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Assessment of Motorway Impact on Agricultural Land with a Simplified Method and GIS Data as a Tool for Selecting the Optimal Route

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Abstract: The highway network has to grow because of the increasing vehicle use, the effort to improve road safety, and the needs generated by economic development and efficient international transport. The negative impact of the motorway on agricultural holdings in its vicinity can be determined with general agricultural land valuation methods. However, this approach necessitates an in-depth analysis of land cultivated by each farm, which is rather labour-intensive. Impact on agricultural land should be assessed after the detailed plans for constructing a motorway are ready or even after construction. Nevertheless, simplified methods can be applied as early as the preliminary design stage or when evaluating potential alternative routes. Less labour-intensive, these methods can determine the harmful impact of a motorway on agricultural land with sufficient accuracy. The simplified and automated method presented for assessing the impact of a motorway on agricultural land uses GML files to automatically acquire data for the calculations, using the linear nature of the motorway. The prepared input data is then processed to optimally place the motorway in space. The final step is the visualisation of the road investment. The process has been automated to facilitate rapid analysis and employment of the data in linear project modelling and assessments of available options.

Keywords: rural areas; road network optimisation; sustainable transport; data automation; calculation process

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1. Introduction

Recent events, such as the Russian invasion of Ukraine or the COVID-19 pandemic, demonstrated the importance of domestic agricultural potential for food security [1,2]. Possible risk factors include the climate and environmental changes that cause such problems as poor water availability [3], degraded biodiversity [4], fast-paced population growth entailing food demand [5], or worse efficiency of agribusiness due to such unforeseen drivers as epidemics or socioeconomic conflicts [6]. Agricultural production efficiency depends on several key components such as soil quality [7], but also land ownership structure [8] or land use structure [9]. Unfavourable land fragmentation is crucial [10], if not key, among the numerous determinants of the profitability of small and medium agricultural holdings [11,12].

The area of agricultural land has been declining in Poland since the 1990s through its conversion into anthropogenic grounds, such as for construction, transport, or forest [13]. To protect agricultural land against conversion, one should select such locations and routes of construction projects that affect it the least [14]. This also applies to the construction of roads and motorways, railways, or air transport infrastructure. New linear projects are an unavoidable part of globalisation and the effort to improve transport infrastructure [15].

Improving the accessibility to goods and services in central areas from the peripheries or links from production areas to markets have been priorities for decades [16]. Financial matters, i.e., the cost of a project [17], usually outweigh consideration of the minimal impact on agricultural production space when situating a linear project [18].

The primary adverse effect of the construction of a motorway on agricultural production sites is the reduction in the area of agricultural land due to its conversion into non-productive land [19]. Such losses are apparent near roads and motorways as well [20]. Detrimental effects of a motorway construction for agriculture include, first of all, the deterioration in the configuration of parcels situated on the project centreline, degraded agricultural production close to the motorway, and elongated agricultural transport routes to farm fields [21]. These are the main considerations when investigating the impact of a linear project using the simplified method for assessing the effect of a motorway on agricultural land [22], which can also estimate the influence of motorway route changes on the losses due [18]. An appropriate analysis requires data about the variability of soil quality along the motorway, positions of roads and bridges, areas of agricultural parcels that require crossing the motorway to reach them, and intersected parcel configuration parameters [23]. These data are used to determine the motorway-induced variability of such land parameters that are significant for their production potential and are then employed to estimate the aggregate impact of the motorway on agricultural land.

The simplified method for assessing motorway impact on agricultural land can determine the holistic influence of the motorway construction on agricultural land, including loss of land acquired or the right-of-way, decreased capacities of pieces of land within a specific distance to the motorway, deteriorated configuration of parcels in holdings intersected by the motorway, and increased cost of agricultural transport.

The multifaceted impact of the motorway is measured using the land value determined only through its production capabilities. Therefore, the value is a measure of the valuation of the agricultural suitability of the land for agricultural production [24]. When selecting a location for a motorway, designers estimate the width of the adverse impact zone of the linear project on its surroundings [25–27]. It ranges from 15 to 30 m, but green belts could reduce the impact range of the motorway from 90 to 50 m [24].

The adverse effects of linear projects affect most of all the configurations of the parcels along its centreline. The deterioration of the relative configuration of parcels in agricultural holdings can be estimated by specifying the number of parcels the location of which changed. The linear project area most often bisects parcels. The division into three parts takes place in exceptional circumstances when the parcel length exceeds the width of the motorway right-of-way. The extent of changes in locations of intersected parcels hinges on the ratio of their length to the width of the motorway right-of-way. When parcels are bisected, or their length is not evidently greater than the motorway width, the plot lengths and areas can be assumed to be halved following the bisection. When a parcel is trisected, the average parcel length can be estimated as half of their initial mean length less the motorway width [28].

By intersecting the existing road network, a motorway disturbs other roads in the impact zone. This, in turn, entails longer access to agricultural land, for example [29]. To determine the increase in agricultural transport costs, one has to estimate the area of parcels that are accessed across the motorway and determine the increase in the access to the site. Some roads intersected by the motorway will have overpasses. Access to these areas from such roads will be unaffected by the project, and the resulting distance increase will be zero. Hence, these roads can be excluded from calculations of mean changes in distances to parcels [24]. To calculate the increase in agricultural transport due to the construction of a motorway, one has to determine the area of the parcels the access to which is intersected by the motorway for each road and the increase in the access distance to the area. The increase in the distance to parcels that require motorway crossing can be estimated from the mean distance between roads that intersect the motorway.

The objective of the paper is to present a modified simplified method for assessing the impact of a linear project on agricultural land with algorithms that automatically complete three steps of the method: data acquisition from a map, computation of agricultural land losses due to motorway construction, and route visualisation. The hypothesis adopted in the study was that the specific features of the road investment, related, among other things, to its linear shape, allow for the introduction of simplifications in the estimation of its impact on agricultural land. These simplifications mainly concern the estimation of the quantity and quality of land taken over for road construction and influenced by it, as well as the increase in agricultural transport and the deterioration of the distribution of plots. The method can be applied to road network expansion projects as well as maintenance and upgrading of roads, including improving the management efficiency of the planned, prepared, built, and existing road network.

2. Materials and Methods

2.1. Method for Assessing Motorway Impact on Agricultural Land and Premises for Automation

The proposed simplified assessment of motorway impact on agricultural land involves three stages that were automated to streamline the assessment procedure (see Figure 1). The process could be automated because we used properly formatted vector input data. The first stage employed automated acquisition of Geography Markup Language (GML) data, which replaced analogue field data collection and analogue data feeding to computation modules. In the second stage, the automatically processed input data were used to calculate losses caused by the construction of the motorway along a particular route. The third stage was to create a visualisation of the motorway route for optimal integration with the landscape.

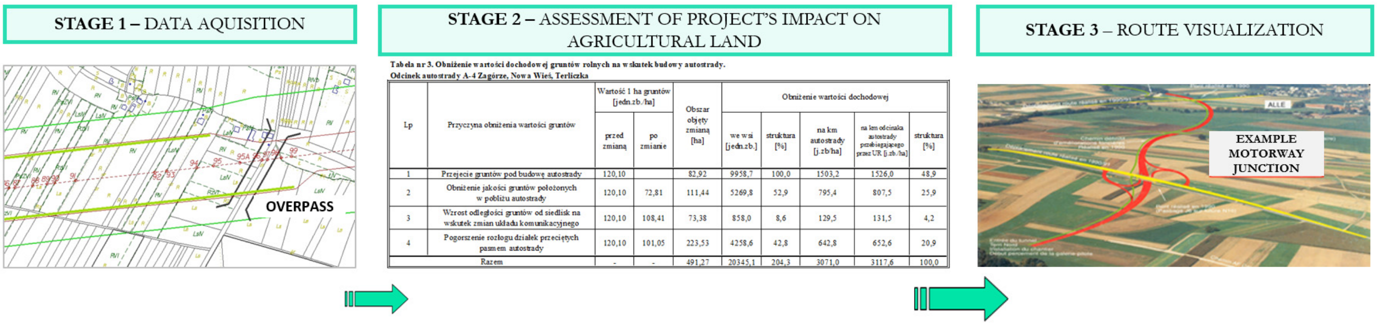

Figure 1. Schematic diagram of automation of the method for assessing linear project impact on agricultural land.

Poland's national road construction plan calls for the construction of 3768 km of roads, including nearly 255 km of motorways and almost 3090 km of motorways. In 2020, the government's programme for the construction of 100 ring roads was launched, which envisages the construction by 2030 of 100 bypasses with a total length of approximately 830 km.

The investigated section of the road investment begins at the Biała Podlaska interchange, without interchange (km 624+830), and ends at the Dobryń interchange (km 640+703). The area to be analysed was shortened, i.e., it includes the section of the motorway from km 626+500 to km 633+000 (Figure 2).

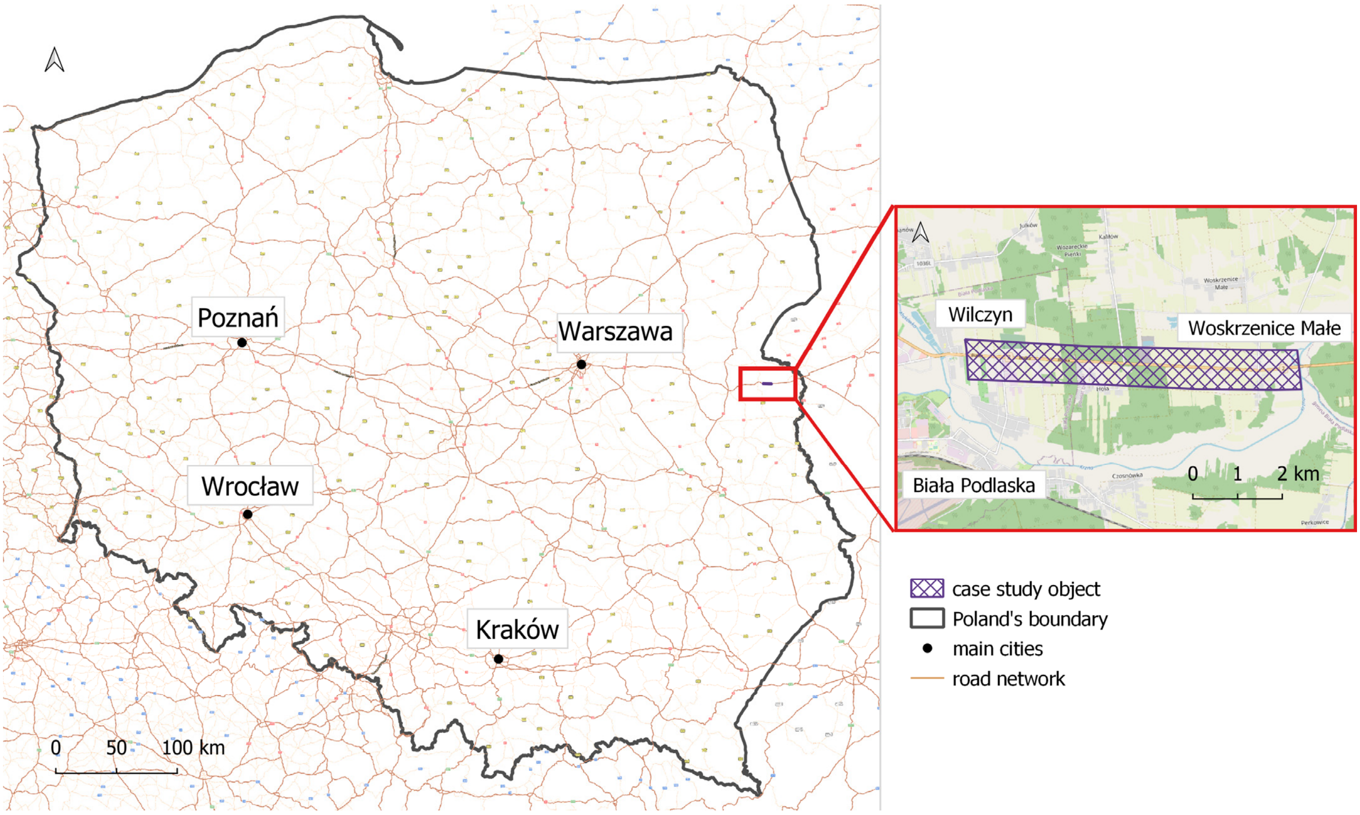

Figure 2. Case study location in Poland, Lubelskie Voivodeship.

2.2. Automation of Input Data Acquisition

The innovative nature of the proposed data acquisition procedure lies in algorithms that automatically read the input file with a vector description of boundaries of cadastral parcels, land use type patches, and soil quality patches to generate a dataset for a program that computes agricultural production losses. This improvement is universal for Poland and was made possible thanks to a nationwide harmonised GML file format for vector input data. In order to automatically acquire data for further computations, one has to combine information on the planned linear project's route with data on the land ownership, land use structure, and agricultural suitability (soil quality) and then identify characteristic points where input data change. An algorithm composed of geoprocessing instructions in QGIS generates points of intersection of the motorway centreline with spatial data on boundaries of parcels, land use patches, and soil quality patches and tabulates the results. Such generated tabulated data can be used directly in a module for computing agricultural land losses.

2.3. Module for Estimating the Impact of Linear Project Situation on Agricultural Land

It takes a significant number of computations to estimate potential losses of agricultural holdings caused by the construction of a motorway. The computation effort has been streamlined by significant automation with macro instructions in Visual Basic deployed in MS Excel. The software was chosen because it can present a large number of tabulated parameters and is commonly used. Moreover, it accepts macro instructions, with which computations can be automated to a greater extent. Visual Basic can create programs with clear structures. Data for the sections are summarised in aggregate tables for a more efficient and precise interpretation of agricultural land value loss along each section of the motorway and its subsections. It also helps with a more accurate assessment of the motorway impact on agricultural land expressed as a sum of land value reductions along the investigated parts of a long section of the motorway. Slightly less labour-intensive computations for an entire project section involve the determination of the reduction in land value based on mean changes in its characteristics caused by the motorway construction.

2.4. The Application for Visualising Motorway Route

The application is developed in HTML/JavaScript(Jquery). It requires a web server and Internet access but does not need a database or nonstandard disc access rights. It is standalone software installed by copying files into a directory on the web server. All access paths to application files are relative except Geoportal resources. The interface has been developed in HTML5, which makes it compatible with most hardware and software platforms. The recommended web browser for the application interface is Google Chrome. The application consists of three main modules (Figure 3): (1) a map viewer module that uses Geoportal's API; (2) a visualisation module; (3) an output data generation module. The Geoportal map module is used to input coordinates of the horizontal alignment of the planned motorway and generate descriptive points with them. It communicates with the visualisation module by duplicating points in the landscape panorama image. The visualisation module allows the user to interactively create the motorway route image and adjust the appearance. It communicates with the Geoportal module to fetch data on descriptive points. The output data generation module saves the output image created in the visualisation module together with data from the Geoportal module and the visualisation module. The image is saved as a lossless .png file. Module data are saved as open JSON for each model separately. This way, the user can generate an array of visualisations, motorway horizontal alignments, and descriptive points for the area. The complete application project consists of an input image and two JSON files.

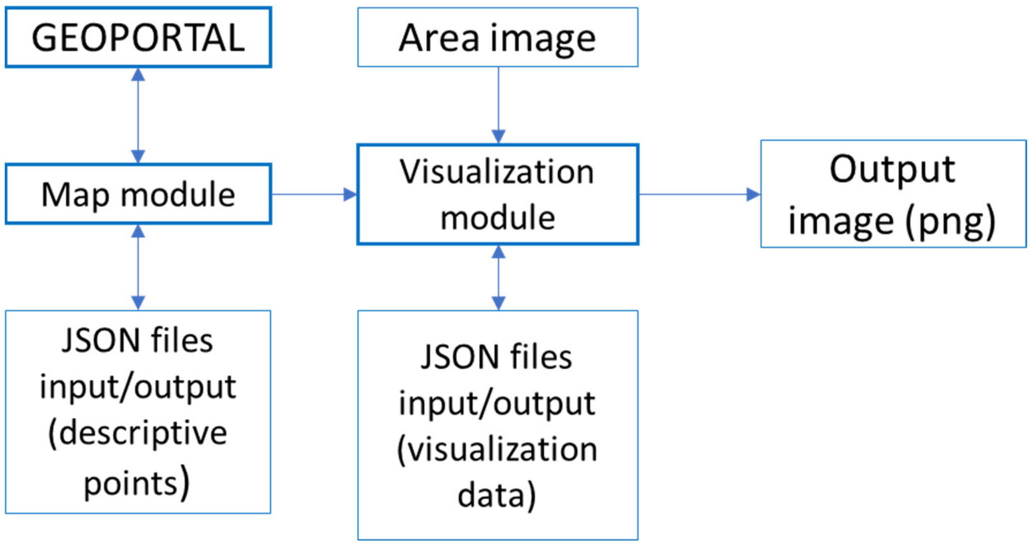

Figure 3. Flow diagram of the motorway route visualisation application.

Descriptive points are created on the map based on their location in the 1992 coordinate system. The application automatically plots a point on the map in a Geoportal box (see Figure 4). If a point has no coordinates, it is not displayed. A descriptive point's data can be input only in a dedicated panel in the right-hand side of the interface.

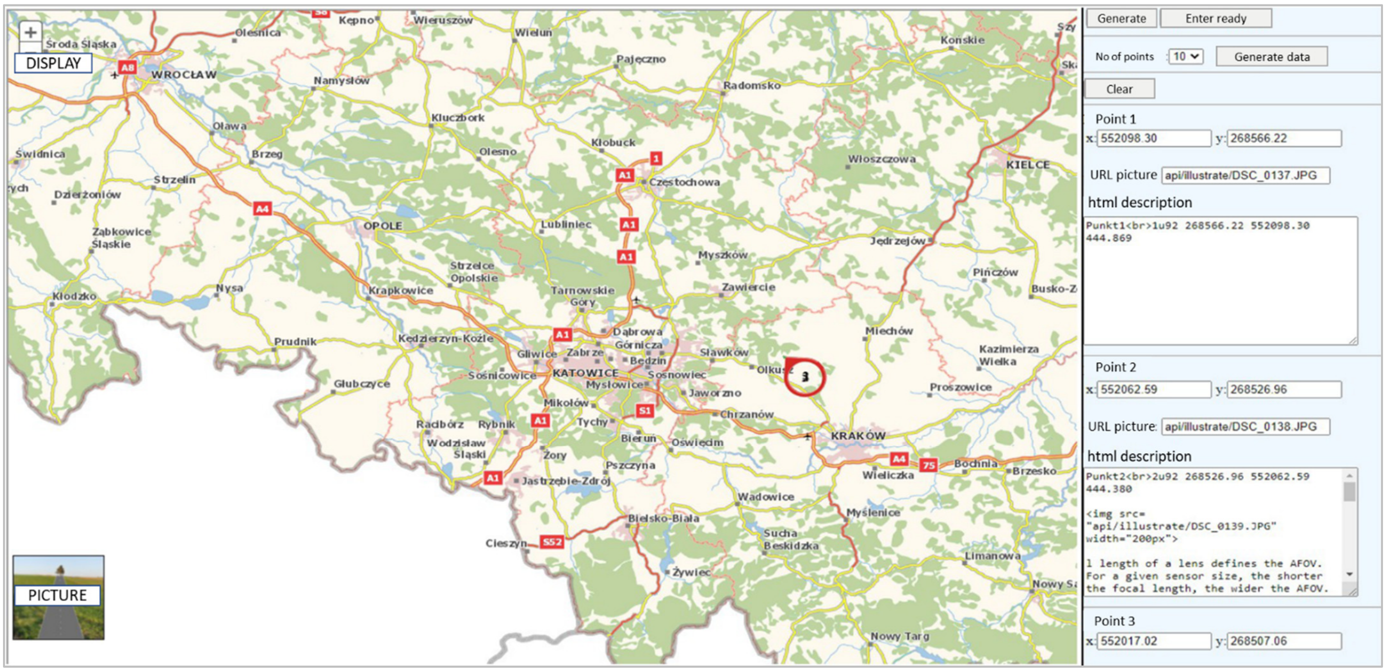

Figure 4. View of the map module.

When the application is launched, the Geoportal map module searches for the default.txt file in the 'api' directory of the application. It contains information on the default descriptive points in a JSON format generated by the output data generation module. The application can also run without predefined route points. The application will run even if the file is absent from the defined directory.

The side interface of the Geoportal map module is used to enter data of descriptive points and convert them to a JSON format. Maps are displayed using the Geoportal's API. The application will automatically generate relevant views from the input data when the map is refreshed. The underpinning of the visualisation is a digital panoramic image of the area where the motorway is planned. The plotting field size is determined by the size of the base image. If the user attempts to generate a visualisation when no plotting field is defined by loading a base panorama, the application displays the following message: 'Load base image'. Visualisations are created through interaction with the application. The user should define the number of node points for the centreline of the linear project (such as a motorway) and then move them to their positions. The algorithm builds the visualisation in real time using data from the Panorama and Image panels. The application automatically applies perspective to the motorway route based on an elementary transformation matrix from the opensource math.js library:

$$\mathrm{Tran}(\mathrm{a},\mathrm{b},\mathrm{c}) = \begin{bmatrix} 1 & 0 & 0 & \mathrm{a} \\ 0 & 1 & 0 & \mathrm{b} \\ 0 & 0 & 1 & \mathrm{c} \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}$$

where a, b, and c are shifts along the X, Y, and Z-axes.

The perspective is applied isometrically with the centre of the field of view in the central point of the base image. The viewing angle is arbitrarily set to 45° for the x and y planes of the field of view. The auto perspective algorithm overwrites all plot values at node points and transforms the entire route to the default values. Plot nodes determine the motorway plot route. The route is plotted in ascending order of the nodes. The number and data of the descriptive points are fetched from the Geoportal map module. The same route can be generated on different base images.

3. Results and Discussion

3.1. Changes in Agricultural Land Characteristics Due to Motorway Construction

- Construction of a motorway obviously improves road transport [23], but it also has many adverse effects, particularly in its immediate vicinity [29]. The primary harmful impact of a motorway is on agricultural land, which it most often intersects, reducing its production capabilities [30];
- Changes in agricultural land characteristics due to motorway construction were estimated using a simplified method that involves an analysis of the motorway centreline considering only general parameters determined when selecting the route of the road, such as the expected right-of-way width or positions of vegetated strips [22]. The following input data are determined after the centreline is plotted on the cadastral map: variability of soil quality along the motorway, areas of agricultural parcels that require crossing the motorway to reach them, intersected parcel configuration parameters, and positions of vegetated buffer strips. A total of 72 landmarks were identified along the surveyed section (Table 1). The variability of land characteristics due to motorway construction is determined using these data. Those characteristics of parcels are mainly taken into account that determine their agricultural usability and may be employed to holistically describe the contribution of motorway construction to the deterioration of the production capacities and income-generation capabilities of the land. This method considers all the types of agricultural land impact mentioned above;
- The streamlining and complete automation of the computations with an original program alleviated the labour intensity of the research. This way, the A2 motorway impact assessment could be performed for its relatively significant stretch between Wilczyn and Woskrzenice Małe in Lubelskie Voivodeship.

Table 1. Reduction in the income value of agricultural land as a result of motorway construction between Wilczyn and Woskrzenice Małe.

No	Cause of Value Reduction	Value of 1 ha [CU/ha]		Affected Area [ha]	Decrease in Profit Value				
		Before Change	After Change		In Village [CU [1]]	%	Per Motorway [CU [1]/ha]	Per Motorway km in Agricultural land [CU [1]/ha]	%
1	Land acquired for motorway	93.55		52.97	4955.3	100.0	760.4	909.6	44.9
2	Decrease in land to settlement distance due to changed transport system	93.55	63.61	75.11	2248.8	45.4	345.1	412.8	20.4
3	Increase in land-to-settlement distance due to changed transport sytem	93.55	65.97	113.18	3120.5	63.0	478.8	572.8	28.3
4	Detorioration in configuration of parcels intersected by motorway	93.55	90.26	218.8	718.0	14.5	110.2	131.8	6.5
	Total	-	-	460.07	11042.7	222.8	1694.4	2026.9	100

[1] CU—Cereal Unit.

3.2. Area of Land Acquired for the Construction and in the Impact Zone of the Motorway

The area acquired for the construction of the motorway along the investigated 6.5 km was 52.97 ha (Table 1). The width of this stretch of the motorway varies from 70 to 130 m depending on the occurrence of vegetated strips (Appendix A Table A1). The average lane width of a motorway is 94 m.

Relatively rare use of vegetated strips results in a width often not greater than the planned width without the strips, i.e., 70 m, especially in villages where soils are of good quality and forests are scarce. Table 1 presents the use and quality classes of the parcels acquired for the construction of the investigated Wilczyn–Woskrzenice Małe section. The data in the table indicate a homogeneous distribution of soil quality over the entire section. The extent of land acquisition for the project is well reflected by the area of acquired land per 1 linear kilometre of the motorway, which is also a measure of the average width of the motorway for the investigated section. As can be seen from the calculations (Table 1), the takeover of land for construction will be associated with a reduction in its value by 4955.3 cereal units in relation to the entire section under study, and, in relation to 1 km of the motorway, it will amount to 760.4 cereal units/ha, which indicates that land of medium quality class (i.e., IVa and IVb according to the Polish six-class classification of soils) will be taken over for construction. As was mentioned above, the motorway width variability across villages is moderate and reflects the occurrence of vegetated strips. The area of land in the impact zone of the investigated section is nearly twice as large as the land acquired for construction. The land area under the adverse impact of road transport is 75.11 ha on average (Appendix A Table A1). The width and area of the motorway agricultural impact zone vary significantly depending on vegetated buffer strips. When there are no vegetated strips, the motorway clearly impacts areas up to 90 m from its boundary, resulting in a 40% degradation of agricultural land quality on average [24]. In the surveyed section, this reduction is slightly higher than the average values reported in the literature and amounts to 45.4% (Table 1), which is due to the increased negative impact and is related to the lack of protective green belts in most of the surveyed section. The total maximum impact zone width reaches 180 m in such a case with the motorway width of 70 m. The land acquired for the construction and in the impact zone of the motorway includes various land-use patches along the motorway route. Agricultural land in Poland is a significant part of the mix. When the right-of-way covers little to no agricultural land, it is usually because of a large share of forest land and poor soil quality.

3.3. Parcel-Settlement Separation due to Motorway Construction

The horizontal alignment of the investigated section of the motorway had been designed correctly considering the boundaries of villages and rural residential areas. Therefore, users of only a small part of the land will need to use extended access via motorway bridges to reach their fields. The assessment of the increase in agricultural transport effort focuses on agricultural transport roads included on cadastral maps and does not cover unmarked tracks on agricultural parcels. Such assessment can yield values lower than the actual increase in land access routes even though, in obvious cases, we used best efforts to consider transport over parcels by increasing the traffic volume on the nearest roads separated from settlements by the motorway. Another cause could be small distances between bridges and a favourable arrangement of agricultural transport roads.

The areas of land access to which will be deteriorated after the motorway is constructed are equal to a product of the width of the catchment area of roads crossed by the motorway without bridges and the widths of land strips with extended access via motorway bridges specified for these roads. The average increase in parcel-to-settlement distances for this section of the motorway is 1.1 km, which is relatively significant because, the average distance between roads with viaducts is 1.6 km. However, it does not determine the increase in agricultural transport. These increases result mainly from distances between consecutive bridges and are virtually independent of the motorway route. The increases in land access distances defined by distances between bridges will result in significant increases in agricultural transport costs only if they are accompanied by a large area of land that has to be accessed by roads with no motorway bridges. A poorly designed motorway section will usually have a much greater area of land with increased distance compared to a correctly designed section with a similar increase in distances to parcels. Therefore, a large increase in the distance to parcels caused by the construction of a motorway indicates significant distances between bridges, and the correctness of the horizontal alignment can be assessed using the size of the parcels that it separates from settlements.

The total losses driven by this factor for the investigated section are 3,120.5 cereal units. It constitutes 63% (with an average of 20-30% of this factor reported in the literature [24]) of all losses in the value reduction structure (see Table 1), which may be indicative of the need for readjusting the transport system and considering this fact in land consolidation projects in the area of the motorway.

3.4. Changes in the Configuration of Parcels Intersected by the Motorway

The investigated stretch of the motorway usually intersects parcels perpendicularly to their length. The average width of the parcels intersected by the investigated section of the motorway is approx. 48 m. Considering that the parcels are not particularly long (463 m on average) compared to the motorway width, they should be intersected mid-length on average. The deterioration in parcel configuration due to the intersection by the motorway presented in row 4 of Table 1 covers an area of approx. 218.8 ha, and the total value deterioration amounts to 718.0 cereal units. This factor constitutes 14.5% of the value deterioration, which is relatively little compared to other factors considered in determining the adverse impact of a motorway.

In summary, the total loss of value associated with the acquisition of land and the negative impact of the motorway on agricultural land is 65.3% (Table 1) of the total loss of value, while the factor often accentuated in the literature associated with the increase in the distance to the land and the deterioration of the distribution of plots (shape and area of new plots) has a much lower value at the level of 34.8% (Table 1).

4. Conclusions

The presented simplified and automated assessment of motorway impact on agricultural land can extract GML data for computations from databases by tracking the motorway's centreline in the first module, feeding processed data for loss computation in the second module, and visualising the horizontal alignment of the motorway to integrate it optimally with the landscape in the third module.

In broader terms, the presented set of algorithms automates the assessment of the adverse effect of linear projects on agricultural production space. It can help comprehensively analyse horizontal alignment options for linear projects, calculate the total adverse impact of various proposed project locations intersecting the land layout, and identify the optimum variant that affects the agricultural production effectiveness in the area the least. It is relevant because studies show that the plot layout affects agricultural production costs for dozens of years [21]. An example study shows that the proposed methods give more precise results than the existing methods. Not only is the proposed automation of the computational process simple, but it also has important advantages in terms of automation, ease of handling, and good adaptability to motorway alignment optimisation algorithms.

The method can be applied to road network expansion projects as well as maintenance and upgrading of roads, including improving the management efficiency of the planned, prepared, built, and existing road network in Poland. It can be achieved by promoting innovations at the stages of the preparation and the delivery of road projects based on the most effective research methods that take into account sustainable development over the entire road life cycle.

At present, further research is being conducted related to the full automation of data acquisition for the method, and the comprehensive visualisation of the designed investment in space and its impact on the landscape, water environment, or aesthetic values. An analysis of other aspects of the motorway's impact on agricultural land related to aesthetic feelings, as well as the impact of the investment on changing land values caused by the proximity of well-developed transport systems, would also be worth considering.

It seems that the simplified method of investigating the negative influence of the motorway on the surrounding areas does not have any research limitations, the only difficulty being the lack of access to reliable and credible data used for direct analysis of the sections of road investments proposed for realisation. Taking into account only the agricultural aspect will also be a certain limitation. The analysis of other types of land, e.g., land of an urban character, i.e., land without production potential, will have to involve an extension of this method or another analysis which takes into account the loss of value not related to the production potential of agricultural land, but to the market value of land and buildings.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Initial parameters for assessing the impact of the motorway on agricultural land.

Point No.	Point Name	Chainage on Map [km]	Chainage Measured [km]	Section Distance to Point [m]	Lengths Over [m]																Width of Area Accessible via Motorway [m]	No. of Parcels Intersected by Motorway	Dimensions of Selected Parcels		Vegetated Buffer Strips: None = 1. One Side = 2. Both Sides = 3	Motorway Width [m]
					Other	Arable land								Gereen Areas						Roads			Length [m]	Width [m]		
						I	II	IIIa	IIIb	IV a	IV b	V	VI	I	II	III	IV	V	VI							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1A	466.623	466.623	5																5						
2	1	1. Village	466.695	72	72																				1	70
3	2		466.735	40														40				1	94	29	1	70
...																										
87	79A	3. Village	471.902	100	100																				3	130
88	79B	3. Village	471.998	96	96																				3	130
89	79		472.06	62	62																				3	130
90	80		472.307	247									247									9	206	15	3	130
91	81		472.324	17	17																				3	130
92	82		472.351	27									27									1	265	21	3	130
93	83		472.397	46	46																				3	130
94	84		472.407	10																10	5				3	130
95	85		472.418	11	11																				3	130
96	86		472.519	101								101										4	313	9	3	130
97	87		472.533	14															14			1	264	11	3	130
98	88		472.569	36								36										2	260	13	3	130
99	89		472.6	31	31																				3	130
100	90		472.614	14									14									1	242	12	3	130
...																										
478	431		495.838	80											80							1	115	86	1	70
479	432		495.891	53	53																				1	70
480	433		495.91	19																19	100				1	70
481	434		495.94	30	30																				1	70
Total				29,317	8279	1138	3375	1850	756	937	2611	4575	1458	22	212	222	1213	1264	787	618	4024	705	59,543	10,331		
Average				29,317																	67		261	31	34	87
Area [ha] taken over for motorway construction:				253.81	81.54	7.97	25.09	14.20	5.31	7.37	21.16	38.71	14.51	0.15	1.48	1.55	12.06	10.87	6.74	5.10						
Area [ha] of motorway impact:				462.92	117.58	20.48	58.80	31.63	13.58	15.79	43.15	73.44	20.51	0.40	3.82	4.00	17.07	20.06	12.53	10.09						

References

1. Satori, D.; Tovar, C.; Faruk, A.; Hunt, E.H.; Muller, G.; Cockel, C.; Kühn, N.; Leitch, I.J.; Lulekal, E.; Pereira, L.; et al. Prioritising crop wild relatives to enhance agricultural resilience in sub-Saharan Africa under climate change. *Plants People Planet* **2022**, *4*, 269–282. [CrossRef]
2. Vasylieva, N. Ukrainian Agricultural Contribution to the World Food Security: Economic Problems and Prospects. *Montenegrin J. Econ.* **2018**, *14*, 215–224. [CrossRef]
3. Lengoasa, J. Climate Variability and Change: Impacts on Water Availability(dagger). *Irrig. Drain.* **2016**, *65*, 149–156. [CrossRef]
4. Seppelt, R.; Arndt, C.; Beckmann, M.; Martin, E.A.; Hertel, T.W. Deciphering the Biodiversity–Production Mutualism in the Global Food Security Debate. *Trends Ecol. Evol.* **2020**, *35*, 1011–1020. [CrossRef]
5. Baquedano, F.; Jelliffe, J.; Beckman, J.; Ivanic, M.; Zereyesus, Y.; Johnson, M. Food security implications for low- and middle-income countries under agricultural input reduction: The case of the European Union’s farm to fork and biodiversity strategies. *Appl. Econ. Perspect. Policy* **2022**, *44*, 1942–1954. [CrossRef]
6. Gutsul, T.; Orozonova, A.; Mytrofanova, H.; Artiukh, T.; Kravchenko, N. European and National DIMENSIONS OF INVESTMENT IN AGRICULTURE IN THE CONVENTION OF THE COVID-19 PANDEMIC. *Financ. Credit. Act. Probl. Theory Pract.* **2022**, *1*, 342–350.
7. Wójcik-Leń, J.; Leń, P.L. Proposed algorithm for the identification of rural areas with regard to variability of soil quality. *Comput. Electron. Agric.* **2021**, *188*, 106318. [CrossRef]
8. Bański, J. The consequences of changes of ownership for agricultural land use in Central European countries following the collapse of the Eastern Bloc. *Land Use Policy* **2017**, *66*, 120–130. [CrossRef]
9. Postek, P.; Leń, P.; Stręk, Z. The proposed indicator of fragmentation of agricultural land. *Ecol. Indic.* **2019**, *103*, 581–588. [CrossRef]
10. Wang, Y.G.; Yu, F.; Guo, Y.C.; Li, M.; Meng, Q.X. Can farmers’ combined-tillage promote the agricultural production efficiency? -Evidence from land fragmentation. *Ciencia Rural* **2022**, *53*, e20220003. [CrossRef]
11. Tscharntke, T.; Clough, Y.; Wanger, T.C.; Jackson, L.; Motzke, I.; Perfecto, I.; Vandermeer, J.; Whitbread, A. Global food security, biodiversity conservation and the future of agricultural intensification. *Biol. Conserv.* **2012**, *151*, 53–59. [CrossRef]
12. Wojewodzic, T.; Janus, J.; Dacko, M.; Pijanowski, J.; Taszakowski, J. Measuring the effectiveness of land consolidation: An economic approach based on selected case studies from Poland. *Land Use Policy* **2021**, *100*, 104888. [CrossRef]
13. Cegielska, K.; Noszczyk, T.; Kukulska, A.; Szylar, M.; Hernik, J.; Dixon-Gough, R.; Jombach, S.; Valánszki, I.; Kovács, K.F. Land use and land cover changes in post-socialist countries: Some observations from Hungary and Poland. *Land Use Policy* **2018**, *78*, 1–18. [CrossRef]
14. Dimnet, E. 3 Key notions for road transport sustainability: Resilience, Climate action and Energy transition. *Rom. J. Transp. Infrastruct.* **2022**, *11*, 1–20. [CrossRef]
15. Bernacki, D.; Lis, C. Exploring the Sustainable Effects of Urban-Port Road System Reconstruction. *Energies* **2021**, *14*, 6512. [CrossRef]
16. Aworh, O.C. Food safety issues in fresh produce supply chain with particular reference to sub-Saharan Africa. *Food Control* **2021**, *123*, 107737. [CrossRef]
17. Forcada, N.; Rusiñol, G.; MacArulla, M.; Love, P. REWORK IN HIGHWAY PROJECTS. *J. Civ. Eng. Manag.* **2014**, *20*, 445–465. [CrossRef]
18. Dudzińska, M.; Bacior, S.; Prus, B. Motorway Route Planning with Regarding the Adverse Effects on Agricultural Production Space. *Sustainability* **2019**, *11*, 6770. [CrossRef]
19. Zhu, Y.; Huo, C. The Impact of Agricultural Production Efficiency on Agricultural Carbon Emissions in China. *Energies* **2022**, *15*, 4464. [CrossRef]
20. Waldron, R.P.; McCallum, A.B. A review of road infrastructure development and contemporary degradation on K’gari-Fraser Island. *Australas. J. Environ. Manag.* **2021**, *28*, 104–125. [CrossRef]
21. Janus, J.; Markuszewska, I. Forty years later: Assessment of the long-lasting effectiveness of land consolidation projects. *Land Use Policy* **2019**, *83*, 22–31. [CrossRef]
22. Bacior, S.; Prus, B. Infrastructure development and its influence on agricultural land and regional sustainable development. *Ecol. Informatics* **2018**, *44*, 82–93. [CrossRef]
23. Shen, Y.; Bao, Q.; Hermans, E. Applying an Alternative Approach for Assessing Sustainable Road Transport: A Benchmarking Analysis on EU Countries. *Sustainability* **2020**, *12*, 10391. [CrossRef]
24. Harasimowicz, S.; Bacior, S.; Gniadek, J.; Ertunç, E.; Janus, J. The impact of the variability of parameters related to transport costs and parcel shape on land reallocation results. *Comput. Electron. Agric.* **2021**, *185*, 106137. [CrossRef]
25. Khalifa, R.; Daim, T.U.; Stewart, R. Project Delivery: Highway Construction. In *Infrastructure and Technology Management: Contributions from the Energy, Healthcare and Transportation Sectors*; Springer: Cham, Switzerland, 2018; pp. 473–497.
26. Ibrahim, A.H.; Shaker, M.A. Sustainability index for highway construction projects. *Alex. Eng. J.* **2019**, *58*, 1399–1411. [CrossRef]
27. Afolayan, A.; Samson, O.A.; Easa, S.; Alayaki, F.M.; Folorunso, O. Reliability-based analysis of highway geometric Elements: A systematic review. *Cogent Eng.* **2022**, *9*, 2004672. [CrossRef]
28. Bacior, S.; Prus, B.; Dudzińska, M. Analysis of the Variability of the Motorway Impact on Agricultural Land on Example of A1 Motorway Section. In Proceedings of the 10th International Conference Environmental Engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania, 27–28 April 2017. [CrossRef]

29. Moravcikova, K.; Stefanikova, L.; Univ, T.K. Effect of the Road Transport on the Environment and Reduction of Its Negative Impacts through Carpooling as a Part of Corporate Social Responsibility. In Proceedings of the 19th International Scientific Conference on Transport Means, Kaunas Univ Technol, Kaunas, Lithuania, 22–23 October 2015; pp. 51–59.
30. Bacior, S. Veränderungen der Bodentauglichkeit zur landwirtschaftlichen Produktion infolge eines Autobahnbaus. *Ber. Uber Landwirtsch.* **2017**, *95*, 1–20. [CrossRef]