Impact of some ecological factors on natural regeneration of recreational Scots pine stands

EDVARDAS RIEPŠAS, GINTAUTAS URBAITIS
Lithuanian Agricultural University
4324 Kaunas - Akademija

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Studies were conducted on the impact of some ecological factors on natural regeneration in recreational Scots pine stands. Correlation between these factors and the amount of pine undergrowth in the stands was determined. Canopy density has the greatest impact on the amount of undergrowth (correlation coefficient in *cladoniosum* forest type r= -0.361, *vacciniosum* r= -0.226, *vaccinio-myrtillosum* r= -0.356). The best natural regeneration of pine is observed in the *vacciniosum* type, where changes in undergrowth depending on canopy density can be expressed by a logarithmic equation y= -2278.9Ln(x) +10709; (R^2= 0.6706). In the *oxalidosum* forest type, natural regeneration of Scots pine is insufficient. In this forest type intensive substitution by deciduous species is found.

As canopy density increases, other forest ecosystem elements undergo changes as well. In most forest types studied, increasing canopy density led to increasing stocking level, forest litter depth, the number of underbush and undergrowth species, decreased the aggressiveness of grass cover on natural regeneration.

Scots pine seed germination in the understory depends on forest litter depth, grass cover aggressiveness and the degree of soil compaction. A reliable correlation was found between these factors and the number of viable pine seedlings in most cases. No viable pine seedlings are found when forest litter depth exceeds 4 cm.

The impact of recreation on natural regeneration is especially distinct during seed germination due to compaction of upper soil horizons. With increasing soil compaction, the number of viable pine seedlings decreases. No viable seedlings are found when at a depth of 3 cm soil compression is over 36 kg/cm^2.

Key words: natural regeneration, recreational forest, Scots pine, canopy density, soil compaction.

Introduction

Natural regeneration is the natural change of forest generations. This characteristic of stands has developed through natural selection and insures the survival of some tree species. There is abundant literature on natural forest regeneration. However, natural regeneration of pine stands in Lithuania, except studies by B. Labanauskas and K. Narbutas (1969), were not studied more deeply and were undeser – vably forgotten, for natural stands are more viable and resistant than planted ones (Leibendgut, 1981; Kolobov, 1980, et al.). Natural regeneration should be considered when managing recreational forests. Natural regeneration saves money that would be spent on artificial reforestation.

Intensively visited suburban and town forest undergo degradation processes. Vegetation is poor and changes in forest litter, soil physical and chemical properties are observed. Changes in biotic and abiotic environmental factors predetermine a peculiar appearance of natural seedlings and their survival in a stand. Some changes have a positive impact on the natural forest regeneration, while some have negative impacts. The aim of our investigations is to find this out and to use it in stimulating natural regeneration in recreational forests.

Methods

Cladoniosum, vacciniosum, vaccinio-myrtillosum and *oxalidosum* pine stands on Nae, Na, Nb and Nc site types were studied in suburban and town forests. The age of stands studied ranges from 80 – 210 years, bonitet – III – V, stocking level from 0.3 to 0.7, canopy density from 20 to 90%. In each stocking group, 3 sites were studied (a total of 72 taxational sites). In all studied sites stand, species composition, age, height, diameter, stocking level, canopy density, bonitet as well as a simplified soil investigation were carried out by common forest inventory methods. While studying natural regeneration, all measurements were conducted in rectangular 2x2 m observation plots by locating them in a systemic way evenly within the investigation area. Number of observation plots per site : up to 1ha area – 20, 1.1 – 3ha – 30, over 3ha – 40. On the total, 73 mensuration sites were researched through (3 or more mensuration sites in every stocking level group from 0.3 to 0.7). This kind of studies was conducted on 1231 observation plots. In each plot the following was assessed :

- species composition of the undergrowth, its number, age, height, viability, number of damaged seedlings and saplings;
- species composition of underbush, number according to

height groups (up to 0.5 m, 0.6 – 1.5 m, 1.6 – 3 m and over 3 m), number of damaged and dead saplings and bushes;

- aggressiveness of grass cover on regeneration (Karazija, Vaičiūnas, Jurelionis, 1994);
- litter thickness
- stand stocking level (by Bitterlich's pole) and canopy density (by spheric densiometer);
- soil compaction (by Reviakin's instrument at 5 replications);
- the stage of recreational digression (Riepšas,1990).

Enlightment percentage from open place was measured on sunny days from 8 a.m. – till 8 p.m. every half hour on temporary investigation plots seeking to establish the link between 20, 30, 40, 50, 60, 70, 80 and 90% canopy density and enlightment. Measurement was performed by 2 luxmeters 10-16 at a time with 5 replications in each canopy density group. Study data was processed by a computer with the help of Excel program. Statistical indices were calculated, correlation ties were established, regression analysis was performed.

Results

The effects of direct or indirect impact of some ecological factors on natural regeneration were elucidated (Table 1).

saplings, therefore they will not be analysed in this respect. A much weaker correlation exist between stand stocking level and the amount of viable undergrowth. This shows that the appearance of pine undergrowth and its survival is essentially preconditioned by light regime and other relevant ecological factors (warmth, moisture), because a direct correlation was established between canopy density and enlightment (Fig. 1).

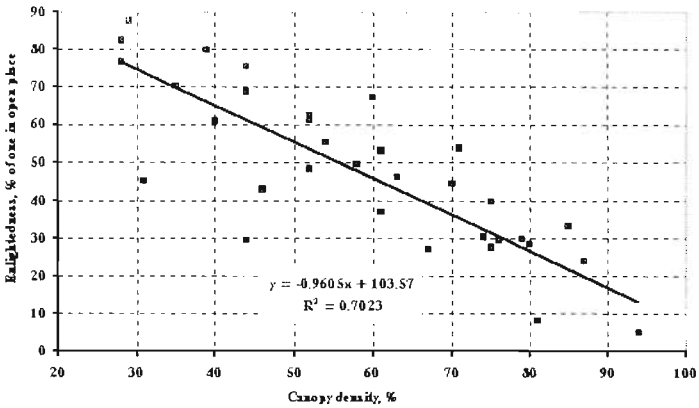

Fig. 1. Influence of Scots pine canopy density on enlightedness of undercanopy

Litter thickness and soil compaction have, a negative impact on the number of natural seedlings, although this correlation is unreliable. There are doubts about a relatively high positive

Table 1. Correlation coefficients among some ecological factors and natural regeneration parameters in stand of different forest site types

Ecological factors	Natural regeneration parameters					
	number of viable undergrowth			number of viable seedlings		
	forest site type			forest site type		
	P.cl. (Nae)*	P.v. (Na)*	P.v-m. (Nb)*	P.cl. (Nae)*	P.v. (Na)*	P.v-m. (Nb)*
Stand stocking level	-0,189**	-0.251**	-0.221**	0,001	-0.105**	-0.05
Relative ccanopy density	-0,361**	-0.226**	-0.356**	0,016	-0.06	-0.037
Litter thickness	-0,099	-0.019	-0.148**	-0,156**	-0.102**	0.039
Grass layer aggressiveness to the natural reforestation	0,351**	-0.046	-0.049	-0,139**	-0.238**	-0.173**
Soil compression in depth of 3 cm	-0,071	-0.006	0.048	-0,142**	-0.049	-0.117**

* - forest site types: P. cl. (Nae) - Pinetum cladoniosum, P. v. (Na) - Pinetum vacciniosum, P. v. - m. (Nb) - Pinetum vaccinio - myrtillosum.
* - correlation significant at p = 0,05.

The most reliable reverse correlation was established between canopy density and the number of viable undergrowth (r= -0.361 in *cladoniosum*, r= -0.226 in *vacciniosum* and r= -0.356 in *vaccinio – myrtillosum* pine stands). In *oxalidosum* pine stands viable pine undergrowth comprised individual

correlation coefficient (0.351) in *cladoniosum* pine stands between grass cover aggressiveness to natural regeneration and the number of viable undergrowth. It could be explained by the fact that mean age of the viable undergrowth in this forest type is 20 years and grass cover since its appearance

could have essentially changed. Also, grass cover aggressiveness to regeneration in *cladoniosum* pine stands rarely exceeds 3 points.

In most cases reliable reverse correlations were established between the number of viable seedlings and litter thickness, grass cover aggressiveness to regeneration and soil compaction at 3 cm depth. It shows that all these factors have obvious negative effect on the germination of pine seeds. In *vaccinio – myrtillosum* type forest litter is the thickest (2.7 cm on an average) of all forest types studied. This could be predetermined by the fact that no reliable correlation was observed between this index and the number of viable seedlings.

Regression analysis of investigation data shows how the number of viable pine undergrowth changes with changing canopy density (Fig. 2). In *cladoniosum* type under canopy density 20% viable undergrowth comprises on an average 2600 per ha, while its occurrence makes up 30% (occurrence – percentage of observation plots where the object under study was detected, from the number of all observation plots). With increasing canopy density the number of undergrowth decreases almost proportionally. Under canopy density exceeding 70% viable undergrowth is practically not found. In *vacciniosum* and *vaccinio-myrtillosum* forest types under canopy density of 20% viable undergrowth is more abundant – 3800 per ha on an average (occurrence 44%). With increasing canopy density, like in *cladoniosum* type, pine undergrowth number decreases almost proportionally, only the critical canopy density when no viable undergrowth is found in these forest types is greater. In *vaccinio – myrtillosum* type it makes up 85%, while in *vacciniosum* type only individual samples are found even under canopy density over 90%. This partially confirms the statement that on richer soil, plants (in this case pine) are more tolerant to shading (Spur, Barnes, 1984). In *cladoniosum* forest type mean canopy density on observation plots with viable pine undergrowth comprised 45%, in *vacciniosum* type 58%, while in *vaccinio – myrtillosum* – 37%. Mean age of the undergrowth is 20, 12 and 7 years respectively. Obviously these canopy densities in corresponding site types should be considered optimal for Scots pine undergrowth at this age. On the whole, from all types studied pine regenerates best in *vacciniosum* forest type.

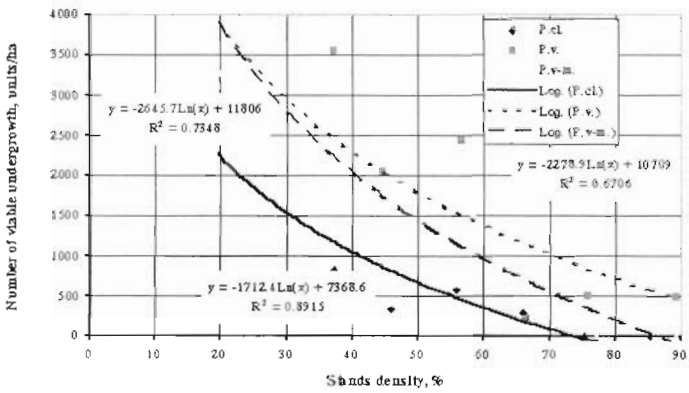

Fig. 2. Influence of stand density on natural regeneration in Scots pine stands

As canopy density changes, other forest elements changes as well (Table 2). These changes also impact the appearance and survival of pine seedlings. With increasing canopy density increases stocking level, litter thickness,

Table 2. Respense of some components of forest ecosystem to the stand density change

Forest site types												
P. cl. (Nae)				P. v. (Na)			P. v-m. (Nb)			P. ox. (Nc)*		
Relative canopy density, %	stand stocking level	litter thickness, cm	grass level agressiveness to the natural regeneration, in degree	stand stocking level	litter thickness, cm	grass level agressiveness	stand stocking level to the natural regeneration, in degree	litter thickness, cm	grass level agressiveness	stand stocking level to the natural regeneration, in degree	litter thickness, cm	grass level agressiveness to the natural regeneration, in degree
20	0.3±0.01	0.7±0.2	0.9±0.3	0.4±0.02	1.7±0.3	2.6±0.4	0.4±0.01	1.8±0.3	2.6±0.3	-	-	-
36	0.4±0.01	0.6±0.2	0.3±0.1	0.4±0.01	2.2±0.4	2.6±0.4	0.5±0.03	2.3±0.4	2.7±0.3	0.5±0.04	2.0±0.4	5.0±0.01
46	0.4±0.02	0.9±0.1	0.2±0.1	0.4±0.02	2.3±0.3	2±0.3	0.5±0.02	2.4±0.3	2.4±0.3	0.5±0.02	1.1±0.1	4.6±0.1
56	0.4±0.02	1.3±0.2	0.5±0.1	0.6±0.02	2.3±0.2	1.4±0.2	0.6±0.03	2.8±0.2	2.0±0.2	0.5±0.03	0.8±0.1	5.0±0.01
66	0.5±0.02	1.9±0.1	0.4±0.1	0.6±0.02	2.1±0.2	1.9±0.2	0.6±0.02	3.0±0.3	2.0±0.2	0.5±0.02	1.2±0.1	3.3±0.2
76	0.6±0.02	2.7±0.3	0.5±0.1	0.6±0.02	2.7±0.1	1.9±0.2	0.7±0.02	3.1±0.2	2.1±0.2	0.6±0.01	1.3±0.1	1.8±0.2
86	0.7±0.01	3.1±0.3	0.3±0.1	0.7±0.01	2.5±0.1	2.3±0.1	0.7±0.03	3.0±0.3	1.6±0.2	0.6±0.01	1.2±0.1	1.3±0.2

* - forest site type P. ox. (Nc) – *Pinetum oxalidosum*

decreases aggressiveness of grass cover to regeneration. In some forest types these changes are more vivid, in others less distinct. For instance, the greatest increase in litter thickness is observed in *cladoniosum* forest type with increasing canopy density, while grass cover aggressiveness to regeneration decreases in *oxalidosum* forest type. In the latter type, apart from others, with increasing canopy density litter thickness even decreases.

According to authors who have studied pine self – regeneration, underbush has a negative impact on the process. It is a serious competitor with undergrowth for moisture and light, while its fallings form a thick, poorly decomposing litter, inhibiting the germination of pine seeds (Sannikov, 1961; Polyakova, 1972). According to our data the best underbush is found in *vaccinio – myrtillosum* forest type (Fig. 3). Under

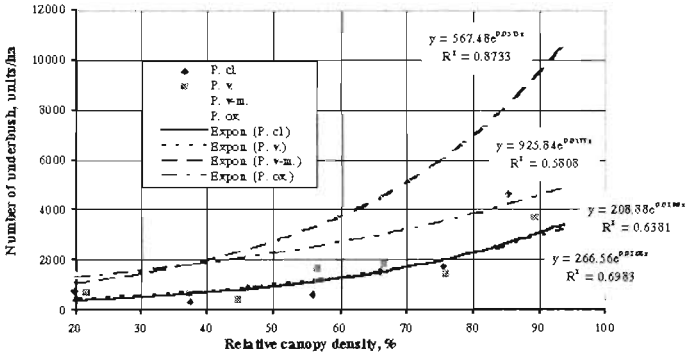

Fig. 2. Influence of stand density on amount of underbush

canopy density increment from 20 to 93% in these stands, the amount of underbush increases from 1500 up to 11000 per ha. Also, with increasing canopy density the amount of underbush grows up in all studied forest types. It worsens the existing poor ecological conditions for pine regeneration due to light shortage.

Increasing canopy density also increases undergrowth of other tree species (Table 3), which occupy Scots pine's ecological niche and in some forest types cause serious preconditions for stand species substitution. In *cladoniosum* forest type undergrowth of other species was not found, while in *vacciniosum* type some birch and aspen (sometimes over 400 per ha) were present. These forest types are safe from species substitution. In *vaccinio-myrtillosum* forest type undergrowth of this category comprised over 1000 per ha, mainly spruce and aspen. Aspen is most abundant, as in *vacciniosum* type, under canopy density 57%, while spruce abundance is constantly rising with increasing canopy density. When it reaches 87%, spruce makes up 1300 per ha. In *oxalidosum* forest type, as mentioned, viable pine undergrowth was not found. Here undergrowth is formed from common maple (*Acer campestre*) with an admixture of other deciduous species, the amount of which increases with growing canopy density. Therefore, it can be said, that in this forest type pine self-regeneration is impossible without special silvicultural measures. Here pine substitution by deciduous species is ongoing.

Litter thickness has no observable impact on the growth of pine seedlings, but it undoubtedly influences seed germination. This is well demonstrated by a small number of viable seedlings and their occurrence in denser stands. Under canopy density 86% enlightment in pine stands is 20% of what it would be in an opening (Fig.1). It is enough for seed germination. Grass cover agressiveness to regeneration under such a density, depending on forest type, is more or less reduced, though viable seedlings under forest litter thickness over 4 cm were not detected in all forest types (Table 4).

Table 3. Influence of forest litter thickness on Scots pine seeds germination

Litter thickness, cm	Forest site type					
	P. cl. (Nae)		P. v. (Na)		P. v-m. (Nb)	
	number of viable seedlings, units/ha	probability of viable seedlings, %	number of viable seedlings, units/ha	probability of viable seedlings, %	number of viable seedlings, units/ha	probability of viable seedlings, %
0	6223±1873	47	4839±1790	19	7142±4610	26
1	9668±2813	43	2325±1138	12	1282±527	15
2	3992±1313	27	2524±732	19	1111±452	9
3	135±130	3	1535±506	12	4100±1628	16
4	0	0	1940±776	15	11833±1628	33
5	0	0	0	0	0	0

Table 4. Influence of soil compression on numbber of viable Scots pine seedlings

Soil compression in depth of 3 cm, kg/cm²	Forest site type					
	P. cl. (Nae)		P. cl (Nae)		P. v-m. (Nb)	
	number of viable seedlings, units/ha	probability of viable seedlings, %	number of viable seedlings, units/ha	probability of viable seedlings, %	number of viable seedlings, units/ha	probability of viable seedlings, %
4	2500±1110	42	1591±1272	9	0	0
8	7654±1354	50	2204±632	16	7806±3145	27
12	5842±2804	14	1168±362	14	2537±1099	12
18	691±352	9	5320±1862	17	2132±825	12
23	278±270	6	3108±1118	22	1400±723	16
27	0	0	270±118	5	625±310	17
36	0	0	0	0	0	0

The impact of forest visitors on natural regeneration of *cladoniosum* pine forest was attempted to be quantified in various ways, although reliable correlations between viable undergrowth and recreational digression stage were not established. Over a longer period recreational forests have a more or less settled balance and no observable changes occur, or they show off already in the first stage of undergrowth appearance – seed germination. It shows the impact of compaction of upper soil horizons on the number of viable seedlings (Table 5).

Table 5. Influence of grass layer agressiveness on Scots pine seeds germination

Grass layer agressiveness, in degree	Forest site type					
	P. cl. (Nae)		P. v. (Na)		P. v-m. (Nb)	
	number of viable seedlings, units/ha	probability of viable seedlings, %	number of viable seedlings, units/ha	probability of viable seedlings, %	number of viable seedlings, units/ha	probability of viable seedlings, %
0	13555±2711	73	5305±1273	33	3939±1512	24
1	300±183	6	2767±802	19	5897±2049	21
2	0	0	1250±487	8	2500±1200	16
3	0	0	125±87	3	375±191	10
4	-	-	0	0	0	0

With increasing soil compaction at 3 cm depth in *cladoniosum* and *vaccinio – myrtillosum* forest types from 4 to 8, while in *vacciniosum* even up to 23 kg/cm², the number and occurrence of viable seedlings even increases, which testifies to our previous investigations and the statement that in initial stages of recreational digression undergrowth in some cases may even become more abundant (Riepšas, Urbaitis, 1994). Besides, it can be stated, that in richer sites pine seedlings are more resistant to soil compaction, although under compaction exceeding 36 kg/cm² viable pine seedlings in all forest types were not found.

As an indirect recreational impact on pine seeds germination could be considered the effect of grass cover, as far as recreation causes changes in grass cover species composition and abundance, leading to turfening as well as to greater agressiveness of grass layer to regeneration. Increasing agressiveness of grass cover constantly decreases the amount of viable pine seedlings, while under grass agressiveness exceeding 4 points, no viable seedlings were detected in all studied forest types.

Discussion

Some investigators hold the opinion that any efforts to relate the appearance of undergrowth and growth under canopy to enlightment under natural conditions is not purposeful, for under changing canopy density as well as enlightment, the whole complex of ecological factors changes as well, such as moisture, temperature, etc. (Spurr, Barnes, 1984). Based on this, we didn't study the direct impact of enlightment on the appearance of pine seedlings, but we have established the relation between canopy density and enlightment (Fig. 1) and tried to relate it with natural regeneration. The correlation (r= -0.84) between canopy density and enlightment is reliable, because at 35 replications under validity 0.05, it exceeds 0.35 (Rokickij, 1973).

Most scientist think that minimal enlightment for Scots pine seedlings is 5 – 10% of that in an opening. In our case it corresponds to 92 – 95% canopy density. Our results do not contradict this statement, because in stands of this density viable pine seedlings, though scanty, were found. Opinions of investigators differ concerning optimal enlightment. Some think that Scots pine seedlings grow best under full enlightment, others, that it is enough to receive 25 – 35% which in our case corresponds to 83 – 73% canopy density. In this respect we keep to the first opinion, because according to our data, under canopy density decrease and enlightment increment at the same time, the occurrence and amount of viable pine undergrowth constantly grows. Besides, in poorer sites pine requires more light, for in *cladoniosum* type under canopy density over 70% (38% enlightment) viable pine undergrowth is not found, while in *vacciniosum* type even under 90% density (18% enlightment) it is observed. Apart from this, according to our opinion under greater canopy density natural pine regeneration is negatively influenced by other environmental factors, especially underbush and in some forest types undergrowth of other tree species, the amount of which rises with greater canopy density (see Fig. 3 and Table 3). This phenomenon, observed by us, contradicts the opinion of most scientists. However, it is obviously peculiar to recreational pine stands, as far as it was found in all forest types studied. It can be explained by the fact that in recreational forests a group spatial

structure of phytocoenoses is naturally formed. The outskirts of biogroups have sufficient enlightment and relatively uncompressed soils, while more open areas are used for recreation more intensively. They are used for walking, and often even for hay – making. Undergrowth and underbush in the outskirts of biogroups and inside comprise mostly deciduous species of trees and bushes, which are more resistant to recreation and require less light.

Conclusions

1. Canopy density has the greatest impact on natural regeneration of recreational pine stands. With increasing density, the amount and occurrence of viable pine undergrowth decreases.

2. From pine stands most often used for recreation, natural regeneration of pine is most successful in *vacciniosum* type, while in *oxalidosum* type it fails to regenerate.

3. The number of viable pine seedlings under canopy is predetermined by forest litter thickness. When litter thickness exceeds 4 cm, viable pine seedlings are not detected.

4. The impact of recreation on natural pine regeneration is expressed through soil compaction and grass cover agressiveness in the stage of seed germination. With increasing compaction of upper soil horizons and grass cover agressiveness, the number and occurrence of viable seedling decreases.

5. Without assistance measures natural regeneration of sufficient density in recreational pine stands is impossible, although in individual cases, when it is necessary to form semi – open landscapes with groups of trees, sufficient self-regeneration of dense *cladoniosum* and *vaccinio-myrtillosum* type pine stands is possible without additional silvicultural measures.

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ВЛИЯНИЕ ЭКОЛОГИЧЕСКИХ ФАКТОРОВ НА ЕСТЕСТВЕННОЕ ВОЗОБНОВЛЕНИЕ СОСНЯКОВ РЕКРЕАЦИОННОГО НАЗНАЧЕНИЯ

Э. Репшас, Г. Урбайтис

Резюме

Провсдены исследования влияния некоторых экологических факторов на естественное возобновление типов сосняков, чаще всего используемых для рекреации. Установлены корреляционные связи между этими факторами и количеством

соснового подроста в древостоях. Выяснено, что на количество соснового подроста больше всего влияет сомкнутость древостоя (коэффициент корреляции в сосняках лишайниковых r=-0.361, в брусничных r=-0.226, в бруснично-черничных r=-0.356). Лучше всего сосна естественным образом возобновляется в сосняках брусничных, где изменчивость количества соснового подроста в зависимости от сомкнутости древостоя можно выразить логарифмическим уравнением y=-2278.9Ln(x) + 10709; (R^2=0.6706).

При повышении сомкнутости древостоя меняются и другие элементы лесной экосистемы. В большинстве исследованных типах сосняков при повышении сомкнутости древостоя увеличивается его полнота, мощность лесной подстилки, количество подроста других древесных пород и подлеска, уменьшается балл агрессивности травяной растительности на естественное возобновление.

Прорастание семян сосны под пологом материнского древостоя обусловливает мощность лесной подстилки, агрессивность травяной растительности на естественное возобновление, а также уплотненность почвы. Между этими факторами и количеством жизнеспособных всходов сосны в большинстве случаев установлены достоверные корреляционные связи. При мощности лесной подстилки более 4 см жизнеспособных всходов сосны не обнаружено.

Воздействие рекреации на естественное возобновление проявляется через уплотненность почвы в стадии прорастания семян. При повышении уплотненности почвы количество и встречаемость жизнеспособных всходов сосны постепенно уменьшается. При уплотненности почвы на глубине 3 см более 36 кг/см2 жизнеспособных всходов сосны уже не обнаружено.

Ключевые слова: естественное возобновление, сомкнутость древостоя, уплотненность почвы.