IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Assessment of the influence of natural and climatic conditions on forest carting out

Assessment of the influence of natural and climatic conditions on forest carting out

A Mokhirev*, N Bragina, S Medvedev

Lesosibirsk Branch of Reshetnev Siberian State University of Science and Technology, 29 Pobedy Street, Lesosibirsk 662543, Russian Federation

*Corresponding email: ale-mokhirev@yandex.ru

Abstract. There were many factors that influence the volume of forest carting out. They were divided into managed and unmanaged. The human impact on unmanaged factors was minimized. These included the natural and climatic conditions under which the wood carting out took place. However, these factors were among the most significant, especially in Siberia, in sharply continental conditions. The purpose of this study was to assess the influence of natural and climatic factors on forest carting out using the mathematical tool. For research data were collected on the volume of daily carting out of wood from forest areas for several years in the winter time. For the same dates, information was collected on climatic conditions: air humidity; wind speed; type of precipitation; precipitation duration; maximum air temperature; minimum air temperature; amount of precipitation; visibility range; snow depth. Multivariate analysis was performed using the Microsoft Office Excel software product, as well as controlling calculations in the Statistica 10.0 statistical product. As a result, the linear multiple regression equation was obtained.

1. Introduction

There were two types of logging roads: year-round or temporary use [1]. The main means of transport were timber road trains on this type of road. The main purpose of each logging road was to take out the planned amount of wood in a given time, while minimizing costs and using the fleet effectively. [2]. A significant number of studies [1, 3-6] highlight a number of key issues in this area. Among them were:

- the problem of increasing transport accessibility of forest resources;
- the need to take into account and neutralize the negative impact of factors that affect the carting out of harvested wood;
- minimize costs across the entire supply chain.

These problems were identified when analyzing the works of both domestic and foreign scientists. All these problems were affected by natural and climatic factors.

Using one of the classification options, natural production conditions could be divided into two groups: internal and external [7]. The first of them were determined by a specific structural scheme and the organization of its use. For example, production conditions, basic parameters and design features of machines. The seconds were determined by the action of the environment.

It is obvious that internal factors directly depend on the way of organizing logging operations. At the same time, managing external factors was extremely difficult, and often impossible. Therefore, there was a need to minimize their influence.

This approach has led to a number of important consequences for science and practice. The main one was the need for additional research on the capacity of logging roads. This term was interpreted in the scientific literature [8, 9] as the largest volumes of cargo that could pass through a certain section of road per unit of time in one or two directions under certain weather, climatic and road conditions. The main traffic was directed in one direction when carting out wood from the forest.

The capacity of General-purpose roads has been studied in sufficient detail to date. However, the problem of the capacity of logging roads was not widely presented in the scientific literature, so additional and targeted research in this direction was necessary.

Among the studies in this direction, the research of Platonova E V was highlighted [10]. She suggested defining the capacity as the sum of the road and siding capacity. However, in her work, she did not take into account external factors that affected the time of passing through the roads, which may had a different nature. Many unmanageable natural and climatic factors affected the passage time [5, 6].

Uncontrolled natural and climatic factors are natural phenomena, as well as the influence of climate on road conditions, in which human impact is minimized.

In foreign sources on this issue, heavy rain was given as the main role in reducing the capacity [2, 3]. They blured roads, thus limiting traffic. In this connection, the authors recommended a variety of drainage structures for different types of soil in order to solve the problem.

From the information obtained during the analysis of literary data, it followed that in the materials of domestic and foreign studies, there were many different factors that affected the capacity of roads. However, a comprehensive assessment of the impact of unmanaged factors in different seasons of the year was practically not carried out.

The purpose of this study was to assess the influence of natural and climatic factors on forest carting out using the mathematical tool.

2. Methods and Materials

In the framework of this study, the analysis of the influence of natural and climatic factors on the carting out of forest on roads of year-round and temporary use in the Yenisei district of the Krasnoyarsk territory of the Russian Federation in the winter and winter-spring periods was carried out. The export route passed through year-round and seasonal roads. The route mainly passed through flat areas. The total distance of wood transportation is 226 km.

Statistical data on indicators characterizing natural and climatic conditions were taken for the period from 2017 to 2019. At the same time, the periods of wood carting out were characterized by the following time intervals [11]:

1. Winter period: 15.12. – 31.12.2017., 17.12. – 20.03.2018., 01.01. – 20.03.2019.
2. Winter-spring period: 21.03 – 10.04.2018., 21.03. – 08.04.2019.

The influence of the following factors on wood carting out was investigated.:

- air humidity (x_1);
- wind speed (x_2);
- type of precipitation (x_3);
- precipitation duration (x_4);
- maximum air temperature (x_5);
- minimum air temperature (x_6);
- amount of precipitation (x_7);
- visibility range (x_8);
- snow depth (x_9).

Dependent variable taken as y - volume of forest carting out (capacity).

Multivariate analysis was performed using the Microsoft Office Excel software product, as well as controlling calculations in the Statistica 10.0 statistical product.

In accordance with the subject of the study, in addition to multivariate analysis, the dependence of carting out on individual factors was evaluated. The Statistica 10.0 software package was used to build regression mathematical models and calculations.

3. Results and Discussion

In the course of the study, it became necessary to translate qualitative indicators of precipitation into quantitative. In particular, the existing precipitation database contains information about the type of precipitation-fog, snow, haze, etc. Such data cannot be used for calculations.
The following coefficients were assigned to precipitation types (x_3):
– continuous light snow– 3;
– fog or ice fog– 2;
– drifting snow low- 1;
– shower sofslight snow– 4;
– haze – 0.5.

If precipitation increased or stopped during the day (x_4), they were assigned the following coefficients:
– snow or sleet– 2;
– fog or ice fog– 1;
– a sand or dust storm or a blowing snow – 3;
– heavy rain– 4;

The study evaluated multiple regression, which was a relationship equation with several independent variables:

$$y = f(x_1, x_2, \dots, x_m), \tag{1}$$

where, y – was a dependent variable (a result attribute); $x_1, x_2, \dots, x_m$ – were independent variables (factors).

Multiple regression was used in situations where a single dominant factor cannot be identified out of the many factors that affected a dependent variable, and therefore it is necessary to take into account the influence of several factors.

The main purpose was to build a model with a large number of factors. In this case, their combined impact on the simulated indicator was determined. The analysis was carried out in the following stages.

3.1. Stage 1 - selection of factors

First the factors are selected based on the nature of the problem.

Then formal statistical criteria were applied, for example, the presence of a high correlation was detected by the value of the linear correlation coefficient $r_{x_i x_j}$. If the condition $r_{x_i x_j} \geq 0.8$ was met, then the factor variables $x_i,\ x_j$ were in linear relationship with each other, and the variables $x_i,\ x_j$ were called explicitly collinear.

Only one of the collinear factors was included in the regression equation. In this case, preference was given to the factor that, with a high degree of closeness to the result, had the least closeness to other factors.

In the course of the study, a correlation matrix was formed using the "Data. Data analysis. Correlation" of the MS Excel table processor (table 1).

It follows from the matrix that x_3 and $x_4 (r_{X_3 X_4} \geq 0.8$ were collinear, so it was necessary to exclude one of the factors. The x_4 factor was the least closely related to other factors, so the x_3 factor was included in the regression equation

Thus, the regression y was based on factors $x_1, x_2, x_3, x_5, x_6, x_7, x_8, x_9$

Table 1. Correlation matrix.

	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
y	1									
x_1	0.11	1								
x_2	-0.82	-0.16	1							
x_3	-0.56	0.11	0.52	1						
x_4	-0.59	0.03	0.55	0.89	1					
x_5	0.21	-0.08	-0.24	-0.19	-0.18	1				
x_6	0.28	-0.1	-0.31	-0.27	-0.26	0.74	1			
x_7	0.74	0.04	-0.68	-0.46	-0.49	0.18	0.24	1		
x_8	-0.88	-0.07	0.76	0.56	0.62	-0.27	-0.37	-0.66	1	
x_9	0.46	0.05	-0.5	-0.39	-0.42	-0.02	0.15	0.4	-0.5	1

Figure 1 shows statistical indicators of the dependent variable y and independent variables $x_1, x_2, x_3, x_5, x_6, x_7, x_8, x_9$. There was a significant mutual change in y and independent variables.

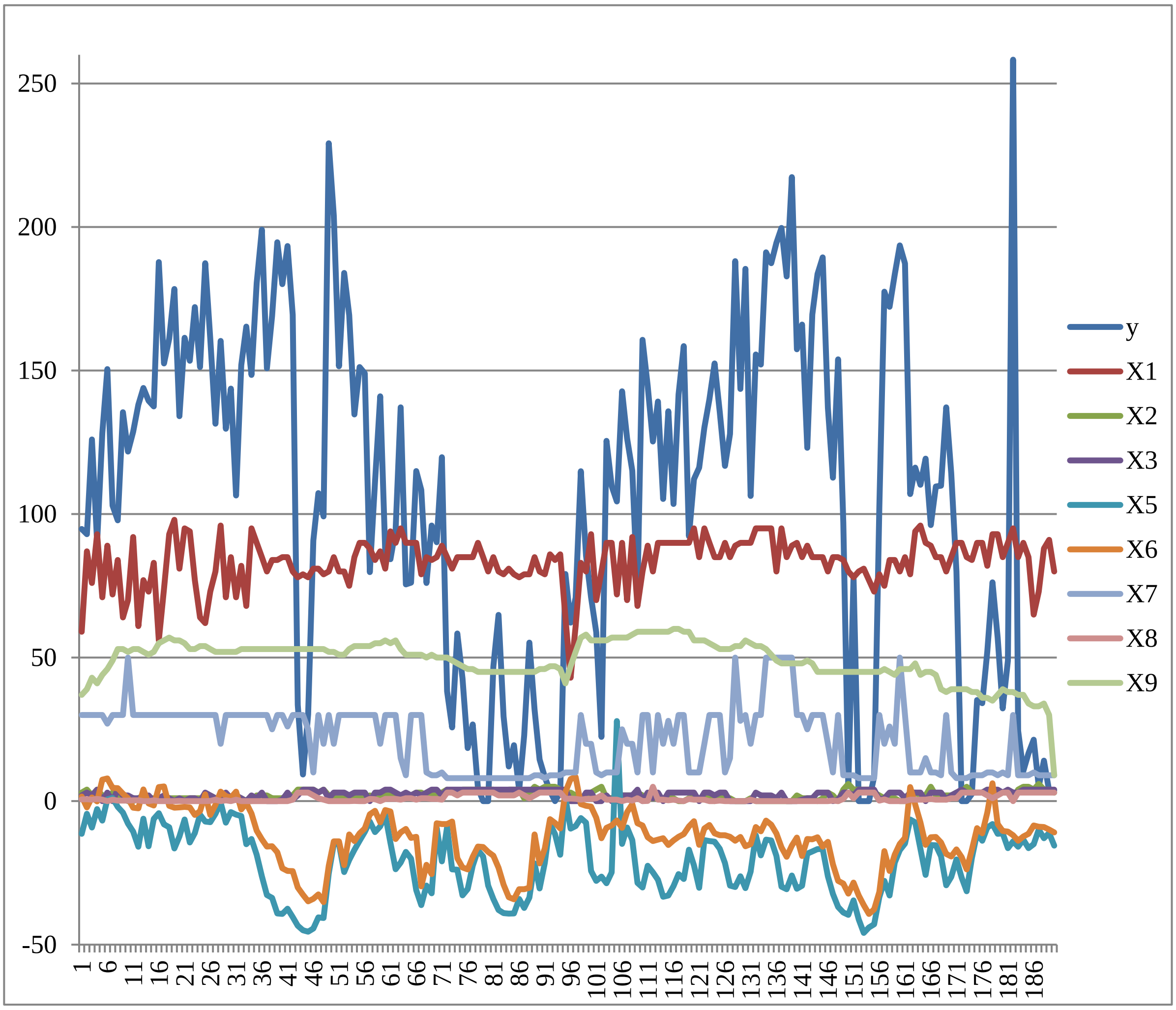

Figure 1. Statistical data on natural and climatic conditions and forest carting out in the winter and winter-spring periods.

3.2. Stage 2 - construction of the linear multiple regression equation

The "Data. Data analysis. Correlation" function of the MS Excel table processor was used to construct the linear regression equation:

1) the function was opened through the menu items: <Data> - <Data Analysis> - <Regression>;

2) cells that contain input data for the y and x_i variables were specified;

3) if there was no free term in the regression equation, we selected the "Constant is zero" checkbox;

4) we specified where the function results were displayed (output range on this worksheet, new worksheet ply, new workbook);

5) the required values of the coefficients of the linear regression equation (a, b_i) were taken from the "Coefficients" column of the regression results table.

The results of the function were shown in the tables 2, 3, 4.

Table 2. Results of correlation analysis.

Multiple R	0.92	Multiple correlation coefficient R
R square	0.85	Coefficient of determination R^2
Adjusted R-square	0.84	Modified determination coefficient R
Standard error	244.90	Standard error in defining *y*
Observations	190.00	Number of observations

Table 3. Results of variance analysis.

Explanations	Number of degrees of freedom df	The sum of the squared deviations SS	The mean sum of squares MS	Fisher's F-statistic F	Significance level Significance F
Regression	8	60273942.75	7534242.84	125.59	1.07338E-69
Residual	181	10858085.86	59989.42		
Total	189	71132028.61			

Table 4. The results of the regression analysis.

Explana tions	Coefficients of the regression equation	The standard error of determination of the coefficients	t-statistics	Probability of error	Lower 95% - limits	Upper 95% - limits
	Coefficients	Standard error	t-stat	P-Value	Lower 95%	Upper 95%
y	1373.73	258.62	5.31	3.16E-07	863.43	1884.03
x_1	1.87	2.19	0.85	0.40	-2.46	6.19
x_2	-106.98	20.95	-5.11	8.28E-07	-148.32	-65.64
x_3	-27.88	15.87	-1.76	0.08	-59.19	3.43
x_4	0.56	3.08	0.18	0.85	-5.51	6.64
x_5	-4.32	3.66	-1.18	0.24	-11.54	2.91
x_6	10.77	2.22	4.85	2.61E-06	6.39	15.15
x_7	-287.12	26.39	-10.88	1.55E-21	-339.19	-235.05
x_8	-3.39	3.06	-1.11	0.27	-9.42	2.64

Table 4 shows that the regression equation had the following form:

$$y = 1373.73 + 1.87 \cdot x_1 - 106.98 \cdot x_2 - 27.88 x_3 + 0.56 \cdot x_4 - 4.32 \cdot x_5 + 10.77 \cdot x_6 - 287.12 -\cdot -x_7 - 3.39 \cdot x_8 \quad (2)$$

IOP Conf. Series: Earth and Environmental Science **507** (2020) 012021 doi:10.1088/1755-1315/507/1/012021

3.3. Stage 3 - determining the values of the multiple correlation coefficient R and the determination coefficient R^2

The multiple correlation coefficient characterized the closeness of the connection of the considered set of factors with the studied argument, or, in other words, estimated the closeness of the joint influence of factors on the result and was calculated using the formula:

$$R = R_{yx_1x_2\dots x_m} = \left(1 - \frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y}_i)^2}\right)^{0.5} \quad (3)$$

where, *n* – was the number of observations; x_i, y_i – observational data; $\bar{y},$ - mean values of variables and y; $\hat{y}_i$ - values of the variable y, calculated using the multiple regression equation - $\hat{y} = f\,(x_1, x_2, \dots, x_m)$.

The square of the multiple correlation coefficient was called the determination coefficient and was denoted by R^2. The value of the determination coefficient was used to evaluate the quality of the regression model. The larger the value, the better the model was consistent with the observational data.

The values R and R^2 are also available in table 1

R = 0.92; R^2= 0.85.

According to Chaddoke scale qualitative assessment of the closeness of the correlation was very high for R = 0.92, and is high for R^2 = 0.85.

3.4. Stage 4 - checking the significance of the regression equation

The actual value of the F – criterion and its critical value of the F were calculated.

The condition that F calculated > F critical was checked. If the condition was met, the equation was considered statistically significant.

The actual value of the criterion we calculate using the formula

$$F = \frac{R^2}{1-R^2} \cdot \frac{n-m-1}{m}, \quad (4)$$

where, R^2 – is a coefficient of determination; *n* – number of observations; *m* – number of factors;

$$F = \frac{0.847353069}{1-0.847353069} \cdot \frac{190-8-1}{8} = 125.59285$$

The same value was available in table 2, "Fisher statistics F".

F critical was the table value of the F-test at the significance level α and the number of degrees of freedom $k_1 = m, k_2 = n - m - 1$.

The table value of the F-test was determined using the function MS Excel «FINV»

- significance level α = 0,05
- the number of degrees of freedom k_1= 8, k_2= 190 – 8 – 1=181.
- F critical = FINV (0.05; 8; 181) = 0.99993973

Since F > F critical, therefore the equation is significant.

It followed from table 2 that the significance level of the regression equation $\alpha = 1.07338 \times 10^{-69}$, that is obviously lower than the required level α = 0.05, so the equation was significant even at a lower significance level.

3.5. Stage 5 - checking the significance of the coefficients of the regression equation

The Student's t-test is applied. Table 3 shows that the significance levels of the regression equation coefficients had the next values:

$$\alpha_a = 3.16 \times 10^{-7};\ \alpha_{b_1} = 0.39;\ \alpha_{b_2} = 8.28 \times 10^{-7};\ \alpha_{b_3} = 0.08;$$
$$\alpha_{b_4} = 0.85;\ \alpha_{b_5} = 0.24;\ \alpha_{b_6} = 2.61 \times 10^{-6};\ \alpha_{b_7} = 1.55 \times 10^{-21};$$
$$\alpha_{b_8} = 0.27.$$

Thus, the estimates of parameters$\alpha_a, \alpha_{b_2}, \alpha_{b_6}, \alpha_{b_7}$ (wind speed, visibility range, amount of precipitation) were significant at the significance level of α = 0.05, and the values of $\alpha_{b_1}, \alpha_{b_4}, \alpha_{b_5}$, α_{b_8}were not significant at the significance level of α = 0.05.

3.6. Stage 6 - construction of the linear multiple regression equation taking into account only significant factors

Significant factors were $\alpha_{b_2}, \alpha_{b_6}, \alpha_{b_7}$.

To construct a linear regression equation, we used the function «Data. Data analysis. Regression" of the MS Excel table processor.

The corresponding data ranges were set in the regression parameter input window, and the following results were obtained:

multiple correlation coefficient R = 0.9167540,

coefficient of determination R^2 =0.840438,

F= 326.5639,

significance level of the regression equation α = 0.0001.

The regression equation had the next form:

$$y = 1332.44 - 108.88 \cdot x_1 + 10.97 \cdot x_2 - 281.06 \cdot x_3. \tag{5}$$

4. Conclusion

As a result of the study, the following results were obtained:

1) Checking factors for collinearity showed that factors x_3 and x_4 are collinear and factor x_4 is excluded.

2) The linear multiple regression equation had the form:

$$y = 1373.73 + 1.87 \cdot x_1 - 106.98 \cdot x_2 - 27.88 x_3 + 0.56 \cdot x_4 - 4.32 \cdot x_5 + 10.77 \cdot x_6 - 287.12 -\cdot x_7 - 3.39 \cdot x_8 \tag{6}$$

The main task of multiple regression was to build a data model containing a huge amount of information in order to further determine the influence of each of the factors individually and in their totality on the indicator that needs to be modeled, and its coefficients. It is also possible to use a regression line to predict the y value by the x values in the limit of the observed range.

3) The values of the coefficient of multiple correlation R and the coefficient of determination R^2 were R = 0.92; R^2= 0.85.

In winter, the carting out of forest depends on the air temperature, precipitation types, and their quantity. The correlation coefficient for carting out to intermediate warehouses was higher than for lower warehouses. In both cases, the coefficient was higher than 0, 7, that is, the influence of factors was strong.

4) Checking the significance of the regression equation.

The constructed regression equation was significant at the significance level α = 0.05.

5) Checking the significance of the coefficients of the regression equation.

Thus, the estimates of parameters $\alpha_a, \alpha_{b_2}, \alpha_{b_6}, \alpha_{b_7}$ (wind speed, visibility range, amount of precipitation) were significant at the significance level of α = 0.05, and the value of $\alpha_{b_1}, \alpha_{b_4}, \alpha_{b_5}$, α_{b_8} were not significant at the significance level of α = 0.05.

6) Construction of the linear multiple regression equation taking into account only significant factors. The regression equation had the next form:

$$y = 1332.44 - 108.88 \cdot x_1 + 10.97 \cdot x_2 - 281.06 \cdot x_3 \tag{7}$$

Acknowledgement

The reported study was funded by RFBR, the Government of Krasnoyarsk Territory, Krasnoyarsk Regional Fund and LLC "Krasresurs 24", project number 20-410-242901; by Russian Foundation for Basic Research, Government of Krasnoyarsk Territory, Krasnoyarsk Regional Fund of Science, to the research project: «Research and modeling of economic development of the forest industry in the region in the context of climatic conditions and resource potential», grant № 18-410-240003.

References

[1] Grigorev I V, Khitrov E G, Kalistratov A V and Stepanishcheva M V 2014 Dependence of filtration coefficient of forest soils to its density. *Proceedings of the 14th International Multidisciplinary Scientific Geoconferences, "Water Resources. Marine and Ocean Ecosystems"*, 16 -26 June 2014, (Albena, Bulgaria). vol 2 pp 339-44

[2] Cenderelli D, Clarkin K, Gubernick R and Weinhold M 2011 Stream simulation for aquatic organism passage at road-stream crossings. *Transportation Research Record*. 2011. **2203** pp 36-45.

[3] Luce Ch H 1997 Effectiveness of road ripping in restoring infiltration capacity of forest roads. *Restoration Ecology*. 1997. **5. 3**. pp 265-70

[4] Wong J Y and Reece A R 1966 Soil Failure Beneath Rigid Wheels. *Proc. 2nd Int. Conf. of the International Society for Terrain Vehicle Systems. (Toronto. Canada: University of Toronto Press)*, 1966.

[5] Vasil'ev A P 1986 *Design of roads taking into account the influence of climate on traffic conditions*. (Moscow. Transport), p 248

[6] Vinogorov G K 1982 Some forest exploitation characteristics of soil conditions and terrain. *Issues of technology and mechanization of logging operations. Works of tsniime. (Khimki: tsniime)*, pp 5-7

[7] Lukashevich V M and SHHegoleva L V 2014 Methods of planning the development of forest resources taking into account the seasonality of logging. *Global scientific potential* **8 (41)** pp 134-136

[8] Bellman R 1958 On a routing problem. *Quart. of Applied Mathematics*, **16** p 87

[9] Mokhirev A P, Medvedev S O and Smolina O N 2019 Factors affecting the capacity of logging roads. *Forest Engineering journal* **9 3 (35)** pp 103-113

[10] Platonova E V 2006 *Justification of the capacity of logging roads at different speed modes and models of traffic flow* (Arkhangelsk). p 151

[11] Mokhirev A P, Pozdnyakova M O, Medvedev S O and Mammatov V O 2018 Assessment of availability of wood resources using geographic information and analytical systems (the Krasnoyarsk territory as a case study). *JAES* 2018**. 3 (16)** pp 313-9. DOI: 10.5937/jaes16-16908