Optimization of arable land structure in land survey design

O P Kolpakova, S A Mamontova, O I Goryunova, N E Lidyaeva and A Yu Schekin
Krasnoyarsk state agrarian university, 90, Mira street, Krasnoyarsk, Russia
E-mail: Gorunova11@mail.ru

Abstract. The paper defines methods for the quantitative assessment of arable land structure by productivity, soil-protective ability and humus recovery balance. The dependence of quantitative indicators of arable land structure on the ratio of annual and perennial crops was established. The method of assessing the structure of arable land allows us to determine the optimal structure.

The earth is the main natural resource, which, due to the existing natural features and differences, has different quantitative and qualitative characteristics. All this has a huge impact on the territory of agricultural enterprises. In search of ways of rational land use, preservation of soil fertility and the living environment and its protection, one cannot do without a scientifically based approach in the territorial organization of agricultural production. Creating a system for organizing land use requires preliminary study and detailed justification, which will ensure sustainable development of land use [1]. In the changed socio-economic conditions of Russia, there was an urgent need to reconsider the fundamental ideas about how to use the land and how to restore soil fertility critically.

The established structure of the acreage is aimed at ensuring economic efficiency. The issues of restoring and improving soil fertility are of secondary importance. Such an approach to the use of land resources undermined the natural-biological basis of crop rotation. The structure of arable land use, violated the optimal proportions of crop and livestock production, led to the dehumification of soil, increased degradation, erosion, aggravated environmental problems.

The structure of sown areas developed in the Krasnoyarsk Territory determined the following ratio of crop groups and steam in soil-climatic zones. In the steppe zone, it was recommended to occupy 48-50% of arable land for grain crops, for forage - 25-28%, for pure couples - 20-25%. In Kansk-Krasnoyarsk forest-steppe and southern forest-steppe zone, the ratio of grain, fodder crops and steam is as follows: 50-55%, 27-30% and 16-18%. In the zones of taiga and podtaygi - 53-55%, 28-30% and 12-15%. This approach to agriculture has led to the fact that the balance of fertility has always remained negative.

We support the point of view of many scientists about the need to increase the share of perennial grasses in the structure of sown areas. Perennial cereal-legume mixtures not only increase the productivity of arable land, its soil-protective ability, restore the water-resistant structure, but also contribute to the accumulation of humus in the soil. So, according to doctor of agricultural sciences P S Tregubov (soil institute named after V V Dokuchaev), “... the greatest accumulation of organic matter of 317 centners per hectare in a layer of 0-40 cm ensures crop rotation, in which 33 percent accounted for perennial grasses and 67 percent for a group of grain, leguminous plants and cereals. It is also more productive and it provides for the rotation of 214 feed units from 1 hectare and the greatest economic effect” [2]. The structure of arable land is the basis for the preservation and restoration of soil fertility.
and an element of the rational organization of agricultural landscapes and the fate of not only the current generation but also the subsequent ones depends on how we organize this territory. Despite the obviousness of the problem, the method of determining the optimal structure of arable land, based on its quantitative characteristics, productivity and environmental safety, has not yet been developed.

Offered by associate professor I P Iliev the methodology of assessing the arable land structure by productivity, soil-protective ability and the balance of humus restoration will allow a more objective assessment of existing and designing arable structures for soil-climatic zones of the Krasnoyarsk Territory taking into account the specialization of farms and natural conditions. Further improvement of the proposed methodology will allow obtaining more reliable results [3]. For an objective assessment of the arable land structure, in our opinion it is advisable to determine its productivity, soil-protective ability and the balance of humus recovery. The obtained data is compared with the actual figures in the farms of the region, the structure recommended for this zone and the calculated one.

Evaluation of arable land structure productivity is carried out according to the formula:

$$ P = F_{n1} * Y_{1} * S_{1} + F_{n2} * Y_{2} * S_{2} + ... + F_{np} * Y_{p} * S_{p} $$

where $P$ is yield of feed-protein units per 100 ha of arable land, c; $F_{n}$ is feed protein ratio for each product with a zootechnical norm of 100 or 110 g of protein; $Y$ is the yield of the main agricultural products, t/he; $S$ is share of culture in the structure of arable land, %.

The obtained data of the productivity of the actual structure of arable land is compared with that recommended for this zone and determine the optimal structure for the rural administrative region. When designing the structure of arable land, along with other indicators, it is necessary to take into account the soil-protective ability of crops, depending on the steepness of the slopes.

Tillage capacity of arable land is determined by the formula:

$$ A_{zc} = \frac{(P_{k1} * S_{lv1} + P_{k2} * S_{lv2} + ... + P_{kp} * S_{lvp})}{100} $$

where $A_{zc}$ - arable structure, %; $P_{k}$ - soil culture protection, %; $S_{lv}$ - crop share in crop rotation or arable land structure, %.

Perennial grasses and winter crops for grain have the highest soil-protective ability. The soil-protective ability of other crops does not exceed 50%. But since winter crops occupy a very small percentage in the Krasnoyarsk Territory, this crop can be neglected in the calculations. Consequently, the soil-protective ability of the structure of arable land is determined by the ratio of annual and perennial crops. The greater is the proportion of perennial grasses in the structure of arable land, the higher is its soil-protective ability. Taking into account this situation, it is possible to construct a graph of the dependence of the soil-protective ability on the percentage of perennial grasses. It should take into account the area of steam, because it has zero soil-protective ability (figure 1).

**Figure 1.** The dependence of the soil protective ability of arable land on the share of perennial grasses.
The calculation of the balance of the restoration of humus is carried out according to the formula:

\[ B_h = \frac{(Y_1 \times R_1 \times S_1 + Y_2 \times R_2 \times S_2 + \cdots + Y_p \times R_p \times S_p) + 0.35 - (M_1 S_1 + M_2 S_2 + \cdots + M_p S_p)}{100} \]

where \( B_h \) - balance of humus recovery in soil, t/ha per year; \( Y \) - the yield of the main products of each crop, t/ha; \( R \) - the ratio of the main products to the amount of crop and root residues; \( M \) - humus mineralization under each crop, t/ha per year; 0.35 - humus yield from 1 ton of crop and root residues; \( S \) - share of culture in the structure of arable land, %.

The analysis of the arable land structure of a significant number of farms in Abansky district carried out according to the above methodology showed that the productivity of arable land with average long-term indicators of crop yields amounts to 1,462.1 kg of feed protein units per 100 ha of arable land (figure 2).

The share of perennial grasses in the structure of arable land does not exceed 11 percent (10.9%). An increase in the share of perennial grasses to 27% with a corresponding decrease in the area of grain crops increases the productivity of arable land to 1,777.0 kg (table 1) of forage-protein units, or by 21.6%.

**Table 1.** Productivity of the recommended and calculated structures of arable land of Abansky district, c. of feed-protein units per 100 ha of arable land.

| Culture, pairs                  | Recommended Productivity, c, f. c. un. | Productivity, kg/ha | Feed coefficient | Calculated Productivity, c, f. c. un. |
|--------------------------------|----------------------------------------|---------------------|-----------------|---------------------------------------|
| Cereals and legumes, including |                                        |                     |                 |                                       |
| Winter rye                      | 5.1                                    | 86.0                | 16.0            | 1.054                                 | 5.1                                    | 86.0                                    |
| Yar wheat                       | 38.0                                   | 548.2               | 16.3            | 0.885                                 | 21.5                                   | 310.0                                   |
| Oats                            | 8.1                                    | 69.0                | 12.5            | 0.682                                 | 8.1                                    | 69.0                                    |
| Peas                            | 4.6                                    | 72.3                | 9.7             | 1.621                                 | 5.0                                    | 78.6                                    |
| Feed, including                 |                                        |                     |                 |                                       |                                        |                                        |
| Corn (silo)                     | 12.5                                   | 193.5               | 120.0           | 1.29                                  | 12.5                                   | 193.5                                   |
| Roots                           | 1.8                                    | 26.7                | 93.4            | 0.159                                 | 1.8                                    | 26.7                                    |
| Single grass (hay)              | 3.6                                    | 95.8                | 11.4            | 0.239                                 | 3.6                                    | 95.8                                    |
| Many herbs:                     | 10.9                                   | -                   | -               | 27.0                                  | -                                      |                                        |
| Hay                             | -                                      | -                   | -               | -                                     | -                                      | -                                       |

**Figure 2.** Dependence of arable land productivity on the share of perennial grasses.
Changing the ratio of annual and perennial crops, without changing the percentage of steam, in the direction of increasing the share of perennial grasses increases the soil-protective ability of the structure from 46.1 to 53.3 % (table 2).

Table 2. Soil-protective ability of recommended and calculated structures of arable land of Abansky district, %.

| Culture, pairs | Recommended S* | Pr* | PrS | S | Pr | PrS |
|----------------|----------------|-----|-----|---|----|-----|
| Cereals and legumes, including | 55.8 | - | - | 39.7 | - |
| Winter rye | 5.1 | 83 | 423.3 | 5.1 | 83 | 423.3 |
| Yar wheat | 38.0 | 50 | 1900 | 21.5 | 50 | 1075.0 |
| Oats | 8.1 | 42 | 340.2 | 8.1 | 42 | 340.2 |
| Peas | 4.6 | 47 | 216.2 | 5.0 | 47 | 235.0 |
| Feed, including | 28.8 | - | - | 44.9 | - |
| Roots | 1.8 | 47 | 84.6 | 1.8 | 47 | 84.6 |
| Corn (silo) | 12.5 | 35 | 437.5 | 12.5 | 35 | 437.5 |
| Single grass, green feed. | 3.6 | 47 | 169.2 | 3.6 | 47 | 169.2 |
| Mn grass, green feed. | 10.9 | 95 | 1035.52 | 27.0 | 95 | 2565.0 |
| Steam | 15.4 | - | - | 15.4 | - |
| Total | 100.0 | 4606.5 | 100.0 | |

Soil protective ability 46.1 53.3
*S – share of culture in the structure of arable land, %
*Pr – soil culture protection, %

Similar data were obtained for the humus reduction balance (table 3, 4).

Table 3. The balance of the restoration of humus recommended structure of arable land of Abansky district, t/ha per year.

| Culture, pairs | Y* | R* | S* | YRS | M* | S | MS |
|----------------|-----|-----|-----|-----|-----|---|-----|
| Winter rye | 1.6 | 1.1 | 5.1 | 9.0 | 1.35 | 5.1 | 6.8 |
| Yar wheat | 1.6 | 0.9 | 38.0 | 55.7 | 1.10 | 38.0 | 41.8 |
| Oats | 1.2 | 1.0 | 8.1 | 10.1 | 1.20 | 8.1 | 9.7 |
| Peas | 1.0 | 0.8 | 4.6 | 3.6 | 1.50 | 4.6 | 6.9 |
| Roots | 9.3 | 0.04 | 1.8 | 0.7 | 1.59 | 1.8 | 2.8 |
| Corn (silo) | 12.0 | 0.16 | 12.5 | 24.0 | 1.47 | 12.5 | 18.4 |
| Single grass, green feed | 11.1 | 0.2 | 3.6 | 8.0 | 1.10 | 3.6 | 4.0 |
| Mn grass, green feed. | 12.6 | 0.2 | 10.9 | 27.5 | 0.60 | 10.9 | 6.5 |
| Pairs | - | - | 15.4 | - | 2.0 | 15.4 | 30.8 |
| Total | - | - | 100.0 | 138.6 | 100.0 | 127.7 |

Balance of humus recovery -0.79

Table 4. The balance of the restoration of the humus of the calculated structure of arable land of Abansky district, t / ha per year *.

| Culture, pairs | Y* | R* | S* | YRS | M* | S | MS |
|----------------|-----|-----|-----|-----|-----|---|-----|
| Winter rye | 1.6 | 1.1 | 5.1 | 9.0 | 1.35 | 5.1 | 7.0 |
| Yar Wheat | 1.6 | 0.9 | 38.0 | 30.9 | 1.10 | 21.5 | 23.6 |
| Crop Type            | Y1 | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | Y8 |
|----------------------|----|----|----|----|----|----|----|----|
| Oats                 | 1.2| 1.0| 8.1| 9.7| 1.20| 8.1| 9.7|
| Peas                 | 1.0| 0.8| 4.6| 4.0| 1.50| 5.0| 7.5|
| Roots                | 9.3| 0.04| 1.8| 0.7| 1.59| 1.8| 2.8|
| Corn (silo)          | 12.0| 0.16| 12.5| 24.0| 1.47| 12.5| 18.4|
| Single grass, green feed. | 11.1| 0.2| 3.6| 8.0| 1.10| 3.6| 4.0|
| Mn grass green feed. | 12.6| 0.2| 10.9| 68.0| 0.60| 27.0| 16.2|
| Pairs                | -  | -  | 15.4| -  | 2.0| 15.4| 30.8|
| Total                | 100.0| 154.3| 100.0| 120.0| 0.66| 0.66| 120.0|

Thus, an increase in the area of perennial grasses from 10.9% to 27% reduced the humus deficit from -0.79 to -0.66 t/ha per year, i.e. at 0.13 t/ha for the year.

As it can be seen from the above calculations and figures, an increase in the share of perennial grasses with a proportional reduction in grain crops leads to an increase in the productivity of arable land, its soil-protective ability and a decrease in the deficit of humus.

The established regularity (dependence) allows us to determine the optimal structure of arable land, depending on the specialization of farms and the soil-climatic zone.

Thus, the analysis of existing farming systems showed that the long-term use of arable land for the cultivation of agricultural products led to a decrease in their fertility and loss of productivity.

Currently, in this regard, there is a real need to develop ways of using the land and restoring its fertility, which are able to a certain extent to reduce the previously mentioned negative effects.

The proposed methods for assessing the structure of arable land use by quantitative indicators allow us to establish the level of productivity, soil-protective ability and the balance of humus recovery.

Such an assessment of the structure of arable land will make it possible to single out the optimal variant of the structure corresponding to the soil and climatic conditions of the region and the specialization of the farm.

References

[1] Kolpakova O P, Kogoyakova V V, Mamontova S A and Nezamov V I 2019 The project of intraeconomic land management as the main tool for the formation of environmentally and economically sound agricultural land use Vestnik KrasGAU 5 36-42

[2] Tregubov P S 1992 Erosion and deflation of chernozem, a system of measures for their prevention and reproduction of fertility The scientific heritage of V.V. Dokuchaeva and modern agriculture (Moscow) p 208.

[3] Iliev I P and Khlanstskaya A P 2007 To the question of optimizing the structure of arable land use // Vestnik of KrasGAU 1