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URBAN SPACE OPTIMIZATION – A CASE STUDY OF THE CITY OF BARTOSZYCE

Abstract: In the optimization process aimed at identifying the most effective solution while accounting for all existing constraints, the objective is to determine the optimal variant from a set of admissible alternatives. In the field of spatial management, the term "optimization" is employed to assess the most efficient – optimal – allocation and utilization of land. This assessment primarily pertains to the spatial distribution of economic entities and is frequently applied to urban areas and their surroundings. Moreover, it serves to coordinate human activities while safeguarding ecological structures and natural resources to achieve sustainable development.

This article presents a procedure for urban space optimization, which could be incorporated into the process of modifying land-use functions. The primary objective of the analysis is to determine a new, optimal land-use function by considering key social, economic, and environmental criteria that significantly influence urban space utilization. Additionally, the study introduces the concept of optimizing spatial processes, the methodology for identifying optimal land-use states, and the potential application of optimization methods, which are regarded as decision-support tools in spatial planning and management. Particular emphasis is placed on the use of Geographic Information System (GIS) tools as analytical instruments facilitating the optimization of spatial structures.

Keywords: spatial management, spatial planning, GIS, optimization of urban space.

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Introduction

The contemporary era is characterized by an exceptionally high level of human activity, whereby individuals continuously adapt their surrounding space to meet their needs. The rapid pace of urbanization, particularly in the vicinity of cities, generates a wide range of social, spatial, economic, and environmental challenges. Urbanization is one of the most visible manifestations of global change, inducing profound transformations in land-use structures. It is perceived as a process that accelerates urban development, increases urban population density and concentration, contributes to the expansion of urbanized areas, and enhances the role of cities as centers of business and administration (Gao & Bryan 2017; Sterling et al., 2013). The spatial configuration of urban land-use, which allows for diverse functions, is of fundamental importance in addressing the social, economic, environmental, and functional needs of the city. The conceptual division of land significantly influences the spatial structure of every urban area, and changes in land-use functions depend on the adopted approach. Frequently, public expectations regarding land-use transformation differ substantially from those of landowners seeking potential profits and from environmental protection perspectives (Ligmann-Zielinska et al., 2008; Yao et al., 2018).

Land-use changes exert a profound impact on the structure and functioning of cities, ecosystems, and, most importantly, human populations. With the intensification of human intervention and the growing consequences of spatial transformations, urban development and the associated challenges increasingly necessitate the optimization of urban space. Consequently, urban land-use optimization has become a crucial topic within various studies on sustainable development (Liu et al., 2022; Cotter et al., 2014).

Optimization is a process aimed at identifying the best possible solution for a given activity while considering all existing constraints (Broniewski & Suchorzewski, 1979). The goal is to determine the most optimal alternative from a set of feasible options (Tarnowski, 2011). According to the definition, optimal land use refers to the utilization of land that maximizes its value among all physically possible uses permitted by law, i.e., those compliant with its designated function (Kinzy, 1992). In the context of spatial management, the term "optimization" is employed to assess the most efficient (optimal) utilization of land. This evaluation primarily concerns the spatial distribution of economic entities and is frequently applied to urban areas and their surroundings (Bajerowski et al., 2003). Particularly in these areas, the optimization of land-use functions, as an initial phase of the decision-making process, requires the execution of numerous tasks aimed at minimizing spatial conflicts encountered during the study and analysis stages.

The essence of the optimization process lies in the assumption that, for any given spatial unit, at any given time, an optimal land-use state can be attained. However, the presence of specific characteristics and conditions within a given space does not inherently necessitate a change in land use. Instead, it should be recognized that the probability of transitioning from the current land-use state to an optimal state is at its highest when demand aligns with spatial attributes. Consequently, areas that exhibit suitable characteristics for a particular land-use function are prioritized, or modifications to existing attributes may be required to achieve an optimal state. Every land-use state is simultaneously a function of demand for a given type of spatial utilization (Bajerowski et al., 2003).

The optimization of spatial processes (spatial functions) aims to identify mismatched land-use functions and propose their replacement with functions better suited to the existing natural and anthropogenic characteristics, as well as to social, economic, and environmental needs. The adaptation of problematic areas – those generating so-called spatial conflicts – should be based on public opinion, reflecting current urban needs, a concept referred to as social optimization. Additionally, economic calculations, known as economic optimization, and environmental impact minimization, referred to as ecological optimization, should also be considered in this process (Biłozor, 2013; Biłozor & Renigier-Biłozor, 2015). The spatial optimization of land use is to adjust the rationality of the quantitative structure of the distribution of regional land resources and human social and economic activities and the spatial layout in accordance with the principles of population, resource, and environmental balance and economic, social, and ecological benefits. It is also to coordinate human activities and protect the ecological pattern and natural resources to achieve the sustainable development of the human-land system (Cao et al., 2019; Fang et al., 2018). This makes the spatial optimization of land use not only an important segment of global climate and environmental change research but also the core of various sustainable development studies (Liu et al., 2022; Gao et al., 2017; Turner et al., 1995).

This study presents an urban space optimization procedure that could be integrated into the process of modifying land-use functions. The primary objective of the analysis is to determine a new, optimal land-use function by incorporating various criteria – social, economic, and environmental – that significantly influence urban space utilization. The article introduces the concept of optimizing spatial processes, the methodology for determining optimal land-use states, and the potential application of optimization methods, which are regarded as decision-support tools in spatial planning and management. Additionally, the study outlines methods for formulating and solving problems related to selecting the most optimal land-use strategy, with a particular focus on leveraging Geographic Information System (GIS) tools as analytical instruments for optimizing spatial structures.

Material and methods

The optimization of spatial structures aims to assess land-use functions that are poorly aligned with existing needs and propose their replacement with new functions that better meet social, economic, and environmental demands. The adaptation of problematic areas – those generating spatial conflicts – should be based on residents' opinions, reflecting their current needs, a process referred to as social optimization. Additionally, it should incorporate economic optimization, which involves cost-benefit analysis, and ecological optimization, which focuses on minimizing environmental impact (Biłozor, 2013; Biłozor & Renigier-Biłozor, 2015). The land-use optimization procedure can be applied at various spatial scales and levels of analytical detail. The fundamental criterion guiding this optimization process is the objective function f(x), which includes:

– maximization of social expectations, where: $f(x) = x_{social} \rightarrow max$,
– maximization of economic revenue, where: $f(x) = x_{economic} \rightarrow max$,
– minimization of transformation costs, where: $f(x) = x_{cost} \rightarrow min$,
– maximization of ecological values, where: $f(x) = x_{ecological} \rightarrow max$ (Biłozor & Renigier-Biłozor, 2015).

Optimization is a process that seeks to identify the best possible solution that meets all constraints and requirements. In prior studies (Biłozor & Jędrzejowska, 2012; Biłozor, 2013, 2014), a land-use transformation algorithm was developed as an instrument for spatial optimization, facilitating informed decision-making regarding the use of a given area. This set of operations, designed to determine the most optimal land-use scenario, has been refined and adapted to the specific needs of spatial management. The decision-making procedure for selecting the optimal land-use function follows these key steps:

1. Spatial Monitoring – Identification of areas requiring functional transformation using GIS tools.
2. Determination of Social Conditions for Optimization – Development of methods for assessing public expectations regarding land-use changes and interpretation of collected data.
3. Definition of Economic Conditions for Land-Use Optimization – Analysis of land transformation in terms of functionality, costs, and revenue potential.
   3.1. Economic Revenue Optimization – Examination of local real estate market transaction prices, assessment of economic factors affecting land transformation, determination of an optimal function that maximizes profit, and evaluation of legal and technical feasibility.
   3.2. Economic Cost Optimization – Identification of natural and anthropogenic spatial attributes that determine the current land-use state, geoinformation analysis for spatial optimization, and identification of an optimal function using a feature matrix to establish optimal land use.
4. Definition of Ecological Conditions for Land Optimization – Assessment of environmental constraints and sustainability criteria.
5. Comprehensive Analysis of Social, Economic, and Environmental Determinants – Evaluation of the legitimacy of proposed land-use changes based on multi-criteria decision analysis.
6. Land-Use Optimization Process – Formulation and implementation of land-use decisions based on the integration of social, economic, and environmental assessments (Biłozor et al., 2014).

The criteria applied in the optimization process emphasize the necessity of ensuring that new land functions comply with established social, economic, and ecological conditions. Social optimization involves conducting surveys to assess public demand for land-use modifications in monitored areas. The survey research technique, commonly employed in social sciences, was utilized as it allows for the collection of a substantial amount of information on a given topic based on public opinion. Economic optimization focuses on evaluating potential revenues and transformation costs. Within this approach, revenue-driven economic optimization seeks to maximize profits. The objective of cost-driven economic optimization is to minimize the costs associated with land-use transformation while maximizing the potential of the site and its surrounding environment. To achieve this, a matrix of spatial function correlations was applied, linking urban space functions with land characteristics and existing infrastructure (Biłozor & Jędrzejowska, 2012). The matrix consists of 23 anthropogenic and 13 natural spatial attributes, for which positive and negative indicators were assigned. These indicators reflect the extent to which a given attribute influences the necessity of incorporating one of eleven selected urban space functions into the analyzed area (Table 5). The total score derived from the matrix columns represents the probability value, with a negative total indicating a probability equal to zero. The function from the matrix that achieves the highest probability is considered the optimal land-use function for the analyzed area, based on the existing spatial characteristics.

Ecological optimization, in turn, prioritizes the protection and conservation of the natural environment in its optimal state.

Each spatial unit is either in an optimal usage state or possesses the potential to reach such a state. However, any land-use transformation should be preceded by an assessment of its necessity and economic feasibility. In some cases, the difference between the value of land under an optimal future use scenario and its current use may be smaller than the associated transformation costs. The analysis and interpretation of spatial, economic, and social data serve as the foundation for implementing urban space optimization as a planning tool. This approach facilitates a deeper understanding of interdependencies within the spatial planning system, integrating insights from spatial management, economics, finance, governance, demography, and ecology.

Study area

The procedure for selecting the optimal land-use strategy was conducted in the city of Bartoszyce, located in the northern part of Poland, within the Warmian-Masurian Voivodeship. Bartoszyce is situated 17 km from the Russian border (Kaliningrad Oblast) and 71 km from the voivodeship's capital, Olsztyn. Cross-border traffic is facilitated through the Bezledy-Bagrationovsk road border crossing (Fig. 1). The city serves as a significant transportation hub for international transit. National Road No. 51, which runs through the city center, is one of the most critical transportation routes in the voivodeship. All transit traffic heading toward the border crossing passes through the city's internal road network. Additionally, Bartoszyce is intersected by two regional roads, No. 512 and No. 592. According to data from the municipal office, Bartoszyce covers an area of 11.79 km^2. The city has approximately 23,500 inhabitants and is the most economically developed urban center in the Bartoszyce County. The dominant land-use categories within the city are built-up and urbanized areas, which constitute 50% of the total land area, followed by agricultural land (35%) and forests (7%). Wooded and shrub-covered land, as well as water bodies, each occupy approximately 3% of the total area, while wasteland accounts for less than 1% (https://bartoszyce.pl).

Table 5. Matrix of correlations between urban space functions (land-use designation), land characteristics, and existing infrastructure

No.	Urban space function / Land feature	MN	MW	U	US	UC	P	ZP	ZC	WS	K	IT
1	Electricity	8	8	9	8	8	10	0	5	3	4	10
2	Telephone	7	7	6	4	8	7	-8	3	-7	0	8
3	Waterworks	9	8	9	7	9	9	3	6	3	2	9
4	Sewage system	7	8	6	3	5	9	-6	1	3	3	8
5	Gas	7	8	4	2	4	8	-8	-2	3	4	9
6	Easy access by road	7	7	8	2	6	7	1	5	4	6	4
7	Railway	-10	-10	-7	-10	6	9	-9	-5	-8	9	9
8	Piers, beach	-7	-7	-6	8	-9	-10	0	-10	7	-8	-8
9	Restaurants	3	4	7	2	3	-7	1	-6	1	6	-9
10	Swimming pools	-5	1	4	8	4	-3	-7	-9	-7	-4	-1
11	Multi-family blocks of flats	-7	10	-2	-6	5	-4	2	-9	-8	-3	-7
12	Single-family houses	10	-8	-3	-3	-3	-9	5	-8	-9	-6	-8
13	Public buildings	-3	1	8	-9	2	-4	4	-7	-8	0	-5
14	Clubs, pubs	-6	3	7	1	4	-4	-8	-7	3	2	-4
15	Historical monuments	-9	-10	-7	-9	-6	-5	8	3	-6	-7	-7
16	Neighborhood with same function	3	2	-8	-6	1	8	-9	3	2	-4	3
17	Access to education	4	5	2	-6	1	-2	-9	-7	-9	3	-1
18	Cinemas, theatres, cultural centers	-4	-3	6	-9	-5	-7	-7	-6	-8	3	1
19	Small floor space shops	4	4	10	3	-7	1	-4	2	-3	4	-1
20	Large format stores	-7	-5	1	-10	10	4	-10	-6	-9	9	5
21	Hard-surfaced roads	6	7	8	2	9	10	-3	9	-2	10	6
22	Cemeteries	-10	-10	-9	-10	-10	-10	2	10	-6	4	-2
23	Religious buildings	-1	3	-5	-3	-6	-2	4	9	-8	4	-6
24	Lake shorelines	-6	-10	-7	10	-9	-8	7	-9	10	-7	-8
25	Rivers and streams	-2	-7	1	4	-8	-4	3	-8	10	-6	-5
26	Canals and ditches	-10	-10	-10	-6	-4	1	-9	-1	7	5	4
27	Small standing waters	1	1	-5	6	-8	-4	4	1	6	-6	-7
28	Rows of trees	-4	-3	-6	-2	-1	-1	9	7	6	-6	1
29	Groups of trees, groves	1	-6	-9	6	-3	-1	7	3	6	-8	-1
30	Single trees	-2	-3	-3	4	-1	0	9	7	6	-6	3
31	Bush belts, hedges	3	3	5	-2	-1	0	10	7	6	3	2
32	Observation decks	-7	-8	-3	9	-8	-5	7	0	4	-7	-7
33	Southern exposure	5	4	-3	6	-5	-5	6	3	3	-10	-8
34	Western exposure	3	2	-4	5	-6	-5	3	3	3	-10	-4
35	No land slope	6	3	-3	-6	10	10	-3	6	-2	9	9
36	Small land slope	6	1	6	-3	5	7	5	7	4	8	8
Sum of positive points		100	100	100	100	100	100	100	100	100	100	100
Sum of negative points		-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Sum total		0	0	0	0	0	0	0	0	0	0	0

MN – areas of single-family residential development, MW – areas of multi-family residential development, U – areas of service development, US – areas of sports and recreation, UC – areas of commercial facilities, P – areas of production facilities, warehouses and storages, ZP – areas of arranged greenery, ZC – cemeteries, WS – areas of inland surface waters, K – areas of communication, IT – areas of technical infrastructure.

Source: Biłozor & Jędrzejowska, 2012

Fig. 1. Location of the city of Bartoszyce
Source: own elaboration

In the process of so-called "spatial monitoring," ten areas were identified where a change in land-use function is either possible or necessary. These areas are located in various parts of the city and are currently utilized inappropriately, leading to a range of spatial conflicts. The locations of the areas designated for optimization are presented in Fig. 2.

During the identification process, particular attention was given to determining whether a given area aligns with or significantly deviates from the land-use patterns of adjacent areas. Additionally, it was assessed whether the designated function of the land represents a typical urban use, such as agricultural areas or allotment gardens. A brief characterization of the selected areas is presented in Table 1.

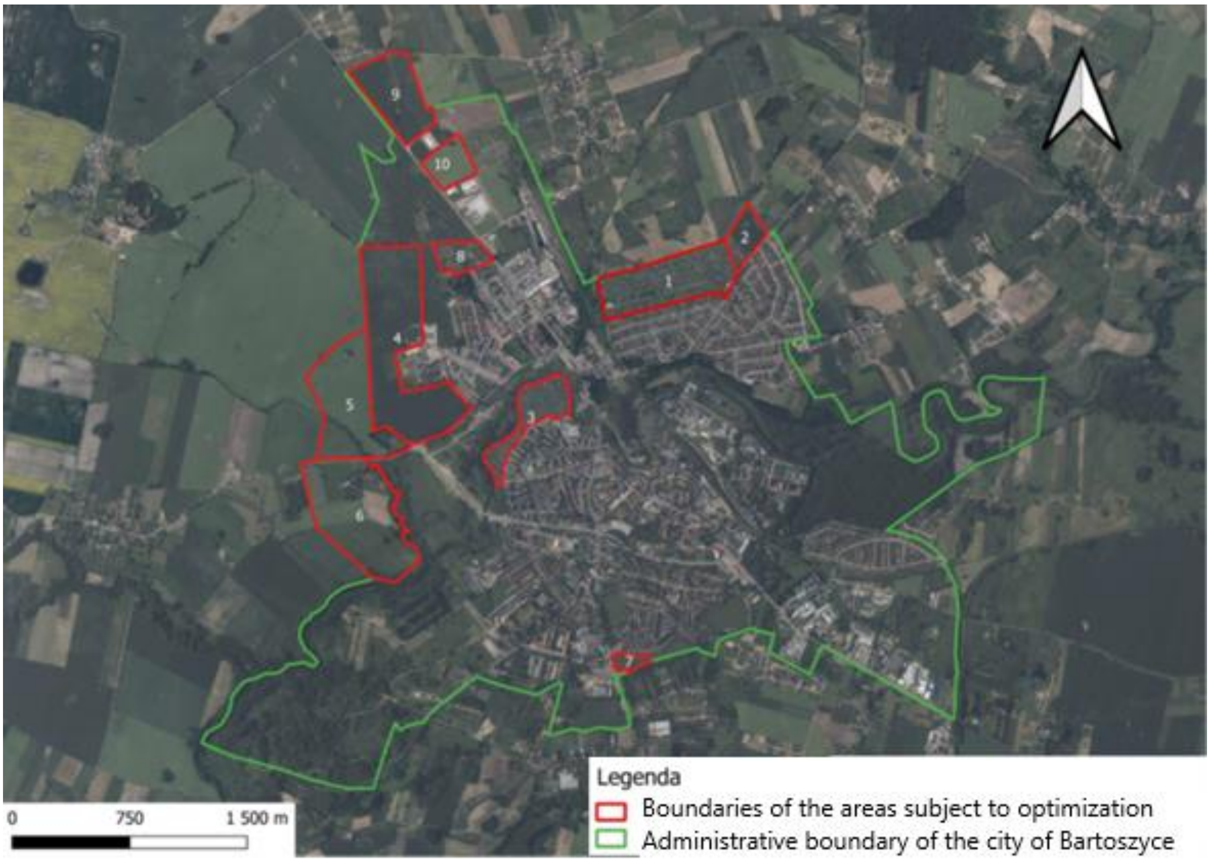

Fig. 2. Location of areas selected for the optimization process.
Source: own elaboration

Table 1. Characteristics of the areas selected for the optimization process

Area No.	Description of the area	Area boundaries
1	Area of 24.7690ha, located at the northeastern border of the city, use: allotment gardens.	
2	Area of 5.8378ha, located at the northeastern border of the city of Bartoszyce, use: agricultural land.	

3	An area of 11.3705ha, located in the central part of the city between the shoreline of the Lyna River and areas of multi-family housing, use: allotment gardens.	
4	An area of 45.8507ha, located at the western border of the city, use: agricultural land.	
5	Area of 28.4922ha, located at the western administrative border of the city, use: agricultural land.	
6	Area of 36.5952ha, located at the western border of Bartoszyce, use: homestead buildings, agricultural land.	
7	Area of 1.8643ha, located at the southern administrative border of the city, use: agricultural land.	

8	Area of 5.7285ha, located in the northern part of the city, use: allotment gardens.	
9	Area of 17.0789ha, located in the northern part of the city, use: agricultural land.	
10	Area of 6.8852ha, located in the northern part of the city, use: agricultural land.	

Source: own elaboration

Results and discussion

In the process of social optimization, primary emphasis was placed on residents' opinions and their proposals for the utilization of selected areas. The survey included responses from 134 residents, who were asked about the city's development directions, the functions that are currently lacking, and their optimal land-use preferences for the ten previously identified areas. According to the majority of respondents, the city of Bartoszyce is developing in a cultural and educational direction, promoted as the "City of Three Cultures" (32% of responses). The second most frequently indicated development path was investment-oriented growth (23% of responses), followed by sports and recreational development (18% of responses). The most desirable development directions, as indicated by respondents, were residential expansion (35% of responses), investment areas (31% of responses), and tourism (16% of responses). Bartoszyce faces a significant shortage of investment areas that could be designated for residential or industrial development. The subsequent ten questions in the survey addressed the proposed changes in land-use functions for the areas undergoing optimization.

Respondents were asked to indicate which of the proposed land-use functions would represent the optimal form of development for each location. The proposed functions for each area were selected to ensure minimal legal and spatial conflicts with the surrounding land uses. The aggregate results of the social optimization process are presented in Table 2.

Table 2. Social optimization – survey results summary

Area No.	1	2	3	4	5	6	7	8	9	10
Optimal Function	MN	MN	ZP	MN	MN	ZD	U	MN	P	P

Source: own elaboration

Economic optimization focuses on the most financially efficient utilization of urban space. This approach prioritizes maximizing municipal revenue while ensuring the optimal use of the spatial potential of designated areas.

Revenue-driven economic optimization aims to maximize the income generated by changing the function of a given area. Analyzing transaction prices of real estate traded in the local property market enables the determination of the optimal function that yields the highest possible financial return. Table 3 presents the average transaction prices obtained from the Municipal Office for selected property types that were subject to market transactions between 2021 and 2023.

Table 3. Revenue-driven economic optimization – summary of analysis results

Function	MN	MW	U	ZP	US	P
Transaction price PLN/m^2	78,70	81,05	129,00	24,38	56,20	74,03

Source: own elaboration

The most financially viable land-use functions for the city include service development areas, residential areas, and production facilities. Allocating these areas for the aforementioned functions would not only generate significant revenue for the city but also meet the needs of its residents. The results of the revenue-driven economic optimization, following an analysis of technical and legal feasibility, are presented in Table 4.

Table 4. Revenue-driven economic optimization – summary of analysis results

Area No.	1	2	3	4	5	6	7	8	9	10
Optimal Function	MW	U	MN	MW	U	P	U	U	P	P

Source: own elaboration

The geoinformation analysis, specifically the identification of anthropogenic and natural spatial attributes that define the current state of land-use and infrastructure, along with the application of GIS tools (Jażdżewska & Urbański, 2013; Bielecka, 2006), enabled the determination of the optimal land-use function for the ten selected areas. The summary results of the spatial attribute identification process are presented in Table 6.

Table 6. Result matrix of urban space functions for the ten analyzed areas

Area No.	Urban space function										
	MN	MW	U	US	UC	P	ZP	ZC	WS	K	IT
1	**43**	34	40	25	21	42	14	34	40	16	41
2	48	43	27	15	31	**51**	-22	25	15	11	46
3	**55**	38	41	39	28	50	27	43	49	10	45
4	**61**	50	12	29	34	56	-16	34	21	-3	50
5	**34**	20	-1	14	10	30	-1	25	29	0	21
6	16	3	-17	7	-2	22	30	**51**	48	-8	15
7	**61**	55	36	21	41	58	-16	31	15	10	53
8	**64**	54	42	31	44	58	16	54	29	13	58
9	53	49	28	15	45	**68**	-19	46	26	19	64
10	66	65	30	26	47	**67**	-23	40	13	15	53

Source: own elaboration

The results of the cost-driven economic optimization are presented in Table 7.

Table 7. Cost-driven economic optimization – summary of analysis results

Area No.	1	2	3	4	5	6	7	8	9	10
Optimal Function	MN	P	MN	MN	MN	ZC	MN	MN	P	P

Source: own elaboration

Ecological Optimization primarily focuses on environmental protection and the preservation of its original form. The ecological analysis was conducted using all available documents related to urban space and its environmental impact. The key documents subjected to detailed analysis included: Environmental Protection Program for the Municipality of Bartoszyce (https://bip.gmina-bartoszyce.pl), Development Strategy for the City of Bartoszyce (https://bip.gmina-bartoszyce.pl), Environmental Impact Assessment of the Development Strategy for the City of Bartoszyce (https://bip.gmina-bartoszyce.pl), Study of Conditions and Directions of Spatial Development for the City of Bartoszyce (https://bip.gmina-bartoszyce.pl), Current Local Spatial Development Plans (https://sip.bartoszyce.pl). The Environmental Protection Program for the Municipality of Bartoszyce stipulates that spatial planning within the city should comply with environmental protection principles, water management policies, and flood prevention measures based on eco-physiographic studies while integrating ecological aspects. According to the Environmental Impact Assessment and the City Development Strategy, Bartoszyce should prioritize expanding green spaces, protecting surface water areas, educating residents on environmental conservation, and reducing sources of low-emission pollution and noise. An analysis of current planning documents revealed that the designated areas are predominantly planned for residential, service, and industrial development. The optimal and environmentally acceptable solution within the ecological optimization process involves reallocating some land to: Organized green spaces, Allotment gardens (relocated away from high-density urban areas), Single-family residential areas with a maximum plot development ratio of 30%, as specified in local spatial development plans. Table 8 presents the proposed land-use allocations for each analyzed area, incorporating the principles of ecological optimization.

Table 8. Ecological optimization – summary of analysis results

Area No.	1	2	3	4	5	6	7	8	9	10
Optimal Function	MN/ZP	MN/ZP	ZP	MN/ZP	ZD	ZD	ZP	ZD	ZD	ZD

Source: own elaboration

In the city of Bartoszyce, areas were identified that, due to their current land-use, generate the highest levels of spatial conflicts. To assess the necessity and feasibility of changing specific land-use forms, these areas were analyzed from social, economic, and environmental perspectives. The results of these analyses aim to determine the most optimal and beneficial land-use allocations while considering the aforementioned aspects. By incorporating residents' opinions, economic considerations, and ecological factors, it is possible to infer which functions are most advantageous for the selected areas. The optimal function selection is based on the overlay method, in which the most favorable land-use scenario is derived from the product of individual optimization results. This method integrates the best attributes of each area, allowing for the selection of functions that maximize the spatial potential of the designated locations. Table 9 presents the final land-use designations for the selected areas, as determined through the social, economic, and ecological optimization processes.

Table 9. Optimal forms of development of the analyzed sites – summary of the results of the analysis

Area No.	Social Optimization	Revenue-Driven Economic Optimization	Cost-Driven Economic Optimization	Ecological Optimization	Optimal Land-Use Form
1	MN	MW	MN	MN/ZP	MN
2	MN	U	P	MN/ZP	MN
3	ZP	MN	MN	ZP	MN/ZP
4	MN	MW	MN	MN/ZP	MN
5	MN	U	MN	ZD	MN
6	ZD	P	ZC	ZD	ZD
7	U	U	MN	ZP	U
8	MN	U	MN	ZD	MN
9	P	P	P	ZD	P
10	P	P	P	ZD	P

Source: own elaboration

The urban space optimization process demonstrated that most areas should be designated for residential development (5 or 6 areas – Area No. 3 has two equally optimal land-use functions) and industrial development (2 areas), with one area each designated for service infrastructure, allotment gardens, and organized green spaces (Area No. 3 – equally optimal for MN).

Conclusions

The optimal utilization of space is influenced both by human activity and anthropogenic factors, as well as by random factors, since the development trajectory of a given space, planned based on its characteristics, can follow multiple distinct scenarios. At any given time, each spatial unit has the potential to reach an optimal land-use state and tends toward achieving this state. This implies that a specific configuration of spatial characteristics promotes the adoption of a particular land-use function, aiming for functional optimization, yet without necessarily mandating its implementation (Bajerowski et al., 2003).

The proposed urban space optimization procedure involves selecting the most advantageous land-use strategy within the city's administrative boundaries, taking into account social, economic, and environmental aspects. The procedure described in this study was applied to the city of Bartoszyce, a location characterized by diverse land-use patterns and a significant number of undeveloped or inappropriately utilized areas. Based on spatial monitoring, ten areas were identified – predominantly agricultural land and allotment gardens – that were subjected to the optimization process. The overlay method was employed to determine the optimal land-use scenario, where the final spatial allocation was derived from the combined results of individual optimization components.

After verifying the optimal land-use allocations, the analysis indicates that residential areas in Bartoszyce will expand by over 122 hectares, while industrial areas will increase by nearly 24 hectares. The largest reductions will occur in agricultural land (over 142 hectares) and allotment gardens (over 5 hectares). The transformation of the selected areas – particularly agricultural production zones and allotment gardens – is expected to have a positive impact on the city's social and economic development, including an increase in municipal revenue from property taxes. Moreover, the designation of these areas for residential, service, and industrial purposes may attract new investors and residents, facilitating faster urban development and ensuring the maximum utilization of spatial potential.

The optimization of spatial functions in Bartoszyce was aimed at identifying misaligned land-use functions and proposing transformations that better align with existing social, economic, and environmental needs. Despite its considerable development potential, the city of Bartoszyce has yet to fully capitalize on its spatial assets. The implementation of an optimization-based approach in spatial analysis can help eliminate conflict-prone areas while simultaneously providing strategic recommendations for urban development. The developed procedure, with clearly defined action steps, can also serve as a support mechanism for the urban management system, where the primary tool for spatial governance is the land-use transformation process.

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