International Journal of Plant & Soil Science

22(6): 1-9, 2018; Article no.IJPSS.41098
ISSN: 2320-7035

The Evaluation of Water Regulation Agroecosystem Services in Context with Risk Area Determination

Makovníková Jarmila[1*], Houšková Beáta[1], Široň Miloš[1], Pálka Boris[1], Kanianska Radoslava[2] and Kizeková Miriam[3]

[1]National Agricultural and Food Centre, Soil Science and Conservation Research Institute, Bratislava, Slovakia.
[2]Department of Environment, Faculty of Natural Sciences, Matej Bel University Banská Bystrica, Slovakia.
[3]National Agricultural and Food Centre, Grassland and Mountain Agriculture Research Institute, Banská Bystrica, Slovakia.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2018/41098
Editor(s):
(1) Aamir Raina, Department of Botany, Aligarh Muslim University, Aligarh, India.
Reviewers:
(1) Şana Sungur, Mustafa Kemal University, Turkey.
(2) Fábio Henrique Portella Corrêa de Oliveira, Universidade Federal Rural de Pernambuco, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/24673

Original Research Article

Received 11th February 2018
Accepted 23rd April 2018
Published 18th May 2018

ABSTRACT

Aim of this study is to assess and map the retention capacity of the soil in agroecosystem, the capacity of the ecosystem to provide water regulation in Slovak Republic, as well as to describe the use of GIS techniques in creating an uniform spatial units for agroecosystem services inventor. We have created a mapping unit combining these input layers: slope topography, soil texture and usage of land in four climatic regions. Potential of water regime regulation (soil water storage) is determined on the basis of the value of retention water capacity recalculated to soil water storage in context with the soil depth. Evaluated potential of water regulation service was categorised into five categories (very low, low, medium, high and very high). In Slovakia 27.47% of the area of agricultural ecosystems has very high potential for regulation of water regime (accumulation of water in the soil). They are mostly ecosystems of arable land located in Eastern Slovak Lowland, Danubian Upland, South-Slovak Basin and Košice Basin with heavy clay loam and clayey deep soils without skeleton. Ecosystems with very low and low potential for water storage occupy

**Corresponding author: E-mail: j.makovnikova@vupop.sk;*

32.04% and these are predominantly grasslands. To identify the risk areas, we evaluated the potential of water regulation in relation to factor R, which represents the risk of torrential rain. In Slovakia 18.20% of the area of agricultural ecosystems has from very high to high risk of agroecosystem degradation. The methodology developed in this paper is replicable and could be applied by planners in the case they are proficient in geographical information systems.

Keywords: Agroecosystem services; soil water storage; water regulation potential; mapping units.

1. INTRODUCTION

Service-providing ecosystems are denoted as natural capital [1]. On the basis of this, it could be perceived the linkage between economy and ecological dimensions [2,3,4,5]. To achieve this in sustainable way, natural capital has to be related to other forms of capital, such as production, human and social or cultural capital. Ecosystem services (the provisioning, regulating and cultural one) are basically determined by the interaction between ecological and social systems, because only those ecosystem processes contributing to the satisfaction of human needs are defined as ecosystem services [3,5,6]. Understanding the interactions between properties and processes is therefore essential for the mapping and assessment of ecosystem services. Biophysical assessment of ecosystem services is a quantification of the flow of services in biophysical units [7]. However, it also requires a regular measurement of indicators of ecosystem services [7]. Explicit quantification and mapping of ecosystem services is considered to be one of the key requirements for implementing the concept of ecosystem services into institutional decision making. Models and their map views should reflect biophysical factors on one hand, but on the other hand they should also be applicable within administrative [8,9,10].

According to Burkhard [3], the potential of ecosystem services is defined as a hypothetically maximum possible fulfilment of ecosystem services. The potential of ecosystem services is comparable to natural capital stock and ensures the current and future flow of ecosystem services [11]. In agroecosystems, current flows may be higher than potential due to the anthropogenic subsidization of agroecosystems in the form of nutrients and irrigation. Agroecosystems of arable soils are in the assessment of ecosystems according to the Corine Land Cover classification, which is also used for assessing ecosystems within Europe, categorized as having a high potential for supply services and low potential of regulating and cultural services, regardless of their location and potential for soil fertility [12]. The agroecosystem based on soil is multifunctional in all conditions, both in terms of its processes and functions and services [13]. Experts also often discuss whether ecosystem services only provide natural and semi-natural ecosystems or artificial [14]. The agroecosystem services are the only issue to be discussed. Agroecosystems, such as arable soils, are mostly biotopes for only a few plant and animal species and are very poor in biodiversity because of the targeted cultivation of monocultures. On the other hand, arable land has better infiltration capacity, which significantly contributes to the fulfilment of regulatory services. Services provided by agroecosystems may vary considerably depending on soil quality, localization and soil management. Improper land management can lead to land degradation and a significant reduction in the productive and service functions [15].

In ecosystems of the agricultural land, regulation of water regime (water storage), control of soil erosion (erosion control), climate regulation (C reserves in the soil) and filtration of pollutants are main regulation services [16]. The presence or absence of water in the country significantly affects provisioning services, other regulating services as well as support processes and biodiversity [17,18]. Water that is not adequately controlled by the ecosystem represents a much higher risk of fluctuations, which can lead to flooding or water scarcity [19]. According to the Burkhard [19], the flow of water through the landscape can be influenced by the following natural processes that all of which contribute to the storage of water and thus to the reduction of the surface runoff: vegetation capture, surface water storage, infiltration and retention in the soil and penetration into groundwater stores in context with the slope of the landscape. In addition to these processes the availability of water in agroecosystems depends on its accumulation in the soil [20], as well as on the degree of permeability of the soil. The retention capacity of the soil belongs to the main parameters that influence the capacity of the ecosystem to provide water regulation as a service. The soil's capacity to accumulate water depends on soil parameters (soil texture, soil mineralogical composition, soil quality and composition, soil compaction or bulk density, soil structure, content and quality of soil organic matter and the environment properties [21]. It depends strongly also on the depth of soil – amount of soil material and the kind and arrangement of soil horizons. Total amount of potentially stored water in agricultural soils of Slovakia is in range 2,27 - 4,89 mld. m^3 water, thus soil can be considered as thirs water resource where oceans and sees are the first and rivers and lakes the second resource [22,23].

The aim of this study was to assess and map the retention capacity of the soil in agroecosystem as the capacity of the ecosystem to provide water regulation as a service on national level in Slovak Republic as well as to describe the use of GIS techniques in creating an uniform spatial units for agroecosystem services inventory, too. To identify the risk areas, we evaluated the potential of water regulation in relation to factor R, which represents the risk of torrential rain.

2. MATERIALS AND METHODS

2.1 Potential of Water Regime Regulation of Agroecosystem

Potential of water regime regulation (soil water storage) was obtained from maps and databases [21]. Its values are given in mm and are determined on the basis of the value of retention water capacity recalculated to soil water storage in context with the soil depth (depth 0 – 100 cm). Values were categorised into five groups and the categories are as follows: 1 – very low potential (<135 mm), 2 – low potential (135-175 mm), 3 – medium potential (176-215 mm), 4 – high potential (216-275 mm), 5 – very high potential (>275 mm).

2.2 Rain Erodibility Index

An erosive effect of torrential rain - factor R (rain erodibility index - EI index). According to Wischmeier and Smith (1978), this factor is the product of the total kinetic energy of rain and its maximum 30-minute intensity. The map of the erosion impact of the rain was created on National Agricultural and Food Centre/ Soil Science and Conservation Research Institute using the tools of Geographic Information system. The following bases were used to derive the R factor: An altitude layer was derived from the digital elevation model of the Slovak Republic with a resolution of 20x20 m, the layer of the climatic areas of SR and the average precipitation sums in the Slovak Republic in the vector data format, created from cartographic data from the Landscape Atlas of Slovak Republic [24,25] and ombrographic stations of Slovak Republik layer (86 stations) with data of R factor calculated by [26].

Values were categorised into five groups and the categories are as follows: 1 - very high, 2 – high, 3 – medium, 4 – low, 5 – very low. http://www.podnemapy.sk/portal/verejnost/erozia/r_faktor/r_faktor.aspx)

2.3 Assessment of Risk Areas of Agroecosystem Degradation

Assessment of risk areas of agroecosystem degradation was determined as a sum of the potential of water regime regulation (very low potential – 1 point, low potential – 2 points, medium potential – 3 points, high potential – 4 points, very high potential - 5 points) and rain erodibility index (very low potential – 5 point, low potential – 4 points, medium potential – 3 points, high potential – 2 points, very high potential - 1 points) transformed into a point rating as follows: very high degradation risk – less than 3 point, high degradation risk – from 3 to 4 points, medium degradation risk – from 5 to 6 points, low degradation risk – from 7 to 8 points, very low degradation risk – more than 8 points. The high degradation risk was evaluated by the low point value.

2.4 Study Area

Slovakia is a land-locked country in Central Europe between latitudes 47º and 49ºN and longitudes 15º–21ºE. Its terrain is mostly hilly, upland and mountainous in the central, north and north-eastern parts of the country where the permanent grasslands mainly occur. According to the LPIS system, in Slovakia in 2016 there were 1 411 294 ha of arable land and 858 601 ha of grasslands. The LPIS is one of the five components of the Integrated Administration and Control System (IACS) and is a necessary prerequisite for subsidies in the EU agricultural sector.

2.5 Mapping Units

The cartographic basis for agroecosystem evaluation and mapping units was the LPIS (Land Parcel Identification System) layer (https://podnemapy.vupop.sk). For spatial quantifying of regulating agroecosystem services of used agricultural land in Slovakia, we have created a mapping unit combining four input layers: climatic region (four categories- moderately cold, moderately warm, warm and very warm [27], slope topography (four categories 0-2º, 2.1º-5º,5.1º–12º, more than 12º), soil texture (three categories) and land use (arable land, grassland and other cultures (orchards, vineyards, hops fields)). The layer for evaluating and mapping agroecosystem services is the result of a combination of all four layers, creating 100 functional aggregate units. Each mapping unit was designed so that it represented one cell of 100 m resolution regular grid. Layer spatial aggregate function unit is also compatible with the spatial units in international use database (Corine Land Cover) as carries information on the use of land. Within each unit created space, we calculated a weighted average of the water regulation potential. Software package of the geographic information system ArcGIS® was used for processing the input geo-referenced digital data and the resulting maps. The SYSTAT 13 program and Spearmann correlation analysis were used for statistical evaluations.

3. RESULTS AND DISCUSSION

The water regulation potential was evaluated in 5 categories based on the value of retention water capacity converted to the water content in the soil in mm in context with the depth of the soil. Because the provision of ecosystem services depends on biophysical conditions, land use and climatic changes [28], the supply and demand of water regulation may differ geographically, as shown in Fig. 1.

These factors are involved in the formation of soil cover which absorbes the majority of atmospheric precipitation within ecosystems and makes it available to plants. The rate of water accumulation depends on soil type, which characterizes the spatial variability of soil texture and soil organic matter horizontally in the landscape as well as vertically the depth of soil profile which is created from soil horizons (determined by their thickness, quality and layout. With increasing depth, usually humus content decreases, stoniness increases and clay content changes are present. Soil retention is adversely affected by higher content on the skeleton in soil [29,30,21,31,23]. Rawls et al. [32] found a rise in water retention in the soil of the USA with soil organic carbon growth, which increased mainly in sandy soils. In Slovakia 27.47% of the area of agricultural ecosystems has very high potential of water regime regulation (accumulation of water in the soil) (Table 1). They are mostly ecosystems of arable land (Table 1) located in Eastern Slovak Lowland, Danubian Upland, South-Slovak Basin and Košice Basin with heavy clay loam and clayey deep soils without stonyness, which are developed on clay sediments of former seas and lakes, as well as rivers situated in the foothill parts of lowlands and in basins [33]. The high values of water retention in the soil report in their work Bujnovský et al. [21] for clay soil in the East Slovak lowlands. According Matti and Kotorová [31], the retention capacity of water in the deep soils of the East Slovak lowlands amounts to 286 - 420 $m^3.ha^{-1}$. In arable land ecosystems, particularly in high and very high potential categories, water retention is mainly due to a higher proportion of clay fraction or soil organic matter content. Agroecosystems of arable soils have a regulatory capacity

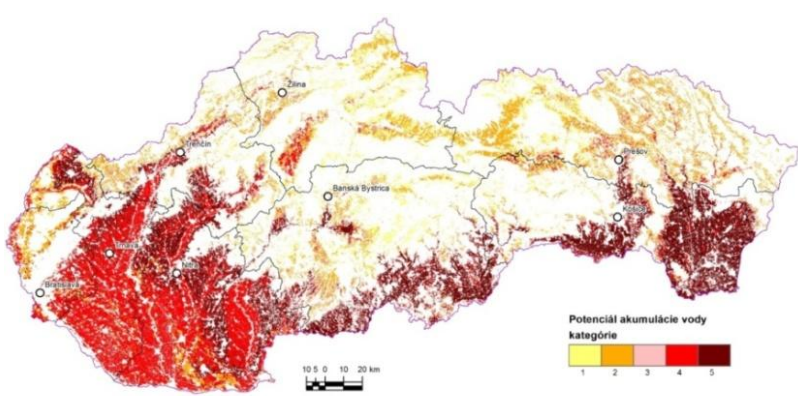

Fig. 1. Potential of water regulation in Slovak republic
1 – very low potential, 2 – low potential, 3 – medium potential, 4 – high potential, 5 – very high potential

influenced by melioration and modified water flows, which results in accelerated water drainage, as well as inadequate groundwater formation. Semi-natural grasslands also reduce drainage extremes by ensuring a gradual infiltration of water and adequate groundwater replenishment [34,35]. Ecosystems with high potential of water regime regulation (Fig. 1) have the highest proportion (35.96%) of the total area of agricultural land. Ecosystems with very low and low potential for water storage occupy 32.04% and these are predominantly grasslands of submountain and mountain areas on the edge of the agricultural landscape with moderately cold to moderately warm climate and considerable inclinations. They are located on shallow to deep soils from slightly to medium content of soil skeleton and higher content of sand.

The greatest influence on water storage potential has climate, but the impact of soil texture is also significant (Table 2) in both ecosystems. Warm, dry and lowland region has a higher potential of water regime regulation in comparison to moderately warm and cold regions.

Transparency and explicit evaluation and assessment of ecosystem services and their benefits are important in the processes of democratic decision-making [6]. Concept of agroecosystem service combines environmental and socio-economic approach to the analysis and evaluation of natural capital. Multi-criteria approach to spatial quantification of ecosystem services related to socio-economic indicators which are districts as statistics territorial units (Local administrative units according EUROSTAT - LAU, [36]), allows explicitly assess potential of ecosystems of agricultural land to provide agroecosystem services and adapt the land management under the local conditions. Fig. 2 shows the assessment of potential of agroecosystem services in regions and districts of Slovakia.

In Bratislava region, more than 70% of agricultural land use has a high potential for regulating the water regime in most districts. In the Nitra region, the category of high potential of regulation of the water regime ranges from 40.30% to 90.86% in individual districts, with three districts slightly dominating a category of very high potential. In the Trenčín region, the five regions have a high share of the low to very low potential of water regime regulation and four districts of high to very high potential. In Trnava, most agroecosystems are in the high-end category of the very high potential of regulation of the water regime, where the percentages of ecosystems of agricultural land with high potential in districts (except two) range from 69.58% to 92.82%. In the Banská Bystrica region there is a high representation in six southern districts and in the remaining seven districts of category very low to low potential. In Žilina region, most districts have a high share of the low to very low potential for water regime egulation, without representation of category of very high potential. Most of the districts of Košice region have a very high potential for regulating the water regime with a share of 49.65% to 91.89%. In the Prešov region, most of the districts have a high representation of the low category. even the very low potential of regulation of the water regime, with the exception of Vranov nad Topľou district, which has more than a third of the area of agricultural land in the category of very high potential.

Integrated, dynamic, non-linear system linking natural systems with production capital, human capital and social or cultural capital is required for the purpose of assessing economic indicators, total progress and well-being [6].

Assessment of risk areas of agroecosystem degradation determined as a combination of the potential of water regime regulation and rain erodibility index shows [26,37] the Fig. 3.

Table 1. Potential of water regulation in Slovak Republic in % of total area of agricultural land

Potential	In % of total area of agricultural land		
	Agricultural land	Arable land	Grass land
Very low	10.83	0.56	10.28
Low	21.21	11.58	9.76
Medium	4.53	2.89	1.50
High	35.96	33.25	2.72
Very high	27.47	26.47	1.00

Table 2. Spearmann correlation coefficients

Correlation coefficients	Agricultural land	Arable land	Grassland
Climatic region	-0.54***	-0.59***	-0.53***
Slope	-0.35**	-0.34**	-0.42**
Soil texture	0.36**	0.46***	0.27
Height above sea level	-0.22	-0.28	-0.10

*Significance labels: *** P <0.001,** P <0.01,* P <0.05, P >0.05*

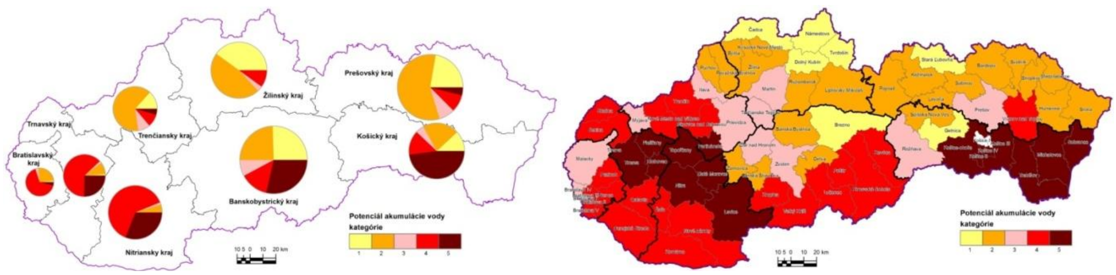

Fig. 2. Average values of water regime regulation potential in individual regions of the Slovak republic

1 – very low potential, 2 – low potential, 3 – medium potential, 4 – high potential, 5 – very high potential

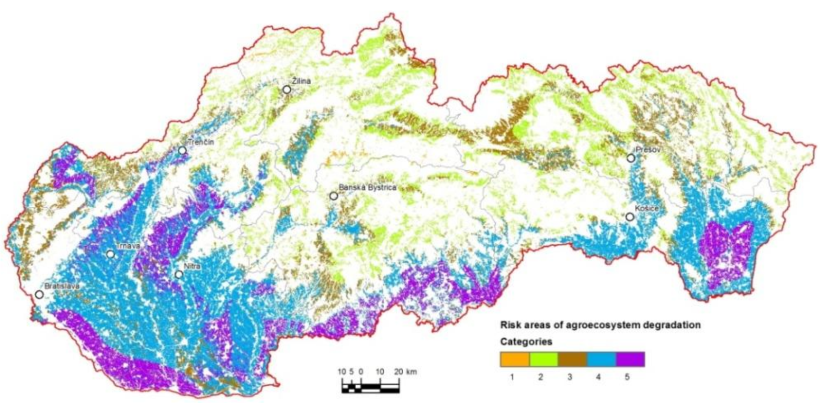

Fig. 3. Assessment of risk areas of agroecosystem degradation (risk of soil erosion)

1 – very high risk, 2 – high risk, 3 – medium risk, 4 – low risk, 5 – very low risk

In Slovakia 18.20% of the area of agricultural ecosystems has from very high to high risk of agroecosystem degradation (Table 3). Lower risk of grassland is in line with the results of several authors [38,39,40].

Table 3. Risk areas of agroecosystem degradation in Slovak Republic in % of total area of agricultural land

Degradation risk	Agricultural land
very low	0.40
low	17.80
medium	18.34
high	45.64
very high	17.82

Water courses of soils are also affected by longer periods of drought, alternated by floods. The combination of water accumulation potential layer in the soil with the erosive effect of torrential rain, which allows the identification and mapping the risk of agricultural land degradation in terms of its endangerment of production properties, frequent occurrences of erosion events, local floods, marsh floods. The food security of Slovakia envisages the supply of a certain amount of agricultural production.

4. CONCLUSION

Agroecosystems can provide a range of regulating services to human communities, in addition to provisioning services. Evaluation of agroecosystem services brings new knowledge, targeted information and spatial quantification of services of agroecosystems as well. The variety of agricultural systems results in a highly variable quantity of water regulation ecosystem services. In Slovakia more than 50% of the area of arable ecosystems has high and very high potential of water regime regulation. The greatest influence on water storage potential has climate. In maximizing the value of ecosystem services appropriate management of key processes may improve the ability of agroecosystems to provide a broad range of ecosystem services [20]. The high potential of water regime regulation is linked to the high potential of provisioning services. The management of agroecosystems can influence the regulation of the water regime by the appropriate soil bulk density of soil surface layer, and the depth of the previous layer that influences the rate and amount of infiltrated water [41] is also important. In agroecosystem, vegetation is predominantly involved in regulating soil retention, regulating erosion. In arable ecosystems, the risk of degradation increases leaving arable land in the winter without vegetation cover, the use of arable soils on slopes with a higher slope and the elimination of boundaries, draws and hedges. In Europe, water erosion affects approximately 115 million hectares of land. Knowing the water regulation in context with erosive threat to agricultural land is a limiting factor for optimizing the use of agricultural land in terms of its sustainability and for the proper arrangement of agricultural land. With the optimization of the use of the landscape we meet in the present practice mainly in the sphere of spatial planning such as the plans of territorial plans of various settlement units, land consolidation projects, territorial systems of ecological stability and others. For practical use as well as legislative use of the concept of agroecosystem services in planning and prospective studies, qualitative and quantitative analysis and evaluation of agroecosystem linked to spatial visualization at the required level are essential. Incorporation of agroecosystem services assessment into decision-making frameworks of management can protect them and is an important step towards the sustainable use of agroecosystems. The knowledge the distributing the risk area of soil degradation in the country can greatly help in the planned management of farmland used. The layer of agroecosystems degradation risks can serve as a basis for determining the necessary conditions for sustainability of the soil production potential by formulating its good management and creating conditions for long-term sustainability.

ACKNOWLEDGEMENTS

The authors acknowledge the Slovak Research and Development Agency for the financial support via Project No. APVV- APVV-15-0160 "Elimination of degradation processes in soil by biodiversity restoring" and Project No. APVV-0098-12 "Analysis, modeling and evaluation of agroecosystem services".

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Costanza R, Daly HE. Natural capital and sustainable development. Conserv. Biol. 1992;6(1):37-463.
2. Nieto-Romero M, Oteros-Rozas E, Gonzáles JA, Martin-López B. Exploring the knowledge landscape of ecosystem services assessments in Mediterranean agroeco systems: Insights for future research. Environ. Sci. Policy. 2013;37: 121-133.
3. Burkhard B, Kandziorai MS, Müller F. Ecosystem service potentials, flows and demands - concepts for spatial localization, indication and quantification. Official Journal of the International Association for Landscape Ecology - Regional Chapter Germany (IALE-D); 2014. Available:http://www.landscapeonline.de/103097lo201434
4. Frélichová J, Vačkář D, Párt, A, Loučková B, Harmáčková Z, Lorencová E. Integrated assessment of ecosystem services in the Czech Republic. Ecosystem Services. 2014;8:110-117.
5. Birghofer K, Diehl E, Andersson J, Ekroos J, Früh-Müller A, Machnikowski F, Mader VL, Nilsson L, Sasaki K, Rundlöf M, Wolters V, Smith HG. Ecosystem services - current challenges and opportunities for ecological research. Front. Ecol. Evol. 2015;2:87. Available:http://dx.doi.org/10.3389/fevo.2014.00087
6. Costanza R. Twenty years of ecosystem services: How far have we come and how far do we still need to go? Ecosystem Services. 2017;28:1-16.

7. Vačkár D, Frélichová J, Lorencová E, Pártl A, Harmáčková Z, Loučková B. Methodological framework for integrated assessment of ecosystem services in Czech Republic. Academie Ved ČR. 2013; 26. Czech.
8. MEA (Millennium Ecosystem Assessment). Ecosystems and human well-being: Our human planet: Summary for decision makers. The Millennium Ecosystem Assessment Series. Washington DC: Island Press. 2005;5.
9. MEA (Millennium Ecosystem Assessment) A toolkit for understanding and action. Protecting Nature´s Services. Protecting Ourselves. Washington DC: Island Press. 2007;28.
10. TEEB. The Economics of ecosystems and Biodiversity: Ecological and economic foundation. Earthscan. London and Washington: Edited by Pusham Kumar; 2010.
ISBN 978-1-84971-212-5
11. Costanza R. Ecosystem services: Multiple classification systems are needed. Biological Conservation. 2008;141:350-352.
12. Burkhard B, Kroll F, Müller F, Windhorst W. Landscapes‘ capacities to provide ecosystem services – a concept for land-cover based assessments' landscape Online. 2009;15:1-22.
13. Coyle C, Creamer RE, Schulte RPO, O'Sullivan L, Jordan P. A functional land management conceptual framework under soil drainage and land use scenarios. Environmental Science & Policy. 2016;56:39–48.
Available:http://dx.doi.org/10.1016/j.envsci.2015.10.012
14. Cowling RM, Egoh B, Knight AT, O´Farrel PJ, Reyers B, Rouget M, Roux DJ, Welz A, Wilhelm-Rechman A. An operational model for mainstreaming ecosystem services for implementation. Proc Natl Acad Sci USA. 2008;105:9483-9488.
15. Asmin. Managing land use and its constrains in developing agriculture: A policy brief to Indonesia. International Journal of Plant & Soil Science. 2018; 21(6):1-6.
16. Dominati EJ. Natural capital and ecosystem services of soils. In Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Lincoln, New Zealand: Manaaki Whenua Press; 2013.
17. Kanianska R, Jaďuďová J, Makovníková J, Kizeková M. Assessment of relationships between earthworms and soil abiotic and biotic factors as a tool in sustainable agricultural. Sustainability. 2016;8(9):906.
18. Makovníková J, Pálka B, Širáň M, Kanianska R, Kizeková M, Jaďuďová J. Modelovanie a hodnotenie agroeko-systémových služieb. Banská Bystrica: Belianum. Slovak. 2017;150.
ISBN 978-80-557-1242-0
19. Burkhard B, Maes J. Mapping Ecosystem Services. Advanced Books; 2017.
Available:https://doi.org/10.3897/ab.e12837
20. Power AG. Ecosystem services and agriculture: Tradeoffs and synergies. Philos. Trans. Roy. Soc. B. 2010;365: 2959–2971.
DOI: 10.1098/rstb.2010.0143
21. Bujnovský R, Balkovič J, Barančíková G, Makovníková J, Vilček J. Hodnotenie a oceňovanie ekologických funkcií poľnohospodárskych pôd Slovenska. Bratislava: Soil Science and Conservation Research Institut. Slovak. 2009;72.
ISBN 978-80-89128-56-3
22. Styk J, Pálka B. Potenciálna ohrozenosť poľnohospodárskych pôd SR vodnou eróziou vyhodnotená využitím empirického modelu USLE. In Zborník prednášok. VII. zjazd Slovenskej spoločnosti pre poľnohospodárske, lesnícke, potravinárske a veterinárske vedy pri SAV. Pedologická sekcia. Bratislava: Soil Science and Conservation Research Institut; Slovak. 2005;73-77.
23. Houšková B. Retenčná kapacita poľnohos-podárskych pôd Slovenska. Proceedings Soil Science and Conservation Research Institute. Bratislava: Soil Science and Conservation Research Institute. Slovak. 2011;33:72-77.
24. Lapin M, Faško P, Melo M, Šťastný P, Tomlain J. Klimatické oblasti. In Atlas krajiny Slovensko. Ministerstvo životného prostredia SR Bratislava a Slovenská Agentúra Životného Prostredia. Slovak. 2002;95.
ISBN 80-88833-27-2
25. Faško P, Šťastný P. Priemerné ročné úhrny zrážok 1: 2 000 000. In Atlas krajiny Slovenskej republiky. Ministerstvo životného prostredia Bratislava a Agentúra životného prostredia Banská Bystrica. Slovak. 2002;99.
ISBN 80-88833-27-2

26. MALÍŠEK A. Zhodnotenie faktora eróznej účinnosti prívalovej zrážky. Geografický časopis. Slovak. 1990;42(4):410–422.
27. Kizeková M, Hopkins A, Kanianska R, Makovníková J, Pollák Š, Pálka B. Changes in the area of permanent grasslands and its implications for the provision of bioenergy: Slovakia as a case study. Grass and Forage Science, 2017;00:1-15. Available:https://doi.org/10.1111/gfs.12333
28. Burkhard B, Kroll F, Nedkov S, Müller F. Mapping supply, demand and budgets of ecosystem services. Ecological Indicators. 2012;21:17-29.
29. Damaška J. Skeletovitost, jako limitující faktor úrodnosti zemědělských půd. Rostlinná Výroba. Czech. 1987;33:785-791.
30. Brodová M. Ohodnocovanie environmentálnych funkcií poľnohos-podárskej pôdy (Valuation of environmental functions of agricultural land). Ekon. Poľnohosp. (Economics of agriculture). Slovak. 2008; 8(4):53–58.
31. Mati R, Kotorová D, Naščáková J. Evaluation and pricing of soil water retention capacities in the East-Slovak Lowland. Agriculture (Poľnohospodárstvo). Slovak. 2009;55(4):189-196.
32. Rawls WJ, Pachepsky YA, Ritchie JC, Sobecki TM, Bloodworth H. Effect of organic carbon on soil water retention. Geoderma. 2003;116:61-76.
33. Kvitkovič, J. Concerning the basic geomorphological problems of the east-Slovakian Lowland. Geografický časopis. Slovak. 1964;20(2):143-159.
34. Lhotský J. Zhutňování půd a opatření proti němu. Praha: ÚZPI; Czech. 2000;66.
35. Hönigová I, Vačkár D, Lorencová E, Melichar J, Götzl M, Sonderegger G, Oušková V, Hošek M, Chobot K. Survey on grassland ecosystem services. Report to the European Topic Centre on Biological Diversity. Prague: Nature Conservation Agency of the Czech Republic. 2012;78.
36. Decree 438/2004. Vyhláška 438/2004 Z.z. Štatistického úradu Slovenskej republiky z 19. júla 2004, ktorou sa vydáva klasifikácia štatistických územných jednotiek. Slovak.
37. Wischmeier WH, Smith DD. Predicting rainfall erosion losses: Guide to conservation planning. Agricultural Handbook No 537. USDA. 1978;58.
38. Nedkov S, Burkhard B. Flood regulating ecosystem services–mapping supply and demand, in the Etropole municipality, Bulgaria. Ecological Indicators. 2012;21: 67–79.
39. Pert PL, Butler JR, Brodie JE, Bruce C, Honzak M, Kroon FJ, Metcalfe D, Mitchell D, Wong G. A catchment-based approach to mapping hydro-logical ecosystem services using riparian habitat: A case study from the Wet Tropics, Australia. Ecol. 2010;7:378–388.
40. Fisher B, Turner RK, Morling P. Defining and classifying ecosystem services for decision making. Ecological Economics. 2009;68:643-653.
41. Rehák Š, Janský L. Fyzika pôdy I. Základné fyzikálne vlastnosti pôdy. Bratislava: Comenius University; Slovak. 2000;108. ISBN 80-223-1544-3

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24673