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An Analysis of an Area's Vulnerability to the Emergence of Land-Use Conflicts

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Abstract: The optimization of space is the priority goal of spatial planning. Spatial planning policies have numerous objectives, including the prevention of land-use conflicts. Conflicts arise whenever two entities have contradictory expectations regarding the surrounding space. In the process of spatial development, humans impart new characteristics to space, which, under specific circumstances, can give rise to land-use conflict. The elements of space that are particularly vulnerable to conflict include boundary points, property boundaries, density of development, or the shared use of infrastructure. The main aim of this study was to develop a procedure for evaluating the risk of land-use conflict based on the characteristic attributes of space. The proposed procedure for assessing the accumulation of conflict-generating traits in space was developed with the use of databases, GIS tools, and statistical data processing methods.

Keywords: land management; land-use conflicts; components of space; spatial analysis; GIS tools

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1. Introduction

Conflict is a widespread phenomenon that always involves at least two parties, where one party attempts to derive personal gain at the other party's expense and without its explicit consent [1]. Conflict is a concept that can be examined in various contexts, including as a social (social approach) or an economic (functional approach) process, where one party attempts to maximize its own gain by eliminating or dominating over the other party to the conflict [2].

The potential sources of conflict have to be determined to identify the existing or potential conflicts. The main categories of conflict have been systematized by Bogetoft and Pruzan [3] who posited that conflicts can arise from one or several different factors. These factors can be divided into four main groups:

1. Value system factors:
    - 1.1. The parties have different values and aims;
    - 1.2. The parties take different measures to represent their aims;
    - 1.3. The parties have different preference hierarchies (for example, by applying different weights for different solutions);
2. Effect distribution factors:
    - 2.1. The parties can incur different costs and derive various indirect benefits associated with the anticipated effects of their actions;
    - 2.2. The breakdown of costs and benefits is perceived as uneven and unfair;
3. Uncertainty factors:
    - 3.1. The parties cannot reach agreement on the probable effects of actions;
    - 3.2. The parties are not certain of the effects of their actions;
    - 3.3. The evidence and the rationale behind the effects of their actions may be insufficient or incomprehensible;

    3.4. The parties may have doubts about the associations between the effects of an action and other actions;

4. Process factors:
    4.1. The parties find it difficult to exchange information about their values, aims, criteria, preferences, and expectations.

All of the above factors have a common denominator: the actions undertaken by the parties are contradictory, and each action is localized in space. A big proportion of conflicts are directly or indirectly associated with space. Conflicts that are directly related to space are referred to as spatial conflicts [4].

Spatial conflict is an inseparable element of spatial development and human existence [5]. The significance and progression of land-use conflicts are irreversibly linked to the use of space, and the quality of life is influenced by the quality of the surrounding space [6–8]. Profit maximization has been the driving force behind land-use conflict ever since humans discovered that land can be a critical source of capital and wealth [9,10]. The struggle for land took on various forms and progressed on a different scale, and due to the nature and the object of that struggle, it became known as spatial conflict or land-use conflict [11,12].

Spatial conflicts are widely encountered, and they can occur at any time and in any location. Changes in the hierarchy of needs and needs satisfaction, as well as individual traits (greed, envy, etc.) can promote the belief that the existing space is insufficient. This conviction increases the value of space, and it is the main cause of spatial conflict.

Most spatial conflicts have highly negative consequences for the economy, society, space, and the environment [13]. The above applies particularly to developing and transition countries, where the real estate market is weakly developed and where illegal practices involving land create an opportunity for rapid wealth accumulation [14]. In this case, land ceases to be a public good, and land ownership is often transferred to a small and wealthy social group. However, the extent to which the parties to a conflict manifest their views is correlated with the level of democracy in a given country [15]. The causes, course, and consequences of land-use conflict should be analyzed to develop effective spatial planning tools [16].

In theory, land-use conflict does not differ from other types of conflict, but space is always the subject matter of such disputes [17]. Land-use planning shapes our living and working environment; the integrity and sophistication of the overall planning process govern the sustainability of proposed spatial allocations in urban and rural areas [18]. Spatial conflict is usually driven by various land-use options, contradictory interests, and goals, including those pertaining to the use of natural resources [19–23].

Spatial conflicts can have different causes, and they are rarely homogeneous. In other words, spatial conflict is not driven by a single factor, and it is a complex and multidimensional phenomenon. This complexity can be attributed not only to the physical characteristics of space, such as size, diversity, and form, but also to changes in space and subjective perceptions of space [24]. Humans have different needs and expectations that are satisfied in space [25]. Land is a common good that is essential for human activity. Due to the diversity of human needs and the limited supply of land, land has been the source of conflict throughout human history [26]. Owing to the complexity of space, various spatial relationships can be identified, but not all of them can be described in detail. However, they can be generalized [27]. The main types of conflict relationships are associated with environmental features, economic activities, and social expectations [28]. The conflict relationships based on these three main pillars of human existence are presented in Figure 1.

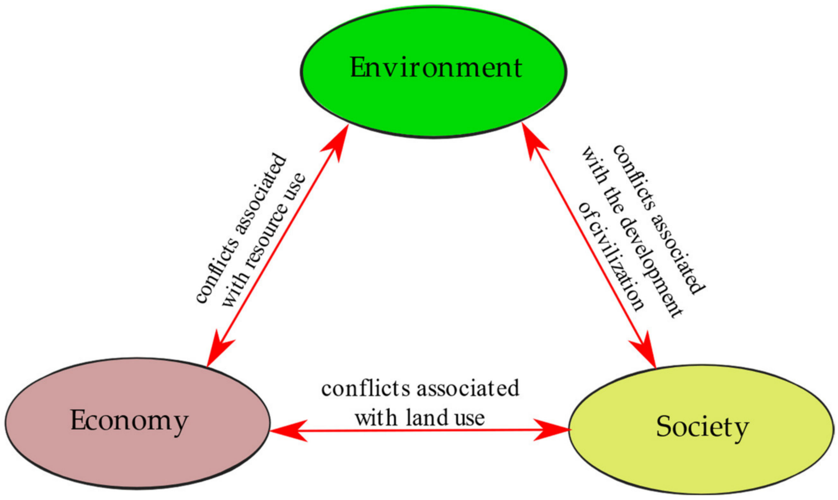

Figure 1. Conflicts arising from relationships in space. Source: Own compilation based on [29].

Conflicts between the economy and the environment relate to the use of natural resources and the extent to which the environment is transformed by human activity [30]. Mineral resource mining and the acquisition of land for development projects are prime examples of the above. The expectations associated with environmental protection stand in opposition to the maximization of profit derived from resource use.

Conflicts between the society and the environment have a similar context, but they focus on the quality of human life. The expected comfort and convenience of the modern lifestyle, such as access to public infrastructure or pest-free households, run contrary to environmental protection.

Conflicts between the economy and the society generally result from contradictory expectations regarding access to public infrastructure and natural resources between the consumers, investors, and public administration bodies that analyze the economic consequences of various uses of space. Disputes surrounding the location of land development projects are an example of such conflicts [31]. These types of conflict gave rise to NIMBY (not in my backyard) syndrome, where residents generally agree that a facility producing goods or services is needed, but oppose its construction in their neighborhood [32]. Conflicts can also erupt in a reverse scenario, when local communities advocate for the construction of certain types of infrastructure, but are faced with opposition from supralocal groups that derive benefits from the use of space in its existing form [33].

Conflicts waged on a wider scale are referred to as functional-economic conflicts [34], where factors leading to the aggregation and dispersion of various land-use functions occur simultaneously and undermine the welfare of local communities [6,35]. These factors are usually associated with considerable disproportions in the development of adjacent areas. Selected functions are excessively concentrated in some areas (such as cities), but they are lacking in peripheral and underdeveloped areas. Globalization contributes to the emergence of spatial conflict in the social-economic dimension. Urban sprawl increases the prices of agricultural land, leads to conflict over farmland protection and, consequently, drives conflict over land ownership [5].

The presented classification of spatial conflicts is not exhaustive or sufficiently detailed. Many conflicts combine the features of all of the above categories, where contradictory expectations regarding land use are influenced by the object of the dispute and the involved parties [36].

Spatial conflicts can emerge over land ownership and land-use rights, but also over land itself, the neighborhood, or the use of private or public land [37]. Regardless of the above, space is always the essence of conflict. The object of conflict can also differ in scale or magnitude, and it can include buildings, undeveloped land, or property boundaries. Entire regions and countries can be embroiled in spatial conflict.

In view of the above, the object of spatial conflict can be classified based on its location, scope, and specific claims. When these criteria are taken into consideration, the objects of spatial conflicts can be divided into the following groups:

- space in the geodetic sense:

  cadastral plot;
  building;
  property boundaries.

- land-use rights:

  ownership, perpetual usufruct, co-ownership;
  other rights to derive income from land: easement, lease, tenure, etc.;
  specific land-use (land management) rights.

- space in the geographic sense:

  immediate space (own—private);
  local space (neighborhood, municipality);
  regional and ethnic space;
  national space;
  global space.

The object of spatial conflict should be classified to identify the scope of the dispute and the involved parties. The resulting classification also contributes to the selection of the optimal conflict resolution tools [38].

Many land-use conflicts are caused by different expectations regarding the attributes of space [39]. The above implies that space cannot be evaluated unambiguously [40]. However, fragments of space with a high accumulation of potentially conflict-generating attributes can be identified [41]. Most spatial conflicts are caused by social factors as conflicts are driven by humans and do not exist without humans [42]. Conflicts are often fueled by personal traits which are difficult to assess and are rarely analyzed in studies on spatial conflicts. However, the risk of social conflict can also be exacerbated by the characteristic traits of entire social groups [43]. These include:

- high population density;
- major cultural and political differences among local community members;
- number of households;
- differences in educational attainment.

The above factors strongly influence the quality of life and individual expectations towards space. In less affluent societies, land-use strategies are implemented to generate economic benefits and improve the standard of living, and these goals are accomplished at the expense of other attributes, such as the quality of the natural environment [44]. Social attributes that contribute to spatial conflict can also influence economic factors, including:

- land prices;
- unemployment;
- differences in economic status;
- sources of income (different types of employment).

These differences are often responsible for various expectations towards land use and land management. In many cases, different expectations can be the secondary cause of local and personal land-use conflict [45].

The risk of spatial conflict increases in communities and regions with diverse social characteristics and contradictory expectations towards land management. These differences are manifested by:

- real estate prices;
- fragmentation of ownership (fragmentation of cadastral plots);
- development density;
- building height;

- length of property boundaries;
- diverse land-use types in the immediate neighborhood;
- large area of ecologically valuable land.

The specificity of land-use conflict has to be explored to expand our understanding of the scope and potential consequences of such conflicts, which could play a key role in rational and sustainable management of space [46–48].

The attributes of space where land-use conflicts occur usually have a local character. Land division, changes in land-use, and urbanization take place locally, and spatial conflicts are generally intensified by anthropogenic factors [49]. Some of these attributes can be identified and evaluated intuitively, whereas others become apparent only when a conflict erupts or when the causes of the conflict are analyzed in detail [50].

One of the goals of spatial planning is to limit the negative impact of conflict-generating attributes on human existence [51]. Such attributes have to be identified, eliminated, or minimized [52]. However, conflict-generating factors can be reliably assessed only if they can be unambiguously identified and described in the entire area under analysis. The above can be achieved with the use of GIS databases which are characterized by extensive thematic content and broad spatial coverage [53,54].

The characteristic attributes of space that incite spatial conflict usually evolve at the local level [55]. Land division, changes in land use, and urbanization are processes that occur locally, and spatial conflicts are fueled mostly by anthropogenic factors.

As previously mentioned, space has many attributes that can generate land-use conflict. Some of these attributes are recognized and evaluated intuitively, whereas others are identified only when a conflict erupts or after its causes have been thoroughly analyzed [49]. The authorities responsible for land management have to limit the negative effects of these factors on human life [56]. Therefore, conflict-generating factors need to be identified, eliminated, or minimized. However, such factors can be determined, and their conflict-generating potential can be evaluated only when these factors are unambiguously identified and described during the entire research process. Not all factors that increase the risk of spatial conflict are described; therefore, they are not listed in the databases that are accessible to analysts [57,58]. Undoubtedly, such factors can be described in individual cases for the needs of specific analyses [59]. However, this is a highly laborious process that is not always cost-effective. The identified factors also tend to have limited spatial coverage. Therefore, the use of the existing databases appears to be a much simpler and sensible solution [60].

Local space is usually described in considerable detail. Legal regulations and, increasingly often, market processes necessitate the creation of geospatial databases with different content and significance. Geospatial databases differ in the homogeneity, validity, and reliability of the accumulated information [61]. Databases developed by centers for geodetic and cartographic documentation appear to be the most robust sources of homogeneous, valid, and reliable data.

In view of the above, the main aim of this study was to develop a procedure for evaluating an area's vulnerability to land-use conflict based on the spatial attributes described by geodetic and cartographic databases and with the use of GIS tools.

2. Materials and Methods

2.1. Study Area and Data

For the needs of this study, the attributes of space that can potentially contribute to the risk of land-use conflict were identified based on an analysis of the existing databases and the relevant literature. Spatial attributes were selected for the study based on the extent to which they can be identified in space. The studied area was divided into comparative units for the needs of delimitation based on the results of the conducted analysis. Comparative units were created within the cadastral districts of the examined municipalities. This approach was adopted to ensure the cohesiveness of research stages, to minimize susceptibility to spatial conflict, and, potentially, to integrate the results with the findings of social studies [62]. Cadastral districts are often associated with settlement units (in particular in rural areas) or city districts, which implies that they can be linked with local communities. Therefore, the extent to which the characteristic traits of local communities contribute to the risk of spatial conflict can be analyzed in greater detail.

Spatial features that can contribute to the intensification of land-use conflicts were identified with the use of GIS data and based on a review of the literature [63,64]. The analyzed traits were selected based on the extent to which they can be identified and based on the results of a survey involving fifteen teams of real estate and spatial planning experts, including researchers and practitioners such as land surveyors and real estate agents. In each of the fifteen teams, the experts and the moderator (leading researcher) discussed the extent to which the identified attributes contribute to spatial conflict. The results of these discussions were used to prepare 15 questionnaires and determine the conflict-generating potential of each attribute. A questionnaire survey was conducted between 20 May and 25 September 2020 in organizations employing real estate and spatial planning experts. This approach was adopted due to the complex nature of the undertaken research. Direct communication with the experts generated valuable insights about the studied topic. The two-tiered survey procedure also enhanced the objectivity of the results.

The study area was the rural municipality of Purda in the Olsztyn county, Region of Warmia and Mazury in Poland. The Region of Warmia and Mazury has a rather unique settlement structure. The region abounds in natural resources, and agriculture has long been the main source of income for the local population [65]. The rapid development of Olsztyn county drives growth in the surrounding municipalities, including Purda. The Purda municipality has an area of more than 300 km^2, with a prevalence of agricultural land and forests. Due to local specificity and the proximity of a large urban center, Purda is susceptible to spatial conflict in both the social (progressive exploitation of natural resources resulting from local population growth) and the economic dimension (growing number of land development projects). The influx of new residents whose land-use preferences differ from those of the local population also drives conflict. These problems are typically encountered at the rural–urban interface. The location of Purda municipality is presented in Figure 2.

Purda is undergoing rapid urbanization, and it is an important source of land reserves for the spatial development of Olsztyn, the capital city of the Region of Warmia and Mazury. To facilitate a cohesive evaluation and classification of results, the municipality was divided into territorial units corresponding to cadastral districts. The availability of cohesive information regarding the intensity of the evaluated attributes in the analyzed units and the calculation of indices relating to every attribute played an important role in the selection process.

The analyzed municipality was divided into comparative units within the cadastral districts of Purda municipality. The aim of this procedure was to guarantee the consistency of the adopted measures for investigating possible triggers of land-use conflict and to consolidate our findings with research into social causes of conflict [66]. Cadastral districts are often equated with settlement units (in particular in rural areas) or city districts, which implies that they are closely linked to local communities [67]. The above assumption can be taken into account in spatial analyses to determine the extent to which the characteristic features of local communities can incite or exacerbate land-use conflict. The attributes were selected for analysis based on two considerations. The first consideration was the list of attributes that were identified by the surveyed experts. Each of the fifteen surveyed expert teams developed a list of attributes that could potentially contribute to spatial conflict. The second consideration was the extent to which the identified attributes could be measured with the use of the existing geospatial databases. Not all attributes can be evaluated in this approach. Databases characterizing local communities are not available. A total of 12 features that are described in the geospatial database were identified and assessed in 33 districts of Purda municipality.

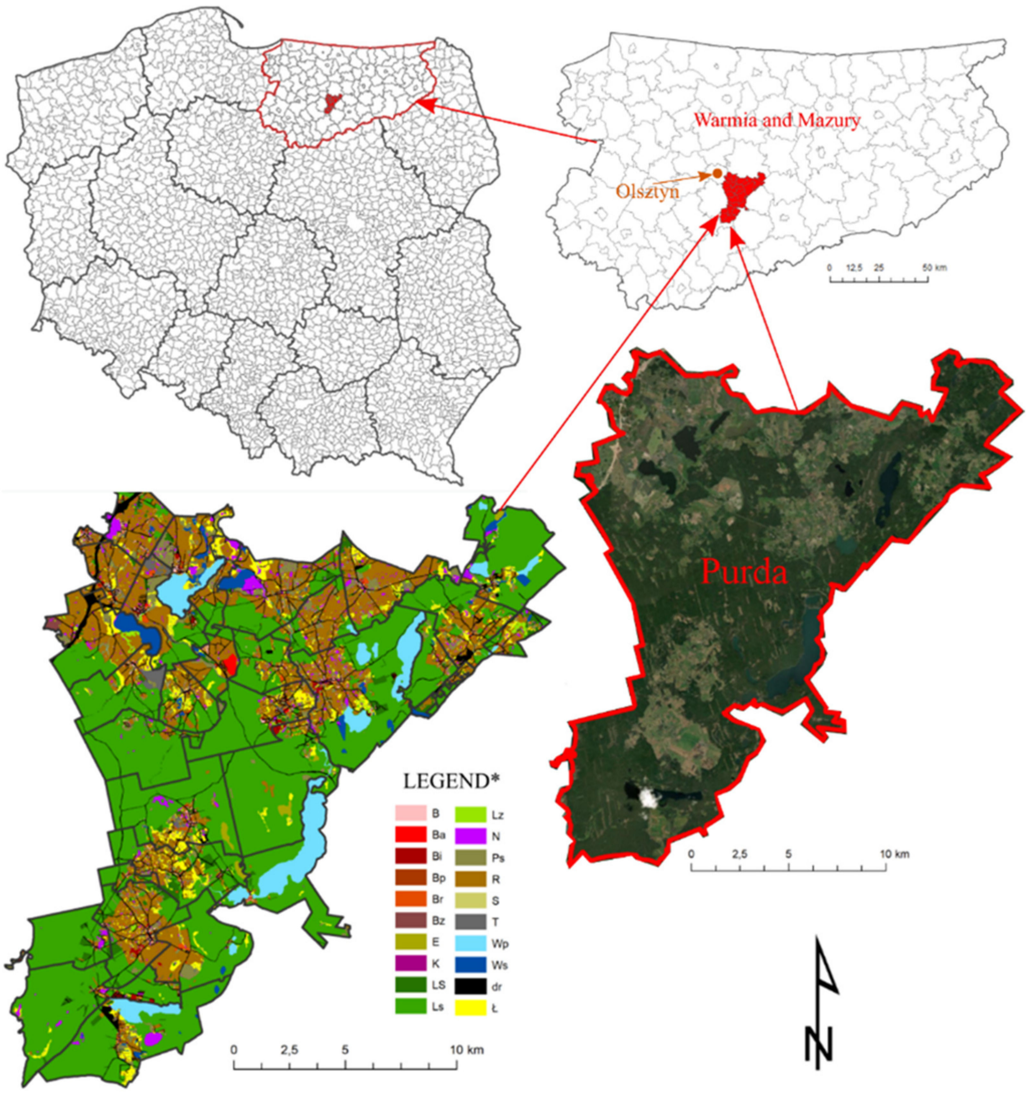

Figure 2. Location of Purda municipality and the local land-use pattern. * B—residential areas; Ba—industrial areas; Bi—other built-up areas; Bp—urbanized areas that are not built-up or are under construction; Br—developed agricultural land; Bz—recreational areas; E—ecological sites; K—mining sites; Ls—forests; Lz—areas with tree and shrub cover; N—fallow land; Ps—permanent pastures; R—arable land; S—orchards; T—transport routes; Wp—flowing waters; Ws—standing waters; dr—roads; and Ł—permanent meadows.

Most conflict-generating features have anthropogenic origin. Land-use conflicts can also be driven by factors that are not always associated with human activity, including topography and various types of land cover such as water bodies and forests. However, human activities exert a considerable influence on these attributes of space [68,69].

The significance of the identified spatial features was determined. The extent to which the analyzed attributes contribute to land-use conflict was described with the use of dedicated measures or indices [70]. These indices and the relevant measurement methods are described below:

Length of cadastral plot boundaries (**A.1**)—expressed by the ratio of the total length of all cadastral plot boundaries to the area of the cadastral district.

Complex boundaries (**A.2**)—expressed by the ratio of the number of boundary points in cadastral districts to the area of the cadastral district.

Area of cadastral plots (**A.3**)—expressed by the average area of a cadastral plot in a cadastral district.

Density of cadastral plots (**A.4**)—expressed by the ratio of the number of cadastral plots to the area of the cadastral district.

Development density (**A.5**)—expressed by the ratio of built-up areas in a cadastral district to the area of that district.

Land-use homogeneity (**A.6**)—expressed by the land-use homogeneity index SJ_i [71]:

$$SJ_i = \sum_{z=1}^{u} J_{iz}^2 \quad (1)$$

where: J_{iz} is the proportion of a given land-use type (z) in the total area of cadastral district i and u is the number of land-use types in cadastral district.

Technical infrastructure—the availability of technical infrastructure was evaluated in three categories: roads (**A.7**), power grid (**A.8**), and the water supply network (**A.9**). All networks and grids were evaluated with the same key. Cadastral districts were assessed based on the proportion of plots without access to each of the three types of infrastructure in the total number of plots in that district. The availability of roads was defined as the presence of a road in the plot's immediate vicinity, whereas the availability of the remaining infrastructure was defined as the presence of the relevant utilities at a distance of up to 100 m from the plot. The studied municipality was inventoried based on the above principles, and the results are presented in Figure 3.

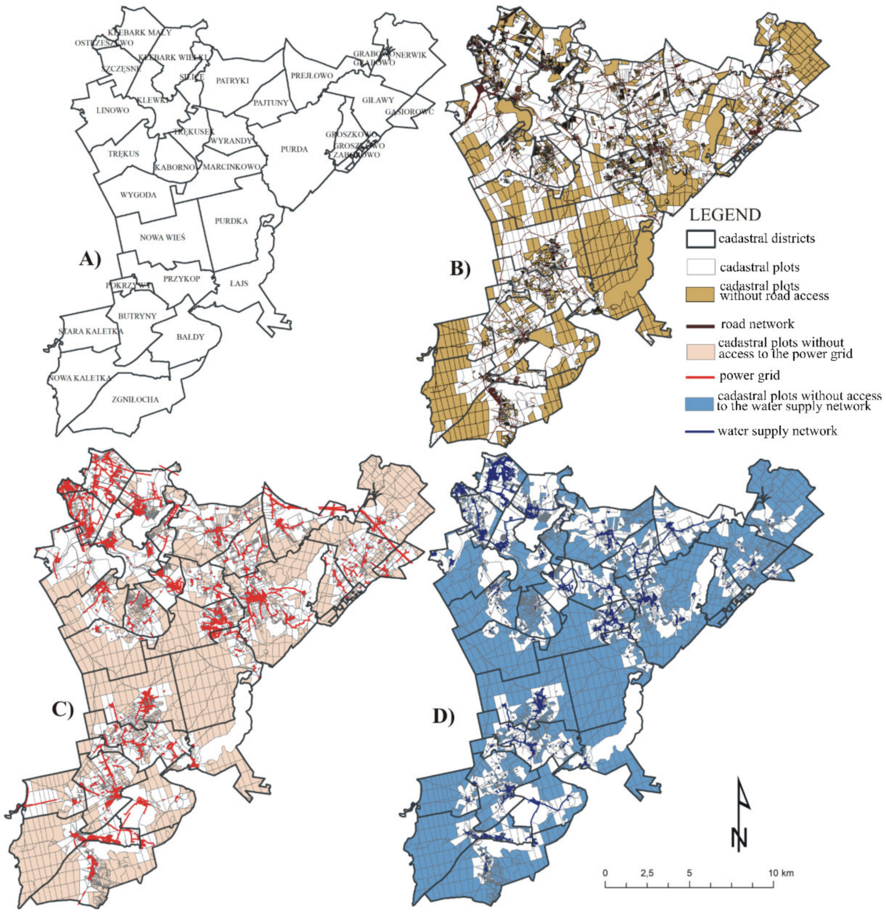

Figure 3. Division of Purda municipality into cadastral districts (**A**); Cadastral plots without access to: roads (**B**), power grid (**C**), and water supply network (**D**). Source: own elaboration based on data from the County Centre for Geodetic and Cartographic Documentation (PODGiK) data.

Topography (**E.1**)—topographic features were determined based on the maximum terrain curvature in the cadastral district. Terrain curvature was calculated based digital elevation model data from the Municipal Center for Geodetic and Cartographic Documentation. Digital elevation model data were interpolated (Figure 4A), and terrain curvature was determined at the nodes of a regular grid with a side length of 100 m. The results were used to calculate the range of curvature values in area K in the analyzed cadastral districts. The calculated values were used to evaluate conflict-generating attributes in these districts (Figure 4B).

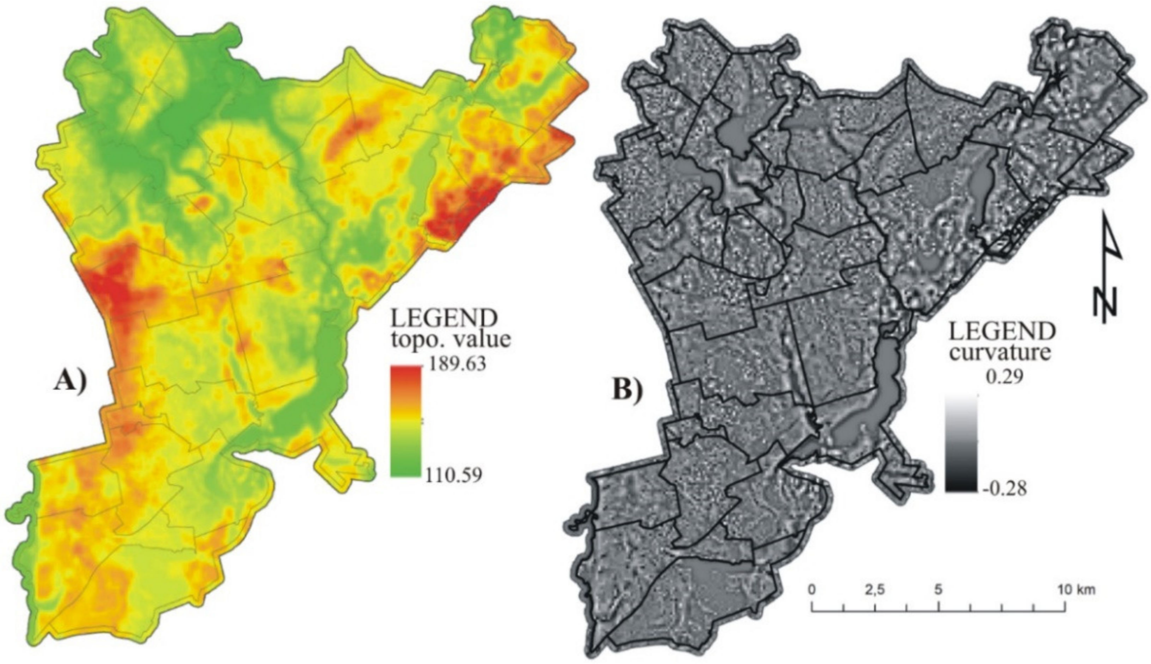

Figure 4. (**A**) Topography of Purda municipality; (**B**) Terrain curvature in Purda municipality. Source: own elaboration based on data from the Municipal Centre for Geodetic and Cartographic Documentation (GODGiK).

Boundaries of areas with natural land cover—this analysis included forests (**E.2**) and surface water bodies (**E.3**). This indicator was expressed by the ratio of the length of boundaries of forests and surface water bodies to the area of forests and water bodies in the analyzed cadastral district.

The results of the evaluation of conflict-generating attributes in the cadastral districts of Purda municipality are presented in Table 1.

2.2. Methodology

The identified attributes had a varied contribution to the risk of land-use conflict. These attributes were weighed to assess their importance. Shannon's entropy method [72] is widely used to determine the weights of various evaluation criteria. The concept of Shannon's entropy plays an important role in information theory, and it is regarded as a general measure of uncertainty. In transportation models, entropy is a measure of the dispersal of trips between the point of origin and the destination [73]. In physics, entropy represents the state of disorder of a system [74]. Entropy associated with an event is also a measure of the event's degree of randomness. The concept of entropy can also be used to measure fuzziness [75]. This method is relatively objective, and it can be effectively deployed in the decision-making process [76]. The entropy weight method is also widely used to determine the weights of criteria and attributes [77–80]. In the discussed method, relative importance is assigned to the analyzed attributes by measuring the existing differences between sets of data [81].

Table 1. Conflict-generating attributes in the cadastral districts of Purda municipality—matrix **M**.

		FEATURES *											
	District	**A.1**	**A.2**	**A.3**	**A.4**	**A.5**	**A.6**	**A.7**	**A.8.**	**A.9**	**E.1**	**E.2**	**E.3**
j	*i*	1	2	3	4	5	6	7	8.	9	10	11	12
1	Bałdy	63.11	0.73	8.21	0.12	13.89	0.99	0.31	0.34	0.31	0.35	21.80	41.78
2	Butryny	146.50	2.42	1.60	0.63	29.79	0.96	0.20	0.24	0.31	0.29	14.68	58.07
3	Gąsiorowo	161.52	2.46	1.69	0.59	22.18	0.99	0.34	0.23	0.58	0.38	29.47	123.32
4	Giławy	135.24	1.98	2.86	0.35	14.83	0.98	0.32	0.31	0.63	0.49	25.91	82.14
5	Grabowo	3362.40	12.23	0.27	1.88	0.00	1.00	0.17	1.00	1.00	0.05	912.47	0.00
6	Groszkowo	96.01	2.18	3.06	0.33	11.02	0.99	0.21	0.24	0.30	0.53	14.13	132.96
7	Kaborno	191.10	3.71	1.12	0.89	19.74	0.99	0.43	0.43	0.68	0.41	62.98	61.67
8	Klebark Mały	217.56	4.97	0.74	1.35	44.43	0.97	0.54	0.05	0.08	0.26	16.98	55.40
9	Klebark W.	157.61	2.80	1.23	0.81	32.52	0.37	0.43	0.19	0.28	0.31	41.09	7.81
10	Klewki	130.99	3.37	1.15	0.87	46.49	0.87	0.15	0.12	0.25	0.35	38.58	60.22
11	Łajs	67.10	0.99	6.52	0.15	5.22	0.83	0.75	0.36	0.40	0.48	19.10	37.07
12	Linowo	71.23	1.16	5.28	0.19	7.51	0.43	0.17	0.19	0.35	0.35	17.98	40.25
13	Marcinkowo	146.40	3.04	1.25	0.81	33.79	0.95	0.38	0.19	0.20	0.49	23.08	46.17
14	Nerwik	91.04	1.66	4.85	0.21	4.24	0.95	0.45	0.50	0.69	0.40	35.27	118.69
15	Nowa Kaletka	91.33	1.43	2.22	0.45	17.59	0.94	0.23	0.16	0.19	0.33	4.83	56.69
16	Nowa Wieś	117.55	1.78	2.35	0.43	22.06	0.88	0.32	0.30	0.34	0.36	16.83	53.10
17	Ostrzeszewo	508.80	14.56	0.22	4.57	270.18	0.96	0.40	0.02	0.02	0.18	33.02	3.96
18	Pajtuny	172.19	2.95	1.58	0.63	18.53	0.99	0.35	0.37	0.46	0.28	27.35	57.37
19	Patryki	146.83	2.56	1.85	0.54	19.67	0.92	0.33	0.29	0.37	0.37	37.51	55.72
20	Pokrzywy	135.96	1.66	3.07	0.33	21.29	1.00	0.18	0.20	0.23	0.23	0.00	81.95
21	Prejłowo	106.38	1.72	2.10	0.47	27.24	0.94	0.27	0.17	0.21	0.27	23.40	51.56
22	Przykop	141.55	2.38	1.73	0.58	19.08	0.93	0.27	0.20	0.32	0.31	23.78	79.78
23	Purda	121.11	2.52	1.86	0.54	21.25	0.85	0.30	0.19	0.30	0.56	27.82	87.01
24	Purdka	72.54	0.89	6.24	0.16	5.72	0.83	0.44	0.53	0.68	0.46	9.85	46.60
25	Silice	145.20	3.16	1.11	0.90	24.93	0.99	0.34	0.42	0.54	0.32	26.92	38.26
26	Stara Kaletka	91.56	1.13	4.55	0.22	7.63	1.00	0.32	0.34	0.51	0.27	0.79	60.25
27	Szczęsne	224.58	5.77	0.61	1.65	77.83	0.97	0.37	0.08	0.19	0.27	30.64	10.01
28	Trękus	135.05	2.04	2.18	0.46	16.09	0.87	0.43	0.30	0.44	0.34	15.59	60.23
29	Trękusek	163.54	2.82	1.22	0.82	124.92	0.38	0.42	0.23	0.28	0.34	14.83	50.59
30	Wygoda	75.35	0.86	6.60	0.15	5.40	0.99	0.25	0.53	0.67	0.40	1.08	48.84
31	Wyrandy	126.34	2.03	2.89	0.35	27.69	1.00	0.30	0.26	0.37	0.29	19.59	107.36
32	Zaborowo	203.20	2.75	2.53	0.40	12.87	1.00	0.13	0.34	0.40	0.40	33.13	74.21
33	Zgniłocha	110.37	1.51	2.50	0.40	9.68	0.95	0.31	0.49	0.53	0.32	37.06	45.52

* all attributes were measured with the use of the described procedure in the analyzed units.

The identified conflict-generating attributes were used to build decision matrix **M** (Table 1), which was normalized with the following equation:

$$n_{ij} = \frac{m_{ij}}{\sum_{i=1}^{k} m_{ij}} \tag{2}$$

where m_{ij} is the results of the evaluation of conflict-generating attributes; i is the successive districts in the total number of districts k; and j is the successive attributes in the total number of attributes z.

The normalized matrix **N** with elements n_{ij} was used to assign weights to conflict-generating attributes (Table 2).

Table 2. Elements of matrix **N** in the analyzed districts.

	DISTRICT	**A.1**	**A.2**	**A.3**	**A.4**	**A.5**	**A.6**	**A.7**	**A.8.**	**A.9**	**E.1**	**E.2**	**E.3**
j	*i*	1	2	3	4	5	6	7	8.	9	10	11	12
1	Bałdy	0.01	0.01	0.00	0.01	0.01	0.03	0.03	0.03	0.02	0.03	0.01	0.02
2	Butryny	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.01	0.03
3	Gąsiorowo	0.02	0.03	0.02	0.03	0.02	0.03	0.03	0.02	0.04	0.03	0.02	0.06
4	Giławy	0.02	0.02	0.01	0.02	0.01	0.03	0.03	0.03	0.05	0.04	0.02	0.04
5	Grabowo	0.42	0.12	0.15	0.08	0.00	0.03	0.02	0.10	0.08	0.00	0.55	0.00
6	Groszkowo	0.01	0.02	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.05	0.01	0.07
7	Kaborno	0.02	0.04	0.04	0.04	0.02	0.03	0.04	0.04	0.05	0.04	0.04	0.03

Table 2. *Cont.*

j \ i	DISTRICT	A.1	A.2	A.3	A.4	A.5	A.6	A.7	A.8.	A.9	E.1	E.2	E.3
		1	2	3	4	5	6	7	8.	9	10	11	12
8	Klebark Mały	0.03	0.05	0.05	0.06	0.04	0.03	0.05	0.00	0.01	0.02	0.01	0.03
9	Klebark W.	0.02	0.03	0.03	0.03	0.03	0.07	0.04	0.02	0.02	0.03	0.02	0.00
10	Klewki	0.02	0.03	0.03	0.04	0.04	0.03	0.01	0.01	0.02	0.03	0.02	0.03
11	Łajs	0.01	0.01	0.01	0.01	0.01	0.03	0.07	0.04	0.03	0.04	0.01	0.02
12	Linowo	0.01	0.01	0.01	0.01	0.01	0.06	0.02	0.02	0.03	0.03	0.01	0.02
13	Marcinkowo	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.04	0.01	0.02
14	Nerwik	0.01	0.02	0.01	0.01	0.00	0.03	0.04	0.05	0.05	0.03	0.02	0.06
15	Nowa Kaletka	0.01	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.01	0.03	0.00	0.03
16	Nowa Wieś	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.01	0.03
17	Ostrzeszewo	0.06	0.15	0.18	0.20	0.26	0.03	0.04	0.00	0.00	0.02	0.02	0.00
18	Pajtuny	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.04	0.04	0.02	0.02	0.03
19	Patryki	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.03
20	Pokrzywy	0.02	0.02	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.00	0.04
21	Prejłowo	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.03
22	Przykop	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.01	0.04
23	Purda	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.05	0.02	0.04
24	Purdka	0.01	0.01	0.01	0.01	0.01	0.03	0.04	0.05	0.05	0.04	0.01	0.02
25	Silice	0.02	0.03	0.04	0.04	0.02	0.03	0.03	0.04	0.04	0.03	0.02	0.02
26	Stara Kaletka	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.04	0.02	0.00	0.03
27	Szczęsne	0.03	0.06	0.07	0.07	0.08	0.03	0.03	0.01	0.01	0.02	0.02	0.01
28	Trękus	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.03	0.03	0.03	0.01	0.03
29	Trękusek	0.02	0.03	0.03	0.04	0.12	0.07	0.04	0.02	0.02	0.03	0.01	0.03
30	Wygoda	0.01	0.01	0.01	0.01	0.01	0.03	0.02	0.05	0.05	0.03	0.00	0.03
31	Wyrandy	0.02	0.02	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.06
32	Zaborowo	0.03	0.03	0.02	0.02	0.01	0.03	0.01	0.03	0.03	0.04	0.02	0.04
33	Zgniłocha	0.01	0.02	0.02	0.02	0.01	0.03	0.03	0.05	0.04	0.03	0.02	0.02

The information content of matrix **N** was determined by calculating the entropy value E_j of every conflict-generating attribute with the use of the below formula [82]:

$$E_j = -K \sum_{i=1}^{k} n_{ij} \ln n_{ij} \quad (3)$$

where i is the successive districts in the total number of districts k; j is the successive attributes in the total number of attributes r; and $K = 1/\ln k$ (for $k = 33$ $K = 0.29$) is the constant value which guarantees that the value of E falls within the range of [0;1] (Table 3).

Table 3. Value of E in the analyzed districts.

	DISTRICT	A.1	A.2	A.3	A.4	A.5	A.6	A.7	A.8.	A.9	E.1	E.2	E.3
	j	1	2	3	4	5	6	7	8	9	10	11	12
i		n_{ij} lnn_{ij}											
1	Bałdy	−0.04	−0.04	−0.03	−0.03	−0.06	−0.09	−0.10	−0.12	−0.09	−0.11	−0.06	−0.08
2	Butryny	−0.07	−0.09	−0.09	−0.10	−0.10	−0.10	−0.07	−0.09	−0.09	−0.09	−0.04	−0.11
3	Gąsiorowo	−0.08	−0.09	−0.09	−0.09	−0.08	−0.09	−0.11	−0.09	−0.14	−0.11	−0.07	−0.18
4	Giławy	−0.07	−0.08	−0.06	−0.06	−0.06	−0.09	−0.10	−0.11	−0.15	−0.14	−0.07	−0.13
5	Grabowo	−0.36	−0.26	−0.28	−0.20	0.00	−0.09	−0.06	−0.23	−0.20	−0.02	−0.33	0.00
6	Groszkowo	−0.05	−0.08	−0.06	−0.06	−0.05	−0.09	−0.08	−0.09	−0.09	−0.14	−0.04	−0.18
7	Kaborno	−0.09	−0.12	−0.12	−0.13	−0.08	−0.09	−0.13	−0.14	−0.15	−0.12	−0.12	−0.11
8	Klebark Mały	−0.10	−0.15	−0.16	−0.17	−0.14	−0.10	−0.15	−0.03	−0.03	−0.09	−0.05	−0.10
9	Klebark W.	−0.08	−0.10	−0.11	−0.12	−0.11	−0.18	−0.13	−0.08	−0.08	−0.10	−0.09	−0.02

Table 3. *Cont.*

	DISTRICT	A.1	A.2	A.3	A.4	A.5	A.6	A.7	A.8.	A.9	E.1	E.2	E.3
	j	1	2	3	4	5	6	7	8	9	10	11	12
i		$n_{ij}\ \ln n_{ij}$											
10	Klewki	−0.07	−0.12	−0.12	−0.12	−0.14	−0.10	−0.06	−0.05	−0.07	−0.11	−0.09	−0.11
11	Łajs	−0.04	−0.05	−0.03	−0.03	−0.03	−0.11	−0.18	−0.12	−0.11	−0.13	−0.05	−0.08
12	Linowo	−0.04	−0.05	−0.04	−0.04	−0.04	−0.17	−0.07	−0.08	−0.10	−0.11	−0.05	−0.08
13	Marcinkowo	−0.07	−0.11	−0.11	−0.12	−0.11	−0.10	−0.12	−0.08	−0.06	−0.14	−0.06	−0.09
14	Nerwik	−0.05	−0.07	−0.04	−0.04	−0.02	−0.10	−0.13	−0.15	−0.16	−0.12	−0.08	−0.17
15	Nowa Kaletka	−0.05	−0.06	−0.07	−0.08	−0.07	−0.10	−0.08	−0.07	−0.06	−0.10	−0.02	−0.10
16	Nowa Wieś	−0.06	−0.07	−0.07	−0.07	−0.08	−0.10	−0.10	−0.11	−0.09	−0.11	−0.05	−0.10
17	Ostrzeszewo	−0.18	−0.28	−0.31	−0.32	−0.35	−0.10	−0.12	−0.01	−0.01	−0.06	−0.08	−0.01
18	Pajtuny	−0.08	−0.11	−0.09	−0.10	−0.07	−0.09	−0.11	−0.12	−0.12	−0.09	−0.07	−0.10
19	Patryki	−0.07	−0.10	−0.08	−0.09	−0.08	−0.10	−0.11	−0.10	−0.10	−0.11	−0.09	−0.10
20	Pokrzywy	−0.07	−0.07	−0.06	−0.06	−0.08	−0.09	−0.07	−0.08	−0.07	−0.08	0.00	−0.13
21	Prejłowo	−0.06	−0.07	−0.08	−0.08	−0.10	−0.10	−0.09	−0.07	−0.07	−0.09	−0.06	−0.10
22	Przykop	−0.07	−0.09	−0.09	−0.09	−0.07	−0.10	−0.09	−0.08	−0.09	−0.10	−0.06	−0.13
23	Purda	−0.06	−0.09	−0.08	−0.09	−0.08	−0.10	−0.10	−0.08	−0.09	−0.15	−0.07	−0.14
24	Purdka	−0.04	−0.04	−0.03	−0.03	−0.03	−0.11	−0.13	−0.16	−0.15	−0.13	−0.03	−0.09
25	Silice	−0.07	−0.11	−0.12	−0.13	−0.09	−0.09	−0.11	−0.14	−0.13	−0.10	−0.07	−0.08
26	Stara Kaletka	−0.05	−0.05	−0.04	−0.04	−0.04	−0.09	−0.10	−0.12	−0.13	−0.09	0.00	−0.11
27	Szczęsne	−0.10	−0.17	−0.18	−0.19	−0.19	−0.10	−0.12	−0.04	−0.06	−0.09	−0.07	−0.03
28	Trękus	−0.07	−0.08	−0.07	−0.08	−0.06	−0.10	−0.13	−0.11	−0.11	−0.10	−0.04	−0.11
29	Trękusek	−0.08	−0.10	−0.11	−0.12	−0.26	−0.18	−0.13	−0.09	−0.08	−0.10	−0.04	−0.10
30	Wygoda	−0.04	−0.04	−0.03	−0.03	−0.03	−0.09	−0.09	−0.16	−0.15	−0.12	0.00	−0.09
31	Wyrandy	−0.07	−0.08	−0.06	−0.06	−0.10	−0.09	−0.10	−0.10	−0.10	−0.09	−0.05	−0.16
32	Zaborowo	−0.09	−0.10	−0.07	−0.07	−0.05	−0.09	−0.05	−0.12	−0.11	−0.12	−0.08	−0.13
33	Zgniłocha	−0.06	−0.06	−0.07	−0.07	−0.04	−0.10	−0.10	−0.15	−0.13	−0.10	−0.08	−0.09
	SUM	−2.61	−3.19	−3.03	−3.10	−2.88	−3.44	−3.43	−3.33	−3.36	−3.45	−2.16	−3.34
	$\boldsymbol{E_j}$	0.75	0.91	0.87	0.89	0.82	0.98	0.98	0.95	0.96	0.99	0.62	0.95

The differences in the value of n_{ij} relative to successive attributes were calculated with the following formula:

$$d_j = 1 - E_j \quad (4)$$

where j is the successive attributes in the total number of attributes r.

The result is the attribute vector $\boldsymbol{d_j}$.

$$\boldsymbol{d_j} = [0.25\ \ 0.09\ \ 0.13\ \ 0.11\ \ 0.18\ \ 0.02\ \ 0.02\ \ 0.05\ \ 0.04\ \ 0.01\ \ 0.38\ \ 0.05] \quad (5)$$

The value of d_j was used to determine the weights w_j of conflict-generating attributes with the use of the below formula:

$$w_j = \frac{d_j}{\sum_{j=1}^{r} d_j} \quad (6)$$

The result is the vector of attribute weights **W**.

$$\mathbf{W} = [0.19\ \ 0.07\ \ 0.10\ \ 0.08\ \ 0.13\ \ 0.01\ \ 0.01\ \ 0.04\ \ 0.03\ \ 0.01\ \ 0.29\ \ 0.03] \quad (7)$$

The normalized matrix **N** was multiplied by vector ***W*** to produce matrix **D**. The risk of land-use conflict in the analyzed districts was expressed by the sum of the rows of matrix **D**. The results were represented by indicator V_i for improved readability.

$$V_i = 100 \times \sum_{j=1}^{r} (n_{ij} w_j) \quad (8)$$

where i is the successive districts in the total number of districts k.

The value of indicator V_i can range from 0 to 100. Districts with higher values of V_i are characterized by a greater accumulation of attributes that can give rise to spatial conflict.

3. Results and Discussion

Indicator V_i was calculated for the analyzed districts, and the results are presented in Table 4. In Grabowo district, V_i considerably exceeded the average value for the examined districts (27.60). The above result could be attributed to the very small area of Grabowo relative to other districts, as well as the fact that other attributes in Grabowo also substantially exceeded the average value. Grabowo was thus eliminated from classification. Only districts where the value of V_i ranged from 0.00 to 10.00 were included in the classification.

Table 4. Value of V_i in the analyzed districts.

	DISTRICT	**A.1**	**A.2**	**A.3**	**A.4**	**A.5**	**A.6**	**A.7**	**A.8.**	**A.9**	**E.1**	**E.2**	**E.3**	**SUM**	V_i
	j	1	2	3	4	5	6	7	8.	9	10	11	12	$r = 12$	
i								$n_{ij}\ w_j$							
1	Bałdy	0.0015	0.0005	0.0005	0.0004	0.0018	0.0003	0.0004	0.0013	0.0007	0.0003	0.0038	0.0008	0.0123	1.23
2	Butryny	0.0035	0.0016	0.0025	0.0023	0.0039	0.0003	0.0003	0.0009	0.0007	0.0003	0.0026	0.0010	0.0198	1.98
3	Gąsiorowo	0.0039	0.0017	0.0024	0.0022	0.0029	0.0003	0.0004	0.0009	0.0013	0.0003	0.0051	0.0022	0.0235	2.35
4	Giławy	0.0033	0.0013	0.0014	0.0013	0.0019	0.0003	0.0004	0.0011	0.0014	0.0004	0.0045	0.0015	0.0189	1.89
5	Grabowo	0.0811	0.0082	0.0147	0.0069	0.0000	0.0003	0.0002	0.0037	0.0022	0.0000	0.1587	0.0000	0.2760	27.60
6	Groszkowo	0.0023	0.0015	0.0013	0.0012	0.0014	0.0003	0.0003	0.0009	0.0007	0.0005	0.0025	0.0024	0.0152	1.52
7	Kaborno	0.0046	0.0025	0.0036	0.0033	0.0026	0.0003	0.0006	0.0016	0.0015	0.0004	0.0110	0.0011	0.0329	3.29
8	Klebark M.	0.0052	0.0033	0.0054	0.0049	0.0058	0.0003	0.0007	0.0002	0.0002	0.0002	0.0030	0.0010	0.0302	3.02
9	Klebark W.	0.0038	0.0019	0.0032	0.0030	0.0042	0.0008	0.0006	0.0007	0.0006	0.0003	0.0071	0.0001	0.0263	2.63
10	Klewki	0.0032	0.0023	0.0035	0.0032	0.0060	0.0003	0.0002	0.0004	0.0005	0.0003	0.0067	0.0011	0.0277	2.77
11	Łajs	0.0016	0.0007	0.0006	0.0006	0.0007	0.0003	0.0010	0.0013	0.0009	0.0004	0.0033	0.0007	0.0121	1.21
12	Linowo	0.0017	0.0008	0.0008	0.0007	0.0010	0.0007	0.0002	0.0007	0.0008	0.0003	0.0031	0.0007	0.0114	1.14
13	Marcinkowo	0.0035	0.0020	0.0032	0.0030	0.0044	0.0003	0.0005	0.0007	0.0004	0.0004	0.0040	0.0008	0.0233	2.33
14	Nerwik	0.0022	0.0011	0.0008	0.0008	0.0005	0.0003	0.0006	0.0018	0.0015	0.0004	0.0061	0.0021	0.0183	1.83
15	Nowa Kal.	0.0022	0.0010	0.0018	0.0016	0.0023	0.0003	0.0003	0.0006	0.0004	0.0003	0.0008	0.0010	0.0127	1.27
16	Nowa Wieś	0.0028	0.0012	0.0017	0.0016	0.0029	0.0003	0.0004	0.0011	0.0007	0.0003	0.0029	0.0010	0.0169	1.69
17	Ostrzeszewo	0.0123	0.0098	0.0184	0.0167	0.0350	0.0003	0.0005	0.0001	0.0000	0.0002	0.0057	0.0001	0.0990	9.90
18	Pajtuny	0.0042	0.0020	0.0025	0.0023	0.0024	0.0003	0.0005	0.0014	0.0010	0.0003	0.0048	0.0010	0.0226	2.26
19	Patryki	0.0035	0.0017	0.0022	0.0020	0.0025	0.0003	0.0004	0.0011	0.0008	0.0003	0.0065	0.0010	0.0224	2.24
20	Pokrzywy	0.0033	0.0011	0.0013	0.0012	0.0028	0.0003	0.0002	0.0007	0.0005	0.0002	0.0000	0.0015	0.0131	1.31
21	Prejłowo	0.0026	0.0012	0.0019	0.0017	0.0035	0.0003	0.0004	0.0006	0.0005	0.0003	0.0041	0.0009	0.0179	1.79
22	Przykop	0.0034	0.0016	0.0023	0.0021	0.0025	0.0003	0.0004	0.0007	0.0007	0.0003	0.0041	0.0014	0.0198	1.98
23	Purda	0.0029	0.0017	0.0021	0.0020	0.0028	0.0003	0.0004	0.0007	0.0007	0.0005	0.0048	0.0016	0.0205	2.05
24	Purdka	0.0017	0.0006	0.0006	0.0006	0.0007	0.0003	0.0006	0.0019	0.0015	0.0004	0.0017	0.0008	0.0117	1.17
25	Silice	0.0035	0.0021	0.0036	0.0033	0.0032	0.0003	0.0005	0.0016	0.0012	0.0003	0.0047	0.0007	0.0249	2.49
26	Stara Kal..	0.0022	0.0008	0.0009	0.0008	0.0010	0.0003	0.0004	0.0013	0.0011	0.0003	0.0001	0.0011	0.0102	1.02
27	Szczęsne	0.0054	0.0039	0.0066	0.0060	0.0101	0.0003	0.0005	0.0003	0.0004	0.0002	0.0053	0.0002	0.0392	3.92
28	Trękus	0.0033	0.0014	0.0018	0.0017	0.0021	0.0003	0.0006	0.0011	0.0010	0.0003	0.0027	0.0011	0.0173	1.73
29	Trękusek	0.0039	0.0019	0.0033	0.0030	0.0162	0.0008	0.0006	0.0009	0.0006	0.0003	0.0026	0.0009	0.0349	3.49
30	Wygoda	0.0018	0.0006	0.0006	0.0006	0.0007	0.0003	0.0003	0.0020	0.0015	0.0004	0.0002	0.0009	0.0097	0.97
31	Wyrandy	0.0030	0.0014	0.0014	0.0013	0.0036	0.0003	0.0004	0.0010	0.0008	0.0003	0.0034	0.0019	0.0187	1.87
32	Zaborowo	0.0049	0.0018	0.0016	0.0015	0.0017	0.0003	0.0002	0.0013	0.0009	0.0004	0.0058	0.0013	0.0215	2.15
33	Zgniłocha	0.0027	0.0010	0.0016	0.0015	0.0013	0.0003	0.0004	0.0018	0.0011	0.0003	0.0064	0.0008	0.0192	1.92

Indicator V_i was used to determine the risk of land-use conflict in the analyzed cadastral districts. Classification results are presented in Figure 5.

The analyzed districts were divided into five classes with the use of the geometric interval classification method. Class 1, with the highest accumulation of conflict-generating attributes, comprised only one district, Ostrzeszewo, where V_i reached 9.90. Class 2, with a high accumulation of the analyzed attributes, contained districts subjected to considerable urbanization and human pressure. Classes 4 and 5, with the lowest accumulation of conflict-generating attributes, were composed of ecological sites (forests and water bodies) in their entirety or in most part. The analysis of land-use types in the Purda municipality indicates that the proposed method generates reliable results. The value of indicator V_i was markedly higher in areas subjected to considerable anthropogenic pressure.

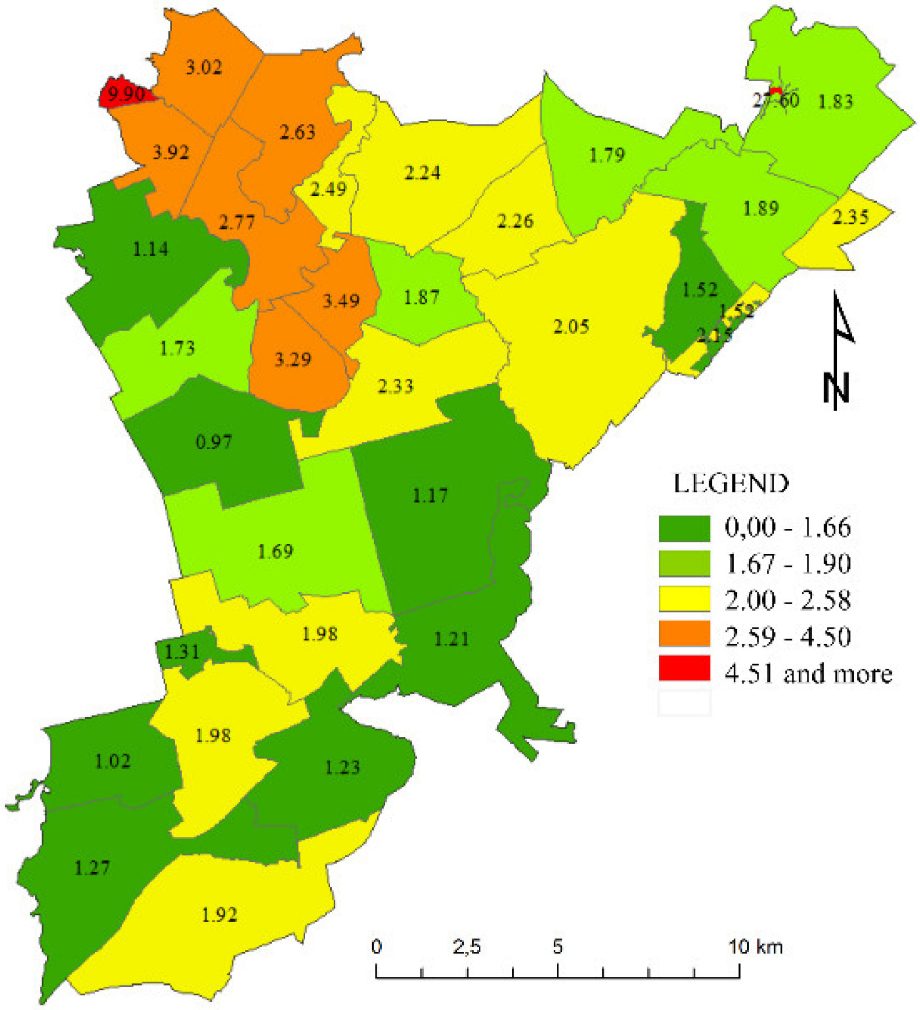

Figure 5. Values of indicator V_j in the cadastral districts of Purda municipality.

4. Conclusions

One of the greatest challenges in land management is to minimize the "pretexts" for spatial conflict. Conflict-generating factors should be eliminated or minimized in all stages of the process, including land-use planning, land protection, and land management. The aim of all land management procedures and decisions should be to improve land-use comfort. Therefore, the identification of potential hotbeds of conflict is a very important consideration that tends to be overlooked in research.

In this study, attempts were made to fill in this knowledge gap. The present research is by no means exhaustive, but the results indicate that geospatial databases can be used effectively to reduce the risk of spatial conflict.

This study proposes a procedure for evaluating the risk of land-use conflict based on the attributes that increase the probability of such risk. Conflict-generating attributes were calculated based on data that are available in municipal centers for geodetic and cartographic documentation. The analysis was conducted with the use of GIS tools in ArcGIS 10.4.1 software.

The proposed procedure was tested in a rural municipality with a varied spatial structure in the Region of Warmia and Mazury. The physical and geodetic attributes of space were identified in considerable detail at the local level. A procedure for weighing and measuring the intensity of attributes that can compromise spatial harmony and contribute to spatial conflict was proposed. The importance of conflict-generating attributes was assessed with Shannon's entropy method, and indicator V_i was calculated as the sum of attribute weights. The procedure of calculating indicator V_i involved well-known metrics as well as the measurement methods proposed by the authors. The results of the analysis indicate that anthropogenic factors are the main drivers of land-use conflict. Therefore, the developed procedure can be used to identify areas with a higher risk of land-use conflict. Conflict-prone areas should be identified based on analyses of cadastral data, local zoning plans and social participation to optimize spatial planning and improve the quality of life in local communities.

The results of the study demonstrated that the risk of land-use conflict is particularly high in the immediate vicinity of areas that are subjected to considerable anthropogenic pressure. Areas where human activities generate social controversy should be identified to promote sustainable land-use planning and prevent conflict.

The proposed procedure can be modified to account for specific research objectives, the characteristic features of the studied area, and access to spatial data. The developed methodology constitutes a valuable tool which supports planning and monitoring of sustainable land-use practices. The results of the analysis can be used to plan future actions with the aim of enhancing harmonious spatial development and minimizing the risk of land-use conflict.

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