonal rain distribution is regular. Precipitations are almost frontal and in aerographic type. There is no arid season or month close to research area.

Research area is in Euro-Siberian (Euxin-Colchis) Flora region. Euro-Siberian region covers whole part of north Turkey and go over to Caucasia, Crimea and Dobrudja Mountain. Euro-Siberian region in Turkey is separated into two sub region as Euxine and Colchis by Ordu-Melet River. Euxin Province extends between Istıranca Mountains and Melet River. On the other hand Colchis Province where the research is in starts from the east side of Melet River (Yaltirik and Efe, 1996).

Data collection

To maximize spatial variation in the dataset, stratified random sampling was used to layout transects, mostly oriented from alpine to sub alpine zone (pasture sample plots are in the alpine zone; treeline, timberline, regular forest and control (zero) sample plots are in the sub alpine zone). 15 plots (3 in pasture, 4 in tree line, 4 in timberline and 4 in regular forest) of 20 x 20 m (Figure 2) were sampled at intervals of at least 50 m and totally 45 soil samples were taken within these plots. The stand profiles were determined and painted with using the “ARGUS Forstplanung” simulation program (Staupendahl, 2003). Slope gradient, aspect, coordinates of every tree, diameter (in 1.30 m high), tree height, crone beginning high, etc. was measured in the sampling plots (20 x 20 m) to determine and paint the stand profiles in the study area.

Each plot was mapped using a GPS. Altitude above sea level (asl) was assessed with an altimeter and the bedrock was derived from existing maps. Landscape position, surface roughness and landform were recorded at sight. Surface stoniness (%) and slope (%) were assessed by stabbing the soil at 5 random locations with a steel probe and clinometers respectively. The slope exposition, measured in degrees relative to N, was transformed to a relative measure of Heat Load (HL) using the formula described by Mc Cune and Keon (2002) $HL = [1 - \cos \theta] / 2$. Species (woody and herbaceous) presence and absence also the stand closure (0: 0-10%, 1: 11-40%, 2: 41-70%, 3: 71-100%) were determined and recorded. Aggregate classes, surface stoniness (BK, 1994), Permeability (Saxton et al., 1986), Soil depth was measured at 5 random places in every plot and the values were averaged. In every plot soil samples were taken and pooled for further analysis. Soil texture (Bouyoucos hydrometer method (Bouyoucos, 1962)) and organic matter content (Walkley-Black wet oxidation method (Allison, 1965)), etc. were determined in the laboratory.

Soil loss predicting with the universal soil loss equation

The international version (where the values are turned in to metric system and adapted to the European conditions) of the simulation

Table 1. Descriptive statistics of some variables used in the simulation model.

	N	Minimum	Maximum	Mean	Std. deviation	Variance
Slope (%)	45	20.00	52.00	40.8000	12.33178	152.073
Hıllsıde (m)	45	20.00	20.00	20.0000	0.00000	0.000
Depth (cm)	45	25.00	30.00	26.0000	2.02260	4.091
Organıc (%)	45	2.84	5.51	4.2220	0.70613	0.499
Permea (cm/hr)	45	0.19	0.94	0.5142	0.16709	0.028
Surface (%)	45	10.00	30.00	16.0000	8.09040	65.455
Sand (%)	45	29.20	51.20	40.1013	4.55554	20.753
Loam (%)	45	19.20	43.20	26.5562	4.49492	20.204
Clay (%)	45	25.60	42.32	33.5236	5.01613	25.162
Canopy (%)	45	0	90	38.00	36.964	1366.364
Soıl loss (ton/ha/year)	45	4.48	73.60	29.7949	21.30703	453.990
Valid N (listwise)	45					

model USLE was used to determine the soil loss amounts according to Schwertmann et al. (1990). 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 USLE is written as follows Equation 1:

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

where A is the average annual soil loss (t/ha per 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 monograph 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.

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.

Statistical methods

For the evaluation of the research results, SPSS statistical program was used to determine the averages and correlation between some of the variables.

RESULTS AND DISCUSSION

The naturally oriental spruce forested mountainous research area in the alpine to sub alpine zone is located between 1800 to 2100 m asl. In this elevation range gives tree different stand structure types (tree line, timberline and regular forests) which are shown in Figures 3, 4 and 5).

The pasture lands are in the alpine zone (above 2100 m asl). Many different variables have been measured and determined to obtain the requirements of the used predicting model (USLE). Some of these variables and their average values are given in Table 1.

According to this measurement results the average slope gradient is very high and occupied about 32% (minimum 20% and maximum 52%) of the sample plots. It is well known that a positive and strong correlation between the slope gradient and soil loss exists (Wischmeier and Smith, 1978; Hacisalihoglu, 2004). The very significant and positive correlation (Table 2) between the predicted soil loss amounts and slope gradients in the sample plots supports this general knowledge. Canopy closure values vary in big interval in the study sites. It is known that the canopy closure effects the interception function of the forests and this protects the top soil against the destroy effect of the rain drops. There are also a negative correlation between soil loss amounts and canopy closure. The forest stand closures in the study sites (Figures 3, 4 and 5) are varies between 0%

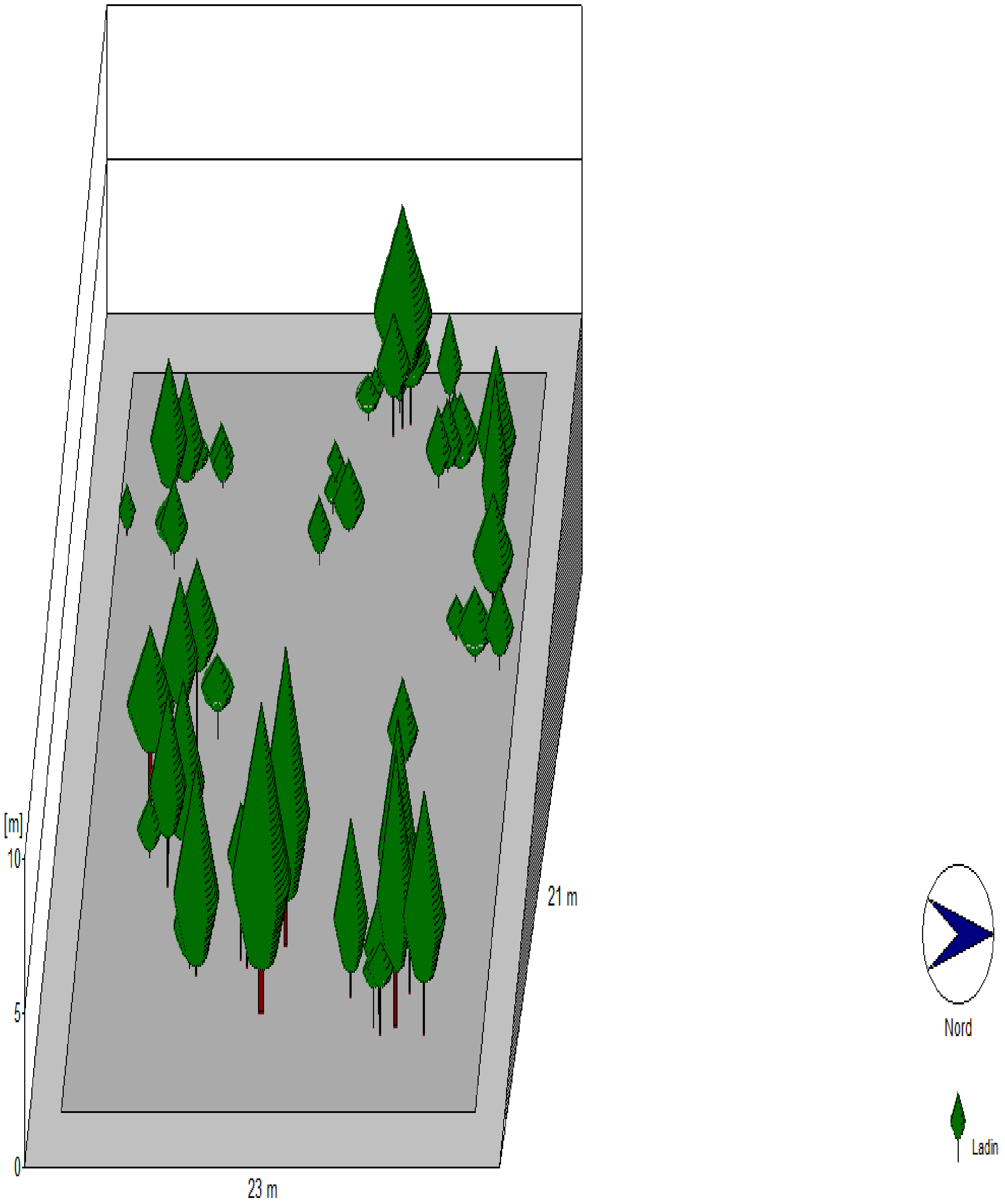
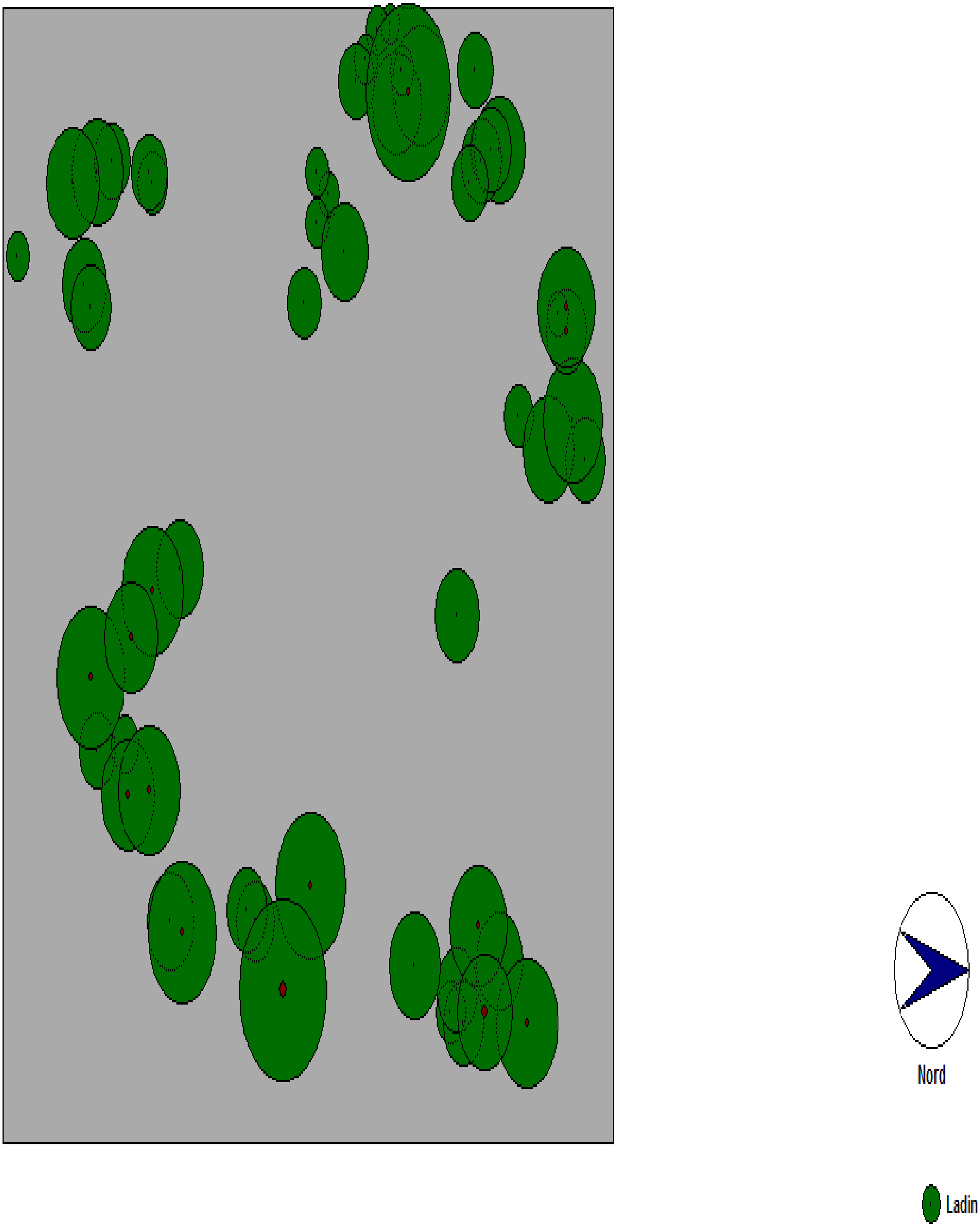


Figure 3. Tree line stand structure.



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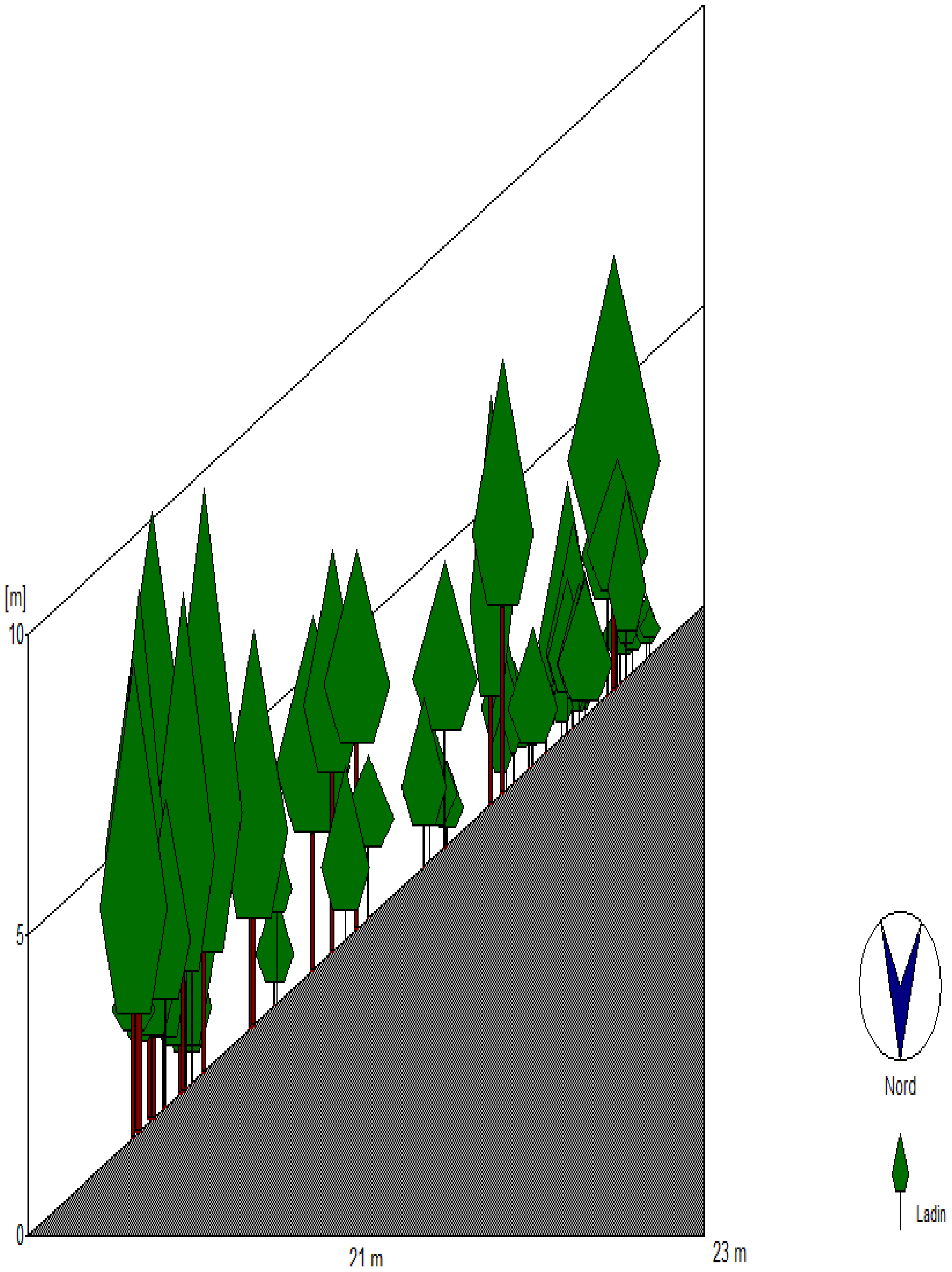

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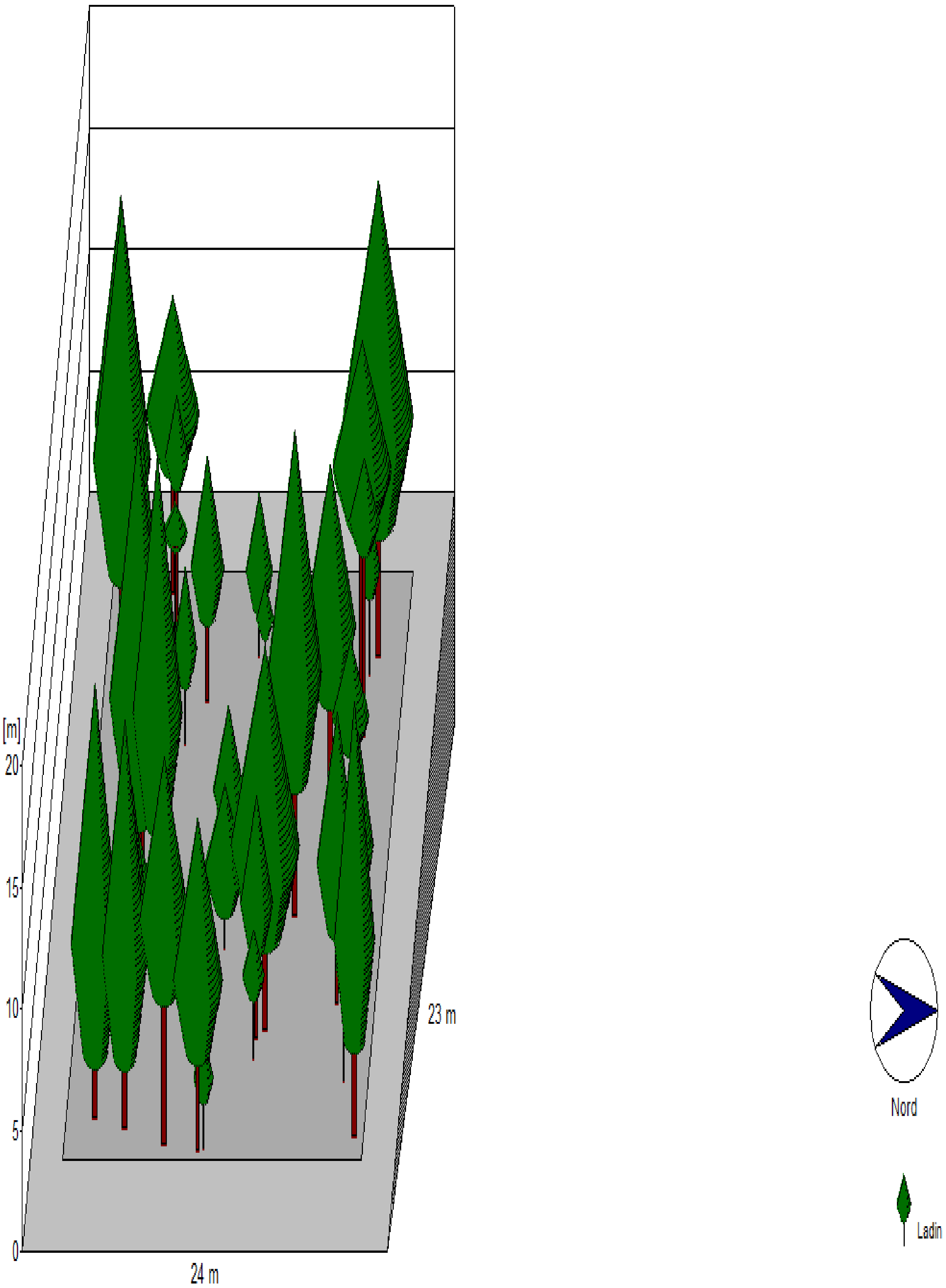
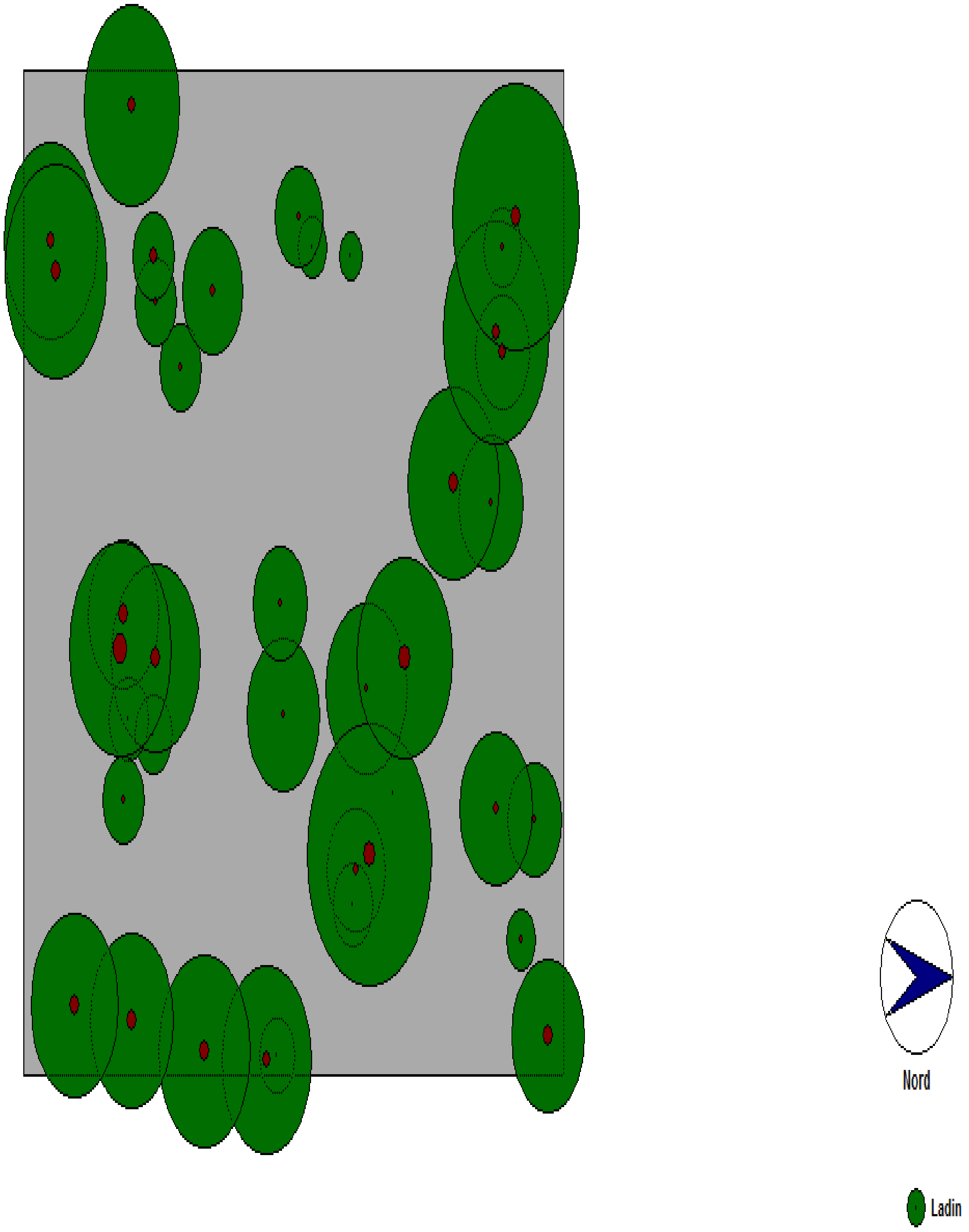


Figure 4. Timberline stand structure.



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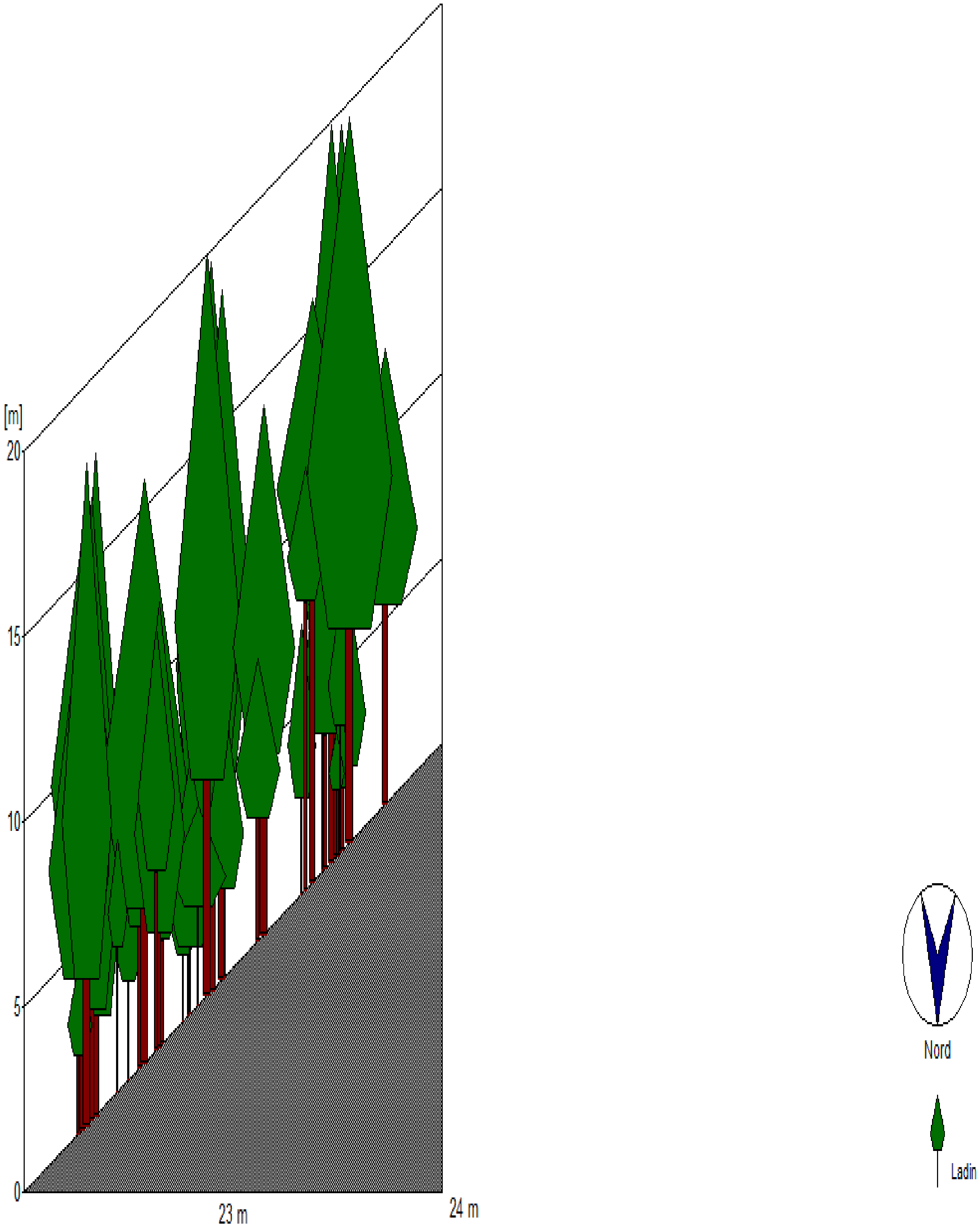

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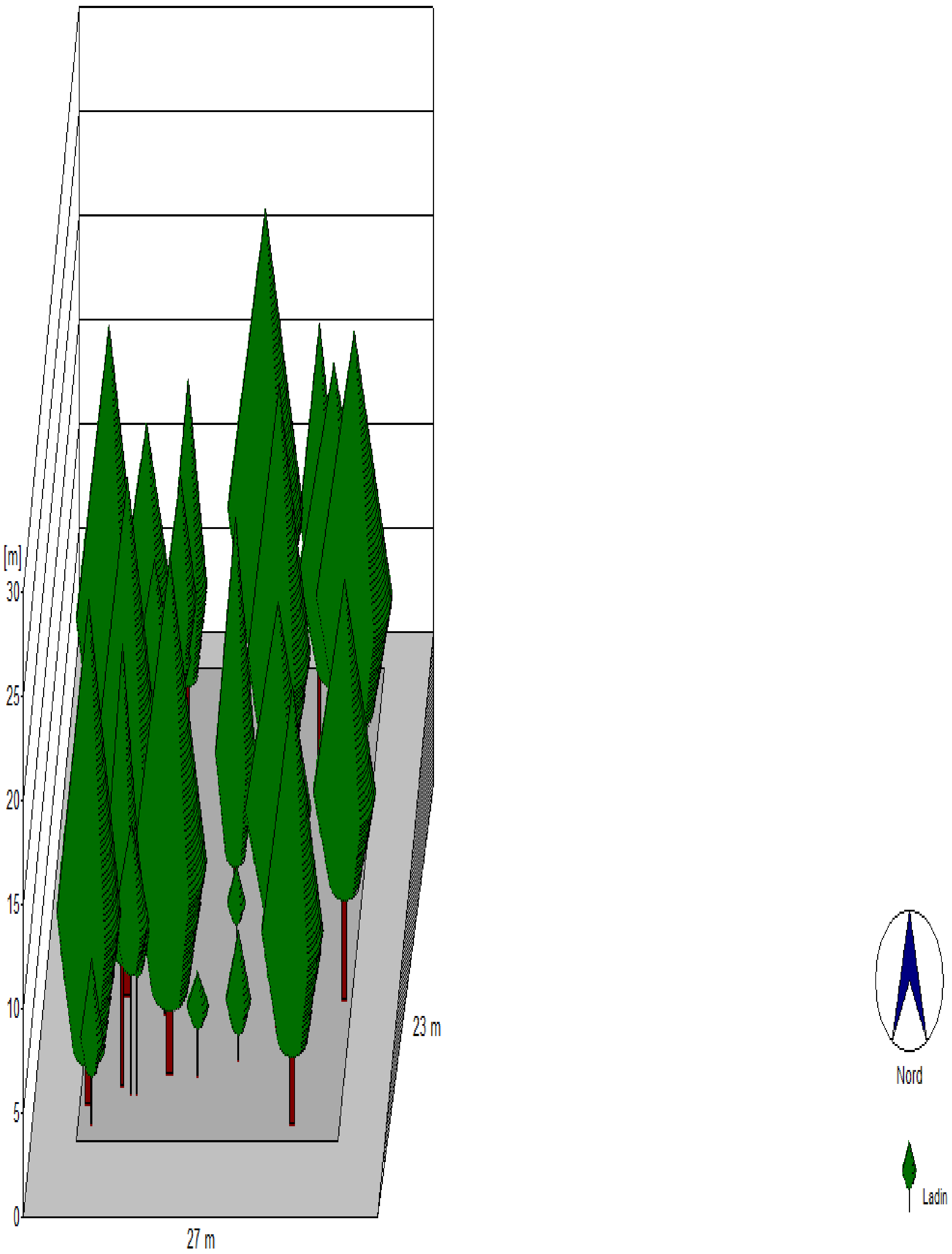
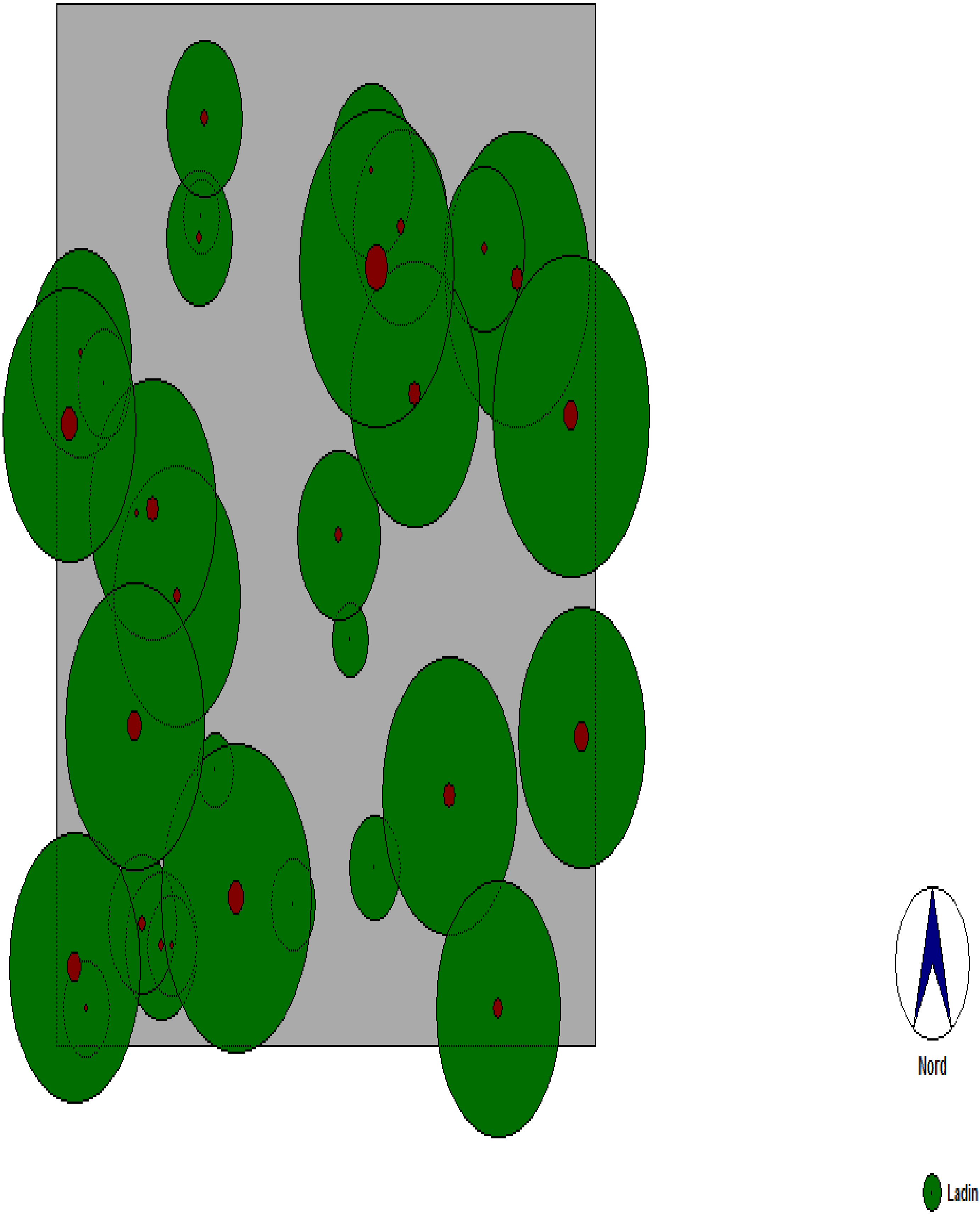


Figure 5. Regular Forest stand structure.



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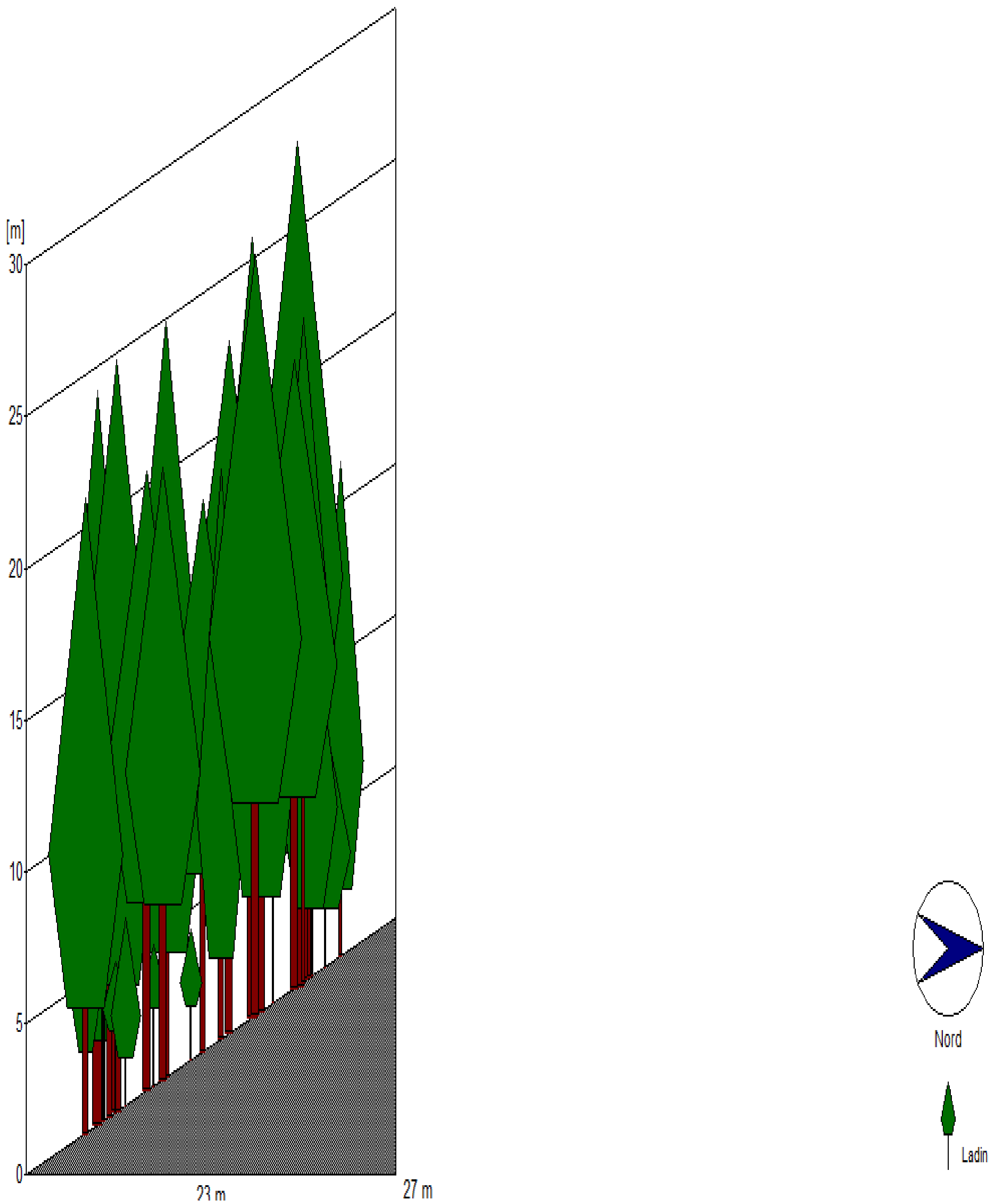

Figure 5. Cont'd.

Table 2. Correlation data sheet between soil loss amounts and the other variables.

Variables		Slope	Depth	Organıc	Permea	Surface	Sand	Loam	Clay	Canopy	Soıl loss
Slope (%)	Pearson correlation	1	-0.853(**)	0.128	-0.013	-0.213	0.023	0.136	-0.109	0.246	0.726(**)
	Sig. (2-tailed)	0.	0.000	0.402	0.932	0.160	0.882	0.374	0.476	0.103	0.000
	N	45	45	45	45	45	45	45	45	45	45
Depth (cm)	Pearson correlation	-0.853(**)	1	-0.030	0.058	0.250	-0.079	-0.153	0.190	-0.520(**)	-0.444(**)
	Sig. (2-tailed)	0.000	0.	0.845	0.706	0.098	0.604	0.317	0.210	0.000	0.002
	N	45	45	45	45	45	45	45	45	45	45
Organıc (%)	Pearson correlation	0.128	-0.030	1	-0.500(**)	0.552(**)	0.181	0.316(*)	-0.440(**)	-0.609(**)	0.562(**)
	Sig. (2-tailed)	0.402	0.845	0.	0.000	0.000	0.235	0.034	0.002	0.000	0.000
	N	45	45	45	45	45	45	45	45	45	45
Permeabılıty (cm/hr)	Pearson correlation	-0.013	0.058	-0.500(**)	1	-0.448(**)	0.108	-0.908(**)	0.706(**)	0.215	-0.276
	Sig. (2-tailed)	0.932	0.706	0.000	0.	0.002	0.482	0.000	0.000	0.156	0.067
	N	45	45	45	45	45	45	45	45	45	45
Surface stonıness (%)	Pearson correlation	-0.213	0.250	0.552(**)	-0.448(**)	1	-0.012	0.298(*)	-0.281	-0.780(**)	0.432(**)
	Sig. (2-tailed)	0.160	0.098	0.000	0.002	0.	0.935	0.047	0.061	0.000	0.003
	N	45	45	45	45	45	45	45	45	45	45
Sand (%)	Pearson correlation	0.023	-0.079	0.181	0.108	-0.012	1	-0.334(*)	-0.537(**)	-0.011	0.053
	Sig. (2-tailed)	0.882	0.604	0.235	0.482	0.935	0.	0.025	0.000	0.941	0.730
	N	45	45	45	45	45	45	45	45	45	45
Loam (%)	Pearson correlation	0.136	-0.153	0.316(*)	-0.908(**)	0.298(*)	-0.334(*)	1	-0.603(**)	-0.065	0.267
	Sig. (2-tailed)	0.374	0.317	0.034	0.000	0.047	0.025	0.	0.000	0.672	0.076
	N	45	45	45	45	45	45	45	45	45	45
Clay (%)	Pearson correlation	-0.109	0.190	-0.440(**)	0.706(**)	-0.281	-0.537(**)	-0.603(**)	1	0.060	-0.254
	Sig. (2-tailed)	0.476	0.210	0.002	0.000	0.061	0.000	0.000	0.	0.696	0.092
	N	45	45	45	45	45	45	45	45	45	45
Canopy closure (%)	Pearson correlation	0.246	-0.520(**)	-0.609(**)	0.215	-0.780(**)	-0.011	-0.065	0.060	1	-0.456(**)
	Sig. (2-tailed)	0.103	0.000	0.000	0.156	0.000	0.941	0.672	0.696	0.	0.002
	N	45	45	45	45	45	45	45	45	45	45
Soıl loss (ton/ha/year)	Pearson correlation	0.726(**)	-0.444(**)	0.562(**)	-0.276	0.432(**)	0.053	0.267	-0.254	-0.456(**)	1
	Sig. (2-tailed)	0.000	0.002	0.000	0.067	0.003	0.730	0.076	0.092	0.002	0.
	N	45	45	45	45	45	45	45	45	45	45

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

(in the control plots), 30% (in tree line), 70% (in timberline) and 90% (in regular forest) (Table 2).

Organic matter contents of the sample plots soils are in average 4.22% where the minimum amount 2.84% and the maximum amount 5.51% is. Organic matter content of the top soils have a very positive effect on the physical, chemical, hydrological etc. soil characteristics and, absorbs noninfiltrated surface water and reduces in this way the soil loss (Singer and Bissonnais, 1998). The minimum and maximum hydraulic conductivity (permeability) amounts of the top soils varies from 0.19 (cm/hr) to 0.94 (cm/hr) with an average of 0.51 (cm/hr). Surface stoniness (soil fractions bigger than 2 mm diameter) contributes to increase the infiltration ratio of the soils, decrease the surface flow and thus reduces the soil loss (Descroix et al., 2001). The average surface stoniness in the study sites are about 16% which could be considered as a low value. The minimum and maximum surface stoniness amounts vary from 10 to 30% in the measurement plots. It is known that surface stoniness increases the infiltration value and reduces therunoff and soil loss. The study results show that the predicted soil loss amounts in the sample plots are quite high. Average soil loss amount is about 29.79 (ton/ha/year). The minimum soil loss amount is 4.48 (ton/ha/year) (in regular forest stands) and the maximum 73.60 (ton/ha/year) (in control (zero) plots). Average Soil depth in the study area is about 26 cm and this value could be considered as very low. Soil loss tolerance concept is strongly related with the soil depth. According to the average soil depth in the sample plots it is clear that the soil loss tolerance in the study area is the class 1 (0 to 1 ton/ha/year). According to obtained findings from the results, the average soil loss tolerance class is about 6 (more than 5 ton/ha/year) and, this indicates that soil loss tolerance was exceeded in almost all of the sample plots. The study area is under considerable soil erosion risk due to fact that the soil erosion amounts increase with increasing the precipitation and the slope degree. The low canopy closure, especially in the tree zone is one of the main reasons for the high soil loss amounts. Overgrazing and uncontrolled grazing conditions are the main reason for the very high soil loss risk in the pasturelands.

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