Agro-ecological characteristics of arable soils of the forest-steppe and steppe in Omsk region

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Abstract. The study is based on the results of agro-ecological assessment of the main arable soils of the forest-steppe and steppe zones in Omsk region. Agro-ecological regions and categories of natural and economic score of lands are determined: from medium (50–75) to very high (more than 175) score, with focus on Irtysh as a region with a lowered score. The agro-ecological assessment of the main arable soils of the forest-steppe and steppe zones enabled ranking the soils in descending order by scores and by favorable natural conditions of the zone: leached chernozems – ordinary chernozems – carbonate chernozems – podzolized chernozems – brackish chernozems – meadow-black-chernozems and gray forest solodized – deep and medium saline soil. The main arable soils of the forest-steppe and steppe zones are ordinary chernozems, southern chernozems, and meadow chernozems. The agro-ecological score of ordinary chernozems varies from 69 to 196 depending on the natural economic zone, southern chernozems – from 62 to 146, and meadow chernozems – from 52 to 146.

1. Introduction

Traditional farming systems aimed to achieve a certain yield of agricultural crops by ensuring biological needs for nutrients, moisture supply, etc.

However, the greening of agriculture is not just knowledge of the laws of ecology and ecological patterns of functioning of individual links of the agro-ecosystem. It is mainly the process of building a farming system, which is a complex multicomponent system, which individual links are in constant interconnection with each other and the environment.

A farming system, along with the main task of obtaining the maximum yield of agricultural crops, poses equally important tasks of ensuring the environmental safety of production and the maximum possible balanced use of the natural resource potential without harming the environment [1–5].

These tasks are met by modern adaptive landscape farming systems that meet the requirements of rational use of agricultural land, soil fertility reproduction, obtaining high and sustainable yields and preserving the components of agro-ecosystems. This can be achieved by the expedient transformation of agricultural land, the selection of appropriate crops and the rationalization of the structure of sown areas adapted to local climatic, geomorphological, soil, hydrogeological conditions, with regard to the mutual effect of each factor. It is necessary to timely adjust the use of natural forage lands, expedient transfer of agricultural lands to other types, etc. [6–9].

To fulfill all these tasks, it is necessary to carry out the classification and typification of agricultural landscapes of a certain territory, and a comprehensive assessment of the areas of the agricultural
landscape with regard to the natural and economic conditions for cultivating agricultural crops and the natural resource potential of the territory [10].

2. Methods and Equipment
The study was carried out in 2015–2017 at the Department of Ecology, Nature Management and Biology, Omsk State Agrarian University, using the equipment of the Center for Collective Use ‘Agrarian and Technological Research’. The object of the study was arable soils of the forest-steppe and steppe zone in Omsk region.

The agro-ecological assessment of soils related to each soil difference in the landscape, with regard to the main natural and economic indicators affecting the formation of the soil cover and the yield of agricultural crops, was carried out according to a comprehensive methodology for calculating agro-ecological points proposed by Ya.R. Reingard and O.V. Nezhevlyak [10].

3. Results
The study aimed to perform an agro-ecological assessment of the main arable soils of the forest zone in Omsk region.

Agro-ecological assessment of the soils in Omsk region enabled identification of agro-ecological regions, with elementary areas of the agricultural landscape characteristic of each region (Figure 1).

The map of agro-ecological zoning of Omsk region shows that the forest-steppe zone covers 4 regions (V–VIII) according to the prevailing agro-ecological group of lands, which elementary areas are assessed within one group:

- region V – North-forest-steppe plain-ridge;
- region VI – Central forest-steppe;
- region VII – Uvalno-Terraced Om-Kamyshlovsko-Irtyshsko-Tarsky;
- region VIII – South forest-steppe plain.

The steppe zone includes 2 regions (IX–X) according to the prevailing agro-ecological group of lands, which elementary areas are assessed within one group:

- region IX – Southern plain-steppe;
- region X – South steppe plain.

Region XI (floodplain of Irtysh River) covers all agro-ecological regions of the forest-steppe and steppe zones with azonal alluvial soils.

Agro-ecological regions, in turn, are divided into smaller territorial units – agro-ecological subregions. The allocation of subregions is necessary for adjusting or creating another farming system, reclamation measures in a separate area of the region due to local natural features.

The category of natural and economic score of lands of the forest-steppe and steppe zones varies from medium (50–75) to very high (more than 175); Irtysh is an area with a lowered score (Table 1).

| Agro-ecological region and category of the natural and economic score of land | Agro-ecological assessment of soils, score |
|---|---|
| V – North-forest-steppe plain-ridge region with an average score | 50–100 |
| VI – Central forest-steppe region with an average and high score | 25–125 |
| VII – Uvalno-terrace Om-Kamyshlovsko-Irtyshsko-Tarsky region with a high and very high score | more than 125 |
| VIII – South-forest-steppe plain region with a higher and high score | 75–150 |
| IX – Southern plain-steppe region with a higher score | 100–125 |
| X – Southern steppe plain region with an average score | 75–125 |
| XII – Floodplain of Irtysh River region with a lowered score | 50–75 |

Assessment of the most common soils of the forest-steppe and steppe zones in agro-ecological scores arranged the soils in a systematized series according to the degree of favorable natural
conditions and the decreasing score: leached chernozems – ordinary chernozems – carbonate chernozems – podzolized chernozems – solonetzic chernozems – meadow chernozems – gray forest solodized – deep and medium solonetzes – meadow – small solonetzes – silt-boggy – solonchak (Table 2).

Figure 1. Agro-ecological zoning of Omsk region

3.1 Gray forest soils
Gray forest soils formed in the forest-steppe natural-climatic zone, on average, have a bonitet score equal to 59. The agro-ecological score of gray forest solodized soils varies quite strongly: from 58 (light gray forest solodized in natural-economic zone V) to 146 (dark gray forest solodized in natural
economic zone VI). In general, gray forest soils are formed in various (V–VII) agro-ecological regions of the forest-steppe zone in Omsk region.

North-forest-steppe plain-ridge region with an average agro-ecological score (region V) is poorly drained, therefore wide inter-ridge areas are occupied by bog soils. On ridges, the soil cover is represented by meadow-chernozem and gray forest soils; in depressions, the soil cover is represented by gray forest gley, negative relief elements are occupied by meadow, bog-saline, solonetz-solonchak soils.

A total of 50–60 % of the region’s area is developed for agricultural needs. Water erosion is poorly spread, up to 6.6 % of the agricultural land is eroded. At the same time, 15–25 % of the region’s area is covered by forests and the plowed area makes up 40–50 %.

**Table 2.** Agro-ecological assessment of the main types of soils in the forest-steppe and steppe zones in Omsk region

| Soil type                        | Bonitet score | Agro-ecological score of soils in various natural and economic zones |
|---------------------------------|---------------|---------------------------------------------------------------------|
|                                 |               | V          | VI         | VII        | VIII       | IX         | X          |
| Dark gray forest solodized      | 73            | 94         | 146        | 123        | -          | -          | -          |
| Gray forest solodized           | 51            | 66         | 102        | 86         | -          | -          | -          |
| Light gray forest solodized     | 45            | 58         | 90         | 76         | -          | -          | -          |
| Podzolized chernozems ms/mh*    | 89            | 116        | -          | -          | -          | -          | -          |
| Leached chernozems ms/mh        | 100           | 130        | 200,2      | 168        | 133        | 105        | 71         |
| Ordinary chernozems ms/mh       | 98            | 127        | 196        | 163        | 131        | 102        | 69         |
| Carbonate and high chernozems ms/mh | 89      | -          | 178        | 151        | 118        | 93         | 63         |
| Solonetzic chernozems ms/mh     | 83            | -          | 140        | 110        | 87         | 58         |            |
| Southern chernozems ms/mh       | 87            | -          | 146        | 115        | 91         | 62         |            |
| Salolchak                       | 5             | 7          | 10         | 9          | 7          | 5          | 3          |
| Cork and small solonetzes       | 10            | 13         | 20         | 17         | 13         | 11         | 7          |
| Medium solonetzes               | 42            | 55         | 84         | 71         | 56         | 44         | 31         |
| Deep solonetzes                 | 51            | 66         | 102        | 86         | 68         | 54         | 36         |
| Meadow chernozem                | 73            | 94         | 146        | 123        | 97         | 76         | 52         |
| Meadow chernozem deeply solonetzic | 66      | 86         | 132        | 111        | 88         | 69         | 47         |
| Chernozem-meadow                | 61            | 79         | 122        | 103        | 81         | 64         | 43         |
| Solod                           | 18            | 24         | 36         | 30         | 24         | 19         | 12         |
| Silt-boggy and peaty-boggy      | 12            | 15         | 24         | 20         | 15         | 12         | 8          |
| Swamp-solonchak                 | 4             | 5          | 8          | 6          | 5          | 4          | 3          |
| Meadow                          | 39            | 50         | 78         | 65         | 52         | 40         | 27         |
| Floodplain alluvial-bedded      | 25            | 33         | 50         | 42         | 34         | 26         | 17         |

ms/mh* – medium-strong, medium-humus.

In agro-ecological region V, gray forest soils are included in agro-ecological group VII with a score of 66, gray forest gleyed – in group VI with a score of 53, dark gray forest solodized – in group X with a score of 94 (Figure 2).

Central forest-steppe region with a medium and high agro-ecological score (region VI) is located in closed watershed territories with a pronounced microrelief. Agricultural development of the territory is 50–70 %. Deflation and water erosion are not widespread here, and the erosion rate is 11.4 %. Gray forest soils are included in agro-ecological group XI with a score of 102, dark gray forest solodized soils – in group XV with a score of 146, and gray forest gleyed soils – in group IX with a score of 83.

Uvalo-terraced Om-Kamyslovsko-Irtyshsko-Tarsky region of high and very high agro-ecological score (region VII) consists of five riverine areas. Agricultural development of the territory is 85–95 %. Deflation is moderately developed and water erosion is weak, the erosion rate is 12 %. At the same
time, 10–50 % of the region’s area is covered by forests, depending on the subregion, and the plowed area is 40–60 %.

![Figure 2. Agro-ecological assessment of gray forest soils](image)

In agro-ecological region VII, dark gray forest solodized are included in group XIII with a score of 123, gray forest soils – in group IX with a score of 86, and gray forest gleyed soils – in group VII with a score of 69.

3.2 Leached chernozems

Leached chernozems formed in the forest-steppe natural-climatic zone, on average, have a bonitet score equal to 100. The agro-ecological score of leached chernozems in various agro-ecological regions of the forest-steppe zone that covers from V to VIII regions varies from 130 to 200 (Figure 3).

![Figure 3. Agro-ecological assessment of leached chernozem](image)
In North-forest-steppe plain-ridge region (region V) with an average agro-ecological score, leached chernozems are included in group XIV with a bonitet score of 130. In Central-forest-steppe region with an increased score, leached chernozems are included in agro-ecological group XXI with a score of 201.

In Uvalno-Terrasovoy Om-Kamyshlovsko-Irtysh-Tarsky region with a high score, the value of the leached chernozem bonitet is 168, and soils are included in agro-ecological group XVII.

In South-forest-steppe plain region VIII with an increased and high agro-ecological score, the agricultural development is 80–85 %. Moderate deflation is widespread and water erosion is poorly expressed, the erosion rate is 12.3 %, forestry and plowing area is 5–15 % and 80 %, respectively. Leached chernozems are included in group XIV with a bonitet score of 133.

3.3 Ordinary and southern chernozems

The agro-ecological score of ordinary chernozems varies from 69 to 196, depending on the agro-ecological region of the forest-steppe zone that covers from 5 to 10 regions. Ordinary medium-thick medium-humus heavy loamy chernozems formed in the southern part of the forest-steppe natural-climatic zone, on average, have a bonitet score of 98. In the southern part of the forest-steppe, the agro-ecological score of these soils varies from 102 to 131 (Figure 4).

In South-forest-steppe plain region VIII with a higher and high agro-ecological score, ordinary medium-thick medium-humus heavy loamy chernozems are included in agro-ecological group XIV.

In Southern lowland-steppe region with a higher score (region IX), agricultural development is 85–95 %. Here, moderate deflation is widespread and water erosion occurs locally. The territory of the region is characterized by a high degree of erosion that attains 54.1 % of the agricultural land area.

This category of lands is formed on the drained areas of the gently undulating plain and is represented by chernozems: mainly ordinary calcareous chernozems, high, solonetzic shallow and low-humus, and in the southern part, soils are southern medium- and low-power chernozems, meadow chernozem.

More than 90 % of these soils are suitable for cultivation of all agricultural crops, but they require agromeliorative, agrochemical, anti-erosion and anti-deflation measures.

In region IX, ordinary chernozems are included in agro-ecological group XI with a bonitet score of 102.

Southern medium-thick medium-humus heavy loamy chernozems formed in the steppe natural-climatic zone, on average, have a bonitet score of 87. Their agro-ecological score varies from 62 to 146 in agro-ecological regions VIII to X (Figure 4).

In South-lowland-steppe region with a higher score (region IX), southern medium-thick medium-humus heavy loamy chernozems are included in agro-ecological group X with an agro-ecological score of 91.

In geomorphological terms, Southern steppe plain region with an average score (region X) is a plain with sparse ridges and ridge-like rises and wide inter-ridge spaces in the northern part of the region. The agricultural development of the territory attains 95 % of the total area. This is a region of strong potential soil compliance with deflation and local (along the ridges) erosion. A high degree of soil degradation attains 65 %.

The soil cover is represented by southern chernozems, thin and shortened thickness ordinary chernozems, meadow-chernozem shallow soils with solod, solonetz and solonchak. The forested area is less than 1 %, and plowed area is more than 95 %. In agro-ecological region X, southern chernozems are included in agro-ecological group VII with a score of 62.
3.4 Meadow-chernozem soils

Meadow-chernozem soils formed in the forest-steppe natural-climatic zone have a bonitet score of 73. The agro-ecological score of these soils varies from 52 to 146 in various agro-ecological regions of the forest-steppe zone that covers from V to X regions (Figure 5).

In North-forest-steppe plain-ridge region (region V), the average agro-ecological score of these soils is 94 (agro-ecological group X). In Central-forest-steppe region VI with a higher score, meadow-chernozem soils are included in agro-ecological group XV with a score of 146.

In Uvalno-Terrasovoy Om-Kamyshlovsko-Irtyshsko-Tarsk region VII with a high and very high bonitet score of 123, soils are included in agro-ecological group XIII. In South forest-steppe plain region with a higher and high agro-ecological score (region X), meadow-chernozem soils are included in agro-ecological group X with a bonitet score of 97 (Figure 5) and southward in the steppe zone, soils have a score of 76 in region IX and 52 in region X.
Meadow-chernozem solonetzes Meadow-chernozem solonetzes formed in the forest-steppe and steppe natural-climatic zone, on average, have a bonitet score from 10 to 51 (small and crustal solonetzes – 10, medium – 42, deep – 51). Agro-ecological score of medium meadow chernozem solonetzes is from 31 to 84 and that of deep meadow chernozem solonetzes is from 36 to 102, which is determined by the agro-ecological region of the forest-steppe and steppe zone that covers from V to VIII regions (Figure 6).

In North-forest-steppe plain-ridge region V, the average agro-ecological score of meadow chernozem solonetzes is 55 (agro-ecological group VI), deep solonetzes – 66 (agro-ecological group VII). In Central forest-steppe region with a higher score (region VI), the agro-ecological score of meadow-chernozem solonetzes is 84 (agro-ecological group IX), deep solonetzes – 102 (agro-ecological group XI). In Uvalno-Terrasovoy Om-Kamyshlovsko-Irtysh-Tarsky region VII, the score of meadow-chernozem solonetzes is about 71 (agro-ecological group VIII), deep solonetzes – 86 (agro-ecological group IX). In South-forest-steppe plain region VIII with a higher and high agro-ecological score, the score of medium solonetzes is 56 (agro-ecological group VI), deep solonetzes – 68 (agro-ecological group VII). In South-plain-steppe region IX, the agro-ecological score of meadow-chernozem medium solonetzes is 44 (agro-ecological group V), deep solonetz soils – 54 (agro-ecological group VI). In South-steppe plain region X, the average agro-ecological score of medium solonetzes is 31 (agro-ecological group IV), deep solonetzes – 36 (agro-ecological group IV).

Assessment of the main arable soils revealed the need for adaptive-landscape farming systems for the arable lands of the study regions, spot application of reclamation measures, introduction of organic and mineral fertilizers in increased doses, and implementation of anti-erosion measures according to individual projects.

4. Conclusion
The results of the study show that the forest-steppe and steppe zone of Omsk region covers 7 agro-ecological regions. The category of natural and economic score of the lands of this zone ranges varies from medium (50–75) to very high (more than 175); Irtysh is an area with a lowered score. At the same time, the main arable soils of the forest-steppe and steppe zones are ordinary chernozems, southern chernozems and meadow-chernozem soils. The agro-ecological score of ordinary chernozems varies from 69 to 196 depending on the agro-ecological region, southern chernozems – from 62 to 146, and meadow-chernozem soils – from 52 to 146.

The natural and economic conditions for cultivating agricultural crops in each agro-ecological region are significantly different. Therefore, the approach to the formation of farming systems in each
region should be different and adapted to local conditions, within each region, subregion, and each elementary area of the agricultural landscape.

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