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Spatial and Temporal Changes in Supply and Demand for Ecosystem Services in Response to Urbanization: A Case Study in Vilnius, Lithuania

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Abstract: Intensification of urbanization is changing the supply capacities and demand levels of ecosystem services (ESs), and their mismatch has become a major problem for the sustainable development of urban areas. In this study, spatiotemporal changes of three ecosystem services (food provision, C sequestration, recreation) were quantified and imbalances between their supply and demand were identified in Vilnius County (Lithuania) in 2000–2020. The most significant land use transformation was the increase in forest and urbanized land at the expense of agricultural land. The lowest supply and the highest demand for food, carbon sequestration, and outdoor recreation were in the urban center. The urban land ratio had a negative impact on the provision of ecosystems' services during the study period, most notably affecting food supply. Urbanization indicators—population density and urban land area—showed a negative relationship with the provision of ecosystem services. The balance of supply and demand changed during the 2000–2020 period—the growth of suburbs led to the distance of the supply areas from the city, and the area of the intense demand increased. The results of the study highlight the importance of spatial scale in determining the impact of urbanization on ecosystem functions.

Keywords: ecosystem services; supply; demand; urbanization; spatiotemporal changes; land cover

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1. Introduction

The overall increase in the world's population has been accompanied by an increase in the number of people living in cities. This relatively new phenomenon in modern human history is the main driver of many environmental changes [1]. Urban land development is a dynamic process that irreversibly and rapidly changes land cover and/or land use from natural ecosystems to artificial and built-up areas [2]. As the population has become more concentrated in urban centers, rural areas have become less dense. On the contrary, agricultural land in the suburban areas is being converted into built-up areas. These land cover changes have significant impacts on ecosystem functioning and represent a challenge for optimal land use management and biodiversity conservation [3].

Population growth and densification increase the scale and nature of supply and demand of ecosystem- and non-ecosystem-services (socioeconomic) [4]. The supply of ecosystem services is the ability of the ecosystem to provide a certain service for human well-being, and the demand is the need for these services. In such case, there was a high risk of oversupply and insufficient demand due to the identified differences in the capacity of ecosystems to provide a service compared to its demand [5]. A mismatch between the supply and demand of ecosystem services was in urbanized areas where demand is higher due to high population concentration [6,7]. The more densely buildings and other urban constructions cover the surface, the lower the ecosystem's capacity to provide human well-being [8]. As urban centers grow, the need for recreation opportunities increases. Only rural areas in rural areas or remaining fragments of green urban areas can meet the demands of the urban population. This creates a gradient of supply and demand in rural and urban areas, and the need for recreational areas in the urban center challenges urban planners [9,10].

Urbanization indicators clearly show a negative relationship with the various welfare benefits that people derive from ecosystems. The direct and effective impact of land urbanization on ecosystem functions was demonstrated by the negative linear relationship between land urbanization and total ecosystem services [11]. As urban land area increased, the provision of ecosystem services such as carbon sequestration, grain production, and habitat quality was negatively associated with urbanization indicators such as the night index, GDP, or population [12]. The potential for ecosystem services, especially regulating, supporting, and provisioning services [7,13–15] and health [16], has been greatly reduced by urban sprawl. However, not all ecosystem services have declined with urban expansion. For example, water yield increased with increasing levels of urbanization [12,15] as urban land reduced water retention, evaporation, and infiltration, resulting in a higher total water yield. Some ecosystem services are not directly related to urbanization and reflect different forms of associations. The relationship between provision of ecosystem service and land cover varied greatly across space and time, being both positive and negative [17]. The relationship between food provisioning and urbanization represented an inverted U shape [15]. In some cases, even a very high level of urbanization does not affect the provision of some ecosystem services—even a megalopolis like Shanghai met the desired amount of PM_{10} removal service [7]. Urban planning and sustainable development play an important role in assessing the ES's losses from urban sprawl.

Studies have shown inconsistent and conflicting findings on the relationships, so there is a need for further research on the relationship between the level of urbanization and the provision of ecosystem services. As most studies have focused on megacities e.g., [7,15,18] there is still a lack of research on the effects of a medium-level urbanization process. Metropolitan areas play an increasing role globally, becoming the centers of population and economic growth, but also having a significant impact on ecosystems and resource management. As is common to the post-socialist Central and Eastern Europe, since 1990, Lithuania has experienced rapid suburbanization, where the expansion of urban sprawl is very pronounced. Despite increases in urban spawl, another interesting fact was that since the 1990s, Lithuania lost almost a quarter of its population, and some regions within the country lost more than 50% of their residents [19]. The population has declined in almost the entire country, except for the areas around the largest cities, where metropolitan growth through urbanization has been observed since the early 1990s. Despite population decline across the country, immigration in major urban centers has generally been higher than emigration. Recent studies raised concern about the rapid urban sprawl of the Vilnius urban zone and its consequences, such as deteriorating ecosystem health [16,20]. However, a more detailed analysis of the spatial distribution ecosystem services, its change and supply–demand of ES in the wider Vilnius metropolitan area, including the suburbs, is needed. The aim of this study was to quantitatively assess the spatial and temporal dynamics of three ecosystem services (food, carbon sequestration, recreation) in the Vilnius metropolitan area from 2000 to 2020 and identify the mismatches between their supply and demand.

2. Materials and Methods

2.1. Study Area

Lithuania is located in a mid-latitude climate zone and belongs to the southwestern sub-region of the Atlantic continental forest zone (Figure 1). The average annual temperature is 6.1–6.8 and the average annual precipitation is 610–700 mm. The study area is Vilnius County located in the east of the country around the capital city of Vilnius. Vilnius County is located around the capital of Lithuania, Vilnius, which is the largest of Lithuania's 10 counties in terms of both area and population (30% of the population of Lithuania). The county consists of Vilnius city, its suburbs, and rural areas located farther away from

Vilnius. There are 8 municipalities which are divided into 105 elderships. We used the elderships with census data as the most comprehensive level in our study.

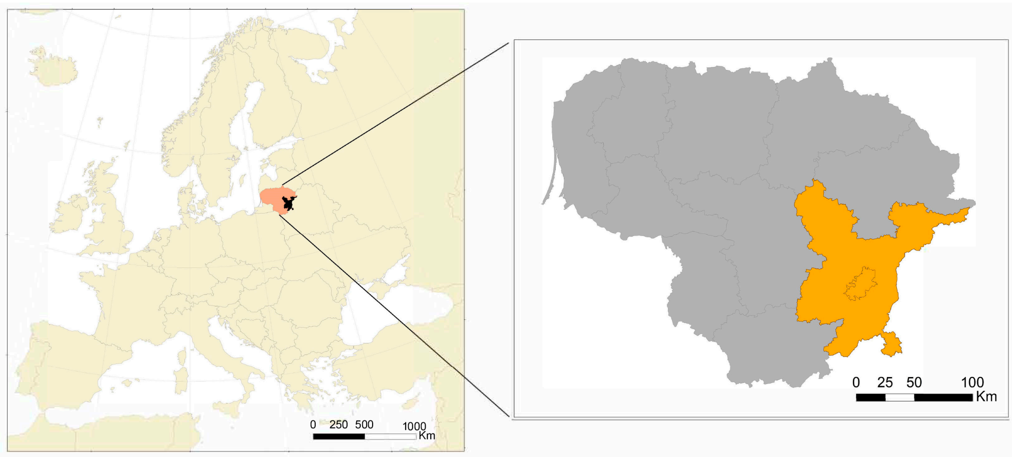

Figure 1. Location of the study area—Vilnius County (orange), Lithuania.

It is the fastest growing city in the region, and it is the only one of Lithuania's major cities where immigration has been higher than emigration and is the second youngest city in the Nordic European countries. The population in the study area decreased by 4.6%, from 850,064 in 2001 and to 810,797 inhabitants in 2021. However, the change was very different in certain regions of the county (Figure 2). Spatial population changes showed that in suburban areas, the share of population has decreased, while in the city center, it has increased, in some cases by more than 150%. This period experienced a large increase in suburban area around the city of Vilnius [21]. At the same time, remote rural areas have lost a significant part of their population, thus inflicting changes in land use as well as ES flows in the county.

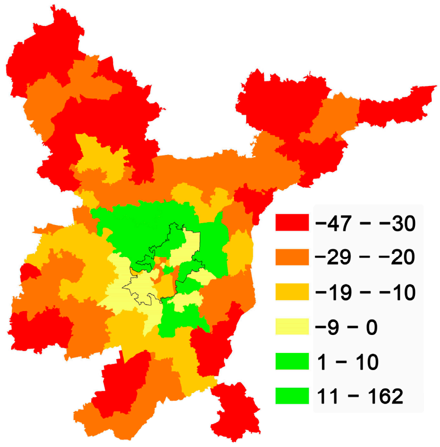

Figure 2. Population change (%) in elderships of Vilnius County, Lithuania from 2001 to 2021.

2.2. Mapping LULC Changes

Land use/land cover (LULC) was obtained from the 2000 and 2018 CORINE datasets. The CORINE dataset is the most comprehensive European land use database which uses remote sensing to classify different LULC types [22]. Its precision is 25 ha. There are 44 LULC classes in the dataset, which were grouped into 5 main classes for this study: urban; agricultural; forest; wetland; water (Figure 3). The dynamics of each LULC type was calculated as the difference of a certain LULC area at the start and the end of the study period, expressed in hectares. The percentage change of LULC type area from the total study area (%) was also calculated.

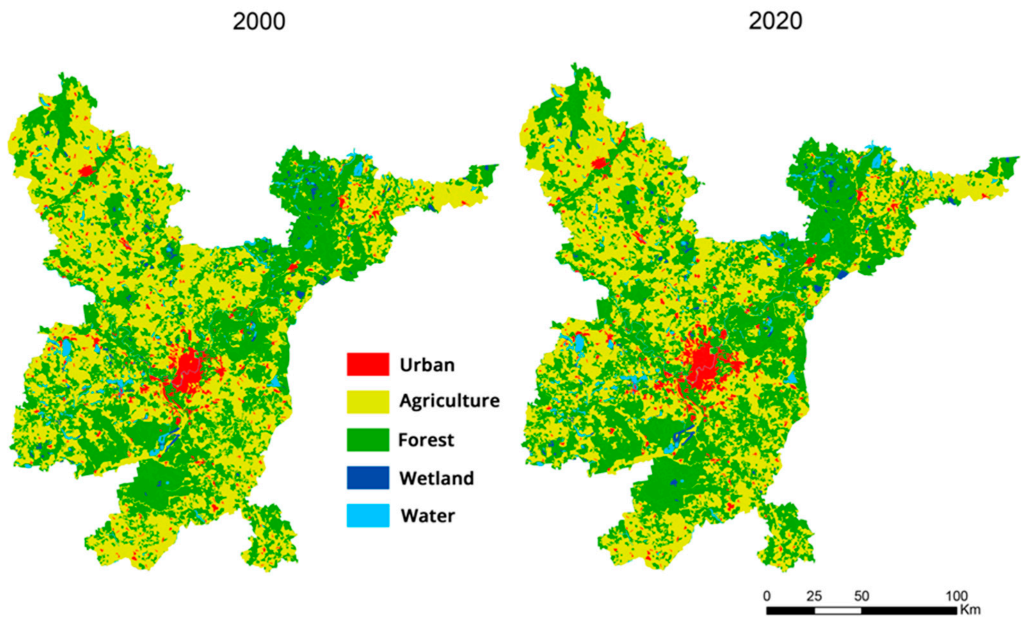

Figure 3. LULC in Vilnius County in 2000 and 2020.

2.3. Mapping Ecosystem Services

Three ecosystem services—food, carbon, and recreation—were quantified out at the eldership level in 2000 and 2020. These services were selected to represent different types of ecosystem services: provisioning (food), regulating (carbon), and cultural (recreation). The data required for the assessment of ecosystem services (population, CO_2 emissions, grain production) were obtained from the Lithuanian official statistics portal (https://osp.stat.gov.lt (accessed on 1 February 2024)). The data for 2000 reflects the post-independence situation, when societal and economic changes began. The year 2020 was chosen to reflect more recent changes such as increasing urbanization.

Since the capacity of an ecosystem to provide ecosystem services depends on its use, we used land use patterns to assess the supply and demand for ecosystem services. The main data we used to assess the ESs, together with their data sources and descriptions, are presented in Table 1.

Table 1. Data and methods used to map supply and demand for ecosystem services.

Services	Year 2000		Year 2020	
	Supply	**Demand**	**Supply**	**Demand**
Food	Eldership LULC (CORINE 2000) grain production in the municipality (2000): recalculated from municipality to eldership according to arable land area	Grain consumption in Lithuania (2001): per eldership according to its population	Eldership LULC (CORINE 2018) grain production in the municipality (2018): recalculated from municipality to eldership according to arable land area	Grain consumption in Lithuania (2021): per eldership according to its population
Carbon sequestration	Eldership LULC (CORINE 2000)	CO_2 emissions per capita (2005) in Lithuania: per eldership according to its population	Eldership LULC (CORINE 2018)	CO_2 emissions per capita (2020) in Lithuania: per eldership according to its population
Recreation	Eldership LULC (CORINE 2000)	Population density of the eldership (2001)	Eldership LULC (CORINE 2018)	Population density of the eldership (2021)

2.3.1. Mapping Food Supply and Demand

The total grain yield of each eldership in Vilnius County was used as its food supply. Food demand was estimated as the per capita consumption of grains in Vilnius County in a given year [18]. The supply and demand of the food ecosystem service (FES) was calculated as follows:

$$S_i^{FES} = I_i \tag{1}$$

$$D_i^{FES} = POP_i \times A \tag{2}$$

where S_i^{FES}—the supply of FES in eldership i, I_i—the grain production in eldership i, D_i^{FES}—the demand of FES in eldership i, POP_i—the number of residents in eldership i, and A represents the per capita consumption of grains in a given year.

2.3.2. Mapping Carbon Sequestration Supply and Demand

Carbon sequestration was quantified from the LULC data based on the carbon storage capacity of each land use type [3]. Carbon sequestration demand was estimated based on the carbon emissions data for each eldership of Vilnius County for the years 2000 and 2020. We assumed that larger emissions equate to a higher demand for carbon sequestration. The supply and demand for carbon sequestration ecosystem service (CSES) was calculated as follows:

$$S_i^{CSES} = \sum CS_{LULC} \times AREA \tag{3}$$

$$D_i^{CSES} = E_i \tag{4}$$

where S_i^{CSES} is the supply of CSEC in eldership i, CS_{LULC} is the carbon sequestration capacity of each LULC type, AREA is the area of each LULC type in the eldership i, D_i^{CSES}—the demand of CSES in eldership i, E_i represents the annual carbon emissions in the eldership i.

2.3.3. Mapping Outdoor Recreation Supply and Demand

The capacity of ecosystems to provide recreational opportunities was considered a service provided by outdoor recreation. Outdoor recreation ecosystem service supply was calculated by LULC type. First, LULC classes were categorized by their recreational potential, then total area of LULC with a coefficient of 7 or above was calculated for each eldership [3]. We defined the potential demand for outdoor recreation as everyone's basic right to connect with nature. For that purpose, we used the optimal area of 50 m^2 of green space per capita which is considered an ideal amount of urban green space per individual [23]. Outdoor recreation demand was calculated by multiplying the population of each eldership with the recreational optimal area. Supply and demand for carbon sequestration ecosystem service (RES) were calculated as follows:

$$S_i^{RES} = \sum RS_{LULC} \times AREA \tag{5}$$

$$D_i^{RES} = POP_i \times 0.005 \tag{6}$$

where S_i^{RES} is the supply of carbon sequestration ecosystem service in eldership i, RS_{LULC} is LULC type considered suitable for recreation, D_i^{RES} represents the demand for outdoor recreation ecosystem service in eldership i, POP_i represents population in the eldership i.

2.3.4. Ecological Supply and Demand Mismatch and Ratio

The mismatch between the supply and demand of ecosystem services was calculated by subtracting the value of estimated ES supply from the demand value at the eldership level. Positive values indicate that the demand for ES in the eldership was met, while negative values indicated that the ecosystem services provided did not satisfy the demand in the eldership. After evaluating the mismatches between supply and demand, it allowed us to determine their differences during the studied period (2000 and 2020).

We used the ecological supply and demand ratio (ESDR) and comprehensive supply–demand ratio (CESDR) to indicate surplus or deficit of a given ecosystem service and determine the status of all ESs considered, respectively. The ratios were calculated as follows [7]:

$$ESDR = \frac{S - D}{(S_{max} - D_{max})/2} \quad (7)$$

$$CESDR = \frac{1}{n}\sum_{i=1}^{n} ESDR_i \quad (8)$$

where S and D are the actual supply and demand for a given ES, respectively; S_{max} and D_{max} refers to the maximum value of supply and demand for a particular ES and year, respectively; n is the number of ESs (n = 3); $ESDR_i$—ecological supply–demand ratio of a given ES.

2.4. Data Sources and Analysis

Statistical data such as population, grain production, GDP, and CO_2 emissions were obtained from the State Data Agency of Lithuania. Census data from 2001 and 2021 were used to estimate the population in the municipality. Population density was measured as the number of inhabitants per unit area of the ward (km^2). The distance from the Vilnius city center to the center of each eldership was calculated as the length of a straight line between these points (km).

Regression analysis was used to indicate trendlines between the supply and demand ratio (ESDR, CESDR) and a certain land use ratio (urban and forest land ratio) for 2000 and 2020. Urban/forest land ratios were calculated as area of urban/forest lands divided by the total land area. Pearson correlation analysis was used to represent relationships between ecosystem services and urbanization indicators (population, natural capital, and urban land ratios). Statistical analyses were carried out using the R statistical software version 4.1. Spatial data were analyzed using ArcMap 10.7.

3. Results

3.1. Land Use Change

Between 2000 and 2020, the area of agricultural land (cropland and grassland) decreased by 49,469 ha (5.1% of the total area, Table 2). The rate of decline in agricultural land was 2473 ha per year. Forest and urban areas increased by 43,432 ha (4.5%) and 5192 ha (0.5%), respectively. The rates of change in forest and urban areas were 2172 ha and 260 ha per year, respectively. The area of wetlands increased by 6% over the period under study (Table 2).

Table 2. Land use changes in Vilnius County from 2000 to 2020.

LULC	Area (ha)		% of Total Area		Change from 2000 to 2020	
	2000	2020	2000	2020	ha	%
Urban	34,296	39,488	3.5	4.1	5192	0.5
Agriculture	496,372	446,903	51.1	46.0	−49,469	−5.1
Forest	412,848	456,280	42.5	47.0	43,432	4.5
Wetland	8397	8909	0.9	0.9	512	0.1
Water	19,785	20,118	2.0	2.1	332	0.0

The most significant land use transformation involved the conversion of agricultural land to forest and a relatively small area of urbanized land (Figure 4). Most of the forest area has been converted to agricultural land. A similar proportion of forest was converted to wetlands and, conversely, a small proportion was converted from wetlands to forest.

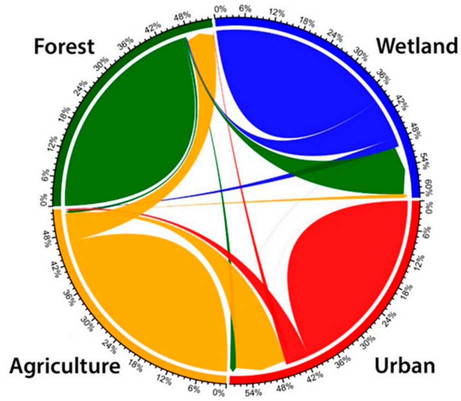

Figure 4. Conversion from one land use type to another (%) in Vilnius County from 2000 to 2020 (only the part of the land that has undergone change is shown).

Spatial changes in land use by type were most pronounced in urban and forest areas. The urban area has increased the most around Vilnius city itself, reflecting suburban development. Conversely, the urban area decreased mainly in the elderships further away from Vilnius. Forest cover has increased in most of the elderships, except in the most densely populated ones of Vilnius city. The area of agricultural land decreased in all elderships, mostly replaced by forests. No spatial trends in the area of wetlands and open water bodies were identified.

3.2. Ecosystem Service Change

The average value of food supply was 0.16 tons per ha in 2000 and 0.24 ton per ha in 2020 (Figure 5). The total food supply in Vilnius County increased from 0.18 million tons in 2000 to 0.27 million tons in 2020. The largest surplus of food supply was in the elderships located in the northwestern part of the County. Vilnius city and suburbs had the lowest values of food supply (Figure 5).

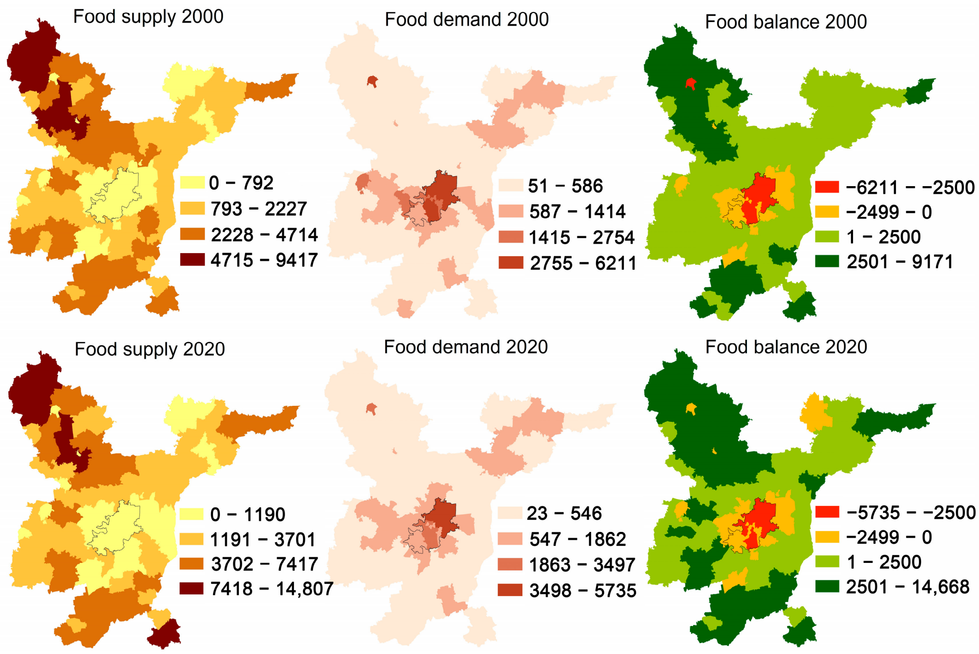

Figure 5. Spatial distribution of food provision service (tones per year)—supply (**left**), food demand (**middle**) and mismatch (**right**) in Vilnius County in 2000 and 2020.

Food service demand showed a decrease of 18.2% from 0.11 million tons in 2000 to 0.09 million tons in 2020. The average value of food demand decreased from 1.15 to

0.92 tons per ha during this period. In 2000, one third of the elderships (32 out of 105) could not meet their food demand and the proportion of elderships with food demand in 2020 increased to 32.4%. During this period, food demand decreased mainly in 94% of the territory. Most of the elderships unable to meet food needs were in the city and the surrounding peri-urban area, where a negative food supply balance was identified (Figure 5). In the elderships further away from the city, most rural districts were able to meet the food demand. The largest surpluses of food stocks were found in the communes located in the northwestern part of the county.

The average value for carbon storage per ha increased from 12.16 tons per ha in 2000 to 13.05 tons per ha in 2020 with a rate of about 0.04 tons per ha every year. The total service supply increased from 13.56 million tons in 2000 to 14.56 million tons per ha in 2020 in the county. The carbon sequestration has increased in most of the study areas (89%). The highest carbon sequestration values were in the most heavily forested elderships farther away from the city center (Figure 6). The city center tended to show the lowest values of carbon sequestration.

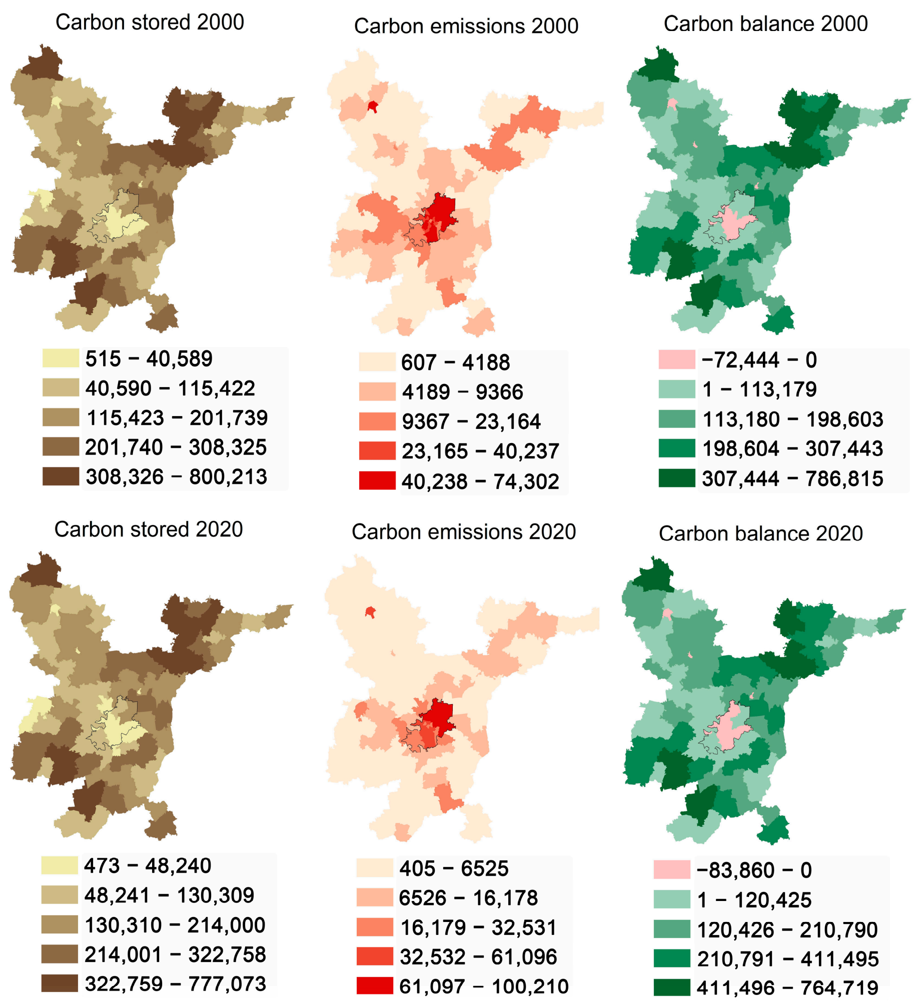

Figure 6. Carbon sequestration (**left**), carbon emissions (**middle**) and mismatch (**right**) in Vilnius County in 2000 and 2020 (tones per year).

Between 2000 and 2020, there was a slight increase in carbon emissions—from 116,546 in 2000 to 123,380 in 2020. Carbon emissions increased, as did sequestration in most of the study areas (70%). Carbon sequestration demand decreased in 2000, 21 out of 105 elderships could not meet their carbon sequestration demand, and the number of such elderships has increased by only one by 2020 (Figure 6). All these elderships were located in urban areas, in the city center and smaller towns across Vilnius County.

Outdoor recreation supply values remained stable over time, with an average value of approximately 0.73 million ha. Recreation supply has increased in half of the study area and decreased in the other half. In the city center area, outdoor recreation had the lowest values (Figure 7). In other parts of the area, medium and high recreational values were unevenly distributed, with the highest values in the areas furthest away from the city center, where the largest areas of forest were located (Figure 7).

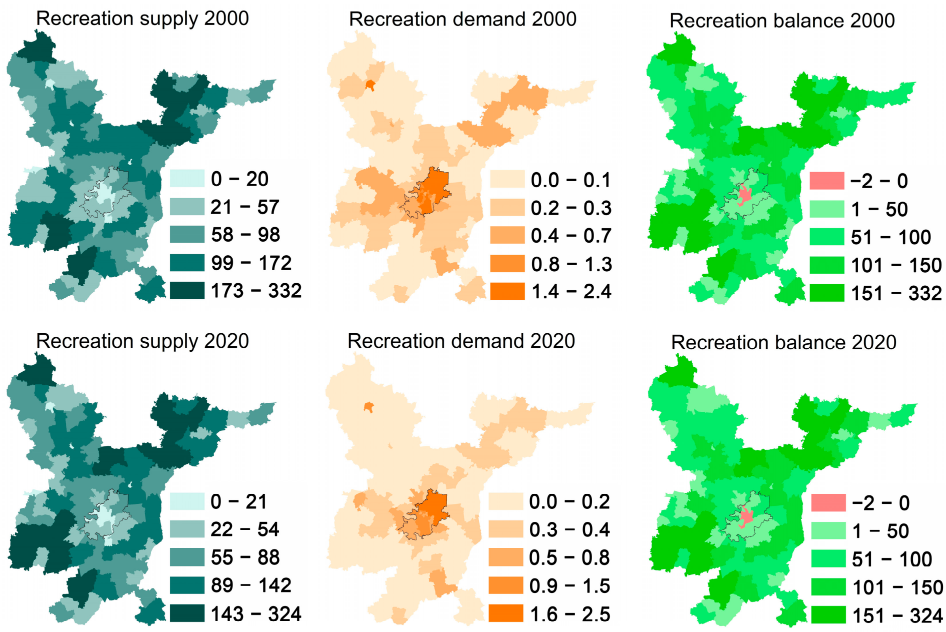

Figure 7. Outdoor recreation service (km^2): supply (**left**), demand (**middle**), and balance (**right**) in Vilnius County in 2000 and 2020.

The demand for outdoor recreation showed a decrease between 2000 and 2020 from 4221 ha to 4054 ha. Over the same period, the number of elderships unable to meet the demand for outdoor recreation was stable (10%). All of these elderships were located in the city of Vilnius, mainly old inner-city neighborhoods with a high population density (Figure 7). Demand for outdoor recreation has declined over the study period in almost the whole area (90%).

3.3. ES Supply–Demand Mismatches

The spatial distribution of food provision service showed a mismatch according to the supply and demand ratio (Figure 8). Lower food supply and higher food demand in the city center led to a shortage and a negative supply–demand ratio. The food supply–demand ratio increased with the distance from the city center: elderships within 20 km had a negative balance of food supply, while more rural areas had a positive ratio (Figure 8). The average balance has increased due to an increase in food supply in 2020 compared to 2000 by 0.72 million tons.

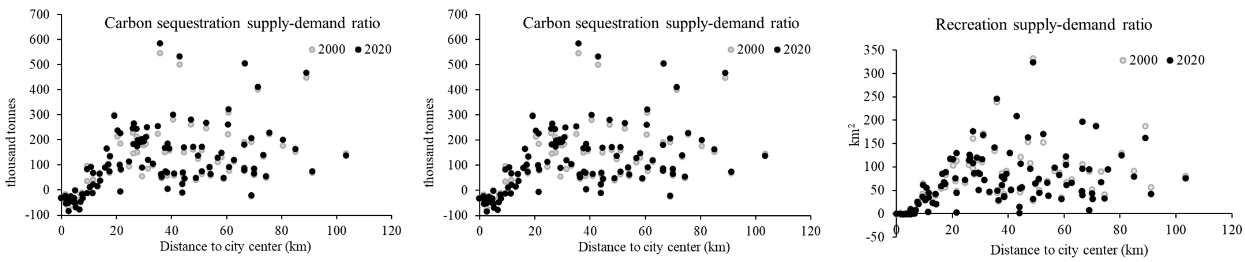

Figure 8. Mismatches between food (**left**), carbon sequestration (**middle**), and recreation (**right**) supply and demand in Vilnius by distance from the city center (km) in 2000 and 2020.

In Vilnius city and its suburbs (up to 20 km from the city center), the carbon sequestration balance was significantly lower compared to more distant areas, where a surplus of 150–200 thousand t of carbon sequestration in the supply–demand ratio was determined (Figure 8). The elderships close to the center of the city had the lowest balance between the supply–demand ratio for outdoor recreation (Figure 8). In those areas 20 km or more from the city center, the surplus of supply–demand for outdoor recreation was between 70 and 110 km^2. The balance of supply–demand for outdoor recreation has remained stable between 2000 and 2020, despite a slight decrease in demand.

Most rural areas could meet their ecosystem service needs. Conversely, many Vilnius urban and suburban elderships had at least one ecosystem service for which they could not meet the demand (Figure S1). Thus, they would have to compensate for this from other regions. Comparing the temporal changes in the ES supply–demand ratio in 2000 and 2020, there was one more eldership in 2020 where there was a mismatch between supply and demand.

3.4. Influence of Land Use Change on ESDR and CESDR

The urban land ratio had a negative influence on the provision of ecosystems services over the study period—the highest values of ESDR were under the lowest area of urban fabric. The highest decrease in service provision with the increase in urban area was characteristic for food supply. The forest land ratio had a positive influence on recreation service and carbon sequestration provision, with a minimum effect on the food supply service (Figure S2). The increasing urban land ratio had a negative impact on the CESDR ($p < 0.001$) and explained about 60% of the variability in 2000 and 2020. In contrast, the proportion of forest land had a positive impact on the CESDR and explained 40–42% of the variability. The proportion of variance in CESDR explained by the urban and forest land ratio was not changed during the study period (Figure 9).

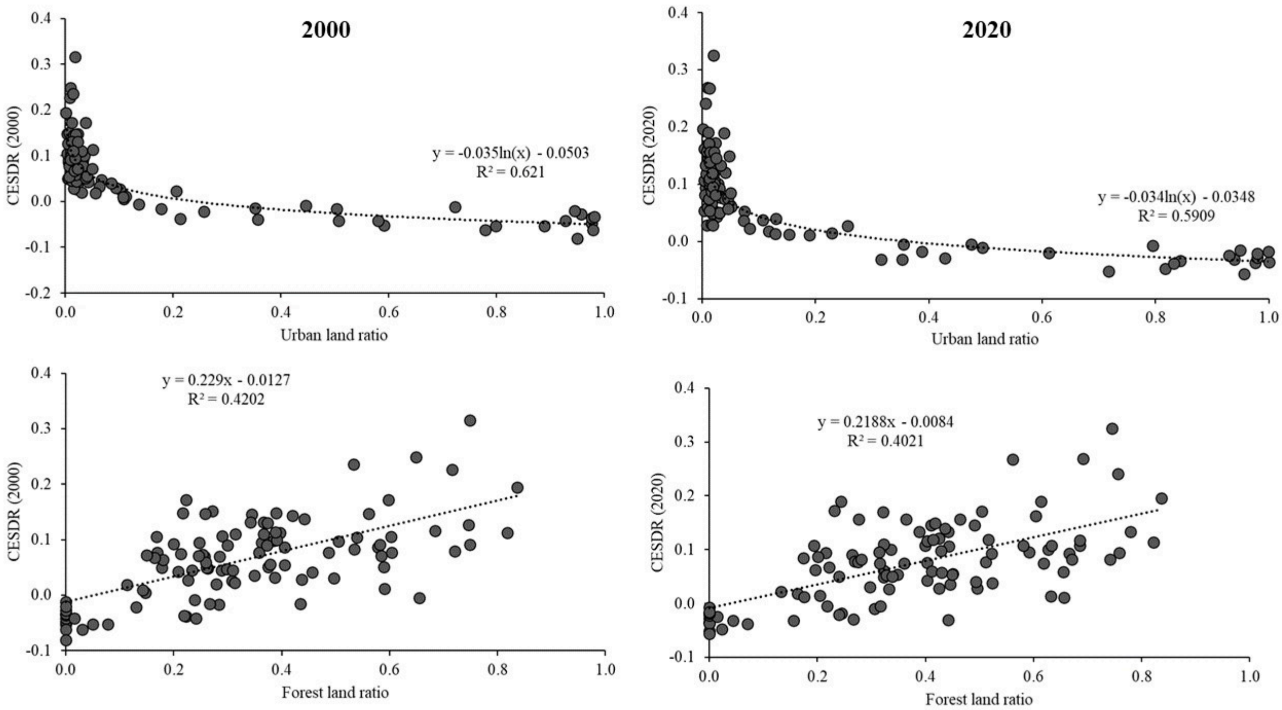

Figure 9. Influence of urban land (**upper**) and forest land (**bottom**) ratios on comprehensive supply-demand ratio (CESDR) in Vilnius in 2000 and 2020.

3.5. Relationship between ESs and Urbanization Indicators

Population was significantly positively related to the increase in urbanized areas (Figure 10). With the increase in distance from the city center, the population density and urban land ratio increased. The correlation analysis showed significant relationships between ESDR and urbanization indicators. The provision of all ESs increased with the distance from the city center with the most significant effect on food provision. Other urbanization indicators—population density and urban land area—showed a negative relationship with carbon sequestration, food provision, and recreational activity. The negative relationship between urban and natural capital increased from 2000 to 2020. Also, the relationship of all ecological indicators strengthened with the distance from the city center during this period (Figure 10).

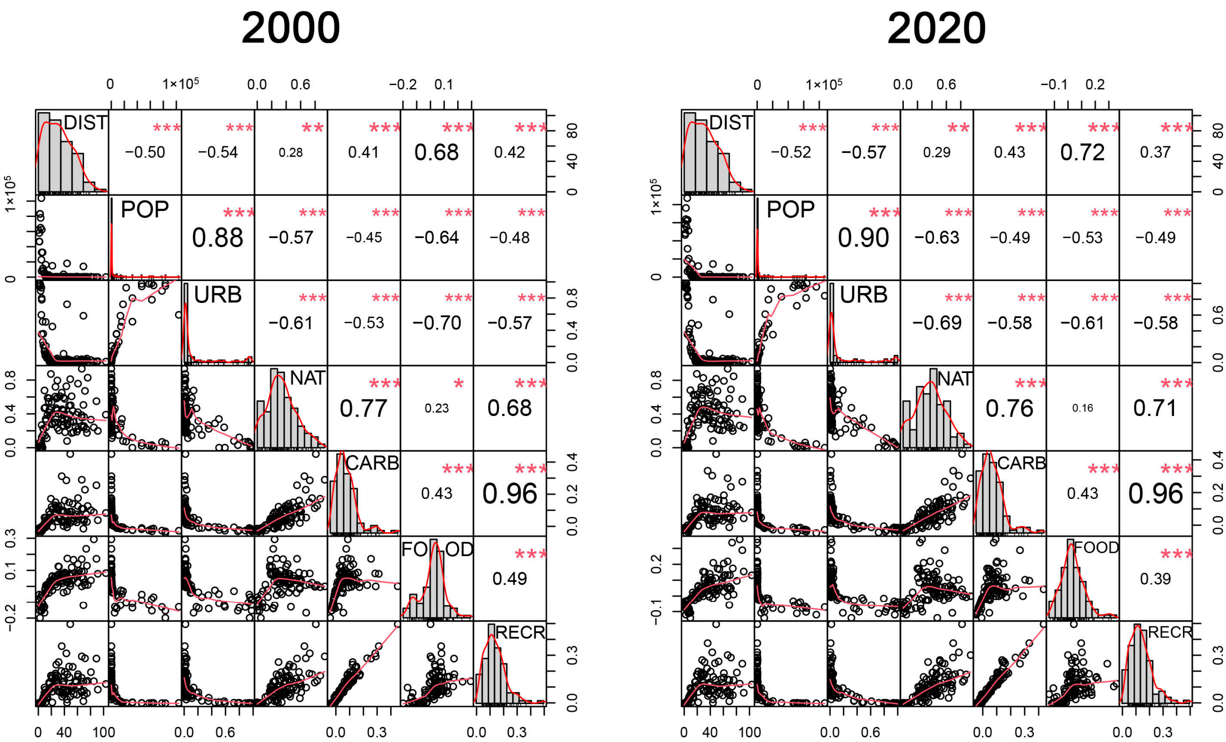

Figure 10. Relationship and fitting curves between ESs (CARB—carbon sequestration, FOOD—food provision, RECR—recreation) and urbanization indicators (DIST—distance to the city center, POP—population density, URB—urban land ratio, NAT—natural capital ratio (including forest, natural grassland, wetland, water). *—$p < 0.05$, **—$p < 0.01$, ***—$p < 0.001$.

4. Discussion

The contribution of the supply of ecosystem services to the public demand was determined in the case of Vilnius County, which is associated with changes in land use related to urbanization during the two decades. The main land use changes were related to the conversion of agricultural land to forest and urban areas. Even though the expansion of the urbanized area was relatively small, the population density increased significantly in the city center. Regarding ecosystem services, the results of the study showed that Vilnius County meets the needs of recreational services, but there are discrepancies between C sequestration and food supply services.

The highest changes in service provision were characteristic for food supply. The food supply has increased over the past along with significant land use changes, such as the conversion of agriculture land to forest and expanded urban areas. Previous studies have shown that the loss of agricultural land dying to urban sprawl did not have a significant effect on overall food production [24,25]. The total increase in food supply despite the reduction in agricultural land indicated that food supply is being ensured using a lower quantity of arable land and modern tools and technology [26]. This is particularly important for achieving greater agricultural efficiency, especially in those areas where the expansion of cultivated land will not be possible [27] and especially when predicting an increase in food demand in the future [28]. On the other hand, the decreases in population led to a decrease in the food demand but did not allow for balancing the relationship between food supply and demand in Vilnius County. Despite the decrease in food demand and increase in supply during the study period, the negative supply and demand balance remained. The provision of food was negatively influenced by the ratio of urban land—the ESDR values of the ecological supply–demand ratio were negative at the largest area of the urban fabric. This finding was consistent with the results showing food availability increasing with distance from the city center [29] and confirmed that urbanization has a significant and positive impact on food insecurity [30]. This could be explained by the loss of potential yields due to the conversion of productive land into unproductive land under the urbanization process [31]. This is also reflected in the general trend, which showed that during the period of 2005–2016, the area of agricultural land in Lithuania decreased [32].

The observed increase in C sequestration during the study period was also confirmed by the results of a study conducted in the Beijing metropolitan area that urbanization has a positive effect on C sequestration capacity [33]. However, it is generally argued that urbanization negatively affects the provision of this ecosystem service [34] by reducing the carbon sequestration capacity of vegetation due to soil compaction, low microbial activity [35], and low organic matter input [36]. As trees play an important role in carbon storage and sequestration—acting as CO_2 absorbers, fixing carbon during photosynthesis, and storing excess carbon as biomass—changes in forest cover are primarily responsible for providing this service. Although urban trees have been suggested to make a small contribution to C sequestration, offsetting the annual CO_2 emissions of cities [7,37,38], the reduction in forest area in the urban center found in our study further reduced this contribution. This was confirmed by the positive effect of forest land ratio on the provision of carbon sequestration. Agricultural land is traditionally considered a source of CO_2 due to disturbance and fertilizer use [39], but in our study, land conversion from agricultural to urbanized areas did not reduce CO_2 emissions. In general, the mismatch between supply and demand for this service increased with urbanization, indicating the loss of carbon storage in the study area during the last two decades.

Both supply and demand for recreational services have changed little during the study period. However, the data showed that the city of Vilnius was characterized by a high provision of recreational service, which confirmed that the accessibility of the population covered by the city's recreational green spaces was high in Vilnius [10]. The analysis of spatial data carried out between 1990 and 2012 showed that the relatively small decrease in greenery over time (0.53%) was determined in Vilnius, which indicates it as one of the greenest European cities with a sufficiently high recreation potential [40]. Research shows that many premature deaths in cities could be prevented by increasing exposure to green spaces, while contributing to sustainable, livable, and healthy spaces [41].

The increasing proportion of urban land has had a total negative effect on the potential of ecosystems to provide services, as shown by the CESDR. In order to ensure the provision of ecosystem services, the urban land ratio needs to be no more than a third of the area. This was typical for all analyzed ecosystem services, which increased further away from the city, while population density and urbanized area decreased [29]. Even a small increase in forest area significantly increases the provision of ecosystem services. Both indicators of urbanization, the proportion of urbanized land and population density, were negatively related to the provision of ecosystem services. The research results were confirmed by other studies, where land use changes caused by urbanization worsened the potential of ecosystem services [42].

According to the results of the quantitative assessment, there was a general lack of supply in the Vilnius central urban area. Such central urban areas are known as the "cold spot" of ES supply zones where high building densities alter the ecological space, while high population density and a high intensity of human activities reduce the potential for the supply of ES [18]. In general, declining population in the study region was not accompanied by a decrease in urbanized land area. This transformation process significantly changed the

LULC around the city of Vilnius, expanding the urban fabric at the expense of agricultural land, and revealed several consequences. Firstly, these changes in land use have not led to a drastic reduction in the supply of ecosystem services. Secondly, the distribution of the population in the suburbs did not create a high demand for ecosystem services for which the supply of ecosystem services would not be ensured. Finally, it was not land use change but population growth in the city center itself that showed the greatest supply/demand mismatch, indicating unsustainable urban development. The demand and supply of only three ecosystem services examined showed some discrepancies, so a larger number of the examined services could be included and useful in the future. A more detailed analysis of the situation would allow a decision to be made on how to change the landscape in order to achieve a sustainable balance between resource supply and use. Understanding the relationship between changes in ecosystems and the services they provide is important for sustainable urban planning and development, environmental protection, and decision making. To better understand changes in ecosystem service mismatches and flows along the urban–rural gradient, further research is needed to assess more spatial and temporal patterns of changes in ecosystem service supply and demand.

5. Conclusions

In this study, analyzing land use changes related to urbanization in the case of Vilnius County, the mismatch between the supply of ecosystem services and the public demand was evaluated. The results of this study demonstrated that the association between land use changes and the provision of ESs may be positive or negative on a local scale. Looking into land use changes—the conversion of agricultural land to forestland and urban areas—resulted in an increase in food supply and C emissions. Even the relatively less intensively urbanized studied area compared to megacities showed a mismatch between the supply and demand of ESs. This spatial mismatch, which indicates the EU's "cold spot" in the city center, would accelerate the ecological degradation of ecosystems. Examining the spatial and temporal relationships between LULC and ESs provides a clear rationale for the need to ensure sustainable land use and decision making in important policy priority areas. A clear assessment of whether the provision of ecosystem services meets their needs at different levels of urbanization will help to decide on effective land management solutions.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13040454/s1, Figure S1: Number of elderships with mismatched ES in Vilnius 2000 and 2020; Figure S2: Influence of urban and forest land ratios on ecological supply–demand ratio (ESDR) in Vilnius in 2000 and 2020.

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