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Section: Sustainable Urban Development

The correlations between natural and anthropogenic land–use patterns as a measure of sustainable regional development

Adam Senetra, Agnieszka Szczepańska, Monika Wasilewicz-Pszczółkowska

University of Warmia and Mazury in Olsztyn, Department of Planning and Spatial Engineering, ul. Prawocheńskiego 15, Olsztyn 10-724, Poland

Abstract

Warmia and Mazury is one of the five Polish regions to have been included in the "Development of Eastern Poland" Operational Program (PORPW) for 2007–2013. The PORPW is the only supra-regional program in the European Union that promotes social and economic growth in Poland's most undeveloped regions in accordance with the principles of sustainable development. Sustainable development means that economic growth should enhance the quality of the natural environment, in particular by protecting natural resources.
The economic growth of a region is inextricably linked with changes in land-use patterns, in particular the steady increase of anthropogenized areas. In line with sustainable development goals, areas with the most natural land cover should be entitled to special protection. The correlations between changes in land cover patterns could be a measure of progress towards sustainable development.
This paper investigates changes in the land cover of developed and urbanized areas (strongly anthropogenic territories), forests and protected areas (sites with the most natural land cover). A spatial analysis has been carried out in the Region of Warmia and Mazury at the level of municipalities, the lowest tier of administration in Poland. Changes in land cover patterns were investigated in 2007–2013, which is the time frame of the PORPW. The results of the analysis will be used to determine whether economic growth in the examined region fulfils sustainable development criteria.

Keywords: sustainable development; land use; forest; protected areas.

1. Introduction

In line with the European Union's strategy for sustainable development, "sustainable development is a fundamental and overearching objective of the European Union, aiming to continuously improve the quality of life and well-being for present and future generations, by linking economic development, protection of the environment and social justice" [1]. According to the provisions of Art. 5 of the Constitution of the Republic of Poland, Poland "initiates environmental protection measures in line with the principles of sustainable development". The Polish Environmental Protection Law defines sustainable development as "social and economic development that integrates political, economic and social measures by respecting the natural balance and the continuity of the key natural processes to meet the basic needs of communities and individuals in the present and future". Various definitions have been offered for sustainable development, and the concept continues to evolve and change over time [2]. The core concept of sustainable development comprises three key elements: social, economic and environmental [3].

The economic growth of spatial units is inextricably linked with changes in land-use patterns. Sustainable development implies a mode of economic growth that preserves the quality of the natural environment, in particular through the protection of natural resources. Its main goal is to maintain a healthy balance between land-use patterns in areas with the most natural land cover (including protected areas) and strongly anthropogenized areas.

The above considerations laid the groundwork for a working hypothesis that sustainable development takes place when an increase in the area of developed and urbanized land is accompanied by a proportional increase in the area of forests and protected areas. The objective of this study was to analyze the above correlations in the Region of Warmia and Mazury at the level of municipalities, the lowest tier of administration in Poland.

Corresponding author: Monika Wasilewicz-Pszczółkowska. E-mail address: monika.wasilewicz@uwm.edu.pl
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2. Indicators of sustainable development

Sustainable development is a process that can be evaluated. Garnåsjordet *et al*. [4] proposed three stages for assessing the pathway to sustainable development:
- choice of criteria associated with different understandings of sustainability,
- choice of narratives regarding sustainability, leading to different definitions of sustainable development indicators (SDIs) based on different attributes of performance,
- choice of how to quantify the chosen attributes in terms of quantitative variables.

Sustainable development indicators (SDIs) are the key element of the evaluation process. They were formulated to verify whether the present human activities pose a threat to the well-being of future generations [5]. Various indicators are applied at local, provincial, national and international level [6, 7]. They are multi-dimensional and multi-disciplinary because every aspect of sustainable development, including moral, environmental, technical, economic, legal, social and political, requires a different set of indicators [8]. Various classification systems have been proposed to account for the complex problem of sustainability, including the guidelines developed by the European Union, OECD and UNCSD [7, 9–11]. Sustainable development is evaluated with the use of the following indicators:
- SDI (*sustainable development indicators*) – a set of 128 sustainable development indicators, including 11 headline indicators, managed by Eurostat,
- CSI (*core set of indicators*) – a core set of 37 indicators formulated by the European Environmental Agency,
- CEI (*core environmental indicators*) and KEI (*key environmental indicators*) – a core set of 24 OECD indicators and 10 key indicators have been developed for assessments of OECD environmental strategies, environmental reviews of OECD member countries and other evaluations conducted by the OECD,
- ISD (*indicators of sustainable development*) – a set of 96 indicators of sustainable development, including 50 core indicators proposed by the United Nations Conference on Sustainable Development (UNCSD).

The components of sustainable development are generally evaluated by defining indicators for every key aspect of sustainability: environmental, economic and social [3, 4, 6, 12–17]. The key indicators will differ subject to the needs of the developing institutions, and they will be modified as living conditions change [18].

This study focuses on indicators of changes in land-use patterns in protected areas, which belong to the group of indicators describing the environment, including indicators of natural resources, indicatorsof security, indicators of protection, environmental indicators and indicators of changes in environmental quality.

Sustainable development indicators are applied in the following processes [6, 7, 11, 13, 19–22]:
- to formulate guidelines for sustainable development strategies and the relevant policies,
- to monitor the formulated and implemented sustainability strategies,
- to identify the consequences of sustainability strategies over time,
- to analyze environmental pressures, environmental conditions and trends,
- to analyze social and economic changes that affect the condition of the natural environment,
- to support decision-making at different tiers of administration (decision-making instrument),
- to support the development of useful technologies for governance; standardized indicators are imperative to an evidence-based, global system of governance,
- to identify change trends in various tiers of administration over time,
- to evaluate the effectiveness of implemented policies.

2.1. Sustainable development indicators in Poland

Poland has not formulated a unified system of sustainable development indicators. As a member of international organizations and a party to global environmental agreements, Poland is under obligation to develop and submit the required statistical data [9]. Several internal classification systems have been proposed, including the Report on the implementation of the national environmental policy for 2003–2006 [23] that groups the indicators of Poland's sustainable development according to the D-P-S-I-R model (driving forces – pressures – states – impacts – responses). The above indicators facilitate an extended analysis of environmental pressures and states by identifying driving forces responsible for major environmental pressures and responses to an environmental imbalance. The indicators of Poland's sustainable development proposed by the Central Statistical Office [24] group national SDIs into the following categories: social, economic, environmental, institutional and political, which correspond to different thematic areas of sustainable development. One of the themes in the environmental category are land-use patterns that are characterized by the following indicators:
- developed and urbanized areas (the surface of the Earth provides space and resources that meet human needs and contribute to economic growth; this indicator can be used to monitor activities aiming to limit permanent land development, in particular in areas of high natural and cultural value),
- devastated and degraded land (monitoring the level of land devastation and degradation across the country),
- forest cover (forests are an integral part of the natural environment, and they play important production and social roles).

3. Developed and urbanized areas, forests and protected sites in Poland

The Regulation of the Minister of Regional Development and Construction on land and building registers [25] defines the following land use categories: agricultural land, forests and land covered by trees and shrubs, developed and urbanized land, ecological sites, wasteland, water bodies and other land categories. This study analyses urban and developed areas that can be further broken down into the following categories: residential areas, industrial areas, other developed areas, undeveloped urban areas, recreational areas, mining areas and areas occupied by transportation networks (roads, railways, other transport corridors).

The Forest Act [26] defines forests as compact land with minimum area of 0.10 ha, covered by forest vegetation (forest crops) – trees, shrubs and groundcover plants. Forests can be temporarily devoid of vegetation, but they have to be intended for forest production or they have to be included in a nature protected area, a national park or a register of monuments. Forests also comprise land used for forest management activities (buildings, structures, forest roads, timber storage yards, etc.).

The most valuable elements of the natural environment are entitled to various types of legal protection. The forms of legal protection are prescribed by the Nature Protected Act of 16 April 2004 [27], and they include: national parks, nature reserves, landscape parks, protected landscape sites, Natura 2000 sites, natural monuments, geological formations, ecological sites, protected landscape complexes, protected plant, animal and fungal species. In most cases, legal protection is offered to entire areas, which is reflected in land-use patterns.

Landscape transformations are largely induced by human activities that significantly contribute to changes in land-use patterns. The most dynamic changes are noted in urban and suburban zones. In recent years, rapid transformations have also been observed in rural areas, leading to the expansion of strongly anthropogenized areas with residential, industrial, service and transport functions. Those processes are accompanied by a steady decrease in the share of sites with the most natural land cover, such as agricultural land and forests [28–33]. Poland has one of the highest levels of biodiversity in Europe, but this natural variety is threatened by the progress of civilization, including progressing urbanization, elimination of natural and semi-natural habitats and changes in land-use patterns [34]. The expansion of developed and urbanized land, the prime consequence of human intervention on the natural environment, poses the greatest threat for the environment. Positive effects of human activity include the steady expansion in the area of forests and protected areas in Poland since 1989. The rates of change in land-use patterns and forest area are influenced by afforestation programs in areas characterized by the lowest soil class. As part of the National Program for Increasing Forest Cover, forest cover is expected to increase to 30% by 2020 and 33% by 2050. A total of 680,000 hectares of land, including 550,000 hectares of privately-owned land, will be included in the afforestation scheme in 2001–2020 [35]. One of the main goals of sustainable development is to maintain adequate proportions between the share of urbanized land and forests.

4. Surveyed region

The Region of Warmia and Mazury is situated in eastern Poland (Fig. 1) which is characterized by lower levels of development than western regions of the country. Five regions from eastern Poland, including Warmia and Mazury, have been included in the “De/velopment of Eastern Poland” Operational Program for 2007–2013 (PORPW). The main objective of the program is to speed up social and economic development in Poland's most lagging regions in line with the principles of sustainable development.

The Region of Warmia and Mazury has the area of 24 173 km^2, it is inhabited by around 4% of the Polish population, and its population density is 59 persons per km^2 (the Polish average is 122 persons). The region is a popular tourist destination on account of its diverse landform, high share of forests and extensive water bodies that cover 6% of the region's territory [36]. Forest cover in the region is estimated at 30.9%, and it exceeds the national average (29.3%). The share of privately-owned forests is low in comparison with other Polish regions at only 7.4% (the national average is 17.7%). The local ownership structure supports sustainable forest management. Warmia and Mazury conducted the most extensive afforestation schemes in 2011 (1045.2 ha) and 2012 (878.7 ha) in the country, which testifies to the effectiveness of the National Afforestation Program [35]. Protected areas have the area of 1,129,458 ha, and they occupy more than 46% of the region's territory. The share of areas with natural land cover has been growing steadily in recent years.

5. Materials and Methods

Changes in the land-use patterns of developed and urbanized areas, forests and protected areas were analyzed based on data supplied by the Central Statistical Office and the Head Office of Geodesy and Cartography. The analyzed period was 2007 to 2013.

A digital map of the region was developed with a division into 116 municipalities as the principle research sites. Warmia and Mazury comprises 16 urban municipalities and 100 rural municipalities (Fig. 1).

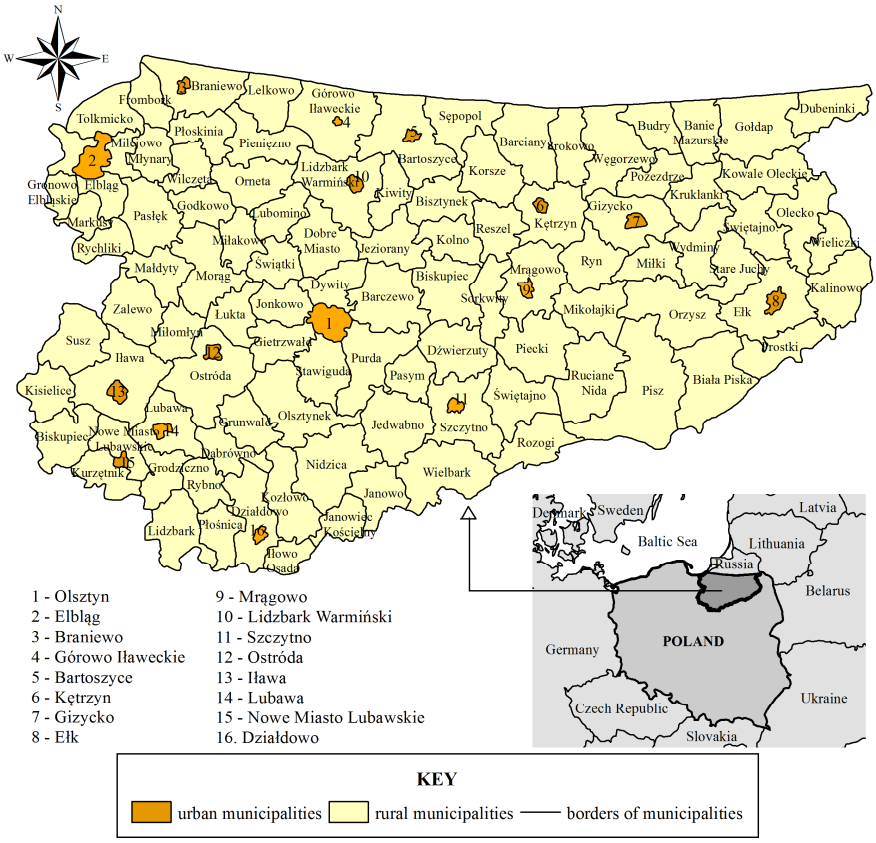

Fig. 1. Administrative division of the Region of Warmia and Mazury.
Source: own elaboration

The changes in the land-use patterns of developed and urbanized areas (strongly anthropogenic territories), forests and protected areas (sites with the most natural land cover) were analyzed. The changes in the evaluated land categories were compared to verify the working hypothesis that sustainable development takes place when an increase in the area of developed and urbanized land is accompanied by a proportional increase in the area of forests and protected areas. The analytical process was divided into the following stages:

- A database was developed for analyzing changes in the area of developed and urbanized land, forests and protected areas;
- Relative fixed-base percent changes in developed and urbanized land, forests and protected areas were calculated for the analyzed period (2007–2013);
- The values of relative fixed-base percent changes were referenced to the level of 100% (no change);
- A digital map of the Region of Warmia and Mazury divided into municipalities was developed with the use of ArcGIS 10 software;
- A spatial analysis of the rates of change in the area of the analyzed land categories was performed in the surveyed sites;
- The results of the analysis were presented in the form of cartograms;
- Indicators of municipal development were introduced as the quotient of the percent change in forest area and the percent change in the area of developed and urbanized land in the analyzed period (2007–2013) (formula 1):

$$w_{rg} = \frac{D_l}{D_{zz}} \tag{1}$$

where:

W_{rg} – indicator of municipal development,
D_l – percent change in forest area,
D_{zz} – percent change in the area of developed and urbanized land,
$W_{rg} = 1.0$ – sustainable development,
$W_{rg} > 1.0$ – environmentally-friendly development,
$W_{rg} < 1.0$ – expansive development.

A supplementary indicator was introduced in the form of relative fixed-base percent changes in protected areas, and it is marked with graphic symbols in the cartogram (Fig. 5). The above indicator has a supplementary character because protected areas and forests partially overlap.

6. Results

The rates of change in the area of developed and urbanized land in 2007–2013 are presented in Figure 2. The rates of change were below 100% in 29 municipalities, including 8 municipalities where they were determined at below 95%. The rates of change were determined above 100% in the largest group of 87 municipalities. The above results are indicative of high levels of economic growth in the analyzed region. A spatial distribution analysis revealed that municipalities characterized by similar parameters generally form large clusters where municipalities with different change rates are encountered on an individual basis.

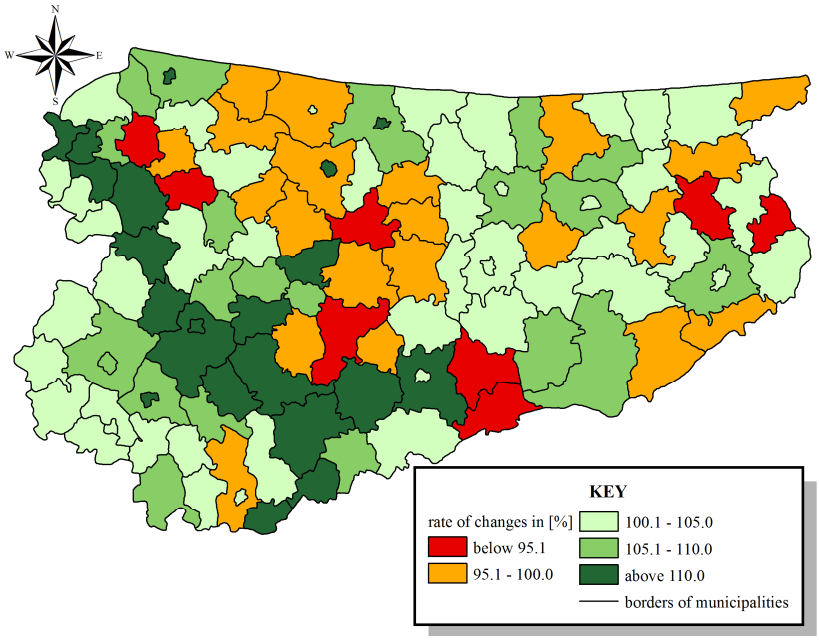

Fig. 2. The rates of change in the area of developed and urbanized land in the Region of Warmia and Mazury in 2007–2013. 2007 = 100%.
Source: own elaboration

The rates of change in the area of forests are presented in Figure 3. Negative rates of change were noted in 13 research units, mostly in the central part of the region and in urban municipalities. The change rate was below 95.1% in only one municipality (urban). The remaining municipalities were characterized by positive rates of change that were determined in the range of 100.1–105% in 71 municipalities. In this land category, a spatial distribution analysis also confirmed the presence of large consolidated areas with similar parameters. The rates of change in forest cover were relatively higher in the northern part of the region and in several municipalities in the eastern part of the region. In municipalities occupying south-western to south-eastern parts of the region, change rates were relatively low and remained similar in many neighboring municipalities. In general, urban municipalities were characterized by different rates of change in forest cover in comparison with the surrounding rural municipalities.

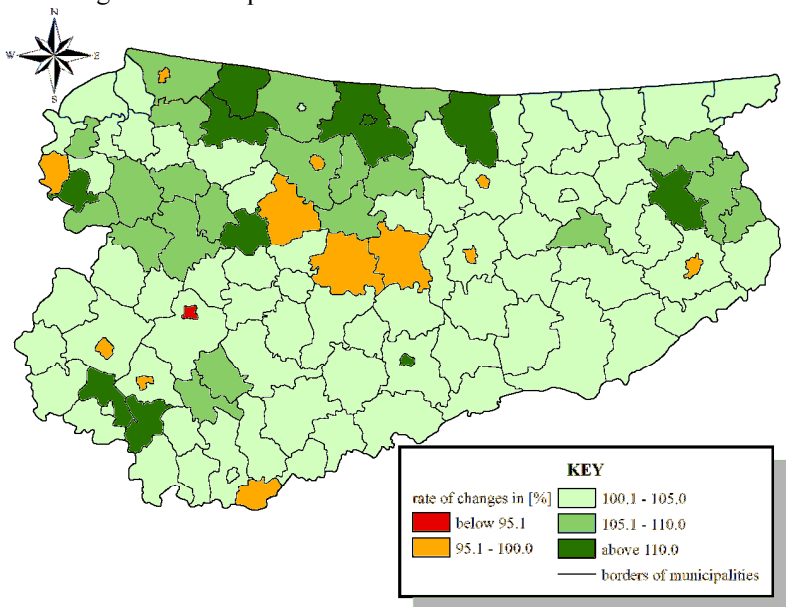

Fig. 3. The rates of change in forest cover in the Region of Warmia and Mazury in 2007–2013. 2002 = 100%.
Source: own elaboration

The rates of change in the area of protected areas in 2007–2013 are presented in Igure 4. The changes in the area of this land category were characterized by greater stability in the analyzed period, therefore, smaller variability intervals were applied to enable a more accurate evaluation of the observed processes. The area of protected areas was reduced in only five municipalities, whereas an increase was noted in 35 municipalities. In the analyzed period, the area of protected areas remained unchanged in 76 municipalities. A spatial distribution analysis produced a somewhat different pattern than that noted in the remaining land categories. Several municipalities are surrounded by areas with different change rates. Municipalities where the area of protected areas remained stable in the evaluated period formed the most dense clusters.

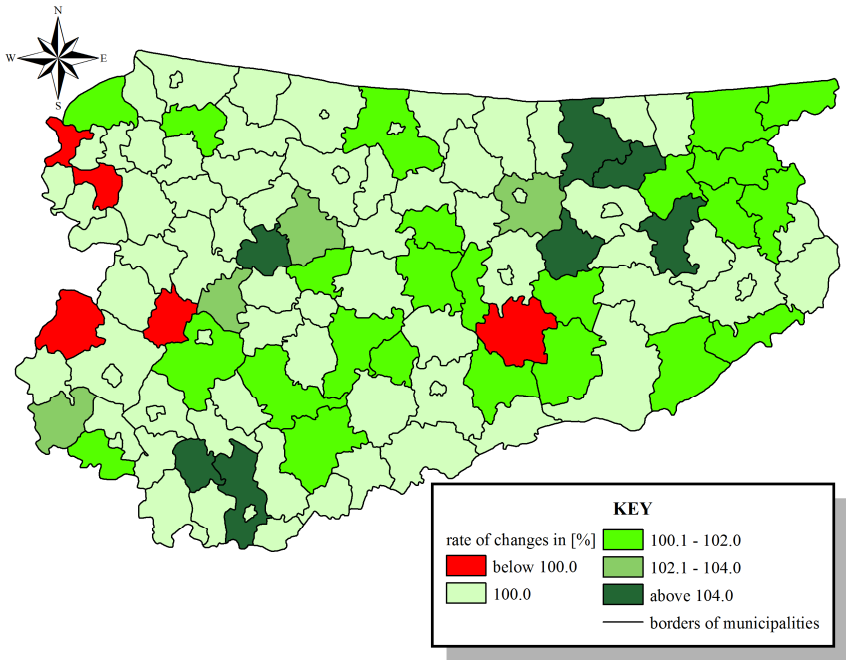

Fig. 4. The rates of change in the area of protected areas in the Region of Warmia and Mazury in 2007–2013. 2002 = 100%.
Source: own elaboration

The distribution of municipal development indicators, calculated as the quotient of the percent change in forest area and the percent change in the area of developed and urbanized land, is presented in Figure 5. The value of the indicator exceeded 1.0 in 50 municipalities, which is indicative of environmentally-friendly growth. Those municipalities are situated mainly in central and eastern parts of Warmia and Mazury, and they form a dense belt in the south-western part of the region. In 10 municipalities occupying mostly the central part of the region, the value of the indicator was equal to 1.0, which is indicative of sustainable development. The value of the indicator was determined below 1.0 in 56 municipalities, which suggests that economic interests take precedence over environmental concerns. Those municipalities are situated mostly in western and southern parts of the region, and they form a large and dense cluster of 14 municipalities near the region's eastern border.

A supplementary indicator illustrating the rates of change in protected areas is marked with graphic symbols (arrows) in Figure 5. The area of protected areas decreased in four municipalities. An increase was noted in 34 municipalities that form dense clusters, mostly in central and eastern parts of the Region of Warmia and Mazury.

7. Conclusions

The results of the analysis illustrate the rates of change in the area of developed and urbanized land, forests and protected areas in 2007–2013. The most dynamic changes were reported in developed and urbanized areas. The rates of change were both positive and negative across the analyzed municipalities, but positive change rates were noted in most municipalities (75%). The noted increase could be stimulated by the “Development of Eastern Poland” Operational Program. In the evaluated period, the area of the analyzed land categories increased in most municipalities, in particular in the period covered by the PORPW (2007–2013) and the associated projects targeting Eastern Poland, including the Regional Operational Program, Infrastructure and Environment Operational Program, Rural Development Program, Human Capital Operational Program and the Innovative Economy Operational Program. In addition to the traditional types of economic activity, agriculture and forestry, the analyzed region also has a thriving tourist industry, which contributes to an increase in the area of developed and urbanized land.

The trends observed in the Region of Warmia and Mazury are similar to the general change processes noted across Poland. In 2004–2009, the average annual rate of increase in the area of developed and urbanized land was determined at 1.01% [37].

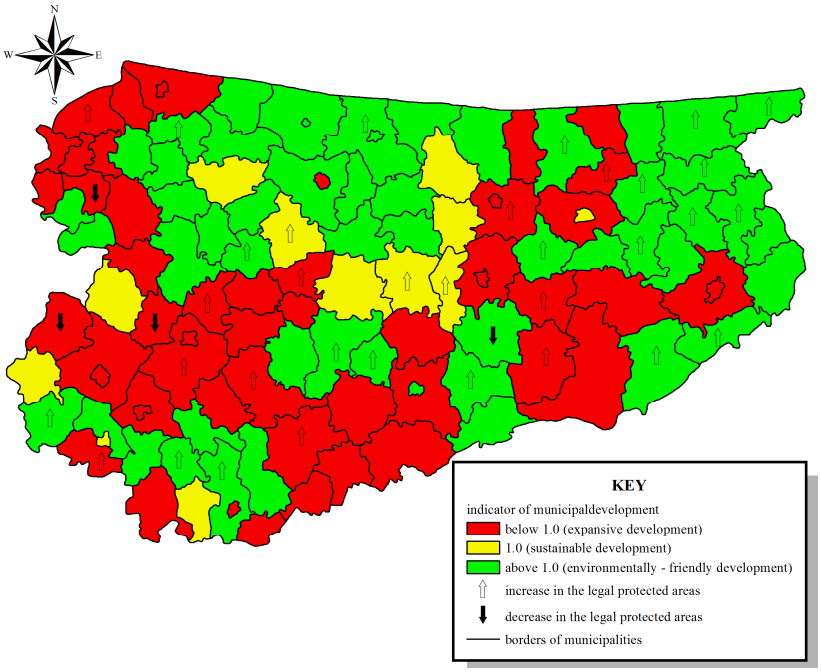

Fig. 5. The rates of change in the area of protected areas in 2007-2013. 2002 = 100%.
Source: own elaboration

Positive rates of change in forest cover were noted in more than 88% of the analyzed municipalities, which testifies to the effectiveness of the National Afforestation Program. Poland's accession to the European Union and the adoption of the Common Agricultural Policy (CAP) also contributed to the steady increase in forest cover. The CAP offers various afforestation financing mechanisms that have been incorporated in Measure 5 of the Rural Development Program for 2007–2013 – "Afforestation of agricultural land and other land" [38].

Forest cover can be increased by establishing legal mechanisms devoted to forest protection. The inclusion of forests in networks of legally protected areas can prevent the conversion of forest resources into alternative, non-forestry uses. Protected plans and documents implementing active protection measures can be introduced to increase the area of Polish forests. This goal can also be achieved by creating protective forest zones, including special bird protected areas and protected natural habitats [38]. The area of forests can be expanded by reclaiming degraded land and converting it into forests. Land reclamation through forest planting is one of the main trends in land improvement in Poland [39].

The least notable changes were reported in protected areas. The area of protected areas remained unchanged in 66% of the analyzed municipalities. There are no national parks in the Region of Warmia and Mazury. The area of sites entitled to the lowest level of legal protection (protected landscape complexes) continued to increase in the analyzed period. The minor changes observed in several municipalities resulted from shifts in the boundaries of protected areas due to the loss or inclusion of new protected resources. In some cases, such changes take place when forests are included in the Polish network of protected areas. The Natura 2000 ecological network of protected areas in the European Union also significantly contributes to an increase in the area of protected areas. Each year, new bird protected areas and special habitat protection zones are established as part of the Natura 2000 project.

The values of the municipal development indicator (W_{rg}) suggest that sustainable development targets have been achieved in 10 municipalities. Fifty municipalities were characterized by environmental-friendly development, whereas the growth of 56 municipalities was indicative of extensive development. Our results indicate that the Region of Warmia and Mazury has successfully entered the path towards sustainable development.

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