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The Impact of Agricultural Land Use Patterns on Natural Vegetation, Plant, and Livestock Diversity in the European Union

Zsuzsanna Bacsi *, Péter Szálteleki and Gabriella Bánhegyi

Institute of Agricultural and Food Economics, Department of Agricultural Economics and Agricultural Policy, Hungarian University of Agriculture and Life Sciences, 2100 Gödöllő, Hungary; szalteleki.peter@uni-mate.hu (P.S.); banhegyi.gabriella@uni-mate.hu (G.B.)
* Correspondence: bacsi.zsuzsanna@uni-mate.hu

Abstract: The preservation of natural heritage is a global concern nowadays, which is equally important for climate resilience and for sustainable resource use. The present research is focused on assessing the trends of natural landscape changes, such as forests, meadows, and pastures, and the preservation of locally kept traditional livestock, and plant varieties as indicators of biodiversity, in the countries of the European Union between 2012 and 2021, using secondary data. The research methodology was a panel analysis according to the Linear Mixed Model method. The results show that while larger areas allocated to agriculture generally enhance plant biodiversity, they have the opposite effect on the number of local livestock breeds. The spreading of organic farming enhances the preservation of local livestock breeds, while the spreading of forest areas is beneficial for plant biodiversity. The share of permanent meadows and pastures increases with increasing agricultural areas, and this also affects plant biodiversity positively. All biodiversity indicators increased during the analyzed period, as did well as the size of forest areas and, permanent meadows and pastures, which reflects the improvement in natural heritage and the enhancement of environmental protection awareness with time. The differences among countries show, that highly developed agriculture does not mean better preservation of natural heritage, nor the opposite, as ecological conditions and agricultural history may influence the natural vegetation and biodiversity. The protection of natural heritage in Europe differs from the rest of the world, as recent agricultural policy of the EU emphasizes the importance of environmental sustainability. The promotion of low-input use in agriculture, however, may be in conflict with the globally increasing demand for food.

Keywords: natural heritage; local breeds; plant genetic resource; biodiversity; agricultural land; forest land; input use; agricultural land use patterns

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1. Introduction

The importance of natural heritage in a country's economy is a well-established fact, affecting its resources and resource use, traditions, sustainable economic practices, and climate change resilience [1]. According to the definition of the UNESCO [2] the concept of natural heritage includes natural features, geological and physiographical formations and habitats of threatened species of animals and plants, as well as natural sites valuable for science, conservation, or natural beauty, such as protected natural areas, zoos, aquaria and botanical gardens, marine ecosystems, sanctuaries, and reservoirs [2]. Cultural and natural heritage are often strongly intertwined, as the environment may be the setting for human-made heritage objects, and it is also valued in itself as heritage [3]. It can be stated, that the most important natural heritage component of an area is its

natural landscape, which provides habitat for its biological diversity [1,4]. The natural heritage of a particular area can be represented by its ecosystems as spatial units [5]. These can be characterized by land cover typology, containing artificial surfaces, arable land, permanent crops, pastures, heterogeneous agricultural areas, forests (planted or natural), shrubs and natural herbaceous vegetation, open spaces with little or no vegetation, wetlands, and waterbodies [6]. The ecological value of a landscape includes genetic resources, biodiversity, water and soil, local knowledge and technology of biological resource utilization, agricultural production, water and soil management and landscape conservation [7–9].

In our research design the leading idea is that changes in agricultural and forest land use, specifically through deforestation, conversion of permanent pastures and meadows, and expansion or conversion of permanent crops, significantly alter the ecological integrity of natural heritage areas by affecting biodiversity, ecosystem services, and landscape connectivity—even when these areas are not designated as protected sites. Traditional agricultural landscapes often have cultural and historical significance tied to natural heritage. Agriculture and forestry are the most ancient economic sectors affecting the utilization of a country's territory, thus directly influencing the fate of natural heritage [10]. The concept of Globally Important Agricultural Heritage Systems (GIAHS) is introduced by FAO [10]. Since 2005 altogether 89 systems in 28 countries have been designated by FAO as agricultural heritage sites, of which 11 exist in 5 European countries [10]. Beside the GIAHS areas, the UNESCO registry contains 291 World Heritage Sites in the EU member states, of which 84 related directly (e.g., development, management) or indirectly (e.g., as buffer zone, or possible threat) to agricultural (typically permanent pastures and meadows, permanent crops such as orchards and vineyards) or forest land utilization and management [11].

Indigenous livestock and plant varieties are reservoirs of genetic diversity essential for maintaining ecological balance, ensuring ecosystem services, many of them co-evolved with the local ecosystem. These breeds and varieties play important roles such as maintaining grassland diversity through grazing patterns. In their absence the decline of traditional grazing practices can lead to deterioration, reducing the diversity of species that are key components of the region's natural heritage [11].

To further support this argument, the case of Hungarian World Heritage sites is briefly presented. Hungary has seven World Heritage sites, and agricultural and/or forestry land use, and/or the presence of indigenous agricultural animal species, are fundamental characteristics in five of them [11]:

- The Hortobágy National Park—The Puszta with nearly 75,000-hectare area is Hungary's largest contiguous grassland, containing alkaline pastures, steppes, meadows and wetlands. The UNESCO emphasizes the importance of traditional animal husbandry, of the grazing hardy livestock breeds that contribute to the maintenance of the unique features of the heritage and states that it is an exceptional surviving example of a cultural landscape constituted by a pastoral society. Five of the country's protected indigenous livestock breeds are bred and kept here and their presence is an essential part of maintaining the typical biodiversity of the surrounding landscape.
- Old Village of Hollókő and its Surroundings in Northern Hungary is a living example of the traditional rural life prior to the green revolution of the agriculture and characterized by strip-field farming, orchards, vineyards, meadows and woods.
- Millenary Benedictine Abbey of Pannonhalma and its Natural Environment has an outstanding universal value, and the principal elements surrounding the complex are the forest and the botanic garden.

- Fertö/Neusiedlersee Cultural Landscape is a cross-border heritage site covering Hungarian and Austrian territory with direct connection to forest and vineyard (permanent crop) land utilization.
- Tokaj Wine Region Historic Cultural Landscape as its name shows is a famous historical wine producing area, where vineyard farms and wine cellars are unseparable part of the landscape.

Similar world heritage site examples are the Mont Perdu area of the Pyrénées (France) with its pastures and meadows, the Causses and the Cévennes, Mediterranean agro-pastoral landscape (France) with its local sheep breeds landscape structure and open grazing lands, or the agricultural landscape of Southern Öland in Sweden, just to mention a few [11].

The quality and quantity of natural heritage components change over time, together with changing land use, including unsustainable or sustainable agricultural practices, leading to the exhaustion or preservation of natural resources, respectively. Agriculture and related land use can significantly affect the environment, plant and livestock biodiversity, cultural and natural landscape. The relationship between farming and landscapes is a highly controversial issue, as various types of agricultural practices may be either beneficial, or harmful to biodiversity conservation and to the whole landscape [3]. The traditional agricultural practices (the use of traditional seed varieties, application of manure instead of fertilizer, use of traditional crop rotation, extensive grazing of local livestock breeds instead of intensive keeping of modern breeds, etc.), being unable to meet the requirements of industrial agriculture, have been neglected in favor of unsustainable intensive agricultural systems [12–14]. These unsustainable agricultural practices, however, contribute to the loss of biodiversity and deterioration of the environment, leading to the loss of natural vegetation, and plant and livestock richness. Therefore, sustainable agricultural practices have become an essential factor in preserving the environment [1].

Modern agricultural production globally has a negative effect on biodiversity [12–14] and the main source of this negative impact is the intensive agricultural practice. Alternative practices, which are based on traditional farming techniques that have low amounts of inputs and produce less pollution [8], can support biodiversity, and while they do not provide outstanding yields compared to industrial techniques, they rely on local, and often scarce, resources [13]. Williams et al. [15] gave a dire forecast by projecting that 87.7% of the 19,859 habitat specific species they investigated will lose their habitat to agricultural expansion by 2050 and urge proactive policies on food production [15]. The more complex agricultural landscapes positively affect biodiversity [16], thus contributing to the productivity and the resilience of agriculture and food systems in several ways [8,17]. To support biodiversity and preserve the range of existing landraces, varieties and species, it is necessary to maintain land use diversity and stop the spread of monocultures, ensuring the balance between agricultural production and environmental protection [18,19]. Ubusiaga et al. [20] suggested that policies should prioritize limiting agricultural land use if proposed biodiversity targets are to be reached [20]. To maintain genetic biodiversity, institutions, private plant breeders, seed banks, and locally acting growers should cooperate [21].

Multifunctional agriculture represents the connection between sustainable agriculture, sufficient food production and territorial ecosystem balance [22–25]. The Sustainable ways of land-use provide ecosystem services [24]. Thus, the ecological and biocultural diversity, and the beauty of the rural landscape provided by multifunctional agriculture have overcome the specialized production in agricultural monoblocks, focused on enhanced productivity and profitability [22,26,27].

Organic farming may be a useful way to enhance biodiversity and conservation of the natural vegetation [28]. In cereal fields in Europe, the abundance of species of wild plants, ground beetles, and breeding birds and the biological resilience of the area are

affected by organic and conventional farming, and the effects are modified by landscape complexity, i.e the percentage of arable land [28]. The simplification of landscape, with a considerable increase in the proportion of arable land reduces biodiversity to a larger extent in conventional fields than in organic ones. The biological resilience of farmland was improved by organic farm practices, but only in heterogeneous landscapes, and not in homogeneous ones. Landis, in his synthesizing paper, also emphasizes that agricultural intensification leads to landscape simplification and loss of biodiversity. Biodiversity losses cause the shrinking of ecosystem function and reduce the resilience of these systems to disturbance [4].

Local plant varieties [29] and local breeds of farmed and domesticated animals and their related wild species [30,31] are elements of biodiversity, and thus, of natural heritage. Modern agriculture has resulted in the replacement of a wide range of local breeds by a few improved breeds along with the intensification of husbandry, and due to this, local breeds have been threatened worldwide [32–34], which is an important loss in livestock richness. However, the growing consumer interest in Europe for quality foods is a motivation against intensive animal husbandry, and for reducing meat consumption in these countries while increasing its quality [35]. Local breeds are often kept in extensive or semi-intensive production systems, being less productive in intensive farming than modern breeds, while more resilient in coarse and resource-poor environmental conditions. In addition, modern innovative technologies, such as genetic engineering can contribute to the preservation of the genetic heritage by creating reproductive barriers between domesticated (cultivated) and wild species [36] or by using cryopreservation of poultry germplasm to save endangered poultry breeds [37]. Precision agriculture can also have a favorable impact on sustainability [38]. Local livestock breeds under traditional management, like pastoralism can ensure the conservation of these genetic resources, of landscapes and biodiversity [39,40].

Forests, as extremely biodiverse habitats, play a crucial role in climate regulation by absorbing carbon dioxide from the atmosphere. The world heritage sites of the UNESCO include 69 million hectares of forests, representing significant climate benefits [41,42]. Out of the 349-million-hectare area of the 257 natural and mixed world heritage sites, the forest area covers 69 million hectares, i.e., 19.8% of the total area. In spite of their protected status, the land-use pressures induced by human activity (illegal logging, wood harvesting, and farming) affect about 60% of the area [43,44]. The forest may also contain abandoned settlements, remnants of cereal cultivation, sacred buildings, etc., which represents cultural heritage [45]. Traditional agroforestry systems have been increasingly approved for their multifunctional role, and are often viewed as a sustainable development model in several areas [46].

Forests in the EU have seen major changes over time, due to the expansion of agricultural land and the overexploitation of forests for wood [47,48]. Forests, especially natural forests, are ecosystems with the highest biodiversity [47]. Although the proportion of forest occupied by plantations continuously increase globally, a dramatic loss of biodiversity is foreseen [49], as plantation forests support fewer native species than naturally regenerating forests and have even acted as a barrier to natural forest regeneration [50]. Plantation monocultures have economic benefits by optimizing timber production, but their long-term sustainability is questionable, even if many of them are being established to overcome ecological degradation (e.g., soil salinity and, erosion) and improve the long-term sustainability of agriculture. The relative roles of planted forests and naturally regenerating forests are rarely examined [51]. An example of the USA suggests that naturally regenerating forests have increased in areas lacking prime agricultural land, with little demand for wood products, while planted forests have typically replaced both agricultural land and natural forest [51].

As the above summary shows, the livestock and plant biodiversity is closely linked to landscape, natural vegetation, and land cover, as well as to agricultural practices and intensity of input use. The present research focuses on the following questions: (1) What parallel trends of the natural land cover and land use patterns can be revealed in the countries of the European Union? More specifically, how do changes in the natural landscape (forest area, natural forest area, permanent meadows and pastures) relate to changes in agricultural land use, and in agricultural input use? (2) What are the impacts of agricultural land use patterns (i.e., the proportion of farmed area and input use levels) on plant and livestock biodiversity (number of locally kept species, and plant genetic resources stored)? Although such issues have been researched locally, in specific regions, this kind of analysis has not been conducted before at the level of the EU to, comparing countries and suggesting policy implications. The experiences about the relationship between agriculture, natural landscape heterogeneity, and biodiversity are controversial; so, the analysis of the European experience is relevant, especially in view of the enhanced environmental awareness in the recent agricultural policy of the EU.

The statistical analysis of secondary data on land use and biodiversity in European countries addressed the two research objectives in the following way. First, significant relationships were looked for between indicators of natural landscape structure—such as forest land cover and permanent meadows and pastures—as dependent variables, and agricultural land use indicators, as independent variables, to see how the latter may influence the former. This analysis was aimed at the first research objective. The second research objective was addressed by analyzing the relationship between biodiversity indicators of livestock and plant breed richness as dependent variables, and the natural landscape and agricultural land use indicators as independent variables. As the analysis included secondary data of these indicators for the countries of the European Union, and for a ten-year period, the results offer a wider spatial and temporal relevance for the region, than previous research results of similar objectives.

The implications of this research can affect not only agricultural land use policy, but are highly relevant for urban planning and urban and regional development. The construction of infrastructure, roads, housing, and industrial developments competes for land with not only agriculture, but also with nature reserves, protected areas, and wildlife, and may endanger natural heritage, particularly in regions of high natural value or in areas affected by degradation and neglect [52].

Theoretical Background of the Present Analysis

To choose relevant indicators for our analysis, the indicator list of the Sustainable Development Goals (SDGs) of the 2030 Agenda is a reliable source [53]. The indicators in Goal 2, and Goal 15 (see Table 1) refer to the physical features of the terrestrial environment, while Goal 14 refers to the physical features of marine and water ecosystems. Table 1 summarizes the indicators that are most relevant for quantifying livestock and plant species richness. As per SDG2, local livestock breeds and local crop varieties are important contributors to agrobiodiversity, and storing the seeds and propagation material in gene banks is an important way of protecting biodiversity and genetic resources, as well as the natural heritage of a region [42]. Therefore the number of local livestock breeds and the number of stored plant genetic resources are relevant measures for our analysis. SDG2 also states, that in maintaining ecosystems the various agricultural practices should be taken into account, therefore the proportion of land used for agricultural production is a relevant indicator influencing the natural vegetation, as well as plant and livestock richness. According to SDG15, the protection of terrestrial ecosystems and biodiversity is measured by forest area—which can be broken down into planted forests and naturally regenerated

forests. In addition to forests, permanent meadows and pastures are also considered to be exceptionally rich in biodiversity, thus representing relevant components of natural heritage [54].

Table 1. SDG indicators related to terrestrial natural vegetation and terrestrial biodiversity (source: authors own construction based on [53]).

Goal Description	Indicator Description
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	
2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters, and progressively improve land and soil quality	2.4.1 Proportion of agricultural area under productive and sustainable agriculture
2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	2.5.1 Number of (*a*) plant and (*b*) animal genetic resources for food and agriculture secured in either medium- or long-term conservation facilities 2.5.2 Proportion of local breeds classified as being at risk of extinction
Goal 15. Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss	
15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.1 Forest area as a proportion of the total land area

Source: [53].

Winquist et al. [28] applied a mixed effects panel model to analyze the influencing factors of plant and bird biodiversity and proved that landscape complexity (measured by the percentage of arable land), and input use type (organic or conventional practice) are significant influencing factors of biodiversity, while random effects were attributed to the regions of Europe. Schelhas et al. [51] showed that changes in both total forest cover and in natural forest cover are also significantly influenced by the proportion of land in agricultural use.

Based on these considerations, our model quantifies the biological diversity of European countries by the number of local breeds kept by unit area, the number of plant resources stored per unit area, and the proportion of forest area and permanent meadows and pastures, as landscape features representing natural vegetation. The factors considered to influence these features are the proportion of agricultural land, and its components,—i.e., the proportion of arable land, and permanent cropland, the indicators of input use, and the share of organic farmland. When building a panel model of these variables, the various countries are considered as random factors, representing the different geographical locations, and economic positions within the EU.

Previous studies have dealt with the relationship between agriculture and biodiversity loss, identifying the negative impact of cropland expansion on natural habitats and the survival of wildlife [22,26,27]. Decreasing proportions of agricultural land were found to be beneficial to the survival of native animal breeds [13]. Heterogeneous landscape structures—i.e., lower proportion of monocultures, and higher proportions of permanent meadows and pastures—were found to support increasing biodiversity, i.e., plant and livestock richness [28]. The positive impact of forest land on biodiversity is also supported by previous research findings [47,48]. Farming practices applying lower levels of chem-

icals were found to enhance the husbandry of traditional livestock, and the richness of plant biodiversity, while high-input, industrial farming was proven to be detrimental to both [4,8,31–34,42].

2. Materials and Methods

2.1. Data

The database contains 27 European countries, i.e., the EU-27 including the UK, but omitting Cyprus for a lack of data. The time span of the analysis was 10 years (2012 to 2021). Table 2 lists the variables and their data sources.

The choice of data to be analyzed is based on the SDG indicators [53], which motivated the selection of biodiversity data about plant genetic resources stored, and local breeds kept or being at risk of extinction. Other relevant studies [51,54] suggested that data on forests and permanent meadows and pastures are relevant indicators of natural vegetation and biodiversity. The inclusion of data on agricultural area, and its classification into cropland, including arable land and permanent cropland is motivated by previous studies [5,28] that refer to these as important indicators of sustainable food production, while the data on farming practices related to input use, such as organic area and land under low or medium input farming are derived from [4,28]. The FAO statistical database [55,56] and the Eurostat database [57] provided the required data for the EU member states for 2012–2021.

Table 2. Variables and data sources (source: authors' own construction based on [55–57]).

Variable Abbreviation	Meaning	Data Source
AgrL	Agricultural land, % of country land area	[55]
OrgL	Agricultural area under organic agriculture, % of agricultural land	[55]
AraL	Arable area, % of agricultural land	[55]
PeCrL	Permanent crops, % of agricultural land	[55]
CrL	Cropland, % of agricultural land, where CrL = AraL + PeCrL	[55]
PeMePa	Permanent meadows and pastures, % of agricultural land, where PeMePa =100 – CrL	[55]
LBrEx	Proportion of local breeds classified as at risk of extinction	[56]
LBrK	Number of local breeds kept in the country/total area (ha)	[56]
PlantR	Plant genetic resources stored (number)/total area (1000 ha)	[56]
For	Forest land as % of the total area of the country	[55]
NatFor	Naturally regenerating forest, % of forest area	[55]
LowIn	Low-input farm area, % of agricultural area	[57]
MedIn	Medium-input farm area, % of agricultural area	[57]

In Table 2, the various land use terms are used according to the FAO definition [9,55]. Arable land is the sum of the areas under temporary crops, temporary meadows and pastures, and land with temporary fallow. Cropland refers to land used for the cultivation of crops, and it is the sum of arable land and permanent crops. Permanent cropland is the land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest.

The analysis is focused on finding relationships between indicators of natural vegetation and biodiversity indicators as dependent variables, and a set of agricultural land use, natural land cover, and agricultural input use indicators, as independent variables, for multiple years (2012–2021) and multiple countries (27 countries). This structure requires a panel regression, including fixed effects (common factors across years and countries) and random effects (different factors between countries and/or years). This approach has been widely used for multivariate, multi-country, and multi-year analyses, including models related to agricultural land use [28,51,52]. The variable structure for the analysis is the following:

Independent variables:

- Land structure variables, describing agricultural land, arable land, cropland, permanent cropland, and area under organic farming: AgL, AraL, CrL, PeCrL, and OrgL. (Note, that CrL = AraL + PeCrL, therefore, to avoid multicollinearity only two of these three variables will be applied in the model).

- Nutrient use and farming method variables and, proportion of farm areas under low input agriculture, and under medium-input agriculture (as the rest is under high-input agriculture): LowIn, MedIn

Variables of natural land cover (either independent, or dependent variables):

- Variables describing permanent meadows and pastures, forests, and naturally regenerating forests: PeMePa, For, and NatFor

Dependent variables of biodiversity:

- Animal and plant heritage variables, local breeds kept, local breeds at risk of extinction, and plant genetic resources: LBrK, LBrEx, and PlantR

2.2. Statistical Analysis Methods

The statistical analysis includes descriptive statistics for all the variables, and correlation analysis between them. The relationship between independent variables (land structure, and nutrient use variables) and the natural land cover variables and biodiversity variables was analyzed using panel regression, for the 10 years (2012–2021) with 27 countries.

Variables were tested for normal distribution, but this assumption was rejected, therefore we used statistics that do not require normality. Thus, the correlations were computed by Spearman's Rho-value, and the panel regression was conducted using the LME4 (Version 1.1-36) package in "R" (Version 4.3.3) [58], which does not require the normality of variables, only that ofresiduals.

The mixed effects modelling of the panel analysis was carried out using the Linear Mixed Model method (LMM) [59] within the framework of the "R" Statistical Software (Version 4.3.3) [58]. The model requirements in the LMM analysis are as follows: the explanatory variables are related linearly to the dependent variable, and, the residual values are of constant variance, of normal distribution, and are independent. The diagnostics for the assumptions were carried out together with the model runs. However, as Schielzeth et al. [60] proved, LMM is a robust procedure, which provides reliable estimates even in the case of minor violations of the assumptions.

The general equation of a panel model is [61]:

$$y(i,j) = a + c(i) + \sum_{k = 1..K} [b(k) + d(i,k)]\, x(i,j,k) + e(i,j), \quad (1)$$

where:

- $y(i,j)$: is the observed dependent variable, with $i = 1...n$ and $j = 1...M$ (e.g., i being the subject and j being the time)
- $x(i,j,k)$: is the value of the observed independent variable k ($k = 1...K$) for K independent variables, for i,j
- a: is the fixed intercept, not depending on i and j
- $b(k)$: is the fixed slope of the independent variable k,
- $c(i)$: is the random intercept, varying by factor i, the subject
- $d(i,k)$: is the random slope, varying by variable k, and factor i
- $e(i,j)$: is the random error

The panel model estimation requires the estimations of a, $c(i)$, $b(k)$, $d(i,k)$ and $e(i,j)$ in Equation (1). This equation gives a general structure of a mixed model, but depending on the number of variables and the length of the data series some simplifications may be necessary.

In our analysis, we have 8–11 independent variables, and 27 countries as subjects, with 10 years of data. This allowed the use of the fullest version of the model. While the

27 countries are taken as random effects, and the other variables were taken as fixed-effect variables, the random effects had to be limited to estimate only random intercepts.

Therefore, our modeled equation contains only with fixed slopes and random intercept, as due to data limitations random slopes cannot be estimated, as in Equation (2):

$$y(i,j) = c(i) + \sum_{k = 1 \ldots K} b(k)\, x(i,j,k) + e(i,j). \quad (2)$$

The actual model structure is the following:

The first step of the analysis was performed with natural land cover variables as dependent variables, and the other land structure and nutrient use variables as independent variables with fixed-effect slopes. Year was also included as a fixed-effect variable. Countries were used as random-effects intercepts.

The second step of the analysis was carried out with the animal and plant biodiversity variables as dependent variables and, land structure variables (including natural land cover variables) and nutrient use variables, as independent variables with fixed-effect slopes. Year is also included as a fixed-effect variable. Countries were used as random-effects intercepts.

Before model specification multicollinearity issues of the independent variables are to be checked. As Table 3 shows, AraL and PeMePa are strongly correlated (their correlation coefficient is −0.95486), and the same is true for AraL and CrL (their correlation coefficient is 0.95775). Therefore, as it was mentioned about Table 2, to avoid multicollinearity in the following panel regression analyses the variable AraL was removed from the independent variables. This move is justified by the fact, that as the variable definitions specify it, CrL = AraL + PeCrL, so keeping CrL and PeCrL in the variable list covers the information content of AraL, too. As by definition CrL + PeMePa = 100 (%), they are also strongly correlated (−0.99996), therefore, PeMePa is also omitted from the independent variables of the regression model, and whenever PeMePa is the dependent variable, then CrL is not included among the independent variables.

As Table 3 shows, there are significant, strong correlations between independent and dependent variables, too. This suggests, that it is reasonable to assume relationships between land use variables, and natural vegetation and biodiversity variables. It is remarkable to observe, that the Year does not present a statistically significant correlation with any of the dependent variables.

Table 3. Correlations between variables of land structure, input use, land cover and biodiversity.

		Land Cover		Animal and Plant Diversity		
	PeMePa	**For**	**NatFor**	**LBrK**	**LBrEx**	**PlantR**
AgrL	0.026	−0.639 ***	−0.398 ***	0.356 ***	−0.118	0.247 ***
AraL	−0.955 ***	0.060	−0.060	−0.130 *	0.094	−0.093
CrL	−0.999 ***	0.056	0.053	−0.127 *	−0.023	−0.059
PeCrL	0.225 ***	−0.149 *	0.461 ***	0.238 ***	−0.282 ***	0.330 **
OrgL	−0.303 ***	0.673 ***	0.081	−0.539 ***	0.124	−0.260 ***
LowIn	0.0212	−0.130 *	0.031	0.072	0.007	−0.164 **
MedIn	−0.057	−0.0900	0.019	0.030	−0.203 **	−0.058
PeMePa	1.000	−0.183 **	0.030	0.262 ***	0.023	0.094
For	−0.183 **	1.000	0.222 ***	−0.551 ***	0.123	−0.267 ***
NatFor	0.030	0.222 ***	1.000	−0.186 **	−0.157 *	−0.342 ***
Year	−0.004	0.018	−0.012	0.021	0.048	0.048

(source: authors' own computation) ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$.

Based on the above, the panel regression equations are set up according to Equation (3), with countries as subjects, and the random effects of them included as random intercepts. As Bates et al. [59] suggest, we start with the most complex model, and then omit insignifi-

cant components step-by-step to arrive to the smallest, but still good model. Therefore, we start our analysis with a full model structure of Equation (3):

$$Y = a1 \times AgrL + a2 \times CrL + a3 \times PeCrL + a4 \times OrgL + a5 \times LowIn + a6 \times MedIn + a7 \times For + a8 \times NatFor + a9 \times Year + country\ intercept \quad (3)$$

where

- Y is one of the following variables: *For*, *NatFor*, *PeMePa*, *LBrK*, *LBrEx*, *PlantR*,
- *NatFor* is omitted from the independent variables when *NatFor* is the dependent variable,
- *For* and *NatFor* are omitted from the independent variables when *For* is the dependent variable,
- *For*, *NatFor* and *CrL* are omitted from the independent variables when *PeMePa* is the dependent variable.

The country intercept differs for each country, so we have 27 country intercepts, resulting in 27 different equations for each dependent variable. When in the full model structure some of the $a1 \ldots a9$ coefficients are insignificant, the next step is to decrease the number of independent variables, keeping only the significant ones in the model, while the goodness of fit remaining as good as in the case of the full model.

3. Results

Figure 1 presents the countrywise values of the most relevant land cover and biodiversity indicators for 2021. Table 4 presents the descriptive statistics of the analyzed variables, and Table 5 presents the final model structures with the significant coefficients.

As Figure 2 illustrates, the fitted values are strongly correlated with the observed ones (panels a, c, e, g, i, and k), while the histograms of the residual values are reasonably close to the pattern of the normal distribution—with occasional outlier values (panels b, d, f, h, j, and l).

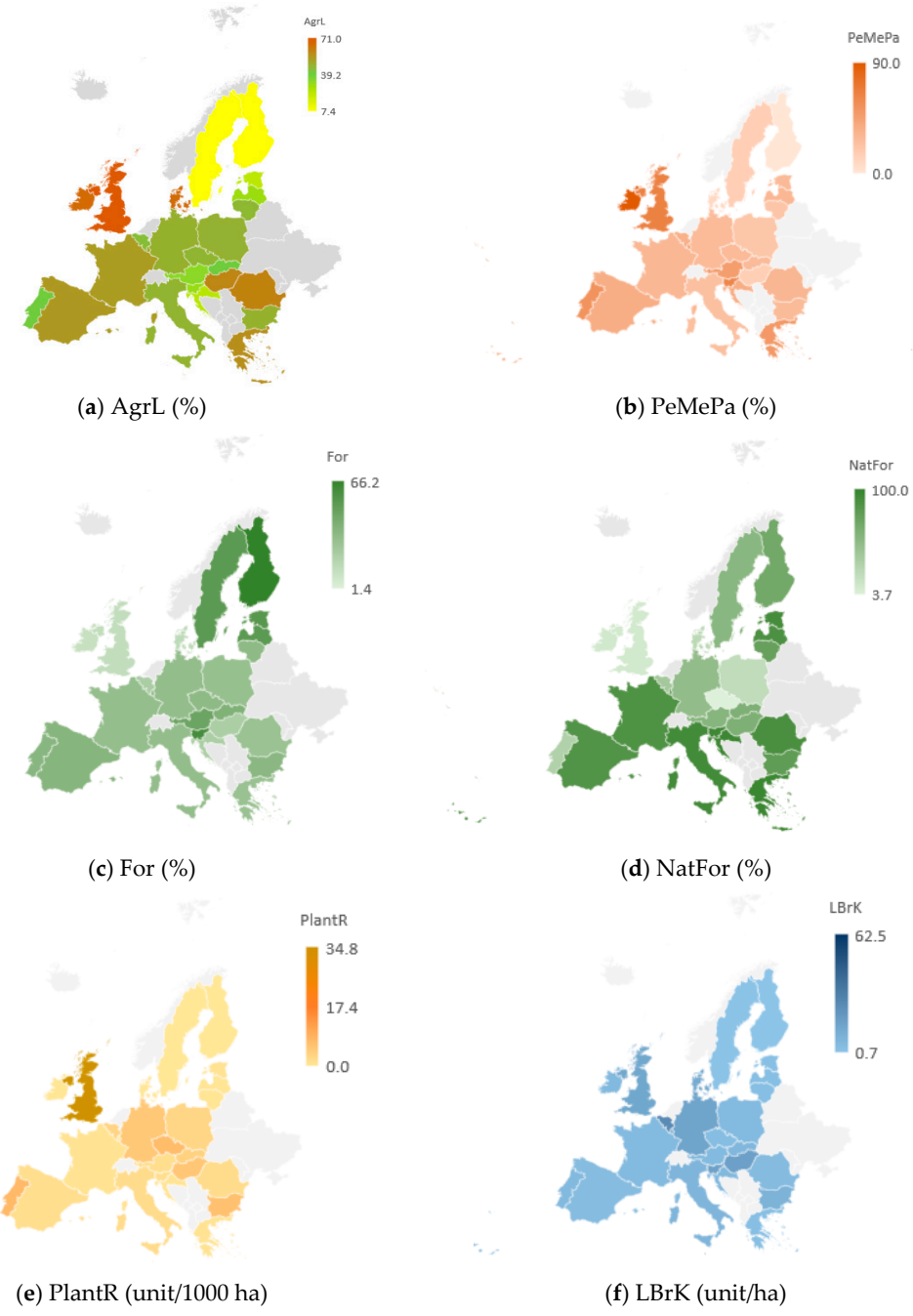
Table 5 and Figure 3 present the coefficients of relationships that are significant at least on the 10% level of significance.

The natural landscape indicators show interesting relationships with agricultural land use.

Table 4. Descriptive statistics of variables.

	Valid	Mean	Std. Deviation	Minimum	Maximum
AgrL	270	43.2944	15.6072	7.4000	72.4000
OrgL	270	8.0430	5.7836	0.1000	26.2000
AraL	270	61.0807	20.8042	9.8000	98.9000
CrL	270	65.9593	19.2799	9.8000	100.0000
PeCrL	270	4.8815	6.4503	0.0000	22.0000
PeMePa	260	35.3531	18.4283	0.9000	90.2000
PlantR	260	3.5451	6.3687	0.0058	34.7784
LBrEx	247	84.6761	11.3482	33.0000	100.0000
LBrK	270	9.9776	12.0000	0.6795	6.2500
For	270	32.5756	15.6054	1.1000	66.2000
NatFor	270	60.7878	30.3226	3.7000	100.0000
LowIn	266	28.2545	11.1813	5.0364	79.0940
MedIn	266	24.5816	6.6858	8.4571	42.6718

Source: Authors' own computation.



(**a**) AgrL (%) (**b**) PeMePa (%)

(**c**) For (%) (**d**) NatFor (%)

(**e**) PlantR (unit/1000 ha) (**f**) LBrK (unit/ha)

Figure 1. Natural heritage values for 2021. (**a**) agricultural area (%), (**b**) permanent meadows and pastures (%), (**c**) forest area (%), (**d**) natural forest area (%), (**e**) plant genetic resources stored (unit/1000 hectare), (**f**) local breeds kept (unit/hectare) (source: authors' own construction).

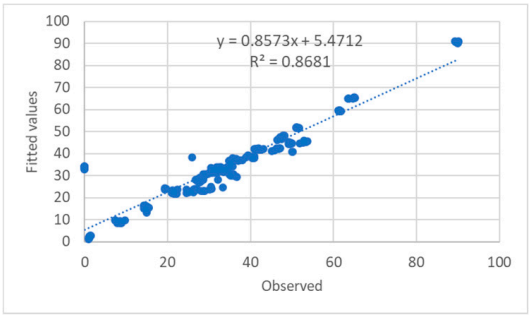
When the share of agricultural land within the total area of the countries increases, it implies a growing share of permanent meadows and pastures within agricultural lands. With the increasing proportion of cropland within agricultural lands, the proportion of forests within the country area also increases. The increasing forest proportion implies that the share of natural forests within the forest area also grows, which means that planted forest share should decrease. This suggests that forest growth is mainly due to natural forest growth. The growing proportion of farmland under low input use also goes together with the growth of the natural forest share within forests. The increase of farmland under medium input use, however, is parallel to a declining forest share within a country, and the increasing share of permanent cropland within agricultural land is parallel to decreasing

shares of permanent meadows and pastures, although at a rate of only 0.231, i.e., 1% increase in permanent cropland reduces permanent meadows and pastures only by 0.231%. As PeMePA + PeCrL + AraL = 100%, it suggests that the share of arable land within agricultural land may increase. Therefore, arable land and permanent cropland seem to expand together, pointing to the spreading of more intensive agricultural practices, and competition with permanent meadows and pastures for land. Finally, year has a positive influence on forests, natural forests, and permanent meadows and pastures, indicating the spreading of more biodiverse landscapes in the EU during the past decade.

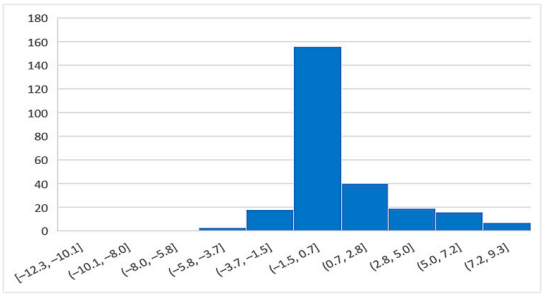
Table 5. Significant fixed slopes of the small models, and random intercepts by country.

Independent	**Land Cover**				**Animal and Plant Diversity**	
Variables (%)	**NatFor**	**For**	**PeMePa**	**LBrK**	**LBrEx**	**PlantR**
AgrL			0.244 ***	−0.0397 **	0.376 +	0.064 **
CrL		0.076 *				−0.056 ***
PeCrL			−0.231 ***	−0.1047 **	−0.812 *	0.292 ***
OrgL				0.0423 ***	0.491 +	
LowIn	0.060 ***					
MedIn		−0.023 *		0.0104 ***		
For	0.316 ***			0.0439 *		0.058+
NatFor						−0.115 ***
Year	0.026 ***	0.015 ***	0.013 ***	0.0058 ***	0.031 ***	0.004 **
Country random intercepts						
Austria	−9.147	14.733	18.495	−8.190	1.006	−3.313
Belgium	−22.599	−9.507	1.113	14.730	9.515	−2.173
Bulgaria	20.264	1.232	−9.413	−3.000	−0.830	5.190
Croatia	39.587	−10.837	6.897	−5.910	4.299	2.097
Czechia	−56.447	1.089	−5.685	−8.790	−6.044	−2.198
Denmark	−24.634	−19.069	−31.087	1.780	−6.306	−4.952
Estonia	22.973	19.962	4.118	−11.000	−8.535	1.649
Finland	−4.443	30.197	−23.207	−14.370	−2.440	0.415
France	27.438	−1.472	−5.530	−5.710	−5.432	−0.157
Germany	−10.047	−0.855	−7.453	2.850	1.209	1.127
Greece	40.812	−1.693	6.017	−6.170	−5.782	−3.759
Hungary	6.342	−11.339	−24.681	4.410	−4.853	2.802
Ireland	−42.502	−16.931	48.978	−4.370	−5.068	−10.700
Italy	36.650	−1.292	−10.427	−3.290	13.069	−1.989
Latvia	19.566	19.506	3.206	−10.780	−9.753	0.404
Lithuania	12.749	0.227	−12.192	−8.720	−2.792	−0.723
Luxembourg	4.810	3.047	13.991	0.430	10.117	n.a
Malta	48.978	−34.236	n.a	53.410	n.a	5.153
Netherlands	−41.699	−22.870	3.334	9.970	12.697	−2.249
Poland	−37.340	−2.986	−14.902	−6.460	2.755	−4.234
Portugal	−25.725	4.830	10.473	−4.470	−9.039	−6.734
Romania	30.441	−3.699	−7.790	−5.410	1.998	1.057
Slovakia	−1.058	5.920	−5.669	−5.920	1.015	1.063
Slovenia	26.765	29.759	27.409	3.880	11.734	−1.699
Spain	28.672	4.919	−7.054	−5.070	−9.862	−4.314
Sweden	−16.550	19.130	−7.836	−13.950	10.508	−1.536
UK	−43.976	−16.518	22.203	3.610	−3.034	22.513
R^2 fitted vs. observed	0.995	0.997	0.868	0.999	0.543	0.996

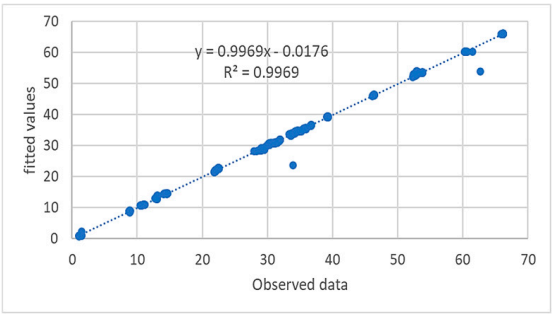
(source: authors' own computation) ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, +: $p < 0.1$; and n.a: data not available.



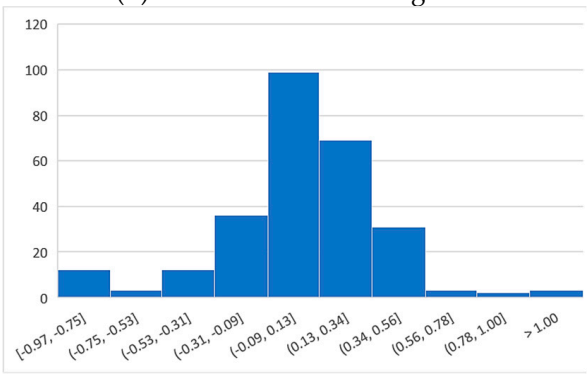
(**a**) *PeMePa* estimation



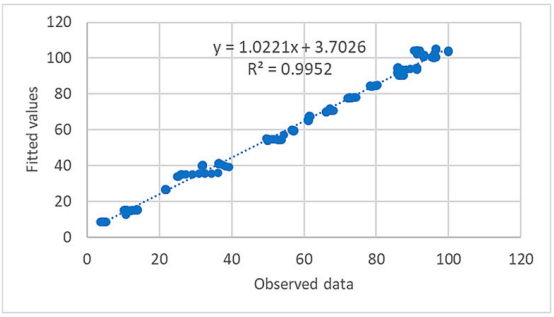
(**b**) *PeMePa* residual histogram



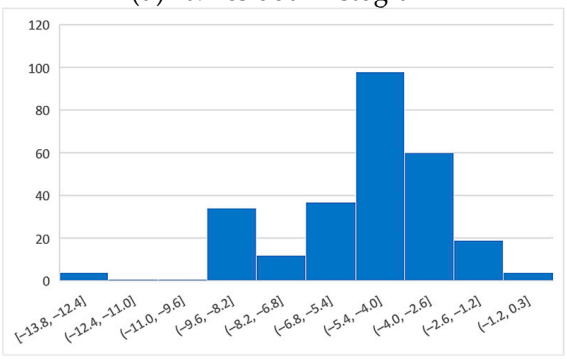
(**c**) *For* estimation



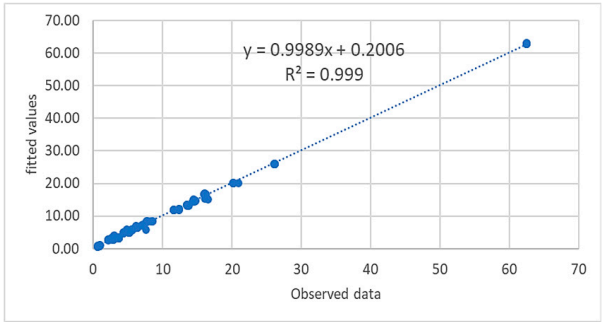
(**d**) *For* residual histogram



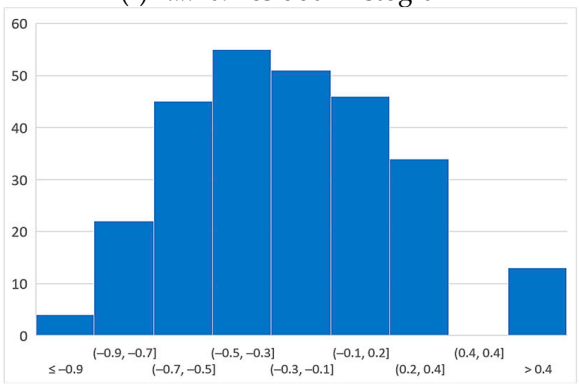
(**e**) *NatFor* estimation



(**f**) *NatFor* residual histogram

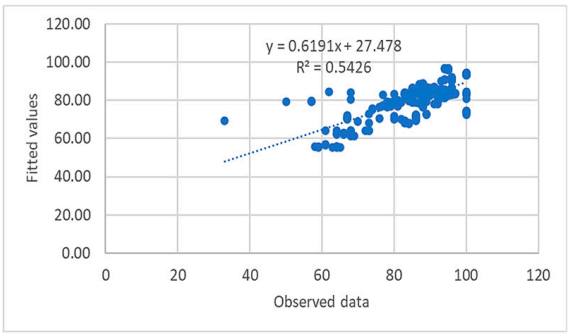


(**g**) *LBrK* estimation

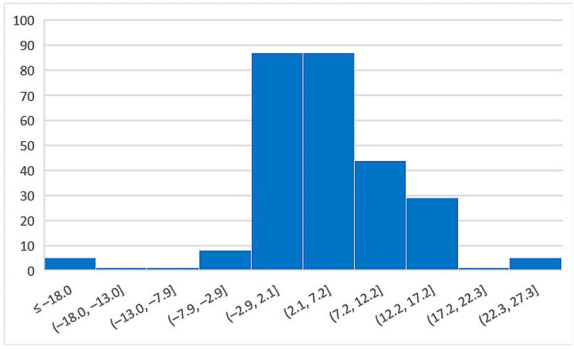


(**h**) *LBrK* residual histogram

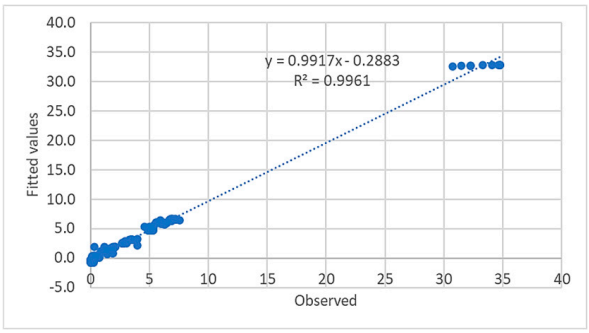
Figure 2. *Cont.*



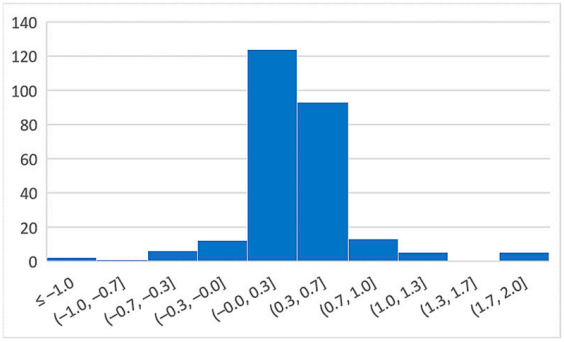
(**i**) *LBrEx* estimation



(**j**) *LBrEx* residual histogram



(**k**) *PlantR* estimation



(**l**) *PlantR* residual histogram

Figure 2. Diagnostics of fitted vs. observed values and histogram of residuals. (**a**,**c**,**e**,**g**,**i**,**k**): fitted vs. observed values for PeMePa, For, NatFor, LBkr, LBErEx and PlantR, respectively; (**b**,**d**,**f**,**h**,**j**,**l**): residual histograms for PeMePa, For, NatFor, LBkr, LBErEx and PlantR, respectively. (source: authors' own computation).

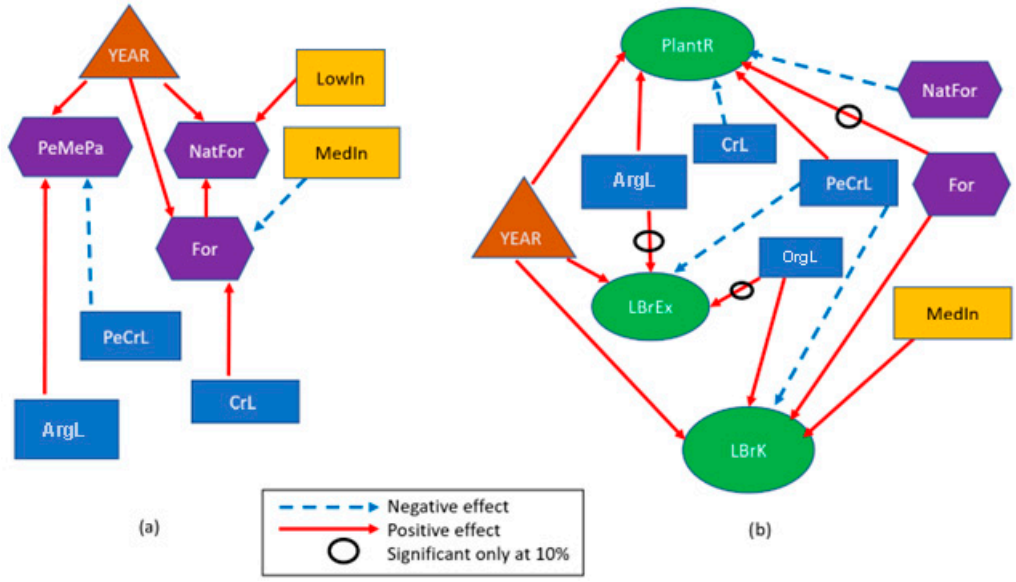


Figure 3. Visual presentation of fixed effects with at least 10% significance level. (**a**) relationship between land use and natural landscape, (**b**) relationship between agricultural practices and biodiversity. (source: authors' own construction).

The plant and livestock biodiversity indicators present a more complex relationship with land use variables. The proportion of agricultural land within the country area positively influences the per-hectare number of plant genetic resources, negatively influences the per-hectare number of local livestock breeds kept, and increases the share of local livestock breeds at risk of extinction. The same holds for the relationship between the pro-

portion of permanent cropland within agricultural land, being beneficial for plant genetic resources, but harmful to local livestock breeds kept. Therefore, agriculture, especially permanent crop farming, seems to be beneficial for plant biodiversity, but harmful for livestock biodiversity. The impacts of the rising share of non-permanent cropland within agricultural land did not influence the per hectare number of local livestock breed kept and were negatively associated with plant genetic resources. As the proportion of cropland is the inverse of the proportion of permanent meadows and pastures within agricultural land, the impacts of permanent meadows and pastures are positive on plant genetic resources are positive, and those on local livestock kept are neutral. This suggests that plant genetic resources benefit both from the expansion of permanent cropland and of permanent meadows and pastures. However, the proportion of local livestock breeds at risk of extinction decreases with the expansion of permanent cropland. The proportion of agricultural land farmed organically had a positive effect on local livestock breeds kept (but also increased the share of them at risk of extinction) but did not influence plant biodiversity. Surprisingly, the input use did not influence plant genetic resources, and the local livestock breeds were positively influenced only by the share of land under medium input use. The positive impact of the proportion of agricultural land under medium input use on local breeds kept also supports this idea, with moderately intensive fodder production requiring medium input use.

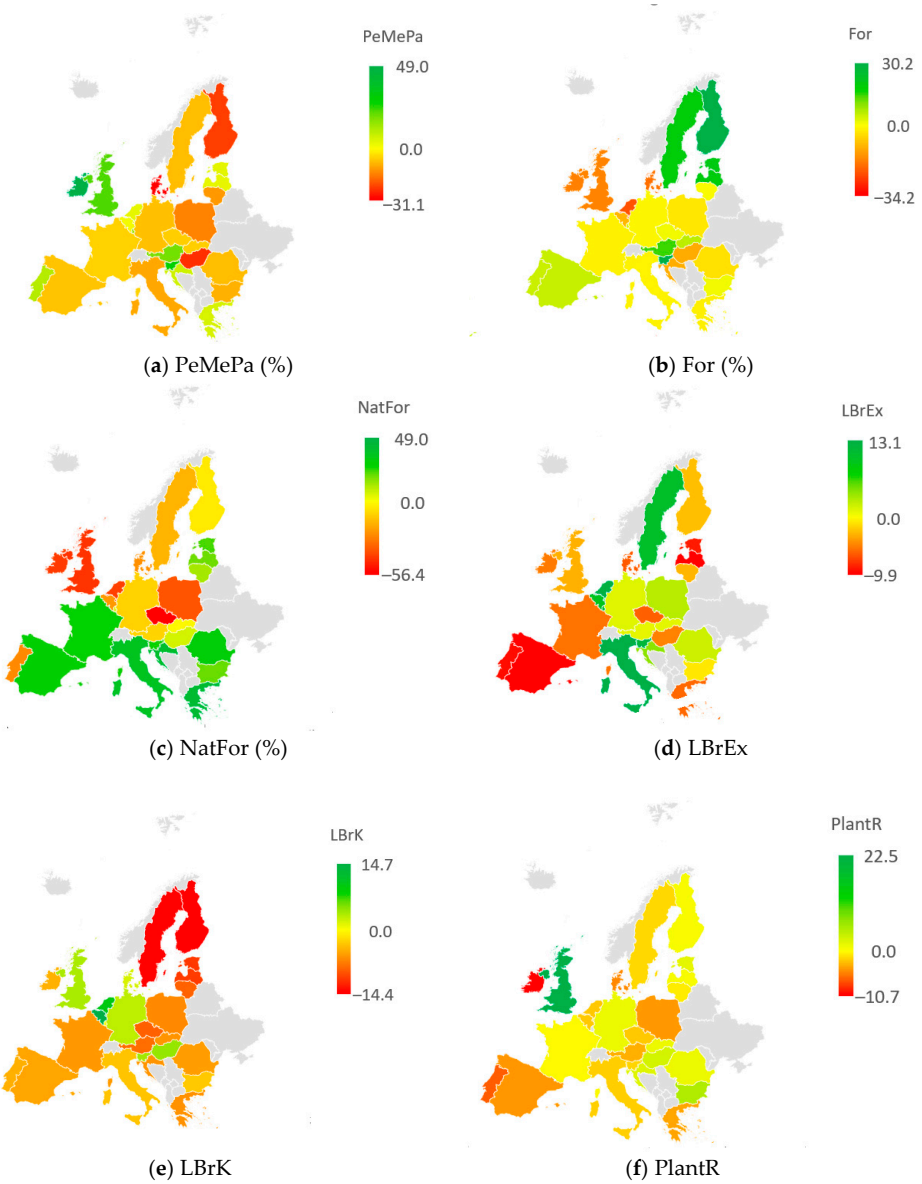
It is also worth noting that the proportion of forests within the country area implies growing plant biodiversity measured by PlantR, although this positive impact is mitigated by the negative impact of the growing share of natural forests. This seems to suggest that planted forests are more beneficial for plant genetic resources, than natural forests, which might be the result of an EU policy of conscious biodiversity-oriented forest plantations.

Time has a positive impact on both livestock and plant biodiversity, though it also positively influences the proportion of local breeds at risk of extinction. Despite considerable active awareness, the loss of local breeds continues to increase.

The country-level random intercepts vary greatly, indicating that although the general impact mechanisms are similar, their actual level differs by country. Figure 4 shows the country-wise differences for the six dependent variables. Higher proportions of permanent meadows and pastures feature the area in Ireland, the UK, Portugal, Austria and Slovenia (Figure 4a, dark green color); on the low proportion side we can find Hungary, Finland and Denmark (red color). According to the forest-related model equation (Figure 4b), the highest values are characteristic of Sweden, Finland, Estonia, and Latvia. Austria (light green) is relatively close to this group, while at the opposite end are the Netherlands, Denmark, the UK, and Ireland—and to a lesser extent, Hungary and Croatia—where the values are low. The proportion of natural forests within total forest areas (Figure 4c) shows high values for countries by the warm Mediterranean and the Black Sea coastlines, such as Spain, France, Italy, Slovenia, Croatia, Greece, Bulgaria, and Romania, and the Baltic countries. On the opposite end, with a low proportion of natural forests, are the UK, Ireland, the Netherlands, the Czech Republic, and Poland. Regarding biodiversity indicators, the largest proportion of local livestock breeds at risk of extinction are predicted for Italy, Belgium, the Netherlands and Sweden, while the lowest ones are predicted for Spain, Portugal, the Baltic states, and Greece (Figure 4d). The number of local livestock breeds kept (Figure 4e) is low for Sweden, Finland, and the Baltic states, while it is high for Belgium, the Netherlands and Germany, the UK, Hungary, and Slovenia. It is interesting to see that for some countries the low number of local breeds kept is accompanied by a low risk of extinction (the Baltic states, Spain, Portugal, and France), and for others, high numbers of local breeds kept go together with high extinction rates (Belgium and the Netherlands), while there is a tendency of having a high risk of extinction with an already low number of local breeds kept in Sweden, Finland, and Italy. Regarding the plant genetic

resources stored (Figure 4f) very high values are seen for the UK, and moderately high values are seen in Bulgaria and Hungary, while the lowest values are seen in Ireland and Portugal, and somewhat in Spain, Greece, Germany, and Austria.

As these figures illustrate, there is no easily recognizable pattern among countries, which points to complex mechanisms at work behind trends of natural land cover, and biodiversity. As an example, both permanent meadows and pastures as well as forests are present in extremely low proportions in Denmark, while the country's agriculture is ranked among the most developed ones in the EU. This might indicate an ongoing deterioration of natural land cover. However, forests, which once covered most of the country, were nearly completely cleared by the early 1800s, and the recent history of Denmark is more characterized by afforestation (restoration efforts). Similarly, the agriculture of the Netherlands is highly developed, while the environmental situation is not outstanding. Behind the actual values different geographical, ecological conditions, and historical processes work to form the present and future of the European Union's natural landscape, and the EU policies have been influencing the state of natural heritage for only in the recent years.



(**a**) PeMePa (%) (**b**) For (%)

(**c**) NatFor (%) (**d**) LBrEx

(**e**) LBrK (**f**) PlantR

Figure 4. Spatial differences according to country intercepts in the model. (**a**) permanent meadows and pastures, (**b**) forest area, (**c**) natural forest area, (**d**) local breeds at risk of extinction, (**e**) local breeds kept, and (**f**) plant genetic resources stored. (Source: authors' own construction).

4. Discussions

The purpose of the present research was to identify parallel trends in natural land cover, livestock and plant biodiversity, and land use practices in the countries of the European Union. In addition, this research intended to quantify the impacts of agricultural land use and input use patterns on plant and livestock biodiversity. As there are abundant research results for various regions and time periods, we intended to pursue a systematic EU-based analysis covering a relatively long time period of 10 years. Our results showed, that the trends and relationships of agriculture, natural land cover and biodiversity are somewhat different from those experienced in the rest of the world. As the recent years show increasing awareness for the need to maintain the environment and natural heritage in the EU policies, the implications of the relationship between agriculture and natural vegetation and biodiversity can reveal the results of this awareness policy as well as the need for further improvements.

4.1. Impacts of Agricultural Practices on Plant and Livestock Biodiversity

Our findings indicate that where agricultural land occupies a larger share in a country, the local animal breeds kept per hectare decrease (although this relationship is significant only at a 10% level), and the share of local breeds at risk of extinction increases. This is similar to previous research results, which show that agriculture is a major factor in biodiversity loss, especially because cropland expansion leads to the loss of natural habitats, and intensification threatens the survival of many species [22,26,27,62]. When primary vegetation took up larger shares of land in forests, or less intensive farming practices were more widespread, local livestock diversity also increased, which is in line with previous results [63–66]. Native breeds are largely threatened worldwide by agricultural intensification, and while the past distribution of livestock diversity was associated with low productivity regions, the current distribution tends to occupy more productive environments, and the highest values of native breed richness are found in areas undergoing farm abandonment processes [13].

The positive impact of the proportion of agricultural land on plant genetic resources seems to contradict the previous research findings [22,26,27], as our results indicate, that larger shares of agricultural land actually increase the number of plant genetic resources stored. However, the negative impact of the proportion of cropland nearly neutralizes this effect, which suggests that it is the spreading of permanent meadows and pastures, that contributes to plant biodiversity within agriculture. This finding is supported by several previous studies, that underline the positive relationship between heterogeneous landscape structures with biodiversity [28,62–64]. As former research states, landscapes rich in biocultural diversity are found in areas where low-intensity small-scale farming prevails, and traditional livestock is kept, utilizing pastures and meadows for grazing [8,31–33,67,68]. The retention of biodiversity in agricultural landscapes is an increasing concern, promoting wildlife-friendly farming, and multifunctional landscapes in Europe [67]. The process of land use change leading to the loss of biodiversity includes the intensification of agriculture, the loss of grazing land to cropland, and the introduction of monocultures, and intensive fertilizer use leads to the loss of species resilience, species extinction, pollution, and degraded ecosystems [68].

Former findings of relevant research also suggest that the agricultural practices associated with low- and medium- input use, less intensive technology, and less industrialized production patterns are beneficial to the richness of the rural landscape [4,34,42,64], while agricultural intensification results in the loss of both plant and livestock biodiversity. Our findings showed the same patterns, suggesting that the proportion of farmed areas under medium input use positively impacts the number of local breeds kept per area. Low input

use was not influential in this context, probably, because this effect was already captured by the impact of organic land use, which was also observed by Tuck et al. [69]. However, this impact was found to be felt on intensively farmed areas, rather than on less intensively farmed ones. As Tscharntke et al. [70] pointed out, organic farming enhances only a limited range of species diversity and may be ineffective on others. This may be the explanation why the organic farmland share was found to influence the local breeds kept but not plant genetic resources.

4.2. Relationship Between Agricultural Practices and Natural Vegetation

In addition to livestock breeds and plant genetic resources the prevalence of natural landscape was also evaluated, by the proportion of forest area and the proportion of permanent meadows and pastures in the total land area of the analyzed countries. Our findings suggest that with more land allocated to agriculture the share of permanent meadows and pastures also increases. The share of agricultural land in itself is not directly linked to the forest share. However, a greater proportion of cropland within agricultural land is associated with larger forest shares in the countries. At the same time, larger forest proportions imply this growth is mainly due to natural forest expansion. This should be good news, considering that natural forests according to the literature, are rich in biodiversity [47,51]. However, our results did not find any relationship between natural forests and livestock numbers, and higher natural forest shares actually decreased the positive influence of forests on plant biodiversity. This somewhat controversial result may be due to the increased awareness of the need to maintain plant biodiversity in Europe [22], which affects forest plantations, too.

The positive relationship between the shares of forest areas and of croplands may be due to the fact, that the cropland share is the inverse of the share of permanent meadows and pastures in agriculture, therefore, when the cropland share grows, the share of permanent meadows and pastures decreases. This means that the spreading of forests is related to the decrease of permanent meadows and pastures in Europe. This is reasonable, as both land use forms are associated with lower quality soils, which are less suitable for crop production, similar to the finding as in [51,54].

The spread of low-input farming is positively related to the proportion of naturally regenerating forests. Both features reflect a growing awareness of environmentally friendly practices and the need to maintain resilience in natural landscapes [54,64]. While higher input use may lead to higher crop yields, requiring less farmland and leaving larger space for forests, more intensive land management practices lead to the loss of resilience in natural landscapes including natural forests [71].

4.3. Spatial Differences and Broader Implications

Although the EU member states widely vary according to their natural vegetation and biodiversity, no easily recognizable spatial patterns can be discerned. Countries with highly developed agriculture, such as Denmark, or the Netherlands, may show low performance regarding their natural vegetation status as is shown by forest areas; others, like Finland, may have low levels of permanent meadows and grasslands but large regarding areas of forests. This may be due to climatic and ecological conditions, and also due to the historical development of their agricultural sectors. Highly developed countries may be low regarding their plant of animal biodiversity, like Sweden and Finland, while less developed ones, like Hungary and Bulgaria may fare much better. Although different country clusters can be formed according to different criteria, such groupings should rather be based on their ecological endowments and the historical evolution of their agriculture, to identify similarities and differences, and find reasonable explanations for these. This

requires considerable additional data collection and analysis, which goes beyond the scope of the present research.

As global studies reveal [72–74] the conflict between biodiversity and the increasing demand for food predicts considerable biodiversity loss, due to the destruction of natural habitats generated by agricultural expansion. The outlook for the end of the 21st century is grim, especially in Central and Latin-America (excluding the Amazonas region), South-East Asia, Central Africa, Siberia, and the Near East. In contrast, the problem is less severe in Europe, North America, Central Asia and Australia. Efforts to mitigate biodiversity loss, including measures such as the establishment of protected areas, and conservation-focused agricultural practices, have already shown good results. However, intensified actions are essential to prevent irreversible damage.

The significance of the present research for regional and global sustainability goals is the quantification of the relationship between agricultural land use and input usage on the one hand, and natural vegetation and biodiversity, on the other. Although low input use seems to be beneficial for natural land cover and biodiversity, the implications have to be considered from the viewpoint of food supply, as low inputs generally imply lower yields. However, this may be offset by larger areas used in agriculture, which are also beneficial for biodiversity. Policymakers dealing with land use strategy must carefully balance the requirements of agriculture and food supply, protection of the environment and natural heritage, and other land use types including residential, commercial, transportation, recreational, and industrial uses.

The results should be viewed by keeping in mind the specific methodology, hindered somewhat by data availability. Due to the large number of countries, and the relatively short time of 10 years, the cross-country variations in the relationships were not possible to assess; thus, we had to rely only on country-level differences as constant mean values. Longer series or analyzing smaller country groups separately could lead to more refined results.

5. Conclusions

Our research shows that the relationship between agricultural practices and components of natural heritage is a relevant research topic. The findings reveal that agricultural land use, and its various components not only have a significant impact not only on plant and livestock biodiversity, but are also related to the natural landscape features, such as forests, or permanent meadows and pastures across Europe.

In Europe, somewhat differently from the rest of the world, larger agricultural areas generally support the preservation of plant genetic heritage but seem to lead to loss of livestock biodiversity. Intensive farming practices and monocultures, particularly the high share of croplands or permanent croplands are important factors in the loss of plant and animal species. In contrast, organic farming, and less intensive input use contribute to the preservation of plant and livestock heritage.

However, when policy measures are introduced to encourage low-input, small-scale farming, policymakers should consider the implications of these on the global food supply and on the livelihoods of rural population. It is a well-known fact [12,14,15], that while intensive and highly specialized large-scale farming can provide high yields and high incomes for farmers, its small-scale, low-input counterparts produce modest yields, and rather low income levels. The common agricultural policy of the EU is trying to balance the requirements of sustainable food supply, rural livelihoods, and the preservation of biological and environmental heritage, but there is still a long way to go to fully achieve the specified targets. Our results indicate a certain improvement in the biodiversity and natural landscape indicators over the analyzed time period. This reflects the growing consciousness of society about the importance of sustainability and environmental resources. However,

the rising proportion of local breeds at risk of extinction indicates that while there is serious concern about conserving natural heritage, the extinction of animal breeds is an ongoing issue that requires further efforts to stop.

The optimal allocation of land between agriculture and construction, allowing for sustainable food production and regional development, is a critical issue in rural development. Rapid spatial and regional development may result in little or no available arable land to be transferred to construction uses, and policymakers have to take this into consideration in urban planning and land use policy [75]. The implications of our research are relevant not only for agriculture, but also for urban planning, urban design, and strategies of urban and regional development, specifically in regions of high natural endowments, and in those suffering from natural degradation and neglect [76].

The limitations of the research are the relatively short time frame, which is determined by data availability, and the geographic range of the European Union. As the threats to the natural landscape and biodiversity are relevant to the whole globe, similar research for other continents is also important, although differences in development level, climate and agricultural structures justify a regionally segmented analysis. Another limitation is the choice of natural landscape and species richness indicators included in the research, and specifically the measurement of biodiversity restricted to local livestock breeds and plant genetic resources, which was set by the availability of secondary data for the EU member states. The analysis also neglects the issue of rural income levels and livelihoods, which could bring opposing interests into the analysis. Another limitation is the rough analysis of spatial differences among countries. Within the context of the present paper this would require further detailed information on the ecological conditions, and agricultural development history of the countries, which is not possible within the context of the present research. These issues are topics for further research.

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