DOI: 10.1515/jwld-2017-0046

JOURNAL OF WATER AND LAND DEVELOPMENT
2017, No. 34 (VII–IX): 131–138
PL ISSN 1429–7426
Available (PDF): http://www.itp.edu.pl/wydawnictwo/journal; http://www.degruyter.com/view/j/jwld

Received 17.03.2017
Reviewed 18.04.2017
Accepted 16.05.2017

A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Impact of the forest succession on efficiency of the arable land production

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For citation: Gniadek J., Pijanowski J.M., Śmigielski M. 2017. Impact of the forest succession on efficiency of the arable land production. Journal of Water and Land Development. No. 34 p. 131–138. DOI: 10.1515/jwld-2017-0046.

Abstract

The paper presents the studies involving analysis of changes in shape of parcels of arable land under the influence of forest succession. The object of the research is the village Grębosze located in Świętokrzyskie voivodeship. The study material will cover all arable land existing in the studied village. The source of data were numerical registry maps from 1998 and 2013. The basic element of research, enabling comparison of changes in the efficiency of the production process are continuous parts of the parcels covered by one form of use. In the course of the output data processing and determination of the necessary technical parameters for the tested surface elements, the specialized tools and statistics were used. The studies were related to the evaluation of formation of these surface structures on the basis of their shape meter in the form of the so-called costs of cultivation. The obtained results make it possible to tell, to what extent the changes resulting from the consequences of the secondary forest succession influence the process of cultivation of neighbouring arable land.

Key words: *forest succession, spatial structure of land, the efficiency of agricultural production, the shape of the parcel*

INTRODUCTION

The rational management of space is the issue which has been the subject of numerous scientific studies [HERNIK *et al*. 2012; KWOCZYŃSKA *et al.* 2014; LITWIN, PLUTA 2015; MAGEL 2015; MIODUSZEWSKI *et al*. 2014; STAŃCZUK-GAŁWIACZEK 2016; TWARDY *et al.* 2011]. The results indicate unambiguously, how important from the point of view of agricultural economics is the correct use of the surrounding us space [BALAWAJDER, NOGA 2016; LEŃ, MIKA 2016; WÓJCIK, LEŃ 2015]. Poland as a country with great potential of agricultural production, should in a special way take care of its production resources by supporting actions aimed to create new solutions and tools modernizing the production process, but also supporting existing farms, the products of which are the important backbone of the national economy.

The dynamic of socio-economic changes, observed in the last few decades, have contributed to a significant decline in set aside areas in Poland. According to [WĘŻYK, GĘCA 2013] between 2002 and 2011 there was a reduction in the size of these areas from 2.3 million hectares to 0.4 million hectares. An important factor in these changes was undoubtedly the Polish accession to the EU structures and the associated with it possibility of receiving subsidies in the form of direct subsidies to the agricultural production. These changes also influenced the creation of new and better jobs outside the agricultural sector, with the

result that in many small farms, cultivation practices were abandoned. The lack of appropriate agricultural procedures associated with the cultivation of land, favored the process of overgrowing by so-called chance seedling, which constituted the nucleus of the formation of a new forest.

Analyzing the definitions of forest in different countries of the world it can be concluded that their interpretation is similar but not identical [JABŁOŃSKI 2015]. According to SKOLUD [2008] full valued forest can develop even up to 350 years. In Poland, a statement whether area covered with permanent vegetation is a forest determines the Forest Act [Ustawa… 1991]. According to its provisions, the forest is defined as the ground (cit.): „a compact area of at least 0.1 hectares, covered with forest vegetation, (forest plantations) – trees and bushes and undergrowth or temporarily deprived of it, designed for forest production or constituting nature reserve or forming part of a national park or entered in the register of monuments".

If the increase itself of the forest area globally, is favorable [FRĄCZEK, DZIEPAK 2015], in regional or local scale can affect adversely both biodiversity and the disappearance of the cultural landscape. As it was already mentioned one of the factors of the new forest formation is a secondary forest succession. It is defined as the process of colonization by living organisms previously populated areas in which the biocenosis was destroyed. According to SZWAGRZYK [2004] the secondary forest succession is not a new phenomenon, but from the point of view of present scale of absorption of adjacent land by existing forest complexes, it can be seen a bit differently.

If we look at the secondary forest succession from the point of view of changes in the shape of the agro-forestry border, it may be presumed, that changes of the shape of adjacent farmlands which is a consequence of the progressive succession, may have a significant impact on the profitability of land located in the immediate vicinity of the forest. According to KORELESKI [2006] the mere proximity of agricultural land with forest causes significant reduction in the profitability of agricultural production, manifested in a decrease in the yield of crops.

The formation of new forest areas as a result of eg. secondary succession, changes the current function of the area, at which this phenomenon takes place. Determination of the actual range of forest land, both those which are the result of planned activities and the resulting from the secondary succession should be subject to ongoing monitoring using the latest IT solutions [WĘŻYK *et al.* 2009]. Unfortunately, despite the current technical possibilities, the lack of information about the current changes to the afforestation of agricultural land covered by secondary forest succession is steel tangible [SZWAGRZYK 2004]. The changes in land use must be currently identified by the appropriate surveying services during the surveying and updating works and presented in the form of new contours of land use. The works undertaken in connection with the modernization or creation of the new documentation of the land and buildings registry (EGiB) may result in a change of outdated land classification, within which new classification contours are determined, forming the basis for its functioning. All these actions lead to changes in classification function of the area and influence on the extent and manner of cultivation.

Modification of the agro-forestry border, resulting from the progressive, secondary succession on registry plots, alters the area and the configuration of the remaining part, not covered by the succession. Changing any of these attributes involves an increase in the cost of cultivation dependent on its the spatial configuration incurred during the production process. According to research of HOPFER (ed.) [1991] improper configuration and arrangement of the plot in the farm, may be the reason for the reduction of income from production up to 30%. This is also confirmed by the research of HARASIMOWICZ, OSTRĄGOWSKA [1996] and MIELEWCZYK [2006; 2012]. By narrowing these losses only to the shape of the plot, it can be assumed on the basis of the test results GNIADEK [2012] and GNIADEK *et al*. [2013], that the reduction of income from the production may be up to about 20%. Assuming, therefore, a variant of the resumption of cultivation on plots covered by the partial succession, it can be predicted the changes which have occurred due to its consequences, may affect the decrease in profitability of the land. Temporary abandonment of agricultural activities in such areas may result in irreversible changes in the spatial structure of the farm land. Its re-adjustment to the optimum production conditions may require a large financial contribution and considerable amount of arrangement-agricultural works, correcting the arising defects. Therefore it seems important to counteract this phenomenon through the periodic monitoring and legal regulations inhibiting or eliminating the process of land setting-aside. Unfortunately, current activities in the field of control of woodland areas changes in our country do not provide information on the basis of which changes in spontaneous afforestation caused by secondary succession could be predicted. Changes posed by uncontrolled forest succession can adversely affect both the income from farm production and reduction of the production area in our country. It seems necessary, therefore, to undertake actions, aimed to determine the changes in the scale of the current phenomenon of secondary succession and its measurable impact on the profitability of agricultural land.

MATERIALS AND METHODS

The development of computerization, favours the creation of new methods to automatize many tasks in the field of research of agricultural production space. Despite the available tools, mainly Geographic Information Systems (GIS) there is still a need to imple-

ment new solutions, enabling execution of a comprehensive research of the spatial structure of agricultural land and identification of phenomena that can significantly reduce its profitability.

The main purpose of this article is to determine the changes resulting from the progressive forest succession and to estimate its impact on the production capacity of the adjacent land. Village Gręboszе located in Świętokrzyskie voivodeship was selected for the study. Several dense forests located in the vicinity of arable land are located on its territory. The percentage of plots under the process of agricultural production in this village, falling in recent years, contributed to the intensification of secondary forest succession, which resulted in significant changes in the pattern of cultivated crops.

For the study the tool allowing to carry out comprehensive research based on data contained in EGiB was selected. Support system for the assessment of the lands layout "SWORG" used in the study, allows including in studies all registry plots or their continuous parts covered by one form of use. These tools enabled the automation of the evaluation process of agricultural land formation in selected village including the following steps:

I. Acquiring and preparing the initial data together with their preliminary processing.
II. The calculation process including: estimation of the size of the basic spatial and technical parameters for plots and cultivated fields together with the determination of the correctness of shape index in the form of so-called costs of cultivation.

The basic surface element of the studies were continuous parts of the registry plots covered by one form of use (arable plots), which can be identified with cultivated field. For simplicity, the study assumed that these surface elements will be abbreviated as the parcels.

The study used data from the numerical registry map of the two periods, ie. from the years 1998 and 2013. The data were subjected to extensive testing separately for each period, what at the final stage allowed show the scale of these changes which occurred in the aftermath of the secondary succession and its impact on the production efficiency of arable land. Estimation of the amount of the layout costs incurred enabling assessment of surveyed parcels shaping was made assuming a yield greater than 5 t per 1 ha, taking into account the full mechanization of field work. The study included 5 features: the area of the parcel, length, width, elongation and costs of cultivation dependent on the layout. Detailed evaluation of the analyzed surface elements was made by comparing the obtained values of the studied parameters with well known recognized as correct or optimal.

In the final phase of research related to the evaluation of the configuration of arable parcels in the village, statistical tools were used, which made it possible to define basic descriptive statistics for the tested characteristics of spatial shaping and elaboration of the necessary frequency distributions allowing the proper interpretation of the results.

Stage I.

The first action connected with the preparation of data to perform research related to the impact of forest succession on the profitability of agricultural land was the acquisition of data from numerical registry maps from 1998 and 2013. For this purpose, a computer program called MicroStation, which is one of many tools applied to create and edit digital maps, was used. Obtaining the necessary information about the surface objects appearing on the map was carried out by means of an additional application "MKTopoGUTR". This application allows for verification of developed digital map as regards topology and generation of information on the area of registry plots, land use and classification contours SIEJKA *et al*. [2014]. It has also the ability to generate information on any surface structures, corresponding to the mentioned above continuous parts of the registry plots, which are used as arable land or permanent grassland. Other information necessary to evaluate the spatial configuration of land belonging to farms included in the descriptive part of the land registry documentation. These data may be obtained by means the software that supports the database of land and buildings registry. Due to the nature of the research obtaining of such data was abandoned, because the determination of changes in the use and profitability of parcels with arable land can be carried out without their belonging to individual farms and the distance to the habitat.

Stage II.

In the course of the calculation data prepared during the mentioned stage I were used. The „SWORG" system enabled the determination of a large number of spatial parameters for all analyzed parcels, together with synthetic index of shaping of each of them. The size of this index depends on all the costs and production losses resulting from the irregular form of the parcel and is expressed in cereal units per one hectare.

The calculation process with the use of the mentioned system runs in a fully automated mode. In a situation requiring access to the estimated value or changes of the initial parameters, can be carried out in particular stages in which the user is obliged to modify the mentioned data and to introduce a specific group of parcels identifier. The final results of calculations, including all or selected parcels are saved as one or separate text files. Apart from specific values of spatial shaping parameters, the system enables the automatic generation on the map selected parcels or their groups, what facilitates the analysis of the selected area.

In the final phase of the evaluation process, the statistical tools are implemented, allowing defining basic descriptive statistics for the studied features of the spatial shaping and the preparation and the necessary frequency distributions reflecting changes in the spatial structure of land.

Fig. 1. Distribution of forest complexes in the Grębosze village before the occurrence of the secondary succession in 1998; source: own study

Fig. 2. Distribution of forest complexes in the Grębosze village after the occurrence of the secondary succession in 2013; source: own study

RESULTS

THE CHANGES OF CONFIGURATION OF ARABLE PARCELS CAUSED BY SECONDARY SUCCESSION

Information on the spatial configuration of the tested surface elements in the village Grębosze, obtained through a calculation process, has been developed separately for each of the specified periods of time. For each of the analyzed features the basic descriptive statistics were defined and illustrations of the occurring changes in respect to the class intervals were made. The obtained results concerning the changes of the parameters of spatial configuration of arable parcels are presented in the form of frequency distributions, which clearly reflect the consequences of forest succession between 1998 and 2013. On their basis it was stated, to what extent the development of the phenomenon of succession shown in Figures 1 and 2, has contributed to the change both areas of the parcels and the shape of their borders.

On the basis of the data contained in Table 1, it can be concluded that the average value of each of the analyzed parameters in the tested time periods has substantially deteriorated.

The consequence of forest succession is also increase in the number arable parcels of approximately 27% as compared to the initial 1998. The obtained data show that at the studied area there has been a change in the average area of arable parcels from 0.55 ha to 0.28 ha, which may suggest a decrease of the production efficiency and reduction of income derived from cultivated crops. The frequency distribution of parcels with respect to their area in particular class intervals shown on Figure 3, presents the real picture of changes in their area structure. According to HARASIMOWICZ [2002] optimal area of arable land for mechanical cultivation should be min. 1 ha. According to WOCH [2001] as the smallest area enabling the full mechanization of field works is assumed size of not less than 1–2 ha. From the analysed distribution it follows that the parcels of this area in 1998 accounted for about 15% of the total arable land. Due to the occurring changes their participation decreased to about 4%. The increase in the number of parcels of arable land is visible in the smallest class intervals. The highest growth was recorded in the range of 0.25 ha.

The observed increase (approximately 90 parcels) within this range corresponds to a 10% increase in their percentage of the total arable land. In the next interval the increase in the number of parcels in 2013 has been gradually reduced and is equal approximately 6%. In two next intervals differences are small, ranging from 0 to 2% in relation to the initial state.

Considering the size of the previously cited optimal areas it can be concluded that the uncontrolled spontaneous afforestation of agricultural land significantly contributed to the reduction of their production capacity. Taking into account current developments in the agricultural sector, namely, the promotion and implementation of modern systems of precision farming, it must be noted that the phenomenon of uncontrolled secondary succession substantially prevents the adopted direction of the development of agriculture.

Table 1. Changes of selected parameters of the spatial configuration of arable parcels in the Gręboszе village in the state before and after the secondary succession

Selected parameters parcels	Year 1998				Year 2013			
	the number of parcels	statistic			the number of parcels	statistic		
		mean	min	max		mean	min	max
Parcel area, ha	277	0.55	0.01	8.64	378	0.28	0.01	2.32
Parcel length, hm		0.98	0.03	3.00		0.87	0.03	3.30
Parcel width, hm		0.56	0.01	13.53		0.30	0.01	2.99
Parcel elongation		4.74	0.04	27.75		4.46	0.15	28.75
Land configuration costs without driving to the parcel, cereal units per ha		48.72	2.55	101.31		90.18	2.55	179.27

Source: own study.

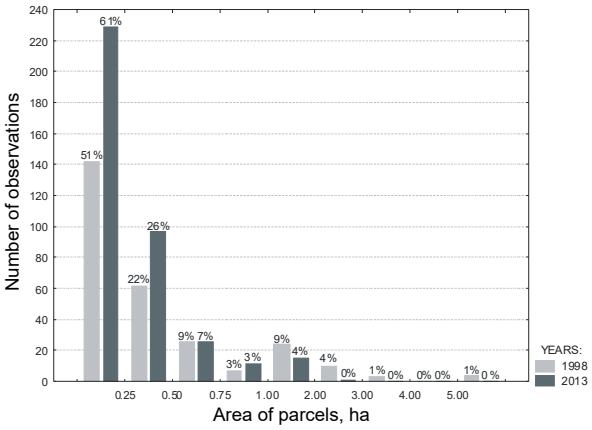

Fig. 3. Number distribution of parcels depending on their area; source: own study

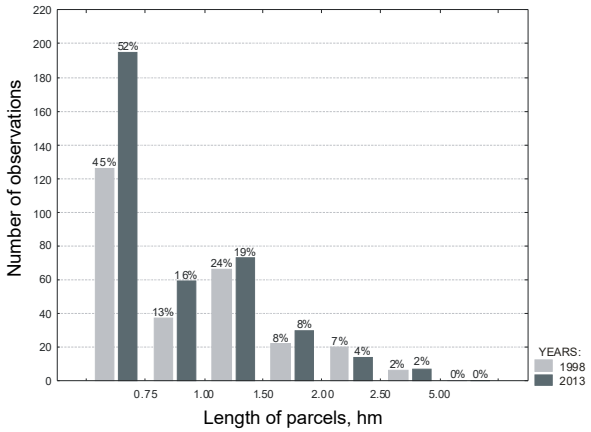

Fig. 4. Number distribution of parcels depending on their length; source: own study

The average lengths of cultivation for the tested parcels in the state before and after the secondary succession are successively 98 and 87 m (Tab. 1). The values of this parameter in both periods have a similar broad range from a few to more than 300 m. According to studies of HARASIMOWICZ [2000] the lengths of the parcels, which are below the range of 100 to 150 m generate too high costs associated with the cultivation reducing the income from the production. In the Figure 4, the largest group consists of parcels with length lower than 75 m. In the initial state their number reached 45%, and in 2013 about a 7% increase in their numbers in the total population is observed. The increase in the parcels number also relates to the following interval with lengths from 75 to 100 m (about 3%).

These results, as in the case of the analysed areas confirm adverse changes of spontaneous reforestation of parcels resulting in reduction in their lengths. In the next two intervals containing the lengths considered appropriate for the full mechanization of field works a slight increase in the number of parcels (from 7 to 9 parcels) can be noted. However, this is not many in comparison to the previous intervals. In other intervals for the lengths of the parcels above 200 m there are the smallest fluctuations in the number of parcels with a slight 3% decrease in the percentage of parcels from 200 to 250 m.

As shown in Table 1 the average widths of the parcels on this area in the years 1998 and 2013 are respectively 56 and 30 m. The observed decrease in this parameter over the analysed period just as the previous parameters confirms change of the parcels configuration, which may affect the efficiency of agricultural production. Reduction of the average value of this parameter to 30 m could be considered to be without any decrease in income from the production. It should be remembered that this is the average value, which includes both the parcels wider and narrower than the present size. A more detailed picture of changes that have occurred shows the further Figure 5, including the frequency distribution of parcels (for both analyzed periods) depending on their width. From the information contained in it, it is clear that the changes that occurred as a result of secondary succession occurred in the area of Gręboszе village, increased the number of parcels (about 80), corresponding to 6% increase in their number as compared to the 1998.

In the concerned interval of widths, there are parcels where the cultivation can cause significant changes in reducing income from the agricultural production, so also this parameter (width) confirms adverse change that has occurred as a result of spontaneous afforestation of arable parcels. In the next interval the observed increase in the number of parcels is not so high (about 45 parcels). In other intervals containing parcels with the correct widths, slight fluctuations in their percentage of the total population may be noticed as well as the complete disappearance of the largest parcels with widths above 150 m.

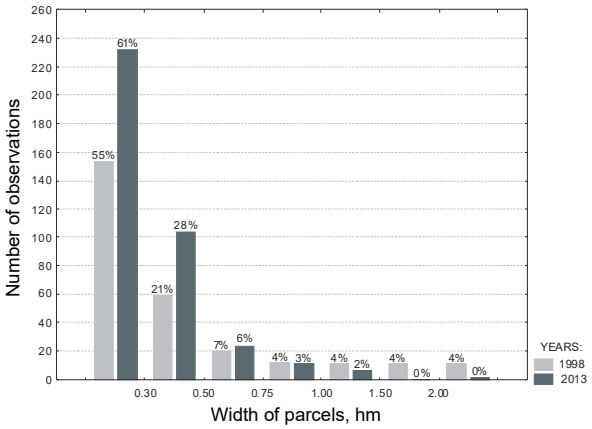

Fig. 5. Number distribution of parcels depending on their width; source: own study

The average elongation of considered parcels before the self-afforestation of land in the studied village was about 1:5 (Tab. 1). The changes that occurred in 2013 practically did not change the average value of this index. According to HARASIMOWICZ and OSTRĄGOWSKA [1996] elongation of 1:5 is a value, which can be considered appropriate on condition, that the land area is greater than 1 ha. As earlier analysis indicated, there were only a dozen percent of the parcels of this area in 1998. Changes in the index of parcels elongation in the studied time periods are shown in the Figure 6. On this basis, the relationship between the number of surveyed parcels and the value of the elongation indicator can be found. Along with the increase of elongation decreases the number of parcels in each class interval.

Therefore, the largest groups of parcels in each of the analysed time periods are those with the smallest elongation. Furthermore, in intervals of less than 1:4 the biggest increase in the number of parcels (about 34 to 40 parcels) in 2013 was seen, and the elongation less than 1:4, is not sufficient and may indicate a reduced level of income derived from the agricultural production. About 12% of the parcels in each of the two studied periods are close to the correct elongation between 1:4 and 1:6. Other parcels in larger class intervals have too high elongation, which may cause an increase in costs associated with the cultivation.

EFFICIENCY OF THE ARABLE LAND PRODUCTION UNDER THE INFLUENCE OF SECONDARY SUCCESSION

Estimation of changes in the efficiency of production for arable parcels resulting from spontaneous afforestation can be made by determining the losses of cultivation depending on the configuration of each of the parcels. The method used for this purpose allows determination of the synthetic index of shape in the form of the cultivation cost. The scope of these costs includes all costs and production losses associated with the cultivation of the parcel, due to its configuration. The value of this index for the plots of the optimal area and the correct shape should not exceed 4 cereal units per 1 ha [HARASIMOWICZ 2002].

The information contained in Table 1 show that the average size of this parameter for the state in 1998 was about 48 cereal units per 1 ha. On this basis, it can be stated that for the studied population of arable parcels in the Gręboszе village very high costs of cultivation were incurred, what shows inappropriate configuration of the parcels existing there in this period. The changes that have occurred in their configuration in years from 1998 to 2013 resulted in a significant increase in this index of about 46%. Such a large (almost twofold) increase in this parameter confirms the negative impact of uncontrolled forest succession on the conditions of agricultural production in this area.

More detailed information regarding changes that have occurred shows a frequency distribution of parcels depending on the costs incurred for cultivation in the two considered periods (Fig. 7).

As it can be seen the number of arable parcels, which have an optimal area and the correct configuration both in 1998 and 2013 years is equal about 2% of the population in each tested period. Within the range of 4 to 6 cereal units per 1 ha, the number of parcels is

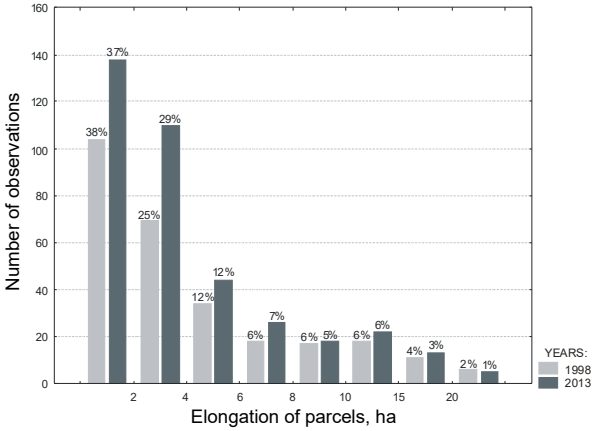

Fig. 6. Number distribution of parcels depending on their elongation; source: own study

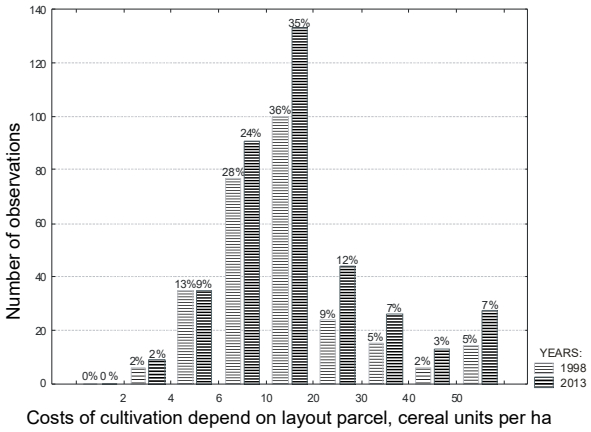

Fig. 7. Number distribution of parcels depending on their exploitation costs connected with land configuration; source: own study

identical, despite a four percent decline in the percentage of these parcels in 2013. In each of the other class intervals in 2013 an increase in both the percentage of land in relation to the studied population and their numbers can be seen. This is partly due to the increase in the number of parcels in 2013 (Tab. 1), as a result of distinguished new irregular enclaves of forest cutting the existing arable parcels and changes in the existing agro-forestry border of forests complexes existing before 1998. In each of these cases there has been a gradual takeover of the areas of adjacent plots by the new forest, which resulted in their complete absorption or in change of configuration often combined with separation of new smaller and improperly shaped arable parcels.

However, it should be noted that re-launch of the cultivation process on land under secondary forest succession, would restore the level of production efficiency of 1998. But, taking into account its low level, high expenditures associated with restoring the previous function of afforested land, difficulties arising from the legislation in force and high costs incurred, such action would be inefficient.

SUMMARY

Problems, presented in the article, related to the impact of secondary succession on changes in the efficiency of the production process on arable parcels in the Grębosze village made it possible to determine the scale of changes of this phenomenon and its real impact on the profitability of production. The conducted research with the use of the SWORG system gave the basis to determine correctness and disadvantages of surveyed surface structures. Detailed analysis of the obtained values of the basic spatial-technical parameters for arable parcels using statistical tools demonstrated increase of their imperfection, the reason of which was the secondary succession. Inappropriate surfaces, length or width of the arable parcels resulting from the consequences of the progressive succession are the reason for the lack of opportunity to obtain adequate income from the carried out production. Estimated values of the synthetic index of shape for each tested parcel in the form of so-called costs of cultivation allowed assessing, the extent to which the uncontrolled succession restricts income of the carried out production.

The presented results of the changes that have occurred over the 15 years clearly show that even in such a short period of abandonment of the cultivation can cause irreversible changes, which prevent or limit further effective use of the area for productive purposes. Its improvement may only be made through the appropriate, costly and time-consuming agricultural-arrangement works enabling the improvement of the faulty spatial structure.

Dofinansowano ze środków
Wojewódzkiego Funduszu
Ochrony Środowiska
i Gospodarki Wodnej w Lublinie
Cofinanced by Voivodeship Fund
for Environmental Protection
and Water Management in Lublin

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Wpływ sukcesji leśnej na efektywność produkcji gruntów ornych

STRESZCZENIE

W pracy przedstawione zostały badania obejmujące analizę zmian ukształtowania parcel na gruntach ornych pod wpływem sukcesji leśnej. Obiektem badań jest sołectwo Grębosze położone w województwie świętokrzyskim. Materiał badawczy obejmie wszystkie grunty orne występujące w badanej wsi. Źródłem danych były numeryczne mapy ewidencyjne z lat 1998 i 2013. Podstawowym elementem badań, umożliwiającym porównanie zmian efektywności procesu produkcyjnego są ciągłe części działek ewidencyjnych objęte jedną formą użytkowania. W procesie przetworzenia danych wyjściowych oraz określenia niezbędnych parametrów technicznych badanych elementów powierzchniowych zastosowano specjalistyczne narzędzia informatyczne i statystyczne. Szczegółowe badania dotyczą oceny ukształtowania wspomnianych struktur powierzchniowych na bazie miernika ich ukształtowania w postaci tzw. kosztów uprawowych. Uzyskany wynik umożliwia stwierdzenie, w jakim stopniu zmiany wynikające z następstw wtórnej sukcesji leśnej wpływają na proces uprawy sąsiednich gruntów ornych.

Słowa kluczowe: *efektywność produkcji rolnej, kształt parcel, struktura przestrzenna gruntów, sukcesja leśna*