Qualitative assessment of the soils of agricultural landscapes in Eastern Siberia

A A Kozlova¹, A A Shpedt²,³, I A Belozertseva¹,⁴, N I Granina¹,
O G Lopatovskaya¹, N D Kiseleva¹, S L Kuklina¹, N A Martynova¹,
D N Lopatina⁴, V S Guzeeva¹, I M Kucherenko¹, K D Kusraev¹ and
S A Korshunova¹

¹ Irkutsk State University, Irkutsk, Russia
² Krasnoyarsk Scientific Center of the Siberian Branch of the RAS, Krasnoyarsk, Russia
³ Siberian Federal University, Krasnoyarsk, Russia
⁴ Sochava Institute of Geography SB RAS, rkutsk, Russia

E-mail: allak2008@mail.ru, shpedtaleksandr@rambler.ru, belozia@mail.ru,
granina_n@list.ru, lopatovs@gmail.com, nata_kis71@list.ru, kukl_swet@mail.ru,
natamart-irk@yandex.ru, daryaneu@mail.ru, valentina.guzeeva@bk.ru,
ivan.kucherenko.1995@bk.ru, doej1620@gmail.com, korshunosveta98@bk.ru

Abstract. At the current agricultural stage, the development of new approaches and concepts of agriculture are required for a more effective use of the soils of agricultural landscapes. The concept of adaptive-landscape model of agriculture implies the system of soil use aimed at the production based on available economic and material resources and providing agricultural landscape stability and raised soil fertility recovery. The realization of this model is based on the soil and ecological assessment of soils which involves complex research of all natural components. It presupposes qualitative assessment of soils based on the soil-ecological index (SEI), an approach which reflects the natural potential of agricultural lands in points (from 1 to 100). The resulting SEI is the product of soil, climate and agrochemical indices. The indices were calculated using automated electronic systems (AES) developed on the basis of Microsoft Excel. Agricultural soil bonitet calculations for the territory of Eastern Siberia showed significant fluctuations in the SEI. In Krasnoyarsk krai the SEI equaled 14.67-53.77 points, in Irkutsk oblast – 15.13-38.76 points, and in the Republic of Buryatia – 24.78-44.18 points. The SEI of the chernozems in Krasnodar krai, on the contrary, reaches 100 points. The resulting SEI of the agricultural soils in Krasnoyarsk krai is mainly determined by soil and agrochemical indices. However, climate index is beginning to play a more significant role in relation to agricultural soils when determining their SEI in Irkutsk oblast and the Republic of Buryatia.

1. Introduction

The value of land as the main means of agricultural production in any economic infrastructure is defined by its fertility, i.e. the ability of soil to provide plants with nutrients, air, water, heat, and biological and physicochemical environment ensuring the sufficient crops of cultivated plants and good production quality. National and international experience shows that high and stable
agricultural productivity is only possible when it is based on an integrated approach to all agrochemical and ecological factors necessary for a normal growth and development of plants, crop formation and quality, and prevention of land degradation [1].

Farmlands, being both an object and means of production, are characterized by spatial variability, heterogeneity, small soil cover pattern, coincident range of soils that differ in fertility and technological properties, which limits their universal use. Therefore, a differentiated assessment of agroecological conditions is required as the initial stage of creating individual approaches to the land resources use. The final stage of the agroecological assessment should be the typification of land as a basic element of the adaptive landscape farming system [2].

In general, the system of adaptive landscape farming implies the land use aimed at manufacturing, taking into account economic and material resources and providing sustainability of agricultural landscapes and raised fertility. It implies a detailed examination of the ecological situation of a particular territory from the perspective of deep adaptation of agricultural production to environmental conditions: through full employment of biological adaptive potential of agricultural plants and through an environmentally safe and economically feasible technological impact on the agrocenosis. The principal stages of this concept implementation are as follows: agroecological land assessment, land typification, soil-landscape mapping, cadastral value determination of agricultural land, geoinformation support, design and development of farming models for agricultural enterprises, development of a regional landscape-ecological land classification and soil rating and land productivity assessment [3].

There are many various methods of soil bonitet in Russia and abroad [4-10]. The method of soil assessment based on soil and ecological indices developed by I.I. Karmanov [11] comprises quantitative reflection of natural potential of agricultural lands in points (from 1 to 100). It is used universally in Russia and gives comparative results on a common basis for the entire territory of the country as it allows us conducting soil assessment of small agricultural households and regions, krais, republics and the entire territory of the Russian Federation. A.A. Shpedt and his co-authors [12] developed an automated electronic system of determining the SEI on the basis of Microsoft Excel.

The territory of Eastern Siberia includes the Republics of Sakha (Yakutia), Buryatia, Tyva and Khakassia, Krasnoyarsk and Zabai kalsky krais, and Irkutsk oblast. Basin and submontane effects and significant variations in altitude observed in the area contribute to the diversity of natural and bioclimatic conditions which leads to the development of dramatically contrasting landscapes and soils. The area comprises North Asian semiarid landscapes including light coniferous pinewood submountain subtaiga and mountain taiga landscapes as well as light coniferous plainland landscapes of various genesis [13]. Forest steppe and steppe landscapes are widespread in the area exhibiting the most fertile soils in their soil cover (grey forest soils, chernozems, meadow-chernozem and alluvial) that are widely used in the agriculture of the regions. The range of ecosystems corresponds to various subcontinents of Asia whose interpenetration is a unique landscape and situational example of the Siberian nature within Northern Asia [14].

The most developed southern part of the regions with the most favourable natural conditions for living and agriculture is characterized by the sharp continentality of the climate and reduced heat and moisture availability. It is here that the soil cover with low resistance to anthropogenic and, primarily, agrogenic impact was formed. The intensification of agriculture leads to an even greater fertility fall, deterioration and degradation of the soil cover.

2. Objects and methods of research
The objects of the research are the soils of the agricultural landscapes in the following East Siberian regions: Krasnoyarsk krai, Irkutsk oblast, the Republic of Buryatia. The soils under study include plowlands and fallow agricultural lands: sod-podzolic, grey forest, sod-forest and sod-carbonate soils, podzolized, leached, regular and southern chernozems, chestnut and intrazonal soils - alluvial and salty.
Sod-podzolic soils of the region are formed under larch and larch-pine grass-shrub vegetation on various deposition environments. As deforestation and stubbing advances, this type of soil takes up only about 2% of the crop land of the agricultural land. Most of the sod-podzolic soils are represented by heavy and medium loams. They have low humus content (up to 2%) with a humus horizon up to 15 cm thick. They have mainly an acidic reaction of the salt suspension media and are weakly base saturated, which necessitates their liming.

Gray forest soils are mainly concentrated in the forest-steppe zone and have three subtypes, which differ in humus content. This type of soil is formed on positive landforms. The underlying rocks are Jurassic sandstones and lime shales, as well as deluvial loams and clays. The humus horizon is 10-30 cm, its structure is lumpy or lumpy-nutty, medium- and heavy loamy. The humus content is from 2 to 8%, the reaction of salt suspension medium is from medium acid to neutral.

The subtype light gray forest has a podzolized horizon E or humus-podzolized AE of a whitish color and platy or platy-nutty structure. The thickness of the humus horizon reaches 10 cm and has a light grey colour, its humus content is less than 3%. The reaction of salt suspension medium is acid, the base saturation percentage is 60-70%, which indicates the need for liming, the granulometric composition, as a rule, is heavy loam. This subtype makes up 12% of the area of gray forest soils in crop land.

The subtype gray forest has a humus horizon of 20 cm or more, is gray in color, the humus content is 3-5%. The structure is lumpy-nutty; the podzolic horizon is usually absent. It is mainly heavy loam. The reaction of salt suspension medium is medium and weakly acid. The base saturation percentage of the upper horizons is 70-80%; the lower ones can vary from 30 to 95%. This subtype occupies 45% of the area of arable gray forest soils.

Dark gray forest soils were formed mainly in the bottom parts of ridges, inter-hillock depressions, lowered areas of terraces, and microrelief depressions. Their area is 44% of arable gray forest soils. These are the most fertile lands, close to chernozems in their properties. The humus content amounts to 7%, the humus layer thickness is more than 30 cm. The reaction of salt suspension medium is close to neutral values and the base saturation percentage is 95-98%.

Sod-carbonate soils are widespread in the taiga-subtaiga and steppe zones, mainly in Irkutsk oblast. They were formed on eluvium and diluvium of marls and limestones of the Upper and Lower Cambrian. These soils are represented by medium and heavy loams. They have a high water and air-holding capacity. This type of soil is characterized by high potential fertility. The humus layer thickness is 20-22 cm, with a humus content of up to 10%. By the humus content the following types are distinguished: low-humus, less than 3% humus, medium-humus, 3-5% humus and high-humus, more than 5% humus. The base saturation percentage is usually above 95%.

Chernozems are soils of high potential. They occupy about 10% of crop land in the regions under study and are represented mainly by leached and regular soils. The leached chernozems are formed under meadow forb-feather grass steppes and are confined to the lower parts of the slopes. They have a powerful humus horizon up to 50 cm, are dark gray in color with a granular-lumpy structure. The humus content ranges from 7 to 12%, the base saturation percentage is more than 90%, and the reaction of salt suspension medium is weakly acid or neutral. Bubbling of soil is observed in the upper part of the illuvial horizon B.

The regular chernozems are formed on ancient terraces composed of alluvial and deluvial loesslike deposits. The humus layer thickness of the horizon A reaches 30 cm; its color is brown or brownish-gray. In the illuvial horizon, there are signs of alkalinity, namely soil consolidation and columnar structure. Bubbling is observed in the humus horizon. The humus content ranges from 7.5-6.5%, the reaction of salt suspension medium is slightly alkaline. The soils have unfavorable water-physical properties due to the presence of exchangeable sodium in the soil-absorbing complex.

Chernozem-like meadow soils occupy 4.7% of crop land. They were formed in the lower parts of the slopes and in the bottoms of ravines, they have a powerful (50-80 cm) humus horizon, the reaction of soil solution is from slightly acid to neutral. Soils thaw late in spring and are exposed to early fall frosts.
Meadow, alluvial, sod-podzolic and other soils in the balance of crop land occupy 3.6% and they do not significantly affect the production of agricultural products. These plots are mainly used for growing late sowing fodder crops.

The method of qualitative assessment of agricultural landscapes based on soil and ecological indices (SEI) allows us determining bonitet points for the soils of plowlands, perennial crop plantations and hayfields for both households and specific areas and sites reaching the levels of regions, republics, zones, etc. A soil bonitet point shows the ratio of soil fertility (in percentage) for a given agricultural crop (or a group of crops) to the fertility of the best of the available widespread plowland soils used for cultivating the given crop. Soil fertility is assessed with the consideration of the comparative level of farming culture and intensity. The bonitet has a 100-point grading scale. That means that the soil bonitet point for the soil used for cultivating a given crop and occupying a significant area must not exceed 100 [11].

The soil-ecological index reflects the complex of agroecological conditions for cultivating agricultural crops in ratios (indices and points). This index can be converted into bonitet points for a specific agricultural crop with the help of additional coefficients. SEI gives comparative results determined on a common basis for the entire territory of the country. Soil-ecological assessment of agricultural landscapes is presently used for the complex monitoring of soil fertility of agricultural lands and is, in fact, approved on a state level [1, 15].

3. Research results and discussion

Soil bonitet points determined for the agricultural landscapes of Krasnoyarsk krai showed that minimum values of the SEI are typical for sod-highly podzolic soils (14.7 points), whereas its maximum values are characteristic of alluvial-meadow soils (53.8 points) (table 1).

Table 1. Interim and resulting soil-ecological index of the agricultural landscapes of Krasnoyarsk krai in points.

| Soil name, agricultural area | Soil (SEIs) | Agrochemical (SEIs) | Climate (SEIc) | Resulting SEI = SEIs·SEIa·SEIc |
|------------------------------|-------------|---------------------|----------------|-----------------------------|
|                             | 12.5 (2-V) | Aq                  | K2O            | K2O               | PEC-P | Cc   | SEIc |             |
| C4U    | SEIs       | SEIs               | SEIs           | SEIa              | SEIc  |      |      |             |
| Sod-highly podzolic soil, plowland | 5.42 | 0.86 | 4.64 | 0.87 | 0.87 | 0.95 | 0.72 | 0.90 | 200 | 4.39 | 14.67 |
| Sod-low podzolic soil, plowland     | 5.42 | 0.81 | 4.39 | 0.94 | 0.94 | 1.00 | 0.88 | 0.90 | 200 | 5.30 | 20.47 |
| Light grey forest soil, plowland     | 5.80 | 0.90 | 5.20 | 0.95 | 0.96 | 1.00 | 0.91 | 0.85 | 200 | 4.33 | 20.49 |
| Grey forest soil, plowland          | 6.10 | 0.98 | 5.96 | 1.00 | 1.00 | 1.10 | 1.10 | 0.85 | 200 | 4.33 | 28.39 |
| Dark grey forest soil, plowland      | 7.03 | 1.15 | 8.09 | 1.08 | 1.06 | 1.14 | 1.19 | 0.85 | 200 | 4.47 | 43.03 |
| Podzolized chernozem, plowland       | 7.82 | 1.10 | 8.64 | 1.08 | 1.06 | 1.00 | 1.14 | 0.85 | 200 | 4.60 | 45.31 |
| Leached chernozem, plowland          | 8.26 | 1.10 | 9.12 | 1.08 | 1.06 | 1.03 | 1.18 | 0.85 | 200 | 4.67 | 50.26 |
| Regular chernozem, plowland          | 7.82 | 1.21 | 9.45 | 1.06 | 1.04 | 1.00 | 1.00 | 0.81 | 200 | 4.50 | 46.78 |
| Southern chernozem, plowland         | 6.90 | 1.05 | 7.22 | 1.06 | 1.04 | 1.00 | 1.10 | 0.81 | 200 | 4.62 | 36.69 |
| Meadow-chernozem soil, plowland      | 7.67 | 1.22 | 9.38 | 1.08 | 1.06 | 1.03 | 1.18 | 0.85 | 200 | 4.53 | 50.14 |
| Alluvial-meadow soil, plowland       | 8.30 | 1.22 | 10.10 | 1.08 | 1.06 | 1.00 | 1.14 | 0.85 | 200 | 4.67 | 53.77 |
The SEI of the chernozems of Krasnodar krai, by comparison, equals 100 points [11]. Soil-ecological indices of the leached and regular chernozems of the krai that are widely used for agricultural purposes equal 50.3 and 46.8 respectively. It should be noted that the value of the resulting soil-ecological index in the soils of the agricultural lands of Krasnoyarsk krai is mostly determined by soil and agrochemical indices. Climate index depending on soil types does not vary greatly, and its contribution to the total soil assessment is even.

The agricultural soils of Irkutsk oblast are characterized by a lower fertility level in comparison with Krasnoyarsk krai (table 2).

Table 2. Interim and resulting soil-ecological index of the agricultural landscapes of Irkutsk oblast in points.

| Soil name, agricultural area | Soil (SEIs) | Agrochemical (SEIs) | Climate (SEIs) | Resulting SEI = SEIs·SEIs·SEIs |
|-----------------------------|-------------|---------------------|----------------|-------------------------------|
|                            | 12.5·(2·VOC·U) | Aq  SEIs  Kve20  Kve20  KpaH2O  SEIs  PEC·P  Cc  SEIs |                |                               |
| Sod-podzolic soil, fallow land | 4.39  0.70  3.77  1.06  1.06  1.00  1.12  0.90  200  4.40 | 15.13 |
| Sod-carbonate soil, plowland   | 5.70  0.78  4.44  1.05  0.96  1.10  1.11  0.80  200  4.14 | 20.40 |
| Light grey forest soil, plowland| 4.92  0.70  3.44  0.95  1.00  0.87  0.83  0.90  200  5.33 | 15.22 |
| Unpodzolized grey forest soil, plowland | 6.73  0.61  4.11  1.05  1.00  1.05  1.10  0.87  200  4.47 | 20.21 |
| Grey forest soil, mown fallow land | 5.07  0.85  4.61  1.00  1.00  0.94  0.94  0.90  200  5.33 | 23.09 |
| Dark grey forest soil, mown fallow land | 6.59  0.85  5.60  1.04  0.97  0.96  0.97  0.90  200  5.22 | 28.36 |
| Dark grey forest gleicy soil, fallow land | 6.54  1.00  6.54  1.04  1.03  0.96  1.03  0.94  200  4.69 | 31.59 |
| Leached chernozem, plowland    | 8.39  0.96  8.05  1.08  1.06  1.03  1.18  0.81  200  4.08 | 38.76 |
| Regular chernozem, plowland    | 7.67  0.96  7.36  1.00  0.98  1.00  0.98  0.82  200  4.11 | 29.64 |
| Regular chernozem, fallow land  | 7.67  1.05  8.05  0.97  0.98  1.00  0.95  0.82  200  4.11 | 31.43 |
| Southern chernozem, plowland   | 7.26  0.85  5.97  0.97  0.98  1.00  0.95  0.78  200  4.29 | 24.32 |
| Meadow-chernozem, plowland     | 9.26  1.05  9.72  1.00  1.00  1.00  1.00  0.67  200  3.47 | 32.13 |
| Meadow-solonchak soil, pasture | 7.06  0.85  6.00  0.93  0.95  1.00  0.88  0.90  200  5.86 | 30.94 |
| Meadow-solonized soil, pasture | 5.40  0.63  3.40  0.91  0.93  1.03  0.87  0.90  200  5.85 | 17.30 |
| Meadow-bog salinized soil, pasture | 5.08  0.53  5.01  0.93  0.95  1.00  0.88  0.73  200  3.50 | 15.43 |
| Alluvial-sod soil, plowland    | 6.90  0.74  5.11  0.87  1.08  1.1  1.03  1.05  200  5.48 | 28.84 |
| Alluvial-meadow soil, plowland | 9.57  1.00  9.57  0.97  1.00  0.96  0.93  0.67  200  3.47 | 30.88 |

The minimum values of the SEI were observed in the sod-podzolic soil of fallow lands where they equaled 15.13 points, whereas the maximum values were found in the soils that are most widely used in the region’s agriculture: leached chernozem (38.36 points) and regular chernozem (31.43 points). Intrazonal agricultural soils of Irkutsk oblast were found to be poorer than those of Krasnoyarsk krai. The range of the SEI was 15.43 points for meadow-bog salinized soil of the pastures and 32.12 points for the meadow-chernozem soils of the plowlands. Climate index is becoming more and more significant in the formation of the SEI for the soils of agricultural lands due to the location of the
region in the arid shadow of the East Sayan Mountains. The territory of the region suffers from the lack of humidification in comparison to Krasnoyarsk krai whose agricultural soils are located in the windward side of the mountains and, therefore, receive more precipitation.

The SEI values determined for the agricultural soils of the Republic of Buryatia have taken the intermediate position between the SEIs of Krasnoyarsk krai and Irkutsk oblast (table 3).

Table 3. Interim and resulting soil-ecological index of the agricultural landscapes of the Republic of Buryatia in points.

| Soil name, agricultural area        | Soil (SEIs) | Agrochemical (SEIa) | Climate (SEIc) | Resulting SEI = SEIs·SEIa·SEIc                              |
|-------------------------------------|-------------|---------------------|----------------|------------------------------------------------------------|
|                                     | 12.5 (2-V)C-U | Aq SEIs  | Kp200 | Kp200 | KPHE13 | SEIa | PEC-P | Cc | SEIc |                        |
| Sod-podzolic soil, fallow land       | 5.62        | 1.00 | 5.62   | 1.11 | 1.00 | 0.95 | 1.05 | 1.10 | 200 | 4.20 | 24.78                    |
| Sod-carbonate soil, plowland         | 9.30        | 1.14 | 10.60  | 1.15 | 1.11 | 1.15 | 1.47 | 0.61 | 200 | 2.50 | 38.96                    |
| Light grey forest soil, plowland      | 5.98        | 0.85 | 5.08   | 1.10 | 1.00 | 1.05 | 1.16 | 0.90 | 200 | 4.26 | 25.10                    |
| Dark grey forest soil, fallow land    | 6.59        | 0.85 | 5.60   | 1.11 | 1.03 | 0.96 | 1.10 | 0.90 | 200 | 4.52 | 27.84                    |
| Leached chernozem, plowland          | 9.78        | 1.05 | 10.23  | 1.08 | 1.06 | 1.03 | 1.18 | 0.74 | 200 | 3.66 | 44.18                    |
| Regular chernozem, fallow land        | 10.14       | 1.15 | 11.66  | 1.08 | 1.05 | 1.00 | 1.13 | 0.49 | 200 | 2.49 | 41.25                    |
| Southern chernozem, fallow land       | 9.13        | 1.15 | 10.50  | 1.08 | 1.04 | 1.00 | 1.12 | 0.47 | 200 | 3.01 | 35.40                    |
| Alluvial-sod soil, pasture            | 8.71        | 0.91 | 7.93   | 1.03 | 1.04 | 1.00 | 1.07 | 0.65 | 200 | 2.98 | 25.29                    |
| Alluvial-meadow soil, pasture, hayfield| 10.55       | 1.15 | 12.13  | 1.08 | 1.06 | 0.96 | 1.09 | 0.61 | 200 | 3.01 | 39.80                    |
| Meadow-bog, plowland                 | 8.36        | 1.03 | 8.61   | 1.03 | 0.98 | 0.91 | 0.92 | 0.91 | 200 | 3.99 | 31.61                    |

The lowest values observed in the sod-podzolic soils of fallow lands (24.78 points) turned out to be higher than those determined for the similar soils of the two previously mentioned regions due to a higher soil index. Among the soils characterized by the generally higher SEI (sod-carbonate plowland soil with 38.96 points and alluvial-meadow (hayfield) – 39.80 points), chernozems showed the highest SEI values: leached plowland chernozem (44.18 points) and regular chernozem of fallow lands (41.25 points). The values were found to be lower than those of the chernozems of Krasnoyarsk krai but higher than the similar soils of Irkutsk oblast. The limiting factor of soil productivity in Buryatia as well as those in Irkutsk oblast is poor precipitation. At the same time, soil and agrochemical indices have shown higher values than the soils of Krasnoyarsk krai and Irkutsk oblast.

4. Conclusion
It has been stated that the value of the resulting soil-ecological index in the agricultural soils of Krasnoyarsk krai is mostly defined by soil and agrochemical indices. However, climate index is becoming more and more significant when determining the SEI of the agricultural soils of Irkutsk oblast and Buryatia.

In general, soil-ecological index of the agricultural soils of Eastern Siberian determined in the course of the research shows that they are 2-4 times less fertile than those of Krasnodar krai. It is therefore necessary to carry out the thorough research of the fertility qualities of the regional soils,
develop and implement agrotechnical, agrochemical and soil-protective measures aimed at the solution of the food issues and preserving ecological functions of the soils of the region.

Acknowledgments
This work is done within the state task SB RAS (number of the project registration AAAA-A17-117041910169-4) and with the financial support from the Russian Foundation for Basic Research for the scientific projects No. 18-45-030039 п.а.

References
[1] Methodology Guidelines for the Complex Monitoring of Agricultural Soil Fertility 2003 (Moscow: Rosinformagrotech) p 240
[2] Agroecological Assessment of Lands. Design of Adaptive Landscape Systems of Agriculture and Agro-technologies 2005 (Moscow: Rosinformagrotekh) p 784
[3] Agroecological Assessment and Typification as a Basic Element of the Adaptive Landscape Farming Design 2011 (Novosibirsk: SSI Sib. Scien. Rsearch Inst. of Agriculture and Chemicalization) p 55
[4] Bulgakov D S Agroecological Assessment of Plowland Soils 2002 (Moscow: V V Dokuchayev Soil Institute) p 250
[5] Ivanov V D and Kuznetsova E V 2004 Soil Assessment (Voronezh: Voronezh State Agrarian University) p 287
[6] Krupkin P I 2009 Methods of Experimental Soil and Land Assessment (Krasnoyarsk: Krasnoyarsk State Agrarian University) p 184
[7] Petersen G W, Nizeyimana E, Miller D A and Evans B M 2000 The use of soil databases in resource assessments and land use planning Handbook of Soil Science (United States: CRC Press) pp 69-94
[8] Mehra M and Singh C K 2018 Spatial analysis of soil resources in the Mewat district in the semiarid regions of Haryana, India Environment, Development and Sustainability 2(20) 661-80
[9] Musakwa W 2018 Identifying land suitable for agricultural land reform using GIS-MCDA in South Africa Environment, Development and Sustainability 5(20) 2281-99
[10] Rousseva S, Malinov I and Stefanova V 2016 Soil erosion risk assessments using GIS technologies – Bulgarian experience Bulgarian Journal of Agricultural Science 2(22) 205-8
[11] Shishov L L, Durmanov D N, Karmanov N I and Efremov V V 1991 Theoretical Foundations and Ways of Soil Fertility Regulation (Moscow: Agropromizdat) p 303
[12] Shpedt A A, Zharinova N U, Yamskikh G U and Aleksandrova S V 2015 Assessment of the agricultural soils of Krasnoyarsk Krai Reflection of Bio-, Geo- and Anthropospheric Interactions in Soils and Soil Cover (Tomsk: National Research Tomsk State University) pp 293-6
[13] Atlas. Irkutsk Region: Ecological Conditions for Development 2004 (Moscow: Irkutsk) p 90
[14] Mikheev V S and Konovalova T I 1998 Geosystems of Northern Asia Regional Ecological Atlas (Novosibirsk: Nauka) pp 169-85
[15] Karmanov I I and Bulgakov D S 2012 Methods of Soil-climate Assessment of Plowlands for National Inventories (Moscow: V V Dokuchayev Soil Institute) p 122