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Региональные риски искусственного лесоразведения в степной зоне Казахстана (на примере зеленого пояса г. Астаны)

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Введение. Риски искусственного лесоразведения связаны с региональными почвенно-климатическими условиями, способами создания лесных культур и финансированием лесохозяйственных работ. Социально-экономическое развитие региона, экологическая ситуация зависит, в том числе, и от состояния лесного хозяйства. Разработка системы лесовосстановления основывается на применении различных способов создания лесных культур, с целью выбора наилучшего результата при наименьших затратах. Одним из критериев является оценка приживаемости и сохранности деревьев во вновь созданных культурах. Цель данной работы заключается в изучении возможности пересадки достаточно взрослых деревьев для интенсификации лесовосстановительных работ. Правильный подбор способа искусственного лесоразведения уменьшает риск гибели деревьев из-за различных неблагоприятных факторов среды и оптимизирует финансирование необходимых лесохозяйственных мероприятий.

Результаты исследований. Изучалась динамика сохранности лесных культур, заложенных разными способами в 2010 году. Сохранность деревьев на низком местоположении резко уменьшилась в период 2013-2014 гг., в дальнейшем снижение показателя происходило без резких перепадов. С помощью рангового критерия Вилкоксона-Манна-Уитни выявлены статистически значимые различия в средней сохранности деревьев, причем различия в сохранности непересаженных и пересаженных на низком местоположении деревьев оказались самыми существенными. Сохранность пересаженных деревьев на высоком местоположении плавно снижалась по годам и достигла 31,9% в 2017 году. Сохранность непересаженных деревьев после 2015 года изменялась незначительно – на 1-2%, до этого наибольший отпад деревьев произошел в период 2013-15 гг. Построен прогноз сохранности деревьев на 2018 г., выраженный в %, при этом использовались модели линейной регрессии и скользящего среднего. Согласно прогнозам, сохранность в 2018 г. продолжит снижаться, тем не менее, в большинстве случаев более точным в смысле минимума средней относительной абсолютной ошибки аппроксимации оказался оптимистический прогноз, самая высокая сохранность прогнозируется у непересаженных деревьев, а самая низкая – у пересаженных на высоком месте, что необходимо учитывать при планировании лесохозяйственных работ по искусственному лесовосстановлению.

Выводы. С помощью статистического моделирования показано, что местоположение лесных культур и факт того, что деревья были пересажены, существенно повлияли на средние показатели сохранности. Получены прогнозы средней сохранности деревьев на 2018 г. Прогнозирование позволит правильно спланировать лесохозяйственные мероприятия по искусственному лесовосстановлению с учетом почвенных условий и месторасположения лесных культур. Продолжение исследований предполагает разработку рекомендаций по комплексной системе мер, основой которых является использование научно обоснованных лесохозяйственных технологий для обеспечения оптимального лесовосстановления.

Regional risks of artificial forestation in the steppe zone of Kazakhstan (the case of the green belt of Astana)

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Abstract. The article studies the regional features of reforestation in the steppe zone of Kazakhstan and the risks associated with the activities aimed at creation of forest plantations. The purpose of this work is to study the possibility of replanting adult trees to intensify reforestation. The authors studied the dynamics of Silver birch preservation for 2011-2015. The Mann-Whitney-Wilcoxon U test was used to prove the presence of difference between considering types of trees' average preservations. On the basis of the obtained data it was concluded that the forest plantations created by different methods differed significantly in

terms of preservation rate, as well as in the height and diameter of the trees. The forecasts of trees' preservations were found for 2018 using moving average and linear regression. The best forecasts were chosen by means of the mean relative absolute error of approximation. The results confirmed the initial hypothesis predicting significant differences between the used methods of artificial reforestation: non-replanted trees are expected to have the highest rate of preservation, whereas the trees replanted to a low location – the lowest preservation rate. The prediction of the preservation rate of forest plantations of Silver birch created by different methods will allow to reduce the risks when conducting forestry activities on artificial reforestation. Regional features suggest the development of recommendations for a comprehensive system of measures which are based on scientific forestry techniques to ensure optimum reforestation.

Introduction. The risks of artificial afforestation are connected with the regional soil and climatic conditions, the ways of creation of forest plantations and financing of forestry activities. The socio-economic development of the region and the environmental situation depend on the state of the forestry as well. The development of reforestation scheme is based on the application of different methods of forest culture creation in order to choose the most effective one at the lowest cost. One of the criteria is the evaluation of tree preservation of newly created plantations. The purpose of this paper is to study the possibility of replanting quite adult trees to intensify reforestation. The green zone around the city of Astana has been created for nearly 20 years. Within that time period, about 78 thousand hectares of artificial plantations were planted. While creating forest plantations, the foresters faced a major problem – almost half of the land allocated for the green zone was unsuitable [1,2]. Soil conditions are a limiting factor for growing valuable and ornamental conifer and deciduous trees in the green zone of the capital. The right choice of the method of artificial afforestation reduces the risk of tree death due to various adverse environmental factors and optimizes financing of necessary forestry activities [3,4].

Materials and methods. The research was carried out in the plantations of Silver birch of the strip type. In spring 2010, 8-year-old trees were replanted ball rooted by the mechanized method. In the strips, consisting of 4 rows, the lowest trees were selected for replanting in the spaces between strips. The distance between the replanted trees in the row and between rows was 3 m. The study of the growth and state of the replanted trees was carried out on the test plots at both low and high locations. In the strips with non-replanted trees, two specimens on both sides of the dug tree in the row were observed. The inventory indices of these trees were found out according to the methodical instructions [5], the height was measured with a measuring rail; the diameter with a caliper. The preservation rate was calculated in relation of the number of survived plants to the total number of replanted (non-replanted) trees and expressed as a percentage. With the help of the Wilcoxon-Mann-Whitney criterion the hypothesis about the existence of statistically significant differences in the tree preservation depending on such factors as being replanted and location was verified; we applied the moving average and linear regression models to predict the preservation for 2018. The best prediction was chosen according to the criterion of the minimum average relative absolute error of the approximation.

The results and discussion. Table 1 shows the data on the dynamics of the preservation rate of the studied forest plantations of Silver birch. Their preservation rate dramatically decreased in 2013-2014 at a low location, further decline in this parameter occurred with no sudden changes. The preservation of the replanted trees at a high location gradually declined and reached 31.9% in 2017. The preservation of non-replanted trees changed slightly – by 1-2% after 2015; the greatest loss of trees occurred in 2013-2015.

Table 1. Preservation of tested artificial plantations of Silver birch.

Considered trees	№ of trial area	Preservation by years (%)						
		2011	2012	2013	2014	2015	2016	2017
non-replanted trees (X)	1	99,1	96,1	96,1	81,6	79,8	79,8	77,6
	2	100,0	96,0	96,0	95,5	80,5	80,5	80,0
	3	100,0	98,0	98,0	91,0	90,0	88,0	87,0
	average	99,7	96,7	96,7	89,0	83,3	82,8	81,2
replanted trees at a low location (Y)	1	87,3	81,3	81,3	81,3	79,3	73,4	73,4
	2	72,7	71,3	71,3	69,3	58,7	56,7	50,6
	3	91,7	69,2	69,2	36,7	32,5	32,5	21,7
	average	83,9	83,8	83,8	64,3	58,6	54,2	49,0
replanted trees at a high location (Z)	1	57,6	51,1	51,1	51,1	49,7	30,5	29,9
	2	66,3	56,0	56,0	41,1	34,8	34,8	34,8
	average	61,5	53,3	53,3	46,7	43,1	32,7	31,9

Statistical hypothesis about the difference between average preservation levels of the trees was checked by means of the Mann-Whitney-Wilcoxon U test [6] which is based on statistics [7]

$$U_{min}\{U_X, U_Y\}, \quad (1)$$

where $U_{X(Y)} = mn + m(m+1)/2 - R_{X(Y)}$, $R_{X(Y)} = \sum_{i=1}^{m} r(X_i)$, is a sum of ranks X (average levels of non-replanted trees' preservation) or Y (average levels of preservation of replanted trees at a low location), m is a sample size of X, n is a size of Y. Here $m = n = 7$. The difference is recognized if U statistics (1) are small enough. For $m, n \leq 8$ the decision rule uses the specific tables with critical levels U_α for different significance level α. For $m = n = 7$ and $\alpha = 0.05$ $U_{0.05} = 8$.

As a result, we obtained $R_X = 50$, $R_Y = 26$, $U_X = 7$, $U_Y = 31$, $U_{XY} = 7 < U_{0.05} = 8$, therefore the statistically significant difference between average levels of preservation of replanted trees at a low location (Y) and non-replanted trees trees (X) is admitted with α = 0.05.

Similarly, the differences between average levels of preservation of trees replanted trees at a low location (Y) and high (Z) locations, high (Z) location and non-replanted trees (X) were confirmed in pairs with α = 0.05, because $U_{YZ} = 1 < U_{0.05} = 8$ and $U_{XZ} = 3 < U_{0.05} = 8$. Note, that the difference between average levels of preservation of trees replanted trees at a low (Y) and high (Z) locations was higher then for other pairs since $U_{YZ} = 1$ is minimum among U_{XY}, U_{XZ} and U_{YZ} . Thus, it can be argued that the location and the fact that the trees were replanted affected the average preservation rate.

We would like to emphasize that the initial height of the replanted plants was less than that of non-replanted plants (Fig. 1). During the observation period, the height of non – replanted plants increased by 1.5 times, of the replanted to a low location – by 1.3 times; the height of the birch replanted to a high location hardly increased. The study of biometric indicators revealed that the trees at a high location significantly lagged in growth from the trees growing at a low location. So, the average height was 4.9 and 6.0 m respectively, and the diameter was 4.7 and 6.1 cm. Moreover, the height of the trees at a low location slightly varied (V=11.7%), and this parameter in the trees at a high location significantly changed (V=22.4%).

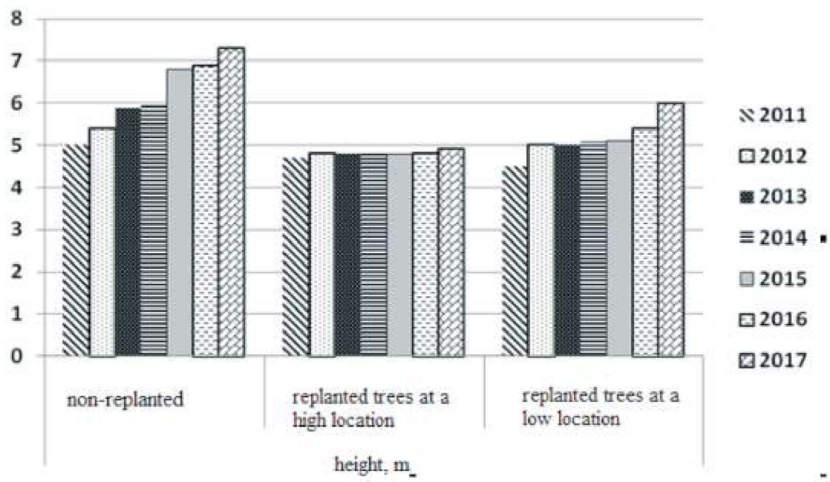

Fig. 1 Dynamics of changes in the height of forest plantations Silver birch.

We also predicted the average preservation levels for 2018 by using moving average and linear regression models [8]. The mean relative absolute error of approximation

$$A = \frac{1}{N}\sum_{i=1}^{N}\frac{|F_i - M_i|}{F_i},$$

was used to choose the best forecast. Here for $i = \overline{1,N}$ F_i are the real values, are modeling values, $N = 7$ is a number of considering years. The results of forecasting, error values A and achieved significance levels (p-values) of the Shapiro-Wilk' test of residuals' normality [9] are given in Tab. 2 and Fig. 2. As all of obtained p-values are very high we proved the normality of the residuals and so used linear regression models correctly.

Table 2. Forecasts of trees' preservations for 2018, %

Considered trees	№ of trial area	Forecasts of preservations for 2018, %		A		p-value of Shapiro-Wilk' test	Final forecasts of preservations for 2018, %
		Moving average	Linear regression	Moving average	Linear regression		
non-replanted trees (X)	1	79.1	71.0	0.03002	0.03058	0.877	79.1
	2	80.3	74.6	0.03209	0.03153	0.864	74.6
	3	88.3	83.6	0.01407	0.01099	0.834	83.6
	average	82.4	76.1	0.01630	0.01607	0.763	76.1

Considered trees	№ of trial area	Forecasts of preservations for 2018, %		A		*p*-value of Shapiro-Wilk' test	Final forecasts of preservations for 2018, %
		Moving average	Linear regression	Moving average	Linear regression		
replanted trees at a low location (Y)	1	75.4	71.1	0.01230	0.01778	0.330	75.4
	2	55.3	48.9	0.02652	0.03500	0.414	55.3
	3	28.9	4.8	0.14126	0.17451	0.126	28.9
	average	53.9	41.2	0.03922	0.04649	0.315	53.9
replanted trees at a high location (Z)	1	36.7	27.9	0.04273	0.09721	0.682	36.7
	2	34.8	23.7	0.07002	0.08605	0.501	34.8
	average	35.9	26.0	0.04164	0.04151	0.124	26.0

In addition, it should be noted that, in general, despite the overall decrease in the forest culture preservation index (see Tab.2), an optimistic forecast turned out to be more accurate in most cases. Meanwhile, the non-replanted trees are expected to have the highest preservation, while the replanted to a high location trees – the lowest, which must be taken into consideration when planning forestry work on artificial reforestation.

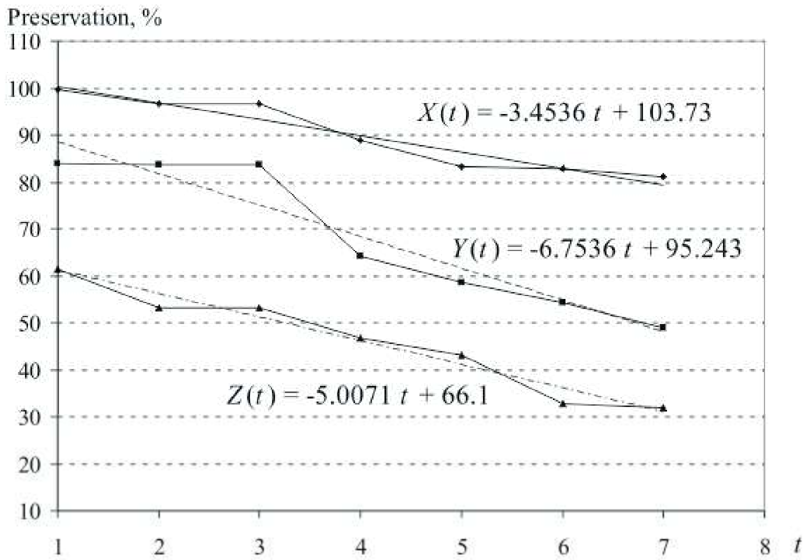

Fig. 2. Average preservations of trees (%) and corresponding linear regressions.

Conclusion. During the observation period, the height of non – replanted plants increased by 1.5 times, replanted to a low location – by 1.3 times; the height of the birch replanted to a high location hardly increased. Consequently, the trees replanted to a low location still grow fairly fast; and the growth rate is slightly lagging behind non-replanted plants, although they have a low rate of preservation. Statistically significant differences in the average tree preservation were revealed. Moreover, the differences in the preservation of non-replanted and replanted trees at a low location turned out to be the most significant. Thus, it can be argued that the location of the forest plantations and the fact that the trees were replanted affected the average preservation rates.

The forecast of indicators of preservation of the forest plantations of Silver birch created by different methods will allow to plan forestry actions for artificial reforestation correctly taking into account soil conditions and locations of forest plantations. The further research involves the development of recommendations for a comprehensive system of measures based on the use of science-based forestry technologies to ensure optimum reforestation. Reforestation activities should be planned and implemented taking into account renewable capacity of different forest plantations.

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Meteorological regime of the beginning and end of the heating season in Tomsk

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In today's world, in the climatic conditions of the Russian Federation, as in other countries, the problem of energy saving, reducing the cost of services creating a comfortable stay of a person in enclosed spaces is topical.

We consider it very important to create a model of thermal comfort for a resident of Tomsk. To solve this problem in this paper, an attempt is made to present and analyze some characteristics of the meteorological block of the model of thermal comfort in the example of Tomsk.

Initial data were the average daily temperature and humidity, wind speed of months of cold period of 2011-2017). The dates of a stable transition of an average daily temperature through 8 ° C were calculated by the method D.A. Pedia, the dates of the actual connection (shutdown) of heating in the city of Tomsk are borrowed from a public website.

One of the most important characteristics of the thermal regime, which is taken into account in the design of enclosing structures, is the number of degree-days (Q). The calculated Q values for the city of Tomsk showed their decrease (by ~ 2000 degree-days) from those given in the reference books of climate, which may be a consequence of the observed climate changes in the region.

As an index of the state of the thermal field surrounding a person in a residential building, it is possible to use indices of effective temperatures (ET - effective temperature, EET – equivalent-effective temperature, REET – radiation-equivalent-effective temperature). In the work, a REET is calculated, which takes into account temperature, relative humidity, wind speed and heating by solar radiation.

In addition, the calendar and temperature characteristics of the beginning and the end of the heating period were determined and analyzed in the work.

The following preliminary results were obtained:

1. It was revealed that the dates of actual switching on and off of heating very rarely agree with the meteorological conditions that characterize comfortable human thermal conditions.

2. In a market economy, energy and heat supply organizations are seeking to generate additional profits, extending the heating period due to earlier connection and later shutdown. For example, in the spring of 2015, the date of the actual heating shutdown is May 12. In this case, the dates for the end of the heating season for SNiP (Construction Regulations and rules of the Russia Federation) are 22 and 24 April (for REER and for the actual temperature, respectively). In autumn 2011, the date of actual connection of heating was observed on September 22, when the dates for the beginning of the heating season for SNiP - October 20 (both for REET and for actual temperature).

3. To resolve the revealed discrepancy of dates it is possible to create a complete model "building - man", in which, in addition to meteorological, both social and psychological factors will be included. In our opinion, it is extremely important to create a model of thermal comfort for a resident of Tomsk.