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1 **Interactions between canopy cover density and regeneration cores of older**
2 **saplings in Scots pine (*Pinus sylvestris* L.) stands**

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6
7 **Abstract**

8 **Aim of study:** This paper provides an analysis of growth and survival of twenty-year-old Scots
9 pine saplings in relation to canopy cover density (CCD) gradients, from dense (D-CCD), sparse
10 (S-CCD), and gap (G-CCD) situations.

11 **Area of study:** Aladag (Bolu) in northern Turkey.

12 **Material and methods:** Sparse canopy cover density (S-CCD), dense canopy cover density
13 (D-CCD) and gap canopy (G-CCD) were chosen within ten different strip sample plots (10 ×
14 50 m) with sapling regeneration cores. Those regeneration cores were divided into two
15 portions (individuals at the edge and middle of the regeneration cores) and from each portion
16 three individuals were obtained from a sample. The growth relationships of individual
17 saplings were calculated with stem analyses. Honowski Light Factor (HLF) (ratio of Terminal
18 sprout length (T) to Lateral sprout length (L)) was used to present growth potential measure of
19 seedlings.

20 **Main results:** The largest sapling regeneration cores were found in the G-CCD followed by S-
21 CCD, and finally D-CCD, all tested for significance with Kruskal-Wallis Test. Compared with
22 saplings in the middle of regeneration cores (crop saplings), those at the edge were always
23 reduced in terms of mean height. Significant difference was only found between the 'Main Crop'
24 and the 'Edge 1' of the regeneration cores for G-CCD suggesting that sapling regeneration cores
25 are more typical under G-CCD conditions. HLF ratios were greater than 1 with high growth
26 potentials for both CCD gradients (G-CCD and S-CCD) and there were no significant variations
27 between G-CCD and S-CCD for main crop and edges. The thinning after 12-14 years increased
28 sapling growth. However, under D-CCD, growth had virtually ceased.

29 **Research highlights:** Naturally occurring Scots pine saplings are suppressed by a dense canopy.
30 However, they are tolerant of shade to the extent that they can survive over relatively long time-
31 periods (10-12 years) and can exploit subsequent opportunities should a canopy gap occur.

32 **Keywords:** Gap regeneration, sapling growth, light regime, canopy cover density, irregular
33 silviculture

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9

1 Introduction

2 In forest understoreys, tree seedling survival and growth are determined mainly by light,
3 water and nutrient availability. Interspecific competition and herbivory may result from
4 variation in canopy cover density (CCD) in the overstorey (Löf *et al.*, 2007), and this may
5 also affect growth and survival. Although forest ecologists and silviculturalists have
6 emphasized the importance of creating canopy gaps (G-CCD) to generate spatial variation in
7 order to promote tree regeneration, the effects of G-CCD on seedling recruitment may be
8 offset by the development of dense forest understoreys. Light is a resource that limits tree
9 seedling recruitment in many forest understoreys and G-CCD can raise light levels leading to
10 increased seedling recruitment. However, many forests support dense understoreys that may
11 compete with tree seedlings for resources such as light. This limits seedling recruitment even
12 in gap conditions (G-CCD), and reduces the effectiveness of gaps in promoting seedling
13 recruitment (Beckage *et al.*, 2005; Ruuska *et al.*, 2008). Understanding the behaviour of the
14 seedlings of different tree species in relation to canopy shade is therefore important.

15 Studies of gap dynamics have contributed significantly to an understanding of the role
16 of small-scale disturbance in forest ecosystems. Yet these have hardly been used by foresters
17 for predicting tree responses to partial cutting (Coates, 2000). It is clear that interactions
18 between heterogeneity in the forest overstorey (*e.g.* canopy gap or closed canopy) and
19 understorey micro-environments may affect seedling performance. The presence of gap-
20 understorey interactions may influence both seedling competitive environments and the nature
21 of resource limitation on seedling growth and survival. For example, understorey herbs, ferns,
22 and shrubs may increase in response to high light availability in gaps (G-CCD) and so may
23 compete with tree seedlings. Conversely, micro-environments characterized by high mineral
24 nutrient availability or soil moisture may have disproportionate effects on seedling
25 performance in high light environments (G-CCD), and little effect in light-limited
26 environments (*e.g.* dense canopy (D-CCD)) (Beckage & Clark, 2003).

27 Scots pine (*Pinus sylvestris* L.) is the most widely distributed pine species and one of
28 the most important timber species in Eurasia. It has high commercial and ecological values
29 (Oleksyn *et al.*, 2002; Stanners & Bourdeau, 1995; Figure 1). Natural Scots pine forests have
30 a wide distribution in Turkey covering nearly 760,000 ha (Figure 1). There is an abundant
31 literature on the factors affecting natural regeneration in Scots pine forests. Scots pine seed
32 trees have an effect on the structure of pine seedlings (*i.e.* morphological characteristics), their
33 spatial pattern, and their size distribution. Both height and seedling density decrease close to

1 the parent trees (Siipiletho, 2006). Competition from the mother trees inhibits development of
2 saplings in close proximity (Montes & Canellas, 2007). However, the growth of naturally
3 occurring saplings in response to variations in CCD of Scots pine stands are poorly studied in
4 the southern zone of its distribution area (Beckage *et al.*, 2005; Coates, 2000; Löf *et al.*, 2007;
5 Pukkale *et al.*, 1993; Cameron & Ives, 1997; Andrzejczyk, 2007). Studies on regeneration and
6 advance growth have shown that the effects of the long-term retention of seed trees has a
7 strong negative impact on the development of young Scots pine stands, especially on
8 relatively infertile sites in northern areas of its natural distribution (Ruuska *et al.*, 2008). The
9 research reported in this paper was designed to address four questions:

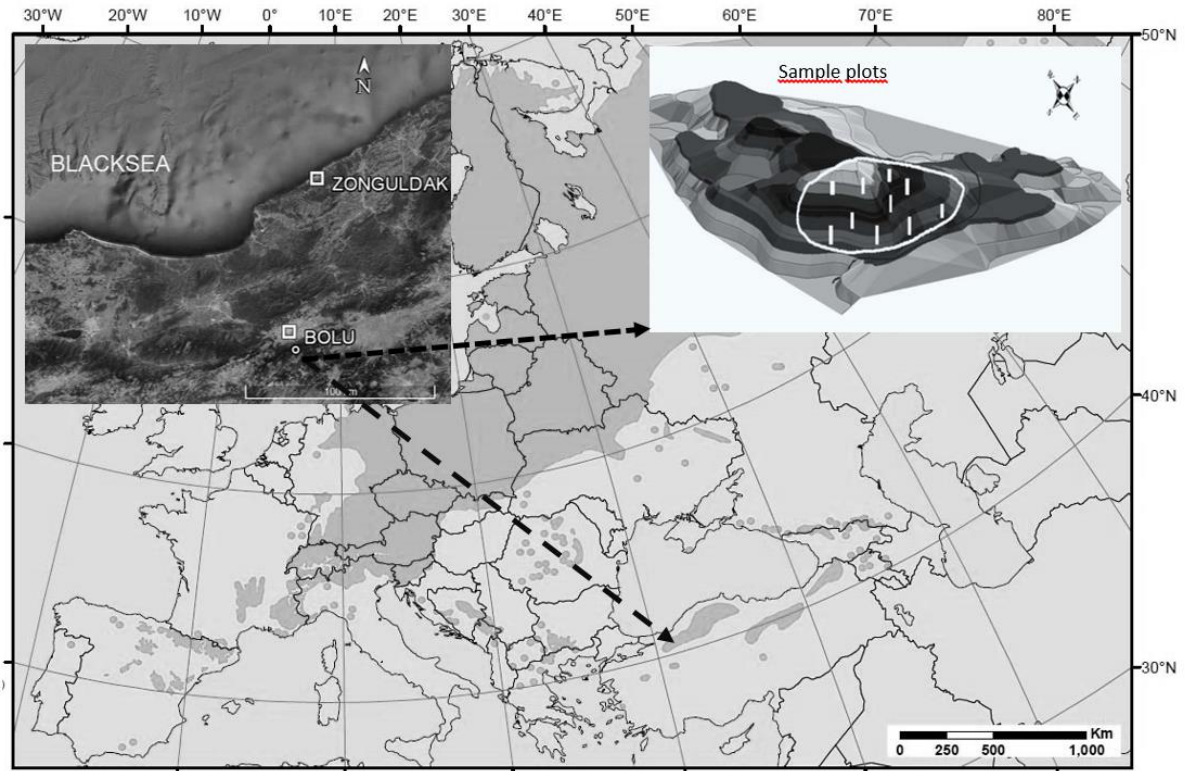
- 10 (1) Are different CCD gradients good predictors of regeneration cores of Scots pine
11 saplings?
- 12 (2) How do CCD gradients affect the growth of Scots pine saplings?
- 13 (3) How was growth affected by the position of the sapling within the regeneration core
14 in Scots pine stands?
- 15 (4) Do these responses vary with the shade tolerance rankings of Scots pine saplings?

16 **Materials and Methods**

17 **Site description**

18 Much of current knowledge of tree species in relation to canopy development is based
19 on studies of trees occurring in naturally regenerated forest communities (Ellenberg, 1996).
20 This research was therefore undertaken in naturally regenerated Scots pine forest in Aladag
21 (Bolu) in northern Turkey (Figure 1: latitude between 40°30' and 40°42' N, longitude between
22 31°39' and 31°52' E) which is characterised by a high degree of naturalness (Colak *et al.*,
23 2003). The research area is typically covered by 120–140 years–old–stands of Scots pine
24 located at 1.380–1.420 m altitude. Silviculture in the area is based on natural regeneration
25 following a shelterwood system and silvicultural interventions are not frequent at early stages
26 of development (Coban, 2007).

1



2

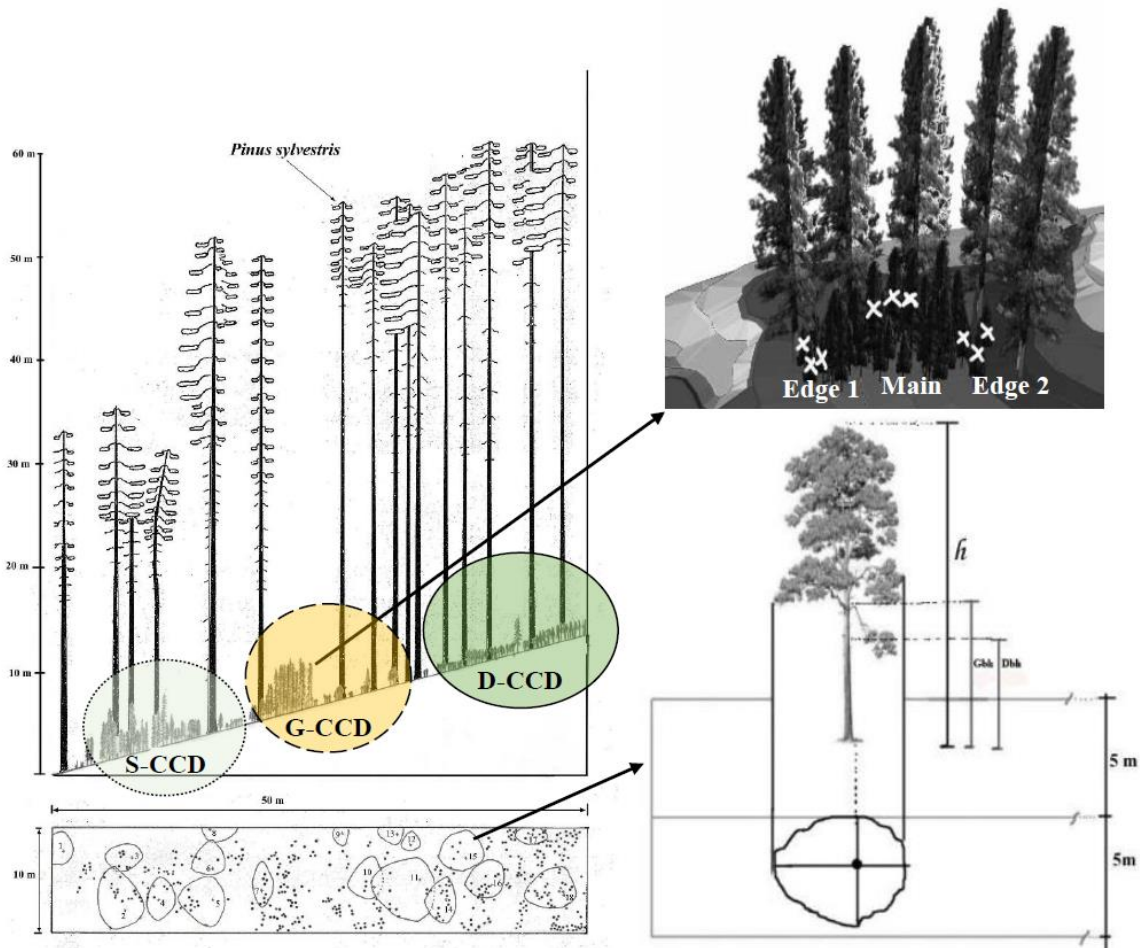
3 **Figure 1.** Natural distribution range of *Pinus sylvestris* L. (EUFORGEN, 2009) and location
4 of sample plots.

5 The climate shows Euxinian influences, with mean annual precipitation of 883 mm
6 and mean annual temperature of 5.7 °C, cool winters, and sub-humid summers without
7 significant droughts (Serin, 1998). The Euxinian region covers the whole of the Euro-
8 Siberian phyto-geographical region and is effectively referred to as the Euxinian province.
9 This is an area that covers much of Georgia and the Caucasus, the Istranca Mountains of
10 European Turkey, and south-east Bulgaria (Davis, 1965–1988). The soils are mainly brown
11 podzols (Tolunay, 1997), and the site quality class of for the research area is I (I–V: “I” shows
12 the high and “V” the low site quality) (Forest Management Plan, 2005–2014; Tolunay, 1997).

13 **Selection of Sample Plots**

14 By the end of 1987, shelterwood cutting areas in the 120-year-old Scots pine stands
15 were at a uniform level of shade (dense: D-CCD) resulting from regular thinning and felling.
16 There were 2- to 5-year-old Scots pine seedlings here. After 10 years, in the second half of
17 1997, the CCD in these stands was assessed and placed into three broad gradients: (1) Dense
18 (D-CCD), (2) Sparse (S-CCD), and (3) Gap (G-CCD) overstorey conditions (Figure 2). In

1 autumn 2007, samples were separated depending on typical sapling regeneration cores under
 2 different CCD within these stands. Sampling in the stands was conducted with a simple
 3 random sampling method. Measurements were taken for 10 rectangular (10×50 m) sample
 4 plots with different CCD gradients and chosen from natural regeneration cores of Scots pine
 5 saplings (Figure 2).



6
 7 **Figure 2.** The CCD gradient models of Scots pine stands with three gradients *i.e.* dense (D-
 8 CCD: Canopy cover is 55%), sparse (S-CCD: Canopy cover is 43%) and gap (G-CCD: gap
 9 size is 87 m^2) (Coban, 2007).

10 **Gradients and measurements of CCD**

11 CCD refers to the proportion of the forest floor covered by the vertical projection of the
 12 tree crowns (Figure 2). This is analogous to the use of the term ‘cover’ by ecologists and
 13 silviculturalists to refer to the proportion of the plan ground area occupied by the above ground
 14 parts of plants. Measures of CCD assess the presence or absence of canopy vertically above a
 15 sample of points across an area of forest. Tree height does not affect CCD, since only the

1 vertical projection of the crown is assessed. CCD is a measure reflecting the dominance of a site
2 by trees or by particular species of tree (Jennings *et al.*, 1999). The Scots pine stands in 1997
3 were allocated into 1 of 3 different CCDs (G–CCD, D–CCD and S–CCD) distinguished by
4 CCD gradients in the shelterwood. These three CCD gradients (Ewald, 2007) are:

5 (1) Dense (D–CCD): CCD over 50% (50–80%; Percent canopy cover; Figure 2).

6 (2) Sparse (S–CCD): CCD up to 50% (20–50%; Percent canopy cover; Figure 2).

7 (3) Canopy gap (G–CCD): no cover; the gap size 25–100 m² (All sample plots areas in the
8 canopy gaps were between 25.09 and 95.42 m², Figure 2).

9 According to the definition by Jennings *et al.* (1999), if CCD is to be measured
10 correctly, the measurements should be made in exact vertical direction (Korhonen *et al.*,
11 2006). The following is the equation (Eq. 1) used to calculate the percentage of tree CCD
12 (CCD–D and CCD–S) in the stand projection (Klumpp *et al.*, 2002; Globe, 2005; Jennings *et*
13 *al.*, 1999; Figure 2):

$$14 \quad \text{CCD (\%)} = \frac{\text{VPTC}}{\text{MA}} 100 \quad (\text{Eq.1})$$

15 VPTC: Vertical projection of the tree crowns (m²)

16 MA: Forest floor cover (m²) of measured area

17 G–CCD and S–CCD area calculated as a ration of the measured transect part by gap area
18 (Figure 2).

19 **Field procedures and calculations/equations**

20 The standard alternative to CCD for the regeneration cores is by means of ‘rectangular
21 sample plots’ (10–50 m) and shows longitudinal (profile) and vertical projection of the stand
22 (Aksoy, 1978). For different CCDs, transects are taken from the strip plots. In this study ten
23 transects from each S–CCD, D–CCD and G–CCD were chosen within ten different strip
24 sample plots with sapling regeneration cores (Figure 3).



1

2 **Figure 3.** Longitudinal (profile) and vertical stand projection of all sample plots with different CCD
 3 gradients (D–CCD: Dense; S–CCD: Sparse; G–CCD: Gap) (Stand profiles from Coban, 2007).

1 The ages of individual saplings were assessed with stem sections cut in order to
2 estimate the age by ring counting (González–Martínez & Bravo, 2001). The saplings were
3 scored considering the position of individuals in regeneration cores: (1) “Main crop sapling”
4 the highest score in both variables (dominant and healthy) and (2) “Edge sapling” with the
5 lowest score in both variables (dominant and healthy). The main crop saplings which were
6 measured were located in the middle of the typical natural sapling regeneration cores (Figure
7 2). The term “main crop sapling”, that is the trees selected to become a component of a future
8 commercial harvest, refers to those saplings with the highest score in both variables
9 (dominant and healthy) (Gonzales–Martinez & Bravo, 2001). Those individuals at the edge of
10 the natural sapling regeneration cores were selected as “Edge saplings” (Figure 2; G). The
11 individuals were distinguished for stem–analysis as follows: Each core divided into three
12 portions (Edge 1, Edge 2 and Main Crop). From each of the edges three individuals were
13 taken (totalling six for edges) and three individuals were taken from the middle (Figure 2).

14

15 **Analysis of saplings**

16 **Sapling–stem analysis**

17 Sample saplings were cut down to ground level and stem cuts were taken at 1 m intervals for
18 stem analysis (Atici, 2003, 1998; Kalipsiz, 1981). For the sapling–stem analysis of the
19 increment and growth data of individual trees the “Computer Supported Statistical Analysis
20 Program (GOVAN)” was used (Atici, 2003). GOVAN is computer software, which provides
21 an opportunity to make computer–based stem analyses to determine the growth relationships
22 of individual trees. Two different forms of graphs of absolute and relative age–height and
23 stem models were drawn with this program. Correlation and regression analyses of the
24 statistical model used for drawing the age–height graph were carried out (Atici, 2003).

25 **Honowski light factor (HLF ratio)**

26 The ratio of Terminal sprout length (T) to Lateral sprout length (L) was presented by
27 Fabjanowski *et al.* (1974) as the growth potential measure of seedlings and saplings under the
28 canopy cover in coniferous species. The factor is referred to as the HLF ratio (Eq. 2).
29 According to this value, the growth condition can be defined as ‘well’ or ‘weak’ (after
30 Fabjanowski *et al.* 1974 from Schütz 2001). The individuals for the HLF ratio were selected
31 from Edge 1, Edge 2 and Main Crop portions and from each part a mean set of data was
32 obtained from a sample of three individuals.

1
$$HLF = \frac{T}{L} \quad (\text{Eq. 2; Schütz 2001})$$

2 Where: T: Terminal sprout length (cm); L: Lateral sprout length (cm)

3 HLF ratio: 1.0 > growth well; 1.0–0.5 growth under the good; 0.5–0.25 growth not good; 0.25
4 < growth very low.

5 **Data analysis**

6 The following equation (Eq. 3) was used to calculate 95% confidence intervals of
7 populations of all measured data (Atici *et al.*, 2008; Kalipsiz, 1981; Sachs, 1972):

8
$$\mu = \bar{x} \pm t SE_{\bar{x}} \quad (\text{Eq. 3})$$

9 Where \bar{x} is arithmetic mean; $SE_{\bar{x}}$ is std. error; t is Student's t coefficient ($t_{1-\alpha/2; n-1}$); for 9
10 degrees of freedom=2.262, n is 10 number of samples.

11 Statistical evaluation including nonparametric test (Kruskal–Wallis H Test), t–tests,
12 one–way variance analyses (ANOVA), and Student–Newman–Keuls (SNK) test were applied
13 to the data collected using SPSS 5.01 software for Windows.

14 **Results**

15 **The effect of CCD gradients on formation of regeneration cores**

16 The results show that different CCD gradients result in major differences for sapling
17 regeneration cores. The maximal sapling regeneration cores were found in the G–CCD,
18 followed by S–CCD and finally D–CCD (Table 1). These differences were shown to be
19 statistically significant by the Kruskal–Wallis H test. This test was applied to the difference in
20 the CCD gradients of regeneration cores, and as a result two typical separate groups (1: D–
21 CCD; 2: S–CCD and G–CCD) were determined ($P < 0.001$, Table 1). This situation was
22 consistent in all sample plots with longitudinal (profile) and vertical projection of stands
23 (Figure 3). Accordingly sapling regeneration cores do not occur in D–CCD.

24

25

26

27

1 **Table 1.** The effect of CCD gradients on formation of sapling regeneration cores. The data
 2 and statistical analysis from 30 sapling regeneration cores with different CCD gradients. This
 3 was confirmed by Kruskal–Wallis H test (Level: 0: saplings without regeneration cores; 1:
 4 saplings with sapling regeneration cores)

5

Number of sample plots	Frequency distribution of natural sapling under different CCD gradients					
	Dense (D-CCD)		Sparse (S-CCD)		Canopy gap (G-CCD)	
	Position in sample plots (Figure 3)	Level	Position in sample plots (Figure 3)	Level	Position in sample plots (Figure 3)	Level
1	D1	0	S1	1	G1	1
2			S2	1	G2	1
3	D2	0			G3	1
4	D3	0	S3	1	G4	1
			S4	1		
5	D4	0			G5	1
					G6	1
6	D5	0	S5	0	G7	1
			S6	1		
			S7	1		
7	D6	0	S8	1		
	D7	1	S9	1		
	D8	0				
8	D9	0			G8	1
9	D10	0	S10	1	G9	1
10					G10	1
	Frequency distribution					
	D-CCD		S-CCD		G-CCD	
Level	0	1	0	1	0	1
Total	9	1	1	9	0	10
Statistical analysis (Kruskal-Wallis H Test)	Descriptive Statistics					
	N		Mean		Std. Deviation	
	30		.6667		.47946	
	Test Statistics					
	Chi-Square			21.170		
	df			2		
Asymp. Sig.			p<0.001			

6

7 **The properties of individuals in regeneration cores**

8 Compared with saplings in the middle of a regeneration core or cluster, those on the
 9 edge were always shorter with μ value (Table 2). These μ value differences were found for the
 10 S-CCD (Edge 1: 1.86±0.57m; Main Crop: 2.27±0.51m; Edge 2: 1.92±0.37m) and for the G-
 11 CCD (Edge 1: 1.79±0.49m; Main Crop: 2.83±0.89m; Edge 2: 2.07±0.43m). Because of
 12 height differentiation between edges and main crop the regeneration core form was
 13 determined (Table 2; Figure 3). The distribution of saplings in different height classes in the
 14 sapling regeneration cores revealed they were shorter beneath the canopy than beyond the
 15 canopy (Figure 3). These were statistically significant between the Main Crop and Edge 1 of
 16 the regeneration core for G-CCD ($t=-2.317$; $\alpha =0.036$), but not significant for S-CCD ($t=-$

1 1.213; P=0.24) (Table 2). This suggests that sapling regeneration cores were more typical
 2 under G-CCD conditions than under S-CCD.

3 **Table 2.** The effect of CCD gradients on height of saplings in the sapling regeneration core.
 4 Data and statistical analysis from twenty regeneration cores (n= 10, v= 9, t= 2.262), μ (Eq.3).
 5 This was confirmed by Student's t-test ($\alpha= 0.05$): 95% confidence interval for arithmetic
 6 mean.

Number of sample plots	Height (m)							
	Sparse (S-CCD)				Canopy gap (G-CCD)			
	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2
1	S1	3.1	2.8	1.9	G1	2.0	3.8	2.1
2	S2	2.4	3.0	1.8	G2	2.0	4.6	1.8
3	S3	2.2	2.8	2.1	G3	3.6	5.2	3.7
4	S4	1.6	2.5	1.7	G4	1.6	2.5	1.7
5	S5	1.4	2.4	2.0	G5	1.5	2.1	1.8
6	S6	0.9	0.9	2.2	G6	1.7	1.9	2.0
7	S7	0.8	1.4	0.7	G7	1.4	2.4	2.2
8	S8	2.2	2.1	1.9	G8	1.1	2.1	1.6
9	S9	2.8	3.0	2.7	G9	1.5	1.9	1.9
10	S10	1.2	1.8	2.2	G10	1.5	1.8	1.9
\bar{x}	-	1.86	2.27	1.92	-	1.79	2.83	2.07
s^2	-	0.63	0.51	0.26	-	0.48	1.54	0.36
s	-	0.80	0.71	0.51	-	0.69	1.24	0.60
$SE_{\bar{x}}$	-	0.25	0.23	0.16	-	0.22	0.39	0.19
n	-	10	10	10	-	10	10	10
μ	-	\pm 0.57	\pm 0.51	\pm 0.37	-	\pm 0.49	\pm 0.89	\pm 0.43

Independent Samples Test										
Levene's Test for Equality of Variances					t-test for Equality of Means					
	F	Sig.	t	df	Sig. (2-tailed)	Mean Dif.	Std. Error Dif.	95% Confidence Interval of the Difference		
								Lower	Upper	
S-CCD	Edge 1 and main crop	.415	.527	-1.213	18	.241 ^{NS}	-.41000	.33805	-1.12022	.30022
	Edge 2 and main crop	2.273	.149	-1.261	18	.224 ^{NS}	-.35000	.27763	-.93328	.23328
G-CCD	Edge 1 and main crop	5.242	.034	-2.317	14.089	.036 [*]	-1.04000	.44883	-2.00206	-.07794
	Edge 2 and main crop	7.409	.014	-1.744	12.996	.105 ^{NS}	-.76000	.43566	-1.70122	.18122

7

8

1 One-way Variance Analyses (ANOVA) were carried out to test the differences in
 2 sapling age under the G-CCD and S-CCD between Main Crop saplings and both Edge
 3 saplings in the regeneration cores. There was no significant difference (G-CCD: $F= 1.891$; $p=$
 4 0.17 , S-CCD; $F= 1.122$; $p= 0.340$) for sapling age (Table 3).

5 **Table 3.** The age distributions in the sapling regeneration cores. Data and statistical analysis
 6 from twenty regeneration cores ($n = 10$, $v = 9$, $t= 2.262$), μ (Eq. 3). This was confirmed by
 7 Student's t-test ($\alpha= 0.05$): Arithmetic mean of 95% confidence interval of total population

Number of sample plots	Age (year)									
	Sparse (S-CCD)				Canopy gap (G-CCD)					
	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2		
1	S1	22	22	18	G1	18	21	18		
2	S2	16	20	13	G2	15	21	16		
3	S3	21	22	19	G3	23	32	19		
4	S4	19	22	19	G4	19	22	20		
5	S5	15	17	18	G5	17	17	17		
6	S6	19	16	18	G6	16	19	20		
7	S7	12	16	16	G7	15	19	20		
8	S8	19	20	19	G8	14	16	16		
9	S9	20	22	22	G9	20	19	16		
10	S10	20	21	20	G10	18	16	19		
\bar{x}	-	18.30	19.80	18.20	-	17.50	20.20	18.10		
s^2	-	9.34	6.40	5.73	-	7.39	21.51	2.99		
s	-	3.06	2.53	2.39	-	2.72	4.64	1.73		
$SE_{\bar{x}}$	-	0.97	0.80	0.76	-	0.86	1.47	0.55		
n	-	10	10	10	-	10	10	10		
μ	-	18.30 ± 2.19	19.80 ± 1.81	18.20 ± 1.71	-	17.50 ± 1.94	20.20 ± 3.32	18.10 ± 1.24		
Independent Samples Test										
Levene's Test for Equality of Variances					t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Dif.	Std. Error Dif.	95% Confidence Interval of the Difference	
S-CCD	Edge 1 and main crop	.194	.665	-1.195	18	.247 ^{NS}	-1.500	1.2547	-4.1361	1.1361
	Edge 2 and main crop	.514	.483	-1.453	18	.164 ^{NS}	-1.600	1.101	-3.914	.71420
G-CCD	Edge 1 and main crop	.643	.433	-1.588	18	.130 ^{NS}	-2.700	1.700	-6.271	0.871
	Edge 2 and main crop	2.022	.272	1.342	18	.196 ^{NS}	2.100	1.565	-1.188	5.388

1 **Honowski light factor (HLF) in the regeneration cores**

2 Table 4 shows that for both CCD gradients (G-CCD and S-CCD), as Edge 1, Edge 2
 3 and, Main Crop, the HLF ratios were found to exceed 1 but the different groups varied in their
 4 values. One-way variance analyses were carried out to test the differences in the G-CCD and
 5 S-CCD between Main Crop saplings and both Edge saplings in the regeneration cores. As a
 6 result, the assessment established a significant difference for G-CCD (F=4.521; P=0.02) but
 7 not for S-CCD (F=1.165; p=0.327). Student-Newman-Keuls (SNK) test was applied to the
 8 difference in the G-CCD and two typical separate groups were determined 1) Main Crop
 9 saplings and 2) Both Edge samples (Table 4). There were no significant variations between
 10 the G-CCD and S-CCD for HLF ratios for each zone in the regeneration core (Main Crop
 11 saplings: t=-1.458; P=0.162, Edge 1; t=0.243; P=0.811 and Edge 2: t=-0.092; p=0.928)
 12 (Tables 4 and 5).

13 **Table 4.** Statistical analysis of difference for HLF ratios between Main Crop saplings and
 14 both Edge saplings in the regeneration core with different CCD gradients. This was confirmed
 15 by one-way variance analyses (ANOVA) and Student-Newman-Keuls (SNK)

Number of sample plots	HLF ratios							
	Sparse (S-CCD)				Canopy gap (G-CCD)			
	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2
1	S1	1.4	1.5	1.3	G1	1.4	1.5	1.5
2	S2	1.3	1.5	1.3	G2	1.1	1.4	1.3
3	S3	1.2	1.3	1.4	G3	1.6	2.3	2.0
4	S4	1.3	1.4	1.2	G4	1.3	1.4	1.2
5	S5	1.1	1.5	1.5	G5	1.3	2.0	1.5
6	S6	2.2	1.6	1.4	G6	1.5	1.8	1.0
7	S7	0.9	1.9	1.8	G7	1.1	1.5	1.5
8	S8	1.3	1.6	1.3	G8	1.0	1.7	1.7
9	S9	1.4	1.3	1.4	G9	1.5	1.6	1.1
10	S10	1.3	1.4	1.3	G10	1.3	1.4	1.2
\bar{x}	-	1.34	1.50	1.39	-	1.31	1.66	1.40
s ²	-	0.11	0.03	0.03	-	0.04	0.09	0.09
s	-	0.34	0.18	0.17	-	0.20	0.30	0.30
	-	0.11	0.06	0.05	-	0.06	0.09	0.10
$SE_{\bar{x}}$								
n	-	10	11	12	-	13	14	15
μ	-	1.34 ± 0.57	1.50 ± 0.58	1.39 ± 0.59	-	1.31 ± 0.60	1.66 ± 0.61	1.40 ± 0.62
ANOVA								
S-CCD	Sum of Squares				Mean Square	F	Sig.	
	Between Groups	.134			.067	1.165	.327 ^{NS}	
	Within Groups	1.553		27	.058			
	Total	1.687		29				
G-CCD	Between Groups	.661			.330	4.521	.020*	
	Within Groups	1.973		27	.073			
	Total	.661	2		.330	4.521	.020*	
Student-Newman-Keuls Test (SNK)								

		Subset for alpha = 0.05		
		N	1	2
G-CCD	Edge 1	10	1.3100	
	Edge 2	10	1.4000	
	Main crop	10		1.6600
	Sig.		.463	1.000

1

2 **Table 5.** Statistical analysis of HLF ratios between G-CCD and S-CCD for each cluster zone

3

		Independent Samples Test								
HLF ratios		Levene's Test for Equality of Variances		t-test for Equality of Means						
Between G-CCD and S-CCD		F	Sig.	t	df	Sig. (2-tailed)	Mean Dif.	Std. Error Dif.	95% Confidence Interval of the Difference	
									Lower	Upper
	Edge 1	.230	.637	.243	18	.811 ^{NS}	.03000	.12351	-.22949	.28949
	Edge 2	4.089	.058	-.092	18	.928 ^{NS}	-.01000	.10899	-.23897	.21897
	Main crop	2.810	.111	-1.458	18	.162 ^{NS}	-.16000	.10975	-.39057	.07057

4 **The growth in the regeneration core after the second cutting (thinning and felling) of**
5 **upper story**

6 The results from examination of the age-height graph of sixty sapling-stems (stem
7 analyses) and derived from correlation and regression analyses (*e.g.* Figure 4) show major
8 differences for growth in height after the first and second cutting stages in the stand. It was
9 found that high overstorey densities (D-CCD) slightly increased sapling growth (Figures 4
10 and 5), and lower overstorey densities (G-CCD and S-CCD) substantially increased sapling
11 growth (Figures 4 and 5). D-CCD gradient exhibited reduced growth in height without
12 mortality, but after the second cutting it was found that the saplings (10–14 years in age) grew
13 very well without any obvious slowing or mortality. This indicates that for the time-periods
14 considered (10–12 years), naturally occurring Scots pine saplings are shade-tolerant in that
15 whilst growth is suppressed they do survive.

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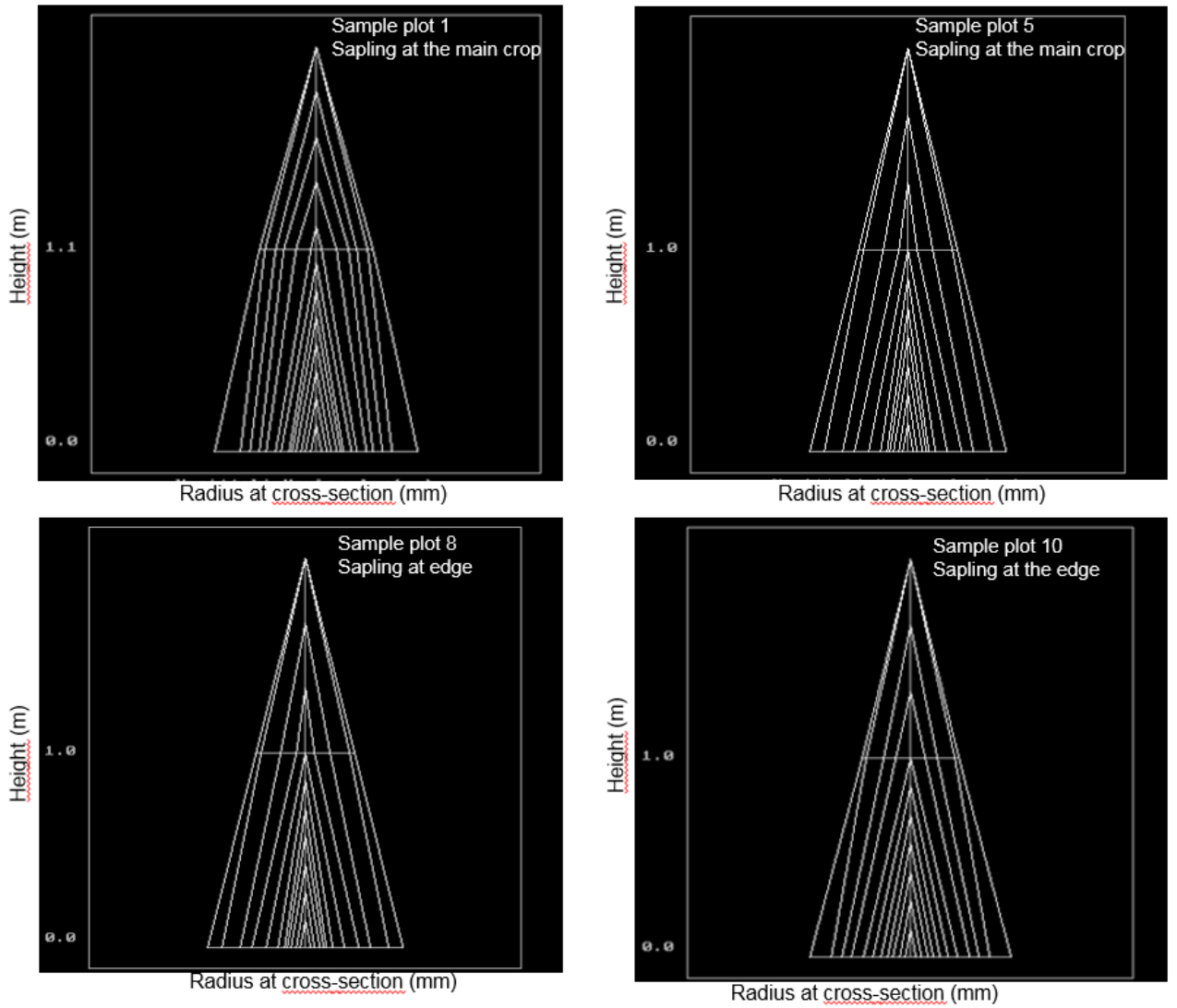
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3 **Figure 4.** The examples of the age–height graph of sapling–stems (stem analyses) (Coban, 2007).

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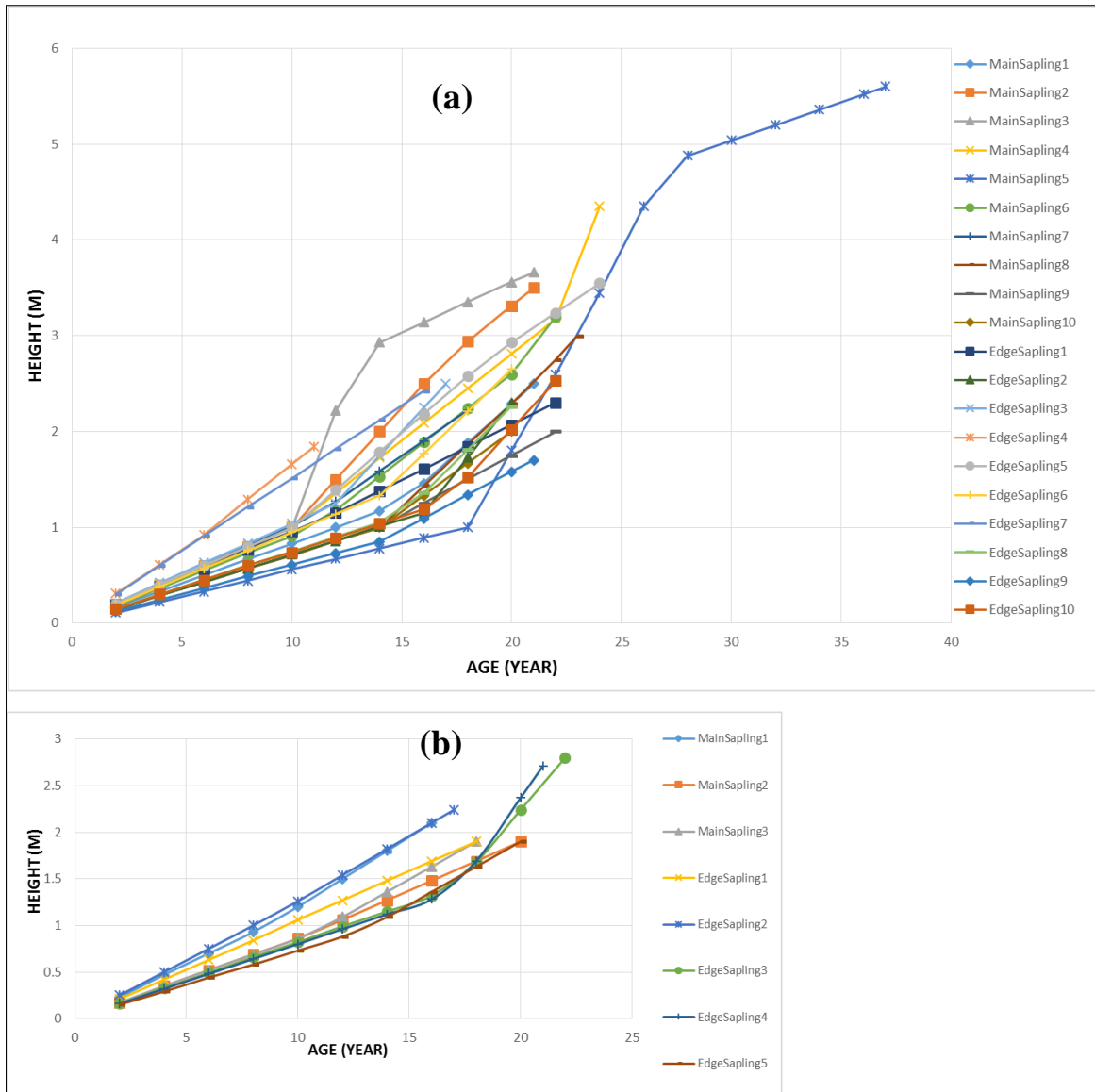
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Figure 5. Height growth of saplings within regeneration cores under G-CCD and S-CCD (a) and D-CCD (b) (only 20 saplings from G-CCD and S-CCD, 8 from D-CCD were shown in the graph).

7 Discussion and Conclusions

8 There is an abundant literature on population structure and factors affecting natural
9 regeneration in Scots pine in Europe (González-Martínez & Bravo, 2001; Valkonen *et al.*,
10 2002; Montes & Canellas, 2007) and in Turkey (Pamay, 1962). However, the characteristics
11 of naturally-occurring saplings of Scots pine under the different CCD gradients are poorly
12 studied. Estimates of CCD are also becoming increasingly important in forest management

1 (Ganey & Block, 1994; Korhonen *et al.*, 2006) and the demand for natural landscapes, the
2 multi-resource use of forests and the high cost of plantations all help to focus European
3 foresters' attention on natural regeneration (González-Martínez & Bravo, 2001). In this
4 context long-term experiments to determine the interactions between different CCD gradients
5 (G-CCD, D-CCD and S-CCD), the regeneration cores of natural Scots pine saplings (Figure
6 3), and the effects on sapling growth rates (Table 1–5) and more have been reported by Pamay
7 (1962), Genc (2004) and Odabasi *et al.* (2004).

8 The practical application of this study requires determination of critical gradients
9 below-CCD (D-CCD, S-CCD and G-CCD) for satisfactory sapling survival and growth of
10 Scots pine. This must then be linked to observations of field light regimes. The studies have
11 revealed a significant relationship between CCD gradients and regeneration core of saplings
12 ($P:0.000$). Decreased canopy cover had a significant positive effect on sapling growth and this
13 has been found by most studies in the past (Pamay, 1962; Genc, 2004; Odabasi *et al.*, 2004;
14 Valkonen, 2000).

15 The maximal regeneration core of sapling was found in the G-CCD, followed by S-
16 CCD and finally D-CCD (Table 1). Similar responses were found by Pukkala *et al.* (1993)
17 with the correlation between the radiation parameters and Scots pine sapling growth
18 significantly positive. The variation in height growth of Scots pine seedlings seems to be
19 caused mostly by the spatial heterogeneity of the stand (i.e. different CCD gradients), which is
20 consistent with some previous studies (Kuuluvainen *et al.*, 1993). As stated by Tegemark
21 (1998), regeneration core of naturally-occurring Scots pine saplings is potentially important
22 in future stand development and sapling properties change with the evolving stages of the
23 stand. As with Beckage *et al.* (2005), G-CCD had only a slight positive effect on seedling
24 survival, and the benefit was offset by a large negative effect of understorey shrubs. This
25 study also found, like Pamay (1962) that high overstorey densities (D-CCD) slightly
26 increased sapling growth (Figures 4 and 5). Lower overstorey densities (G-CCD and S-CCD)
27 substantially increased sapling growth (Figures 4 and 5). Other key factors were intraspecific
28 competition (González-Martínez and Bravo, 2001; Kuuluvainen and Juntunen, 1998) between
29 saplings placed differently in the regeneration cores (Pamay, 1962), and root competition with
30 mature trees (Valkonen, 2000; Siipilehto, 2006; Montes & Canellas, 2007). Compared with
31 saplings in the middle of regeneration cores (crop sapling), those on the edge were shorter
32 with μ value ($\alpha: 0.05$; Eq. 3). This also highlights root competition effects and CDD gradients
33 (Valkonen, 2000; Siipilehto, 2006). Examination of the positions of previously removed trees

1 indicated that root system shape and extent resulted from past competition prior to
2 regeneration works (Valkonen, 2000).

3 The ideas of shade tolerance suggest that there are species-specific physiological and
4 growth adaptations which influence the ability to survive and grow at different levels of light.
5 For example, in low light, shade-tolerant *Abies* species exhibit reduced height and diameter
6 growth without mortality, but this is not true for pine species (Kobe & Coates, 1997; Mason *et*
7 *al.*, 2004). Scots pine is a typical shade-intolerant pioneer (Coates & Burton, 1999; Chantal *et*
8 *al.*, 2003; Ewald, 2007) for which regeneration is practically restricted to open, non-forest
9 vegetation (Ewald, 2007). Its behaviour in native pinewoods in Scotland certainly reflects
10 this. While the broad classification of species as 'shade tolerant', 'intermediate', or 'light
11 demanding' appear to be consistent between regions (Mason *et al.*, 2004). However, the
12 behaviour is not totally fixed and shade tolerance within species may be affected by site
13 quality (Carter & Klinka, 1992). Consequently, the magnitude of the competition effect may
14 vary between geographical areas along with differences in site productivity. However, there is
15 little published research available to evaluate or quantify this hypothesis (Valkonen, 2000).
16 Sapling establishment and development continues out of the dense groups of the younger
17 cohort, under the protection of the low density groups of remaining mother trees. This semi-
18 shade tolerant behaviour found in the southern distribution of Scots pine, i.e. the Sistema
19 Central range, the Iberian Mountain Range and other enclaves in Spain, is quite different from
20 the poor shade tolerance shown by the species in the rest of its distributional area (Montes &
21 Canellas, 2007). Although Scots pine is generally considered a shade intolerant species
22 (Chantal *et al.*, 2003), with increasing site quality it can survive for long periods under a
23 dense forest canopy (Odabasi *et al.*, 2004). Species-specific growth responses show little
24 difference under high available light conditions, but performance at low light levels is
25 generally consistent with shade tolerance rankings in the literature. The exception was that
26 Scots pine shade intolerance was higher [don't you mean lower?? i.e. more shade tolerant –
27 less intolerant??] than expected (Claveau *et al.*, 2002). The results of stem sampling and
28 correlation and regression analyses, age-height graph and age-periodical height increment
29 graph evaluations showed naturally-occurring sapling of Scots pine in the study area were
30 shade tolerant (Figures 4, 5). Some previous studies suggest that Scots pine saplings cannot
31 survive long under a dense forest canopy (Ata, 1995; Genc, 2004). However, as found in this
32 study and earlier investigations (e.g. Pamay, 1962), Scots pine saplings can survive 20–25
33 years under dense forest canopy (Figure 3). According to Pamay (1962), this period may be
34 up to 45–60 years in the case of less dense clustering. Pamay described this situation as the

1 “semi-shade type” of Scots pine. This is important since a more detailed understanding of
2 species response to different light levels can help develop appropriate silvicultural
3 prescriptions to promote varied forest structures with improved species diversity. Linked to
4 other decision-making tools this can help inform the potential impacts of different stand
5 management regimes (Mason *et al.*, 2004).

6 Recent studies of shade tolerance have examined the relationships between mortality
7 and growth in varying light conditions (Kobe *et al.*, 1995; Kobe and Coates, 1997; Wyckoff
8 & Clark, 2002; Kunstler *et al.*, 2005; Löff *et al.*, 2007). In these studies, the interactions
9 between CCD gradients and Scots pine sapling regeneration cores was on the basis of trade-
10 offs between the ability to survive at D-CCD gradients and to achieve a high growth rate at
11 G-CCD and then S-CCD. Edge 1, Edge 2 and, Main Crop HLF ratios ($\alpha:0.05$) were found to
12 be more than 1 for both CCD gradients (G-CCD and S-CCD). According to this value, the
13 growth potential can be defined as high (Eq. 2; After Fabjanowski, 1974 from Schütz, 2001).
14 The results of HLF ratio assessments and stem analyses drawn by correlation and regression
15 analyses, age-height graphs and age-periodical height increment graphs show the growth of
16 sapling regeneration cores to be affected by CCD gradients. It was found that growth
17 continued rapidly in CCD gradients at G-CCD and S-CCD; a response to thinning after 12-
18 14 years suppression by parent trees. In published research it has been suggested that older
19 suppressed saplings were degenerated individuals which under a dense forest canopy lost their
20 vigour (Ata, 1995). However, as this study indicates, these older saplings retain their growth
21 potential during the time of suppression and can recover when the opportunity arises. Vaat
22 and Vildo (2005) concluded that for Scots pine such management intervention with thinning
23 and opening up the canopy needed to be within the first six years and stand densities radically
24 reduced (recommended to be to the to the minimum values allowed by forest legislation or
25 guidance). High-density stands will be unsuitable for shelterwood cutting due to shorter
26 crowns and a higher risk of windfall after repeated overstorey removals. This research found
27 sapling survive for 10-14 years under a dense overstorey (D-CCD) without mortality and
28 with growth at a standstill (Figures 4, 5 and 6; Section A). But after the second cutting, lower
29 overstorey densities (G-CCD and S-CCD) released saplings (10-14 years) to growth well
30 and without mortality (Figures 4, 5 and 6).

31 It is suggested that key elements to the interpretation of this situation are the local
32 differences and distinctiveness of landscapes, together with variations in forest product
33 extraction and management. This finding relates to the idea that application of ‘close-to-
34 nature’ silviculture in Turkey could significantly reduce the problems facing Turkish forests

1 today. However, it will take time and requires a change from current practices. The
2 application of similar management regimes for all forest zones regardless of stand properties
3 is not sustainable. There is a wealth of good practice and evidence from case studies in
4 Europe that can help inform the future management of this unique resource. In the United
5 Kingdom and Germany, and in mountain regions of Italy and Austria, for example, there are
6 many situations where sustainable forest management is increasingly moving towards ‘close-
7 to-nature’ silviculture. This is generally incorporated into development plans that help sustain
8 local communities through jobs and economic regeneration; the forest seen as a key to
9 success. In particular, the concept of multi-functional forest management, including timber
10 and wood production, sustainable tourism and leisure, wildlife, heritage and forest culture
11 (with local food and drink), begins to provide a potential framework for long-term
12 remediation (Çolak & Rotherham, 2006). To conclude, this study supports the point of view
13 that one of the most important rules of close-to-nature silviculture is the protection and
14 generation of irregular stand structures (multi-layer stand, uneven-aged stands etc.).
15 According to the findings of this study, the stands of parent Scots pine and of young-growth
16 stands (old saplings) may occur together under S-CCD and G-CCD gradients. This is
17 particularly the case where site quality is high. This study concluded that stands of young
18 Scots pine can persist under the shelter of the parental canopy. With this information the
19 practice of suitable forest management can be directed to the protection and maintenance of
20 necessary conditions for sustainability. When developing silvicultural systems for Scots pine
21 forests that would produce structural and compositional features as found in natural forests,
22 there must be a better understanding of the role of microhabitats in regeneration dynamics
23 (Kuuluvainen & Juntunen, 1998).

24

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28

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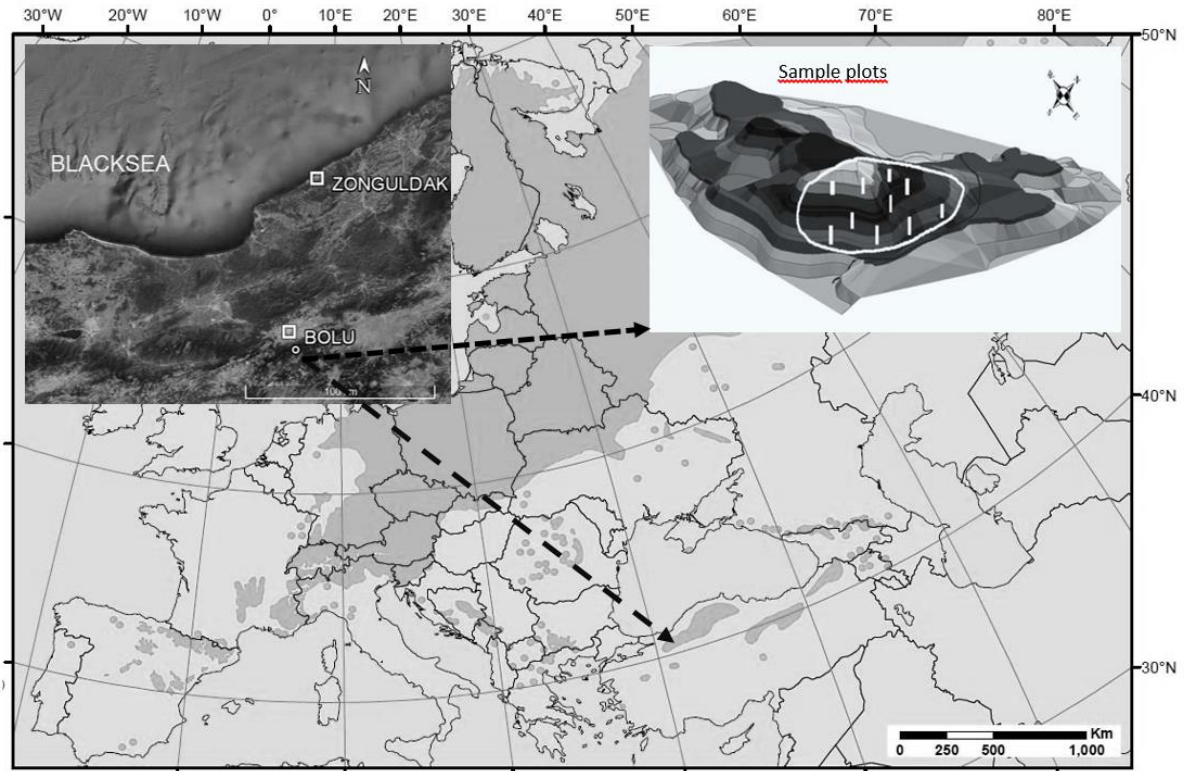
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3 **Figure 1.** Natural distribution range of *Pinus sylvestris* L. (EUFORGEN, 2009) and location
4 of sample plots.

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6

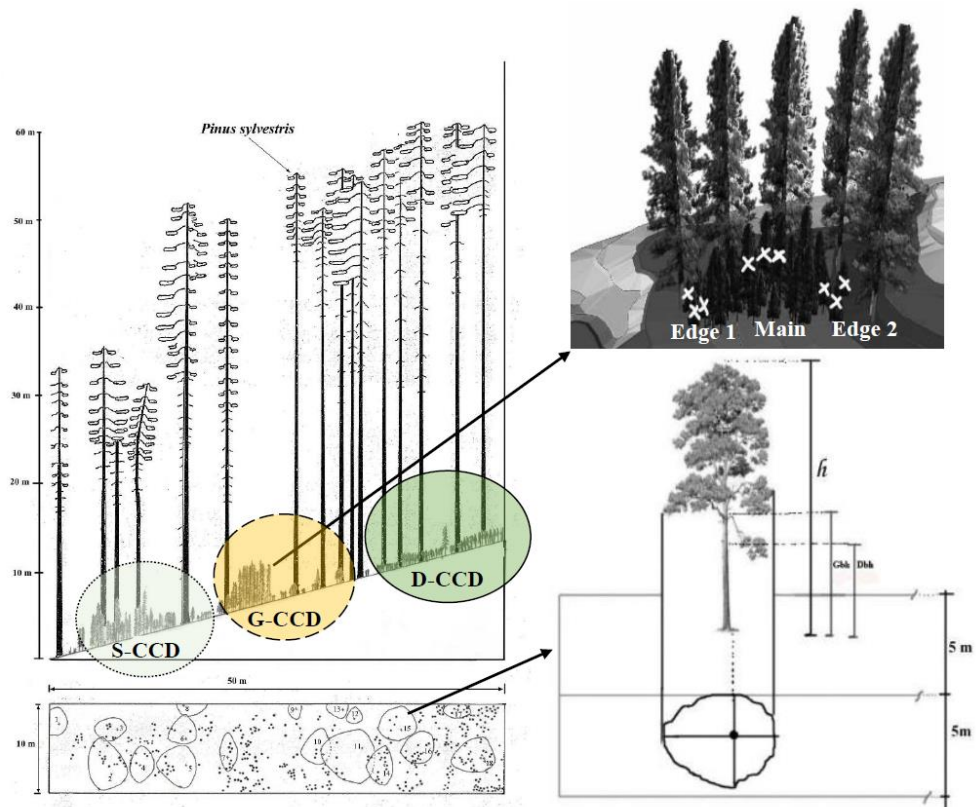
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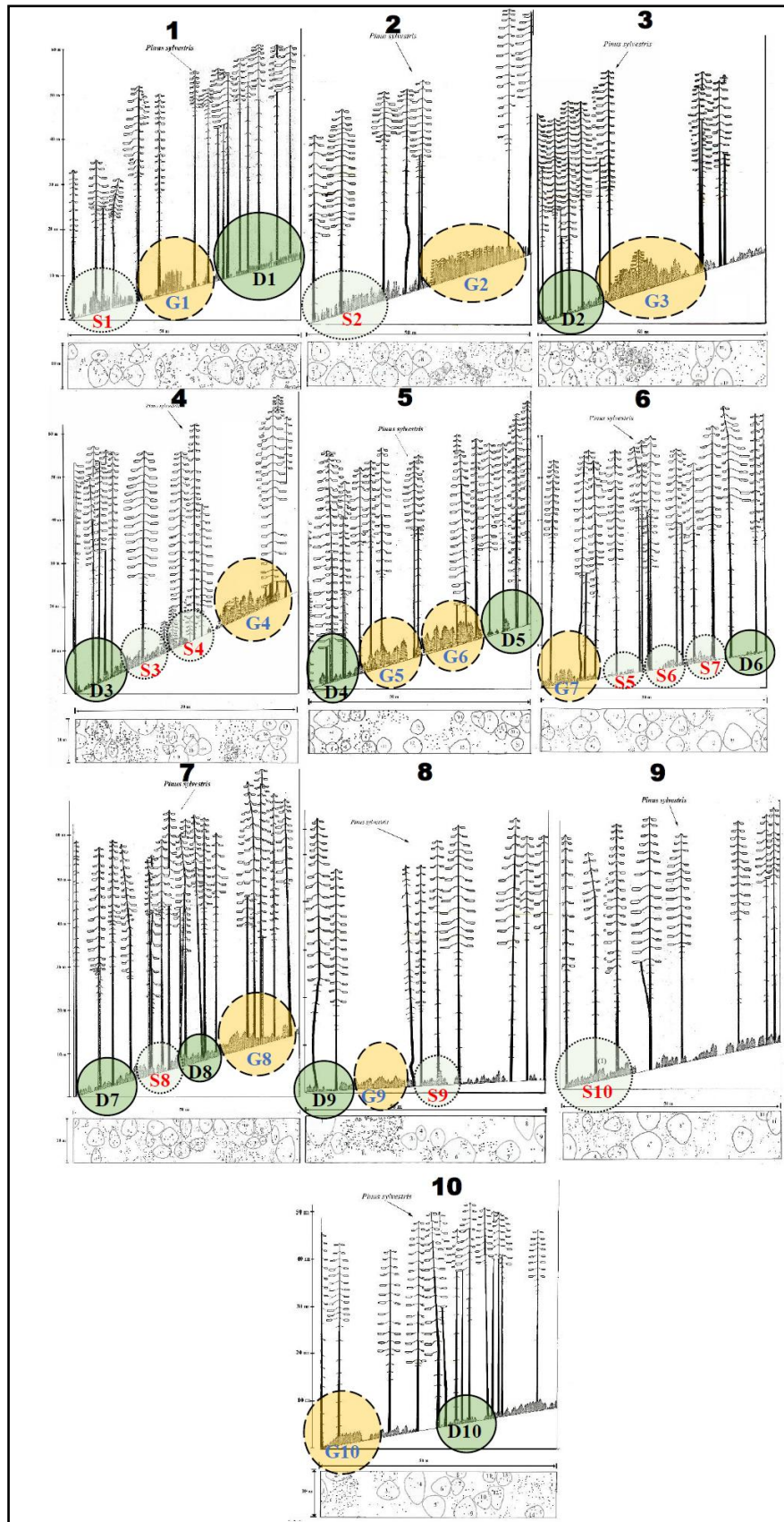
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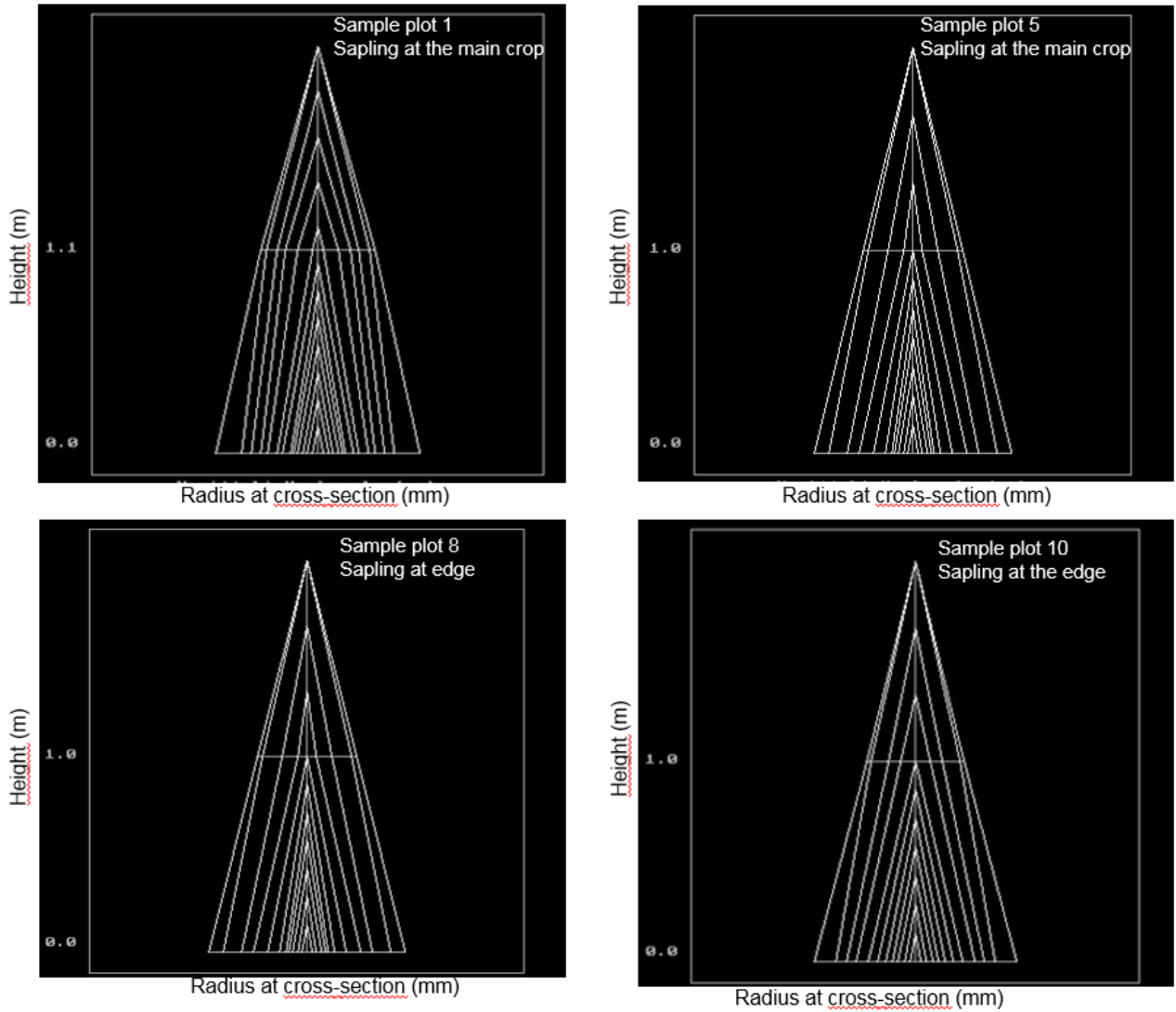


1
 2 **Figure 2.** The CCD gradient models of Scots pine stands with three gradients *i.e.* dense (D-
 3 CCD: 55%), sparse (S-CCD: 43%) and gap (G-CCD: 87 m²) (Coban, 2007).



1

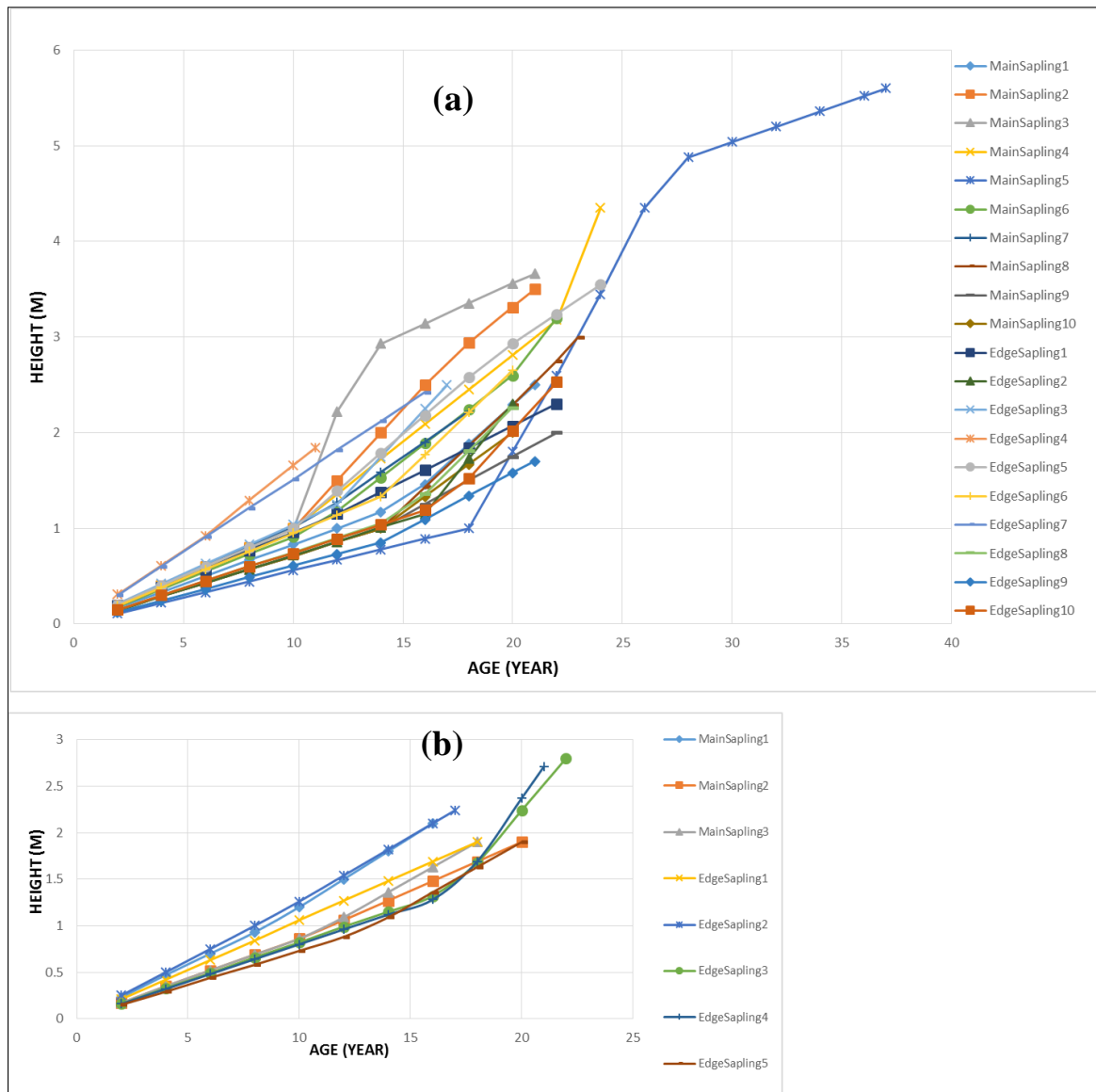
2 **Figure 3.** Longitudinal (profile) and vertical stand projection of all sample plots with different CCD
 3 gradients (D–CCD: Dense; S–CCD: Sparse; G–CCD: Gap) (Stand profiles from Coban, 2007).



1

2 **Figure 4.** The examples of the age–height graph of sapling–stems (stem analyses) (Coban, 2007).

3



1
 2 **Figure 5.** Height growth of saplings within regeneration cores under G-CCD and S-CCD (a) and D-
 3 CCD (b) (only 20 saplings from G-CCD and S-CCD, 8 from D-CCD were shown in the graph).

4
 5 **Table 1.** The effect of CCD gradients on formation of sapling regeneration cores. The data
 6 and statistical analysis from 30 sapling regeneration cores with different CCD gradients. This
 7 was confirmed by Kruskal–Wallis H test (Level: 0: saplings without regeneration cores; 1:
 8 saplings with sapling regeneration cores)

9

Number of	Frequency distribution of natural sapling under different CCD gradients		
	Dense (D-CCD)	Sparse (S-CCD)	Canopy gap (G-CCD)

	Position in sample plots (Figure 3)	Level	Position in sample plots (Figure 3)	Level	Position in sample plots (Figure 3)	Level
1	D1	0	S1	1	G1	1
2			S2	1	G2	1
3	D2	0			G3	1
4	D3	0	S3	1	G4	1
			S4	1		
5	D4	0			G5	1
					G6	1
6	D5	0	S5	0	G7	1
			S6	1		
			S7	1		
7	D6	0	S8	1		
	D7	1	S9	1		
	D8	0				
8	D9	0			G8	1
9	D10	0	S10	1	G9	1
10					G10	1
Frequency distribution						
	D-CCD		S-CCD		G-CCD	
Level	0	1	0	1	0	1
Total	9	1	1	9	0	10
Statistical analysis (Kruskal-Wallis H Test)	Descriptive Statistics					
	N		Mean		Std. Deviation	
	30		.6667		.47946	
	Test Statistics					
	Chi-Square			21.170		
	df			2		
Asymp. Sig.			p<0.001			

1

2 **Table 2.** The effect of CCD gradients on height of saplings in the sapling regeneration core.

3 Data and statistical analysis from twenty regeneration cores (n= 10, v= 9, t= 2.262), μ (Eq.3).

4 This was confirmed by Student's t-test ($\alpha= 0.05$): Arithmetic mean of 95% confidence

5 interval of total population

Number of sample plots	Height (m)							
	Sparse (S-CCD)				Canopy gap (G-CCD)			
	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2
1	S1	3.1	2.8	1.9	G1	2.0	3.8	2.1
2	S2	2.4	3.0	1.8	G2	2.0	4.6	1.8
3	S3	2.2	2.8	2.1	G3	3.6	5.2	3.7
4	S4	1.6	2.5	1.7	G4	1.6	2.5	1.7
5	S5	1.4	2.4	2.0	G5	1.5	2.1	1.8
6	S6	0.9	0.9	2.2	G6	1.7	1.9	2.0
7	S7	0.8	1.4	0.7	G7	1.4	2.4	2.2
8	S8	2.2	2.1	1.9	G8	1.1	2.1	1.6
9	S9	2.8	3.0	2.7	G9	1.5	1.9	1.9
10	S10	1.2	1.8	2.2	G10	1.5	1.8	1.9
\bar{x}	-	1.86	2.27	1.92	-	1.79	2.83	2.07
s^2	-	0.63	0.51	0.26	-	0.48	1.54	0.36
s	-	0.80	0.71	0.51	-	0.69	1.24	0.60
$SE_{\bar{x}}$	-	0.25	0.23	0.16	-	0.22	0.39	0.19
n	-	10	10	10	-	10	10	10
μ	-	\pm 0.57	\pm 0.51	\pm 0.37	-	\pm 0.49	\pm 0.89	\pm 0.43
Independent Samples Test								

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Dif.	Std. Error Dif.	95% Confidence Interval of the Difference	
									Lower	Upper
S-CCD	Edge 1 and main crop	.415	.527	-1.213	18	.241 ^{NS}	-.41000	.33805	-1.12022	.30022
	Edge 2 and main crop	2.273	.149	-1.261	18	.224 ^{NS}	-.35000	.27763	-.93328	.23328
G-CCD	Edge 1 and main crop	5.242	.034	-2.317	14.089	.036*	-1.04000	.44883	-2.00206	-.07794
	Edge 2 and main crop	7.409	.014	-1.744	12.996	.105 ^{NS}	-.76000	.43566	-1.70122	.18122

1 **Table 3.** The age distributions in the sapling regeneration cores. Data and statistical analysis
2 from twenty regeneration cores ($n = 10$, $v = 9$, $t = 2.262$), μ (Eq.3). This was confirmed by
3 Student's t-test ($\alpha = 0.05$): Arithmetic mean of 95% confidence interval of total population

Number of sample plots	Age (year)							
	Sparse (S-CCD)				Canopy gap (G-CCD)			
	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2
1	S1	22	22	18	G1	18	21	18
2	S2	16	20	13	G2	15	21	16
3	S3	21	22	19	G3	23	32	19
4	S4	19	22	19	G4	19	22	20
5	S5	15	17	18	G5	17	17	17
6	S6	19	16	18	G6	16	19	20
7	S7	12	16	16	G7	15	19	20
8	S8	19	20	19	G8	14	16	16
9	S9	20	22	22	G9	20	19	16
10	S10	20	21	20	G10	18	16	19
\bar{x}	-	18.30	19.80	18.20	-	17.50	20.20	18.10
s^2	-	9.34	6.40	5.73	-	7.39	21.51	2.99
s	-	3.06	2.53	2.39	-	2.72	4.64	1.73
$SE_{\bar{x}}$	-	0.97	0.80	0.76	-	0.86	1.47	0.55
n	-	10	10	10	-	10	10	10
μ	-	18.30 ± 2.19	19.80 ± 1.81	18.20 ± 1.71	-	17.50 ± 1.94	20.20 ± 3.32	18.10 ± 1.24

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Dif.	Std. Error Dif.	95% Confidence Interval of the Difference	
									Lower	Upper
S-CCD	Edge 1 and main crop	.194	.665	-1.195	18	.247 ^{NS}	-1.500	1.2547	-4.1361	1.1361

G-CCD	Edge 2 and main crop	.514	.483	-1.453	18	.164 ^{NS}	-1.600	1.101	-3.914	.71420
	Edge 1 and main crop	.643	.433	-1.588	18	.130 ^{NS}	-2.700	1.700	-6.271	0.871
	Edge 2 and main crop	2.022	.272	1.342	18	.196 ^{NS}	2.100	1.565	-1.188	5.388

1

2 **Table 4.** Statistical analysis of difference for HLF ratios between Main Crop saplings and
3 both Edge saplings in the regeneration core with different CCD gradients. This was confirmed
4 by one-way variance analyses (ANOVA) and Student–Newman–Keuls (SNK)

Number of sample plots	HLF ratios							
	Sparse (S-CCD)				Canopy gap (G-CCD)			
	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2	Place in sample plots (Figure 3)	Edge 1	Main crop	Edge 2
1	S1	1.4	1.5	1.3	G1	1.4	1.5	1.5
2	S2	1.3	1.5	1.3	G2	1.1	1.4	1.3
3	S3	1.2	1.3	1.4	G3	1.6	2.3	2.0
4	S4	1.3	1.4	1.2	G4	1.3	1.4	1.2
5	S5	1.1	1.5	1.5	G5	1.3	2.0	1.5
6	S6	2.2	1.6	1.4	G6	1.5	1.8	1.0
7	S7	0.9	1.9	1.8	G7	1.1	1.5	1.5
8	S8	1.3	1.6	1.3	G8	1.0	1.7	1.7
9	S9	1.4	1.3	1.4	G9	1.5	1.6	1.1
10	S10	1.3	1.4	1.3	G10	1.3	1.4	1.2
\bar{x}	-	1.34	1.50	1.39	-	1.31	1.66	1.40
s ²	-	0.11	0.03	0.03	-	0.04	0.09	0.09
s	-	0.34	0.18	0.17	-	0.20	0.30	0.30
S_x^2	-	0.11	0.06	0.05	-	0.06	0.09	0.10
n	-	10	11	12	-	13	14	15
μ	-	1.34	1.50	1.39	-	1.31	1.66	1.40
		±	±	±	-	±	±	±
		0.57	0.58	0.59		0.60	0.61	0.62
ANOVA								
S-CCD		Sum of Squares	df	Mean Square	F	Sig.		
	Between Groups	.134	2	.067	1.165	.327 ^{NS}		
	Within Groups	1.553	27	.058				
	Total	1.687	29					
G-CCD	Between Groups	.661	2	.330	4.521	.020*		
	Within Groups	1.973	27	.073				
	Total	.661	2	.330	4.521	.020*		
Student–Newman–Keuls Test (SNK)								
		Subset for alpha = 0.05						
		N	1	2				
G-CCD	Edge 1	10	1.3100					
	Edge 2	10	1.4000					
	Main crop	10			1.6600			
	Sig.		.463		1.000			

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8 **Table 5.** Statistical analysis of HLF ratios between G-CCD and S-CCD for each cluster zone

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Independent Samples Test									
HLF ratios	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Dif.	Std. Error Dif.	95% Confidence Interval of the Difference	
								Lower	Upper
Edge 1	.230	.637	.243	18	.811 ^{NS}	.03000	.12351	-.22949	.28949
Edge 2	4.089	.058	-.092	18	.928 ^{NS}	-.01000	.10899	-.23897	.21897
Main crop	2.810	.111	-1.458	18	.162 ^{NS}	-.16000	.10975	-.39057	.07057

Between G-CCD and S-CCD

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