Land use parameters ensuring sustainable development of agricultural producers taking into account characteristics of climatic zones and land quality

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Abstract. Land use parameters determine to a large extent not only the scale, but also the efficiency of agricultural production. The article gives a description of the size and other qualitative characteristics of land use resulting from the agrarian transformations. The area of arable land used, including rented and owned by agricultural organizations, is shown by natural agricultural zones and the region as a whole. Based on the analysis of the influence of the size of arable land on the farm, the bonitet score, the technological properties of arable plots and their remoteness from production centers on the productivity and efficiency of crop production, the parameters providing effective and sustainable development of the industry were substantiated. In general, the trend of greater efficiency of crop production with a large land use is confirmed. As a result of the analysis, the marginal parameters of land quality were determined (bonitet score, index of estimated costs of the distance from economic centers to arable land), ensuring efficient crop production. These data were obtained for all natural and agricultural zones of the region. The validity of the parameters is determined by the state of agricultural production and is recommended for the next 5 years. In the future, such an analysis should be repeated periodically. The parameters obtained as a result of the study are recommended for use in the management of agricultural production and land use. They allow one to determine the main priorities in the agricultural policy of the region, including objects of state and regional support for agricultural production.

1. Introduction

The agrarian reform has created a new land system in which land relations and the system of agricultural land use have radically changed [7, 9]. Instead of large state agricultural lands (territories used by one business entity), a system of land plots of private enterprises has a different organizational and legal form of management and a different legal status of land and other property [6, 8].

In the northern zone, 73 % of farms have a size of 1,000 to 5,000 ha, and the average size is about 2,400 ha. In the northern forest-steppe zone, land plots are larger: 70 % of farms have land plots of 3,000 to 20,000 ha, and the average size is 7,500 ha. The largest land size is observed in the southern forest-steppe in which 50 % of households have 5,000–20,000 hectares, and the average size is 9,000 hectares. But this zone is characterized by the presence of large farms. In the steppe zone, the sizes of land plots are closer to each other than in other zones. At the same time, the largest land users are Poltava Tavrichesky District LLC (47.7 thousand ha), Niva Russian-Polyansky District LLC (42.4 thousand ha) and Niva Pavlovgrad District JSC (43.5 thousand ha).
Table 1. The area of arable land used by agricultural organizations

| No | zone                      | Less than 1000 | 1000-2000 | 2000-3000 | 3000-5000 | 5000-10000 | 10000-20000 | More than 20000 | Average size, ha |
|----|--------------------------|----------------|-----------|-----------|-----------|-------------|--------------|-----------------|-----------------|
| 1  | Northern                 | 5              | 12        | 8         | 3         | 1           | 1            | 2400            |
| 2  | Northern forest steppe   | 7              | 5         | 3         | 9         | 13          | 15           | 1               | 7500            |
| 3  | Southern forest steppe   | 27             | 5         | 15        | 13        | 22          | 16           | 4               | 9000            |
| 4  | Steppe region            | 13             | 14        | 8         | 11        | 19          | 16           | 14              | 8500            |
|    |                          | 52             | 36        | 34        | 36        | 55          | 48           | 19              |                 |

In the southern regions, due to agricultural holdings, there is a concentration of arable land plots, which leads to an increase in the land plot size.

However, this is still weakly associated with the formation of the production complex [2]. Agricultural organizations often use land rented from municipalities and citizens, especially in the northern and steppe zones. The largest tenants are LLC Poltava Tavrichesky district (47.7 thousand ha) and LLC Ni-va Russian-Polyansky district (42.4 thousand ha).

Table 2. Arable land rented by agricultural organizations

| No | zone                      | Less than 1000 | 1000-2000 | 2000-3000 | 3000-5000 | 5000-10000 | 10000-20000 | More than 20000 |
|----|--------------------------|----------------|-----------|-----------|-----------|-------------|--------------|-----------------|
| 1  | Northern                 | 9              | 9         | 7         | 4         | 1           |              |                 |
| 2  | Northern forest steppe   | 8              | 6         | 4         | 2         | 6           | 14           | 4               | 2               |
| 3  | Southern forest steppe   | 13             | 20        | 7         | 12        | 12          | 23           | 11              | 5               |
| 4  | Steppe                   | 1              | 13        | 11        | 9         | 14          | 21           | 15              | 8               |
|    | In the region            | 28             | 42        | 31        | 30        | 36          | 58           | 30              | 15              |

Table 3. Arable land owned by agricultural organizations by zones

| No | zone                      | Less than 1000 | 1000-2000 | 2000-3000 | 3000-5000 | 5000-10000 | 10000-20000 | More than 20000 |
|----|--------------------------|----------------|-----------|-----------|-----------|-------------|--------------|-----------------|
| 1  | Northern                 | 30             | 1         | 4         | 1         | 2           | 1            | 1               |
| 2  | Northern forest steppe   | 47             | 6         | 2         | 2         | 3           | 4            |                 |
| 3  | Southern forest steppe   | 67             | 21        | 6         | 2         | 2           | 3            | 4               |
| 4  | Steppe                   | 51             | 24        | 6         | 1         | 5           | 5            | 2               | 3               |
|    | In the region            | 205            | 46        | 16        | 4         | 9           | 9            | 7               | 3               |

In fact, in the northern zone, there is no land owned by farms. The largest owner is Niva Pavlograd district (43.5 thousand hectares). Given the complexity and inconsistency of land-property relations, this state of agricultural land use reduces the stability and efficiency of production.
Therefore, the presented variety of land use parameters (sizes and legal status) creates a need to establish values that ensure the development of agricultural production.

2. Methods
For crop production, the following indicators of the agricultural land use system are crucial [4, 5]:

- size of productive land, ha, score, cadastral value;
- the use of agricultural land (plowing, structure of sown areas, the degree of use of the natural and production potential of land plots);
- quality of agricultural arable land:
  - fertility indicators – score, productivity,
  - technological properties – index, cost of land use
  - remoteness – distance, conventional distance.

All these indicators have a significant impact on the results and efficiency of crop production:

- the cost of produced and sold products,
- the cost of crop products,
- the level of differential rental income
- the level of efficiency of agricultural land use – steadily unprofitable, unstable effective, steadily profitable.

A comparison of these two arrays of indicators allows us to determine the parameters of agricultural land use that ensure the effective and sustainable development of crop production [1,3]. The approach under consideration allows us to determine such parameters taking into account economic realities and existing or forecasted economic problems.

3. Results
The grouping of land use by the size of arable land and parameters of economic activity made it possible to establish the dependence of the main indicators of crop production (yield per 1 ha and net income on the area of arable land. As can be seen from Table 4, the organization with larger land plots has better production results.

The highlighted figures indicate the best land use parameter for one of the indicators of crop production efficiency. The analysis shows that the most effective land sizes are 1000–5000 ha in the northern zone, 5000 ha in the northern forest-steppe zone, more than 10000 ha in the southern forest-steppe zone, 10000–25000 ha in the steppe zone. The greatest efficiency was achieved due to higher crop yields when the size of arable land was large.

These parameters can ensure optimal economic efficiency and sustainable development of agricultural organizations, taking into account characteristics of natural climatic zones and production.

An analysis of the structure of agricultural land showed the absence of its direct influence on the main indicators of effectiveness of agricultural production and land use. The indirect effect of the structure of agricultural land and the use of arable land is manifested in the conditions of diversified production as a reflection of the competitive demand for various types of land, in particular dairy or beef cattle breeding and wheat production.

An analysis of the influence of quality of individual parameters of land use allows us to establish their minimum level, which ensures the efficient crop production. The calculations were carried out using the average indicators by zones (average bonitet score, average grain yield, average cost, average selling price).
Table 4. Assessment of the dependence of production results on arable land size

| Area, ha   | Output per 1 ha, c | Production costs per 1 ha, rub | Net income, rub / ha |
|-----------|-------------------|-------------------------------|---------------------|
| Up to 1000 | 11.5              | 7235                          | 730                 |
| from 1000 to 5000 | 19.1             | 12048                         | 1215                |
| More than 10000 | 17.9             | 11325                         | 1143                |
| Northern forest steppe zone |
| Up to 1000 | 11.5              | 9460                          | 1333                |
| from 1000 to 5000 | 14               | 11585                         | 1633                |
| from 5000 to 10000 | 16.1             | 13271                         | 1870                |
| More than 10000 | 17.4             | 14356                         | 2023                |
| Southern forest steppe zone |
| Up to 1000 | 15.8              | 9913                          | 1784                |
| From 1000 to 5000 | 18               | 11288                         | 2032                |
| From 5000 to 10000 | 18               | 11272                         | 2029                |
| from 10000 to 25000 | 19.6             | 12260                         | 2207                |
| More than 25000 | 20.6             | 12869                         | 2316                |
| Steppe zone   |
| Up to 1000 | 12.7              | 8575                          | 813                 |
| from 1000 to 5000 | 14               | 9471                          | 898                 |
| From 5000 to 10000 | 15.7             | 10614                         | 1006                |
| from 10000 to 25000 | 18               | 12189                         | 1155                |
| More than 25000 | 13.3              | 9014                          | 854                 |

Table 5. Average actual parameters of land use and production by zones taken for calculation

| zone              | bonitet score | technological index | equivalen t distance, km. | Grain yield, kg / ha | grain selling price rub / c | cost of grain / rub. | productio n costs rub / ha |
|-------------------|---------------|---------------------|---------------------------|---------------------|---------------------------|----------------------|---------------------------|
| Northern          | 53            | 1.23                | 59                        | 14.2                | 694                       | 676                  | 12168                     |
| Northern forest steppe | 50            | 1.25                | 53                        | 14.8                | 588                       | 570                  | 8436                      |
| Southern forest steppe | 70            | 1.18                | 42                        | 18.4                | 739                       | 626                  | 11516                     |
| region            | 64            | 1.10                | 50                        | 14.7                | 683                       | 608                  | 9973                      |

The parameters made it possible to determine qualitative land use parameters (bonitet score, technological costs index, remoteness of arable land from production centers) at which the efficient grain production as the main marketable crop production is ensured.
Table 6. Efficiency of grain production depending on the bonitet score for the regions

| bonitet score | Score price e/point | Estimated yield e/ha | Average selling price, rub/c | Average production costs in, rub/ha | Cost of production Rub/ha | Net income, rub/ha |
|---------------|---------------------|-----------------------|------------------------------|------------------------------------|--------------------------|------------------|
|               |                     |                       |                              |                                    |                          |                  |
| Northern zone |                     |                       |                              |                                    |                          |                  |
| 10            | 0.27                | 2.7                   | 694                          | 12168                              | 1875                     | -10293           |
| 20            | 0.27                | 5.4                   | 694                          | 12168                              | 3751                     | -8417            |
| 30            | 0.27                | 8.1                   | 694                          | 12168                              | 5626                     | -6541            |
| 40            | 0.27                | 10.8                  | 694                          | 12168                              | 7502                     | -4666            |
| 50            | 0.27                | 13.5                  | 694                          | 12168                              | 9377                     | -2790            |
| 60            | 0.27                | 16.2                  | 694                          | 12168                              | 11253                    | -915             |
| 70            | 0.27                | 18.9                  | 694                          | 12168                              | 13128                    | 960              |
| 80            | 0.27                | 21.7                  | 694                          | 12168                              | 15004                    | 2835             |
| 90            | 0.27                | 24.4                  | 694                          | 12168                              | 16879                    | 4711             |
| 100           | 0.27                | 27.0                  | 694                          | 12168                              | 18752                    | 6586             |
| Northern forest steppe zone | |                       |                              |                                    |                          |                  |
| 10            | 0.3                 | 3                     | 588                          | 8436                               | 1764                     | -6672            |
| 20            | 0.3                 | 6                     | 588                          | 8436                               | 3528                     | -4908            |
| 30            | 0.3                 | 9                     | 588                          | 8436                               | 5292                     | -3144            |
| 40            | 0.3                 | 12                    | 588                          | 8436                               | 7056                     | -1380            |
| 50            | 0.3                 | 15                    | 588                          | 8436                               | 8820                     | 364              |
| 60            | 0.3                 | 18                    | 588                          | 8436                               | 10584                    | 2148             |
| 70            | 0.3                 | 21                    | 588                          | 8436                               | 12348                    | 3912             |
| 80            | 0.3                 | 24                    | 588                          | 8436                               | 14112                    | 5676             |
| 90            | 0.3                 | 27                    | 588                          | 8436                               | 15876                    | 7440             |
| 100           | 0.3                 | 30                    | 588                          | 8436                               | 17640                    | 9204             |
| Southern forest steppe zone | |                       |                              |                                    |                          |                  |
| 10            | 0.24                | 2.4                   | 738                          | 11516                              | 1773                     | -9743            |
| 20            | 0.24                | 4.8                   | 738                          | 11516                              | 3546                     | -7969            |
| 30            | 0.24                | 7.2                   | 738                          | 11516                              | 5320                     | -6196            |
| 40            | 0.24                | 9.6                   | 738                          | 11516                              | 7093                     | -4221            |
| 50            | 0.24                | 12                   | 738                          | 11516                              | 8867                     | -2649            |
| 60            | 0.24                | 14.4                  | 738                          | 11516                              | 10640                    | -8755            |
| 70            | 0.24                | 16.8                  | 738                          | 11516                              | 12414                    | 897              |
| 80            | 0.24                | 19.2                  | 738                          | 11516                              | 14187                    | 2671             |
| 90            | 0.24                | 21.6                  | 738                          | 11516                              | 15961                    | 4444             |
| 100           | 0.24                | 24                   | 738                          | 11516                              | 17734                    | 6217             |
| Steppe zone              |                     |                       |                              |                                    |                          |                  |
| 10            | 0.21                | 2.17                  | 683                          | 9973                               | 1486                     | -8486            |
| 20            | 0.21                | 4.35                  | 683                          | 9973                               | 2973                     | -6999            |
| 30            | 0.21                | 6.52                  | 683                          | 9973                               | 4459                     | -5513            |
| 40            | 0.21                | 8.70                  | 683                          | 9973                               | 5946                     | -4026            |
| 50            | 0.21                | 10.87                 | 683                          | 9973                               | 7432                     | -2540            |
| 60            | 0.21                | 13.05                 | 683                          | 9973                               | 8919                     | -1053            |
| 70            | 0.21                | 15.23                 | 683                          | 9973                               | 10405                    | 432              |
| 80            | 0.21                | 17.40                 | 683                          | 9973                               | 11892                    | 1919             |
| 90            | 0.21                | 19.58                 | 683                          | 9973                               | 13379                    | 3405             |
| 100           | 0.21                | 21.75                 | 683                          | 9973                               | 14865                    | 4892             |
### Table 7. Efficiency of grain production depending on the technological land properties

| Technological Property Index | Average yield in the zone c / ha | Average selling price rub / c | average cost rub / c | Production costs Rub / ha | Average cost of production rub / ha | Net income, rub/ha |
|-----------------------------|---------------------------------|------------------------------|---------------------|--------------------------|-----------------------------------|-------------------|
| North zone                  |                                 |                              |                     |                          |                                   |                   |
| 0.8                         | 16.17                           | 694                          | 676                 | 8752                     | 11232                             | 2480              |
| 0.9                         | 16.17                           | 694                          | 676                 | 9846                     | 11232                             | 1386              |
| 1                           | 16.17                           | 694                          | 676                 | 10940                    | 11232                             | 292               |
| 1.1                         | 16.17                           | 694                          | 676                 | 12034                    | 11232                             | -801              |
| 1.2                         | 16.17                           | 694                          | 676                 | 13128                    | 11232                             | -1896             |
| 1.3                         | 16.17                           | 694                          | 676                 | 14222                    | 11232                             | -2990             |
| 1.4                         | 16.17                           | 694                          | 676                 | 15316                    | 11232                             | -4084             |
| 1.5                         | 16.17                           | 694                          | 676                 | 16410                    | 11232                             | -5178             |
| 1.6                         | 16.17                           | 694                          | 676                 | 17504                    | 11232                             | -6272             |
| Northern forest steppe zone |                                 |                              |                     |                          |                                   |                   |
| 0.8                         | 14.75                           | 588                          | 499                 | 5898                     | 10350                             | 4452              |
| 0.9                         | 14.75                           | 588                          | 499                 | 6635                     | 10350                             | 3714              |
| 1                           | 14.75                           | 588                          | 499                 | 7372                     | 10350                             | 2977              |
| 1.1                         | 14.75                           | 588                          | 499                 | 8109                     | 10350                             | 2240              |
| 1.2                         | 14.75                           | 588                          | 499                 | 8847                     | 10350                             | 1503              |
| 1.3                         | 14.75                           | 588                          | 499                 | 9584                     | 10350                             | 765               |
| 1.4                         | 14.75                           | 588                          | 499                 | 10321                    | 10350                             | 28                |
| 1.5                         | 14.75                           | 588                          | 499                 | 11058                    | 10350                             | -708              |
| 1.6                         | 14.75                           | 588                          | 499                 | 11796                    | 10350                             | -1445             |
| Southern forest steppe zone |                                 |                              |                     |                          |                                   |                   |
| 0.8                         | 18.4                            | 738                          | 626                 | 9218                     | 13596                             | 4378              |
| 0.9                         | 18.4                            | 738                          | 626                 | 10370                    | 13596                             | 3226              |
| 1                           | 18.4                            | 738                          | 626                 | 11522                    | 13596                             | 2074              |
| 1.1                         | 18.4                            | 738                          | 626                 | 12674                    | 13596                             | 921               |
| 1.2                         | 18.4                            | 738                          | 626                 | 13827                    | 13596                             | -230              |
| 1.3                         | 18.4                            | 738                          | 626                 | 14979                    | 13596                             | -1382             |
| 1.4                         | 18.4                            | 738                          | 626                 | 16131                    | 13596                             | -2535             |
| 1.5                         | 18.4                            | 738                          | 626                 | 17283                    | 13596                             | -3687             |
| 1.6                         | 18.4                            | 738                          | 626                 | 18436                    | 13596                             | -4839             |
| Steppe zone                 |                                 |                              |                     |                          |                                   |                   |
| 0.8                         | 14.74                           | 683                          | 608                 | 7170                     | 11016                             | 3845              |
| 0.9                         | 14.74                           | 683                          | 608                 | 8067                     | 11016                             | 2949              |
| 1                           | 14.74                           | 683                          | 608                 | 8963                     | 11016                             | 2052              |
| 1.1                         | 14.74                           | 683                          | 608                 | 9860                     | 11016                             | 1156              |
| 1.2                         | 14.74                           | 683                          | 608                 | 10756                    | 11016                             | 260               |
| 1.3                         | 14.74                           | 683                          | 608                 | 11652                    | 11016                             | -636              |
| 1.4                         | 14.74                           | 683                          | 608                 | 12549                    | 11016                             | -1532             |
| 1.5                         | 14.74                           | 683                          | 608                 | 13445                    | 11016                             | -2429             |
| 1.6                         | 14.74                           | 683                          | 608                 | 14341                    | 11016                             | -3325             |

When calculating, the sales price and production costs are average for the zone. This allows us to exclude their influence. Based on the calculations, it can be concluded that effective crop production is typical of arable land with a score of more than 70. The northern forest-steppe zone having significant areas with solonetz soils is different. The decreasing effect of soil salinity on crop production was overrated. This has led to the fact that soils having the same rating score with other zones have higher
yields. However, based on the calculations, it should not be considered that arable land with low quality must be removed from arable turnover. The calculations based on long-term average data allow us to talk about patterns of efficient land use. It is necessary to determine the boundaries of effective and risky efficiency depending on weather conditions and fluctuations in agricultural markets. The sustainable efficiency of crop production corresponds to the land quality which is 80–85 scores, and the zone of sustainable inefficiency is 30–35 points.

In Omsk region, land properties vary significantly, affecting production costs. These include soil texture, topography, contouring of arable land. In general, they are combined in the technological land properties and the degree of their favorableness for implementing plant growing operations. This allows you to analyze the efficiency of land use depending on these land properties (Table 7).

**Table 8.** Determination of the efficiency of grain production depending on the remoteness of arable land from production centers

| Indicators, rub/ha | Distance, km | 3 | 5 | 7 | 9 | 10 | 11 | 12 |
|-------------------|-------------|---|---|---|---|----|----|----|
| **Northern zone** |             |   |   |   |   |    |    |    |
| Production costs. Total |             | 10202 | 10447 | 10713 | 11002 | 11158 | 11313 | 11468 |
| Fixed production costs |             | 7142 | 7313 | 7499 | 7701 | 7810 | 7919 | 8028 |
| Transport costs |             | 3060 | 3134 | 3214 | 3300 | 3347 | 3394 | 3491 |
| average cost of production in the zone |             | 11232 | 11232 | 11232 | 11232 | 11232 | 11232 | 11232 |
| Net income |             | 1029 | 785 | 518 | 229 | 174 | -81 | -234 |
| **Northern forest steppe zone** |             |   |   |   |   |    |    |    |
| Production costs. Total |             | 9071 | 9316 | 9582 | 9871 | 9936 | 10182 | 10349 |
| Fixed production costs |             | 6350 | 6521 | 6702 | 6910 | 7016 | 7122 | 7244 |
| Transport costs |             | 2721 | 2794 | 2874 | 2961 | 3008 | 3054 | 3104 |
| average cost of production in the zone |             | 10350 | 10350 | 10350 | 10350 | 10350 | 10350 | 10350 |
| Net income |             | 1278 | 1034 | 767 | 478 | 322 | 167 | 0 |
| **Southern forest steppe zone** |             |   |   |   |   |    |    |    |
| Production costs. Total |             | 11516 | 11761 | 12027 | 12316 | 12466 | 12627 | 12794 |
| Fixed production costs |             | 8061 | 8232 | 8419 | 862 | 8730 | 8839 | 8956 |
| Transport costs |             | 3455 | 3528 | 3608 | 369 | 3791 | 3788 | 3838 |
| average cost of production in the zone |             | 12780 | 12780 | 12780 | 12780 | 12780 | 12780 | 12780 |
| Net income |             | 1263 | 1019 | 752 | 463 | 307 | 152 | -13 |
| **Steppe zone** |             |   |   |   |   |    |    |    |
| Production costs. Total |             | 9973 | 10217 | 10484 | 1077 | 10928 | 10999 | 11084 |
| Fixed production costs |             | 6981 | 7152 | 7338 | 7541 | 7649 | 7704 | 7758 |
| Transport costs |             | 2991 | 3065 | 3145 | 3231 | 3278 | 3324 | 3325 |
| average cost of production in the zone |             | 11016 | 11016 | 11016 | 11016 | 11016 | 11016 | 11016 |
| Net income |             | 1043 | 798 | 532 | 243 | 87 | 10 | -67 |
Table 9. Recommended land use parameters that ensure efficient crop production at the current level of production

| zone                      | arable land size ha | arable land score | index of technological costs | The maximum distance from production centers, km |
|---------------------------|---------------------|-------------------|------------------------------|-----------------------------------------------|
| Northern                  | 1000–5000           | more than 70      | less than 1.0                | less than 10                                  |
| Northern forest steppe    | more than 5000      | more than 50      | less than 1.4                | less than 11                                  |
| Southern forest steppe    | more than 10000     | more than 70      | less than 1.1                | less than 11                                  |
| Steppe                    | 10000–20000         | more than 70      | less than 1.2                | less than 11                                  |

Such indicators as productivity, sales price, cost of production are average for the zone. This ensures a more objective analysis of the impact of technological costs on the efficiency of crop production. Based on the calculations, it is clear that the effective index of technological properties of arable land should be no more than 1.4. The distance from production centers is an important parameter. The average indicators of crop production by zones were used. They showed that the remoteness of production centers should be no more than 10–11 km. The studies allow us to determine the land use parameters for agricultural organizations that improve crop production in the zones of Omsk region (Table 9).

The land use parameters obtained as a result of the analysis have a certain time period. Of course, many parameters have a longer lifespan, but economic ones change quickly (especially the sales price and the cost price). They are average for 5 years and suitable for using during the same period. However, when solving modern problems of agricultural land use, these results allow for the effective management of both agricultural production and land use.

4. Conclusion

The land reform has violated the current course of changes in agricultural land use, as well as the role and purpose of land resources in ensuring the effective and sustainable functioning of agricultural organizations. The variety of organizational and legal forms of management and forms of ownership has led to the formation of a wide range of land use. However, not all of them ensure stability and efficiency of crop production. Therefore, the results allow the competent management of agricultural land use in order to eliminate crisis phenomena in the agricultural industry.

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