Article

Modern Methods and Techniques in Landscape Shaping with Various Functions on the Example of Southern Poland

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Abstract: The aim of this publication is to present the detailed results of research on the formation of landscapes with different functions. The research was conducted in areas typical for southern Poland in Kasinka Mala and Kamionka Wielka communes using the WIT statistical method and photogrammetric techniques. Among the landscape evaluation methods, the publication uses the WIT method of site significance indices, which employs a wide representation of features describing the spatial structure of villages. Using these indicators, the “value” and changes that have occurred in the landscape of each designated area were assessed. Three indicators were determined: WIT 1—for agricultural activities, WIT 2—for non-agricultural activities, and WIT 3—for recreational activities, for each of the villages of the Kamionka Wielka commune, comparing them in a tabular and graphical form. The indicators were used to determine the suitability of the land for agricultural activities, its potential for economic activity, and the development of recreational and tourist activities in the area. Most of the factors determining the character of a landscape can be properly captured using photogrammetric and remote-sensing materials. Thanks to the technological advances provided by photogrammetric methods, visualizations of landscapes with different functions were also used in this study. For landscape analysis, photogrammetric materials in the form of aerial photographs, digital orthophotomaps taken in different time periods (1963–1977–1997–2010–2013), and data from airborne laser scanning were used, which allowed visualization of the studied areas in the form of a DSM and 3D models of Kasinka Mala and Kamionka Wielka.

Keywords: landscape; valorization; orthophotomaps; LIDAR; digital terrain model; the digital surface models

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1. Introduction

Each of us perceives the landscape in a different way. It is variously defined and perceived by each person. The landscape is considered a set of natural and anthropogenic features occurring in a strictly defined area. According to the dictionary of geographical terms [1], the landscape is: “the sum of the typical features that are specific to a given fragment of the Earth’s surface, which individual elements, such as topography, soil, climate, water, flora and fauna, man and his economic activity, merge into one interdependent whole, distinguishing it from the surrounding areas”. The landscape is, therefore, a composition of natural elements (e.g., soil, climate, water) and anthropogenic (e.g., roads, buildings, railway lines, power lines). The prevalence of the second kind of element generally worsens the aesthetics of the landscape [2]. The landscape, being a multidimensional and multi-feature system, changes in time and in space. The landscape changes are, as a rule, holistic, but they usually take place by changing the elements of its structure [3]. The landscape always strives to remove matter from human influence on the environment. Currently, it is often noticed in the literature that landscape research should strive for simultaneous consideration of the subject of research, both in terms of production and in the categories

of perception. Wojciechowski is one of the representatives of the scientific communities dealing with the issues of the aesthetic evaluation of a landscape. In his publications [4,5] he states that the landscape is evaluated and valued as a synthesis of integrated spaces, views and various sensory feelings associated with them, and relevant associations and structures encoded in the mind of the observer.

The term “landscape” is also used colloquially and is, in the traditional sense, limited mainly to its aesthetic–scenic qualities of, for example, land relief, vegetation, or anthropogenic forms covered by the horizon [4,6]. Many forms of cultural landscape can be distinguished, including agricultural, urban, urbanized, and industrial landscapes [7–10]. Cymerman [11] distinguishes the urban and rural landscape among types of landscapes strictly related to human activity. Cymerman et al. [11] state that the rural landscape is the result of the interaction between different historical periods of many factors of a natural, social, economic, and technical nature. Rural landscapes can also be differentiated by taking into account different research methods [12–14]. Landscape research, especially its assessment and forecasting of desired changes and states of conservation, are among the particularly difficult tasks of the natural sciences. Until now, they have often been based on intuitive methods, often encumbered with subjectivism. The complexity of issues, especially spatial parameters describing the landscape, makes it necessary to base its assessment on various scientific fields, which often leads to very subjective or even divergent results of scientific studies regarding its assessment. The evaluation and valorization of the landscape were carried out by specialists from various fields of science. This was reflected in the selection of individual elements of the environment to be assessed. The choice of features depended on the purpose of the evaluation and valorization of the landscape. However, the environment is not only natural elements but also a number of components transformed directly or indirectly by man. On the borderline of these two different types of environmental elements functions the landscape. According to the Law on Environmental Protection [15], it is a particularly important component of the environment, whose values should be absolutely protected through appropriate planning activities and the creation of special areas for its protection. It is defined as the totality of an area perceived by society, “whose character is the result of action and interaction of natural and/or human factors” (European Landscape Convention). Landscape is the sum of many factors and attributes, which can be divided into three main categories: natural (abiotic and biotic elements), socio-economic (anthropogenic elements and features reflecting the influence of human activity), and cultural-aesthetic (intangible landscape features). Based on numerous typologies and studies, the main elements characterizing a landscape are relief, geological structure, and soils. Equally important landscape features are also land use, urban layouts, or historical objects [16]. Elements of the environment transformed by man and those on which he exerts a significant direct or indirect influence make up the broadly defined anthropogenic environment. The basis of its genesis lies in the conscious activity of man, who, with the progressive development of civilization, increasingly transforms the components of nature for his needs. This phenomenon is called anthropopression [17]. The anthropogenic environment is a series of components resulting from human activity in the surrounding space. The changes that man makes in the environment are described by a range of socio-economic characteristics. Some of them stand out, such as the ways of land use and environmental management, the spatial layout of fields and residential areas, cultural heritage objects, and technical infrastructure [18]. These features are the result of human activity, which leads to the formation of more or less complex transformed landscape elements. The main components of the anthropogenic environment may include: settlement networks and related other structures, technical infrastructure, including communication infrastructure, agricultural management, forest management, tourist infrastructure, and facilities, and transformations related to mineral extraction [19]. All the above-mentioned elements of the environment may be subject to more or less detailed assessment. According to the general definition, it is a value judgment that contains a positive or negative reference to a given phenomenon or condition. In the case of geographical sciences, however, evaluation is

understood a bit differently and is defined as determining the meaning and attributing given advantages to particular elements of the environment that determine the possibilities of satisfying particular needs of the society. Such a process is called valorization [20]. Valorization is an activity that consists in ascribing to the elements of the environment the optimal functions of land management due to their natural and anthropogenic features and predispositions [21]. It has a high utility value precisely because of the possibility of a reliable assessment of the environment, which allows us to determine its economic potential, choose the most appropriate way of management, as well as improve the quality of life of society [20].

In this literature review and in previous landscape research, the statistical and photogrammetric methods are not combined, although this was attempted by the authors of this publication.

2. Materials and Methods

Analyzing the methods of landscape evaluation and valorization, one can encounter a different approach to the issue related to the selection of the components of space affecting the landscape. Half of them are classical methods based on selected individual features. Others are based on the assessment of the landscape by comparing its features with the accepted pattern. When examining the methods of landscape valorization in terms of the principles of the assessment itself, it can be seen that the vast majority of methods is based on the assessment of individual elements of the environment that affect the landscape in different ways. Quantitative and qualitative diversity of landscape elements subject to assessment in individual methods results from the fact that they were created by specialists from various fields of science. Methods of landscape evaluation and valorization can also be divided according to the method of measuring individual elements. Some of the methods are based on expert knowledge. The other methods are the measurement methods, and, in the assessment of landscape, they use a given scale of assessments. Among the methods of landscape evaluation, the publication uses the Land Relevance Indicators (WIT) method, developed by U. Litwin [22–24]. Using these indicators, it is possible to assess the “value” and changes that have occurred in the landscape of each of the separated areas. This method uses a broad representation of features describing the spatial structure of the village. However, the appropriate approach to this space and the changes taking place in it is of great importance for the assessment of landscape values and, in particular, for the tracking of changes taking place in it. Correct identification of most of the factors determining the nature of the landscape is possible with the use of photogrammetric and remote-sensing materials. The main directions of the development of modern photogrammetry and remote sensing concern the digital processing of photogrammetric and remote sensing data and building relational databases and geographical information systems. A lot of the information contained in photogrammetric studies is inaccessible or unused, which we sometimes are not even aware of. Photogrammetric studies, similar to remote-sensing ones, are most often used in the description and modeling of the Earth’s surface [25]. They are much less frequently used to describe the micro-space and in the creation of maps and models of photographed objects in thousands of scale reductions, although the methods for generating surface and space models are the same. The photogrammetric methods are mainly used for reconstructing and analyzing structural surfaces, that is, those the display of which contains elements that can be separated in the picture, corresponding to physical spatial objects with the possibility of explicitly locating them. Much more difficult, requiring a different methodology, is the photogrammetric documentation of non-structural spaces (e.g., standing water, areas of homogeneous use) and transparent spaces (e.g., bottoms of watercourses and water reservoirs). However, the structural elements dominate in the assessment of the landscape. The abundance of information provided by aerial pictures, and thus also by orthophotomaps, encourages the users to use them frequently because the information value of an orthophotomap is always greater than the value of line maps. The digital terrain model (DTM), arising in the technological process of orthophotomap

generation, created practically automatically with any mesh selected by the user, allows us to visualize terrain in any place and from any direction. Thanks to DTM, obtaining basic parameters describing the elementary forms of terrain is much easier and more precise. DTM gives an opportunity to visualize the developed area artistically [26–28]. DTM is one of the basic information layers used by systems that describe phenomena in terms of value and is often the basis of spatial organization for them [29]. Interacting with other layers in a spatial information system, the DTM is used to conduct comprehensive spatial analyses in a specific area. Along with the attribute database, it is the basic element of a numerical map. It is used in design and investment processes and in various types of analyses, forecasts, and predictions of physical, social, and economic phenomena [30]. DTM is commonly used, among other things, to determine elevation at any point of the terrain, create axonometric drawings of the terrain surface, calculate volumes and balance landmasses, analyze mutual visibility of points, determine local terrain slopes and their azimuths, analyze floodplains and river basins, create contours and cross-sections, and represent surfaces (visualization) in 2D and 3D [31–33]. It is most often represented by two- or three-dimensional graphics, using a varied pixel color palette, which most often corresponds to the elevation scale. The application of digital photogrammetry methods and, in particular, the use of DTM and digital orthophotos provide new possibilities in the assessment of changes occurring in the landscape. Orthophotomaps allow us to observe the image of different landscape forms, as well as uses, in the same reference scale without using symbols. The use of aerial photographs taken at different time intervals for this purpose provides an extremely rich source of data on environmental changes. Data acquired from aerial scanning are widely used in many fields of science and economy [34–36]. First of all, they are an excellent source of data for generating numerical elevation models. They are also used to develop simulations and flood hazard maps, the orthorectification of aerial photographs, planning, and land use planning. They are also used in such fields as: archaeology, urban planning, forestry, power engineering, telecommunication, ecology, and glaciology. A rich source of information, except for well-known numerical terrain models, is one of the point cloud derivatives—a numerical land cover model [37–39]. Laser scanning is increasingly used worldwide as a method of acquiring information about the topographic surface as well as other elements of land cover. This is due to the undoubted advantages of this technique; among the most important advantages, it is worth mentioning the high elevation accuracy of the data, independence from lighting conditions and partially weather conditions, and the high density of source data. Laser data allow the generation of the numerical terrain model [40,41]. They also allow the determination of basic vegetation parameters such as tree height, crown diameter, forest density, biomass estimates, and forest boundary determinations. [42–45]. Research work on separating different land use classes, including vegetation, using intensity information was also conducted by [46].

The aim of this publication is to present detailed results of research on the formation of landscapes with different functions. The research was conducted in areas typical for southern Poland in the Kasinka Mala and Kamionka Wielka communes using the WIT statistical method and photogrammetric techniques.

Among the many features tested with the use of the WIT method, only those that may have changed over time were selected; at the same time, the changes which could be easily read from aerial and satellite photographs were also selected. They include the changes in agricultural land (arable land, meadows, pastures, orchards), surface changes of forests, changes in land relief, and changes occurring in built-up areas, related to the increase in the number of buildings. Thanks to the application of the latest technology achievements, which are provided by the photogrammetric methods, the article also uses the visualization of the landscape with different functions.

Photogrammetric materials in the form of aerial photographs and digital orthophotomaps made at different time periods were also used for the landscape analyzes (1963–1977–1997–2010–2013), including data from aerial laser scanning, which allowed us to

visualize the studied areas in the form of the numerical model of land cover and the 3D model of Kasinka Mala and Kamionka Wielka.

3. Area of Research

The choice of areas of research covered by the WIT method was determined by the diversity of the natural environment, resulting from the variety of regions in southern Poland: the Kotlina Mszanska commune and the Kamionka Wielka commune. These areas perform various economic and social functions. These functions include, above all, forms of recreation, forest management, and agriculture, skillfully using specific environmental features. Studies on the assessment of landscape shaping in foothill areas were carried out in the area of the villages Kasinka Mala and Kamionka Wielka (Figures 1 and 2).

Figure 1. The study area—Kasinka Mala.

Figure 2. Location of Kamionka Wielka.

Kasinka Mala is located in the area of the Beskid Wyspowy, which is a part of the Beskid Zachodni. In the class of mountain landscapes, they are classified in the lower

subalpine forest category. It is generally characterized by the height of the mountain range, from 500 to 1300 m above sea level; it has low and easily accessible passes as well as a dense water surface network and a large number of springs. Apart from the arable fields, fir and beech forests dominate there. Beskid Wyspowy, as a part of the aforementioned Beskid Zachodni, covers an area of about 1000 km². It stands out in the landscape by having isolated mountains. This view is original and extremely charming; however, it is not very popular with tourists, thanks to which it remains wild and unbridled. The second research object—Kamionka Wielka—is located in the Malopolskie voivodship in the Nowosadecki district. Kamionka Wielka has an uneven terrain relief; it is a submontane terrain. It lies in the valley on the border of the Sadecki Beskid and the Niski Beskid, near the connection of streams: Kamionka, Krolowka, and Wolanka. It is located 8 km from the capital of the Nowy Sacz district and covers an area of 63 km², of which forests cover over 46% of the entire area of the commune.

4. Selected Methods and Techniques in Landscape Assessment

Photogrammetric methods based on orthophotomaps, lidar, NMT, NMPT, and the statistical method—WIT, which are discussed in this chapter, were used in the conducted research.

4.1. WIT

The estimation of the “value” of the landscape is strongly influenced by the right choice of features that will affect this value the most [22]. The following features present the structure of land use, including agricultural land, rural settlement, as well as the natural environment in the analyzed area. The set of features is then subject to statistical analysis to determine the relationships between the features, which allows the characterizing of the spatial diversity of rural landscapes. The following characteristics are considered for the calculation of the WIT index:

1. Average altitude—the average elevation of the location of the village.
2. The soil quality index, calculated according to a 6-point scale by weighting the areas of agricultural land in each class with appropriate weights.
3. The Steinhaus index of relief determines the degree of topographic differentiation of the terrain. The more intensive the terrain is, the higher the index is.
4. The clustering index characterizes the degree to which the village area is filled with built-up land, i.e., it informs how much of the village area is built-up.
5. The average distance between homesteads characterizes the internal spatial structure of a settlement.
6. The settlement’s built-up area shape indicator expresses the ratio of the area’s maximum width to its length. For a square-shaped area, it equals 1 and decreases with lengthening.
7. The number of homesteads per km² characterizes the density of the rural settlement network.
8. The average homestead size informs about the average size of an agricultural habitat in the area under consideration.
9. The number of buildings; this indicator shows the total number of buildings in each settlement.
10. Age of buildings built before 1944.
11. Age of buildings constructed after 1944.
12. Building material—non-flammable wall material indicates the number of buildings constructed with non-flammable materials (brick, concrete).
13. Building material—combustible wall material indicates the number of buildings constructed with combustible materials (wood).
14. Type of ownership determines the predominant character of ownership in a given area. Assumed: for private buildings –1, for non-private buildings 0.
15. Area designated for building development (ha).
16. Area allocated for communication (ha).
17. Area for cultivation (ha).

18. The indicator for the number of watercourses; it defines the ratio of the length of watercourses in a given village to its total area.
19. Number of permanent residents.
20. Percentage of people making their living from agriculture.
21. Dominant terrain character: flat, undulating, hilly, mountainous.
22. Special landscape values: landscape parks, protected landscape areas, protective forests, other.
23. Predominant type of development: one-way compact, one-way loose, square multi-way, dispersed, urban.
24. Number of individual farms with an area of 0.51–1.99 ha.
25. Number of individual farms with an area of 2.00–9.99 ha.
26. Number of individual farms with an area of 10 ha and more.
27. Predominant types of plot layout: block-type, strip-type, block-strip-type.
28. Presence of permanent terrain elements limiting the possibilities of plot layout changes: modification—none, escarpments, ravines, slopes, multi-year plantations, other.
29. Land area under forests and woodlands.

The following study uses a set of features used in the research on the valuation of spatial structures in Kotlina Mszanska [22], which were used in calculating the WIT.

Due to the nature of the study area, the number of features may be limited. Only those features that have changed over time and, at the same time, whose changes could be easily read from photogrammetric data were selected for this study.

In order to determine the three basic functions: agricultural, non-agricultural, and recreational, the land relevance indicator (WIT) was used. This indicator evaluates the value of the analyzed region. For this purpose, indicators WIT 1 (determining agricultural activity), WIT 2 (determining non-agricultural activities), and WIT 3 (determining recreational and tourist activities) are calculated. Using the WIT indicators, it is possible to evaluate the “value” and changes that have occurred in the landscape of each of the separated areas.

This method uses a broad representation of features describing the spatial structure of the village. The diversity of the natural environment determined the selection of the Kasinka Mała village for research. This village area performs various economic and social functions. These functions include, above all, forms of recreation, forest management, and agriculture that skillfully use specific environmental characteristics.

The land relevance indicator (WIT), can be used for the following types of activities: agricultural activity, non-agricultural activity, and recreation.

For each of the considered areas, the WIT is determined as a sum (Equation (1)):

$$WITa = a_1z_1x_1 + a_2z_2x_2 + a_nz_nx_n \quad (1)$$

where:

$x_1 \dots x_n$ —a set of normalized features of the area

$a_1 \dots a_n$ —a set of “favorability” weights

$z_1 \dots z_n$ —a “significance” factor determining the importance of an individual feature

The “favorability” of a feature determines its positive or negative impact on the usefulness of the area in question.

The “significance” is the significance of the feature for a potential given activity in the studied area (e.g., the increase in the number of new buildings in the village is a beneficial feature that changes the landscape).

4.2. Orthophotomap

The abundance of information provided by aerial pictures and orthophotomaps encourages users to use them frequently because the information value of orthophotomaps is always greater than that of cartographic maps. The use of digital orthophotomaps, generated on the basis of aerial photographs taken at various time intervals, gives new

possibilities in the assessment of changes taking place in the landscape. Orthophotomaps make it possible to observe the image of various landscape forms, as well as ways of use, at the same reference scale without the use of symbolism.

The main advantage of orthophotomaps is an objective representation of the land use condition at the moment of taking the photos. Binding the image to a specific moment of registration causes orthophotomaps taken in spring, summer, and autumn to be different, which allows us to monitor changes in the environment. The orthophotomap is an excellent material for separating different types of use. It is easy and effective to identify urbanized, agriculturally used, and natural areas. Permanent grasslands and areas with insufficient agricultural culture, e.g., shrubs, self-seedlings, sandbanks, and waste dumps, can be identified with very high probability. Some problems appear only with detailed functional qualifications, mainly of urbanized areas.

4.3. LIDAR in the Landscape Assessment

One of the modern and fast methods of 3D data collecting is airborne laser scanning. Thanks to the use of LIDAR technology (light detection and ranging), it is possible to effectively scan the terrain surface with laser beams. The possibility of using data from laser scanning for the construction of a DTM is very large. This method is fast and enables the measurement of large surface areas and allows registration of both the height of the terrain relief and the height parameters of the land cover elements, which makes possible the accurate three-dimensional modeling of buildings and infrastructure for spatial visualizations of the developed area. The weakness of the LIDAR measurements is the lower accuracy of determining the height of points (oscillating within 0.15–0.25 m) than in the case of other methods. However, it is sufficient, assuming the vertical resolution requirements of the DTM models, especially ones developed at smaller scales. The absorption of a laser pulse by some surfaces, such as water or asphalt, is also a problem because it can cause some difficulties during the creation of the DTM. Due to the accurate results, speed, and development possibilities of the application of this method, it displaces at a rapid pace the radar methods of measuring the Earth's surface [47].

4.4. DTM and DSM

A digital terrain model (DTM) approximates a part or the whole of the continuous terrain surface by a set of discrete points with unique height values over 2D points. Heights are, in approximation, vertical distances between terrain points and some reference surface (e.g., mean sea level, geoid, and ellipsoid) or geodetic datum. Mostly arranged in terms of regular grids, the 2D points are typically given as geodetic coordinates (latitude and longitude) or planar coordinates (North and East values). DTMs usually assign a single unique height value to each 2D point, so they cannot describe vertical terrain features (e.g., cliffs). DTMs are, therefore, "2.5D" rather than truly 3D models of the terrain [48]. The DTM is commonly used to determine the height of any point on a terrain, create axonometric drawings of the terrain surface, calculate the volume and balance the earth mass analysis of mutual visibility of points, determine local terrain slopes and their analysis of local slopes and their azimuths, analyze flood plains and river basins, and create contour lines and crosses [49] and 2D and 3D surface representation (visualization) [31–33,50,51].

Digital surface models (DSMs) are also widely used. They are a combination of data about the heights of the terrain relief, along with information on the situational and height locations of the objects on the surface of the analyzed area. These objects may be natural, e.g., afforestation formations, shrubs, and lakes, or related to the activity of people, e.g., buildings, roads, and artificial water reservoirs.

5. Results

5.1. Results Obtained Using the WIT

The selected features allowed us to conclude that Kasinka Mala belongs to submontane areas with agricultural activity, currently changing into recreational activity.

On the basis of the WIT Site Significance Indicators, the following results were obtained (Table 1, Scheme 1).

Table 1. The structure of land use.

Agricultural Land—1362 [ha], Including					
Arable Land [ha]	Orchards [ha]	Meadows [ha]	Pastures [ha]	Forests [ha]	Fallow Lands [ha]
1077	32	68	185	1127	20

Scheme 1. The structure of land use.

An attempt to evaluate and assess the landscape using the WIT method allows us to determine the scope of the normal, natural, and anthropogenic processes taking place in the studied area. Attention should be paid to the need for maintaining a certain distance to the obtained results. Numerical values are only an attempt to determine landscape changes in the studied area. Every element of the landscape changes to a certain degree; however, it is a subjective evaluation connected to some degree with intuition. The development of each area is a dynamic process. The changes are constantly occurring. They are caused by various factors and constantly affect the development or regress of each area. Valuation and assessment of landscape changes using the WIT method are useful for larger administrative units, namely, regions. The second object of the study was Kamionka Wielka; the application of the land relevance indicator (WIT) to assess the landscape for particular functions in this commune looks as follows (Table 2).

Table 2. Calculated values of WIT.

No	Village	WIT 1	WIT 2	WIT 3
1	Bogusza	6.68	11.21	17.67
2	Jamnica	2.01	8.17	13.55
3	Kamionka Mała	1.05	4.99	12.97
4	Kamionka Wielka	0.55	14.69	24.80
5	Królowa Górna	9.33	11.50	20.42
6	Królowa Polska	5.17	8.37	15.07
7	Mszalnica	4.23	9.54	12.72
8	Mystków	0.74	10.90	15.69

To determine the degree of “significance”, a number between 0.3 and 1 was adopted for each of the features, where the value of 1 was adopted for the basic characteristics (e.g., soil bonitation for agriculture). The calculations were carried out according to Formula (1). Three indicators were obtained: WIT 1—for agricultural activity, WIT 2—for non-agricultural activities, and WIT 3—for recreational activities for each of the eight villages of the Kamionka Wielka commune. WIT 1, WIT 2—coefficients calculated according to Formula (1). The calculation of the land relevance indicator for the Kamionka Wielka area enabled the identification of individual villages as the areas more or less suitable for agricultural, non-agricultural, or recreational activities. Figure 3 presents the calculated indicators WIT 1 and WIT 2 for the eight villages of the Kamionka Wielka commune. The results are presented in five intervals (below 4.00, 4.01–8.00, 8.01–12.00, 12.01–16.00, above 16). Figure 3 presents WIT 1, that is, agricultural activity for all villages of the Kamionka Wielka commune. The smallest value of WIT 1 is from the village Kamionka Wielka; it is 0.55. The highest value of WIT 1 (9.33) is from the Królowa Górna village. Most villages are in the range below 4.00, they are: Kamionka Wielka, Mystków, Kamionka Mała, and Jamnica. A similar number of villages is in the range 4.01–8.00: Mszalnica, Królowa Polska, and Bogusza. The remaining village, Królowa Górna, belongs to the range 8.01–12.00. When analyzing the results of WIT 1, it can be stated that the Kamionka Wielka commune is not suitable for agricultural activities due to the small number of farms. If there is agricultural activity, in most cases, it is for personal use. Another reason is the presence of escarpments and slopes in the area, impeding agricultural activity, as well as a relatively large area of forests in relation to agricultural land.

Figure 3. WIT 1—agricultural activities for the municipality of Kamionka Wielka.

Figure 4 presents WIT 2—non-agricultural activity, which takes values in the range of 4.99 to 14.69. Here, the smallest value has reached the village of Kamionka Mała, the largest Kamionka Wielka. The remaining six villages: Jamnica, Królowa Polska, Mszalnica, Mystków, Bogusza, and Królowa Górna, fit in one range, from 8.01 to 12.00. WIT 2 presents Kamionka Wielka as a village with the greatest potential for economic activity.

WIT 3 defines recreational and tourist activities and lies in the range of 12.72 to 24.80. The highest recreational and tourist qualities are in the following villages: Królowa Górna and Kamionka Wielka. Kamionka Wielka also has the highest value for business; however, it has the lowest for agricultural activity. The high values of WIT 3 are caused by the opposite values of features for agricultural activity. The forest area and slopes of the land cause bad conditions for agricultural activity but good ones for recreational and tourist activities.

Figure 4. WIT 2—non-agricultural activities for the municipality Kamionka Wielka.

5.2. The Use of an Orthophotomap in Landscape Shaping

The orthophotomaps from various time periods—1963 and 2010—were used to assess the landscape of Kasinka Mala. The time interval between them is equal to 47 years, so this set of materials allowed us to identify the changes occurring in the environment. The use of photogrammetric materials required the creation of thematic layers, named arable land, grassland, orchards, forests, waters, roads, and buildings, for orthophotomaps from 1963 and 2010 (Figures 5 and 6).

Figure 5. Orthophotomap from 1963.

Figure 6. Orthophotomap from 2010.

The layers were successively vectorized, and the results of the work are shown in Figures 7 and 8.

Figure 7. The image created after the vectorization of the orthophotomap from 2010.

Figure 8. The image created after the vectorization of the orthophotomap from 2010.

In the next stage of work, the topology of contoured orthophotomaps was checked. After doing this, both drawings were superimposed to capture the differences that emerged over time. The results of the activities carried out are shown in Figure 9.

Figure 9. The image that emerged after the transformations.

It presents in a pictorial manner the changes that took place during the research period, thanks to marking both years with different colors, so it is easy to see the differences

between black (1963) and green (2010). Table 3 presents the sets of result data included in the report. They show that the area of arable land is the largest, both in 1963 and in 2010, although it has decreased by about 12 ha. The area of orchards and waters have also decreased. As a result of these changes, the area of built-up areas and roads has increased.

Table 3. The list of different use areas from 1963 and 2010.

Type of Terrain	Area of the Site with an Orthophotomap from Year 1693	Area of the Site with an Orthophotomap from Year 2010
B	0.8226	2.3574
R	58.4505	46.3167
S	1.9849	0.359
W	1.1482	0.7953
x	13.4925	10.1121
Dr	2.8649	3.5916
Ls	15.6849	26.8018
Uz	20.3064	24.421
AMOUNT	114.7549	114.7549

Table 4 illustrates what detailed changes have taken place in the studied area in relation to a particular layer. The biggest changes include changing a large part of agricultural land (over 13 ha) into grassland. In grassland, a transformation has taken place, especially to arable land and forests; water has been largely overgrown by forests, and some forests have been adapted for grassland. Most orchards have been turned into arable land and into grassland or other areas. A large part of the roads remained in their original position; the rest have been transformed into forest, a role, or grassland. The other areas have been transformed mostly into forests and grasslands, and some new buildings have been built on them.

Table 4. The list of landscape changes in individual groups.

Buildings			Arable Land		
Type of Terrain (1963)	Type of Terrain (2010)	Surface (ha)	Type of Terrain (1963)	Type of Terrain (2010)	Surface (ha)
B	B	0.4747	R	-	0.7499
B	Dr	0.0300	R	B	0.278
B	Ls	0.0149	R	Dr	0.6233
B	R	0.0172	R	Ls	5.0166
B	S	0.0004	R	R	36.4486
B	Uz	0.0481	R	Uz	13.6086
B	x	0.2372	R	x	1.7255
AMOUNT		0.8225	AMOUNT		58.4505

Table 4. Cont.

Grasslands			Water		
Type of Terrain (1963)	Type of Terrain (2010)	Surface (ha)	Type of Terrain (1963)	Type of Terrain (2010)	Surface (ha)
Uz	-	0.3232	W	-	0.002
Uz	B	0.6257	W	Dr	0.0512
Uz	Dr	0.5390	W	Ls	0.8282
Uz	Ls	3.7568	W	R	0.0014
Uz	R	7.0737	W	Uz	0.0486
Uz	S	0.0038	W	W	0.0902
Uz	Uz	4.9715	W	x	0.1265
Uz	x	3.0127			
AMOUNT		20.3064	AMOUNT		1.1481
Forests			Orchards		
Type of Terrain (1963)	Type of Terrain (2010)	Surface [ha]	Type of Terrain (1963)	Type of Terrain (2010)	Surface [ha]
Ls	-	0.1241	S	-	0.0356
Ls	B	0.2244	S	B	0.0671
Ls	Dr	0.2822	S	Dr	0.0214
Ls	Ls	11.0571	S	Ls	0.0782
Ls	R	0.7956	S	R	0.5827
Ls	S	0.0867	S	S	0.1039
Ls	Uz	1.8039	S	Uz	0.512
Ls	x	1.311	S	x	0.5842
AMOUNT		15.685	AMOUNT		1.9851
Road			Other		
Type of Terrain (1963)	Type of Terrain (2010)	Surface [ha]	Type of Terrain (1963)	Type of Terrain (2010)	Surface [ha]
Dr	-	0.0146	x	-	0.0035
Dr	B	0.0243	x	B	0.6269
Dr	Dr	1.1267	x	Dr	0.8441
Dr	Ls	0.646	x	Ls	3.7863
Dr	R	0.3496	x	R	0.1977
Dr	S	0.0164	x	S	0.1477
Dr	Uz	0.3281	x	Uz	2.3854
Dr	W	0.0067	x	W	0.6885
Dr	x	0.3524	x	x	4.8122
AMOUNT		2.8648	AMOUNT		13.4923

5.3. Results of the Study Using LIDAR

Automatically classified point clouds with a density of 8–9 points/m² served for the research on the shaping of the landscape in Kasinka Mala, as illustrated in Figure 10.

Figure 10. Final version of the classified cloud of points.

These clouds have been limited to the relevant sections according to the current 2000 system and the limits of the Kasinka Mala area (Figure 11).

Figure 11. The approximate border of Kasinka Mala.

The categorized clouds had the following classes: ground, low vegetation, medium vegetation, high vegetation, buildings, low point, default, and model keypoints. In relation to the whole area, from the cloud of several dozen million points, the Model keypoints constituted only 3.2 million points (Figure 12).

The digital surface model in the Kamionka Wielka area was made on the basis of the above-mentioned LIDAR data. The point cloud, classified automatically, has been manually adjusted using the TerraScan program, working in conjunction with Bentley's MicroStation V8i (Figure 13).

The result of the work is the DSM presented in Figure 14.

Figure 12. The Model keypoints for the entire area.

Figure 13. The cloud of points from the fragment of Kamionka Wielka (on the **left**), along with the corresponding digital surface model (**right**).

Figure 14. Digital surface model of the Kamionka Wielka village.

5.4. Results of the Study Using NMT, NMPT

The photogrammetric method is one of the methods of acquiring data concerning the heights of the terrain for later use in creating the numerical model of its surface. The photogrammetric measurements of aerial photographs or satellite images on digital stations allow us to determine the heights of a selected point in space. The process of acquiring height data on the basis of the model can be carried out automatically on a large area or under the user's control. This is an undoubted advantage of this way of collecting data for DTMs. Another strength of this method is the speed of data acquisition and the possibility of developing large areas. The most interesting effects of the spatial modeling process can be observed in areas that are heavily diversified in terms of topography. Based on this belief, a fragment of the municipal commune of Mszana Dolna, along with the village of Kasinka Mala, was adopted as the study area. The research area is characterized by the high potential in terms of the construction of the digital terrain model. When choosing the research area of this study, the possibility of emphasizing the relationship between the terrain shape and the objects present in it, as well as with land use and spatial development, were taken into account. The analyzed area includes, among others, compact forest complexes, agricultural areas, green areas, and urban and rural development areas, together with road and rail infrastructure. The occurrence of these elements gave an opportunity to create a digital terrain surface model (DSM), taking into account their connection with the relief. To create the digital terrain model, a method of triangulation of acquired data was used to create a vector model in the form of a triangulated irregular network (TIN). The model created in this way was supplemented with three-dimensional models of buildings, trees, and road infrastructure, thanks to which the digital terrain surface model was created (Figure 15).

Figure 15. Digital terrain surface model—Kasinka Mala.

A digital terrain surface model was used as a basis for carrying out additional research on the applications of 3D models in the fields related to the branch of geoinformation engineering. The creation of the DTM required the construction of an irregular grid of TIN triangles. The creation of a regular grid could result in the omission of some details of the relief due to the high variability of the terrain configuration of the selected study area. The digital terrain model of the Mszana Dolna and the surrounding area was created as the TIN grid surface (Figure 16).

Figure 16. Digital terrain model of the research area—TIN grid, draft version, view from above.

On the basis of the pre-formed TIN grid, the vectorized contours of mountains and the slopes of embankments were projected onto the created surface. The final version of the DTM is shown in Figures 17 and 18.

Figure 17. Digital terrain model—view from the side of Mszana Dolna, Phong type rendering.

Figure 18. Digital terrain model—view from above, Phong type rendering with solar lighting from the southeast side.

The mean square error of the height determination for the model was equal to ± 0.56 m. It was calculated from the Ackermann formula, Equation (2).

$$m_{\text{NMT}}^2 = m_z^2 + (\alpha \cdot d)^2 = 0.56 \text{ (m)} \quad (2)$$

where:

m_z —the mean square error of the height of the point determination, adopted as 0.1 (m) due to the accuracy of the heights given on the source map,

α —coefficient describing the nature of the terrain. It was assumed as $\alpha = 0.022$ difficult terrain (mountainous with high slopes)

d —the average distance between the measurement points was adopted as 25 m according to the original TIN grid triangulation options.

To build the land cover model, it was necessary to conform the previously created DTM model to the original model, not only in terms of the shape but also the appearance. The basic activity, therefore, was texturing of the terrain surface created earlier. The texturing process is used to give the 3D surface a texture, i.e., a digital image, most often representing the type of material from which the modeled object is made. The process of applying a texture, a map, a satellite image, or an aerial image to a digital terrain model is called draping. The results of the draping of the DTM model, using digital rasters saved in GeoTiff format, are presented in Figures 19–22.

Figure 19. Textured DTM model view from the side of the city of Mszana Dolna.

Figure 20. Textured DTM model—profile view from the east side.

Figure 21. Textured DTM model—isometric view.

Figure 22. Textured DTM model—top view.

To display high resolution textures, the Rendering option set in the Phong display mode was used with the anti-aliasing shading method. Enabling anti-aliasing smoothes the edges of the displayed texture model, making the scene (or render) look more natural. The texture of the topographic map was insufficient for creating a good-looking digital terrain model. In order to give the relief model a similar look to the natural terrain surface, it was necessary to reach for the implementation of aerial photographs. As a result, we decided to create a mosaic of rectified aerial photographs available on the Geoportal website. The calibration was made by similarity, taking into account situational details on the map, such as buildings, roads, and borders of land (Figure 23).

Figure 23. Adjusting the situational details of the map to the aerial photo.

After completing the aerial photograph adjustment, the mosaic fragments were merged into one common file and saved in the GeoTiff format (Figure 24).

Figure 24. Mosaic created from 33 fragments of aerial photographs, being the basis for creating the texture of the DSM model. The yellow color represents the slopes of the relief model.

In this way, a basic texture was developed for the terrain model, which is the “background” of the DSM being built. Then, the renders (Figures 25 and 26) of the surface of the digital terrain surface model (DSM) were presented with a basic texture, which is a mosaic of the aerial photographs. This surface has been extended in the next stage of research, with elements of land cover. The digital terrain surface model illustrates the connection of field elements with the terrain relief. DSMs depict the location, shape, and height of natural objects, such as trees, and artificial ones, such as houses, economic facilities, technical infrastructure, and others. The digital terrain surface model contains a number of applications used in various engineering, planning, and similar branches.

Figure 25. Area of elaboration—DTM model with superimposed texture, bird's eye view.

For the purpose of the research, several groups of land cover details were adapted, and, next, they were implemented in the DTM model covered with a basic texture. These were: building blocks, trees, and elements of technical and engineering infrastructure. The creation of the DTM of the Kamionka Wielka object was carried out using LIDAR data. The

automatic classification consisted of assigning the cloud points to the appropriate type of terrain. In addition to the previously classified classes, it was necessary to determine the model key points, i.e., points that show the relief of the area; based on them, it is possible to generate the digital terrain model (Figure 27).

Figure 26. The render of the development area landscape—a view of the Szczebel mountain slope.

Figure 27. Model keypoints.

The final effect in the form of the DTM of Kamionka Wielka is shown in Figure 28.

Figure 28. DTM of Kamionka Wielka.

The visualization of the Kasinka Mala model is presented in Figure 29.

Figure 29. Isometric view of the generated surface.

The model depicts roads, the Raba river, and its tributary Kasinianka. A separate layer representing forest areas, given a dark green color, was also created.

The final three-dimensional model of the developed area is shown in Figure 30.

Figure 30. Isometric view of the 3D model of the area.

5.5. Use of WIT and Photogrammetric Data in the Literature

The use of WIT and photogrammetric materials in cross-functional landscaping is reflected in the literature.

The site relevance index, as required, has been modified. The paper [52] gives the rules for calculating a new index based on terrain significance indices—ZWIT (Normalized Terrain Significance Index), whose innovation consists of treating as comparable all values of features of a previously assumed model. Another example is the publication where the Economic Site Importance Index (EWIT) was developed as the creative development of the site importance indices (WIT) and valuing land for its agricultural, non-agricultural, and recreational functions [53]. Particularly important in the study were mutual relations of prices of undeveloped building land with the proposed indices, which, after determining the weights of spatial-agrarian features, may serve for preliminary valuation of land in the studied area and thus indicate possible directions of development of particular rural areas.

The use of photogrammetric materials in his research was taken into account by Nita [54] when studying upland landscapes. He attempted to objectify the evaluation of landscape forms on the basis of measurable parameters based on orthophotomaps, numerical models, and analyses of aerial photographs. The basic issue was to determine the rank of inanimate nature forms (mainly, but not only, monadnocks) in the landscape values of the region and to select zones of the highest value for the landscape of the Czeszochowa Upland. Research [55,56] has demonstrated the use of orthophotomaps and NMT to present changes in the ways of agricultural land management as well as recording changes occurring in the landscape from the example of the Domaniow Reservoir.

6. Summary and Conclusions

The aim of this publication was to present detailed results of research on the formation of landscapes with various functions, which were conducted in areas typical for southern Poland, using the WIT statistical method and photogrammetric techniques. Detailed studies were carried out for Kasinka Mala and Kamionka Wielka communes, located in the Malopolska province. Determination of WIT 1, WIT 2, and WIT 3 indices for them, respectively, allowed us to determine the suitability of areas for agricultural activity, to determine their potential for economic activity, and to shape recreational and tourist activity. Conducted analyses showed the high usefulness of using photogrammetric data in the form of orthophotomaps, ALS point clouds, DTMs, and DSMs to identify landscape changes and their graphical visualization and make statistical calculations. This allows us to formulate the following conclusions:

- High-resolution aerial orthophotomaps are increasingly used to identify land cover changes.
- In conclusion, two aspects of the research work can be presented. One is related to the analysis of changes in selected landscape elements. The second is related to the technology that we can use in monitoring land cover changes. As far as the monitoring of changes is concerned, in the case of simple landscape elements, the use of aerial photographs seems obvious. As a result of the conducted research, it has turned out so, i.e., archival aerial photographs were an invaluable source of data in this case. One can even consider this kind of information exemplary.
- Landscape assessment methods based on digital image analysis are based, among others, on research using numerical models that present the surface of the terrain and/or its coverage, most often in the form of a regular GRID. The creation of such models for large areas requires a significant amount of data. Due to the speed of data registration in recent years, the unrivaled measurement method for surface modeling is airborne laser scanning. Acquired data, in the form of a dense point cloud, allow us to generate models with very high accuracy, which guarantees reliable results.

Kasinka Mala has evolved and developed strongly during the research period. In the 1970s, there were few houses and farms (57 buildings), mainly focused on agricultural and forestry activities, usually located by the main road in 6 clusters. It was a village with an agricultural and forestry function. There were dirt roads there that usually led to arable fields, with the exception of the main, hardened road passing through the center of the village. There were 7 orchards on the studied area with a total area of less than 2 ha. The analysis of the 2010 orthophotomap showed that the housing developed intensively, almost three times in relation to the 1970s (164 buildings). They were built near the main road and expanded the clusters where the previous houses were located in such a way that some of them were merged, so their number was reduced to 4. Along with the development of the settlement, the road network with better technical conditions has expanded. Despite the increase in anthropogenic factors, forests have not decreased; on the contrary, they have increased their area by more than 40%. As a result of these changes, orchards decreased from the total area of over 80% (from 7 to 2); the inflow of the Kasinianka River also disappeared. The use of the orthophotomap was an important element for obtaining information about changes in the landscape. This enabled a quick and effective assessment of these changes and the presentation of the spatial arrangement of the objects and their identification because these can be easily done in the displayed image, while avoiding going out, because all the work is carried out in the office. Airborne laser scanning, nowadays, is gaining more and more appreciation due to the huge amount of data obtained in a relatively short period of time. Furthermore, these data are characterized by high accuracy. The terrain development is very accurate, but the very large amount of information to be processed is also time-consuming. Despite the use of better and better algorithms improving the work with the cloud, it is impossible to completely rule out the role of the operator in the project. It is only possible to limit his role. Digital terrain surface models created on the basis of data from aerial laser scanning provide a reliable base of information about the area and are

increasingly used in many areas of life. The latest point cloud computing software is gaining more and more appreciation among users as it enables us to discover new opportunities and save time. After analyzing and comparing different methods of assessing the landscape changes, including the statistical method of WIT, a comprehensive and multidirectional purpose analysis of the use of photogrammetric materials to identify major changes taking place in the foothill landscape was carried out. The presented photogrammetric studies take into account the time vector, giving full quantitative and qualitative characteristics, while the impression and pictorial reception of changes in the landscape are made by visualizing them. The photogrammetric methods can be effectively used for the metric and plastic presentation of the landscape space and also to design changes in the landscape according to our feelings and possibilities of sensual and intellectual perception. One of the important tools used for landscape analysis is DTMs. In the studies, it was used to analyze the variability of the landscape of the submontane area. Analysis using DSMs enables the assessment of the landscape without applying expensive methods related to the development of individual landscape objects in the area. The study is based on the use of aerial photographs and existing, traditional cartographic materials and digital maps. Summarizing the results of the environmental analyses, it should be emphasized that the photogrammetric data can be called full when they are analyzed in conjunction with other information collected in the databases of the spatial information system. Visualization with the use of aerial photographs and aerial scanning enables the identification of objects and the presentation of their spatial arrangement. This is very important due to the complexity of spatial phenomena and their temporal variability. In the image displayed, it is easy to find the sought objects that have changed over time. In the literature related to the study of the natural environment, many methods can be found that assess the landscape. They were created by specialists in various fields and served various purposes. An analysis of the WIT method allows us to conclude that it has features limiting its use in assessing landscape changes (it cannot be used on a macro scale); moreover, it is a labor-intensive method, and it requires cartographic, statistical, and descriptive materials. The proposed new tools allow us to assess landscape changes that are caused by the passage of time and are characterized by high efficiency (a short image processing and analysis time) as well as relatively good results of recognizing changes in buildings, borders, and roads. They were verified on the research object (Kasinka Mala) and compared to the results of the WIT method. The obtained results allowed us to positively assess their suitability for the evaluation of the condition of the landscape at the turn of the analyzed years.

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