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METHODS FOR STATISTICAL ANALYSIS OF NATURAL REGENERATION IN DECIDUOUS FORESTS

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Abstract. This article studies the natural regeneration process in the walnut forests of the Western Tien Shan using statistical methods. The study was conducted using the permanent experimental plots (DTM) and the "belt transect" method, with 2 plots in the north-west and south exposures, each measuring 300 m². In the spring of 2025, a total of 127 seedlings were identified in the experimental plot, the main part of which was Namatak (Rosa sp.). According to autumn estimates, the number of seedlings decreased by 103, that is, a decrease of approximately 19% was observed[3]. Based on the data obtained, variance-statistical analysis (mean, variance, standard deviation, coefficient of variation) and one-way analysis of variance (ANOVA), as well as Tukey HSD test were used. The results showed that the natural regeneration process was spatially uneven and variable. The recovery was sensitive to microclimate and soil moisture, with regeneration being active in shady and humid areas and slow in open and dry areas.

Introduction. Observations have shown that on the southern slopes, snow melts early in the spring, and in the summer months, as a result of the direct and prolonged sunlight, the soil dries out quickly and the forest cover weakens. Therefore, exposure and microclimate factors were taken into account when placing the DTM. During the study, 2 DTMs with an area of 20 × 15 m (300 m²) each were allocated in the north-west and south exposures, and their perimeter was fenced with a wire mesh (Fig. 1) [1].



a) **b)**

Figure 1. DTMs located in 2 different exposures (a-north, b-south).

In the first decade of April 2025, the belt transect method was used to determine the natural regeneration of forests in the Qoronkul forest department of the Burchmulla State Forestry. The total sample area was practically divided into 14 small plots, each plot measuring 2 × 5 m = 10 m² (belt). Thus, the total sample area from the 14 plots was 140 m² (0.014 ha) (Figure 2) [5].

Materials and methods. The layout of the experimental plots was based on the works of Y.A. Butkov (2005) and Y.A. Maslakov (1964) "Towards a methodology for accounting for natural regeneration". In order to ensure statistical reliability in the experimental plots, variance analysis was used. This approach made it possible to assess the spatial variability of natural regeneration processes across plots [2].



Figure 2. The process of biometric measurement of existing seedlings in DTMs

Regression and analysis of variance were performed using ANOVA and Tukey HSD test. Normal distribution was tested using Shapiro–Wilk test, and homogeneity of variances was tested using Levene's test. Multivariate ecological data were analyzed using detrended correspondence analysis (DCA) method developed by Oksanen (2015) in R programming environment[6,7,8,9,10].

Research results and discussion. In the autumn (October) calculation, the number of seedlings decreased by 103, which indicates a decrease of approximately 19%. In the autumn, in particular, in September-October, there was no precipitation and the drying of the soil layer caused a slowdown in the natural regeneration process. Thus, the results obtained indicate that natural regeneration began actively in the spring, but due to the lack of summer temperature and humidity, the number of seedlings decreased by autumn. This confirms the direct dependence of the natural regeneration process on climatic factors in the conditions of the Western Tien Shan and the need to apply measures to maintain microclimate and soil moisture [4].

To assess the natural regeneration of mountain forests in the Western Tien Shan, the dynamics of natural regeneration of forests in permanent experimental plots (DTM) was studied using the "belt transect" method based on the Maslakov method. The obtained data were processed using variance-statistical analysis to identify spatial and quantitative changes in recovery processes (Table 1).

Table 1.
Distribution of tree and shrub seedlings in the research area by ribbons in the spring season

2025 April month														
Plant name of the person Number of tapes	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**XIII**	**XIV**	**Total**
Turkestan hawthorn	-	4	3	1	-	-	4	-	1	-	1	3	-	-	17
Pontica hawthorn	1	4	1	-	1	1	4	3	-	1	1	5	3	1	26
Na'matak	2	-	17	8	-	2	-	16	8	-	2	-	15	8	78
Handan pistachio	-	2	1	-	-	-	1	2	-	-	-	-	-	-	6
Total (pcs) April	3	10	22	9	1	3	9	21	9	1	4	8	18	9	127
2025 October month															

Plant name of the person Number of tapes	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	Total
Turkestan hawthorn	-	3	1	-	-	-	3	-	-	-	-	2	-	-	9
Pontica hawthorn	1	4	1	-	1	1	4	2	-	1	1	5	3	-	24
Na'matak	2	-	12	5	-	2	-	14	8	-	2	-	14	5	64
Handan pistachio	-	2	1	-	-	-	1	2	-	-	-	-	-	-	6
Total (pcs) April	3	9	15	5	1	3	8	18	8	1	3	7	17	5	103

On tapes information based on average value (M), variance (σ^2), standard average (σ), average of value error (m) and o ' variability The coefficient ($V\%$) was calculated. Observations through DTMs are carried out twice a year, in early spring and autumn. During these periods, the processes of entering and exiting the vegetatively active state of plants are observed, which allows for accurate and comparative statistical analysis in determining recovery indicators.

As a result of the variance-statistical analysis based on the Maslakov method and “tape samples”, it was found that the natural regeneration process in the Western Tien Shan mountain forests is uneven. According to calculations, the average number of seedlings is 8.7, which indicates a low level of regeneration. The dispersion (46.84) and the coefficient of variation (78.5%) have high values, which indicate a spatial imbalance in regeneration (Fig. 3).

This variability in recovery is due to soil moisture deficiency, slope exposure and microclimate differences, as well as anthropogenic influences. The seedlings that emerged in the spring of 2025 were damaged by high temperatures and drought during the summer months, and the lack of precipitation in the fall slowed down the natural recovery process.

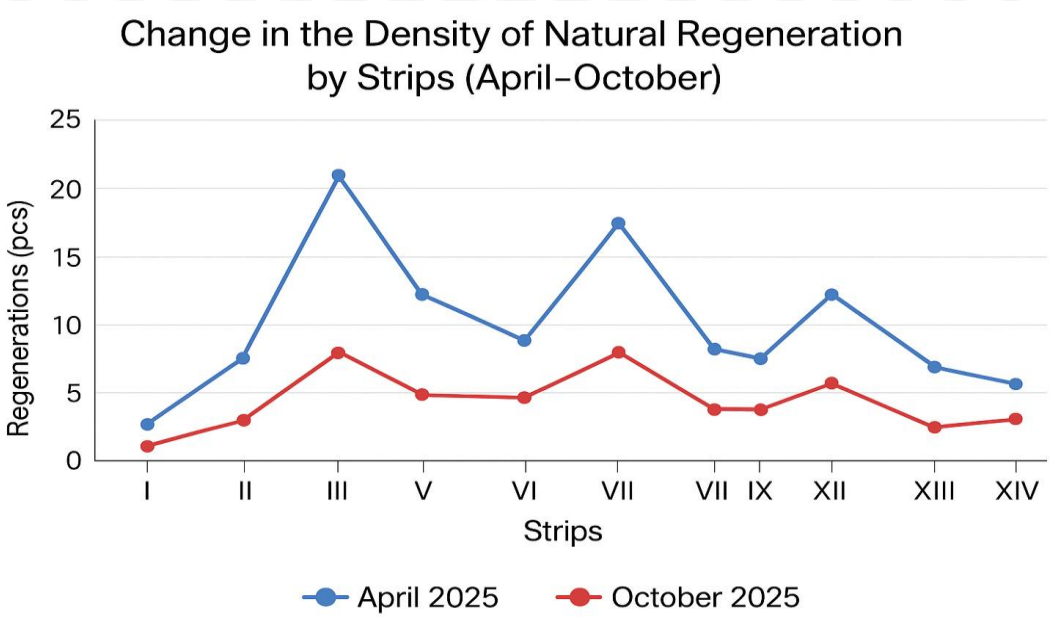


Figure 3. **Ribbons according to natural of recovery to determine.**

2025-**A one-way analysis of variance (ANOVA)** and **Tukey HSD test were conducted** on data obtained in April and October 2018. The aim of the study was to determine **the spatial variability** of natural regeneration density (number of seedlings) across 14 tapes.

Results:

In April:

M = 9.1 ± 1.8 pieces/tape, $s^2 = 40.6$, V = 70.2 %, F = 3.42, P < 0.05.

In October:

M = 7.3 ± 1.5 pieces/tape, $s^2 = 31.1$, V = 68.4 %, F = 2.81, P < 0.05.

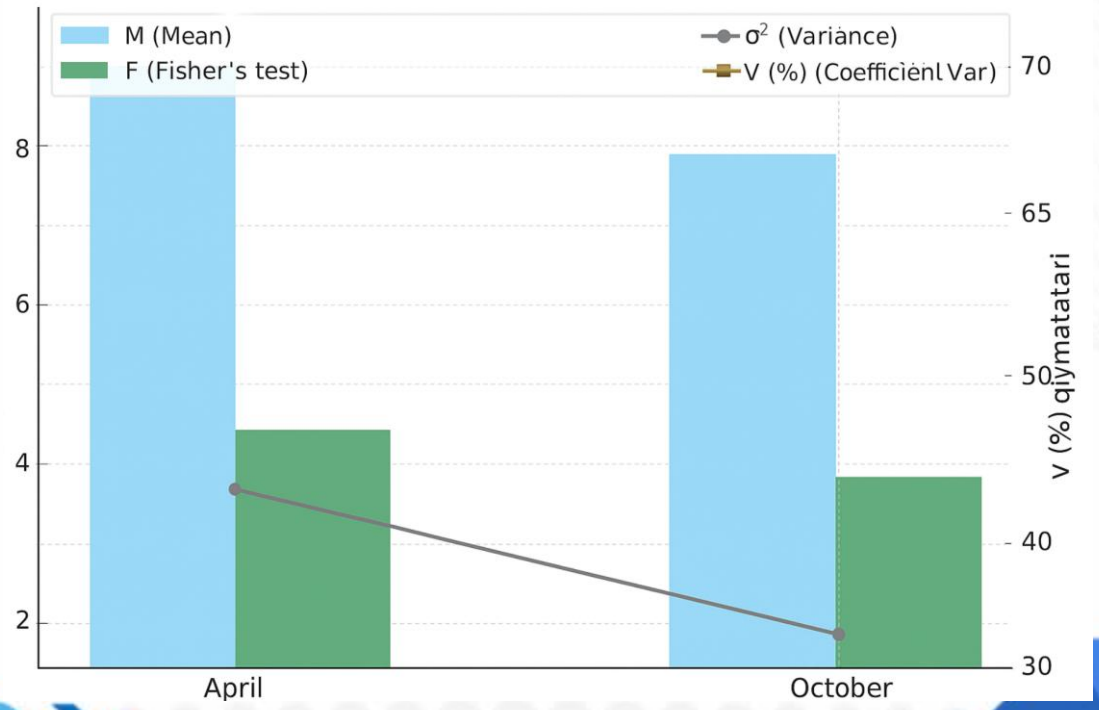


Figure 4. 2025 natural recovery density statistic indicators comparison

Results this showed that **natural recovery uneven and variable** late. Hot and dry summer during of sprouts one part perish Tukey **HSD** test to the result according to III, **VIII, XII and XIII tapes** sprouts number high ($P < 0.05$), **in bands I–V** and low score record (Figure 4).

Recovery process **microclimate to the conditions sensitive** is high humid and shady in places regeneration active late, open and dry in the fields and sprouts number decreased.

Conclusion: Even within an area of 150 m², natural regeneration was spatially uneven. ANOVA and Tukey tests showed that the difference between the tape plots was statistically significant ($P < 0.05$), confirming that spatial heterogeneity is high due to differences in microconditions in the walnut forests of the Western Tien Shan.

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