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ECOLOGICAL-ECONOMIC SUITABILITY OF THE SOILS FOR GROWING OF SPRING BARLEY (HORDEUM SATIVUM L.)

Purpose. To differentiate rural land of Slovakia with aspect to the possibility of effective spring barley growing. **Methods.** Soil investigation oriented to soil reaction study took place in two agricultural enterprises in 2010 and it was repeated after four years again. **Results.** At soil categorization, correlation relationships between the site properties (soil and climatic conditions) and crop biological and agrotechnical requirements were considered. Spring barley requirements were included into yield databases using the software filters in the way that the given site property excluded or limited barley growing, what was reflected in predicted production. The prediction was subsequently interpolated into four suitability categories: soils not suitable for spring barley growing, less suitable soils, suitable soils and very suitable soils. The database formed and each of the Bonited Pedo-Ecological Unit (BPEU) was added in it as well as particular category of suitability for barley growing. By mediation of the Geographic Information System on BPEU distribution in Slovakia, the map of categories of soil suitability for spring barley growing was also generated. **Conclusions.** In Slovakia, there is 20 % of farmland very suitable for spring barley growing, 24 % suitable, 24 % less suitable and 32 % non suitable soils for spring barley growing according to our calculation. In the paper, these categories are characterized in details and specified from the view of geographic, soil, climatic, productivity, economic and energetic parameters.

Keywords: differentiate, rural land, soil suitabilit, growing, spring barley

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ЕКОЛОГО-ЕКОНОМІЧНА ПРИДАТНІСТЬ ҐРУНТУ ДЛЯ ВИРОЩУВАННЯ ЯРОГО ЯЧМЕНЮ (HORDEUM SATIVUM L.)

Мета. Диференціація сільськогосподарських земель Словаччини з встановленням можливості ефективного вирощування ярого ячменю. **Методи.** Диференціація заснована на екологічних, педо-кліматичних і виробничих економічних показниках. **Результати.** Для виділення категорій ґрунтів, розглянуто кореляційні зв'язки між їх властивостями (ґрунтово-кліматичні умови), а також біологічні та агротехнічні вимоги культур. Вимоги до ярового ячменю включені в базу даних врожайності з використанням програмних фільтрів таким чином, що дані властивості дозволяють або обмежують вирощування ячменю, що знайшло своє відображення в плануванні виробництва. Планування потім інтерполювали на чотири категорії придатності: ґрунти не придатні для вирощування ярого ячменю, менш підходящі ґрунти, придатні ґрунти і дуже підходящі ґрунти. Сформовано базу даних та додано в неї Бонітетні Педо-Екологічні Блоки (БПЕБ) і категорії придатності для вирощування ячменю. За допомогою географічних інформаційних систем для БПЕП в Словаччині згенеровано карту категорій придатності ґрунтів для вирощування ярого ячменю. **Висновки.** У Словаччині виявлено 20 % орних земель, які дуже придатні для вирощування ярого ячменю, 24 % придатних, 24% менш придатних та 32 % не придатних ґрунтів для вирощування ярого ячменю за нашими розрахунками. У статті, ці категорії

відрізняються в деталях і уточнюються за допомогою географічних, ґрунтових, кліматичних, виробничих, економічних і енергетичних параметрів.

Ключові слова: диференціація, сільськогосподарські землі, придатність ґрунту, вирощування, ярий ячмінь

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ЭКОЛОГО-ЭКОНОМИЧСКАЯ ПРИГОДНОСТЬ ПОЧВЫ ДЛЯ ВЫРАЩИВАНИЯ ЯРОВОГО ЯЧМЕНЯ (HORDEUM SATIVUM L.)

Цель. Ддифференциация сельскохозяйственных земель Словакии с установлением возможности эффективного выращивания ярового ячменя. **Методы.** Дифференциация основана на экологических, педо-климатических и производственных экономических показателях. **Результаты.** Для выделения категорий почв рассматрено корреляционные связи между их свойствами (почвенно-климатические условия), а также биологические и агротехнические требования культур. Требования к яровому ячменю включены в базу данных урожайности с использованием программных фильтров таким образом, что данные свойства позволяют или ограничивают выращивание ячменя, что отражено в планировании производства. Планирование впоследствии интерполировали на четыре категории пригодности: почвы не пригодные для выращивания ярового ячменя, менее подходящие почвы, пригодные почвы и очень подходящие почв. Сформировано базу данных и добавлено в неё Бонитетные Педо-Экологические Блоки (БПЭБ) и категории пригодности для роста ячменя. С помощью географических информационных систем для БПЭП в Словакии сгенерировано карту категорий пригодности почв для выращивания ярового ячменя. **Выводы.** В Словакии выявлено 20 % пахотных земель очень подходящих для выращивания ярового ячменя, 24 % подходящих, 24 % менее подходящих и 32 % без подходящих почв для выращивания ярового ячменя по нашим расчетам. В статье, эти категории отличаются в деталях и уточняются с помощью географических, почвенных, климатических, производственных, экономических и энергетических параметров.

Ключевые слова: дифференциация, сельскохозяйственные земли, пригодность почвы, выращивание, яровой ячмень

Introduction

Recently, spring barley (Hordeum sativum L.) is in Slovakia grown practically in all types of natural sites ranging from lowlands to mountainous regions. Successful growing of barley, as well as of other crops, is fully dependent especially on environmental climatic and soil conditions. These chief factors influence production and economy of the crop assumptions to a great extent. Although not negligible role is played by genetic and breeding measures, with aspect to heterogeneity of soil-climatic conditions and considerable geomorphologic heterogeneity, various regions show different rates of barley growing suitability.

Soil categorization focused on the crop distribution was in the centre of attention of several works. As early as 1921, economical farmland classification was applied and on this basis, the territory of Slovakia was divided in to four production regions. After 1948 the system of so called geonomical production types was established. In 1958, agricultural production zoning was finished, within which zones with different grow suitability were identified for majority of crops. In the same year, production regions and sub-regions were identified for taxation purposes. They are still used, especially for statistical purposes. The system of soil suitability categories for selected crops, elaborated after 1971, is based on more exact pedological background obtained after completion of Complex Soil Survey and subsequently Soil Appraisal. Important works, done in this area, were published by Korbíni and Facuna [4], Džatko [2], Kováč et al. [5].

Recently, development of information technologies, especially Geographic Information Systems, enables processing of existing and innovated soil databases and more precise quantification and area division of soil suitability categories for crop growing. The aim of this paper is to show such methods for spring barley as an example.

Material and methods

For outlining the regions of soil suitability for barley growing, the bases for us were the crop exact and potential data. Because growing suitability is predominantly judged on the basis of really reached production, this factor played decisive role at the categories formation. Particular data of yields and barley growing economics in Slovakia were obtained for period 1990 to 2000 directly from the farms. Data of 281 agricultural subjects were assessed. They have been farming in various natural conditions on total area exceeding 556 thousand hectares of farmland, which is approximately 23 % of total acreage of farmland in Slovakia.

Both production and economical parameters of successful barley growing are directly connected with pedo-climatic conditions. Data of Slovak climatic regions were analyzed and applied, as well as data of sloping, stoniness, soil depth, soil types and subtypes, soil point values and typological-production soil categories. These data were obtained from the Appraisal Information Database of the Soil science and Conservation Research Institute Bratislava, by mediation of the Bonited Pedo-Ecological Unit (BPEU) planar presentation.

The dependence of studied indicators on soil production potential in analyzed farms (expressed by average point value in 100-point scale) was tested by non-linear polynomial regression analysis. Subsequently, potentially possible yield of spring barley, its share in cropping system as well as potential economical parameters (yields, costs, profit, or loss) were calculated using the regression equations for each of the BPEU and added to database. Soil rate of suitability for spring barley growing was differentiated and qualified using the Geographic Information System ARC INFO, based on vector bonity maps (scale 1:5000) and area distribution of studied factors. All economical indices used in the work were calculated without government subsidy.

Used background:

- Soil Science and Conservation Research Institute database of Bonited Pedo-Ecological Unit (BPEU) data and their point evaluation in 100 point scale [3];
- soil categorization by their allegiance to climatic region, sloping category, texture and stoniness [7, 12];
- typological-production farmland categorization [3] and database of production and economical parameters by the BPEU [10];
- real spring barley yields, their economical parameters (receipts, yields and costs) and real cropping system structure of arable land;
- energetic equivalents for byrley growing energy production, calculated by the methodology of authors Preininger [8] and Strašil [9].

The following codes for the evaluating parameters were chosen:

Soil-climatic regions: *00 - very warm, very dry, plainly, 01 - warm, very dry, plainly, 02 - sufficiently warm, dry, hilly, 03 - warm, very dry, plainly, continental, 04 - warm, very dry, basin-like, continental, 05 - relatively warm, dry, basin-like, continental, 06 - relatively warm, moderately dry, highland-like, continental, 07 - moderately warm, moderately moist, 08 - moderately cold, moderately moist, 09 - cold, moist, 10 - very cold, moist.*

Typological-productivity categories of soils*: O1 – the most productive arable soils, O2 - highly productive arable soils, O3 - very productive arable soils, O4 - productive arable soils, O5 - medium productive arable soils, O6 - less productive arable soils, O7 - low productive arable soils, OT1 - medium productive arable soils and very productive grassland, OT2 - medium productive arable soils and medium productive grassland, OT3 - low productive arable soils and less productive grassland.*

Results and discussion

Generally, rate of successful spring barley growing is judged by real yields of area unit ($t.ha^{-1}$). This, however, with aspect of unequal real energetic and material inputs into plant production process, can be sometimes confusing. Nowadays, production potential of our soils is used only at 68 % by barley growing, as resulted from our previous work [11]. Considerable reserves are particularly in

the crop proper distribution within the conditions that are most suitable for it.

Objective results of the rural country categorization for cropping systems can be reached only by analysis of satisfactory quantity of data and parameters. In spite of statistically sufficient number of respondents, in the case of some parameters there are some exceptions in proposed categories that are not exactly in harmony with the scale chosen.

Starting point for formation of soil suitability categories for barley growing was poly-functional analysis of selected pedo-ecological and economical parameters that remarkably affect the crop successful growing. This analysis showed significant dependence of production and economical characteristics on pedo-climatic conditions.

It is obvious that successful growing is influenced also by other factors that are not included in our analysis. For example, actual soil reaction (pH) was not respected in division of suitability zones. Optimum soil reaction for barley is 6.2 – 7.5 [1]. Therefore genetically acid soils were classified as less suitable for growing. Similar principle was used in classifying compacted soils and soils with clayey gleyic horizon. Although barley is considered as a crop with less requirements for soil properties, economical profitability of its growing assumes acceptation of all pedo-climatic factors.

Based on available data and using an inductive method, four regions were identified with respect to suitability for barley growing.

Rural country characteristics with regards to spring barley growing suitability

Soil category – very suitable – covers 20 % of total acreage of farmland. Primarily, soils of Danubian Lowland, Danubian Hilly Land, Chvojnická Hilly Land and East Slovakia Lowland. Main soil types are Chernozems (48 % of the category area), Fluvisols (35 %, the largest area covered by subtype Mollic Fluvisols - 19 %) and Orthic Luvisols (14 %). Soils are texturally medium heavy (79 %), deep (99 %), without soil skeleton (98 %), mostly on the plane (90 %). The category is located within climatic region 00 and 01 (91%). Soil fertility, expressed in 100-point scale, is between 78 and 100 points.

Mean yields were in the level 4.92 $t.ha^{-1}$. Soils with productivity potential is above 4.63 $t.ha^{-1}$ were included into this category. Assumption of rational spring barley sowing on ploughed land in this category is up to 25 %. According to typological production categorization of farmland, first five soil production categories (O1 to O5) belong to this category. By spring barley growing, profit above 105 $EUR.ha^{-1}$ and profitability rate above 25 % can be attained. Bioenergy produced by barley ranges from 73 to 83 $GJ.ha^{-1}$.

Fig. 1 – Very suitable soils for spring barley growing

Soil category – suitable soils – includes approximately 24 % of Slovak farmland. Geographically, majority of these areas belong to Nitra Hilly Land, South-Slovak Basin, Košice Basin, East-Slovak Lowland and marginal parts of Danubian Lowland. Dominant soil types are Fluvisols (45 %, Mollic Fluvisols cover 14 %), Luvisols (25 %) and Regosols (15 %). As for texture, soils are from medium heavy (61 %), without soil skeleton (89 %), deep (93 %), on medium slopes up to 7^o (91 %). The region is identical with climatic regions 00 to 05 (94 %, the highest proportion belongs to the region 01 – 24 %). Soil point value range is 49 – 77 points.

Potential spring barley yields in the region were in the level 3.83 – 4.60 $t.ha^{-1}$, with mean yield 4.19 $t.ha^{-1}$. In cropping system structure, spring barley can reach up to 20 %. According to typological-production Slovak soils division, the categories located here were identified as high productive arable land to low productive fields (O2 to OT3). The profit obtained by this crop can be assumed in the level 43-104 $EUR.ha^{-1}$ and profitability rate is presupposed within 15-25 %. Spring barley generates 60-73 $GJ.ha^{-1}$ energy

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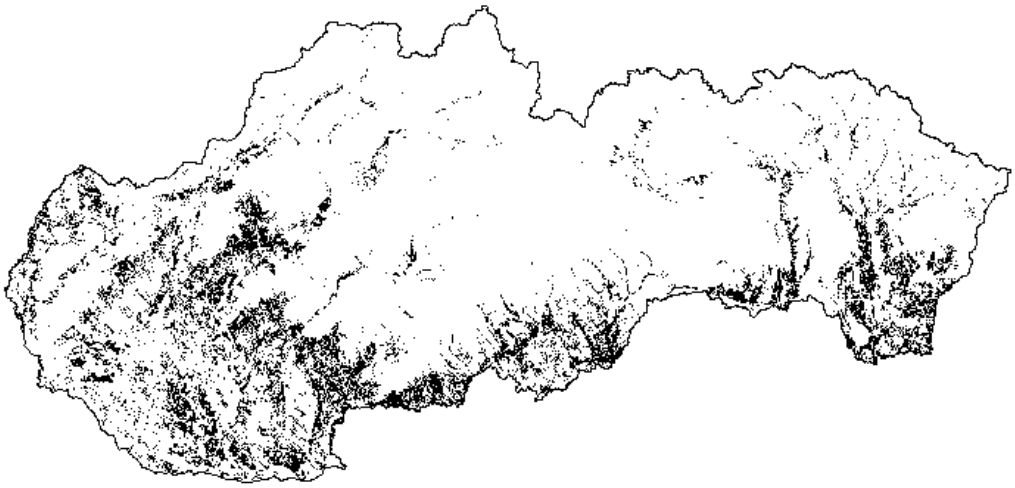

Fig. 2 – Suitable soils for spring barley growing

Soil category – low suitable – covers approximately 24 % of Slovak farmland. It consists of Slovensko-Moravské Karpaty, Borská Lowland, Middle Beskyde, Basin of Turiec, parts of the Southslovakian Basin, parts of Subtatran Basin, Ondavská and Laborecká Highland, Zvolen and Hornád Basin and marginal parts of East-Slovak Lowland. Dominating soil representatives are Cambisols (55 %) and Dystric Planosols (27 %). Texturally soils are ranging from medium heavy (74 %) to heavy (18 %), from deep soils (63 %) to medium deep (35 %), with various stoniness, located on plane (21 %), slopes 3 – 7^o (39 %), and slopes 7 – 12^o (40 %). In this category, climatic regions from 05 to 08 (58 % soils) dominate. The soils point value range is 19 – 48 points.

Spring barley ha-yields were ranging 3.01 – 3.80 $t.ha^{-1}$. Mean yield is 3.44 $t.ha^{-1}$. Categories of productive arable land to low productive fields (O4 to OT3) can be found here according to typological production division of Slovak soils. Spring barley growing economical parameters in this category are following: presupposed profit is under 43 $EUR.ha^{-1}$, and profitability rate up to 15 %. 1 ha of spring barley produces 47 to 60 GJ of energy.

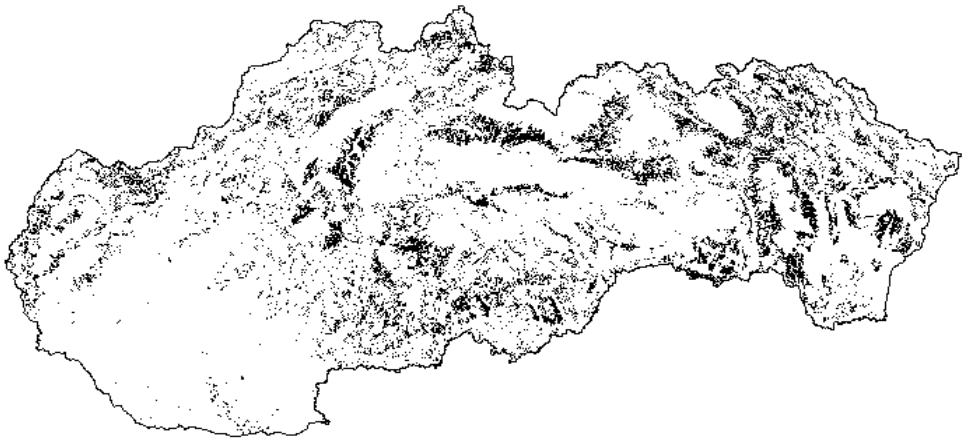

Fig. 3 – Low suitable soils for spring barley growing

Soil category – non suitable – is spread approximately on 32 % of Slovak farmland area. From geographic point of view, it includes particularly Fatra-Tatry region, Eastern Beskyde, Podhôľno-Magurský region, Slovenské Rudohorie and extremely heavy soils of East-Slovak Lowland. From pedological view, soil on slopes above 12^{o}, soils well as heavy, extremely acid, water-logged soils with non beneficial physical and chemical properties can be found here. Dominant soil types are Cambisols (65 %), Rendzinas (11 %) and Haplic Gleysols (7 %). Texturally soils are medium heavy (76 %), with high content of soil skeleton (74 %), shallow (74 %), on slopes 12 – 17^{o} (35 %), on steep slopes above 17^{o} (24 %). Absolutely dominating are climatic regions 07 to 10 (73 %). The soil point value is lower then 19 points.

Hectare-yield level of soils in this category is lower then 2.95 $t.ha^{-1}$. Spring barley should not occur in cropping system structure on arable land of this category. According to typological production categorization of Slovak soils, dominating are soils suitable more or less only for use as permanent grasslands and partially also alternating fields (categories OT and T). In mentioned regions spring barley growing is associated with losses, and thus it is not profitable.

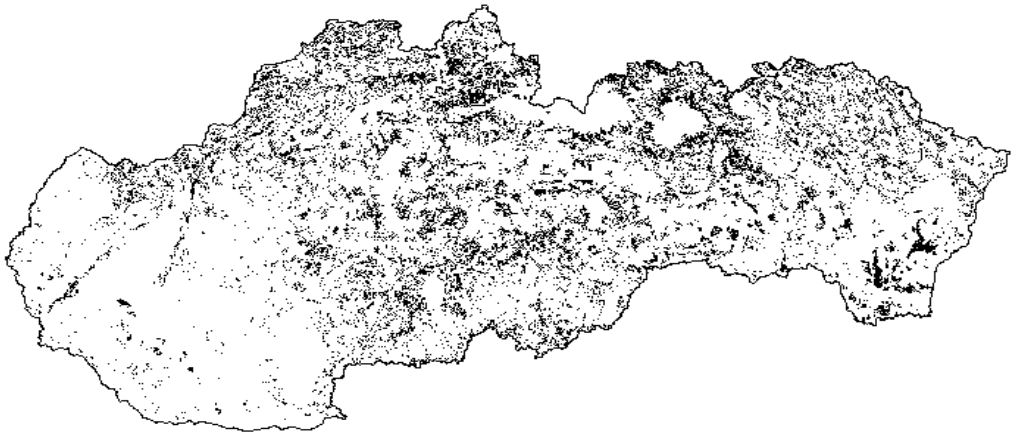

Fig. 4 – Non suitable soils for spring barley growing

Conclusion

In comparison with other previously formulated territorial division systems of production regions and zones in Slovakia, this alternative brings more detailed analysis of pedo-climatic conditions of territory (based on BPEJ basic mapping unit) and it associates economical and energetic aspects of the crop growing. Substantial is that the system enables possible detailed area identification of given category for any region of Slovakia by GIS help. It is obvious that in territory identified by this method, further analysis is possible by using other supplementary parameters. Thus, the method is an open system that does not identify sharp borders of each category, but it creates them more or less mosaic-like based on particular conditions of the crop and site, respectively.

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