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THE RATIONAL USE OF POLISH SOILS AS A CHALLENGE FOR SCIENCE, ADVICE, AND AGRICULTURAL PRACTICE

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ABSTRACT

Aim: To present the rational use of Poland's soils as a challenge for science, advice, and agricultural practice. **Methods:** Comparative analysis using tabular data and graphical presentations. **Results:** Compared to many European Union (EU) countries, Poland has a significant area of agricultural land, which, however, is systematically decreasing. It is of great importance to shape the environmental awareness of both farmers and society as a whole, aimed, among other things, at demonstrating all the functions of soils. **Conclusions:** Rational management of the soil environment should include recognizing all functions of soils, identifying threats, and delimiting areas sensitive to soil degradation processes. It is necessary to implement legal and financial instruments leading to the reduction or elimination of threats and the need to take into account regional specificities. Furthermore, the rational management of Poland's soils is a strategic objective and important call for the whole of society. The basic prerequisites for implementing this program are the comprehensiveness of the assessment and the cooperation of science and counselling with local and administrative authorities and the agricultural self-government.

Keywords: rational use of soils, agricultural production space, challenges, science, advice, agricultural practice
JEL code: Q24.

INTRODUCTION

The rational use of soils is of interest to various scientific institutions and reflects trends in the economy today [Hamidov et al. 2016, Sadowski 2017, Smędzik-Ambroży 2018]. Changes should be considered in dynamic (in years) and regional terms [Kopiński and Matyka 2016].

The area of soils used for agriculture is decreasing due to the allocation of significant areas for non-agricultural purposes mainly related to urbanization and transport [CSO 2000–2020]. These processes also affect very good and good soils, which poses a threat to the country's food self-sufficiency [Krasowicz 2012]. At the same time, the EU CAP rules and international conventions oblige to reduce threats to the natural environment. Rational management of Poland's soil environment is a strategic direction of development, as well as a challenge for science, consultancy, and agricultural practice. It is also a problem of great social importance.

The scientific research carried out in Poland (e.g., at the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy (IUNG-PIB) [Stuczyński et al. 2007]) provides the basis for rational management of the soil environment. They make it possible to diagnose the current state and indicate threats to the soil environment [Resolution 2015].

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The rational management of agricultural productive space includes the following aspects: (1) recognition of all soil functions; (2) identification of environmental threats; (3) designation of areas sensitive to environmental degradation processes; (4) introduction of legal and financial instruments leading to the reduction or elimination of threats; (5) implementation of the concept of multifunctional and sustainable rural development.

The processes of shaping the agricultural environment occur simultaneously with the processes of its use and protection and in connection with the realization of the various functions of soils. Threats to the soil environment result from agricultural and non-agricultural activities. The intensification of degradation processes in extreme cases may lead to the complete loss of the soil's habitat, production or retention functions [Jadczyszyn 2009].

Changes in the use of agricultural space are also a function of economic development, investment, agricultural policy and legally mandated landscape protection measures [Van Vliet et al. 2015, Chyłek et al. 2017]. The instruments of space protection should reduce the risk of economic expansion, favoring the preservation of the original functions and diversity of the landscape. It is widely accepted that agriculture and forest management are among the most important departments responsible for landscape protection and shaping [Gołębiewska et al. 2016]. Land use change processes are largely inevitable and determined by the necessary development of urbanization and transport for the economy. Nevertheless, their dynamics and spatial course should be continuously monitored [Siebielec 2017].

Agricultural production space provides opportunities for the realization of agricultural production and for meeting the demand for food, fodder, and raw materials for industry and energy. The rational management of agricultural productive space is a strategic direction (goal) of development and a necessity. As a problem of great social importance, it is also a challenge for science and advice-serving practice. The essence of rational use of agricultural production space boils down to obtaining a specific volume of crop production in accordance with the demand of the economy, characterized by appropriate quality parameters, and to limiting the adverse impact of agriculture on the natural environment [Gołębiewska et al. 2016]. Changes occurring in the use of agricultural space are also a function of economic development, investments, agricultural policy, and legally mandated landscape protection measures. Estimating the areas necessary to meet the needs of economic growth and urbanization while protecting the resources of agricultural space is becoming a significant problem [Staniszewski and Czyżewski 2019].

The possibilities of rational management of Poland's soil environment are determined by natural and organizational-economic conditions in the broad sense of the term. A comprehensive comparison and analysis of the above conditions is a complex but significant challenge. This makes it possible to assess the rationality of soil use in Poland. The study aimed to present the rational use of Poland's soils as a challenge for science, consultancy, and agricultural practice.

MATERIAL AND METHOD

The primary sources of information were the results of previous research conducted by the research institutes of the Ministry of Agriculture and Rural Development, institutes of the Polish Academy of Sciences, and universities. Statistical data from the Central Statistical Office (CSO) and research results of various authors presented in the literature were also used. A comparative analysis method using tabular data and graphical presentations was applied. A particular problem was the varied time horizon of the data used in the analysis. It should be emphasized, however, that the processes related to changes in the use of utilization agricultural area (UAA) and their quality are characterized by relatively low dynamics. For this reason, the varied time range of the data used did not significantly affect the quality of the analysis presented in the paper.

CHARACTERISTICS OF LAND RESOURCES IN POLAND

Ensuring Poland's net self-sufficiency in raw materials requires looking through the lens of the bioeconomy and biomass production opportunities. Biomass production for the economy can almost exclusively be based on the use of the primary production factor, which – in agriculture – is land. Nationally, their area in 2019 – compared to the state in 2000 – decreased by 20% (3.7 million ha) from 18.4 to 14.7 million ha. Based on the trend equation, it can be concluded that the area of agricultural land was decreasing at a rate of approximately 182,000 ha – yr^{-1} (Fig. 1). The largest agricultural land resources were located in the Mazowieckie, Wielkopolskie, and Lubelskie Voivodeships (Fig. 2).

On the other hand, they are the smallest in the Lubuskie Voivodeship and in the southern part of the country except for the Dolnośląskie Voivodeship. Significant variations in the availability of agricultural land in the voivodeships resulted from their total area, natural conditions, the level of economic development and the degree of urbanization. Changes in land use are strongly regionally differentiated, with the greatest decrease in the area of agricultural land in voivode-

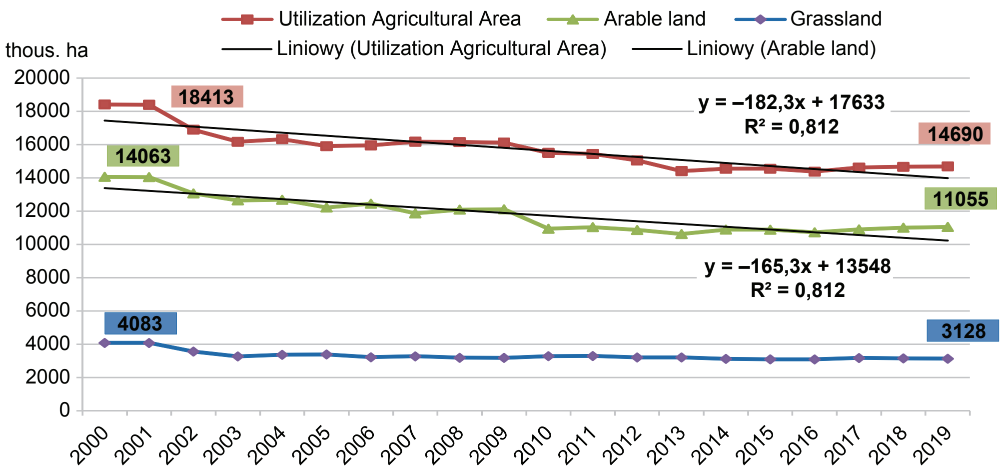

Fig. 1. Changes in the area of agricultural land in Poland between 2000 and 2019

Source: own elaboration based on CSO data [CSO 2000–2020]

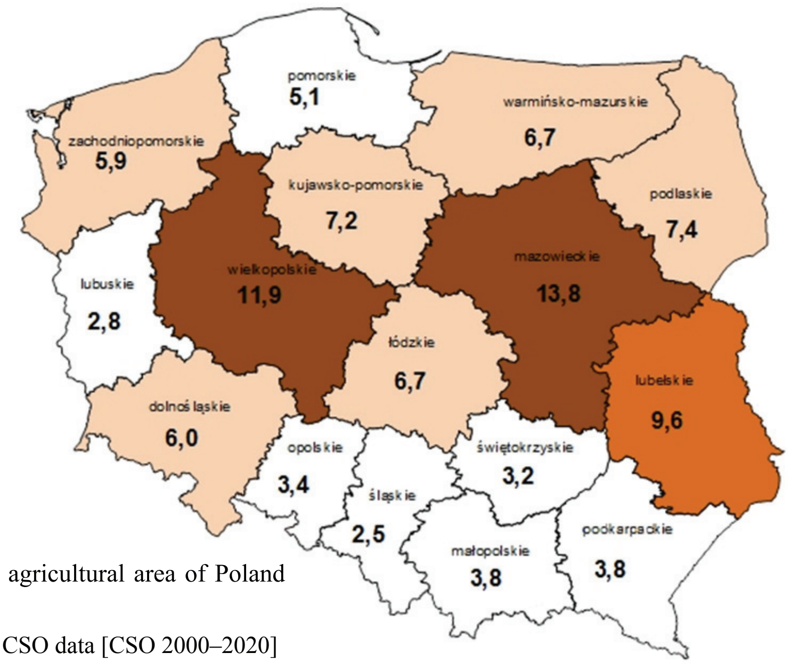

Fig. 2. Share of provinces in the agricultural area of Poland (average 2013–2015)

Source: Own calculations based on CSO data [CSO 2000–2020] ships characterized by high agrarian fragmentation and extensive agricultural production (i.e., Śląskie, Małopolskie, Podkarpackie, and Świętokrzyskie).

On the other hand, in voivodeships characterized by a high concentration of agricultural commodity production (Kujawsko-Pomorskie, Wielkopolskie), the area of agricultural land did not decrease so significantly (Fig. 3).

The structure of land ownership in Poland is dominated by individual farms, which own around 91% of the stock of this production factor. Mainly, due to historical conditions, private ownership dominates in the eastern and central parts of the country. On the other hand, a significant share (about 25%) of land owned by the State Treasury was located in the Opolskie and Zachodniopomorskie Voivodeships [Wrzochalska and Kurowska 2023].

Arable land accounted for the predominant share (around 73%) in the land use structure between 2016 and 2020 nationally, while grassland and pasture accounted for 18.7%. Permanent crops had a small (2.7%) share in the land use structure [Kopiński and Matyka 2016].

Noteworthy, from the point of view of exploiting biomass production potential, is the share of fallow and set-aside land in the land use structure[1]. On a national scale, they represented a significant reserve (3.3%) that could be used to increase production volumes. The share of land not used for production in the years covered by the analysis varied considerably regionally [Czudec et al. 2017].

In addition to the amount of agricultural land, a significant factor determining the volume and efficiency of biomass production is its quality, which – in the case of Poland – is quite low. This is mainly conditioned by the type of parent rocks, more than 70% of which are light clays and boulder sands. Particularly unfavorable natural conditions for agricultural production are found in the Podlaskie Voivodeship, while the best are found in the Opolskie and Dolnośląskie Voivodeships. Apart from the natural properties of soils, the factor determining their agricultural usefulness is fertility, which is also shaped by the farmer's activity, influencing the reaction, macro- and micro-element abundance, and organic matter content [Stuczyński et al. 2007]. The basic indicator for assessing soil quality is the organic matter content. It determines soil's physical and chemical properties, such as sorption and buffering capacities, and biological transformation processes. High humus content in soils stabilizes their structure, reducing their susceptibility to compaction and degradation due to water and wind erosion [Stuczyński and Łopatka 2009].

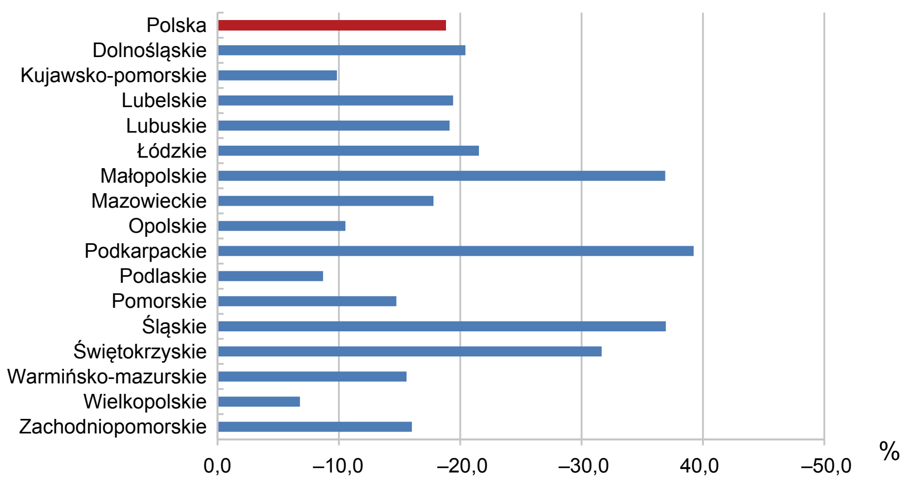

Fig. 3. Changes in the area of agricultural land in Polish voivodeships (on average in 2000–2020)
Source: own calculations based on CSO data [CSO 2000–2020]

[1] Set-aside – as defined by the CSO, this is other agricultural land (i.e., agricultural land that is not used and not maintained in good agricultural condition on 1 June of a given year).

The preservation of soil humus resources is important not only for maintaining the productive functions of soils, but also for the role of soils in sequestering CO_2 from the atmosphere – which contributes to reducing the greenhouse effect.

Loss of humus is an important indicator of deterioration of habitat conditions and soil fertility. The results of soil fertility determinations of agricultural land in Poland (in the 0–25 cm layer) indicate a large variation in humus content (0.5–10%). The average content is 2.2%. According to the division used in Poland, soils with a low humus content (<1.0%) constitute about 6% of the agricultural land, and those with an average (1.1–2.0%) consitute about 50%. Those rich in humus (>2.0%) constitute about 33% of the agricultural land of the country [Stuczyński et al. 2007].

Soils in Poland show great variation in susceptibility to compaction due to the variability in granulometric composition and low organic matter content [Siebielec 2017]. The total area of soils that are highly susceptible to compaction due to inappropriate tillage techniques, the use of equipment with excessive pressures, or the execution of work under conditions of excessive moisture constitutes about 15–20% of agricultural land.

Over 70% of Poland's arable soils are acidic to varying degrees (highly acidic – 13%, acidic – 26%, slightly acidic – 34%). The remaining 27% are neutral and alkaline soils. Acidic and very acidic soils account for about 40%. Improving the reaction of acidic soils is a key factor in changing their use and having a beneficial effect on crop yields [Kuś and Matyka 2013]. A significant threat to the quality of Polish soils is also associated with water erosion phenomena [Jadczyszyn 2009]. Approximately 29% of the country's area, including 21% of agricultural land (mainly arable land and about 8% of forest area), is threatened by water erosion, of which strong erosion is 4%, medium erosion is 11%, and weak erosion is 14% [Józefaciuk and Józefaciuk 1996].

The variation in natural production potential on a national scale is due to the spatial variability of landforms, soil cover, rainfall, and temperature. The poor quality of the productive space not only limits the selection and yield of crops, but has several adverse consequences in economic and environmental terms, potentially leading to land fallowing and landscape degradation. Light sandy soils with high permeability and low retention become very susceptible to soil drought [Stuczyński et al. 2007].

PREREQUISITES FOR THE RATIONAL USE OF SOILS

Compared to many European Union (EU) countries, Poland has a significant agricultural land area, which is systematically decreasing. The structure of soils according to their quality and agricultural suitability is specific. Good and very good soils (classes I–III) account for 26.0%, medium soils (classes Iva–IVb) 39.9%, while poor and very poor soils (classes V and VI) account for 34.1% of the total arable land. In the case of permanent grassland, only 15% is good soil, and about 42% each is medium and poor soil [Krasowicz and Kuś 2010]. The decrease in the area of utilization agricultural area (UAA) recorded in recent decades was due to the transfer of land for non-agricultural purposes, including afforestation and some changes in the classification of agricultural land. The agricultural area in ha per capita in 1980 was 0.53 and, in 2020, only 0.38 [CSO 2000–2020].

The expansion of the country's technical infrastructure, as well as urban and rural housing, will proceed at the expense of agricultural land. It can be expected that by 2030, agriculture will have lost 0.5–0.6 million hectares of agricultural land [Stuczyński and Łopatka 2009]. In addition, a disadvantageous phenomenon in recent years is the transfer for non-agricultural purposes of large areas of very good and good soils, classified as classes I–III. Until 1990, poor and very poor soils accounted for more than 60% of land transferred for non-agricultural purposes, while good soils accounted for less than 15%. Still, in recent years, these proportions have changed unfavorably.

In the post-war period in Poland, the total area of arable land under sowing decreased by about 4 million ha, or more than 25%. Currently, the sown area is 10.8 million ha [CSO 2000–2020].

Common Agricultural Policy (CAP) rules impose responsibility on agriculture for the use of natural environmental resources, including soil resources. In addition to its production functions, the soil environment and its production functions also fulfil environmental and retention functions, shaping human-environment relations [Krasowicz and Kuś 2015]. In view of Poland's food security, the protection of soils of better quality should be a priority for sustainable development. It is necessary to disseminate more widely the knowledge that the rationale for protecting good soils in cities is not their production function, but their role in shaping ecosystem functions and the local climate.

The introduction of the market economy system and Poland's integration into the European Union have resulted in multidirectional changes in agriculture. They became apparent in the organization and intensity of plant and animal production and in the specialization of agricultural holdings. Czudec et al. [2017] showed that the relatively large scale of land-exclusion from agricultural use in the south-eastern macro-region is a derivative of the unfavourable area structure. In this region, farms – in terms of area, surface area, and dispersion of fields, as well as the scale and concentration of production – clearly differ unfavorably from analogous characteristics describing farms in western and northern Poland. The specificity of agriculture in these regions also determines its competitiveness and opportunities to increase innovation [Nowak 2017]. The diversity of natural conditions, mainly soil and agrometeorological conditions, as well as of organizational and economic conditions, is one of the determinants of the overall competitive potential and the degree of its utilization [Krasowicz and Kuś 2010, Krasowicz and Kuś 2015].

On the other hand, based on experiments carried out at IUNG-PIB and other research centres, it has been found that correct agrotechnics are conducive to maintaining or, even increasing, the content of organic matter in the soil to some extent. Moreover, it has been shown that the use of simplified tillage and plant cultivation does not lead to depletion of soil organic matter and bioavailable forms of phosphorus, potassium, and magnesium – provided that agrotechnology is applied taking into account soil liming, intercropping, manure fertilization, and straw ploughing [Kopiński and Matyka 2016].

Soil organic matter balances reflect the influence of various conditions and are of practical importance. In the last 20 years, the soil organic matter balance has been negatively affected by a reduction in the proportion of perennial forage crops in the sowing structure, a large reduction in livestock and stocking rates, and the increasing specialization of farms forced by economic factors. In addition to traditional methods, alternative sources in the form of various types of waste and new biotechnological solutions will play an important role in shaping the organic matter balance.

It is worth emphasizing that the issue of the rational use of soils is an expression of a new view of agriculture. For many years, agriculture was mainly assessed through the prism of its production functions. The increase in environmental awareness, discussions on climate change and how agriculture can adapt to it, the identification of threats – as well as the widespread acceptance of concepts such as sustainable development or bioeconomy – have resulted in fundamental changes in views on the use of the natural environment [Pajewski and Gołębiewska 2018, Sadowski 2017, Smędzik-Ambroży 2018, Staniszewski and Czyżewski 2018, Sulewski et al. 2020].

According to Zegar [2018, 2021], while performing an environmental function, agriculture also produces effects that should be considered public goods. Kapusta [2017] argues that, nowadays, no country should set itself up for complete self-sufficiency. This author points out that state security in the field of food is fulfilled when a country with the existing level of consumption maintains an equilibrium in the trade turnover of food products. However, the issue of the rational use of soils on which biomass is produced both for domestic purposes and for international trade cannot be overlooked [Kapusta 2017, Kopiński and Matyka 2016]. One promising approach that requires in-depth analysis is precision agriculture [Kuś and Matyka 2013]. Spatial variability of soil conditions and other factors important for plant growth causes unified management of agrotechnology to lead to inefficient use of inputs. The findings of studies comparing various tillage strategies can support advising actions by enabling evaluation of the directions of the influence of implemented solutions on the soil environment at the field level [Sadowski 2017].

Soils are subject to varying degrees of direct or indirect human disturbance, constituting a major global change driver. Factoring out natural from direct and indirect human influence is not always straightforward, but some human activities have a clear impact. These include land-use change, land management, and land degradation (erosion, compaction, sealing, and salinization). The intensity of land use also greatly impacts soils, and soils are subject to indirect impacts arising from human activity such as acid deposition (sulphur and nitrogen) and heavy metal pollution [Smith et al. 2016]. Therefore, it is of great importance to shape the environmental awareness of both farmers and society as a whole, aimed, among other things, at demonstrating all the functions of soils. Furthermore, it is necessary to systematically monitor the current state and dynamics of change and identify threats to the rational management of the soil environment. These are important challenges for science, consultancy, and practice [Gołębiewska et al. 2016, Pajewski and Gołębiewska 2018].

In economic analyses, the problem of rational use of soils is often overlooked or taken into account in a fragmentary way [Wrzochalska and Kurowska 2023]. Food security and the country's (net) raw material self-sufficiency are significantly determined by the rational use of soils as one of the main factors of agricultural production [Krasowicz 2012, Smędzik-Ambroży 2018].

According to IUNG-PIB, the most important measures to foster the rational use of soils in support of agricultural advice can be regarded as:

- adaptation of branches and directions of agricultural production to natural and organizational-economic conditions – regionalization of production;
- taking into account the specific characteristics and economic strength of different farm groups when choosing farming systems and levels of technology intensity;
- sustainable fertilizer management and integrated pest management;
- proper (rational) management of soil organic matter;
- implementing efficient and environmentally friendly production technologies;
- shaping the public's environmental awareness;
- promoting various forms of natural resource conservation.

CONCLUSIONS

1. The characteristics of Poland's soil environment and the most critical threats identified against this background made it possible to identify the necessary directions for institutional support. This support should have a wide range and include factual activities, counselling, and financial support. A multi-faceted assessment of the impact of different management systems on soil environment management is also necessary. It is also advisable to make fuller use of the results of scientific research.
2. Rational management of the soil environment should consist of recognizing all functions of soils: production, habitat, and retention, as well as identifying threats and designating areas vulnerable to soil degradation processes. It is necessary to implement legal and financial instruments leading to the reduction or elimination of threats and the need to take into account regional specificities.
3. Scientific agricultural science units and agricultural advisory services can diagnose the current state and support rational soil environment management processes.
4. The rational management of Poland's soils is a strategic goal and an important call for society as a whole. The basic prerequisites for implementing this program are the comprehensiveness of the assessment and the cooperation of science and consultancy with local and administrative authorities, as well as with the agricultural self-government.

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RACJONALNE WYKORZYSTANIE GLEB POLSKI JAKO WYZWANIE DLA NAUKI, DORADZTWA I PRAKTYKI ROLNICZEJ

STRESZCZENIE

Cel: Przedstawienie racjonalnego wykorzystania gleb Polski jako wyzwania dla nauki, doradztwa i praktyki rolniczej. **Wyniki:** Na tle wielu krajów UE Polska dysponuje znacznym areałem użytków rolnych, który jednak systematycznie zmniejsza się. Problemem dużej wagi jest kształtowanie świadomości ekologicznej zarówno rolników, jak i całego społeczeństwa ukierunkowane, między innymi, na ukazywanie wszystkich funkcji gleb. **Metody:** Analiza porównawcza z wykorzystaniem danych tabelarycznych i prezentacji graficznych. **Wnioski:** Racjonalne gospodarowanie środowiskiem glebowym powinno polegać na dostrzeganiu wszystkich funkcji gleb oraz wskazywaniu zagrożeń i wyznaczaniu obszarów wrażliwych na procesy degradacji gleb. Konieczne jest wdrażanie instrumentów prawnych i finansowych, prowadzących do ograniczenia lub wyeliminowania zagrożeń oraz konieczność uwzględniania specyfiki regionalnej. Ponadto racjonalne gospodarowanie glebami Polski jest celem strategicznym i ważnym wzywaniem dla całego społeczeństwa. Podstawowe warunki realizacji tego programu to kompleksowość oceny oraz współpraca nauki i doradztwa z władzami samorządowymi i administracyjnymi a także z samorządem rolniczym.

Słowa kluczowe: racjonalne wykorzystanie gleb, rolnicza przestrzeń produkcyjna, wyzwania, nauka, doradztwo, praktyka rolnicza