

# Assessment of the motorway's impact on agricultural land on the example of the section of motorway A4 Jasień – Bobrowniki Małe

Stanisław Bacior<sup>1,\*</sup>, Małgorzata Dudzińska<sup>2</sup> and Barbara Prus<sup>3</sup>

<sup>1</sup>Department of Geodesy, Cadastre and Photogrammetry, Faculty of Environmental Engineering and Land Surveying, Agricultural University in Kraków, Poland

<sup>2</sup>Institute of Geoinformation and Cartography, Faculty of Geodesy, Geospatial and Civil Engineering, University of Warmia and Mazury in Olsztyn, Poland

<sup>3</sup>Department of Spatial Development and Landscape Architecture, Faculty of Environmental Engineering and Land Surveying, Agricultural University in Kraków, Poland

**Abstract.** The innovative method of assessment of the motorway impact on agricultural land presented in this study allows to estimate all losses related to the directions of this impact. The basis for the determination of losses is the analysis of land use variability and bonitation classes as well as the location of access roads to the land along the axis of the planned motorway. The applied measure of the motorway's impact on agricultural land is the change in land value, at which determination only the diversity of its suitability for agricultural production is taken into account. The developed method of determining the impact of the motorway on agricultural land was presented on the example of the A4 motorway section between the villages Jasień and Bobrowniki Małe. The existing motorway section was evaluated and then the obtained data were compared with the results obtained for the alternative version of the motorway running on the same section.

## 1 Introduction

The simplified method of assessing the motorway's impact on agricultural land was used to conduct the research in this article. This method is particularly useful during initial motorway route design [2]. This method takes into account only the general assumptions concerning the motorway parameters: the axis of the motorway, the width of the road and the occurrence of protective green belts. It involves the analysis of the course of the motorway axis designed on the registry map. To carry out the analysis properly, additional information is needed on the variability of soil quality on the motorway route, the location of roads and motorway overpasses, areas of agricultural land for which access is associated with crossing the motorway lane and parameters of the lay-out of plots cut by the motorway. The received data are the basis for determining the variability - caused by the construction of the motorway - of these land features, which have a particular impact on their production suitability, and then they are used for a comprehensive assessment of the impact of the motorway construction on agricultural land [16].

The simplified method of assessing the motorway impact on agricultural land enables a comprehensive determination of the impact of the motorway construction on agricultural land including:

- the loss of land taken over for the construction of a road lane,
- decrease in the production capacity of land located near the motorway,
- deterioration in the number of farms cut by the motorway axis.

The value of these plots is the measure of the multidirectional impact of the motorway, at which determination only their production usefulness was taken into account. This value is therefore a measure of valorisation of the agricultural usefulness of land for agricultural production. [1]

For the purposes of the presented study, the existing motorway section has been assessed and next the calculations were repeated for the alternative route of the motorway on the same section, between the villages Jasień and Bobrowniki Małe. Thanks to such research, it is possible to show what effect a change in the motorway route has on the losses associated with the construction of the motorway.

The used method is simplified, what reduces its labour intensity, what allows it to be used while assessing various variants of the route of the motorway still at the stage of the initial investment design. The calculation procedure related to the motorway impact determination has been automated using the developed computer program, which also facilitates its application [3].

\* Corresponding author: [geomm@poczta.onet.pl](mailto:geomm@poczta.onet.pl)

## 2 Characteristics of examined section of the A4 motorway

The simplified method of assessing the motorway impact on agricultural land was applied on the A4 motorway section between the villages Jasień and Bobrowniki Małe. This section is located in the Małopolskie voivodship and in the districts of Brześć and Tarnów. The motorway route runs through the villages Jasień, Mokrzycka, Szczepanów, Sterkowiec, Wokowice, Bielcza, located in the brzeski district and Biadolin Radłowski, Łętowice, Bogumiłowice, Wierchosławice, Gosławice, Rudka, Komorów, Bobrowniki Małe, Bobrowniki Wielkie, located in the tarnowski district. It is 29.317 km long, while in the alternative version designed for the needs of the study, the length is 29.784 km. The motorway designed in the right way should run along the borders of the villages and as far as possible from the larger clusters of buildings. Thanks to this run of the motorway route it is possible to limit to a large extent the growth of costs of the agricultural transport on roads caused by cutting off the land from habitats and to reduce the negative effects caused by car traffic for local residents. The examined section in both versions the existing and the alternative one definitely meets the above requirements. The investment is designed in such a way that it bypasses the main settlement centres of the village and the larger dense areas of compact buildings at quite a distance, whereas when it is not possible, it crosses them in places where the density of buildings is small.

The examined section of the A4 motorway crosses 85 roads, 25 of which are equipped with motorway viaducts, however, these are in most cases roads that secure transport only to the plots where they are located. In the case of the designed alternative version, the motorway crosses 83 roads, 25 of which would be equipped with viaducts. In the case of an existing road, motorway viaducts are distant from each other by an average of 1173 meters, while in the alternative version the distance is 1191 meters.

The distance between motorway viaducts is the initial parameter used to assess the motorway's impact on the growth of agricultural transport. A large number of viaducts and short distances between them causes that the impact of the motorway construction on the increase of the distance to the land is relatively low.

When estimating the impact of the test section of the motorway on agricultural land, it was assumed that the road width is close to the maximum and is 70 m in the absence of green protective belts. It was also assumed that the green protective belts have a width of 30 m. Therefore, the total width of the motorway lane will vary from 70 to 130 m depending on the presence of protective belts on one or both sides of it. The adoption of such assumptions makes it possible to estimate the relatively high purchase costs of a wide motorway lane. In practice, however, it happens that they can be reduced according to the actual width of the highway.

In the case of the section under consideration, both in the existing and the alternative version, the occurrence of green protective belts is very different. They occur in all possible configurations. In the case of two-sided belts, which are the least, the width of the motorway is 130 meters, in places where the protective belt is on one side, the road lane width is 100 meters, while for a large part of the section, green protective belts have not been provided and in these places the width of the motorway is 70 meters.

## 3 Methodology

### 3.1 Determination of the initial parameters

In order to correctly estimate the output parameters, it is necessary to enter the axis of the motorway on the registry map, and then determine the characteristic points. These are points that are located in places where there is a change in the way of land use, change of the bonitation class and on the borders of the village.

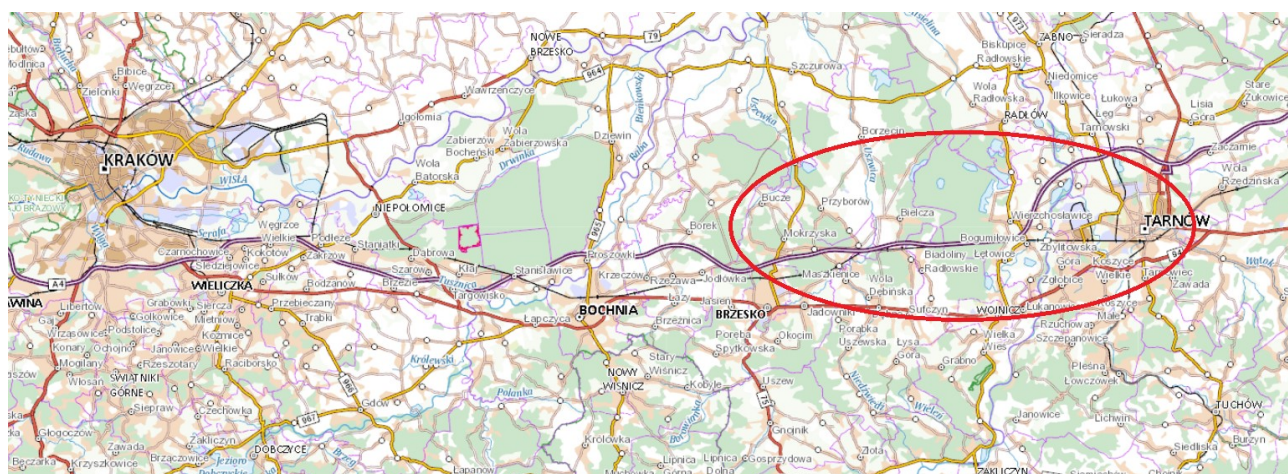


Fig. 1. Location of the analysed section of the A4 motorway (<http://mapy.geoportal.gov.pl/imap/?gmap=gp0>)

The next necessary step is to measure the distance between successive points and enter them into the table containing all the initial parameters.

Then, the width of the area with the access via the motorway is determined. This width is determined for all roads cut by the motorway, except the roads that will be equipped with motorway viaducts. To determine this value, it is necessary to know the rules of agricultural transport. This value is directly dependent on the layout of building zones, the layout of roads used for agricultural transport and the borders of the village.

Another important step is to determine the number of agricultural land plots cut by the motorway axis and the width and length of the representative plot. These data are used to calculate the impact of the motorway on the size and shape of the newly created plot.

The last element is to determine whether there are green protective belts along the motorway. On the basis of this information, the width of the motorway and the decrease of the value of land directly adjacent to the road lane are determined. It is assumed that the width of the protective green belt on one side of the motorway is equal 30 meters.

### **3.2 Area and quality of land taken over for the motorway construction and lying in the range of its impact**

The area of land taken over for the motorway construction can be determined as the product of the motorway axis length and its width. It follows that the area depends on the presence of green protective belts and their width. Depending on the presence of the protective belts, the motorway may have a width of 70m, when these belts are not present, and 100m or 130m, assuming that the designed green belt has a width of 30m.

On the basis of the measured sections between the characteristic points it is possible to calculate the areas of different agricultural use and bonitation classes as the product of the sum of the relevant sections and the width of the motorway lane. Thanks to the calculation of the area of bonitation classes, information on soil quality is obtained. Measurement along the motorway axis enables precise determination of the structure of the land use in the area covering 10 to 20% of the motorway lane area. Despite this, such measurement is fully sufficient because the accuracy of estimation of individual surface elements, taken over for the motorway construction depends on the length of the analysed section and for an approximate length of 2 km, we obtain an accuracy of approx. 5 – 10% [1].

### **3.3 Increase in the access length to the land**

The construction of the motorway greatly affects local transport. It cuts many roads and causes the land to be cut off from the settlements. This increases the length of access road to land and, consequently, the increase in transport costs. Very often it happens that the former access is not possible, and the new one is carried out

using a roundabout route. Most often, new access roads run along the motorway lane to the nearest motorway viaduct. In this case, the extension of the access road to the land is about half of the distance between roads with viaducts [6, 13].

The determination of the area to which the access will be changed as a result of the construction of the motorway and the increase of the distance to this area, using traditional formulas is an extremely labour-intensive activity. This is mainly due to the necessity to determine the area of land with access via the motorway and the increase of access to these lands. Thanks to the data contained in the initial parameters, the estimation of these parameters is very simple. We obtain them on the basis of the mileage of roads and viaducts and the width of the area with access via the motorway. The values thus obtained are very accurate and best reflect the actual situation [15].

### **3.4 Deterioration of the plots layout**

Another extremely important effect of the motorway construction is the deterioration of the plots layout. The motorway crosses the plots causing a reduction in their area and very often giving them an unfavourable shape, usually plots are divided into two parts. In order to be able to estimate the change of the layout of plots, it is necessary to determine the number of plots cut by the motorway axis and their dimensions. Due to the fact that the most often the plots are divided into two parts, it is assumed that the length of newly created plots and their areas are reduced by half. As a result of the intersection of plots with a motorway, the most often two new plots with a smaller area are created. It follows that the level of changes in plots layouts depends on the ratio of the length of the plot to the width of the motorway [9].

### **3.5 Determination of the decrease in land value as a result of the motorway construction**

The presented method of estimating the values of agricultural lands and their changes caused by the construction of the motorway takes into account only the usefulness of land for agricultural production [3]

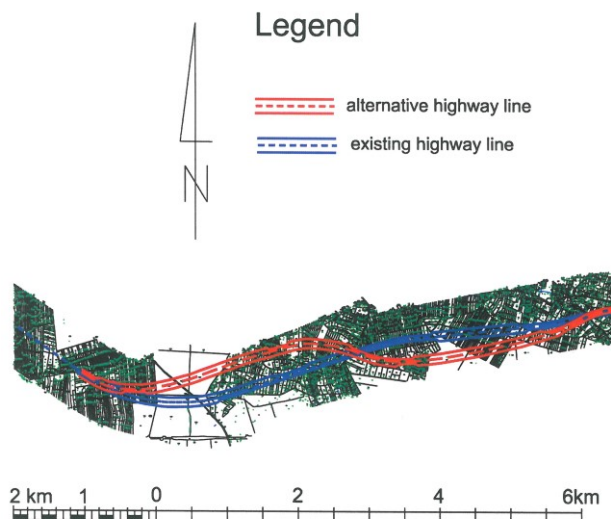
This method covers all the basic directions of the motorway's impact on agricultural land, namely:

- taking over the land for the motorway construction,
- an increase in spending on agricultural transport and deterioration of layout of the plots,
- deterioration of the quality of the land in the immediate vicinity of the motorway.

The value of agricultural land calculated using this method is not applicable when determining its market value or determining the value when purchasing the land for construction. This value should be treated as an indicator of the suitability for agricultural production of land, which was determined on the basis of the features of the plot and the farm. The subject of interest is the range of changes in this value due to the construction and unfavourable impact of the motorway.



The decrease in the value of land that followed the construction of the motorway is directly related to the change of those features that have a particular impact on the suitability for agricultural production. It is estimated on the basis of the difference between the value of agricultural land before the motorway construction and after the investment [10, 12].



**Fig. 2.** Location of the existing and alternative section of the motorway (own elaboration)

## 4 Changes in the characteristics of agricultural land under the impact of the motorway construction

### 4.1 The area of land taken over for the construction and remaining in the range of the impact of the motorway

The area of land acquired for the construction of the motorway on the section under investigation in the case of the existing version is about 167.17 ha, while in the case of an alternative motorway route this value was estimated at 155.90 ha. This is a fairly large area, taking into account the length of the section. The reason for this is mainly the fact that in both considered versions of the course of the investment there are large fragments, where the green protective belts occur on one side and on both sides of the motorway. Surfaces used for the construction of the motorway and those in the zone of its negative impact include various types of the land use. The largest part of these areas are definitely agricultural land. Their percentage in the area for the existing motorway lane running through the examined villages is 65.9%. While, in the case of the alternative concept, this value is lower and amounts to 54.3%. Often, however, there are cases when the percentage of the agricultural land in the motorway belt is negligible and most often it is caused by the high forest cover of the area through which the motorway runs. Agricultural land area taken over for the construction per 1 km of motorway running

through agricultural land for the existing section is equal 7.95 ha, on the other hand, the areas of agricultural land located in the area of its adverse impact are 15.94 ha. For the alternative version of the motorway route, these values are respectively 7.97 ha and 15.97 ha. In both considered cases, the area of land located in the zone of toxic impact of the motorway is twice as large as the area taken over for its construction. The width of the belt, in which there is a harmful effect of the motorway on agricultural land and its surface depends directly on the presence of green protective belts. In the absence of the protective green belts, the negative impact of the motorway can be observed at a distance of up to 90 m from its border and causes a reduction in the quality of agricultural land by an average of 40% [6]. In this case, the width of the toxic impact zone of the motorway is about 180 m, and the assumed width of the motorway itself is about 70 m. The presence of green protective belts on both sides of the motorway causes its width to increase to 130 m, but then the total width of the motorway impact zone is much smaller and is equal approximately 100 m. The presented parameters referring to the area taken over for construction and under toxic impact of the motorway on arable land refer to the assumptions related to the transversal profile of the motorway and regarding the extent of its impact on agricultural land. These values were set in such a way as to highlight the impact of the motorway as much as possible, therefore, the obtained results of this impact may be slightly inflated. An example may be the assumption that the width of the motorway will be equal 70 m, although the minimum width of the motorway with three lanes can be 50 m. However, with the help of the computer software, it is possible very quickly and simply to change the main parameters that define such motorway parameters as: width of the road or the width of green protective belts.

### 4.2 Cutting off land from the settlements

The axis of the motorway in both cases intersects a large number of roads, which means that a large part of the land will require circular access by motorway viaducts.

The area of land to which the access lengths will increase after the construction of the motorway is, in the case of the existing motorway, 131.72 ha, whereas in the alternative version - 100.68 ha. areas of the land cut off from the habitats by the motorway axis calculated on one kilometre of its course through agricultural land were also estimated. Such conversion eliminates the impact on these areas of the length of a given motorway section and the intensity of occurrence of agricultural land on its route. The motorway section running through agricultural lands on the length of 1 km cuts off 6.26 ha of land from settlements, to which the access lengths will increase, while in the case of the alternative section this area will be equal 5.15 ha.

On the basis of the conducted research, it is possible to state that the increase in the distance to the land caused by the construction of the motorway is directly dependent on the distance between neighbouring

viaducts and the number of roads crossed by the section under examination. The increase in distance is bigger when the distance between the viaducts increases and with the great number of roads crossed by the motorway is equal half of that distance.

The increases in distance to land determined by the distances between viaducts are the reason for the increase in expenses for agricultural transport at the moment when they will be accompanied by a large area of land requiring access through roads that will not have viaducts.

### **4.3 Changes to the layout of the plots divided by the motorway**

The existing motorway section on the fragment covered by the study cuts 705 agricultural plots, respectively, while in the alternative concept it is 599 plots. In each case, the motorway most often intersects plots across their lengths, dividing them into two parts.

The average area of plots crossed by the section of the motorway under investigation is about 0.81 ha - in the case of the existing section and 1.06 ha for the alternative section.

The total area of plots for which the land has deteriorated after being crossed by the motorway amounts to 564.37 ha and 640.20 ha in the second concept. This area usually depends on the length of the plots and the length of the motorway section considered, and the size of the percentage of agricultural land in the land use structure in the area covered by the study.

A measure of the deterioration of the plots is the area of plots cut by the motorway calculated for one kilometre of its length running through the agricultural land. In the case under consideration, the area of plots with deteriorated layout referring to one kilometre of the motorway running through agricultural land is 26.83 ha for the existing motorway and 32.73 ha for the alternative version.

In the value of agricultural land caused by the construction of the motorway section, divided into four basic directions of its impact. The obtained values reflect changes in the unit value of the land and the corresponding land areas under the specified direction as a result of the motorway's impact. Table 1 presents the results for the existing section, while Table 2 shows the results for the alternative version in which the course of the investment was changed. For the existing section, the value of land taken over for the motorway construction is 807.7 cereal units / ha per kilometre of the highway running through the agricultural land, while for the section in the alternative concept it is 865.7 cereal units / ha. The land is bought by the investor. The purchase of land occupied by the road lane will cover only about 50% of agricultural land losses caused by the construction of the motorway. Calculated losses in agricultural lands concerning the reduction of their production value may be related to farms with incomplete utilization of their production means, such as farm buildings or agricultural machines. This may be the reason for additional losses incurred by agricultural

farms that will be related to the construction of the motorway. Reducing the farm area may have an impact on the number of animals being farmed. Therefore, taking into account the value of land and fixed assets of agricultural production, the actual losses of farms can be estimated at more than twice as much as the decline in the value of agricultural land [2]. On the basis of many researches, it can be concluded that the purchase of land for the construction of the motorway covers only a part of the losses incurred by agricultural farms in connection with the construction of the motorway. However, in reality, the purchase price of land for the motorway construction is even 4 times higher than the average price of agricultural land [13]. In the examined cases, the acquisition of land for the motorway construction amounts to 47.0% of the total loss of land value caused by its construction for the motorway in the existing version, and 52.0% for the alternative version. Such, relatively high result is due to the fact that in both cases there are sections of the motorway for which the green protective stripes have been designed on both sides of the road. Therefore, the area taken over for the motorway construction is quite high and constitutes the largest percentage in relation to the total loss of value of agricultural land related to this construction. Reduction of the quality of lands located near the motorway is equal 558.4 cereal units / ha per kilometre of the motorway, which includes 32.5% of the total reduction in the value of agricultural land, and 537.5 cereal units / ha per kilometre of the motorway (32.3%) in the alternative version of the motorway route. The area and percentage in the total loss of the value of land cut by the motorway axis is directly dependent on the presence of green protection belts. The lack of safety belts means that less land is taken over for the construction of the motorway, and consequently the losses associated with this direction of the motorway are smaller. However, the depreciation of land subjected to the harmful impact of the motorway increases. In the case of the existing motorway section, the total impact of land acquisition for the construction of the motorway and its harmful impact on the land located in its vicinity is approximately 79% of the total.

Tab 1. Decrease in the value of land caused by the construction of the motorway for the existing section (own study).

No	The cause of lowering the value of the land	The value of one hectare of land [cereal unit/ha]		The area covered by the change [ha]	Reduction of income value				
		Before the change	After the change		In the village [cereal unit]	Structure [%]	Per kilometre of motorway [cereal unit/ha]	Per kilometre of motorway section going through agricultural land	Structure [%]
1	The takeover of land for the construction highway	101.65	-	167.17	16993.4	100.0	579.6	807.7	47.0
2	Deterioration in the quality of land located near the motorway	101.65	66.61	335.25	11748.6	69.1	400.7	558.4	32.5
3	The increase in distance of land from the farm due to changes in the communication system	101.65	90.80	131.72	1429.5	8.4	48.8	67.9	4.0
4	Deterioration of layout of plots cut by the highway lane	101.65	91.06	564.37	5976.0	35.2	203.8	284.1	16.5
Total		-	-	1198.51	36147.5	212.7	1233.0	1718.2	100.0

Tab 2. Decrease in the value of land caused by the construction of the motorway for the new section (own study).

No	The cause of lowering the value of the land	The value of one hectare of land [cereal unit/ha]		The area covered by the change [ha]	Reduction of income value				
		Before the change	After the change		In the village [cereal unit]	Structure [%]	Per kilometre of motorway [cereal unit/ha]	Per kilometre of motorway section going through agricultural land	Structure [%]
1	The takeover of land for the construction highway	108.61	-	155.90	16931.5	100.0	568.5	865.7	52.0
2	Deterioration in the quality of land located near the motorway	108.61	74.74	310.35	10512.0	62.1	352.9	537.5	32.3
3	The increase in distance of land from the farm due to changes in the communication system	108.61	96.73	100.68	1195.5	7.1	40.1	61.1	3.7
4	Deterioration of layout of plots cut by the highway lane	108.61	102.43	640.20	3952.6	23.3	132.7	202.1	12.1
Total		-	-	1207.13	32591.6	192.5	1094.3	1666.4	100.0

## 5 Summary

The simplified method of motorway impact assessment presented in this study takes into account all the most important directions of the motorway's impact on agricultural land and presents this impact in measurable and comparable units. A very big advantage of the used method is its very low labour intensity, which is caused by the fact that many simplifications were introduced in the assessment of the motorway's impact, thanks to which the scope of obtaining the initial data necessary for the analysis of the course of the motorway axis was largely limited. The automation of calculations with the use of computer software has a huge impact on the speed of analysis [3]. The simplified method of motorway impact assessment is particularly applicable during the initial estimation of the impact of the motorway construction on agricultural land still at the stage of making decisions on the course of the motorway and when assessing the considered variants of the course of the planned sections of the motorway [4]. The research conducted for the needs of this study, to which two sections of the motorway were used, where one is an existing fragment of the motorway, while the other is its alternative version differing in mileage, aims to illustrate in a special way the application of the simplified method of the impact of the motorway on arable land during the examination various possible variants of the course of this investment. The reduction in the value of land caused by the construction of the motorway on the existing section is equal 1718 cereal units/ha per kilometre of the motorway section, while in the alternative version, which course has been changed, it is equal 1666 cereal units/ha per kilometre of the motorway section. The difference between the decrease in value in both concepts, in particular, is due to the decrease in value related to the increase in the distance of land from settlements as a result of changes in the transport system and the deterioration of the layout of the plots divided by the motorway lane, which were much more favourable for the alternative motorway concept.

## References

1. S. Bacior, S. Harasimowicz, *The impact of the protective green belts on the influence of a motorway on agricultural land*, Surveying Review, **1**, 14-16 (2000)
2. S. Bacior, S. Harasimowicz, *The method of assessing the impact of motorway on the value of agricultural land. The accuracy of estimation of the area of arable land and classes of land*, International Conference of the Polish Society of Agricultural Engineering, 107-120 (2012)
3. S. Bacior, *The impact of motorway section under construction between the towns of Borek Mały and Boreczek on arable land*, Infrastructure and ecology of rural areas, **3**, 5-15 (2010)
4. S. Bacior, *The impact of the motorway on agricultural land on the example of its section Brzozówka – Nowa Jastrzębka*, Acta Scientiarum Polonorum Administratio, **11/2**, 5-14 (2012)
5. S. Bacior, I. Piech, *The impact of line investments on agricultural land on the example of the A4 motorway Żyraków Paszczyzna*, Acta Scientiarum Polonorum Geodesia et Descriptio Terrarum, **12 (1)**, 19-28 (2013)
6. J. Curzydło, *Drogi i autostrady, a skażenie motoryzacyjne*, Aura, **5**, 7-8 (1994) (in Polish)
7. R. Cymerman, *Arangement agricultural method of valuation of agricultural areas*, Valuation, **1**, 12-13 (1992)
8. P. L. Gilbert, A. Steinherr, *Private Finance for Public Infrastructures: in search of a new Framework*, EIB, **23**, 86-87 (1994)
9. S. Harasimowicz, *The main directions of the motorway impact on the income possibilities of farms*, Science notebooks of Agricultural University in Krakow, 57-62 (1997)
10. S. Harasimowicz, *Evaluation of the motorway impact on the agricultural land*, Surveying Review, **6**, 6-12 (1998)
11. S. Harasimowicz, *Evaluation and organization of the territory of a farm*, Script of the Agricultural University in Krakow (2002)
12. E. Quinet, *Issues in Building the European High-Speed Train Network*, Journal of Infrastructure Systems, **3**, 54 (1997)
13. W. Wilkowski, *Multi-criteria method for assessing the impact of motorway on farms*, Scientific work of the Warsaw University of Technology, **33**, 5-19 (1995)
14. M. Żak, *The issue of valuation of real property located in the belt of construction the motorway network*, Science notebooks of Agricultural University in Krakow, **396**, 17-22 (2002)
15. S. Bacior, *Auswirkungen eines Autobahnbaues auf Ackerböden - am Beispiel des Abschnitts der Autobahn A-4 zwischen den Städten Brzesko und Tarnów in Polen*, Berichte Über Landwirtschaft, **95/2**, 1-20 (2017) (in German)
16. S. Bacior, B. Prus, *Infrastructure development and its influence on agricultural land and regional sustainable development*, Ecological Informatics, **44**, 82-93 (2000)