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Optimization of carrier vehicles for the transportation of rotted straw

The use of roll technology in our country's flax cultivation is hampered due to the lack of special transport. The article analyses and determines the volumes and legs of transporting rotted straw from fields to the Vologda oblast flax-processing plants; several perspective options for using technical means available at enterprises are proposed for transportation of flax rolls. Their influence on saving of time, fuel, and on labour productivity increase is shown.

Flax growing rotted straw rolls, optimization of transportation.

Dmitry F.
OROBINSKIY
Doctor of Technical Sciences, Professor at the Vologda State Dairy Farming Academy named after N.V. Vereshchagin
ic1@mf.molochnoe.ru

Roman A.
SHUSHKOV
Senior Lecturer at the Vologda State Dairy Farming Academy named after N.V. Vereshchagin
roma970@mail.ru

Flax is a multi-purpose plant, and in recent years it has been used for producing new kinds of commodity products in various spheres, from medicine to automotive industry. Flax has turned into a strategic crop.

Fiber flax in the North-West region of Russia accounting for about 15 % of all flax crops in the country is grown in special climate and environmental conditions. They influence the choice of technology, machines and labour organization [6].

Flax cultivation and processing in the Vologda Oblast historically is deeply rooted and has great economic and social importance.

The following data shows the peasants' incomes from flax cultivation in tsarist Russia: in the Pskov province they reached 7.5 million rubles, in the Yaroslavl province – about 6 million rubles in the Tver province – 10.8 million rubles, in the Vologda province – 3.5 million rubles.

The price of dew retted flax (vilegodsky, lalsky, sukhonsky, brusenetsky, verkholalsky) produced in the Vologda province was much higher than that of Pskov and Livland water retted flax. The annual revenues of Russian treasury from flax sales reached up to 90 million rubles in gold [1].

Head of the oblast agricultural administration Yu.A. Yarushnikov described the economic importance of flax for Vologda Oblast farms in the 1970-s as follows, "There is no other branch of crop husbandry that would be cost-effective to the same extent as flax cultivation, and that would help economically weak farms stand on their own feet." [3].

Today, the best and most expensive clinics of the world provide their staff with linen uniform, and wards are decorated with linen. Accommodation in such wards is very expensive [2].

The works of A.V. Maklakhov [4, 5] reveal the essence of the pilot project "Development of the Vologda Oblast flax complex through intersectoral and interterritorial cooperation". An important role in the project belongs to optimizing the number of flax-growing farms up to 24 by 2014, and flax-processing plants – up to 10.

He claims in another work, that linen has become a popular brand. This is confirmed by the wide use of linen in medicine, production of clothes, new fabrics, developed by OJSC Vologda Textile, and it allows exporting the products abroad.

The Strategy of machine and technology modernization of agriculture in Russia for the period up to 2020 indicates that the cost of an upgraded farm machinery and vehicle park may amount to some 2.8 up to 3 trillion rubles, including vehicles – 150 billion rubles. Amount of agricultural carrier vehicles should be optimized at the level of 750 – 850 thousand units.

Priority development of motor transport as compared to tractor transport in Russia can be explained by a considerable average range of cargo transportation as well as a lower cost of motor transportation. Russian agriculture experiences a considerable lack of trucks with different cargo-carrying capacity. Demand for production trucks in the village is rather low because of their insufficient suitability for the operational environment. There are practically no all-terrain trucks, suitable for use in off-road conditions. The shortage of vehicles is acutely experienced in all enterprises, from small to large ones.

Obviously, the state of affairs concerning the provision of agri-sector with new and modern vehicles, suitable for operating in off-road conditions and areas which are difficult to access, as well as on general purpose roads, can't be improved in short term at the expense of domestic production or due to the expansion of vehicles and machinery import [7].

Cultivation of agricultural crops allows for using different technologies, suitable for a particular enterprise. The optimization task is to organize transport-technological support, which would enable to manufacture products with the lowest energy costs.

A roll method of rotted straw gathering is widespread in flax-growing farms, as the share of manual operations in the technological chain from loading the rotted straw to its delivery to a flax-processing plant is reduced. The total labour input during rotted straw harvesting and realization is reduced 9.5-fold, and the need for means of transportation – 2 – 2.5-fold.

Unfortunately, the low performance of vehicles leads to the fact that rotted straw rolls often remain in the field for a long time, get caught in the rain and are spoiled. Trucks and tractor trailers of different types are not quite suitable for the transportation of rolls, as the dimensions of their bodies provide low index of cargo carrying capacity usage. This leads to a significant increase in costs for transporting raw flax to flax-processing plants, which reduces crop profitability.

In Western European countries the transportation of rotted straw rolls is effected using specially equipped road trains or large tractor trailers, in which the rolls are placed in three tiers.

For the solution of the optimization task, rotted straw transportation distances to Vologda Oblast flax-processing plants were analyzed, technical means with greater load index available at the enterprises, more effective variants of their usage are offered.

Analysis of volumes and legs of transporting rotted straw to the nearest flax-processing plant for 2010 – 2011 produced the following results: more than 90 % of the region's flax-growing farms have the leg of transporting that equals 33...39 km, for the rest it equals 160...200 km. This means that transportation costs significantly reduce crop profitability at these farms.

We have studied and proposed a number of perspective options of rotted straw transportation to the nearest flax-processing plants.

It is proposed to use the following transport vehicles available at the Oblast's enterprises: a truck KAMAZ-43118 with a trailer MAZ-837810, a truck MAZ-6310 with a trailer MAZ-837810, a tractor Fendt-930 with a large trailer, suitable for rotted straw transportation.

In this connection, it is necessary to substantiate the application of technical means, ensuring the increase of cargo carrying capacity usage index, transportations efficiency, labour productivity increase.

In order to substantiate the weight of transported rolls, we use average roll dimensions: height H_r = 0.7...1.1 m, diameter D_r = 1.2 m, weight q_r = 200...240 kg.

Number of rolls, placed in the vehicle:

$$N_r = \frac{l_p}{D_r} \cdot N_{rws} \cdot N_{trs}, \qquad (1)$$

where: l_p – platform length, m;

N_{rws} – number of rows;

N_{trs} – number of tiers.

Weight of the transported cargo:

$$W_r = q_r \cdot N_{trs} \qquad (2)$$

Cargo carrying capacity usage index is determined as follows:

$$I_{crg} = \frac{W_r}{q_c}, \qquad (3)$$

where q_c – certified cargo carrying capacity of a vehicle, t

The obtained data are summarized in *table 1.*

The proposed vehicles need to be provided with additional equipment: reinforced front and side pillars, tying them together with a cable 12...14 mm in diameter in two rows.

Table 1. Main indicators of rolls transporting options under consideration

Vehicle type	Indicators	Existing option	Proposed option
KAMAZ-43118 with a trailer	Number of tiers	2	3
	Weight of rolls, t	8.8	13.2
	Number of rolls, pcs.	44	66
	Cargo carrying capacity usage index, I_{crg}	0.34	0.51
MAZ-6310 with a trailer	Number of tiers	2	3
	Weight of rolls, t	9.6	14.4
	Number of rolls, pcs.	48	72
	Cargo carrying capacity usage index, I_{crg}	0.34	0.51
Fendt-930 with a trailer	Number of tiers	2	3
	Weight of rolls, t	8.8	13.2
	Number of rolls, pcs.	44	66
	Cargo carrying capacity usage index, I_{crg}	0.67	1.0

Analysis of data in the table shows that the increase in the number of tiers from 2 to 3 leads to the 1.5-fold increase in the weight of transported rolls, the road trains cargo carrying capacity usage index will increase from 0.34 to 0.51, as for a tractor Fendt-930 with a trailer, it will equal 1.0.

A vehicle's trip duration (T_t), when transporting rotted straw to a flax-processing plant, is determined according to the formula:

$$T_t = T_c + T_{op} + T_l + T_{lv} + T_{pu} + T_u + T_{at} + T_{nl} + 2T_w + 2T_p \qquad (4)$$

T_c – time, allocated for a vehicle's daily technical checkup, h;

T_{op} – time required for setting the equipment in operating position, h;

T_l – loading time, h;

T_{lv} – travelling time of a loaded vehicle, h;

T_{pu} – time required for preparing a vehicle for unloading, h;

T_u – vehicle's unloading time, h;

T_{at} – time required for arranging the equipment into transport position, h;

T_{nl} – no-load run time, h;

T_w – time required for weighting of the cargo, h;

T_p – time required for confirming paperwork, h.

Time allocated for a vehicle's daily technical checkup is determined on the basis of established standards, we assume that T_c = 0.24 h, it is divided by the number of trips per shift.

Knowing the specifications of PRU-05/06 loader, we determine its performance: W_l = = 210 rolls/h. Taking into account movement time, we determine time utilization rate per shift: R_u = 0.5. Then W_l = 105 rolls/h.

A vehicle's loading time is determined as follows:

$$T_l = \frac{N_r}{W_l}. \qquad (5)$$

Travelling time of a loaded vehicle (T_{lv}) and no-load run time (T_{nl}) is determined according to the formulas:

$$T_{lv} = \frac{S}{\upsilon_{lv}}. \qquad (6)$$

$$T_{nl} = \frac{S}{\upsilon_{nl}}, \qquad (7)$$

where: S – leg of transporting, km;

υ_{lv} – travelling speed of a loaded vehicle, km/h;

υ_{nl} – no-load run speed, km/h.

Speed of vehicles depends on the categories of roads.

Time required for setting the equipment in operating position and time required for arranging the equipment into transport position is assumed as equal, it depends on the degree of automation (manual, power-driven, automated) ($T_{op} = T_{at} \approx 0.5$ h).

Time required for rolls weighing (T_w = = 0.25 h) depends on the availability of appropriate scales or the time of random weighing of a roll in each tier ($T_{wgh} \approx 0.15$ h).

Time required for confirming paperwork depends on work organisation ($T_p \approx 0.5$ h).

Direct costs on rolls transportation:

$$C_{rt} = W_d + D + C_{cr} + C_{vm} + C_{lb} + C_{tr} \qquad (8)$$

where: W_d – driver's wage, rub.;

D – vehicle's depreciation, rub.;

C_{cr} – vehicle's current repair costs, rub.;

C_{vm} – vehicle maintenance costs, rub.;

C_{lb} – costs of lubricants, rub.;

C_{tr} – costs of tyres, rub.

Amount of wages including additional payments:

$$W_p = t_h^p \cdot T_t + P \qquad (9)$$

where:

t_h^p – driver's hourly base wage rate, rub./h;

P – overall additional payments, rub.

Depreciation expenses:

$$D = \frac{V_{ib} \cdot R_d}{Y_f} \cdot T_t, \qquad (10)$$

where: V_{ib} – initial book value, rub.;

R_d – rate of depreciation charges, %;

Y_f – yearly working time fund, h.

Current repair expenses:

$$E_{cr} = \frac{V_{ib} \cdot R_{cr}}{Y_f} \cdot T_t, \qquad (11)$$

R_{cr} – current repair expenses rate, %

Route fuel consumption:

$$Q_f = \left(C_f \cdot \frac{S}{100} + C_{ftk} \cdot \frac{W_r \cdot S_l}{100} \right) \cdot I_{fc}, \qquad (12)$$

where: C_f – fuel consumption rate per 100 km, l;

C_{ftk} – fuel consumption rate per 100 ton-kilometers, l;

S_l – operational kilometers of a loaded vehicle, km;

I_{fc} – fuel consumption increase rate (depends on the vehicle's time in commission).

Cost of fuel:

$$C_{lbr} = Q_f \times P_{fl} \qquad (13)$$

where: P_{fl} – price for 1 t of fuel, rubles.

Amount of flax-fiber, transported per trip:

$$Q_{ff} = \frac{N_r \cdot q_r}{I_p}, \qquad (14)$$

where: I_p – index of processing rotted straw into flax fiber.

Weight of short fiber:

$$Q_{ffs} = Q_{ff} + I_{osf} \qquad (15)$$

Weight of long fiber:

$$Q_{ffl} = Q_{ff} + I_{olf} \qquad (16)$$

where: I_{osf} – short fiber output index,

I_{olf} – long fiber output index.

Cost of transported cargo:

$$C_{crg} = Q_{ff} \times (I_{osf} \times P_{sf} + I_{olf} \times P_{lf}) \qquad (17)$$

where: P_{sf} – price for 1 t of short fiber,

P_{lf} – price for 1 t of long fiber, rubles.

Cost of transportation:

$$C_{tr} = S_{tkm} \times S_l \times W_r \qquad (18)$$

where: S_{tkm} – self-cost of 1 ton-kilometer, rubles.

Expenses on rotted straw production:

$$E_{rs} = W_b + D + CR + C + F + T_c + OE \qquad (19)$$

where: W_b – wages including benefits, rub.;

D – depreciation of technical means, rub.;

CR – current repair and service maintenance costs, rub.;

C – cost of seed, rub.;

F – cost of fertilizers, rub.;

T_c – transportation costs, rub.;

OE – other expenses, rub.

After determining production costs and costs of rolls transportation, we can determine the leg of transporting which ensures the efficiency of rotted straw production:

$$S_l = \frac{Q_{ff} \cdot (I_{osf} \cdot P_{sf} + I_{olf} \cdot P_{lf}) - (C_{rt} + E_{rs})}{I_p \cdot S_{tkm}}, \qquad (20)$$

On the basis of the formula (11) fuel consumption per one ton of transported cargo is determined.

Fuel consumption per one ton of cargo in the options under comparison:

a) exsisting

$$q_e = \frac{Q_{fe}}{W_{re}}, \qquad (21)$$

b) proposed

$$q_p = \frac{Q_{fp}}{W_{rp}}, \qquad (22)$$

Table 2. Economic indicators of transporting rolls by road trains

Vehicle type	Indicators	Existing option	Proposed option
KAMAZ-43118 with a trailer	Trip time, h	4.35	4.75
	Fuel consumption per one trip, l	28.46	30.56
	Fuel consumption per one t of cargo, l/t	3.70	2.31
	Fuel saving per one trip, l		18.50
	Working efficiency, t/h	2.02	2.78
	Working efficiency increase, %		38
MAZ-6310 with a trailer	Trip time, h	4.42	4.77
	Fuel consumption per one trip, l	30.31	32.60
	Fuel consumption per one t of cargo, l/t	3.16	2.26
	Fuel saving per one trip, l		12.96
	Working efficiency, t/h	2.17	4.02
	Working efficiency increase, %		85

where: q_e, q_p – specific fuel consumption in the existing and proposed options, l/t.

Q_{fe}, Q_{fp} – fuel consumption in the existing and proposed options, l;

W_{re}, W_{rp} – weight of cargo in the existing and proposed options, t.

Fuel saving per one trip in the proposed option will equal:

$$S_{fl} = (q_e - q_p) \times W_{rp} \qquad (23)$$

Working efficiency in the compared options is determined as follows:

$$WE_e = \frac{W_{re}}{T_{te}}; \; WE_p = \frac{W_{rp}}{T_{tp}}, \qquad (24)$$

where: T_{te}, T_{tp} – trip time in the existing and proposed options, h.

Working efficiency increase (γ):

$$\gamma = \frac{WE_p}{WE_p} \cdot 100\%. \qquad (25)$$

Economic indicators of transporting rolls by road trains MAZ and KAMAZ on the average distance of S = 35 km are shown in *table 2.* Transportation of rolls by tractor with a large trailer is expedient only within the distance of 15 – 20 km.

Thus, the proposed more efficient vehicles ensure the increase in the cargo carrying capacity usage index from 0.34 to 0.51; trip efficiency for KAMAZ – by 38%, for MAZ – by 28%.

References

1. Gunina T.L. Economic development of the Kostroma flax cultivation. The history of Kostroma flax cultivation and linen products trade. Kostroma: KSAA, 2003.
2. Zhivetin V.V., Ginzburg L.N., Olshanskaya O.M. Flax and its complex use. Moscow: Inform-znaniye, 2002.
3. Vereykin V.N. For the best flax in the country: Vologda flax. North-West publishing house, 1968.
4. Maklakhov A. Cluster approach as the basis for development of flax complex of the region. Economic and social changes: facts, trends, forecast. 2010. No 2. P. 73 – 81.
5. Maklakhov A. Linen textiles: a resource for economic growth. Economic and social changes: facts, trends, forecast. 2010. No. 4. P. 80 – 85.
6. Orobinskiy D.F. Development of resource saving technologies and technical means for the production and integrated use of fiber flax seeds in the conditions of the North-West region of the Russian Federation. Doctoral thesis. St. Petersburg, 2009.
7. Izmailov A.Yu. Development of the transport infrastructure of the agroindustrial complex given the requirements of ecological agriculture. Yu. Izmailov. Machinery in agriculture. 2012. No.1. P. 19 – 21.