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# Spatial adequacy of afforestation in Poland: do afforestation needs and environmental preferences matter?

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**Abstract.** The article concerns the afforestation of agricultural land, especially soils of low quality classes with little suitability for agriculture. The assumption was made that in order to effectively implement afforestation and optimize spatial structures, these lands should be analyzed from the point of view of environmental and spatial conditions (including the quality of the land and its suitability for field crops, cohesion of the forest ecosystem, the presence of naturally valuable areas), according to the potential of a given area. Land that is ineffective in cultivation and does not improve the cohesion of the ecosystem should be treated as preferred for afforestation. The assessment of the spatial adequacy (optimization) of afforestation in the context of afforestation needs and predispositions was carried out for Poland in terms of municipalities using the spatial autocorrelation model and methods. The research results indicate the need to strengthen the effectiveness of solutions that take into account the endogenous potential of municipalities.

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## 1. Introduction

Forest policy is an integral part of the rural development policies of the future EU (European Commission, 1997; Kennedy et al., 1998). Both the EU and national governments emphasise the importance of forestry in diversifying rural development by reforesting and planting new forests on marginal land, including former agricultural land (Elands & Wiersum, 2001; Ashalós et al., 2017). In addition, a major challenge – one that is being increasingly emphasised – is posed by environmental and climate change issues and, consequently, by the question of how to put the EU on the track of the green transition towards attaining climate neutrality by 2050. In this connection, one of the priorities of the Union's environmental policy entails supporting afforestation, i.e. the establishment of forest plantations on non-forest land unsuitable for agricultural production, or on idle land. This gains particular importance in the light of the fact that, in recent decades, Europe has seen accelerated loss of forest cover due to the intensification of logging for economic purposes (*Note* 1). Meanwhile, the future and well-being of societies depend on healthy, biodiverse and resilient forests. The EU's *New Forest Strategy for 2030* (NFS, 2030; European Commission, 2021), which forms part of the European Green Deal (EGD) and builds on the *Biodiversity Strategy for 2030* (EC 2020), aims to boost afforestation and improve the health and resilience of forests as well as to exploit the potential of forests, which play an important role in the ecosystem. This will be undertaken by, inter alia, helping protect soil (mainly against erosion), reducing air pollution, participating in the hydrological cycle (e.g., through evapotranspiration in the field), and working for the climate (in particular through carbon storage and sequestration). Being habitats for numerous species, forests also help to halt the loss of habitats and species, as well as protect and restore biodiversity.

In order for the above strategic objectives to be attained, there is a need for intensified activities towards reconstructing and enlarging forest cover and protecting and restoring forest biodiversity. One means of achieving this is by letting forests regrow through natural succession. However, another option is to pursue active and sustainable afforestation, in particular on agricultural land of low valuation classes and former agricultural land. Afforestation of this type is an alternative to natural succession, which progresses slowly and is the most effective method of biological reclamation (Skłodowski, 2005; Węgorek, 2008; Wiśniewski & Wojtasik, 2012). It is also an effective way of mitigating climate change and produces socio-economic benefits, including new job creation. One barrier to the use of agricultural land for afforestation is the loss of income by farming families due to the exclusion of land from agricultural production (Łupiński, 2006). These concerns are of particular concern for small farmholders who become dependent on forests for their livelihoods. Pursuing a policy that takes into account both the needs of the natural environment and social considerations requires a compromise between agricultural producers (maximisation of earnings) and the public interest (care for the condition of the natural environment). This leads to the redefinition of agriculture: from a production-focused activity to one that entails holistic, sustainable and rational management of the natural resources considered to deserve special protection as public goods (Bateman & Balmford, 2018; Rudnicki et al., 2021). Given that afforestation offers low economic viability, farmers need financial incentives, which has prompted the EU to put in place an instrument to support the afforestation of agricultural land implemented under the *Rural Development Programme* (RDP). However, enhancing the efficiency of afforestation of agricultural land towards more sustainable (i.e., biodiversity-friendly) forest management requires the optimisation of the spatial structure of forests to correspond to local natural conditions. This in turn requires that environmental and economic priorities and afforestation preferences be identified for individual spatial units (regions, municipalities). In near-natural ecosystems (forests, grassland, wetlands), the sustainability and species composition of the plant cover are largely adapted to the habitat conditions, which ensures ecological efficiency. Therefore, not all areas can be considered preferable for afforestation. For instance, those with soils classed as of good value are not suitable. Their high suitability for crops requires a prudent approach when it comes to excluding them from agricultural production and using them for afforestation purposes. This is all the more pertinent given that the uncoordinated afforestation underway until the early 1990s entailed the creation of monocultural stands of pine, even in fertile environments, and has led to an incoherence of habitats and the prevalence of pine even in areas of fresh mixed deciduous forest and fresh broadleaved forest (Puchniarski, 2000; Wiśniewski, 2015). On the other hand, the cultivation of some soils (e.g., sands) that are naturally poor in nutrients and water is unreasonable and economically unviable from the perspective of the agricultural economy (Siuta, 2002). Poland makes excessive use of land with little

potential for crops (referred to as "marginal land") for agricultural purposes. Land that is inefficient for field cultivation should be designated for afforestation as the best way to manage it. Factors relevant for afforestation preferences also include the presence of areas that have a high natural value or are valuable for ecosystems but are greatly fragmented, which requires the creation of ecological corridors. A major problem is posed by the large spatial diversity and irregular distribution of forests as well as by their significant fragmentation and dispersion. Hence, in light of the implementation of the EU's environmental policy, it is important that afforestation be targeted at agricultural lands of low suitability for agriculture and that the ecological sustainability of forest complexes be enhanced by reducing their fragmentation and creating ecological corridors (Polna, 2006).

Given all the considerations relevant to afforestation referred to above and the need to optimise the structure of forest land use, research has been conducted to answer the question of how the spatial optimisation (spatial differentiation) of afforestation has been developing in the context of the natural conditions and potential of individual municipalities. The analysis comprises a long-term perspective and includes all afforestation completed in Poland in 2000–2020. This has enabled us to compare the afforestation measures taken and the afforestation needs as set out in the National Programme for the *Augmentation of Forest Cover* (Pol. *KPZL*), which is the main forest policy instrument in Poland, and to assess the optimisation of afforestation in terms of the natural conditions. The study has assumed that the overriding criterion for assessing the needs for afforestation of agricultural land should be the optimisation of the structure of land use in relation to natural factors, e.g. the quality of land and its suitability for field crops, the cohesion of the forest ecosystem, or the coexistence of environmentally valuable areas. In view of the above, land that yields poor crops and does not improve the cohesion of the ecosystem should be treated as preferred for afforestation.

## 2. Theoretical background

### 2.1. The problem of afforestation in the light of the literature

Recent years have seen an enhanced interest on the part of researchers in studying environmentally-friendly forms of spatial management (Biczkowski, 2018; Frueh-Mueller et al., 2018; Jezierska-Thöle et al., 2021; Wiśniewski et al., 2021; Rudnicki et al., 2023), including the afforestation of agricultural land and soils of low suitability for agricultural production (Wiśniewski & Wojtasik, 2012; Wójcik et al., 2014; Sulewski, 2018). This is related both to the growing interest in ecology, sustainable development and bioeconomy (Anderson, 2010; Birch, 2010; Hanley et al., 2012; Wood et al., 2015) and to the pace of changes in EU policies and associated funding schemes (European Commission, 2005, 2012, 2013). This has translated into a package of initiatives known as the European Green Deal (European Commission, 2019; Siddi, 2020), a key objective of which is to expand the area of forests, improve their condition and resilience and define, map, monitor and strictly protect ancient and old-growth woodland (Wiśniewski & Marks-Bielska, 2022). Afforestation is of interest to researchers representing a wide range of fields: economists, geographers, foresters, planners and lawyers. The spectrum of research in Poland is very wide and comprises analysis of afforestation in the context of environmental protection and natural conditions (Strzemski, 1961; Partyka, 1973; Siuta, 1974, 1996; Obmiński, 1977; Tałałaj, 2002; Żmija, 2014; Kaliszewski et al., 2016a), spatial planning and optimisation of spatial structures, including the National Programme for the Augmentation of Forest Cover (Maruszczak, 1950; Siuta et al., 1980; Łonkiewicz, 1996; Puchniarski, 2000; Kwiecień et al., 2002; Zając & Kwiecień, 2002; *KPZL*, 2003; Siuta & Żukowski, 2017), the rationalisation of agricultural land development (Strzelecki & Sobczak, 1972; Smykała, 1990; Michna, 1998; Gorzelak, 1999; Łukaszewicz & Mikułowski, 2002), economic factors (Fonder, 2002; Sulewski, 2018), rural development (Grzywacz, 2002), legislation (Act of … 1991, 2001), or the effects of afforestation co-funded by the EU under the RDP (Ogryzek, 2015; Polna, 2018; Klepacka, 2020; Wysocka-Fijorek et al., 2020). In addition, such research has significant practical importance for local government, farmers and landowners, especially given the availability of financial tools and incentives in support of afforestation. The growing interest in environmental forms of farming and managing environmental resources (Mijatovic et al., 2013; Bàrberi, 2015; Treasury, 2018) stems from the increasing importance of environmental issues in EU policies and the related increase in Common Agricultural Policy (CAP) funding dedicated to afforestation (Biczkowski, 2018). This induces changes in the management of agricultural areas in favour of more environmentally friendly methods (Kleijn & Sutherland, 2003; Kassioumis

et al., 2004; Schmidtner et al., 2012; Grajewski & Schmidt, 2015; Zimmermann & Britz, 2016). From the scientific point of view, this has created an interesting testing ground for quantitative and qualitative analyses of changes in the structure of land use towards increased importance of forests and their contribution to sustainable development (Yirenkyi-Boateng, 2001; Bowers, 2005), nature conservation and improvement of biodiversity (Gluck et al., 1999; Farrell et al., 2000; Nabuurs et al., 2001), improving the quality of the natural environment and the functioning of ecosystems (Kleijn & Sutherland, 2003; Kennedy & Koch, 2004; Giovanopoulou et al., 2011; Whittingham, 2011; Scheper et al., 2013; Lakner et al., 2020), which are carried out at various spatial scales and units. This makes it possible to assess the territorial rationality of spending from the organic farming fund in the light of the natural potential of the land and the existing environmental conditions (e.g., protected areas, quality of areas for agricultural production, marginal soils, contamination of soil with heavy metals, etc.; Cumming et al., 2006; Matzdorf et al., 2008; Pelosi et al., 2010).

The issue of afforestation fits in well with the concept of the green economy and the sustainable use of resources (Arbolino et al., 2017, 2018; Aldieri & Concetto, 2018; Jezierska-Thöle et al., 2021; Kowalska & Bieniek, 2022). The "greening" of development strategies and policies pertains to different levels of territorial division and various sectors of the economy and is one of the topics of discussion on how to model sustainable development on global, European, national and regional scales (Rudnicki et al., 2021; Jezierska-Thöle et al., 2021). As is assumed in the *NFS for 2030* (EC, 2021), it is considered that the promotion of the most biodiversity- and climate-friendly forest management practices proceeds in synergy with support for a strong and sustainable forest-based bioeconomy. Forests act as carbon sinks and reduce the impacts of climate change, for example by protecting against floods and mitigating the effects of droughts (Europa Bio, 2011; ETP, 2011). Land afforestation is one of the key components that implement the strategic environmental goals of the EU, which takes into account the economic and social importance of agriculture, including for the bioeconomy as a direction of development based on sustainable production (Birch, 2010; Hanley et al., 2012; Ratajczak, 2013; Wood et al., 2015; Jezierska-Thöle & Biczkowski, 2018; Früh-Müller et al., 2019).

The legal framework for afforestation has been defined by a number of national and EU documents. The *Forest Act of 28 September 1991* is the key legislative act that governs land afforestation in Poland. One particularly important provision is Article 58(3), which concerns, inter alia, the allocation of Forest Fund resources for the delivery of forest management tasks. The *KPZL*, with Afforestation Needs updates (the most recent one in 2014), is the leading instrument for rationalising the intensity and spatial distribution of afforestation. In the last dozen or so years, the situation of forests and nature protection in Poland has also been influenced by EU legislation, e.g. the *Birds and Habitats Directives*, which underlie the European network of Natura 2000 sites. In addition, there is the ecological network project known as ECONET, which is an extension of the programme towards creating ecological links between protected areas, in particular with a view to maintaining and expanding forest corridors.

The economic efficiency of a specific type of land use depends on multiple factors. Potentially fertile soils are preferred for agricultural use, with the use of poor-quality soils being marginalised. This implies that land with a low valuation class that is not suitable for growing crops is in need of solutions other than the traditional methods of management. Afforestation is one such method. According to the assumptions of the study, preference for afforestation in terms of the natural potential should be given to areas with low valuation classes of agricultural land (V, VI, VIZ), which are part of the NATURA 2000 network or of the ECONET network and form a cohesive forest ecosystem (ecological nodes, ecological corridors, buffer areas, reconstruction areas). The *KPZL* defines priority areas, with afforestation needs calculated separately for each municipality, which makes it possible for afforestation to be analysed and assessed at a high resolution (at municipality level).

### 2.2. Afforestation needs and preferences: natural potential for and optimisation of afforestation

Forests cover nearly 9.5 million hectares (ha), i.e. 29.6% of Poland's territory (Statistics Poland, 2021) (*Note* 2), which is lower than the European average (32.8%) and the EU average (38.7%) (*Note* 3). All of the country's neighbours except Ukraine have more forest cover: Belarus – 38.8%, Czech Republic – 34.7%, Lithuania – 35.1%, Germany – 32.7%, Slovakia – 41.9% (FAO, Global…, 2020). This is an important argument in favour of afforestation in Poland. In 1945–2001, 1,346,000 hectares of agricultural land and wasteland were

afforested in Poland, which translates into 23,600 hectares per year on average. At this point, it is worth emphasising one specific feature of Poland, namely the dominant share of state-owned forests, which cover 7.1 million ha.

The area of utilised agricultural land (UAA) in Poland is 14.6 million ha, (*Note* 4) i.e. 45.5% of the total area of the country. Light soils (valuation classes V, VI and VIZ) account for ~34.0% of the total UAA, (*Note* 5) of which soils of the poorest quality (VI and VIZ) cover 2.1 million ha (11.5% of UAA) (Skłodowski & Bielska, 2009; Biczkowski & Głaz, 2012; Roszkowska-Mądra 2020). A large proportion of the area of light soils is represented by marginal land (2.3 million ha – 12.4% of UAA), i.e. those that are used for agriculture, but, due to unfavourable natural conditions (low yield), should be reclassified to other forms of use, including afforestation (Biczkowski & Głaz, 2012). The average or sometimes low quality of soils in Poland (Skłodowski & Bielska, 2009) affects the productivity of agriculture and the value of areas for agricultural production. Hence, the afforestation of low-productivity farmland is of great economic and environmental significance (Źróbek-Różańska et al., 2014). The natural limitations to the development of agriculture are also evidenced by the fact that over 56% of UAA is classified as less-favoured areas (LFAs) (Czapiewski et al., 2008), i.e. such that need to receive CAP support as compensation for the difficulties in agricultural production. The supply of land preferred for afforestation and land that can be transferred from agriculture to forestry is estimated in various ways, with the estimates ranging from 1.5 to 4.5 million ha (Partyka, 1978; Michna, 1998; Siuta & Żukowski, 2017). This depends on the criteria adopted for the delimitation exercise, which comprise soil quality (supply of soils of the poorest valuation classes), as well as climatic, recreational and economic considerations (financial potential). Based on the analyses carried out in the *KPZL*, it is assumed that up to 1.5 million hectares of land are realistically available for such conversion. It follows from studies on afforestation needs that expansion of the forest cover is most needed in the following provinces: Wielkopolskie, Kujawsko-Pomorskie, Łódzkie, Mazowieckie, Podlaskie, Lubelskie and Świętokrzyskie (Liro, 1998; Michna, 1998; Siuta, 1996; Puchniarski, 2000).

Long-term studies (Obmiński, 1977; Partyka et al., 1981; Łonkiewicz, 1990; Siuta, 2002; Kwiecień et al., 2002) have found that, given the structure of land use and the topography of the environment, the optimal forest cover in Poland should be 33–34%. As a tool for rationalising the level and spatial structure of afforestation, the *KPZL* is working towards the creation of conditions for increasing the forest cover up to 33% by 2050, ensuring a rational spatio-temporal distribution of afforestation and categorising municipalities in terms of afforestation preferences as its main objectives. The afforestation needs and preferences of municipalities have been determined on the basis of 12 criteria (*Note* 6) – mainly environmental ones – which describe their applied ecological, hydrological and geomorphological functions determined through the summation of relative values. The sum ranges from 2.32 points (municipality with the lowest afforestation preferences) to 61.81 points (municipality with the highest preferences). Out of all municipalities, those with very high (over 20.0 points) and high (15.0–20.0 points) afforestation preferences have been distinguished. In this way, 944 municipalities (32.3% of the total number of units) with particularly high afforestation preferences have been identified. Their largest shares have been found for the following provinces: Lubelskie, Łódzkie, Kujawsko-Pomorskie, Małopolskie, Mazowieckie, Podlaskie, Świętokrzyskie, Warmińsko-Mazurskie and Wielkopolskie.

## 3. Research materials and methods

The study used data and information from numerous sources. A detailed methodology for assessing afforestation preferences and needs was developed on the basis of a set of indicators (Appendix A) developed by the Forest Research Institute (IBL) and adopted in the KPZL (Stage 1; Fig. 1). The information for the analyses developed at Stage 2 was mainly sourced from the Local Data Bank (LDB) of Statistics Poland, on the basis of which the dynamics of changes in the area of forest land (*Note* 7) and afforestation in the years 2000–2020 were assessed.

The research entailed assessing the spatial suitability or match (optimisation) of afforestation in the context of the natural conditions and potential of Polish municipalities. It was assumed that the optimisation of the structure of land use in relation to natural factors should be the overriding criterion for assessing the needs for afforestation of agricultural land. Given that determining the mechanism for modelling the spatial system of afforestation is of key importance for implementing

an environmental policy, the study was completed at two spatial resolutions:

- a local scale (graphical analysis) that comprised all municipalities in Poland (2,477 units – gminas),
- a regional scale (tables) that comprised the 16 Polish provinces – voivodeships (regions).

The achievement of the study objective required the development of a multi-stage research procedure, the compilation of reference materials, and the use of a wide set of research methods (see Fig. 1).

In order to rationally assess the need to allocate agricultural land for afforestation, the criteria to be used were based on factors involving natural, agricultural and environmental-protection-related factors, which were used to construct the afforestation preference index (API). In the first stage of the research, use was made of the categorisation (ranking) of municipalities on the basis of their afforestation preferences developed by the Forest Research Institute (FRI). The ranking was developed in 2000/01 as part of a revision of the KPZL. The revised KPZL employs a multi-criterion method of evaluating these preferences based on a set of twelve diagnostic features aggregated for each municipality (Appendix A). The second stage of the study involved the identification of the level of afforestation. For this purpose, the study constructed an index capturing the share of the area afforested in 2000–2020 in the total area of the administrative unit concerned. The above indexes (API and level of afforestation) were given in the form of normalised values (*Note* 8)(Racine & Reymond, 1977), which enabled an objective comparative analysis of the indexes to be conducted. Based on the normalised values, the municipalities were divided into classes in which each index value was deemed to be low (below –0.50δ), medium (±0.50δ) and high (above 0.50δ). Pearson's linear correlation coefficient (r) was used to assess the strength and direction of the relationship between the current spatial targeting of afforestation and the afforestation needs and preferences of the individual territorial units. In the last (third) stage of the assessment, the results of the previous stages were compiled and compared (aggregated into three groups to which individual

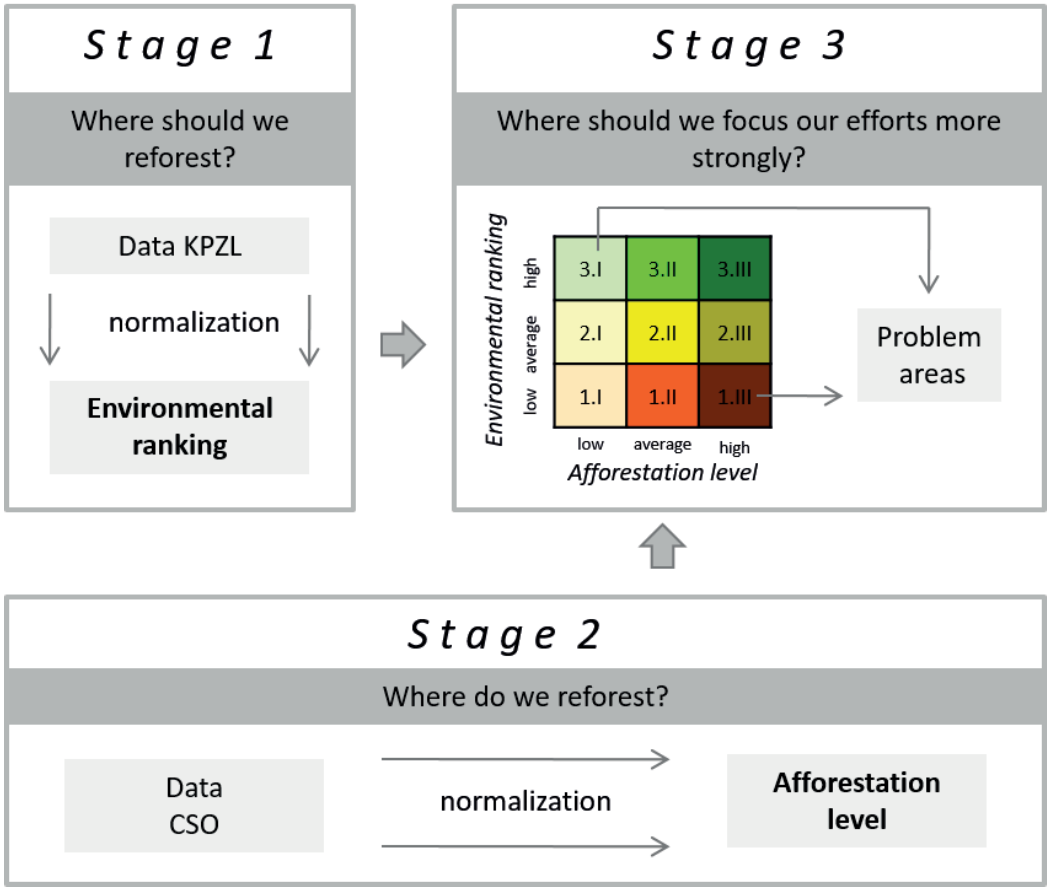


**Fig. 1.** Research procedure employed
Source: own study

units were assigned). The comparative analysis of the spatial systems identified was completed on the basis of the possible variants of combinations of both sets of compiled data ($3^2$), which resulted in the identification of nine types of municipalities (Fig. 1), including problem areas.

In addition, the analysis used Getis–Ord Gi statistics (Getis & Ord, 1992a, 1992b; Ord & Getis, 1995) to identify hotspots in terms of afforestation preferences and needs. The results reveal where features with high or low values form spatial clusters, with each feature analysed in the context of adjacent features. A function with a high value is interesting but may not be a statistically significant hotspot. In order for it to be a statistically significant hotspot, a feature will have a high value and will be surrounded by other features with high values (*Note* 9). The Hot Spot Analysis tool (ArcGIS 10.3) was used in the analyses.

## 4. Research results

### 4.1. Spatial differentiation and change of forest area in Poland

The area of forest land in Poland is nearly 9.5 million ha (2020; Table 1). Forest areas differ considerably from one region to another, ranging from 258,000 ha in Opolskie Province to ~845,000 ha in Mazowieckie and Zachodniopomorskie Provinces. As regards municipalities, absence of forest land has been found for 11 urban municipalities (mainly in the Kujawsko-Pomorskie Province – Chełmża, Inowrocław, Kowal). By contrast, record-high acreages have been identified for five municipalities: Borne Sulinowo (30,900 ha) and Kalisz Pomorski (30,900 ha) in Zachodniopomorskie Province, Płaska (31,800 ha) in Podlasie, Osiecznica (37,700 ha) in Dolnośląskie and Lutowiska (39,400 ha) in Podkarpackie. In 2000–2020, Poland gained 404,800 ha of forest land, from ~5,000 ha in Opolskie and Małopolskie to ~55,000–56,000 ha in Mazowieckie and Warmińsko-Mazurskie, respectively (Table 1). In terms of the share of forest land in the total area, forests – as a form of land use – dominate in Lubuskie Province, where they cover more than half (50.8%) of the region's entire area. By contrast, there is a very low share of forest in the provinces of central Poland: Łódzkie (21.8%), Mazowieckie (23.8%), Kujawsko-Pomorskie (24.1%) and Lubelskie (23.7%) in the east of the country (Fig. 2); in all four of these, forests cover less than a quarter of the total territory.

Changes in the area of forest land in the years 2000–20 show that the share of forests increased in most municipalities (Fig. 3). A decrease was seen by 385 municipalities (15.5%) scattered all over the country, but mainly in the central and southern parts. In most units, these changes were not significant. A decrease of more than 10% was observed in 92 municipalities. The remaining 2,092 municipalities (84.5%) saw an increase in the area of

**Table 1**. Forest land in Poland – selected elements of the spatial analysis (2000-2020)

| Description | The area of forest land | | | Forest cover 2020 [%] - share of forest land in the total area | Share of private land in the total area of forest land | |
|---|---|---|---|---|---|---|
| | 2020 [thous. ha] | Change in 2000-2020 [thous. ha] | 2000-2020 [2000=100] | | 2020 [%] | Change in 2000-2020 [2000=100] |
| POLSKA | 9 464.2 | 404.8 | 104.5 | 30.3 | 18.9 | 117.3 |
| Dolnośląskie | 611.8 | 34.0 | 105.9 | 30.7 | 3.6 | 175.1 |
| Kujawsko-pomorskie | 432.2 | 19.0 | 104.6 | 24.1 | 11.5 | 122.1 |
| Lubelskie | 596.0 | 36.3 | 106.5 | 23.7 | 40.5 | 115.7 |
| Lubuskie | 710.3 | 18.1 | 102.6 | 50.8 | 1.8 | 174.0 |
| Łódzkie | 397.5 | 18.1 | 104.8 | 21.8 | 33.7 | 112.9 |
| Małopolskie | 439.3 | 5.3 | 101.2 | 28.9 | 43.1 | 101.9 |
| Mazowieckie | 845.3 | 56.4 | 107.1 | 23.8 | 44.4 | 115.8 |
| Opolskie | 257.9 | 5.0 | 102.0 | 27.4 | 5.0 | 123.6 |
| Podkarpackie | 691.8 | 31.2 | 104.7 | 38.8 | 17.5 | 129.0 |
| Podlaskie | 634.8 | 30.4 | 105.0 | 31.4 | 32.4 | 111.6 |
| Pomorskie | 685.0 | 19.4 | 102.9 | 37.4 | 11.3 | 116.3 |
| Śląskie | 405.8 | 7.0 | 101.8 | 32.9 | 19.5 | 103.0 |
| Świętokrzyskie | 338.0 | 17.6 | 105.5 | 28.9 | 28.1 | 119.8 |
| Warmińsko-mazurskie | 787.1 | 54.4 | 107.4 | 32.6 | 8.1 | 195.8 |
| Wielkopolskie | 788.8 | 18.5 | 102.4 | 26.4 | 10.7 | 115.2 |
| Zachodniopomorskie | 842.6 | 34.1 | 104.2 | 36.8 | 2.7 | 264.4 |

Source: own elaboration based on IBL; KPZL

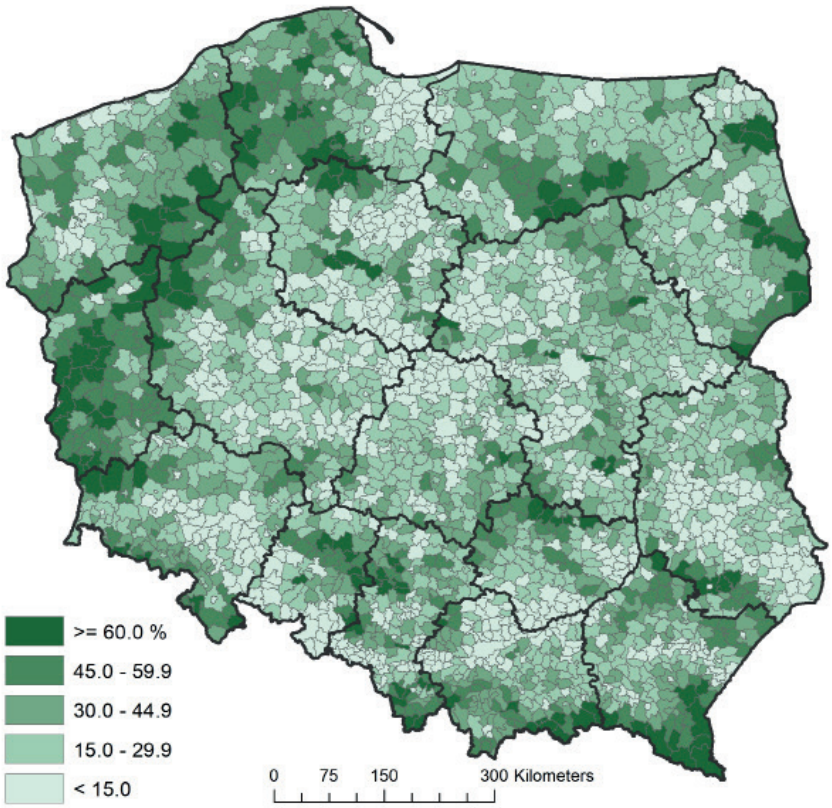


**Fig. 2.** Share of forests in the total area (%; by municipality)
Source: own elaboration based on LDB CSO

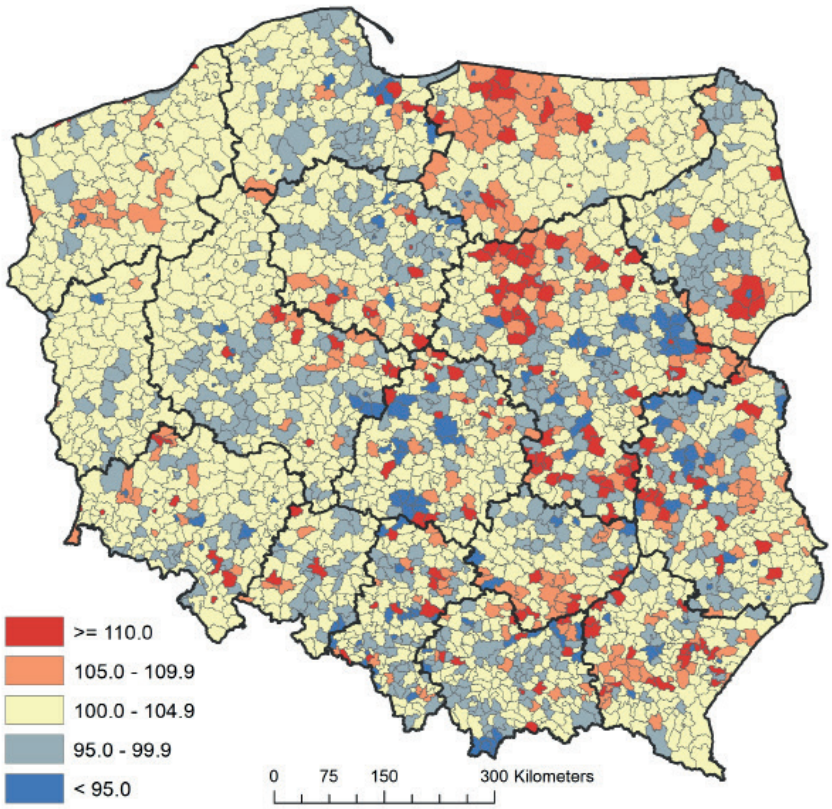


**Fig. 3.** 2000-2020 changes in the share (%) of forests in total area (2010=100)
Source: own elaboration based on LDB CSO

forest land. In the context of afforestation, particular attention should be drawn to the municipalities that saw the greatest gains in forest area. The analysis has identified 29 municipalities where the area more than doubled, and another 30 that gained between 50 and 100%. These municipalities are mainly concentrated in Mazowieckie and Warmińsko-Mazurskie Provinces, as well as in Świętokrzyskie, Lubelskie and Podkarpackie.

### 4.2. Where is afforestation advisable? Spatial model of increasing the country's forest cover: the afforestation preference index (API)

In order to build a spatial model for increasing the forest cover in keeping with the methodological assumptions adopted, a categorisation (ranking) of all administrative units was compiled using the afforestation preference index (API). The analysis has shown considerable spatial differentiation of the API both from one region to another (from 10–11 points in Opolskie and Śląskie to 18.2 points in Wielkopolskie) and, above all, among the municipalities (from 5.5 points and below in the municipalities of Hel in Pomorskie, Koszalin in Zachodniopomorskie, Katowice in Śląskie, Oleszyce in Podkarpackie and Skarżysko-Kamienna in Świętokrzyskie to over 40 points in the municipalities of Chorzele and Gostynin in Mazowieckie, Lipnica in Pomorskie and Ustrzyki Dolne, Komańcza and Dukla in Podkarpackie, the last of which has a record API value of 56.75 points). As regards the increase in afforestation, a special rank is shown by municipalities with high (15.0–20.0 points) and very high (over 20.0 points) preference for afforestation. In total, 927 such units (37.4%) have been identified, which implies a large potential for afforestation in Poland (Table 2). The spatial divergence of municipalities with a high API displays great variations. In Opolskie Province, the total share of municipalities with a high or very high API is only 4.2%, whereas in Wielkopolskie and Kujawsko-Pomorskie it exceeds 60% (64.2% and 66.7%, respectively). Such a high rank of both regions stems from, inter alia, a very high share of farmed land and a low ratio of forest cover. The need to increase the share of forest in these areas is also linked to the needs of nature conservation and the presence of areas at risk of steppe formation. The above is particularly relevant to the Kujawy region, which has the lowest level of precipitation in Poland (below 500 mm/year).

The results of the evaluation of territorial units in terms of afforestation preferences, as quantified by means of the synthetic indicator of afforestation needs (API) for municipalities, imply relatively favourable conditions for a large proportion of the areas. In accordance with the underlying assumption, the procedure employed (see the method chapter) has distinguished three classes of units, i.e. those

**Table 2**. Afforestation Preference Index

| Description | Afforestation Preference Index (API) | | Afforestation needs of the API (share of municipalities in their total number) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | pts. | Synthetic indicator SI (δ) | up to 10 pts. | 10-15 pts. | 15-20 pts. | above 20 pts. | Total 15-20 and above 20 pts. | |
| | | | | | | | Number of municipalities | Share (%) |
| POLSKA | 14.40 | 0.00 | 21.2 | 41.3 | 23.7 | 13.8 | 927 | 37.4 |
| Dolnośląskie | 11.48 | -0.51 | 32.5 | 55.0 | 10.1 | 2.4 | 21 | 12.4 |
| Kujawsko-pomorskie | 17.74 | 0.58 | 5.6 | 27.8 | 39.6 | 27.1 | 96 | 66.7 |
| Lubelskie | 14.96 | 0.10 | 15.5 | 37.1 | 33.3 | 14.1 | 101 | 47.4 |
| Lubuskie | 14.09 | -0.05 | 23.2 | 40.2 | 24.4 | 12.2 | 30 | 36.6 |
| Łódzkie | 13.29 | -0.19 | 17.5 | 51.4 | 27.7 | 3.4 | 55 | 31.1 |
| Małopolskie | 14.43 | 0.01 | 17.0 | 47.3 | 23.6 | 12.1 | 65 | 35.7 |
| Mazowieckie | 14.80 | 0.07 | 17.2 | 41.7 | 27.4 | 13.7 | 129 | 41.1 |
| Opolskie | 10.37 | -0.70 | 52.1 | 43.7 | 2.8 | 1.4 | 3 | 4.2 |
| Podkarpackie | 15.55 | 0.20 | 15.6 | 43.1 | 23.8 | 17.5 | 66 | 41.3 |
| Podlaskie | 15.14 | 0.13 | 13.6 | 44.9 | 28.0 | 13.6 | 49 | 41.5 |
| Pomorskie | 13.63 | -0.13 | 24.4 | 46.3 | 18.7 | 10.6 | 36 | 29.3 |
| Śląskie | 10.44 | -0.69 | 54.5 | 33.5 | 8.4 | 3.6 | 20 | 12.0 |
| Świętokrzyskie | 14.67 | 0.05 | 12.7 | 47.1 | 31.4 | 8.8 | 41 | 40.2 |
| Warmińsko-mazurskie | 15.80 | 0.24 | 24.1 | 34.5 | 14.7 | 26.7 | 48 | 41.4 |
| Wielkopolskie | 18.20 | 0.66 | 6.2 | 29.6 | 28.8 | 35.4 | 145 | 64.2 |
| Zachodniopomorskie | 11.82 | -0.45 | 36.3 | 44.2 | 16.8 | 2.7 | 22 | 19.5 |

Source: own elaboration based on IBL; KPZL

with low (1), average (2) and high (3) afforestation needs and preferences. The class that is particularly important in the context of assessing the spatial match between land afforestation and afforestation needs, i.e. the optimisation of the afforestation structure, is class 3, which comprises 570 units (25.3% of the total) with above-average afforestation preferences. Such municipalities mainly concentrate in the central part of Poland forming a belt that stretches from the northern part of Lubuskie Province, across Wielkopolskie, Kujawsko-Pomorskie, the southern parts of Pomorskie and Warmińsko-Mazurskie and the northern part of Mazowsze, as far as the middle part of Podlasie (Fig. 4).

Smaller groupings of units are observed in the south-eastern areas of Lubelskie, Podkarpackie and Małopolskie. Such a distribution indicates a very diverse set of determinants relating to the scale of afforestation needs. In addition to units with a large proportion of land used for agricultural purposes, there are areas where the relatively large supply of land preferred for afforestation results from its low value for agricultural production, as well as areas with a very varied morphology. Class 1 has been assigned to 765 municipalities (34%) that show little need for afforestation. They mainly occur in the southern part of the country, with the main cluster extending from the south of Łódzkie Province, across Śląskie, Opolskie and Dolnośląskie. In addition, smaller clusters are found in the central and northern parts (the coastal strip of the Baltic Sea). The remaining units (915 municipalities; 40.7%) have been attributed to class 2, which is identified as having medium afforestation needs and preferences.

The KPZL (2014) planned an area of 680,000 ha for afforestation over the years 2001–2020, mostly on non-state land (550,000 ha). The average annual afforestation area was to be 34,000 ha. In terms of area, the largest afforestation was planned in the following provinces: Wielkopolskie (110 700 ha; 16.3% of the total area to be afforested), Mazowieckie (75 200 ha; 11.1%), Lubelskie (64 000 ha; 9.4%), Łódzkie (58 600 ha; 8.6%) and Świętokrzyskie (55 700 ha; 8.2%). Most of these are regions with a low proportion of forest cover (less than 25%) are in the central and eastern parts of the country. However, in the first two regions – given their expansive areas (the largest in the country) – this will translate into a slightly smaller impact on the change in the forest cover ratio. The smallest acreages to be afforested were planned for Opolskie (11,000 ha; 1.6%) and Kujawsko-Pomorskie (13,100 ha; 1.9%).

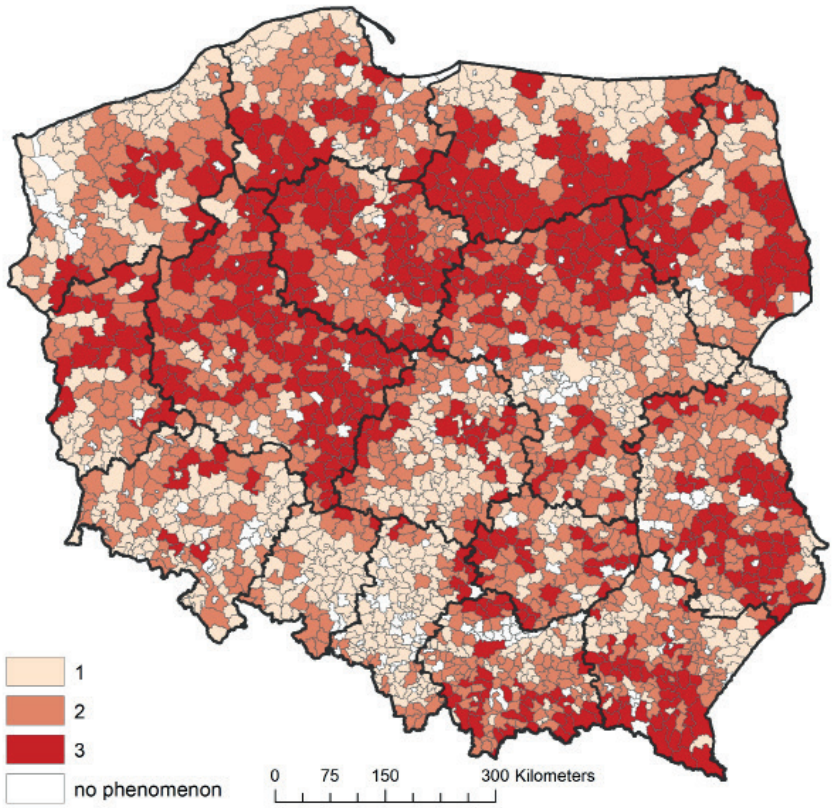


**Fig. 4.** Environmental ranking of afforestation preferences (1 – low; 2 – average; 3 – high)
Source: own elaboration based on IBL; KPZL

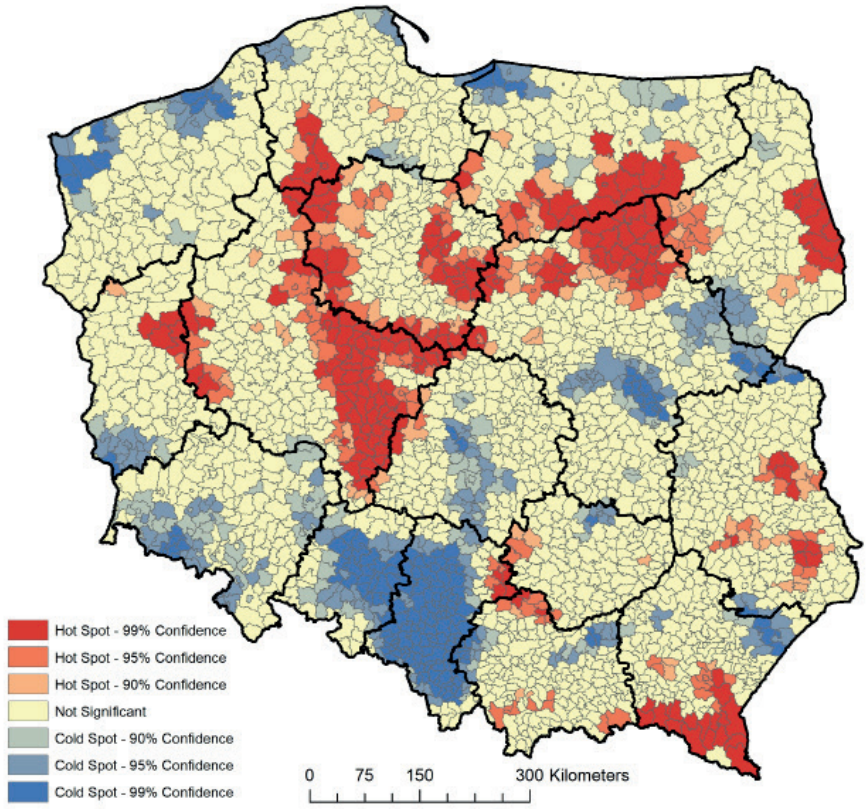


**Fig. 5.** HotSpots (spatial autocorrelation) analysis for afforestation needs v afforestation preferences of municipalities
Source: own elaboration based on IBL; KPZL

The research into spatial relationships and the strength of connections between municipalities has distinguished clusters of units similar to one another in terms of the phenomenon being evaluated. Spatial autocorrelation is defined as the degree of correlation of the observed value between a variable in a given location with the value of the same variable in another location. The findings of the hotspot analysis (Fig. 5) reveal a high level of spatial clustering in terms of the differentiation of afforestation preferences and needs.

Territorially compact clusters of municipalities are visible that have high (hot spot) or low (cold spot) statistically significant afforestation needs as determined on the basis of the synthetic API. There is a discernible spatial duality manifested by higher afforestation needs in northern and central Poland and lower needs in the south of the country (with some exceptions). Areas in need of more afforestation are largely made up of traditional agricultural land (Wielkopolska, Kujawy), with a high percentage of agricultural land, including meadows and pastures (northern Mazowieckie and Podlasie). By contrast, the largest compact area with low (cold spot) afforestation needs is formed by the historical region of Upper Silesia. It is the most urbanised and industrialised area in Poland (Katowice agglomeration), which partly also transforms into areas with a high level of agriculture (Opolskie Province).

### 4.3. Where is afforestation carried out? Spatial distribution of afforestation

The total area that underwent afforestation in 2000–2020 was 195,520 ha. However, the period saw a disturbing gradually decreasing trend in the area afforested in successive sub-periods: 135,600 ha in 2000–2006, 46,900 ha in 2007–2013, and 13,000 ha in 2014–2020. This was due to a number of reasons. At the state level, this was attributable to a restriction put in place by the Agricultural Land Agency (Pol. *ANR*) (*Note* 10) on the transfer of agricultural land to the State Forests Company for afforestation purposes, which – coupled with restrictions related to the delimitation of Natura 2000 sites – has led to a substantial decrease in the area of state-owned land designated for afforestation. As regards private forest owners,

the decline in their interest in afforestation is attributable to, inter alia, economic considerations (e.g., a gradual increase in the purchase prices of seedlings and high prices of specialised equipment, which translates into rising costs of forest services), which creates a dilemma for farmers – is this a viable option for managing low-productivity land? (Źróbek-Różańska et al., 2014). Moreover, the increased interest in the purchase of land for agricultural purposes, as a result of which their average price per hectare has increased several-fold, and there was also a decline in farmers' interest in implementing afforestation under the *RDP* due to the introduced modifications resulting in a decrease in the attractiveness of the programme (Źróbek-Różańska et al., 2014; cf. Kurowska & Kryszk, 2017). The largest areas afforested were in Warmińsko-Mazurskie (34,650 ha), followed by Zachodniopomorskie (19,510 ha) and Mazowieckie (18,870 ha). By contrast, Śląskie (2,180 ha), Opolskie (3,350 ha) and Małopolskie (4,010 ha; Table 3) demonstrated the lowest activity. The results of the directions of spatial differentiation of afforestation coincide with the results of research by other authors, e.g. Polna (2016), which indicates that in almost half (49.2%) of rural communes, farmland afforestation intensity did not exceed 3 ha/1000 ha AL, this index being lower than 1 ha in about one quarter of them. The highest – over 10 ha/1000 ha of UAA – was found in 368 rural communes, mainly in Warmińsko-Mazurskie, Dolnośląskie and Zachodniopomorskie. In turn, 160 communes saw no afforestation of agricultural land carried out – mainly in Śląskie, Małopolskie and Mazowieckie.

The benefit obtained by Poland's territorial units in terms of the share of afforestation in their total area in 2000–2020, as quantified using the synthetic indicator, has allowed the municipalities to be aggregated into three distinct groups with a low (1), medium (2) and high (3) level of afforestation (Fig. 6). This has identified units active in pursuing afforestation and problem units where no larger-scale afforestation activities were observed despite clear needs. A distinct concentration of afforestation in the form of compact clusters of municipalities is mainly observable in the following voivodeships: Warmińsko-Mazurskie, Zachodnio-pomorskie, Podlaskie and Dolnośląskie. Slightly less numerous clusters have been found in Podkarpackie, Pomorskie and Świętokrzyskie. In the other regions, the activities took the form of local initiatives rather than dedicated large-scale projects.

Spatial autocorrelation analysis of the hotspots (Fig. 7) reveals a high degree of spatial clustering in terms of the level of afforestation. Territorially compact groupings of units with a high (hotspots) and low (coldspots) level of land afforestation are clearly discernible. The areas where afforestation forms clusters are dominant in the northern part of the country, especially in Warmińsko-Mazurskie

**Table 3**. Afforestation in Poland in 2000-2020 – selected elements of the assessment

| Description | Total afforestation in the years 2000-2020 | | | including period | | | | | | Change 2000-2020 | Share of municipalities by afforestation level (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | thous. ha | afforestation in % of the total area | | 2000-2006 | | 2007-2013 | | 2014-2020 | | | I - low | II - average | III - high |
| | | % | SI (δ) | thous. ha | % | thous. ha | % | thous. ha | % | % | | | |
| POLSKA | *195.52* | *0.57* | *0.00* | *135.6* | *69.4* | *46.9* | *24.0* | *13.0* | *6.7* | *2.16* | *40.1* | *44.2* | *15.6* |
| Dolnośląskie | 14.56 | 0.73 | 0.21 | 10.9 | 75.2 | 2.9 | 20.1 | 0.7 | 4.8 | 2.52 | 37.9 | 40.8 | 21.3 |
| Kujawsko-pom. | 10.22 | 0.57 | -0.01 | 7.0 | 68.7 | 2.6 | 25.0 | 0.6 | 6.3 | 2.47 | 29.2 | 56.9 | 13.9 |
| Lubelskie | 11.25 | 0.45 | -0.17 | 7.6 | 67.3 | 2.6 | 23.3 | 1.1 | 9.4 | 2.01 | 39.9 | 49.8 | 10.3 |
| Lubuskie | 10.36 | 0.74 | 0.22 | 7.6 | 73.1 | 2.2 | 21.7 | 0.5 | 5.2 | 1.5 | 23.2 | 51.2 | 25.6 |
| Łódzkie | 10.42 | 0.57 | 0.00 | 7.4 | 70.8 | 2.3 | 21.9 | 0.8 | 7.4 | 2.75 | 29.4 | 55.9 | 14.7 |
| Małopolskie | 4.01 | 0.26 | -0.41 | 3.1 | 77.9 | 0.6 | 15.3 | 0.3 | 6.8 | 0.92 | 57.7 | 39.0 | 3.3 |
| Mazowieckie | 18.87 | 0.53 | -0.06 | 13.1 | 69.2 | 4.5 | 24.0 | 1.3 | 6.8 | 2.39 | 40.4 | 45.2 | 14.3 |
| Opolskie | 3.35 | 0.36 | -0.29 | 2.2 | 65.3 | 1.0 | 30.0 | 0.2 | 4.7 | 1.32 | 47.9 | 46.5 | 5.6 |
| Podkarpackie | 11.4 | 0.64 | 0.09 | 6.8 | 59.2 | 3.2 | 28.4 | 1.4 | 12.4 | 1.73 | 31.9 | 44.4 | 23.8 |
| Podlaskie | 13.35 | 0.66 | 0.12 | 9.5 | 71.5 | 2.8 | 21.0 | 1.0 | 7.5 | 2.21 | 37.3 | 45.8 | 16.9 |
| Pomorskie | 11.26 | 0.61 | 0.05 | 7.8 | 69.0 | 2.6 | 22.7 | 0.9 | 8.3 | 1.69 | 44.7 | 38.2 | 17.1 |
| Śląskie | 2.18 | 0.18 | -0.53 | 1.6 | 73.9 | 0.5 | 22.3 | 0.1 | 3.8 | 0.55 | 76.6 | 22.8 | 0.6 |
| Świętokrzyskie | 7.96 | 0.68 | 0.14 | 5.0 | 62.6 | 2.3 | 28.5 | 0.7 | 9.0 | 2.49 | 31.4 | 45.1 | 23.5 |
| Warmińsko-maz. | 34.65 | 1.43 | 1.15 | 23.1 | 66.6 | 10.2 | 29.4 | 1.4 | 4.0 | 4.73 | 19.0 | 31.9 | 49.1 |
| Wielkopolskie | 12.18 | 0.41 | -0.22 | 9.1 | 75.0 | 2.5 | 20.7 | 0.5 | 4.3 | 1.58 | 42.5 | 50.9 | 6.6 |
| Zachodniopom. | 19.51 | 0.85 | 0.37 | 13.9 | 71.2 | 4.1 | 20.9 | 1.5 | 7.9 | 2.41 | 33.6 | 38.9 | 27.4 |

Source: own elaboration based on LDB CSO

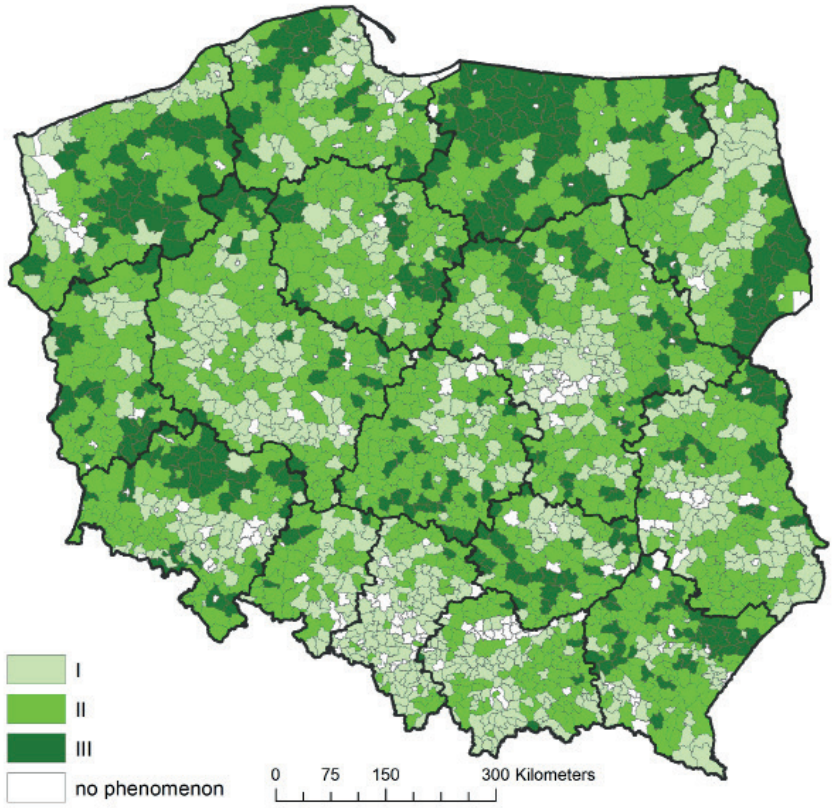


**Fig. 6.** Synthetic afforestation index in 2000-2020
Source: own elaboration based on IBL

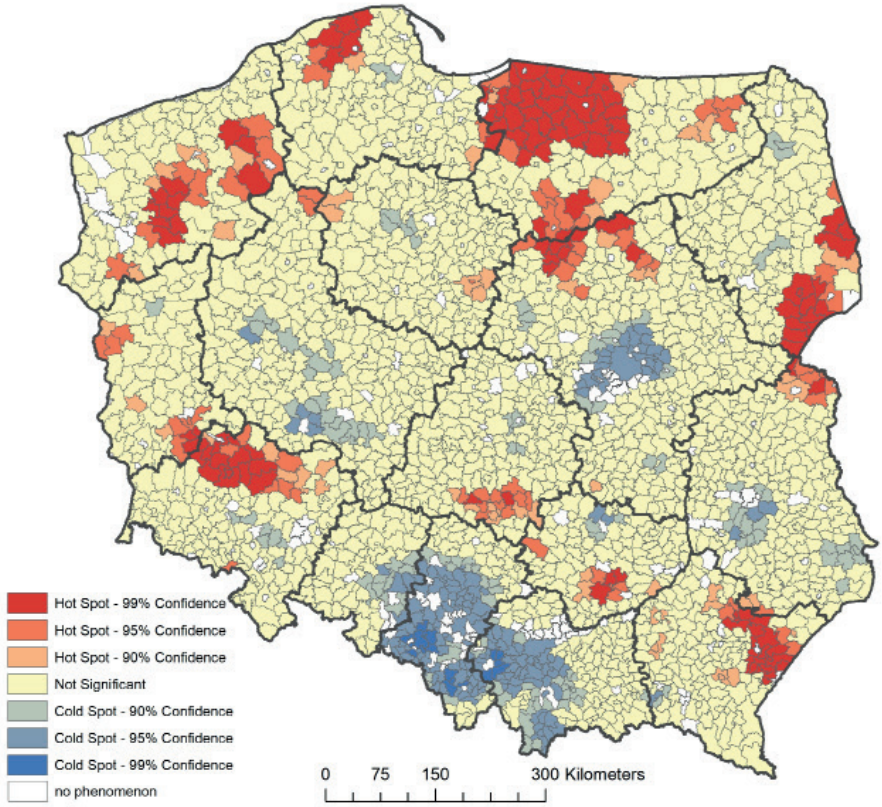


**Fig. 7.** Hotspots (spatial autocorrelation) analysis of the afforestation ratio
Source: own elaboration based on IBL

and on the border with Mazowieckie, as well as in Zachodniopomorskie. In addition, slightly more numerous clusters occur in Dolnośląskie, Podlaskie and Podkarpackie. The study has also identified a coldspot area in the southern part, which extends from the eastern part of Opolskie, across Śląskie, to the western part of Małopolskie.

### 4.4. Where should we target afforestation more strongly? Optimisation of afforestation using the afforestation preference index (API): typology

Optimising afforestation of agricultural land is a crucial issue given the nature of Polish agriculture, which is distinguished by a high proportion of farmland in the total area of the country (58%) and by excessive agricultural use of poor-quality land that is susceptible to threats (e.g., erosion, water pollution). This being the case, the de-farming and afforestation of land can have a positive impact on the development of agriculture and rural areas – both directly (by increasing the forest cover and thereby strengthening ecosystems and biodiversity) and indirectly (by creating new jobs and income opportunities). The study assumes that the overriding criterion for assessing the needs for afforestation of agricultural land should be the spatial optimisation of the land-use structure within a specific area in relation to natural factors, e.g. the quality of the land and its suitability for field crops, the cohesion of the forest ecosystem, or the coexistence of environmentally valuable areas. Land that yields poor crops and does not improve the cohesion of the ecosystem should be treated as preferable for afforestation.

In keeping with the assumptions adopted, spatial optimisation of afforestation should entail diversification of afforestation in line with afforestation needs and preferences. To meet this objective, the present study has compiled and compared afforestation levels (Fig. 6) and afforestation needs and preferences (Fig. 4). For both these analyses, the results were aggregated into three groups, to which individual municipalities were assigned. The results were used to identify nine ($3^2$) possible variants of combinations of both datasets compiled (Fig. 8; Table 4). Considerable convergence has only been observed for two areas, namely Warmińsko-Mazurskie (hotspots) and the abovementioned southern region (coldspots). The results of the analysis imply a relatively low level

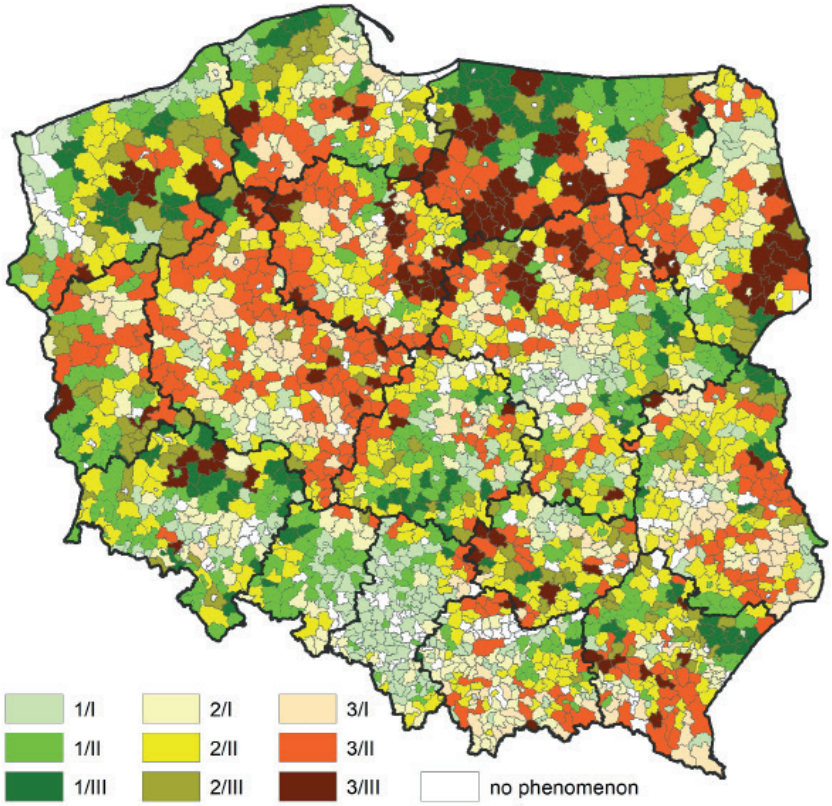


**Fig. 8.** Typology of spatial suitability of afforestation in Poland
Source: own elaboration based on IBL

**Table 4**. Matrix of relationships between afforestation level and afforestation needs and preferences – number and share of municipalities

| Afforestation level indicator | Index of afforestation needs and preferences | | |
|---|---|---|---|
| | 1 (low) | 2 (average) | 3 (high) |
| I - low | **290 (12,9%)** | **305 (13,6%)** | **129 (5,7%)** |
| II - average | **359 (16,0%)** | **461 (20,5%)** | **324 (14,4%)** |
| III - high | **116 (5,2%)** | **149 (6,6%)** | **117 (5,2%)** |

Source: own elaboration

of spatial optimisation (match or suitability) of afforestation and a considerable mismatch between how afforestation has been oriented to date and afforestation needs and preferences. The mismatch is evidenced by the low value of the linear correlation coefficient *r=0.0663*. The aggregation into nine types has found that the most numerous type is 2/II, i.e. that with average (medium) afforestation preferences and average (medium) level of afforestation, which characterises one in five units (20.5% of all municipalities). Areas with the largest gap between the indicators evaluated, i.e. with high afforestation needs (preferences) and a low level of afforestation, and vice versa, are particularly noteworthy. These types (assigned to the extreme classes) display a significant mismatch between the preferred and actual afforestation. The analysis has identified 116 municipalities with an above-normative level of afforestation under conditions of low afforestation needs (5.2% of all units) – type 1/III. The largest concentration of such units is found in the northern part of Warmińsko-Mazurskie. The opposite situation, i.e. a low degree of afforestation versus a high level of afforestation preferences (type 3/I), is observable in 129 municipalities (5.7% of the total). Their greatest concentration occurs in Wielkopolskie (intensive farming), i.e. the region that has the highest afforestation needs and preferences. Its high rank stems from a very high share of farmed land and a low ratio of forest cover. It should be noted that other units that qualify for intensive afforestation include Kujawsko-Pomorskie (intensive farming, low share of forest land) and Podkarpackie (difficult terrain, large share of LFAs). Such a distribution reveals an unfavourable situation with regard to the spatial match (optimisation) of afforestation and, at the same time, enables problem units to be identified. The most desirable type (3/III) is found in 117 municipalities (5.2% of the total), where a high level of afforestation needs and preferences goes hand in hand with intensification of afforestation efforts. In spatial terms, such units are mainly concentrated at the interface between the Warmińsko-Mazurskie, Kujawsko-Pomorskie and Mazowieckie Provinces. In addition, a compact area of type 3/III units is observed in the east of Podlaskie. The remaining units occur at isolated points (locally) and do not form clusters.

The study has identified a relatively small group of municipalities that has a high degree of afforestation of agricultural land (382 municipalities) but that is strongly differentiated in terms of the needs and natural potential for afforestation: low (116 municipalities), medium (149 municipalities) and high (117 municipalities). On the other hand, there is a large group of municipalities with high potential but a low degree of actual afforestation. This group includes, for instance, the municipalities of Chojnice, Piecki, Pilica and Ruciane-Nida (the latter, because it already has a very high forest cover of ~74%). Other examples are municipalities that are among the most active ones in terms of afforestation, but rank low in terms of their environmental potential, e.g.: Wicko (API=*10.19 points*) and Pieniężno (API=*9.99 points*). The above implies that there is a wide range of factors behind interest in afforestation, especially in the private sector.

## 5. Discussion

The spatial distribution of afforestation is rather poorly matched (i.e., poor territorial targeting) to afforestation needs and preferences. The afforestation of land exhibits large disproportions between one region and another, which – given the existing structure and spatial distribution of forests in Poland – implies a need for change. Afforestation policy should be aimed at reducing the inadequacy of forest cover in the central-eastern part of the country (Siuta, 1996; Liro, 1998; Michna, 1998; Puchniarski, 2000), which is characterised by a significant lack of forestation, especially in comparison with the "western wall" (Lubuskie). When compared across the period 2000–2020, the forest cover ratio shows the greatest increase in areas with high and very high proportions of forest area, and the least in areas with high and very high deficit of such areas – in the central-eastern part

of Poland. The latter areas also include those with the lowest precipitation, low water retention due to the presence of sandy soils, strong winds and high daily temperature fluctuations. One of the key findings of the study is the heterogeneity of rural areas in Poland, which is attributable to the diverse natural conditions that determine the effectiveness of afforestation in individual areas. From the point of view of enhancing natural ecosystems and biodiversity, these are preferable areas for such measures (Jezierska-Thöle et al., 2021). One difficulty in matching support for afforestation of agricultural land to afforestation needs and preferences stems from the lack of correlation between environmental and management processes (Pelosi et al., 2010), mainly as regards proper targeting of payments (Kleijn et al., 2001; Kleijn et al., 2004; Pe'er et al., 2014), or mismatches of spatial scale (Cumming et al., 2006; Matzdorf et al., 2008), which in turn prejudices the effectiveness of agri-forestry policy-making.

The study has found a decline in interest in afforestation and a gradual decrease in the re-designation of land for afforestation, which is also confirmed by research by other authors (cf. Polna, 2016). The strong decline in afforested area, despite the presence of large agricultural areas suitable for re-designation, mirrors a reorientation of the policy of the state, which is the main owner of forests. This is evidenced by changes in the criteria for designating agricultural land for afforestation (as also emphasised by Kurowska and Kryszk, 2017), inter alia by increasing the minimum compact afforestation area, excluding land located within Natura 2000 sites from eligibility for support for afforestation, precluding permanent grassland (meadows and pastures) from afforestation, limiting the area of afforestation per farmer and reducing the area of former agricultural land and wasteland that can be turned into forest, as well as competitiveness from direct subsidies for agricultural production (Lasy ..., 2016). Kaliszewski et al. (2016b) in their research emphasise that, without a stable afforestation financing system, a further decline in the annual afforestation area may become a fact. The interest in afforestation has also declined as a result of administrative developments, e.g. the increase in the minimum surface area of a plot not neighbouring on forest eligible for afforestation subsidies from 0.1 to 0.5 ha. An additional barrier is formed by the requirement for an eligible plot to have a minimum width of 20 m, which is highly consequential in the case of Poland, given the highly fragmented structure of its land, especially in the southern, central and eastern parts of the country (Polna, 2006).

The targeting of afforestation as identified by the study indicates a significant proportion of municipalities with land of limited suitability for afforestation. This significantly hampers the synergy effect, which means that it is necessary to consider redirecting the allocation of funding for afforestation of agricultural land (at least partially), i.e. make it better targeted in territorial terms. Nevertheless, as for geographically targeted measures, it must be kept in mind that they may have a positive effect and prevent abandonment of agricultural land in these areas, especially with regard to seminatural habitats with low agricultural productivity (Dupraz & Rainelli, 2004) and a negative effect where more profitable intensive practices are limited (Desjeux et al., 2014). The approach towards stronger territorial targeting should be revamped in a manner that corresponds to the natural specificities of individual municipalities. The results of the analysis confirm the conclusions of research inter alia by Bàrberi et al. (2010), which has found that there is a tendency towards spatial segregation between highly specialised production areas and areas with small-scale agriculture. From the point of view of the intensity of agricultural production, the study has confirmed that the proportion of afforestation activity is low in regions of intensive production (Wielkopolska, Podlasie, Dolnośląskie, Wyżyna Lubelska, Kujawy, Opolszczyzna). Farmers are more willing to engage in afforestation where the prospects for deriving income from agricultural production are low enough to render the subsidy-based scheme of incentives for afforestation a viable alternative.

In addition, the factors behind the decrease in the supply of land for afforestation comprise market conditions, including rising prices of agricultural land (including that of poor valuation classes) or increased demand for land for agricultural purposes. They have changed the approach to agricultural land, which has come to be considered as a safe capital investment. The activity of beneficiaries is most often driven by economic (income-related) motivation (Źróbek-Różańska et al., 2014). Hence, the loss of income of farming families related to the exclusion of land from agricultural production is a significant barrier to the allocation of agricultural land for afforestation (Łupiński, 2006). Thus, the pursuit of afforestation is affected by the effectiveness and economic viability of other measures implemented under the RDP (Kurowska & Kryszk, 2017). Farmers can benefit from more viable forms of support – including environmental measures, e.g. support for LFAs, direct payments, agri-environmental measures, and climate payments (Biczkowski, 2018) – and they are therefore not inclined to permanently convert

their land from agriculture to forest (Ogryzek, 2015; Klepacka, 2020; Wysocka-Fijorek et al., 2020). The competitiveness of direct payments adds to the intensification of agricultural production on land that is classified as unsuitable for effective farming (i.e., preferred for afforestation). This is evidenced by the fact that financial attractiveness drives above-average interest among beneficiaries from municipalities where the existing conditions do not necessarily offer a high environmental potential for afforestation. The above also confirms the negligible importance of natural conditions as a contributor to decisions on afforestation. In fact, economic considerations, i.e. availability of EU funds, are the predominant incentive. At the same time, this has driven the demand for agricultural land, which is reflected in a steep increase in its price in private transactions. There is a noticeable deficit of environmental criteria in territorial targeting of public funds, which prejudices the reasonableness of their spending. This is counterproductive (including in the light of the assumptions of the *KPZL*) and is a major factor hampering afforestation.

## 6. Conclusions

The research presented in the paper proves that there is a need to boost the territorial dimension of afforestation measures in order to better match (optimise) afforestation to the natural conditions prevailing in a given area. The multi-factor modelling of the country's potential forest cover has confirmed the point that the natural environment of Poland is very diverse in terms of the features that underly afforestation needs and preferences, but afforestation decisions are mostly driven by non-natural (mainly economic) motivations. With the attractiveness of afforestation declining, it is essential that this unfavourable tendency be reverted. This requires optimising the spatial system by defining the ecological and economic priorities and afforestation preferences of municipalities, and thus ensuring optimal distribution of afforestation with an enhanced ecological effect. Afforestation should lead to the formation of compact forest complexes adapted to the nature of the habitats and should produce coherent natural systems that perform vital ecological functions. Efforts should also be exercised to create ecological corridors between large forest complexes, such that would protect landscape, play an environment-forming and nature conservation role, help transport matter and energy, play a central role as habitats, and shape space and human living conditions.

## Notes

1. http://www.fao.org/faostat/en/#data/FO
2. as of December 31, 2021; https://www.lasy.gov.pl/pl/nasze-lasy/polskie-lasy; https://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5510/3/3/1/lesnictwo_w_2021_r.pdf
3. https://www.europarl.europa.eu/factsheets/pl/sheet/105/unia-europejska-i-obszary-lesne
4. Information on the preliminary results of the 2020 General Agricultural Census; PSR 2020, Statistics Poland
5. *Statistical Yearbook, 2008*, Statistics Poland Warsaw
6. A detailed list of the indicators and diagnostic features is included in Appendix A
7. The area of forest land includes the area of forests and land related to forest management, and comprises both forest owned by the state (including that under management of the State Forests company) and private forests
8. The normalisation entailed replacing the original value with the value that represented the quotient between the difference of the values of a given feature and the mean value and its standard deviation
9. The selection of the method for conceptualising spatial relations is an important element. Here, use was made of the FIXED_DISTANCE_BAND method, in which each feature is analysed in the context of neighbouring features. Neighbouring features within the specified critical distance (distance band or threshold distance) are given a weight of one and influence the calculation for the target feature. Neighbouring features that fall beyond the critical distance are given a weight of zero and are irrelevant for the calculation of the target. Distances were calculated on the basis of Euclidean distance
10. since 2017 – National Agriculture Support Center, pl. KOWR

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## Appendix 1

### Methodology for the identification of afforestation preferences and needs (after the Forest Research Institute)

List of the diagnostic features included in the study of afforestation preferences:

1. the share of the poorest soils in the surface area of agricultural land (%),
2. quality of areas of agricultural production, i.e. suitability for agriculture as per the scoring of the Institute of Soil Science and Plant Cultivation (IUNG) (score; inhibitor – it is assumed that the higher the score, the lower the afforestation needs should be),
3. relief (score; inhibitor – it is assumed that flat or plain relief is more suitable for agricultural production than for afforestation),
4. occurrence of steppe-formation (ha),
5. risk of surface water erosion (ha),
6. supply of land for afforestation according to surveys in municipalities (ha),
7. forest cover (%; inhibitor – it is assumed that the greater the forest cover of a municipality, the lower its afforestation needs),
8. share of meadows and pastures within the municipality (%; inhibitor – it is assumed that the higher the rank of permanent grasslands, the lower the need for afforestation),
9. the degree of increasing the forest cover in the light of nature conservation needs (%),
10. major watersheds (ha),
11. protected basins (ha),
12. groundwater protection (ha).

[It has been assumed that the numerical values of the individual characteristics influence the afforestation needs of municipalities in direct proportion so four of the above characteristics, i.e. Nos. 2, 3, 7, 8 – are expressed in the form of reverses of their real numerical values]

The above features, as normalised, formed the basis for the construction of a synthetic index for assessing the afforestation needs of municipalities. In order to convert the absolute values of the individual features into relative values, use was made of a method that entailed summing the relative values obtained through the division (quotient) of the absolute values of a specific feature by the maximum or average value within this feature. Then the calculated relative values for all features were summed up for each municipality. The sum of the relative values for the individual municipalities represents a synthetic indicator for assessing the afforestation needs of municipalities (scoring). Based on the above methodological assumptions, all municipalities in Poland were ranked in terms of their afforestation preferences using a system of three variants differing in the number and size of the weights applied, i.e. 1 – no weights applied, 2 – higher weights for the features that add to the rationalisation of the land use structure as a result of afforestation, 3 – higher weights for the features that enhance the environmental functions of afforestation (soil and water protection and nature conservation). Given the paramount importance of forests in counteracting adverse developments in the natural environment and the great overall social importance of non-production functions of afforestation (future forests), it is proposed that variant 3, – environmental, be adopted.