Journal of Engineering and Applied Sciences 13 (Special Issue 10): 8353-8359, 2018
ISSN: 1816-949X

The Bioenergetic Approach to Evaluation of Arable Land Fertility

[1]Marat Ishbulatov, [1]Radik Mindibayev, [2]Khalil Safin, [1]Aydar Baykov, [1]Ilnur Miftakhov,
[1]Guzel Baygildina, [1]Nailja Zamanova, [1]Rail Khisamov and [3]Ruzil Yagafarov
[1]Department of Real Estate Cadastre and Geodesy,
[2]Department of Land management,
[3]Department of Soil Science, Botany and Plant Breeding, Bashkir State Agrarian University,
Street 50 Years of October, 34 Ufa, Russia

Abstract: In recent years, there has been a tendency to develop new views on the problem of the qualitative assessment of lands in which not only soil properties are of key importance but also the entire complex of natural and anthropogenic conditions for the formation of crop yields. The importance of researching natural processes on an energy basis makes it possible to present the phenomenon in the most general terms. The productivity of soils is associated with energy-enriched components the products of the transformation of photosynthetic substances with humus and other substances of organic origin. All this testifies to the great importance of studies of the energy of biogeocenoses as self-regulating systems. The study used soil survey materials conducted in 2017. Fertile leached ordinary chernïzem (black soil), the cost of 1 ha of which amounts to $61956.18 or 4 008 564.85 rub. has the greatest bioenergetic potential in terms of humus and nutrients reserves equal to 12043.3 GJ/ha, leached mid-deep medium-humic weakly-eroded chernozem has the lowest energetic potential, the cost of 1ha being 30384.64 $ or 1965886.21 rub.

Key words: Cadastre of land resources, land evaluation, bioenergy estimation, soil fertility, chernozem, bioenergetic, potential

INTRODUCTION

Any land plot has a certain value, from which the amount of payment for land is determined. The price of the land plot depends on many parameters: location, type of use, humus content and other indicators. The need to obtain a reliable value of land plots is required by both state and municipal bodies in the management of land resources, determining the prospective lines of long-term development of settlements, conducting rational land and tax policies and by private entities of land law in the performance of various transactions with land. The aim of these studies is the development of a scientific and methodological justification for bioenergetic assessment of soil fertility for use in cadastral assessment of soils of agricultural land.

In Dalmatia, the Austrian authorities carried out a large-scale reform of the tax system based on a cadastral survey in the second half of the nineteenth century. The land tax, based on the cadastral valuation was introduced in 1852 (Ipsic and Maslek, 2015).

In the Russian Federation, the tax on land is calculated based on the cadastral value of land, since, 2006. A special category of land that has the priority right of use and is protected by law is the category of agricultural land which is the most valuable productive land. The state cadastral valuation of agricultural land is carried out in accordance with the guidelines for state cadastral valuation of agricultural land, approved by the order of the Ministry of Economic Development of September 20, 2010. The evaluation is carried out in three stages. First, a list of land plots is formed and then specific indicators of their cadastral value are determined. After that, the cadastral value of the land plot itself is calculated. The list of sites is formed by the Regional Directorate of Rosreestr (Federal Service for State Registration, Cadastre and Cartography) as of January 1 of the year of work. It should contain information about all the lands located on the assessed territory. Specific parameters of land plots depend on the type of their use (for example, suitable for arable land, hayfields, pastures or occupied by buildings, farm buildings or on which forests are located). The first type of land use includes agricultural land, suitable for tillage, hayfields, pastures occupied by fallows as of the assessment date, perennial plantations, on farm roads, communications, forest

Corresponding Author: Marat Ishbulatov, Department of Real Estate Cadastre and Geodesy, Bashkir State Agrarian University, Street 50 Years of October, 34 Ufa, Russia

plantations designed to protect the land from negative (harmful) natural, anthropogenic and man-made phenomena as well as water objects designed to provide on-farm activities. This type of use is the main one for carrying out the economic activities of agricultural enterprises. For such lands, the specification of relative indicators of the cadastral value of land presupposes the following sequence of actions; the determination of the list of soil variants and their areas, the determination in the context of soil variants of a list of all agricultural crops possible for cultivation and permissible crop rotations, normative productivity and market price of each crop from the list of crops, calculation of gross income per unit area for each crop and for each crop rotation, determination of costs per unit area, calculation in the context of soil variants of costs per unit area to maintain soil fertility for each crop rotation.

The calculation of the relative indicator of land rent for each crop rotation in the context of soil variants within the land plot is carried out by subtracting the value of unit costs for cultivation, the specific costs of maintaining soil fertility and the profit of the person conducting business in agriculture from the value of specific gross income. Then, the maximum value of the relative indicator of land rent is determined from the relative indicators of land rent of crop rotations and the value of the coefficient of capitalization of land rent. Calculation of the relative indicator of cadastral value of each soil variant within the land plot is determined by dividing the relative indicator of land rent of the soil variant by the capitalization coefficient. The relative indicator of cadastral value of land within the land plot is calculated as a weighted average value of relative indicators of cadastral value of soil variants. The cadastral value is determined by summing up the products of relative indicators and areas occupied by these lands within the boundaries of the plot.

The main problems that arise in practice in evaluating agricultural lands include, land evaluation, mainly by income-based approach methods and as a result, inability to verify results by other methods, obtaining official information on agricultural transactions, determining the discount rate, obtaining information on crop yields on the land of different quality and quality of agricultural land within farms, land evaluation, the rights to which are different from full ownership (land shares, the right to land lease), land evaluation in depressed regions with low population density, taking into account significant fluctuations in prices for agricultural products; assessment of agricultural land, the most efficient use of which is not farming but development for summer houses, cottages and recreational facilities (prestigious suburbs of large cities and recreational-attractive places), evaluation of land under perennial plantings-orchards, vineyards, shelterbelts and forest vegetation (Tyuklenkova *et al*., 2014).

Yakupova and Galimova (2016) believe that the calculation of cadastral and market costs, essentially is based on the same market information. Differences between the information bases of the assessment are in fact reduced to the magnitude of the error in determining the value of certain objects for which all the information required by law should be taken into account in the database of the state real estate cadastre but no particular features of this or that object are taken into account. In this case, the definition of market value gives a more correct result, since, it is an individual assessment that takes into account all the factors affecting the value and the definition of cadastral value determined by methods of mass evaluation has a large error due, for example, to inaccurate or incomplete reflection of the characteristics of the object in the cadaster (Yakupova and Galimova, 2016).

The cadastral value of land is close to market value and therefore cannot be a constant criterion. Approaches to the methodology of cadastral evaluation in different countries are different but there are also general trends. Assessment of soil quality is one of the most important characteristics affecting the cadastral value of agricultural purposes. As Baumane (2011) notes an assessment of the quality of soils in the parishes of Latvia was carried out. The conducted study led to the conclusion that assessment of soil quality is an important information for determining the cadastral value and for the actualization of these indicators, a set of government measures is needed. In the Czech Republic, according to the data of the Department of Geodesy, Cartography and Cadastre for 2008-2016, a decrease in the cadastral value of agricultural land was recorded. The main causes are erosion processes, non-compliance with agricultural practices and incorrect selection of crops in crop rotations (Gebeltova and Halova, 2017).

Tai *et al*. (2016) propose the conservation of some parcels of land to improve soil fertility. They note that in the short term such a policy may have an adverse effect on the economy but it will pay off in the long term. In Latvia, on the contrary, new solutions are constantly being sought to prevent inefficient use of agricultural land and reduce land resources. Arika and Mazure (2017) concluded that in Latvia, the agricultural land used is decreasing every year, the decrease is 2.78% for 6 years.

Abandoned lands and changes in purposiveness mainly reduce the areas of land. The main reasons for the abandonment of land are inefficient land management because of their poor quality (soil fertility) as well as the lack of financial resources for landowners. In order to avoid land degradation and land resources reduction, an additional real estate tax rate of 1.5% was introduced to agricultural lands that were not cultivated in 2010 and since 2016, fines have been imposed on those landowners who leave the land abandoned.

There are also questions about the quality of evaluation work and actualization of data. In 2008, a nation-wide land assessment was conducted in Slovenia. However, there are some questions about the reliability of the data as evidenced by requests for changes in land assessments based on the results of field research. Grchman *et al*. (2017) compared the results of official information from the open databases and the values of the land-rating assessment based on calculations with precise data on soil characteristics obtained from the analysis of 44 soil profiles located in various pedosystematic units. On average, the difference between the evaluation based on accurate calculations and official information was 5 points. Large differences were found on agricultural land with a lower production potential, on agricultural land with higher production potential, the differences were smaller.

Mackiewicz and Karalus-Wiatr (2017) give evidence that in Poland untimely changes are made to the real estate cadastre. In 2014, almost 7% of all land in the commune of Rokietnica, located in the immediate vicinity of Poznan were built up with housing, mostly separately standing single-family houses with land plots. Almost half (49.4%) of the total area of these plots (42 ha) still remained agricultural land in the real estate cadastre and was taxed not by a property tax but by a much lower agricultural tax. The same problem exists in the Czech Republic. After the analysis of the land registry data, Yaroslava Janku, Pavel Sekac and Yaroslava Barakova indicate a significant reduction in the acreage of agricultural land in the period 1966-2013 up to 25 ha/day (Janku *et al*., 2016). In addition, the actual building area, apparently is greater than in the records of land for construction in the cadastral register. There is an obvious discrepancy between the actual state and cadastral data, so the actual reduction of arable land in the Czech Republic may be even greater. Based on the quality of land, the Czech law on land protection classifies soils into five protection classes. Sites with first and second-class soils should not be used for construction purposes. Nevertheless, the study showed that the municipalities often ignored the law and the areas with the best quality soils were often taken for construction. Ineffective land protection is a very serious pan-European problem.

Gosa and Mateoc-Sirb (2014) notice that the work on compiling maps and cadastral soil classification allows creating a graphic and descriptive database necessary for inventory, classification and assessment of soil resources. The upper layer of the soil is studied in connection with natural and anthropogenic factors that determine its characteristics and, accordingly, natural fertility.

Inan *et al*. (2011) also register a discrepancy between the real uses of agricultural land with accounting data in Turkey. Kidd *et al*. (2018) take their stand and recommend using digital technologies for mapping agricultural lands. They also propose to make a separate assessment of land in terms of use in agriculture, nature conservation and forestry.

As noticed by Giuffrida and Gagliano (2012), agriculture is one of the most fragile sectors of the economy of Italy and Sicily and is largely subject to fluctuations in the financial crisis. Therefore, it needs active measures to maintain sustainability and improve land resources by introducing innovations and increasing efficiency. The cadastre has always been the most important source of data for accounting for fiscal property, especially with the introduction of GIS technology. When carrying out a balanced land and agricultural policy, one should take advantage of modern GIS technologies. These authors offer their evaluation model for estimating cadastral land plots.

As we can see from the cited sources, different methods are used for cadastral valuation of agricultural land. However, none of them gives optimal results, therefore many issues of cadastral evaluation remain controversial.

MATERIALS AND METHODS

In this study, a methodology for assessing soil fertility by energy criteria for determining the cadastral value of land is considered. The basis of the bioenergetic approach to the assessment of soil fertility was the concept of the soil-formation energy developed by Kovda (1981), Volobuev (1974) and Dobrovol'skii and Nikitin (1990). When developing a methodology for bioenergetic assessment of soil fertility, we proceeded from the effect of the global law of nature-the law of conservation of energy and matter-on the agroecosystem. The possibility of estimating the level of soil fertility in energy units is based on the assumption that the amount of chemically bound light energy in the process of photosynthesis is constant and equals 974 kcal or 2822 kJ/1 carbohydrate molecule. Hence, 3.74 kcal or 15.66 kJ of solar energy (974 cal/180 g/mole $C_6H_{12}O_6$) binds to produce 1 g of photosynthesis material and according to the data of Kovda (1981), 20.938 kJ of energy is spent on producing 1 g of humus.

Soil fertility in energy units (MJ/ha) is estimated from the energy reserves of humus and energy equivalents of forms of nitrogen, phosphorus and potassium available for plants. To determine the cost of land we used energy equivalents: 1 ton of humus-20938 MJ, 1 ton of spring wheat-16310 MJ, 1 ton of oil -53400 MJ, 1000 m^3 of natural gas -49500 MJ, 1 kWh. of electricity -12 MJ, 1 kg of nitrogen -86.8 MJ, 1 kg of phosphorus -12.6 MJ, 1 kg of potassium -8.3 MJ.

RESULTS AND DISCUSSION

The cadastre of agricultural land parcels should be based on accounting for all factors that affect the size of the rental income. At the same time, it is necessary to take into account the soil and climatic factors. For example, bioenergetic assessment of soil fertility can be used. The tension of soil-formation energy is the primary cause of the heterogeneity of soil cover by the level of natural fertility. Accounting for the material-energy flows intensity in agroecosystems makes it possible to evaluate the fertility level quantitatively in energy units.

In 2017 in the territory of Karmaskalinsky District of the Republic of Bashkortostan, work was done to adjust the soil map of agricultural land in the context of rural settlements. Karmaskalinsky District is located in the central part of the Republic of Bashkortostan within the left bank area of the middle reaches of the Belaya River. Leached and ordinary chernozems predominate in soil cover of arable land in the district (about 70%). Gray forest soils take about 26% of the tillable land. The eroded soils account for about 20% with the bias to water erosion (Fig. 1).

The materials obtained as a result of soil surveys were used to assess the quality of the fertility level and to determine the alternative cadastral cost of arable soils. For bioenergy estimation of land quality and determination of their alternative cadastral cost, we used for energy equivalents, 1 ton of humus -20938 MJ, 1 ton of oil -53400 MJ, 1000 m^3 of natural gas-49500 MJ, 1 ton of spring wheat -16310 MJ, 1 kWh. of electric energy-12 MJ, 1 kg of nitrogen -86.8 MJ, 1 kg of phosphorus-12.6 MJ, 1 kg of potassium -8.3 MJ. Hence, the energy of 1 ton of humus is equivalent to the energy of 1.28 tons of grain of spring wheat, 0.392 tons of oil, 423 m^3 of natural gas or 1.745 kWh of electricity. One must note that energy prices in the world market are the most sustainable and can serve as an objective criterion for estimating land in energy units or in their monetary equivalents.

On this basis, the energetic potential and the monetary value of the soils and arable land of the rural settlement Sakhaevsky Village Council of Karmaskalinsky District of the Republic of Bashkortostan is determined. To identify the alternative cadastral land cost, the following indicators were used:

- The price of oil at $43.8/barrel
- Exchange rate -64.7 rub./dollar

These indicators of the oil and currency markets were included in the budget of the Russian Federation for 2018-2020. A detailed calculation for the transition to the cost of humus from the cost of oil as its energy equivalent is given as:

- 159 l = 1 barrel of oil
- 1 barrel -$43.8
- 1 ton of oil -1 000*$43.8 /159 l = 275.47$
- 1 ton of humus = 0.392 tons of oil
- 1 ton of humus = 0.392*$ 275.47 = $107.98 or 6986.31 rub.($107.98*64.7)
- 1 ton of humus = 20938 MJ = 20.938 GJ

Thus, the cost of 1 ton of humus with energy of 20 938 MJ for oil equivalent is $107.98 or 6 986.31 rub. From here, you can get a monetary assessment of soil fertility based on their energy potential.

Consequently, the energy and dollar equivalents of 1 ton of humus in rubles of the Russian Federation in the future can be objectively used for bioenergy assessment of soil fertility and determination of the cadastral value of land in the natural areas of the Republic of Bashkortostan.

Analyzing the results of the bioenergetics evaluation of fertility by soil variants, it can be concluded that fertile leached ordinary chernozem, the cost of 1 ha of which amounts to $61 956.18 or 4 008 564.85 rub. has the greatest bioenergetic potential in terms of the reserves of humus and nutrients equal to 12 043,3 GJ/ha; leached mid-deep medium-humic weakly eroded ordinary chernozem has the lowest energy potential, equal to 5 913.7 GJ/ha, the cost of 1 ha being $30 384.64 or 1 965 886.21 rub. The large variation in the results of the assessment is due to the diversity of the soil cover of the territory.

The weighted average value of the energy potential of soils in the rural settlement is 7 576.3 GJ/ha, the average cost of one ha of soil is 38 849.22$ = 2 513 544.32 rub.

For comparison, we present the results of the evaluation of the neighboring Ufa district. Bioenergetic cost of arable land in Zubovsky village council by energy of soil fertility averages 2 966 852.27 rub. with a deviation of soil from 2 228 637.61-3 751 646.3 rub./ha.

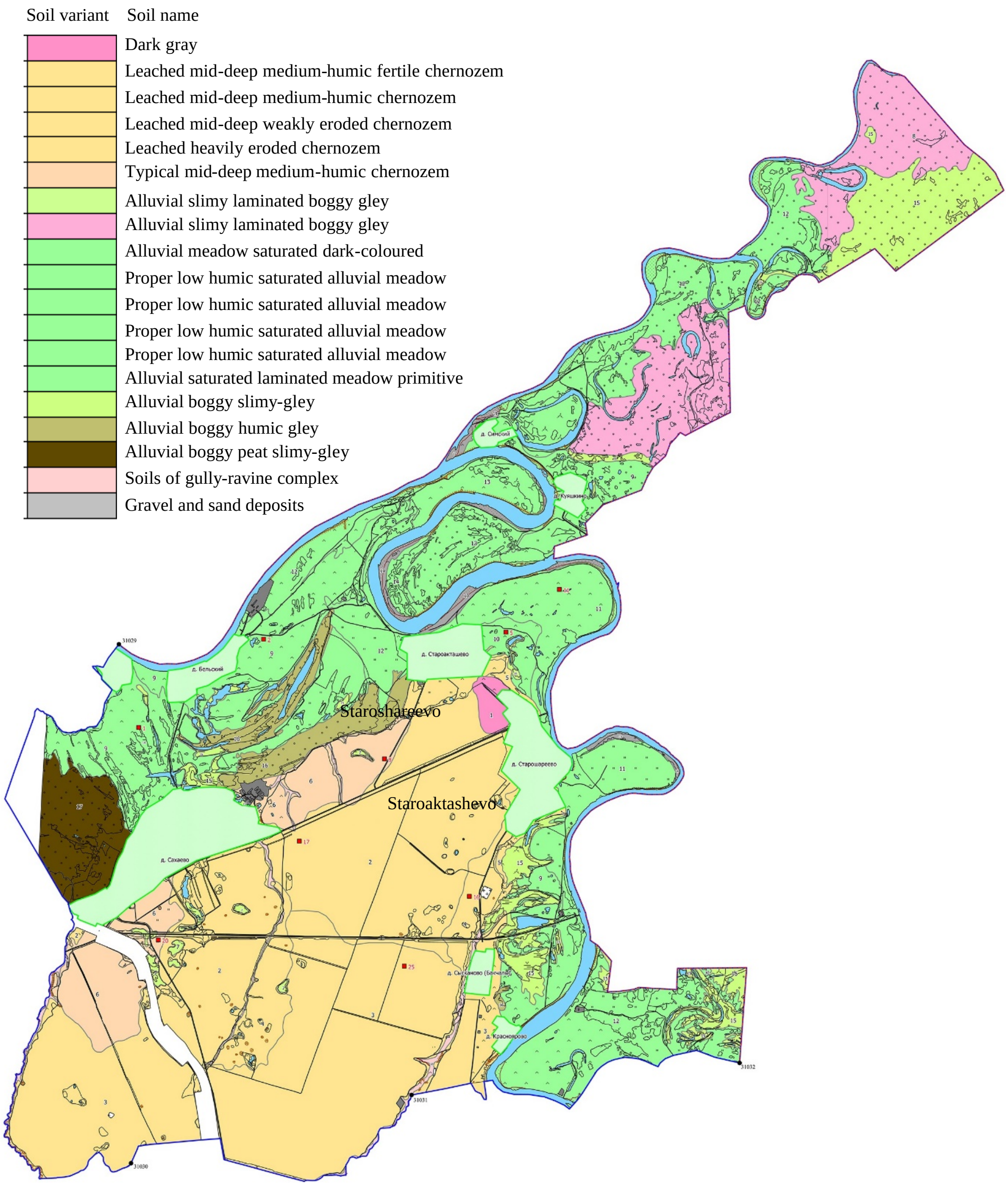

Fig. 1: Soil map of agricultural land, rural settlement Sakhaevsky village council, corrected in 2017

The results consideration: According to Sventitsky (1981) in the conditions of intensive economic use of soils, the yield of the plants cultivated on them is limited mainly by the inflow of the energy of solar radiation to the plants, temperature and humidity.

However, these natural factors of output yield in production conditions at the current level of development of science and technology require high energy and material costs.

According to the state (national) report on the status and use of land in the Republic of Bashkortostan in 2017, the average value of the relative indicator of the cadastral value of agricultural land was 48,000 rub./ ha. We believe that the official valuation method does not reflect the real value of agricultural land. Only the high cost of agricultural lands will protect them from irrational use. Some scientists believe that the high cost of land will affect the value of land tax. However, the rate of land tax is regulated by the state and therefore the amount of tax can be regulated through the tax rate.

The energy and dollar equivalents of 1 ton of humus, in terms of Russian rubles can later be objectively used for bioenergetic assessment of soil fertility and determination of the alternative cadastral value of land by natural zones of the Republic of Bashkortostan.

The testing of the land evaluation method was carried out in typical land cover farms located territorially in various natural and climatic zones of the Republic. At the same time, we believe that the bioenergetic potential of soil fertility in terms of humus reserves in energy units corresponds to the total energy of its potential fertility and the level of effective fertility is determined by the energy equivalents of nitrogen, phosphorus and potassium in the soil in a form accessible to plants.

At the international level, there is growing interest in land administration and land cadastre management and especially in their role as part of the national Spatial Data Infrastructure (SDI). The important role of the cadastre in supporting sustainable development of agriculture is also widely recognized (Rajabifard *et al*., 2007). Both developed and developing countries recognize the need to assess cadastral systems in order to identify areas that require improved inventory management and cadastral valuation. Almost all countries are constantly restructuring the system of cadastral accounting and cadastral valuation, comparing systems and trying to determine the best method in countries with the same socio-economic situation.

CONCLUSION

The land as an object of cadastral valuation has a twofold essence: first, in agriculture it serves as the main means of production and secondly, it is the bearer of immovable property value.

A characteristic feature of the current state of arable soils is the imbalance in energy-mass transfer in the soil-plant-environment system, the negative balance of humus, depending on the type of arable soils, the genetically low content of available forms of phosphorus and mineral nitrogen, the reduction in the number of waterproof structural aggregates and re-consolidation of arable layer of soils, accompanied by a significant decrease in air-heat exchange and biological activity of soils, development of erosion processes and flushing of fine soil.

In order to protect fertile agricultural land, they must be assessed higher than other lands. According to the results of evaluation, fertile leached ordinary chernozem, the cost of 1 ha of which amounts to 61 956.18$ has the greatest bioenergetic potential in terms of humus and nutrients reserves equal to 12043 GJ/ha, leached mid-deep medium-humic weakly eroded ordinary chernozem has the lowest energetic potential, the cost of 1 ha being 30 384.64$.

The weighted average value of the energetic efficiency of the soil on the rural settlement Sakhaevsky village council makes 7 576.3 GJ/ha, the average cost of one ha of soil makes 2 513 544.32 rub. Moreover, according to official data, the average value of the relative indicator of cadastral value of agricultural land in this area was 48 000 rub/ha.

The bioenergetic estimation method allows more accurate (higher) assessment of the potential of lands. Therefore, when transferring agricultural land to other categories, the results of bioenergy assessment must be taken into account. Fertile land should be used only for the production of agricultural products.

REFERENCES

Arika, E. and G. Mazure, 2017. Problems and solutions for abandonment of utilised agricultural areas in Latvia. Econ. Sci. Rural Dev. Conf. Proc., 1: 307-314.

Baumane, V., 2011. Soil quality assessment impact on the real property cadastral value. Econ. Sci. Rural Dev. Conf. Proc., 1: 24-30.

Dobrovol'skii, G.V. and E.D. Nikitin, 1990. Soil Functions in the Biosphere and Ecosystems. Nauka Publisher, Moscow, Russia, Pages: 281.

Gebeltova, Z. and P. Halova, 2017. Analysis of changes in official agricultural land prices in the CR in years 2009-2017. Proceedings of the 26th International Conference on Agrarian Perspectives XXVI, Competitiveness of European Agriculture and Food Sectors, September 13-15, 2017, Czech University of Life Sciences Prague Prague, Czech Republic, ISBN:9788021327870, pp: 64-70.

Giuffrida, S. and F. Gagliano, 2012. Cadastral civil uses and socio-economic recovery: A GIS based analysis-appraisal model to boost agricultural sustainability. Proceedings of the 42nd Meeting on Research-Centre-for-Appraisal-and-Land-Economics (Ce.S.E.T.), November 22-23, 2012, Medimond Srl, Bologna, Italy, ISBN:978-88-7587-690-6, pp: 103-116.

Gosa, C.I. and N. Mateoc-Sirb, 2014. Agricultural lands bonitation and estimation of crop production in almajului valley, caras-severin county. Proceedings of the 14th International Multidisciplinary Scientific Geoconference on Surveying Geology and Mining Ecology Management (SGEM), June 19-25, 2014, Bulgarian Publishing Company, Bulgaria, Balkans, ISBN:978-619-7105-14-8, pp: 11-14.

Grchman, H., S. Vozel and V. Zupanc, 2017. Soil characteristics and agricultural land evaluation. Geodetic Newspaper, 61: 13-22.

Inan, H.I., T. Yomralioglu and N.E. Ulger, 2011. Evaluation of national farmers registry data in geo-information context: Case study of Trabzon, Turkey. Sci. Res. Essays, 6: 422-429.

Ipsic, I. and J. Maslek, 2015. Cadastral revenues and direct taxes on the peljesac peninsula in the latter half of the nineteenth century. Anal. Inst. Historical Sci. Croatian Acad. Sci. Arts Dubrovnik, 53: 379-405.

Janku, J., P. Sekac, J. Barakova and J. Kozak, 2016. Land use analysis in terms of farmland protection in the Czech Republic. Soil Water Res., 11: 20-28.

Kidd, D., D. Field and A. McBratney, 2018. A preliminary estimate of the spatial dimension of Tasmania. Geoderma, 322: 184-200.

Kovda, V.A., 1981. The Problems of Protecting the Soil Cover and the Biosphere of the Planet. Nauka Publisher, Moscow, Russia, Pages: 182.

Mackiewicz, B. and C. Karalus-Wiatr, 2017. Agricultural land on built-up housing lots and the incomes of communes: An example of rokietnica commune in the poznan agglomeration. Quaestiones Geographicae, 36: 95-106.

Rajabifard, A., I. Williamson, D. Steudler, A. Binns and M. King, 2007. Assessing the worldwide comparison of cadastral systems. Land Use Policy, 24: 275-288.

Sventitsky, I.M., 1981. Bioenergetic assessment of fertility. Bull. Agric. Sci., 1: 32-38.

Tai, M.Y., C.C. Chao, L.J. Lu, S.W. Hu and V. Wang, 2016. Land conservation, growth and welfare. North Am. J. Econ. Finance, 38: 102-110.

Tyuklenkova, E.P., V.V. Presnyakov and G.Y. Sinitsina, 2014. Modern problems of assessment cadastral value agricultural land. Mod. Prob. Sci. Educ., Vol. 1,

Volobuev, V.R., 1974. Introduction to the Energy of Soil Formation. Nauka Publisher, Moscow, Russia, Pages: 128.

Yakupova, N.M. and L.I. Galimova, 2016. Challenging the cadastral value of land. Mod. Prob. Sci. Educ., 1: 417-422.