PLANNING LAND USE STRATEGIES: MEETING BIODIVERSITY, CLIMATE AND SOCIAL OBJECTIVES IN A CHANGING WORLD

D2.1 – PAN-EUROPEAN SYNTHESIS OF LAND USE CHANGES OVER TIME

WORK PACKAGE 2, TASK 2.1

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Table of Contents

Figures

Tables

List of Abbreviations

Term	Description
CLC	Corine Land Cover
EU	European Union
FADN	Farm Accountancy Data Network
LUC	Land Use Change
NUTS2	Nomenclature of territorial units for statistics, basic regions for regional policies
UAA	Utilized Agricultural Area
UNESCO	United Nations Educational, Scientific and Cultural Organization

Executive Summary

This Deliverable is part of Task 2.1, Characterizing historical changes to land use across Europe and their consequences within Work Package 2, Historical Land Use Change.

Based on an analysis of land cover and land management data as well as participatory processes, this report provides a synthesis of land use change across Europe since 1990. Overall, at the EU scale, the amount of land use change is limited, but its strong spatial clustering, leads to profound local impacts. Agricultural intensity has shown polarization, with already intensive areas becoming more intense and less intensive areas de-intensifying. This trend has been accompanied by an expansion of natural areas, resulting in an increased separation between human activities and nature-like land cover Consequently, this separation is likely reducing the benefits humans derive from nature.

A specific inventory has been done about the scope and extent of novel land uses. Novel land use includes land use types that are unprecedented or emerging, or previously not of major importance in the given region. The use of the land and landscape undergo extreme transformations, resulting in either the provision of entirely different ecosystem services or a fundamentally different mode of operation. In many cases, its ecological function changes. The associated changes can be fast, have a profound impact on the ecosystem, alter the functioning of the land or have a large emotional impact. Emerging categories of novel land uses, such as recreational landscapes, renewable energy landscapes, agricultural land with novel crops, landscapes for climate adaptation, logistics and digital landscapes, and rewilded landscapes, each introduce new ways of engaging with and benefiting from the land, challenging traditional notions of landscape function and value.

Comparing the practice cases shows a wide range in land use change dynamics. The total area percentage undergoing gross change between 1990 and 2018 ranged between 0.3% of the total area in the Parc Ela practice case to 7% in the Kaigu practice case. Comparing dynamics of the main specific land covers shows that built-up area has expanded in all practice case locations, with low amounts (<0.1% increase of area) in the more nature dominated ones (Green Karst, Kaigu peatland) and a 2% gain in the Amsterdam case. Arable land instead shows decreases in the more urban practice cases (Île-de-France, Amsterdam Metropolitan Area, Warsaw Metropolitan Area), and striking gross changes in the more intermediate urban cases (Three Countries Park, Surrey). While the area of complex vegetation patterns net decreased in most practice cases, there was also a lot of gross change in this land cover type. The high gross land cover dynamics were also striking for nature and forests.

Two change trajectories can be distilled from the information about the practice cases. First, several practice case regions are characterized by scale enlargement of agriculture, intensification of agriculture, and rationalization. This often goes together with a decrease in complex vegetation patterns and an increase in forest and nature. The practice cases Three Countries Part, Surrey, Lucca, Green Karst, Warsaw Metropolitan Area, and Kaigu peatland are in this change trajectory. Secondly, a few practice cases do see increasingly complex land use and land cover patterns. This applies to Île-de-France, Nitra, Moravia, and Parc Ela. However, change trajectories are not static and endless; the practice cases Amsterdam Metropolitan Area and Flanders seem to shift from the intensification trajectory to a trajectory of increasing complexity.

Content alignment with other PLUS Change deliverables

The PLUS Change project encourages collaboration and exchange between partners and Work Packages. The content of this Deliverable has been checked for alignment with Deliverable 3.2. The following table lists the deliverables/milestones that were input for this deliverable and the upcoming deliverables/milestones that this deliverable will contribute to.

Input	Output
D3.2: Report on the Policy Drivers of Land Use Change	D2.2 Narratives of determinants of land use change and their diversity across Europe
Milestone 2: Indicator selection (for monitoring impact to biodiversity, climate and well-being)	

1 Introduction and methods

1.1 Purpose & Scope

This deliverable describes how land use has changed since 1990 and how this has impacted climate, biodiversity, and well-being. It does so at European scale based on a literature and data inventory and participatory processes in 12 practice cases across Europe. This chapter outlines the terminology used.

Land cover describes the land surface as can be seen from space, e.g. if there are buildings, trees, crops, or bare soil. It, therefore, describes the physical or biological cover of the earth surface (European Commission, 2015a). Mapping land cover can be done from satellite imagery. Land use describes the activities that take place on land and links to the economic sectors that depend on the land. It can be defined as the "purposes and activities through which people interact with land and terrestrial ecosystems" (Ellis, 2021) or the description of the purpose of the land in socio-economic or ecologic terms (European Commission, 2015b). Examples of land use include agriculture, plantation forest, meadow, or industrial areas. As such specific uses cannot be directly observed from space, mapping land use requires insight into those activities through statistical data that should be linked to locations. Mapping land use therefore requires data on the functioning of economic sectors, and e.g. commonly relies on statistics of agricultural production or inputs to agriculture such as manure or fertilizers, to provide insight into the intensity of use, or cadastre data that provides insight into the use of (built) area (Kuemmerle et al., 2013) or survey data on land use (d'Andrimont et al., 2021). Recently, remote sensing time series have been used to derive land use, by e.g. quantifying the change of biomass over the cropping season to obtain insight into the crops being grown (d'Andrimont et al., 2021) or grassland use (Stumpf et al., 2020). Land management is here defined as the inputs into the land in the form of labour (e.g., tree felling regimes, intensity of tillage) or products (e.g., fertilizer, pesticides, water) (Jepsen et al., 2015).

Changes in land cover, use, and management are driven by a range of factors. First, population size and consumption patterns set a demand for products to be produced on land globally (Lambin and Meyfroidt, 2011) as well as for other societal demands (Van Vliet et al., 2015). Consumption patterns are driven by, among others, economic development and cultural factors (Lambin and Meyfroidt, 2011). Furthermore, policies at scales from global to municipal influence how and where land-based production takes place and in which intensity. For example, globalization and trade policies influence the balance between domestic production and import and export (Meyfroidt et al., 2018); European and national-scale nature protection and other zoning policies protect nature areas from conversion to other land cover / use and with that trigger spillovers to other areas (Fuchs et al., 2020), and local-scale planning details where conversions take place. Finally, location factors including accessibility, climate, topography, and soil quality set the limits for which land use and management is possible at what location (Van Vliet et al., 2015). All these drivers jointly steer the decisions of the land manager to change the land cover, use, or management.

In the European Union, policies influencing land use act in the sectors land use, energy, transport, urban environment and waste (Bassi and Guzzetti, 2025). Policies aiming to directly influence land use generally set targets for land use extent or management for the year 2030. In the energy sector, land is targeted to be dedicated to renewable energy, and in the infrastructure sector attention is given to network expansion while limiting fragmentation of nature. Urbanization policies affecting land use aim towards sustainable urban development and finally, policies on waste set limits to the amount of waste to be landfilled and sets targets for recycling (Bassi and Guzzetti, 2025). These policies all affect land use extent and management.

Land use and management in turn affects biodiversity, ecosystem services, and well-being. Expansion of agriculture, urban and infrastructure area can reduce natural habitats and cause fragmentation, while increased management intensity can deteriorate habitat conditions and lead to biodiversity loss. These changes in turn affect the benefits that society derives from ecosystem (ecosystem services) that are a basis for human well-being.

1.2 Methods

This report provides a general overview of land use and cover change in Europe and its impacts, as well as a detailed analysis of the PLUS Change practice cases. The analysis primarily relies on three sources of data: 1) time series of Corine Land Cover Change (European Environmental Agency, 2015); 2) Time series of the Farm Accountancy Data Network (DG Agri, 2022) and 3) a series of workshops in all PLUS Change practice cases.

1.2.1 Corine Land Cover Analysis

Corine Land Cover is available for 1990 (not including United Kingdom (UK), Sweden, Finland, Cyprus), 2000, 2006, 2012, and 2018. For the sake of consistency, land cover changes were therefore analysed for the 2000-2018 timeframe. For the European scale as well as for the PLUS Change practice cases, gross changes and net changes were quantified for a selection of land cover changes. Both gross change and net change analysis compare land cover / use of two-time steps. In this, gross change identifies all area where loss or gain of a land use / cover type occurs. However, often multiple shifts in land use / cover occur. For example, arable land is lost by conversion to urban areas at the fringe of a village, while at the same time elsewhere pasture is converted into arable land. Gross land use / cover analysis identifies both the gain and loss of arable land, while net land use / cover analysis counts the total area change over a larger area – and might, in this case, result in no net change. Gross changes were selected and quantified for smaller regions from the specific CLC change raster files (https://land.copernicus.eu/en/products/corine-land-cover).

To identify land use / cover changes, the Corine Land Cover maps were first simplified into nine main classes: urban and infrastructure; extraction, dump, and construction sites; arable land; permanent crops; pastures; complex vegetation patterns; forests; nature; and water. A classification table is provided in Annex 1. Next, changes were summarized into 11 classes (Table 1). Note that the same change can be classified in multiple ways. For example, a change from forest to agricultural land can be interpreted both as deforestation and as agricultural expansion.

Table 1: land use and cover changes inventoried in this study based on Corine Land Cover

Code	Name	Definition
1	No change	The same land use / cover occurs at the same location in both analysed years
2	Urbanization	Change to urban and infrastructure from any land use / cover
3	De-urbanization	Change to any land use / cover from urban and infrastructure
4	Agriculture expansion	Change from nature, forest, water, or extraction sites to any agriculture land use / cover
5	Intensification	Change from complex vegetation patterns to any agriculture land use / cover
6	Change of agricultural land	Any change between arable land, permanent crops, and pasture
7	Extensification	Change to complex vegetation patterns from any agriculture land use / cover
8	Abandonment	Change to nature, water, or extraction sites from any agriculture land use / cover
9	Afforestation	Change from any agriculture land use / cover to forest
10	Deforestation	Change from forest to nature or extraction sites
11	Other	Any other changes

To gain additional insight into the provision of ecosystem services to society, a simple indicator was calculated based on the land covers where ecosystem services are provided and where benefits are perceived. It is widely acknowledged that land cover is a key determinant for ecosystem service provision and that it can provide a reliable proxy for the level of ecosystem service provision (Schulp et al., 2014) (however, see chapter 2). In general, natural land cover provides the largest quantity and variation of ecosystem services and urban land cover the least (Burkhard et al., 2012). The benefits of ecosystem services are perceived by humans, meaning that the greatest benefits are found where humans are present, or where land cover/use is present that provides direct benefits to people (Burkhard et al., 2012). However, benefits of ecosystem services can only become operational once the amounts supplied by land cover can also reach beneficiaries (Serna-Chavez et al., 2014). This implies that for ecosystem service supply, a mix of natural, agricultural, and urban land cover is needed. To identify to what extent this mix is present and to quantify changes therein over time, the area percentage of natural, agricultural, and urban land cover was calculated from the simplified land cover maps. Next, correlations between these three map layers were calculated for all years available, providing insight in the co-occurrence of the land covers and with that of the ecosystem service supply and changes therein.

A general appraisal of biodiversity and ecosystem services was done using the "matrix approach" (Burkhard et al., 2012), based on the CLC 2000 and 2018 maps. In this approach, each land cover type was assigned a level of provision or demand of three groups of services (cultural, regulating, and provisioning) that directly support well-being. Next, the resulting 2018 and 2000 maps were compared for each group of services, resulting in change maps for demand and of supply for each group of services. Finally, for each group of services, a combined map was made, by on a cell-by-cell basis compare where demand and supply increase or decrease. General statistics of change were calculated at EU level as well as on PC level.

1.2.2 FADN Analysis

The Farm Accountancy Data Network regularly collects farm-level information at a balanced, stratified sample of farms across Europe. Data collection includes information on, among others, crop areas, yields, livestock numbers, inputs (labor, fertilizer, pesticides, irrigation, feed, etcetera), assets, income, expenditures. Micro data was used where each sampled farm is anonymized and where the farm's NUTS2 region is the only location information provided. For this study, a selection of indicators was made that provides additional insight in the management intensity of farms (Table 2). Data from 1990, 2000, 2012, and 2018 were compared and summarized into temporal trends; however, for the countries that joined the EU in 2004 and later, only data from 2006 onwards were available. Also, no data were available for Switzerland.

Table 2: FADN Land management intensity indicators used in this report (from https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FADNDatabase.html)

Name	Description	Unit, Scale
UAA	Utilized Agricultural Area; the land under arable, grassland and permanent pasture, and permanent crops.	Total area (km2) per NUTS2 region
Number of farms	Number of farms with a standard output larger than the lowest decile per country	Total (number) per NUTS2 region
Economic size	Average monetary value of the agricultural output at farm-gate price	Average (€) per NUTS2 region
Labor	All paid and unpaid labor which has contributed to the work on the farm	Annual work Units (total) per NUTS2 region
Livestock units	Number of farm livestock expressed in standard livestock units	Total (number) per NUTS2 region
N fertilizer	Quantity of N in mineral fertilizers used	Average (kg/farm) per NUTS2 region
Crop protection	Plant protection products, traps and baits, bird scarers, anti-hail shells, frost protection, etc. (excluding those used for forests).	Average expenditures (€/farm) per NUTS2 region

1.2.3 Practice case level land use history inventory

In each PLUS Change practice case, a workshop was organized where stakeholders inventoried and discussed the history of the practice case. The workshop constructed a timeline of the land use history since approximately 1950 and identified major land use change events and drivers thereof. Between 6 and 50 people participated in the workshops. In this report, basic information about main events is compared with trends derived from maps and statistical data, while the majority of the workshop results will be used in other PLUS Change tasks.

1.3 Document Structure

The document is organised as follows:

Section 1 - Introduction and methods: description of the purpose and scope of the document and its structure; methods used for data analysis

Section 2 - Land Use Change in Europe: synthesis of land cover and land use change at European scale and its impacts on wellbeing and ecosystem services, with special attention for the emergence of novel land use.

Section 3 - Land use change in PLUS Change Practice Cases: description of land use change in individual PLUS Change practice cases

Section 4 – Discussion: synthesis of practice case level land use change, comparison with European scale processes, and discussion of methodological limitations.

2 Land Use Change in Europe

2.1 Land use and cover change in Europe

Over the past decade, a number of studies analysed the recent history of land use in Europe from different perspectives, with different levels of detail. A long -term overview of broad agricultural land management change regimes (Jepsen et al., 2015) showed that around 1950, most of western Europe was in a regime focusing on intensification or industrialization. While intensification is characterized by the uptake of new inputs and technologies, this is taken to full adoption in industrialized countries, where specialization and commercial farming with fewer but larger farms occur. At the same time, eastern Europe was characterized by collectivization. Similar changes in input and management practices occurred here, but were government driven rather than market driven. Around 1990, a major shift in increasing environmental awareness occurred across most of western Europe. Externalities of nutrient and pesticide use became more apparent, especially in the aquatic environment, triggering the implementation of agro-environmental policies that aimed to reduce emissions. In some countries, however, industrialization continued, probably as a consequence of a system lock-in (Debonne et al., 2022; Williams et al., 2024). In eastern Europe, the dissolution of collectives resulted in two contrasting regimes, with large-scale intensification on the one hand and land being granted to smallholders who continued with a lower-intensity management regime on the other hand.

Fuchs et al. (2013) integrated historical maps and datasets and analysed land changes in Europe at a 1-kilometer resolution and a thematic detail of six land classes: settlement, cropland, forest, grassland, other land. Over the 1950-2010 timeframe analysed in the study, between 13% (Western Europe) and 19% (Southern Europe) of the land changed. Most common land transitions were from grassland to forest and from cropland to grassland.

Kuemmerle et al. (2016) created and compared spatially explicit indicators for land use extent and land use intensity for the years 1990 and 2006. An increase in pasture and urban area was observed throughout Europe, while cropland extent showed diverging trends: a slight increase was seen in the northwest of Europe and a decrease elsewhere. Both cropland and grassland were mainly characterized by stable trends over the timeframe considered. Forest expansion had hotspots in the Mediterranean, Baltics, Denmark, the UK and Ireland and showed an increasing trend overall, while urbanization was found predominantly close to coasts and major cities.

Within these broad land use trends, Kuemmerle et al. (2016) also mapped changes in intensity. For croplands, areas that were already intensively managed in 1990 tended to stay in the high-intensity category. Furthermore, in many regions, fertilizer use as well as yield increased, while decreases were primarily found in south-eastern Europe. A similar spatial pattern was visible for grassland, where grazing intensity showed strong declines in south-eastern Europe and increases elsewhere, and livestock density declined throughout Europe. Forest management intensity increased in central and northern Europe and remained relatively stable elsewhere.

Levers et al. (2015) used a clustering approach to identify archetypical change trajectories of land system archetypes over the years 1990-2006. Similarly, Fuchs et al. (2013) found that stable land systems were most widespread, with around 40% of the EU area being stable, with stability being observed in large parts of Sweden and Finland as well as smaller stretches elsewhere. However, this European-scale analysis focusing on land cover does not address local-scale structural changes in the farming sector, meaning that more detailed studies that not only address land cover but also use might contradict these aggregated findings

(Wästfelt, 2021). Intensification, as demonstrated by increasing yields, was found in around 11% of the area, primarily on croplands and in forests. However, deintensification was the most widespread change trajectory, with around 30% coverage. Intensification was generally observed in areas with good accessibility, relatively even terrain, and above-average socio-economic conditions. Intensification specifically operationalized by increased fertilizer use was found in areas with nutrient-poorer soils, closer to cities. At the same time, deintensification was found in areas with similar characteristics, probably because of their former intensive use. Declining yields in grasslands and abandonment of permanent crops were primarily seen in regions with low economic activity, yet high labour input.

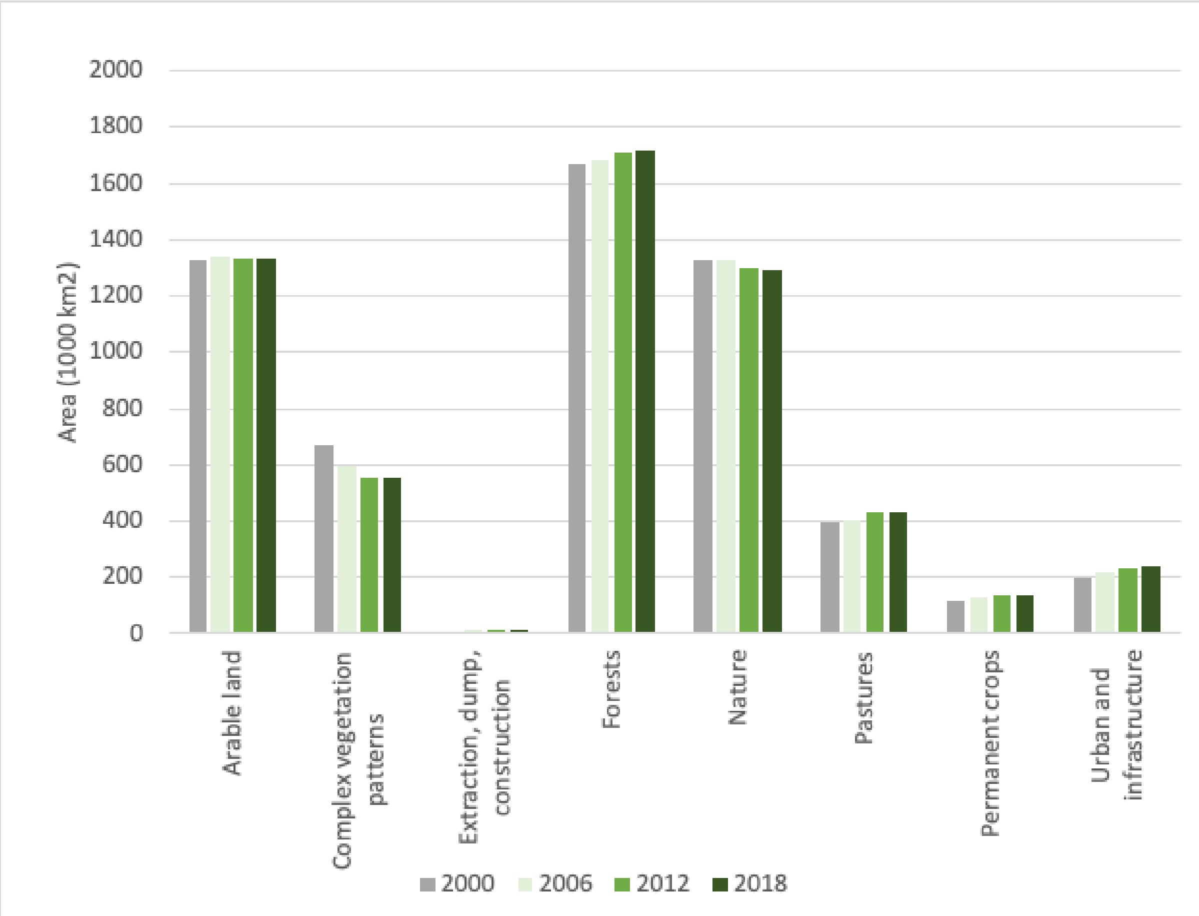

Figure 1: Net land cover change in Europe.

Comparing a time series of land cover maps (Corine Land Cover) confirms that net changes at European scale are small (Figure 1), but that change is clustered and that gross changes are considerably bigger (Figure 2). While overall the different land cover categories show minor amounts of change, often less than 1% per year, the trends do suggest a simplification of land cover. Complex vegetation patterns and other types of nature contract, while forest, arable land, pasture, and urban area expand. This is consistent with consequences of productivism and post-productivism megatrends (Debonne et al., 2022), where widespread increases in farm size are seen. An analysis of gross changes suggests that the rate of land cover change is currently slower than it was around the turn of the century (Figure 2).

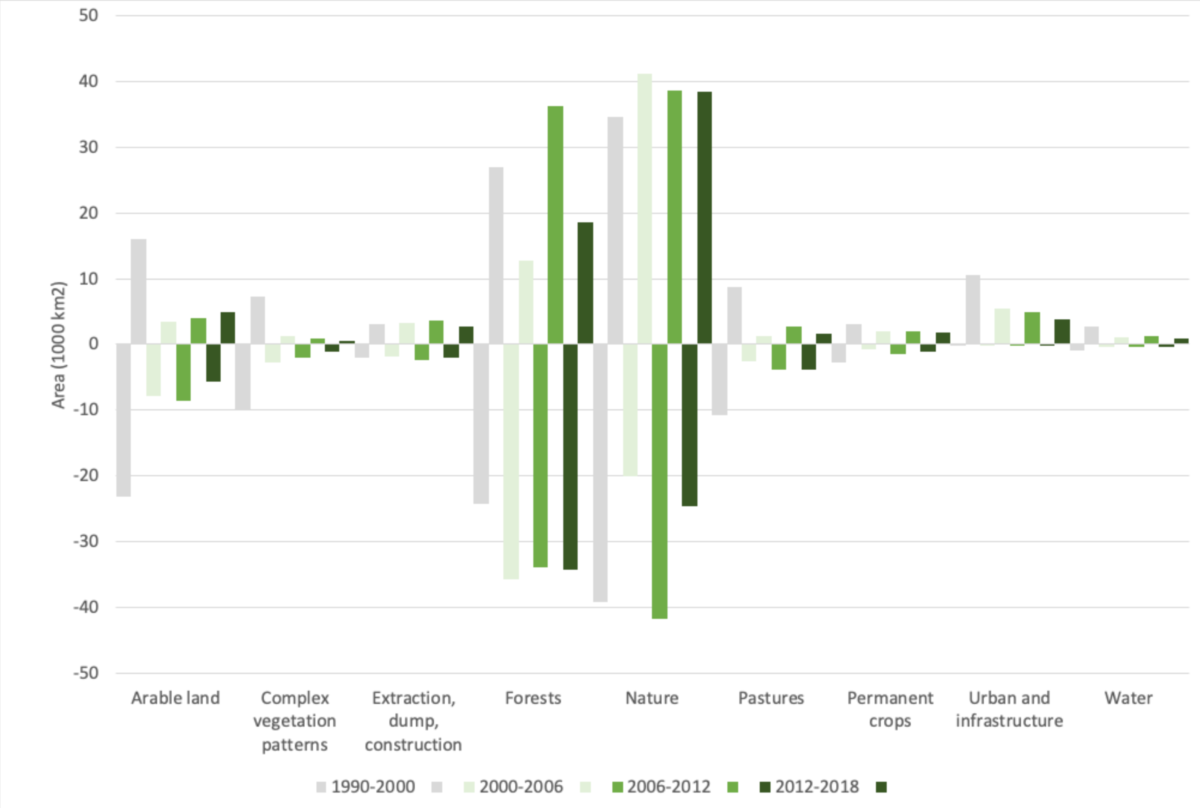

Figure 2: Gross land cover change in Europe

2.2 Novel Land Use

This section consists of direct quotes from the following paper:

Nijensteen, I.L., P.H. Verburg, C.J.E. Schulp, 2025. Novel land uses in Europe: conceptualization, trends in space and time and impacts. Landscape and Urban Planning, in preparation.

2.2.1 Introduction

Research on monitoring land use change has primarily focused on the spatial patterns associated with two key dimensions: land cover type conversions and changes in land management intensity. Land use type conversions, such as deforestation, urbanization or forest expansion, are often characterized by broad archetypical change trajectories or regimes (Jepsen et al., 2015; Levers et al., 2016; Schulp et al., 2019). These changes are often driven by a combination of demographic, socio-economic, political, biophysical and technological factors, leading to subsequent socio-economic and biophysical impacts (Shaw et al., 2020).

While remote sensing (Liping et al., 2018; Rahman et al., 2012) and national-scale statistics (Kuemmerle et al., 2013) have been used to monitor land cover change, current EU-scale methods tend to generalize, overlooking changes that fall outside established data frameworks.

This is exemplified by the Corine Land Cover (CLC) map with the conversion of land to solar and wind farms, under broad classes like 'industrial and commercial development'. In the United Kingdom between 2012 and 2018, the agricultural classes that changed from agricultural areas (classes 2xx in CLC) to industrial and commercial development (class 121) were often converted to solar energy farms (72%), while the forest and semi-natural classes in the uplands that changed to class 121 were mainly converted to windfarm developments (92%) (Cole et al., 2022). Most of these areas retained their vegetation but were repurposed primarily for renewable energy generation. Although windfarm projects in vegetated regions require access roads and minor clearings near turbines, the surrounding land cover generally remains intact. However, the CLC guidelines still reclassify these areas under a different land use category. This omission is problematic, as solar and wind farms often have distinct land use and environmental impacts that differ significantly from traditional industrial sites which is how they are currently classified.

In this chapter, the authors aim to fill this gap by placing a specific emphasis on trends associated with novel land use.

Novel land use includes land use types that are unprecedented or emerging, or previously not of major importance in the given region. The use of the land and landscape undergo extreme transformations, resulting in either the provision of entirely different ecosystem services or a fundamentally different mode of operation. In many cases, its ecological function changes.

The associated changes can be fast, have a profound impact on the ecosystem, alter the functioning of the land or have a large emotional impact. These emotional impacts are closely tied to the relational values humans attach to land, which encompass deep connections between people and nature that go beyond purely instrumental and intrinsic values (Kachler et al., 2024; Mattijssen et al., 2020). These relational values, such as place attachment and cultural significance, influence how people perceive and engage with transformed landscapes, sometimes leading to resistance to novel land uses (Martin et al., 2024). Understanding these emotional and cultural reactions is crucial for effective land use planning and policy. Yet, while these responses are important, it is equally essential to examine the novel land uses themselves, as they represent large shifts in how landscapes are valued and utilized.

When assessing whether a land use change qualifies as novel, it is crucial to consider the scale and extent of impact of the change. For example, agricultural diversification, such as diversified crop rotations and habitat diversification, represents changes that can influence the delivery and stability of ecosystem services (Bommarco et al., 2018). However, these changes are often not substantial enough in scale or impact to be classified as novel land uses. This distinction underscores the importance of evaluating both the magnitude and the transformative effects of land use changes when determining their novelty.

2.2.2 Novel land use trends

Emerging categories of novel land uses, such as recreational landscapes, renewable energy landscapes, agricultural land with novel crops, landscapes for climate adaptation, logistics and digital landscapes, and rewilded landscapes, each introduce new ways of engaging with and benefiting from the land, challenging traditional notions of landscape function and value.

2.2.2.1 Recreation

The first category, recreation, includes the emergence of land grazing for recreational horse keeping (Bomans et al., 2011; Collins, 1978; Saastamoinen et al., 2017; Sutherland, 2021), golf courses (Ortuño Padilla et al., 2016; Romero et al., 2012) and holiday villages (Barke, 2007; Gürsoy and Yüğrük Akdağ, 2019; Krause, 2018).

Horse keeping

Recreational horse keeping has emerged as a novel land use in Europe and is referred to in literature as 'horsification' (Sutherland, 2021). This trend is largely driven by amenity migration and rural gentrification, where middle-class households move to peri-urban areas, bringing horses and reshaping landscapes traditionally used for agriculture (Sutherland, 2021). The rise of recreational horse keeping, particularly in countries like Belgium, Germany and Scotland, leads to the establishment of livery yards, riding schools and stud farms (Sutherland, 2021). Recreational horse keeping provides positive impact on human well-being, including therapeutic effects through animal interaction and enhance recreational opportunities. The emotional and aesthetic attachment to horses fosters strong connections to rural life.

The European agricultural census often overlooks horses kept for recreational purposes, necessitating more comprehensive data collection approaches to accurately assess the sector's impact (Rzekęć et al., 2020). In Figure 3, FAOstat data for a few countries showing a moderate upward trend of horses per 1000 citizens is summarized. The source and uncertainty of this data vary by country and year, and there is no distinction made between horses used as livestock and those used for recreation.

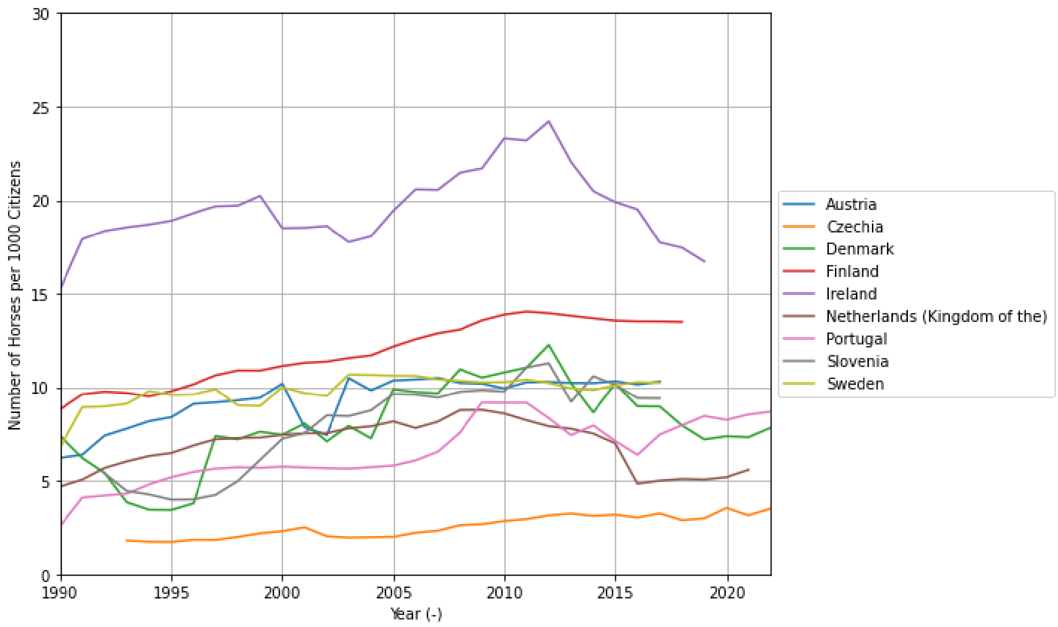

Figure 3. Number of horses per 1000 citizens of some European countries with moderate upward trends, based on FAOstat and Eurostat data.

Golf courses

Golf courses have long been an established form of land use in Europe, particularly in Scotland, where the game has deep historical roots. In Scotland, golf has been played since the Middle Ages, especially by royalty, and the 19th century saw a significant expansion of golf courses, driven by new wealth and the rise of leisure time, cementing the country as the birthplace of modern golf. In contrast, the development of golf courses as a novel land use in regions such as the southeast of Spain is a more recent phenomenon, where their development often accompanies residential holiday villages (Ascensión Molina Huertas et al., 2010; Ortuño Padilla et al., 2016). These projects have significantly influenced local land use patterns, with municipalities leveraging golf courses to boost revenue from building permits and real estate developments.

From 1985 onwards, the number of golf courses in Europe grew steadily, reflecting wealth and changing societal values towards leisure and recreational pursuits (see Figure 4). In 1985, Europe had 3,029 golf courses, and this number increased significantly over the subsequent decades, peaking at 7,000 around 2014. However, recent data indicate a slight decline. This trend could be attributed to changing land use priorities, environmental regulations, or a shift in recreational preferences.

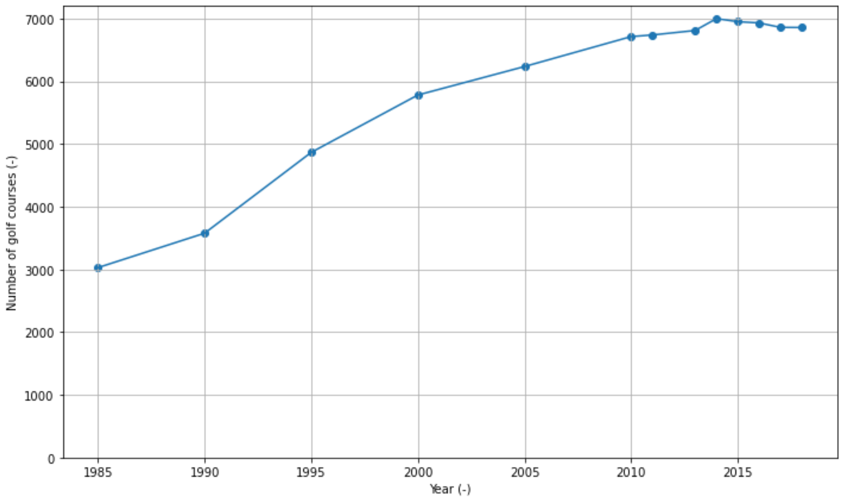

Figure 4. Number of golf courses in Europe. Source: KPMG, European Golf Association.

Holiday parks

Holiday villages in Europe represent a novel land use that significantly impacts ecosystem services, biodiversity, well-being and the environment. In many countries, there is limited data available on residential recreational areas, but the number of beds in tourism facilities can often serve as a proxy for assessing the impact. However, in the Netherlands, there exists data on land use of residential recreational areas from CBS (Central Agency for Statistics). This data shows a consistent increase in the number of residential recreational areas (holiday parks) in the Netherlands from 1996 to 2017, indicating an increase of approximately 30% over this period.

Monitoring of holiday parks in Spain presents challenges due to the relationship between migration and tourism (tourism-led migration) (O'Reilly, 2003; Provenzano, 2020). This includes, for example, the transition of former tourists, mainly retirees, into permanent residents. Along the Spanish coast, large resorts for permanent residence with luxury facilities such as golf courses, have been established. These developments, while not formally categorized as 'holiday villages', closely resemble the novel land use described here. Consequently, they are often overlooked in statistics on holiday villages.

2.2.2.2 Renewable energy

The second category, renewable energy, involves the development of renewable energy resources, leading to energy landscapes, often called energyscapes, with wind and solar farms (Delafield et al., 2024; Picchi et al., 2019; Salak et al., 2024). This is different from more traditional or industrial energy forms. Whereas renewable energy landscapes can integrate more harmoniously with natural ecosystems, more traditional energy forms have a different, often more disruptive relationship with the landscape.

Renewable energyscapes, particularly solar and wind energy, have emerged as novel land uses in Europe with significant implications for ecosystem services, biodiversity, well-being and environmental impact. Wind energy contributes to balancing the electricity grid when combined with solar energy. However, the installation of wind turbines can cause noise pollution, shadow flicker and visual disruption, impacting both human communities and wildlife, particularly birds and bats through habitat destruction and collision mortality (Kadaster, 2022). In regions like the Ijsselmeer in the Netherlands, dense wind farms illustrate the spatial concentration of such impacts. Solar energy, especially ground-mounted photovoltaic systems, competes with agricultural land use, leading to changes in visual landscapes. While agrivoltaics systems, which combine solar energy production with agriculture, offer a potential dual use of land, they still introduce artificial elements that disrupt traditional landscapes (Hastik et al., 2015; Sirnik et al., 2024). Despite their promise, the development of agrivoltaics systems in the European Union remains hampered by a lack of comprehensive land use policies that address their environmental and societal impacts (Pascaris et al., 2021). The environmental and societal implications of renewable energy infrastructure are manifold. Both wind and solar energy projects often lead to land use changes that can compromise biodiversity. The construction of wind turbines and associated construction of access roads can fragment habitats and extend human pressures into natural areas, exacerbating biodiversity loss (Kati et al., 2021). Additionally, renewable energy projects impact cultural ecosystem services by altering landscapes that communities value for their aesthetic and heritage significance. The visual intrusion of wind turbines and solar fields can lead to opposition in local communities, as seen in the Not In My Backyard (NIMBY) syndrome, highlighting the importance of integrating ecosystem services into landscape planning and design to achieve sustainability (Picchi et al., 2022). Balancing renewable energy development with the preservation of ecosystem services requires careful consideration of trade-offs, ensuring that energy landscapes do not undermine ecological integrity and the well-being of local communities.

In Figure 5 and Figure 6, the primary energy production of respectively solar photovoltaic and wind energy per land area is shown from 1990 till 2023. Wind power development began during the period of 1990-1995, whereas solar photovoltaic technology only started to emerge around 2005. The most pronounced increase in both renewable energy technologies has been observed in the Netherlands, which has experienced rapid growth in renewable capacity. Other countries demonstrating significant expansion include Belgium and Germany.

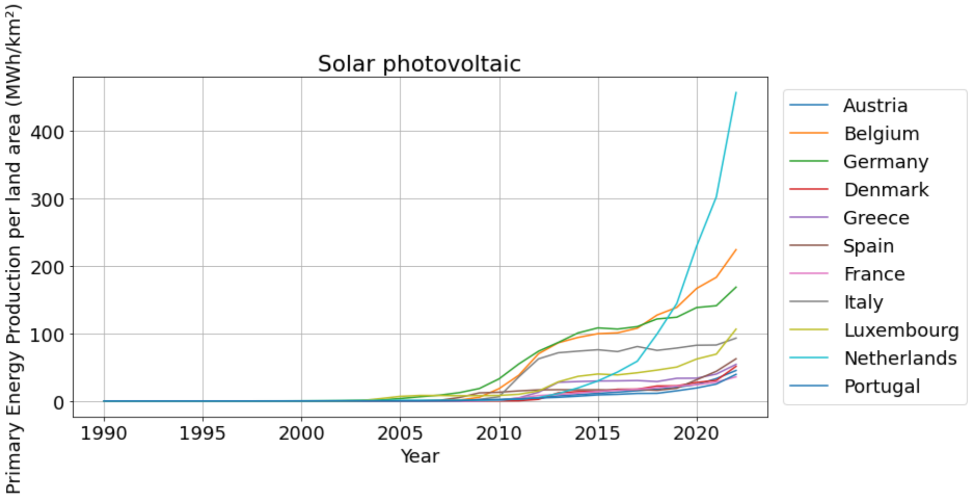

Figure 5: Primary solar photovoltaic energy production per land area of some European countries. Source: Eurostat

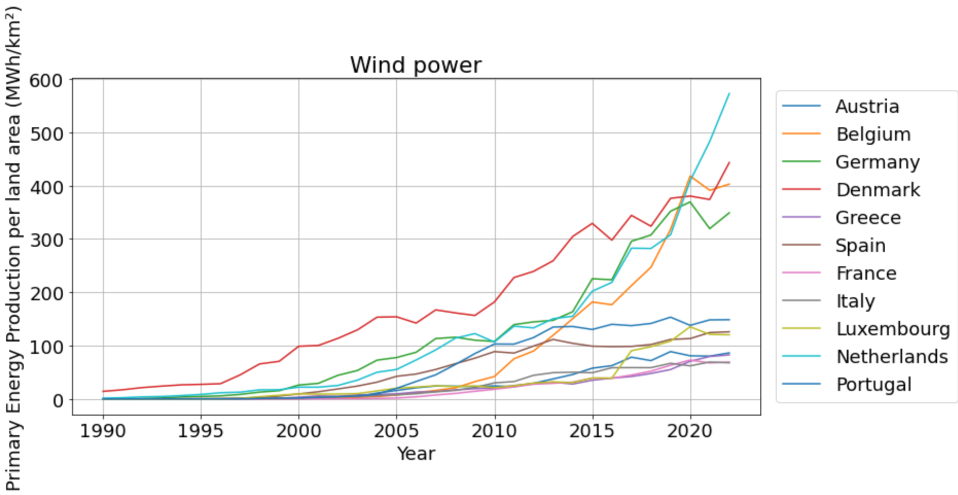

Figure 6: Primary wind energy production per land area of some European countries. Source: Eurostat.

2.2.2.3 Distribution and data centers

Logistical and digital landscapes represent a more recent form of novel land use, characterized by the expansion of distribution and data centres, which serve global supply chains and the digital economy (Hesse, 2020; Nefs and Daamen, 2023).

The rapid expansion of distribution centres (DCs) and data centres across Europe has significantly altered landscapes and raised concerns about sustainability and land use efficiency. In the Netherlands, the logistics complex, which includes an increasing number of very large (XXL) distribution centres, now occupies approximately 80 million square meters, a footprint that has quadrupled since 1980 (Nefs, 2024). Since 2000, there has been a trend of so-called XXL DCs with floor areas above 40,000 square metres (Hesse, 2020; Nefs et al., 2023). This shift, fuelled by the rise of e-commerce giants like Amazon and Alibaba, has transformed the logistics landscape into one of large-scale facilities that support global supply chains (Hesse, 2020). These developments are concentrated in regions like the logistics corridor between Rotterdam and Germany, where land costs and accessibility drive the establishment of massive DCs (Flämig and Hesse, 2011). The environmental impact of these structures is considerable, with increased truck traffic leading to air pollution, congestion, and the elimination of alternative land uses (Kuipers et al., 2018).

In addition to environmental impacts, the visual "boxification" of landscapes due to the increase of XXL DCs is a growing concern. These facilities often form vast clusters near transport infrastructure, disrupting the aesthetic and cultural value of natural or agricultural regions. The repetitive and large-scale architecture of these centres contributes to significant landscape clutter, diminishing scenic beauty and fragmenting local ecosystems (Mitchell et al., 2015; Wagtendonk and Vermaat, 2014). Logistics landscapes represent one of the most significant transformations in the built environment, reshaping land use through distributed, highly engineered facilities that emphasize flow and efficiency (Waldheim and Berger, 2008). This shift underscores the fundamental reorganization of landscapes in response to the demands of global supply chains, often leading to stark visual and functional changes in the environment.

Data centres, essential for supporting the digital economy through cloud computing and data storage, also contribute to significant environmental challenges. A key issue is their water consumption for cooling purposes. For instance, the water usage of data centres surged from 738 million litres in 2015 to more than 840 million litres in 2021 (Zhang et al., 2024). This is particularly problematic in regions facing water scarcity. However, reporting on water usage is still not as widespread as energy efficiency metrics, highlighting the need for better transparency and water management practices (Zhang et al., 2024). These developments underscore the growing pressure on both land and water resources as the demand for digital infrastructure continues to rise.

2.2.2.4 Novel crops

Another form of novel land use is the emergence of novel crops or farming practices, such as vineyards in Northern Europe (Atkinson et al., 2013; Iglesias et al., 2009; Ijsselmuiden, 2022; Nesbitt et al., 2018) and plastic greenhouses in Almería, Spain (Castro et al., 2019; Mendoza-Fernández et al., 2021). In history, there are many other examples of novel crops in European agriculture. Two illustrative examples are potatoes (18th-19th century) (Hawkes' and Francisco-Ortega, 1993) and maize (17-18th century) (Rebourg et al., 2003), which were both introduced from South and North America.

Greenhouses

Agricultural greenhouses have emerged as a novel land use across Europe in various moments in time. In the Netherlands, the first industrial greenhouses emerged in the 1940s and saw a rapid increase till stabilization around 2000. The development of greenhouses has been substantial, with approximately 9,000 specialized greenhouse businesses covering 10,000 hectares.

A region where greenhouses have emerged as a novel land use more recently is Almería in the South of Spain. In Almería, greenhouses have transformed one of Spain's poorest areas into an economic powerhouse, significantly boosting local employment and productivity. This region's extensive greenhouse agriculture covers almost 200 km^2 and has led to substantial economic development, but also to serious environmental impacts such as overexploitation of aquifers and degradation of natural scrublands (Mendoza-Fernández et al., 2021).

Vineyards

The appearance of vineyards as a novel crop in Northern Europe, particularly in The Netherlands and the United Kingdom, highlights a shift in agricultural practices driven by climate change and evolving market demands. The warming climate makes Northern European regions increasingly suitable for viticulture. This shift offers new opportunities for regions traditionally deemed unfit for grape cultivation.

In the Netherlands, viticulture is small in scale with 165 vineyards (total of 275 ha) in 2022 (Verbiesen, 2022). Around the early 1970s, some first changes for the viticulture in The Netherlands were noticed with some planting of new vineyards in Limburg and North Brabant. Since then, there has been a steady growth in the Dutch wine industry. However, the economic viability of Dutch wine production remains questionable.

The UK has seen a more dramatic increase in vineyard land, with plantings expanding by 74% over the past five years, driven by a rise in demand for English and Welsh wines (Nesbitt et al., 2018). This rapid expansion, now accounting for nearly 4,000 hectares, positions viticulture as the fastest-growing agricultural sector in the UK. This shift supports local economies by diversifying agricultural outputs and potentially increasing land value.

The suitability of land for vineyards is determined by factors such as elevation, aspect, and soil properties, with climate change further facilitating this expansion. This shift of agricultural land to viticulture could impact regional biodiversity by reducing the diversity of land use and potentially introducing monocultures, which can alter the balance of local ecosystems and reduce the availability of ecosystem services like pollination and water regulation.

2.2.2.5 Climate adaptation and rewilding

Landscapes for climate adaptation represent another novel category of land use. These landscapes are designed to enhance resilience to climate change through measures such as floodplain restoration, urban green infrastructure, and coastal wetlands to buffer against rising sea levels (Bongarts Lebbe et al., 2021).

Rewilded landscapes aim to restore ecosystems to their natural states by reintroducing native species and allowing natural processes to shape the land. Examples include rewilding initiatives in Europe that bring back species such as bison, beavers, and large predators, contributing to biodiversity restoration and enhancing ecosystem functioning (Carver et al., 2021; Pereira and Navarro, 2015).

Over the past centuries, European landscapes have been shaped by agriculture which was traditionally low-intensity and multifunctional (Gellrich et al., 2007 economic shifts and agricultural globalization have led to farmland abandonment, particularly in mountainous and other marginal land areas {Ceaușu, 2015, ce002). Rewilding has emerged as an alternative to prevent this abandonment, promoting natural succession and enhancing ecological functions. This approach supports biodiversity through forest regrowth, carbon sequestration, and soil recovery, but also results in biodiversity shifts, with some species benefiting while others decline.

Rewilding projects are diverse in scope and scale, with notable examples across Europe. For instance, initiatives in the Greater Côa Valley (Portugal) and Central Apennines (Italy) focus on reintroducing semi-wild data livestock, such as cattle and horses, and creating coexistence corridors that connect fragmented habitats. These efforts enhance ecological connectivity and support more diverse landscapes (Pereira and Navarro, 2015). Other examples, such as the Carpathian Mountains in Eastern Europe, involve the reintroduction of large predators like lynxes and wolves to help restore trophic cascades and maintain ecosystem balance.

The success of these initiatives is highly context-dependent, and their impacts on ecosystem services such as fire risk, carbon sequestration and hydrological systems vary with local conditions (Hart et al., 2023). Standardizing the assessment of rewilding success should therefore also be approached with caution due to the site-specific nature of rewilding outcomes. Long-term plans are necessary to manage herbivore populations and address unforeseen effects. The true measurements of rewilding success may take decades (Hart et al., 2023; Van Klink and WallisDeVries, 2018).

2.2.3 Synthesis

Novel land uses in Europe present both synergies and differences that impact biodiversity and ecosystem services, economic opportunities, human well-being, and landscape transformation. Understanding these elements helps to appreciate the broader implications of land use changes and their contribution to sustainable development.

One common feature of novel land uses is that it frequently occurs on land that was previously in agricultural use, which leads to a complete redefinition of its functionality and the ecosystem services it provides. Many of these novel land uses – such as rewilding, renewable energy projects, and golf courses – contribute to enhancing or transforming ecosystem services (Figure 7). Rewilding, for example, aims to restore ecological processes and biodiversity, while renewable energy installations help mitigate climate change through low-carbon energy production. However, some novel land uses, like data and distribution centres, can have negative impacts (Figure 7). These centres often lead to increased land consumption and contribute to landscape clutter, posing challenges to ecosystem services and altering visual and functional aspects of rural areas.

Novel land uses also generate large economic opportunities. Recreational activities such as golf courses, holiday villages, and vineyards create avenues for tourism, recreation, and specialty agriculture. These economic activities can diversify local economies, boost employment, and help maintain economic vitality, particularly in rural areas that have faced challenges due to the decline of traditional farming (Figure 7).

Human wellbeing and recreation are also mostly positively impacted by most novel land uses. Rewilding initiatives, recreational horse keeping, golf courses, and holiday villages provide spaces for recreation and leisure, promoting physical activity and enhancing mental health through increased contact with nature. This transformation of landscapes into multifunctional spaces reflects preferences towards more recreational and nature-connected lifestyles.

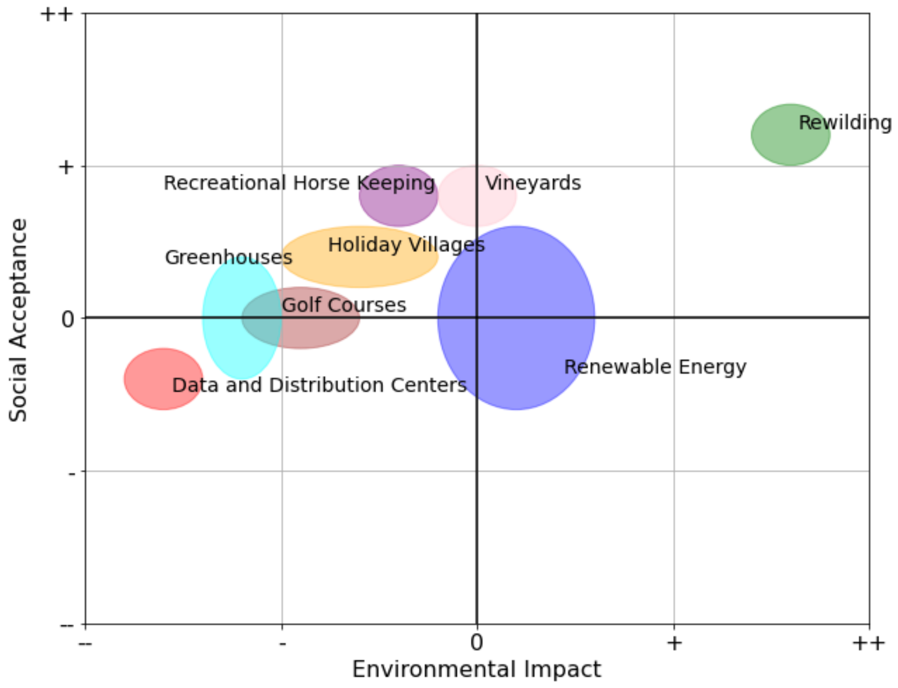

Figure 7: summary of expected impact and social acceptance of novel land use in Europe.

The impact of novel land uses varies significantly depending on the specific type of land use. First of all, environmental impact can range widely. While rewilding aims to restore natural habitats and enhance biodiversity, other land uses, such as greenhouses and golf courses, can lead to habitat fragmentation and resource overuse, including considerable water consumption and fertilizer application.

Resource use also differs across novel land uses. Greenhouses and golf courses require substantial amounts of water and energy, adding pressures on local resources, particularly in regions facing water scarcity. In contrast, rewilding aims for minimal human intervention and low resource use.

Social acceptance of novel land uses is another key difference. Renewable energy projects, such as wind turbines, often face local resistance due to concerns about aesthetics and noise, whereas holiday villages and golf courses have a more complex social acceptance. While some locals appreciate the economic benefits they bring, others worry about the increased nuisance and disruption from tourists from holiday villages and social inequality associated with limited access to golf courses. In contrast, community-supported agriculture projects, such as some vineyards, often face little to no resistance, as they provide locally grown food and promote community engagement without the environmental and social drawbacks.

The temporal scale of the impacts of novel land uses also varies. Projects like rewilding may take decades to fully realize their ecological benefits, while the economic gains from holiday villages and golf courses can be more immediate. However, on the other hand, these economic benefits may come at the cost of long-term environmental degradation if not managed sustainability.

Finally, spatial scale is another point of differentiation. Some novel land uses, such as golf courses and data centres, can occupy vast areas and have region-wide impacts, whereas others, like small-scale vineyards, may focus on more localized landscape changes.

Renewable energy projects like wind farms or large solar arrays don't just affect the specific land they occupy; they can influence surrounding areas through visual impacts, noise, changes in local ecosystems, and even alterations in regional economic activity. This means their consequences can be felt across a broader region, affecting landscapes, biodiversity, and communities far beyond the physical boundaries of the installations themselves.

2.3 Impacts on biodiversity, well-being and climate change

This section explores how land use change over recent decades has influenced biodiversity, ecosystem services, and well-being.

Many studies exist on the impacts of land use change over the past decades on biodiversity. Pilotto et al. (2020) synthesize evidence from over 160 long-term studies, showing a decline in abundance of terrestrial invertebrates, but overall a considerable variability between regions and taxons. The level of naturalness at site level was found to be the most important predictor of biodiversity trends. Other studies do observe declines of bird and insect populations and species richness in farmlands, related to the intensity of agriculture (Burns et al., 2021; Rigal et al., 2023). At the same time, the polarization and scale enlargement of agriculture goes together with land abandonment. It is often observed that this can provide opportunities for either active or passive rewilding, contributing to biodiversity (Fayet et al., 2022).

While there are several studies about changes in ecosystem services in Europe, these have many limitations and do not allow a full picture of the impact of land use change on wellbeing through the provision of ecosystem services. Studies on temporal changes of ecosystem services have two limitations: 1) they assume a static relation between landscape configuration and ecosystem service supply (Dick et al., 2016; Stürck et al., 2015). In reality, the supply of ecosystem services by vegetation and landscapes might face legacy effects or non-linearities (Dallimer et al., 2015; Schulp and Veldkamp, 2008). This makes comparison of one-time efforts to map ecosystem services in order to trace changes over time challenging. 2) they assume a static demand for ecosystem services over time, e.g., (Bürgi et al., 2014; Egarter Vigl et al., 2016). In reality, over time, even over the past 30 years addressed in this report, the benefits that people expect from the environment might have changed, in quality and in quantity. Furthermore, while there are case studies on past changes of ecosystem services across Europe, few studies address the EU as a whole.

Two studies were identified that provide an overview of recent change of ecosystem services across Europe. Stürck et al. (2015) modelled changes of carbon sequestration and flood regulation supply and demand over the 1960-2000 timeframe. The supply of the services was quantified based on empirical relations between land use and land cover patterns and biophysical variables on the one hand, and data on provision of the service on the other hand. The demand for flood regulation was quantified based on the number of people living in flood prone areas and the presence and amount of flood prone infrastructure and built-up land in flood prone areas. The demand for carbon sequestration was related to the EU's greenhouse gas emissions from fossil fuel and cement production, assuming that carbon sequestration in land use contributes to compensating these emissions.

Their study found that over the period 1960-2000, levels of carbon sequestration decreased in a few countries (Spain, Italy, Scandinavian countries) but throughout most of the EU carbon sequestration increased, with the strongest rises in Romania, Poland and Germany. The demand for carbon sequestration increased strongly between 1960 and 2000 and the demand that could be fulfilled was 13% in 1960 and 11% in 2000.

Flood regulation supply has not changed so much in this period; most drastic river basin changes and their effects happened before1960. Between 1960 and 2000, decreases in flood regulation supply were observed in Romania, Austria, Baltic, Scandinavia, while increases were noted particularly in France and Denmark. The demand has increased since 1960, driven by a growing number of people living in flood-prone areas. The extent of built-up areas was 10% smaller in 1960 compared to 2000.

Mohr et al. (2024) focused on six case studies, in Spain, France, the Netherlands, Germany, Switzerland, and Slovakia. Building on an analysis of historical maps and oral history interviews, this study explored landscape change in rural landscapes as well as the perspectives of farmers on the changes identified in historical maps.

An increase of median field size in cropland between 1960 and 2020 was observed, but with a wide variance between the sites. Cropland sites (the Netherlands, Spain, Germany) demonstrated a high level of persistence over time, grassland and forest dominated sites showed more land use dynamics. Nevertheless, in each site, there were a few interviewees that did not perceive any landscape change. Otherwise, in particular changes in farm management were reported by the stakeholders interviewed. Primarily an increasing field size was often mentioned, followed by changes in farm strategy (e.g., a switch from conventional to organic farming), landscape interventions such as changing irrigation systems, and finally shifts in farm composition across the landscape were mentioned, highlighting phenomena like scale enlargement and farm abandonment. More specifically, many respondents appreciated field trees, and mentioned the rationalization of agricultural landscapes, as demonstrated by the disappearance of field trees.

Next, Mohr et al. (2024) inventoried the impacts of the historical land cover and land use changes on ecosystem services, biodiversity, and well-being. A change in flora and fauna composition was reported by the interviewed stakeholders. This included the disappearance of field trees, but also a loss in diversity in meadows and hedgerow vegetation. This has gone together with a decrease in farmland animals like hares and frogs, while a simultaneous trend of farmland abandonment has resulted in increases of beavers and wild boars. With regards to ecosystem services, interviewees in particular mentioned increasing recreational pressure, sometimes through deliberate action of creating recreation areas. Furthermore, the role of windbreak hedgerows was an explicitly mentioned ecosystem service. Several links to well-being and changes therein could be distilled from the study, where interviewees observed that scale enlargement in agriculture has deteriorated social cohesion, and also a feeling of regret or melancholy about the loss of the traditional landscape was mentioned.

Based on the land cover patterns identified in the previous chapter, it is likely that the demand for ecosystem services has increased and the supply decreased, resulting in a decrease in the extent to which land in Europe supports human well-being. An analysis of the spatial co-occurrence of land use where a demand for ecosystem services can be expected (inhabited land and agriculture) and where ecosystem services are supplied (natural land use types) (Table 3) suggests that supply and demand levels for ecosystem services have become increasingly separated over time (Table 3).

Table 3: correlation between percentage of agriculture, nature, and inhabited land per 1km^2 grid cell across Europe over time

Time	Agriculture – nature	Inhabited – nature	Agriculture – inhabited
1990	-0.280	-0.138	-0.021
2000	-0.283	-0.145	-0.009
2006	-0.305	-0.151	0.014
2012	-0.318	-0.158	0.014
2018	-0.316	-0.158	0.013

Comparing the supply and demand of main groups of ecosystem services between 2000 and 2018 (Figure) shows that, for cultural and regulating services, in almost 10% of the area an increase or decrease in supply or demand is seen. For provisioning services, increases in demand are widespread and are seen in over 80% of the area. Areas that combine an increasing demand with an increasing supply are, for cultural services and provisioning services, seen in Scotland, and for provisioning and regulating services large areas are seen in Spain. In these areas, the support of wellbeing by the landscape has therefore likely been decreasing by increased pressure on recreation opportunities combined with decreased availability, and reduced risk regulation. However, for cultural services, areas where the supply increases without an increasing demand are widespread, and for provisioning and regulating services many of such areas are found in e.g. Germany, the Baltic countries, and Romania.

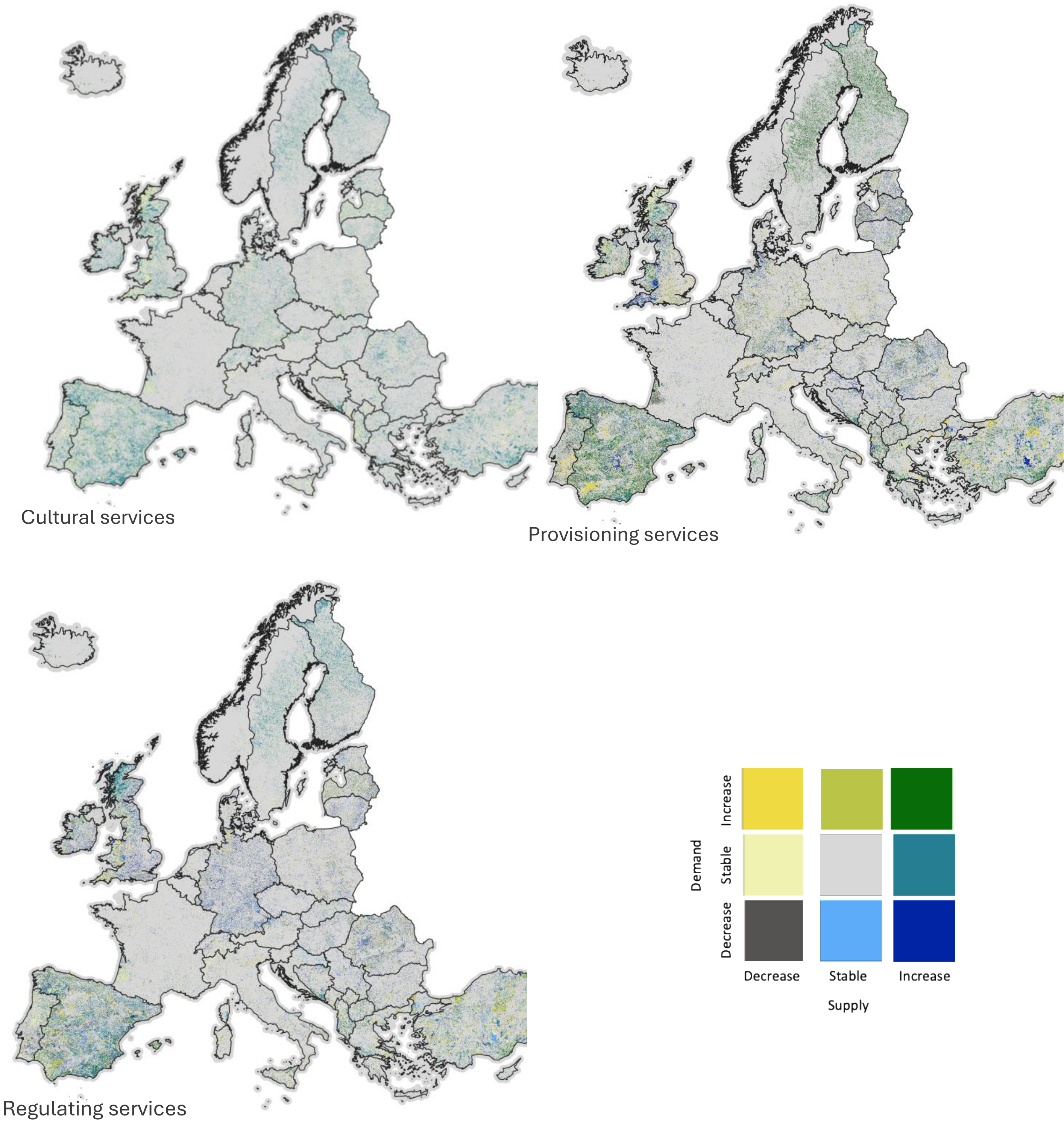

Figure 8: Change in ecosystem service supply and demand over 2000-2018

2.4 Synthesis

Overall, at the EU scale, the amount of land use change is limited, but its strong spatial clustering, leads to profound local impacts. Agricultural intensity has shown polarization, with already intensive areas becoming more intense and less intensive areas de-intensifying. This trend has been accompanied by an expansion of natural areas, resulting in an increased separation between human activities and nature-like land cover Consequently, this separation is likely reducing the benefits humans derive from nature. An aggregated estimate of changes in the demand and supply of ecosystem services shows a similar pattern, with a widespread increase of demand of provisioning services and other increases of demand concentrated in the urbanizing regions, separated from supply changes. These changes mean that wellbeing components directly derived from nature might have decreased over the past decades. Additionally, changes in societal values, wealth, and population growth have changed what society demands from the landscape, while the impacts of climate change have become more apparent.

Broad regimes of agricultural management changes interacting with natural areas show distinct regional trends. In Western Europe, increasing environmental awareness is currently influencing land use patterns, while across Europe, industrialization of agriculture continues alongside de-intensification in certain regions. In response to shifting societal demands and climate change impacts, novel land systems are emerging. These include large-scale restoration of natural areas and the adoption of agricultural practices better suited to changing climate conditions or contributing to climate change mitigation, such as vineyards, other novel crops, green infrastructure, and renewable energy-dedicated areas. Additionally, an increasing demand for recreation is increasingly shaping land use across Europe.

3 Land use change in PLUS Change Practice Cases

This chapter outlines land cover and land use change in the 12 PLUS Change practice cases, based on combining secondary data with findings from expert workshops carried out in the practice case areas (Figure 8). Secondary data include a time series analysis of Corine Land Cover combined with a time series analysis of data from the Farm Accountancy Data Network (FADN, (DG Agri, 2022), Table 2). The workshops provided context on the land use changes, and a first insight into the impact of recent land use change on biodiversity and wellbeing. Detailed data and descriptions are found in specific workshop reports. The brief practice case descriptions at the start of each section are the default descriptions used throughout PLUS Change and are integrally copied here, for the sake of consistency and completeness.

The PLUS Change practice cases differ strongly in scale and cover different territorial administrative levels. While some practice cases unite parts of municipalities or e.g. a national park, others are defined at province level or even cross-national borders. This makes comparing and synthesizing practice cases challenging. Another challenge is in the availability of harmonized data on farmland management statistics. The most detailed information on farm management that is available at European extent does not provide more detail than NUTS2 level. While for some indicators for management intensity more detailed data is openly available at province or municipality level (e.g., farm labor data in Italy), a lack of consistent data availability hampers a more detailed synthesis. Because of these data availability issues and for the sake of consistency, land cover and land use changes are here detailed for the actual practice case and compared to the encompassing NUTS2 region(s). The analysis of agricultural land management intensity is applied at the level of the NUTS2 regions in which the individual practice cases are located.

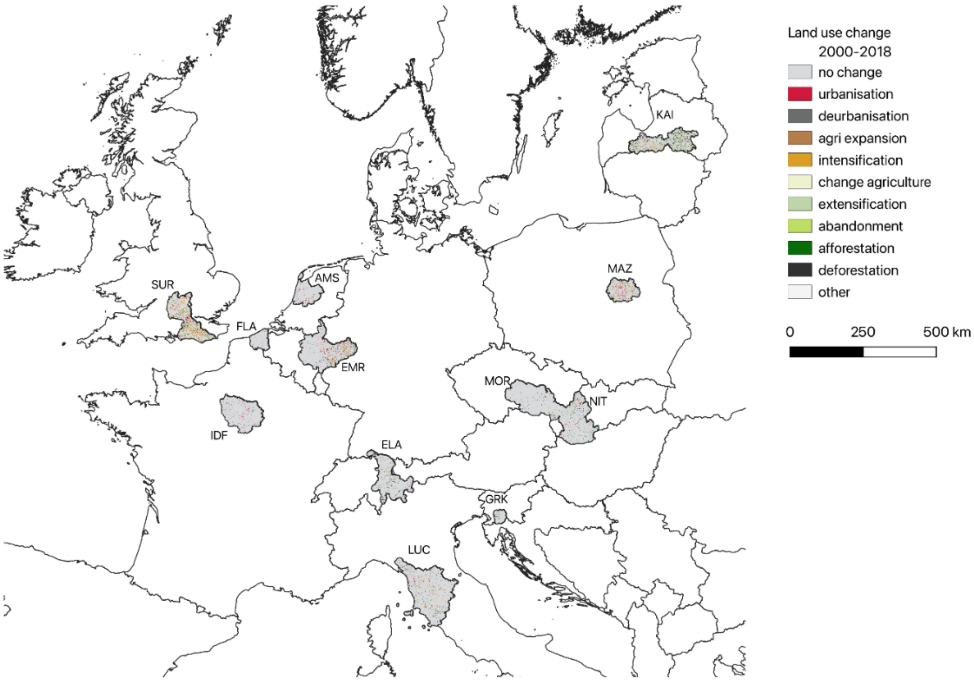

Figure 9: land use change between 2000 and 2018 in the PLUS Change practice cases. Detailed maps are provided in the subsequent sections. Practice case abbreviations are elaborated in the chapter text

Table 4: overview of gross land use change (LUC) in the practice case NUTS2 regions between 2000 and 2018, in area percentage of NUTS2 region. These regions are defined at the level of the NUTS2 regions of which the practice cases are part

Land use	Loss / gain	Flanders	Three Countries Park	Amsterdam Metropolitan Area	Surrey	Île-de-France	Lucca	Green Karst	Nitra	South Moravia	Warzaw Metropolitan Area	Kaigu Peatland	Parc Ela
Urban and infrastructure	Loss	-0.02%	-0.03%	-0.12%	-0.06%	-0.04%	-0.01%	0.00%	0.00%	-0.01%	-0.11%	0.00%	0.00%
	Gain	0.44%	0.53%	2.01%	0.36%	0.78%	0.25%	0.04%	0.30%	0.20%	1.11%	0.04%	0.02%
Extraction, dump, construction	Loss	-0.15%	-0.46%	-1.13%	-0.18%	-0.40%	-0.09%	-0.03%	-0.07%	-0.02%	-0.37%	-0.02%	-0.01%
	Gain	0.22%	0.59%	1.20%	0.37%	0.51%	0.09%	0.00%	0.10%	0.10%	0.47%	0.05%	0.01%
Arable land	Loss	-0.19%	-0.58%	-1.51%	-0.36%	-0.83%	-0.20%	0.00%	-0.54%	-1.60%	-1.01%	-0.16%	-0.02%
	Gain	0.00%	0.23%	0.15%	0.03%	0.03%	0.02%	0.00%	0.19%	0.24%	0.03%	1.24%	0.00%
Permanent crops	Loss	0.00%	-0.01%	-0.07%	0.00%	-0.01%	-0.01%	0.00%	-0.16%	-0.22%	-0.01%	-0.07%	0.00%
	Gain	0.00%	0.00%	0.00%	0.02%	0.00%	0.03%	0.00%	0.05%	0.51%	0.04%	0.01%	0.00%
Pastures	Loss	-0.07%	-0.17%	-0.64%	-0.24%	-0.10%	-0.01%	0.00%	-0.03%	-0.08%	-0.46%	-1.24%	0.00%
	Gain	0.02%	0.06%	0.02%	0.04%	0.03%	0.00%	0.00%	0.01%	0.84%	0.06%	0.20%	0.00%
Complex vegetation patterns	Loss	-0.19%	-0.24%	-0.15%	-0.01%	-0.04%	-0.07%	0.00%	-0.05%	-0.02%	-0.29%	-0.06%	0.00%
	Gain	0.01%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.18%	0.02%	0.28%	0.02%	0.00%
Forests	Loss	0.00%	-0.62%	-0.13%	-0.14%	-0.44%	-1.62%	-1.26%	-0.89%	-0.71%	-0.32%	-5.13%	-0.06%
	Gain	0.01%	0.26%	0.14%	0.01%	0.28%	0.84%	0.02%	0.27%	0.50%	0.11%	0.47%	0.01%
Nature	Loss	-0.15%	-0.39%	-0.26%	-0.02%	-0.32%	-1.34%	-0.02%	-0.32%	-0.53%	-0.18%	-0.62%	-0.17%
	Gain	0.07%	0.73%	0.38%	0.14%	0.48%	1.77%	1.25%	0.90%	0.73%	0.65%	5.21%	0.22%
Water	Loss	-0.01%	-0.01%	-0.05%	-0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	0.00%	0.00%
	Gain	0.02%	0.05%	0.08%	0.02%	0.03%	0.02%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%
Total area undergoing LUC		0.8%	2.5%	4.0%	1.0%	2.2%	3.3%	1.3%	2.1%	3.2%	2.8%	.3%	0.3%

Table 5: overview of land use intensity indicators and changes therein 1990-2020 in the practice case NUTS2 regions. These are defined at the level of the NUTS2 regions of which the practice cases are part. Data source: FADN; no data available for Par

	number of farms per region			average economic size (€/farm)			labour (AWU/region)			livestock (LSU/region)			average crop protection purchase (€/farm per year)		
	1990	**1990-2004**	**2004-2020**	**1990**	**1990-2004**	**2004-2020**	**1990**	**1990-2004**	**2004-2020**	**1990**	**1990-2004**	**2004-2020**	**1990**	**1990-2004**	**2004-2020**
Flanders	10727	-45%	-60%	282	533%	73%	18342.96	29%	-57%	841416.1	85%	-50%	2525	566%	67%
Three Countries Park	19589	-47%	-57%	371	308%	82%	35881.18	-19%	-53%	1452282	19%	-48%	2784	319%	65%
Amsterdam MA	10825	-51%	-62%	441	203%	78%	23815.05	-33%	-54%	929544.8	-15%	-48%	3047	249%	97%
Surrey	5738	-27%	-60%	288	158%	46%	19738.8	-35%	-55%	476083.8	0%	-52%	13584	61%	21%
Île-de-France	6400	-39%	-51%	473	125%	91%	11648	-33%	-58%	25152	-41%	-62%	10931	128%	27%
Lucca	48680	-51%	-67%	789	125%	18%	84703.2	-55%	-70%	243886.8	-46%	-82%	781	129%	26%
Green Karst	0	nd	-42%	0	nd	112%	0	nd	-65%	0	nd	-50%	nd	nd	nd
Nitra	0	nd	-42%	0	nd	136%	0	nd	-73%	0	nd	-59%	nd	nd	nd
S Moravia	0	nd	-54%	0	nd	86%	0	nd	-67%	0	nd	-59%	nd	nd	nd
Warzaw MA	0	nd	-50%	0	nd	129%	0	nd	-57%	0	nd	-47%	nd	nd	nd
Kaigu Peatland	0	nd	-42%	0	nd	210%	0	nd	-57%	0	nd	-34%	0	nd	112%

3.1 Flanders

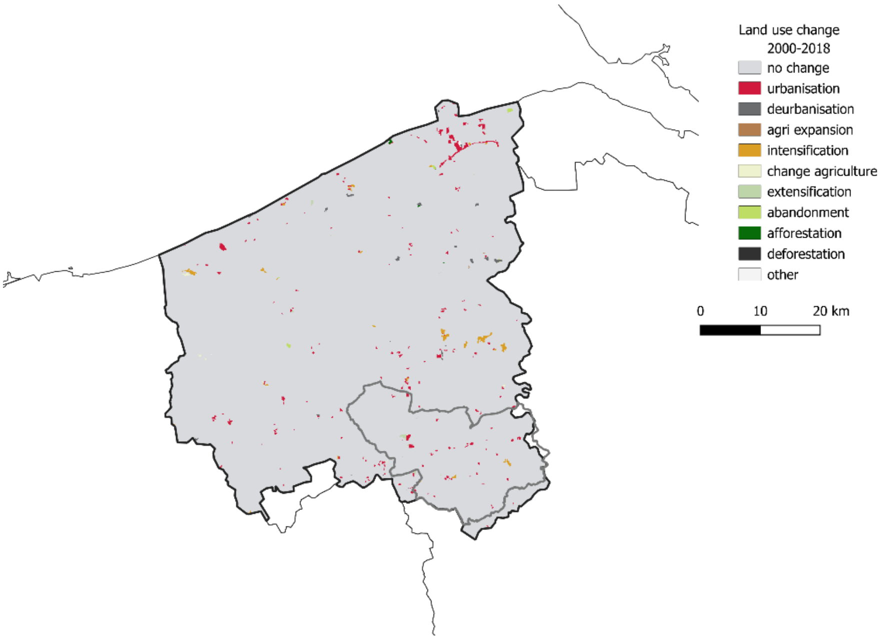

Figure 10: land use change between 2000 and 2018 in the PLUS Change practice cases. Detailed maps are provided in the subsequent sections. Practice case abbreviations are elaborated in the chapter text

Flanders is the Dutch-speaking region in northern Belgium. With a population of 6.5 million and a total area of 13,500 km^2, the region accounts for 57% of the country's total population and 45% of Belgium's territory, making it one of the most densely populated regions in Europe. It is a region of economic significance and is home to a mix of urban centres, picturesque towns, and scenic countryside.

Flanders faces a range of challenges within its focus area that are closely tied to mitigating the effects of climate change. These challenges include delivering environmental goals related to soil sealing, habitat restoration, expansion of forest areas, establishment of national and landscape parks, and the management of floods and droughts. To address these challenges, Flanders aims to implement measures such as reopening streams and allowing them to meander freely, which can aid in improving water flow and restoring natural ecosystems. Additionally, collaborative efforts with farmers are being pursued to combat erosion and enhance soil health. Specific focus is on four development programs where smaller regions were explored. The regions are spread throughout the south of Flanders.

Since 1990, the number of farms in Flanders has decreased continuously by 60% (), while economic size has increased by more than 70% and the total area of utilized agricultural land per farm expanded. This continuous scale enlargement trend is also reflected in the number of laborers per farm, that has also continuously increased. Scale enlargement was primarily seen in the arable sector; livestock numbers have decreased over time. The arable sector also faced intensification, with increased nitrogen use and crop protection.

Gross land cover changes were limited to 1.21% of the practice case region between 1990 and 2000 and were below 1% in other timesteps (Table 4). In general, the area of arable land, pastures, and complex vegetation patterns decreased, while the area of urban and infrastructure land increased. Nature and extraction sites were characterized by a shift in location rather than by a net gain or loss (Figure 10). The focus area is no exception in these general land cover trends.

Stakeholders in the practice case workshops indicated that large-scale land consolidations happened in the practice case, which is reflected in the scale enlargement and the land turnover. Also, residential extension was mentioned as a notable land use change that happened throughout the practice case. The stakeholders indicated that more recent land consolidations gave more attention to nature conservation, which aligns with the gross changes of nature in the practice case.

3.2 Three Countries Park

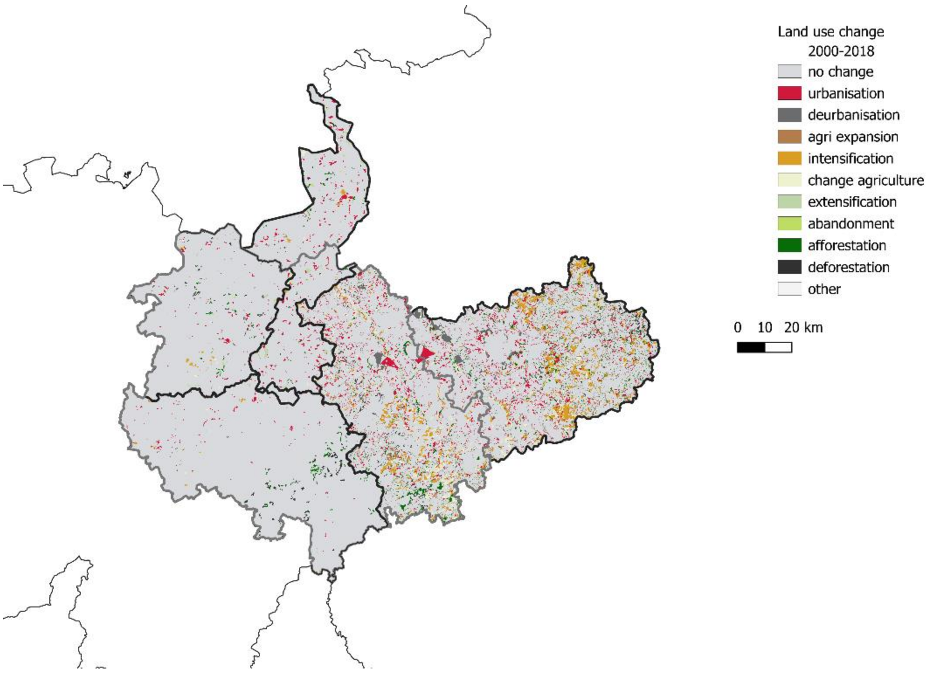

Figure 11: Land use change in Euregio practice case NUTS2 regions. The practice case region itself is indicated in grey.

The Three Countries Park is a landscape area and partnership located at the intersection of Germany, Belgium, and the Netherlands. The lead partner, Euregio Meuse-Rhine (EMR), is the cross-border cooperation organization (European Grouping of Territorial Cooperation) that aims to enhance sustainable regional development, quality of life, and cultural exchange among these neighbouring regions. Three Countries Park faces several challenges, including the persistent issues of floods and droughts, environmental impacts of nitrogen, urbanization pressures, agricultural changes, and fragmentation affecting both habitats and governance. In terms of habitat, the region grapples with connecting diverse ecosystems via cross-border corridors. The governance aspect presents unique challenges due to sectoral administration, varying competence levels, and the presence of multiple languages and cultures across the three countries involved.

Within the territory of the EMR (covering about 11.000 km^2 with a population of nearly 4 million), the Three Countries Park area constitutes the peri-urban heart hosting about 2.4 million of its inhabitants. Several cities like Liège (BE), Aachen (DE), and Maastricht (NL) are embedded in a beautiful hilly hedge landscape stretching over 3500 km2 across the borders.

Since 1990, the number of farms in the NUTS2 regions of the Three Countries Park has decreased continuously throughout the region by almost 60%, while throughout the NUTS2 regions the average economic size of farms tripled and the number of laborers per farm decreased (Table 5). The intensity of arable land has increased in the Belgian and Dutch NUTS2 regions, while trends in the German part are not clear. Simultaneously, the nitrogen use increased, while the level of crop protection decreased up to 2000 and then started increasing. Livestock trends are also different throughout the region. In the Dutch and Belgian NUTS2 regions, increases per farm were seen up to 2012, followed by a decrease, while livestock numbers have decreased continuously in the German part of the region.

Gross land cover changes were slightly higher than in Flanders, with 2.63% of the area changed between 1990 and 2000 and almost 1% in the other timesteps (Table 4). Overall, the area of urban land and pasture increased (Table 6), while arable land and complex vegetation patterns decreased. However, this region shows land turnover of all land cover types except urban land, and overall, gross change is more widespread in the German part of the region than in Belgium and the Netherlands (Figure 11). In the Netherlands, urbanization is the dominant land use change, while in the Belgian part of the region also afforestation occurs and in the German part of the surrounding NUTS2 region, widespread intensification occurs (Figure 11). Compared to the surrounding NUTS2 regions, the practice case itself seems to face slightly less gross land cover change than the remaining area. Especially in the German part, dynamics in agriculture seems to be lower, while afforestation is slightly more widespread.

The workshop focused on the practice case highlighted the changes in mining, that were closely related to re-naturalization and therefore contributed to the turnover of forest and nature. Stakeholders also emphasized the intensification and scale enlargement of the region was highlighted by the stakeholders. The urban and infrastructure expansion is driven not only by expansion, but by a shift from urban to peri-urban lifestyles as well as by significant infrastructure expansion.

3.3 Amsterdam Metropolitan Area

The Amsterdam Metropolitan area is comprised of 32 municipalities and two provinces (North Holland and Flevoland). Approximately 2.5 million people live in the area, making up more than 14 percent of the population of the Netherlands.

With high level infrastructure, strong economic standing, and a rich cultural history, the area aims to develop in such a way that fosters greening and sustainability, while maintaining quality of life for its inhabitants. The Amsterdam metropolitan area encounters noteworthy challenges stemming from population pressure, housing demand, the conservation of valuable cultural landscapes, nitrogen deposition, biodiversity loss, noise pollution generated by Schiphol Airport, and the distinctive aspect of being situated below sea level. These various issues exert tremendous pressure on the limited space available, thus calling for innovative and sustainable solutions.

In this region, the number of farms and number of farm laborers decreased by over 60% since 1990 (Table 3), while the average economic size of farms increased, and the increasing use of nitrogen fertilizer and crop protection suggest ongoing intensification in crop production.

Livestock numbers increased until 2012 and decreased afterwards. The utilized agricultural area shows diverging trends throughout the area.

Between 1990 and 2000, 6% of the surrounding NUTS2 regions have undergone land use change. Also in the 2000-2006 and 2006-2012 timeframes, gross change affected over 1% of the practice case area. Most striking are the increase of urban area and the decrease of pasture and arable land. Strikingly, the area of complex vegetation patterns has increased in this region. Urbanization happened throughout the surrounding NUTS2 regions, while trends towards less intensive agriculture occurred primarily in the east and north of the region.

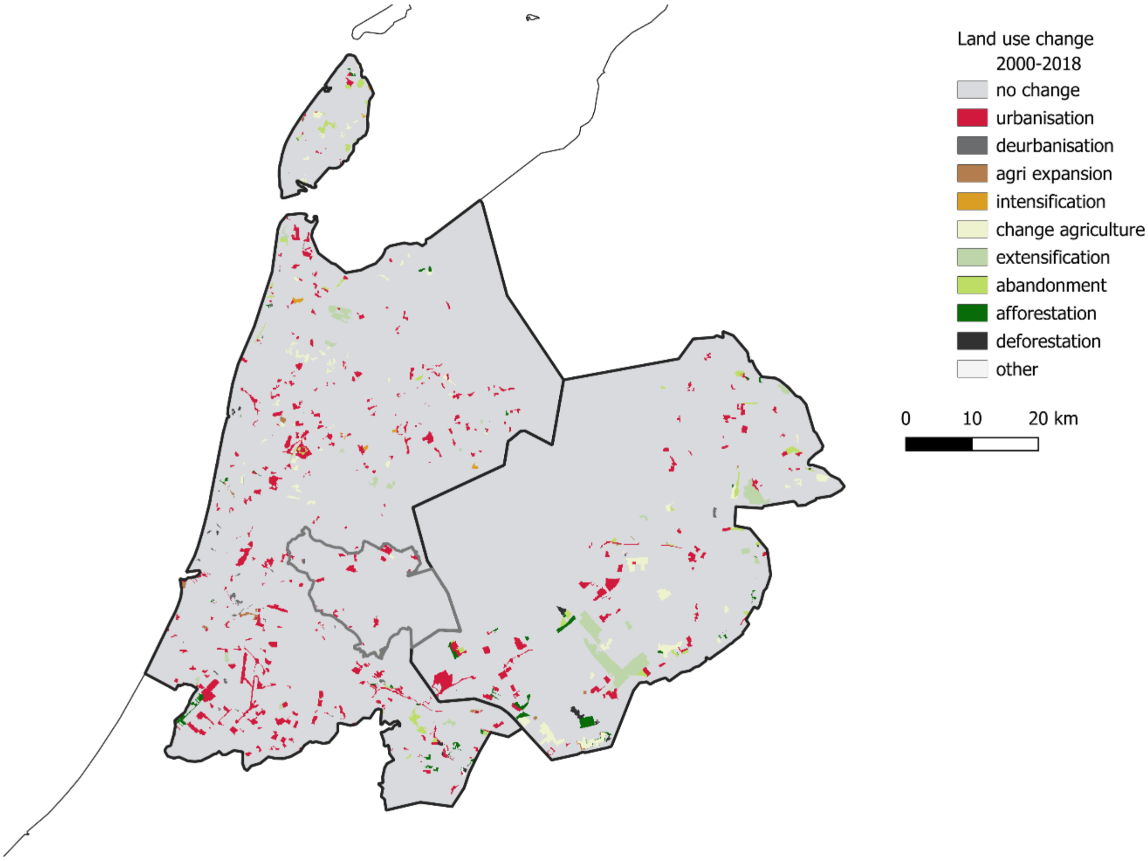

Figure 12: Land use change in Amsterdam Metropolitan Area NUTS2 regions. The practice case region itself is indicated in grey.

The land turnover in this region is relatively limited. Urban areas expand, agriculture contracts, and nature expands, although there are small losses of nature as well (Figure 12, Table 6).

In the workshop, focus of attention was the region Waterland-Zaanstreek (highlighted in Figure 12). Compared to the surrounding NUTS2 regions, land use dynamics in this region were slightly less pronounced and primarily resulting from urbanization (Figure 12). The stakeholders have highlighted the urban expansion in big neighbourhoods connected to the existing urban cores. Also, the establishment of nature protection areas is mentioned as an important land use change. Agricultural intensification is also prominent according to the stakeholders but is mitigated since recently due to the “nitrogen crisis” and the increasing importance of recreation and nature protection.

3.4 Surrey

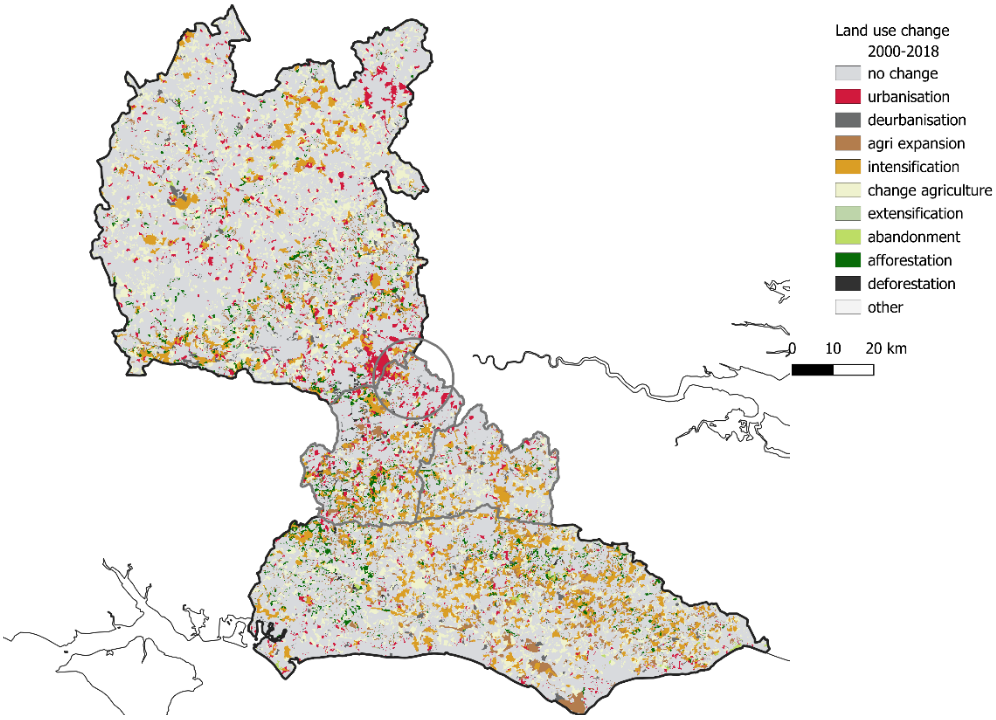

Figure 13: Land use change in the Surrey practice case NUTS2 regions. The practice case region itself is indicated in grey.

Surrey is a county located in the south-eastern part of England, United Kingdom. It is known for its green spaces and a mix of urban and countryside living. It contains 1.2 million people and covers an area of 1663 km^2. The county faces diverse land use planning challenges. Key challenges include the need for effective community engagement and overcoming land fragmentation and issues related to multiple ownerships. Preserving the green belt while accommodating urban growth presents also a significant challenge, and decisions about development costs and brownfield remediation versus greenfield expansion require careful consideration. Flood risk and flood plain management, water management, and habitat protection are essential concerns, alongside biodiversity preservation and species management. Additionally, addressing air quality and transportation issues, particularly around Heathrow and Gatwick airports remains vital. The practice case focuses on a region on the northern edge of the Surrey County, touching upon the NUTS2 region of Berkshire, Buckinghamshire, and Oxfordshire (Figure 13).

The NUTS2 regions of the Surrey practice case have experienced a continual decrease of farm numbers (-60%) and farm labour, increase of economic size (+46%) and UAA per farm, and intensification of crop production. Livestock numbers per farm decreased up to 2012 but increased recently (Table 3).

With regards to land cover, only data from 2000 onwards are available. The NUTS2 regions show a modest increase in urban land only, but a vast decrease of complex vegetation patterns and a vast increase of pasture. Gross land use changes are modest, below 1% in all timesteps (Table 2). Land turnover is modest as well; extraction and dump sites show both contraction and expansion while arable land and pastures are dominated by contraction oftentimes and nature by expansion (Figure 13). The practice case region itself shows less land use dynamics than the broader NUTS2 regions, and more dynamics in urban areas.

Comparing the trends with stakeholder knowledge suggests that the modest urban expansion might be related to targeted green belt policies and other policies to reduce urban sprawl. Stakeholders also highlighted specific mining area restoration efforts.

3.5 Île-de-France

Île-de-France is a region in France, centred around Paris. The region covers an area of more than 12000km^2 and has a population of 12.3 million. It is made up of 75% natural areas and 25% urban areas, spread in a heterogeneous way over its territory, which is at once urban, peri-urban and rural. Île-de-France serves as the economic, political, and cultural heart of France, attracting millions of tourists each year. The region is renowned for its iconic landmarks, world-class museums, and vibrant arts scene. The Île-de-France region confronts the critical task of managing urban growth and population increase while maintaining its international appeal. To address these challenges, the region has devised the Île-de-France Environmental Master Plan (SDRIF-E), targeting key issues. These include curbing soil artificialization and preserving biodiversity, reducing CO_2 emissions, balancing housing demands with community well-being, enhancing attractiveness, improving mobility and public services, promoting circular economy practices, and increasing climate change resilience.

The Île-de-France NUTS2 region has seen a continuous decrease of the number of farms (-51%) and farm laborers (-58%) since 1990, alongside an increasing UAA per farm. The average economic size per farm increased up to the turn of the century but remained rather stable since then. Livestock numbers per farm decreased; nitrogen use increased continuously but crop protection use has levelled off since 2012 (Table 3).

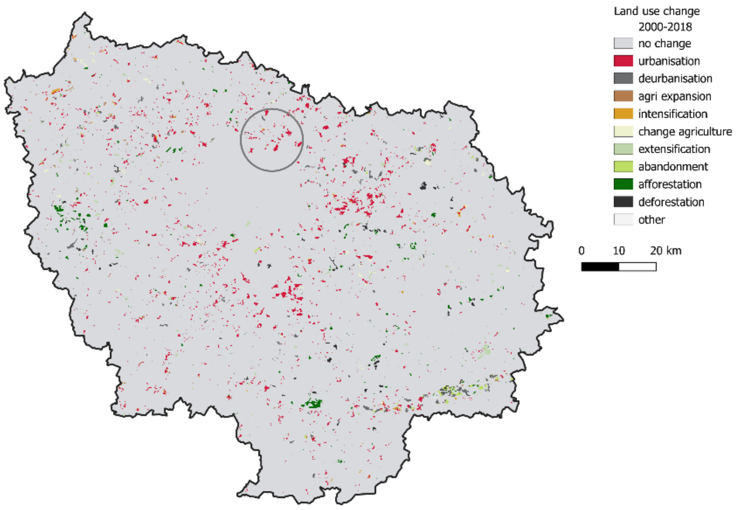

Figure 14: Land use change in the Ile de France practice case NUTS2 regions. The practice case region itself is indicated in grey.

The overall area of arable land and pastures has decreased, while urban land and infrastructure increased (Table 6). Contrary to other practice cases, the area of forests decreased while more complex vegetation patterns emerged (Table 3).

Land turnover was over 2% between 1990 and 2000, and close to 1% in later timeframes. The area experienced gross gains and losses of forest and nature and extraction sites, while other main land uses were mainly characterized by net gains or losses (Figure 14).

The workshop focused on a specific area north of Paris (Figure 14). Stakeholders in the region also mentioned the agricultural intensification and urban expansion as major land use changes and the changes observed (Figure 14) are in line with the changes in the wider NUTS2 region. However, the laws aimed at reducing urban sprawl mentioned by the stakeholders, may have contributed to the relatively modest urban expansion compared to other practice cases. Furthermore, several specific events were identified as causes of the forest area decline, that led to the decrease in forest area, mainly related to leisure facility expansion. Finally, the preservation of complex cultivation patterns might be related to recent deliberate nature development throughout the area that specifically aimed to preserve agricultural area within the boundaries of the national parks.

3.6 Lucca

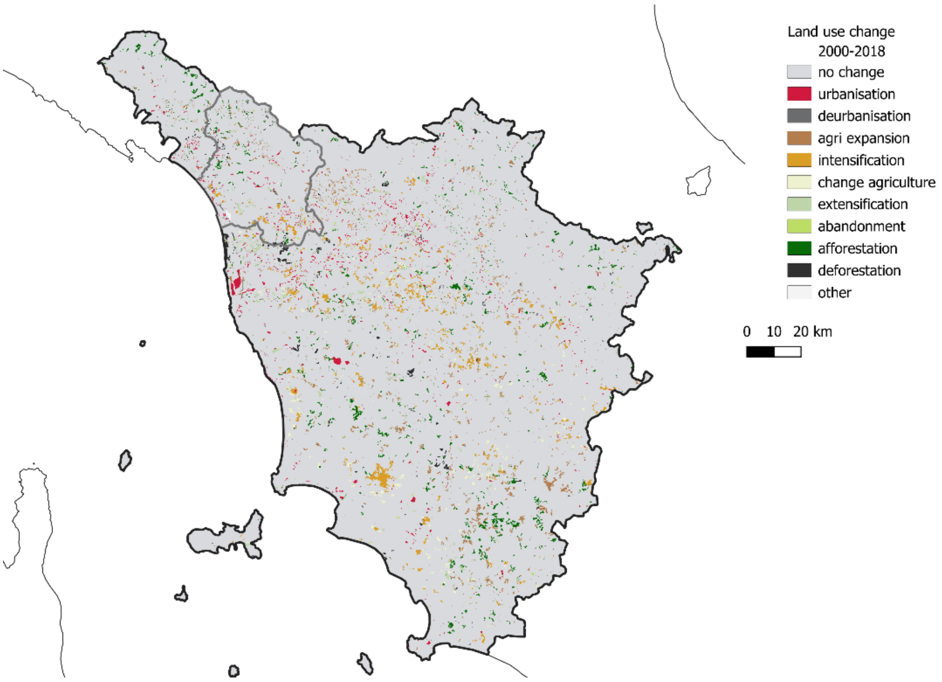

Figure 15: Land use change in the NUTS2 region of the Lucca practice case. The practice case region itself is indicated in grey.

The Province of Lucca, located in the Tuscany region of north-western Italy, boarders the Ligurian Sea and hosts a sprawling, mountainous landscape and multiple medieval towns. With a population of 387,876, it is a mostly rural province, consisting of 33 communes. The province harboured around 7% of the Tuscany region's farms, with a wide variety of specializations, where vegetable production and feed production are most frequent.

Key challenges in the Province of Lucca revolve around climate-driven changes in agriculture and land use planning, energy and water consumption reduction, air quality improvement measures, and the complex interplay between climate change, natural risks, and local development.

The most notable land cover change is a decrease in permanent crops up to 2000, which bounced back afterwards. Furthermore, agricultural land and complex vegetation patterns have decreased while forest and urban areas have increased (Figure 15).

The region shows a relatively high land turnover, with over 1% of the land changed per timestep. Forest and nature show considerable gross gains and losses in each timestep, while urban and arable land primarily showed net changes only (Table 2). In the Lucca province specifically, some polarization of land use is taking place. While over the 2000-2018 time frame 91% of the region remained unchanged, among the changed area, intensification (17% of the changed area) and afforestation (16% of the changed area) were dominant. Furthermore, almost 16% area undergoing change was urbanized, while 12% of the changed areas undergone agricultural expansion.

The Tuscany NUTS2 region has experienced a continual decrease in the number of farms, farm labourers and livestock numbers per farm. Economic farm size has increased, as has nitrogen use. While the UAA per farm decreased up to 2000, increases have been observed since then (Table 3). Given the expansion and intensification of land cover / use in the encompassing NUTS2 region of Tuscany, it is likely that the Lucca province followed similar trends.

The workshop focused on the Lucca province itself. The practice case stakeholders indicated an increasing interest in wine tourism and agri-camping since the 1990s. Also, the high level of land ownership fragmentation is mentioned. In 2000, a territorial coordination plan was established to safeguard the rural agricultural areas. Abandonment of agriculture due to lack of income generation opportunities was also mentioned – this clearly aligns with the trends in land use intensity.

3.7 Green Karst

The Green Karst region boasts a rural and well-preserved natural landscape, with 73% of land covered by woods and 54% designated as a Natura 2000 area. It covers 1456 km^2 and has a population of 53,092. The developmental paradigm is to combine sustainable economic growth with nature preservation. The landscape is made up of karst stone formations and numerous bodies of water, as well as forests and meadows. It has a high level of biodiversity, hosting all three European large carnivores and a UNESCO site consisting of primeval beech forests. Notably, the region has three remarkable caves—Postojna, with a cave train that takes visitors underground, Križna, containing subterranean lakes, and Planina, which is famous for Europe's largest confluence of subterranean rivers.

Despite its rich natural landscape, the area is also one of the less economically developed regions, due to its traditional industry and production-oriented economy. The main challenges and priorities stem from the lack of strategic land use planning in Slovenia over the past decades. To address this, the region must prioritise areas for focused efforts in regional spatial planning, aiming to ensure sustainable and strategic land use planning within the Green Karst region.

This practice case is part of the SI03 NUTS2 region. In this NUTS2 region, land use intensity in agriculture shifted in last decades, it decreased in crop production, land use changed from crop land to grassland. However, at NUTS2 level, all land use intensity indicators considered here increased (Table 2). In the practice case itself a contrasting pattern is seen; the livestock numbers and rearing practices increased. The number of farms decreased, farms became bigger in size, economic size, number of laborers, and livestock numbers, and nitrogen and crop protection use increased. There was also a considerable change in livestock structure and rearing practices. A shift was noticeable from sheep and goat rearing in remote, poor soil areas that is almost completely abandoned, to increase in number and intensification in cattle rearing.

However, agriculture is of limited importance in the region and only covers 5% of the land area of the NUTS2 region. There has been a considerable urban expansion in the area, but the most notable change is a constant increase in forest and consequently loss in open land – pastures and grasslands. There has been very little land turnover up to 2012, but after 2012 land cover change occurred in over 1% of the area (Figure 16).

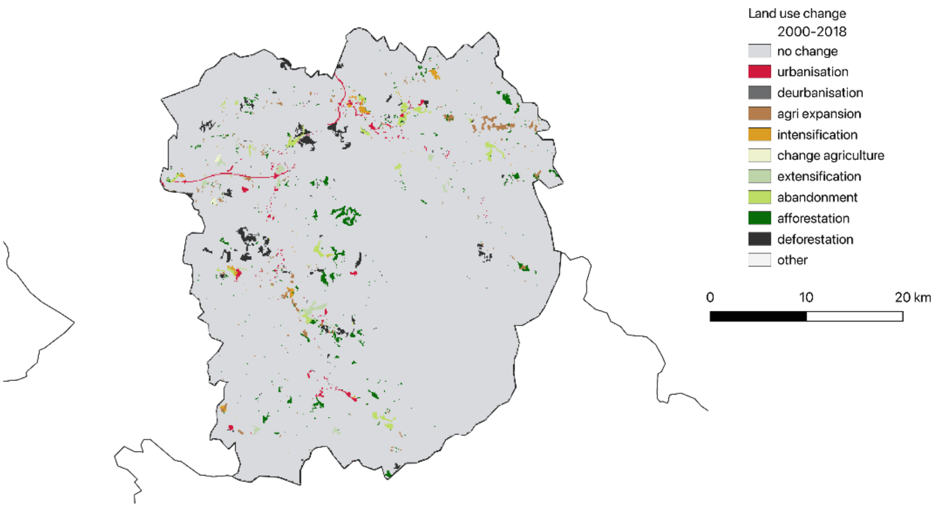

Figure 16: Land use change in the Green Karst practice case NUTS2 region.

The workshop focused on the Green Karst park itself, where participants explained that farming as economic activity and employment was turned upside down after nationalization in 1950s and the sector was severely influenced by loss of own land, break in family tradition, lost in knowledge and relationship to arable land and post war industrialization, followed by introduction of the Common Agricultural Policy. Nowadays farming is limited to a few bigger cattle farmers who export products to markets with higher prices, while additionally there are small-scale niche farmers with local sales networks. Also, the workshop participants emphasized the Natura2000 network that covers half of the area and comes with several nature protection and restoration measures.

3.8 Nitra

Nitra is a city located in western Slovakia in the Danubian Lowland (valley of the river Nitra) and at the foot of the Tribeč mountains, with a population of around 100,000. Nitra is known as one of the oldest cities in the country, with evidence of human habitation dating back to the Neolithic era. It has also been a political and economic centre of the region since the 9th century. Modern-day Nitra strikes a balance between preserving its historical legacy and natural environment and embracing contemporary development.

The City of Nitra in Slovakia serves as regional economic centre, acting as a traffic crossroad and holding historical significance for the area. The landscape within the region consists of urban areas, agricultural land, and forests, creating a diverse and complex environment.

Nitra faces several core land use challenges, including intensive sub-urbanization processes and land take of fertile agricultural soils for the purposes of new manufacturing and logistic facilities, which impact various aspects such as housing, transportation, and recreation. These activities also contribute to environmental problems concerning soil, air, and water quality, posing a threat to the overall health of the local ecosystems.

This practice case is part of the SK02 NUTS2 region, which only has data on land use intensity in agriculture from 2000 onwards, showing increases in all land use intensity parameters.

At the same time, the area of arable land decreased while forest and complex vegetation patterns increased and also urban areas showed an expansion. Land turnover was close to 1% in the early 21st century and lower after 2012 (Table 2). Many of the land cover types show considerable gross changes, with gains and losses in the same timeframe. This is most striking for forest, nature, and arable land (Figure 17). However, changes to forest primarily happened elsewhere in the NUTS2 region, while the city and its direct surroundings are primarily characterized by expansion of urban and infrastructure areas, as well as small changes in intensity of agriculture (Figure 17).

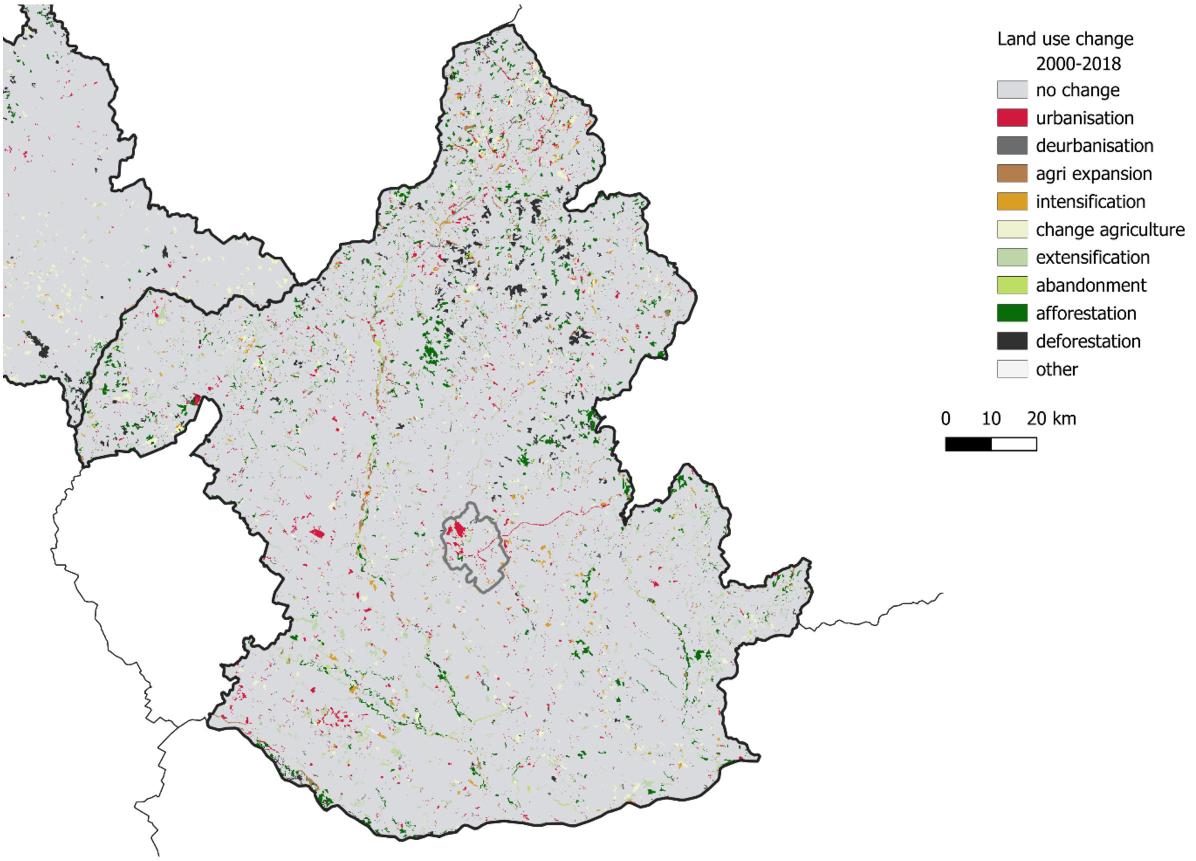

Figure 17: Land use change in the NUTS2 region of the Nitra practice case. The practice case region itself is indicated in grey.

Stakeholders emphasized the suburbanization process and the increasing attention for agri-environmental measures, that align with the expansion of complex cultivation patterns and extensification seen in the direct vicinity of the city itself.

3.9 South Moravia

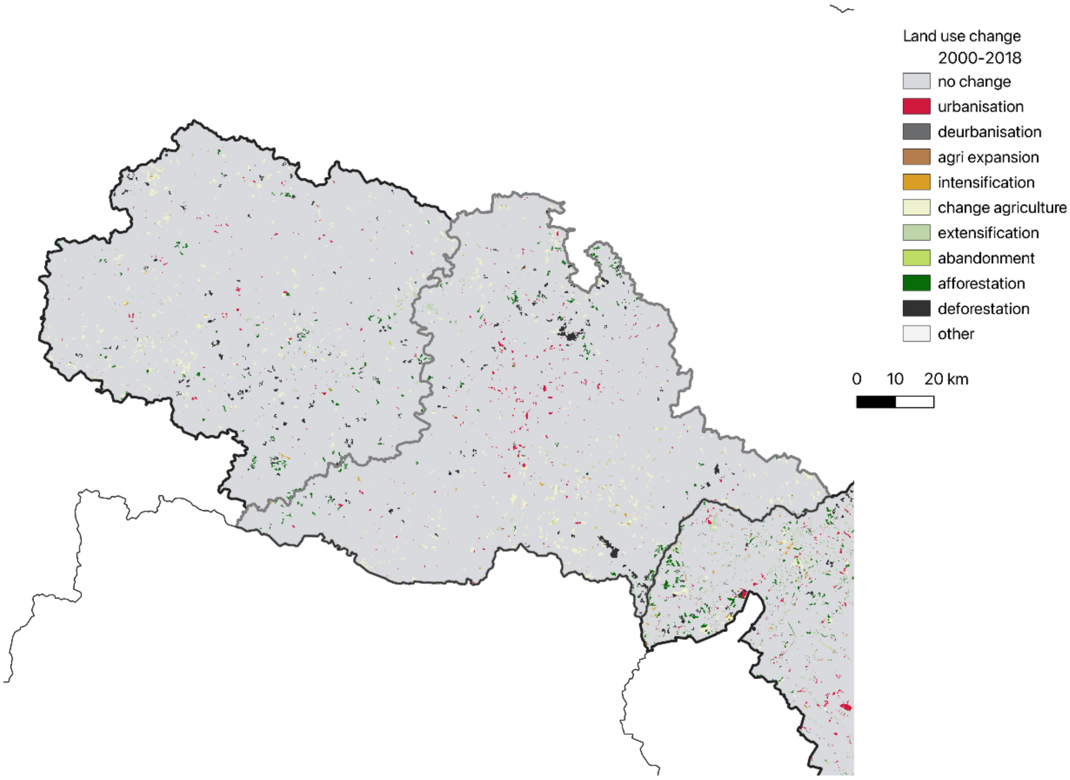

Figure 18: Land use change in the NUTS2 region of the South Moravia practice case. The practice case region itself is indicated in grey.

South Moravia, Czechia, is a region situated in the south-eastern part of the country and is characterized by its rolling hills, wine production, and the meandering Morava River. With a total of 7 districts and nearly 700 municipalities, approximately 1.3 million people live in the region. The region faces a diversity of challenges, specifically when it comes extreme weather events leading to drought and flash flooding. It also contends with ongoing processes of land consolidation, and conflicts between agricultural and environmental interests.

This practice case is part of the CZ06 region, and data on land use intensity in agriculture is only available from 2000 onwards. This data shows increases in all land use intensity parameters since 2000.

The land cover changes are a strong decrease in arable and nature, with increases in urban, complex vegetation patterns, permanent crops, and pastures (Table 6). Gross land cover changes are over 1% up to 2012, and 0.7% of the area has undergone land cover change afterwards. Forest, nature, and arable land show considerable gross changes in particular, while pastures and urban areas are mostly characterized by expansion only (Table 2; Figure 18). Compared to the full NUTS2 region, the practice case itself shows larger areas of deforestation and slightly more changes in agricultural land.

As in other Eastern European practice cases, land management and land cover changes are strongly shaped by the fall of communism. This led to privatization of agriculture, in this region sometimes accompanied by diversification, which might be the cause of the expansion of complex vegetation patterns. Revitalization of brownfields was in terms of area not a notable change but has had profound impacts locally. There has been a lack of support for agriculture through funding, causing the decrease of agricultural land and an increase in larger farms as reported in the land management statistics – these disregard smaller farms. Furthermore, biofuel production is understood to be related to the intensification of agriculture.

3.10 Mazovia

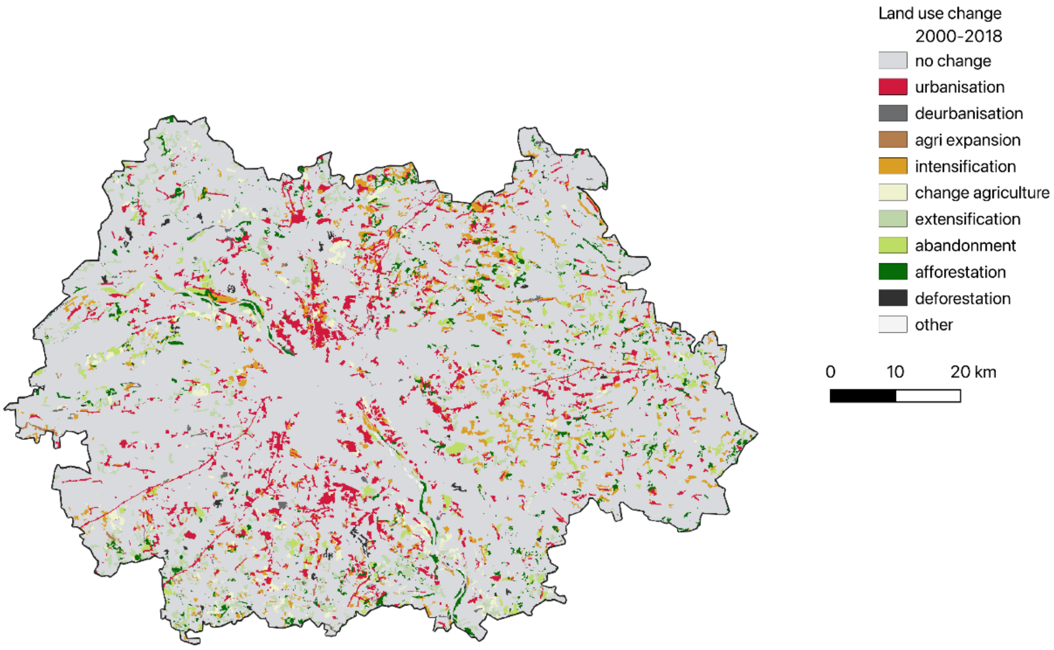

Figure 19: Land use change in the Mazovia, Warsaw Metropolitan Area practice case NUTS2 region.

Mazovia is a province in Poland with the metropolitan area of Warsaw at its centre. The region is home to 5.5 million residents in an area of 36 thousand km2. Mazovia is a region of beautiful river valleys, the dynamic capital city and 5 subregional cities, as well as fields and orchards. In the last two decades it has been one of the most rapidly developing regions in the EU.

The Mazovian region faces significant land use challenges, including the absence of a uniform spatial planning system, which limits possibilities for new investments, and restricted zoning coverage, enabling unregulated construction outside of the spatial planning system. There is also a lack of legally binding metropolitan spatial planning documents.

The area has also experienced rapid growth over the last decade, which is accompanied by rapidly progressing (sub)urbanisation. At the same time, agriculture plays an important role in the region's economy as many the region's inhabitants live in rural areas. Fast economic growth has resulted in multiple undesirable effects such as rising land prices, negative demographic trends in rural areas, landscape degradation and urban pressure on areas of natural beauty. Addressing these challenges is crucial for effective and sustainable land use in the region. The project focuses on part of the Mazovia region (Warsaw Metropolitan Area; NUTS2 –

Warszawski stołeczny) to better illustrate the challenge of countering uncontrolled suburbanization which affects all cities in the region.

This practice case only has data on land use intensity in agriculture from 2004 onwards, showing increases in all land use intensity parameters. The number of farms decreased from 47,000 to 28,000 between 2010 and 2020. At the same time, the number of farms of 10 ha or more increased by around 200 and their total area decreased by around 5,000 ha[1].

Net land cover changes since 1990 show a strong decrease in arable land that has bounced back since 2012, minor increases in forest, and increases in nature and urban areas, as well as decreases in complex vegetation patterns. Forest, nature, and complex vegetation patterns show strong gross changes with both losses and gains (Table 6). Shortly after Poland's accession to the EU, forest area increased as a results of subsidies. However, more recently pressures on forests have increased, resulting in fragmentation. Altogether, gross changes are modest, with between 1% and 2% of the area undergoing change during each timestep (Figure 19,Table 1).

The stakeholders indicated that the introduction of a market economy and deregulation triggered a decline in profitability of small-scale agriculture, resulting in a decrease of agricultural land and scale enlargement. This is in line with the land cover changes and the land use intensity changes, as the land use intensity data only considers bigger farms, which are likely to have increased in the scale enlargement process. Also, the notable gross changes in land can very well be caused by the scale enlargement and consolidation process. The stakeholders emphasized the widespread and strong urban sprawl, second home development, and infrastructure development, which affect agricultural land and forests.

3.11 Kaigu

Kaigu peatland is a natural territory located in the central part of Latvia. In the peatland, diverse land use practices co-exist in a complementary manner: industrial peat extraction, recultivation of peatland, nature and biodiversity conservation, and recreational activities.

Kaigu peatland practice case focuses on sustainable management of peatlands. Peatlands cover approximately 10% of Latvia's territory (Nacionālā Enciklopēdija). They are of significant environmental, economic, and socio-cultural value. Peatlands contribute to biodiversity, landscape preservation, act as natural carbon storage, provide valuable minerals such as peat and sapropel, and support foraging and recreational activities. The primary use of extracted peat of Kaigu peatbog is horticulture and forestry, where peat products and substrates serve as a natural input for cultivation of plants and food production. However, after peat extraction, the peatlands transform into degraded land that emits greenhouse gases. The emissions pose challenges in aligning with climate neutrality goals and the EU taxonomy for environmentally sustainable economic activities. To address these challenges, environmental impact assessments and recultivation plans are mandatory components of peat extraction projects.

[1] https://bdl.stat.gov.pl/bdl/dane/podgrup/temat

The NUTS2 region representing the Kaigu practice case only has data on land use intensity in agriculture from 2000 onwards, showing increases in all land use intensity parameters.

The land cover data show a decrease in forest, complex vegetation patterns, and pastures, and an increase in nature and arable land. Urban area has also increased, but changes are modest. Gross changes are relatively abundant; around or over 2% of the region has undergone a land cover change during most timesteps. Simultaneous losses and gains are most common for pastures and nature, but are also seen in arable land and forest (Figure 2, Table 2).

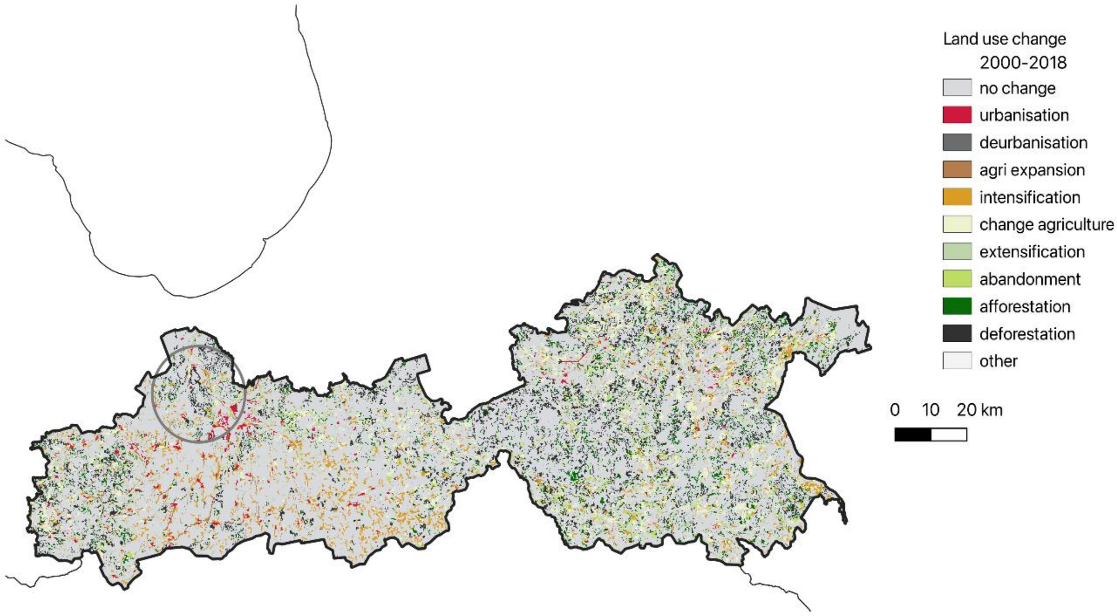

Figure 20: Land use change in the NUTS2 region of the Kaigu peatland practice case. The practice case region itself is located in the grey circle.

The stakeholder workshop focused on the Kaigu peatland specifically. While broad land use change patterns are in line with the NUTS2 trends, the discussed processes should be considered specific for the peatland. Stakeholders of the Kaigu peatland also here mentioned the profound impact of the collapse of the Soviet Union and the subsequent privatization. Land ownership of the peatland changed in the early 1990s, following by peat extraction and berry production. Peat extraction is currently the main viable economic activity in the area, although increasingly contested.

3.12 Parc Ela

Parc Ela is located in the heart of Grisons, Switzerland, and combines the three language cultures of Romansh, German and Italian. Its alpine landscapes offer many opportunities for outdoor activities and nature experiences. In the valleys, historic villages and churches are reminders of the former importance of the trade routes over the Albula, Julier and Septimer Alpine passes.

Parc Ela is facing a number of challenges due to the effects of climate change, particularly in the agricultural and tourism sectors. For example, changing precipitation patterns are being observed, characterized by heavy rainfall and longer dry periods. These weather fluctuations have an impact on cultivation methods and affect crop yields. Farmers and foresters in the park also need to effectively control new pest species that are emerging due to climate change. Warmer temperatures jeopardize snow safety in winter sports areas and require adjustments to the region's leisure activities. In addition, the region faces the socio-economic challenges of high housing prices and limited job opportunities for the local population.

In the NUTS2 region (CH05) of the practice case, no data on agricultural land use intensity changes consistent with the other region are available for this practice case, and land cover data are only available from 2000 onwards. The data shows limited dynamics compared to other practice cases. The area of forest, arable, and pasture decreased slightly, while nature, complex vegetation patterns, and urban increased slightly. In the practice case itself, extensification of agricultural land is furthermore striking, and abandonment as well as expansion of agricultural land is seen. There are very little gross changes; around 0.1% of the area undergoes land cover change in each of the timesteps. Nature areas show simultaneous increases and decreases (Figure 21, Table 2).

The stakeholders provided a partly contrasting view. While they acknowledge the expansion of urban and infrastructure land, they also indicate that more agriculture land and forest is getting used since 1990.

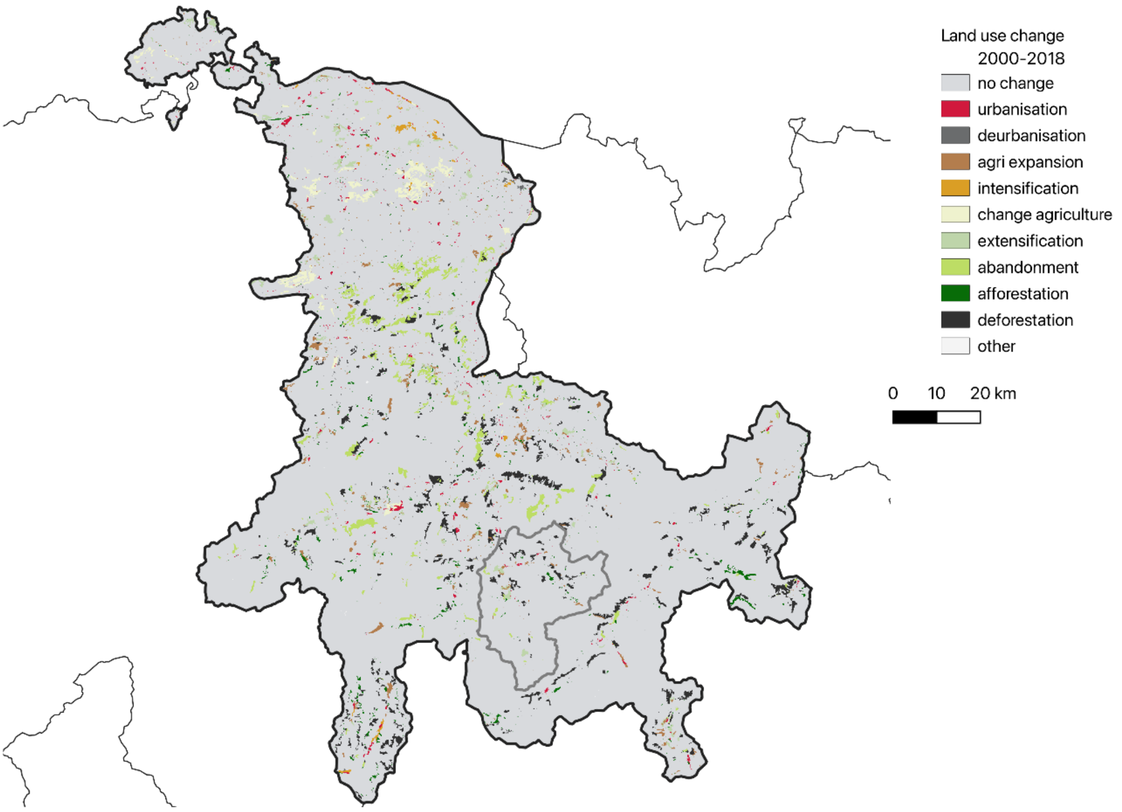

Figure 21: Land use change in the NUTS2 region of the Parc Ela practice case. The practice case region itself is indicated in grey.

Table 6: : area percentage of the NUTS2 regions in which practice cases are located undergoing ten main land use change types. The numbers between brackets indicate the extent of the land use change types as a percentage of the changed area.

	No change	Urbanisation	De-urbanisation	Expansion of agricultural land	Intensification of agricultural land	Change of agricultural land	De-intensification of agricultural land	Abandonment	Afforestation	Deforestation	Other change
Flanders	98%	0.8% (41%)	0.2% (11%)	0.0% (2%)	0.2% (12%)	0.1% (4%)	0.2% (9%)	0.1% (4%)	0.2% (11%)	0.1% (5%)	0.0% (1.6%)
Three Countries Park	87%	3.7% (28%)	1.4% (10%)	1.0% (8%)	2.7% (20%)	1.6% (12%)	0.3% (2%)	0.2% (1%)	1.9% (14%)	0.6% (4%)	0.0% (0%)
Amterdam MA	94%	2.8% (50%)	0.1% (2%)	0.1% (2%)	0.0% (1%)	0.8% (15%)	0.9% (16%)	0.4% (8%)	0.3% (6%)	0.1% (2%)	0.0% (0.1%)
Surrey	66%	3.8% (11%)	1.5% (5%)	3.9% (12%)	8.3% (24%)	13.4% (40%)	0.1% (0%)	0.3% (1%)	2.5% (7%)	0.2% (1%)	0.0% (0%)
Île-de-France	96%	1.7% (48%)	0.5% (14%)	0.1% (3%)	0.1% (3%)	0.2% (5%)	0.2% (6%)	0.1% (3%)	0.4% (11%)	0.2% (7%)	0.0% (0.1%)
Lucca	94%	0.8% (13%)	0.2% (3%)	1.3% (19%)	1.3% (20%)	0.6% (9%)	0.6% (9%)	0.1% (1%)	1.3% (20%)	0.4% (6%)	0.0% (0.4%)
Green Karst	96%	0.5% (12%)	0.0% (1%)	0.6% (13%)	0.2% (5%)	0.0% (1%)	0.3% (7%)	0.6% (14%)	1.1% (24%)	1.0% (23%)	0.0% (0.0%)
Nitra	91%	1.1% (13%)	0.4% (5%)	0.6% (7%)	0.5% (6%)	1.0% (12%)	1.7% (19%)	0.3% (3%)	2.3% (26%)	0.9% (10%)	0.0% (0.4%)
S Moravia	96%	0.4% (10%)	0.0% (1%)	0.0% (1%)	0.1% (2%)	1.7% (46%)	0.2% (6%)	0.0% (1%)	0.5% (14%)	0.8% (20%)	0.0% (0.1%)
Warzaw MA	81%	6.1% (32%)	0.4% (2%)	0.2% (1%)	3.2% (17%)	1.7% (9%)	2.9% (15%)	2.0% (10%)	2.4% (12%)	0.3% (2%)	0.0% (0.2%)
Kaigu	73%	0.9% (3%)	0.1% (0%)	1.5% (5%)	4.2% (15%)	5.4% (20%)	2.0% (7%)	2.4% (9%)	3.9% (14%)	6.7% (25%)	0.1% (0.3%)
Ela	93%	0.4% (5%)	0.1% (2%)	0.8% (11%)	0.2% (3%)	0.8% (11%)	0.7% (9%)	1.5% (21%)	0.6% (8%)	2.2% (30%)	0.0% (0.1%)

4 Discussion

4.1 Synthesis

Comparing the practice cases shows a wide range in land use change dynamics. The total area percentage undergoing gross change between 1990 and 2018 ranged between 0.3% of the total area in the Parc Ela practice case to 7% in the Kaigu practice case. Comparing dynamics of the main specific land covers shows that built-up area has expanded in all practice case locations, with low amounts (<0.1% increase of area) in the more nature dominated ones (Green Karst, Kaigu peatland) and a 2% gain in the Amsterdam case. Arable land instead shows decreases in the more urban practice cases (Île-de-France, Amsterdam Metropolitan Area, Warsaw Metropolitan Area), and striking gross changes in the more intermediate urban cases (Three Countries Park, Surrey). While the area of complex vegetation patterns net decreased in most practice cases, there was also a lot of gross change in this land cover type. The high gross land cover dynamics were also striking for nature and forests.

Two change trajectories can be distilled from the information about the practice cases. First, several practice case regions are characterized by scale enlargement of agriculture, intensification of agriculture, and rationalization. This often goes together with a decrease in complex vegetation patterns and an increase in forest and nature. The practice cases Three Countries Part, Surrey, Lucca, Green Karst, Warsaw Metropolitan Area, and Kaigu peatland are in this change trajectory. This land use trajectory is related to polarization; increasing pressures on agricultural land lead to concentration and specialization, while at the same time more natural and remote areas are dedicated to nature. Secondly, a few practice cases do see increasingly complex land use and land cover patterns. This applies to Île-de-France, Nitra, Moravia, and Parc Ela. However, change trajectories are not static and endless; the practice cases Amsterdam Metropolitan Area and Flanders seem to shift from the intensification trajectory to a trajectory of increasing complexity. These practice cases face a strong pressure from urbanization and face economic growth. This leads to a strong increase in well-being related demands on the landscape, such as recreation facilities and recreation housing. This also goes together with an increase in combined-objective natural areas that combine fostering biodiversity with providing space for recreation.

These two main trajectories are in line with Jepsen et al. (2015) where increasing environmental awareness is currently shaping land management regimes in many parts of Europe, while industrialization and commercialization are common elsewhere. The trajectory of scale enlargement and intensification is driven by markets and by the pressure of globalization on local markets, as well as by a push towards farm size increase embedded in the Common Agricultural Policy. The collapse of the Soviet Union and the following privatization is also seen as a driver for this trajectory. The trajectory where increasing complexity of land use is observed seems to be driven by two different causes. In some practice cases, there are limited opportunities to adapt to the changing markets, e.g., because the practice case is nature dominated or because markets are physically or value chain wise remote. The practice cases that more recently shifted from the intensification trajectory to the increasing complexity trajectory on the other hand saw increased attention for a pleasant living environment and policy action to achieve that as a driver for change. Specific action to establish recreation opportunities is several times mentioned as a reason to create a more varied landscape, and this is seen back in the data.

The polarization trajectory and the increasing complexity trajectory are likely to have different effects on well-being. The trajectories can be mapped on the paradigms of land sparing (polarization) and land sparing (increasing complexity). In the global discourse on biodiversity conversation, it is often assumed that setting aside large areas for biodiversity is more beneficial than planning approaches where low-intensity agriculture is combined with smaller patches of nature {Luskin, 2018, lu008}. However, a quantitative review of available studies up to 2017 showed that effects of different planning paradigms are different for biodiversity than for ecosystem services and subsequent well-being effects (Luskin et al., 2018). While indeed in the polarizing regions positive impacts on biodiversity might be expected, the trajectory towards more complex land use is likely to have resulted in more wellbeing outcomes. At the same time, all practice cases have seen a net increase of nature area over the past decades (Figure 22). It is therefore likely that also in the practice cases facing increasing complexity this has contributed to biodiversity, because of a likely higher connectivity and a likely higher coherence between larger nature areas and a more varied landscape in between (Kremen, 2015).

Land use change and forestry is a minor factor in climate mitigation, and given the small size of the practice cases, the contribution of land use change in the practice cases to European and even national climate mitigation targets will have been limited. Gross changes of pastures and forests are likely to have resulted in CO2 emission from land use change and forestry in all practice cases except Moravia. Climate adaptation (similar to other ecosystem services) in general benefits from land sharing, and therefore is likely to have increased in the practice cases that are on the trajectory of increasing complexity.

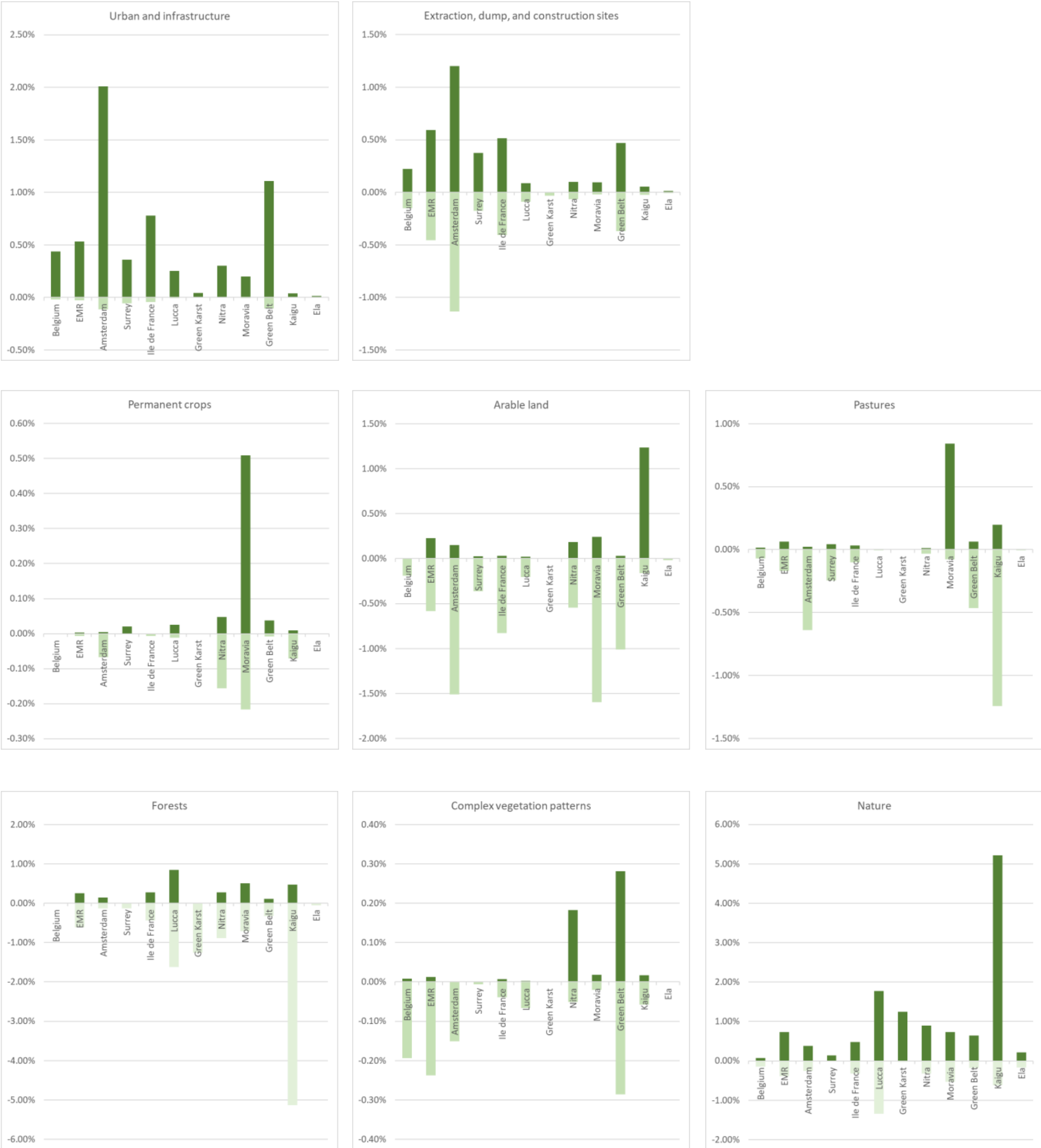

Figure 22: Gross land use changes per main land use type in all practice case NUTS2 regions.

4.2 Reflection

A full analysis of land use and land cover changes over the 1990-2020 timeframe and its effects on wellbeing, biodiversity, and climate change in Europe requires high-resolution time series of wall-to-wall data. This brings several challenges. First, timeseries of data are incomplete for countries that have not been part of the EU for the whole timeframe. Second, there are inconsistencies between the 1990 and 2000 land cover datasets, and the six- or ten-year timestep of the land cover data might overlook part of the dynamics. Third, data are in general scattered and incomplete. Farm intensity data are for example only available for the commercial farms and disregard to 10% smallest farms, and data on farm management is only available at an intermediate spatial resolution of NUTS2 regions. While it is likely that the larger farms addressed in the database might have a stronger negative impact on biodiversity and wellbeing, the smaller farms might ameliorate this effect, and hence the dataset does not allow a complete picture of the impacts of farm management change on biodiversity and wellbeing. Also, the dataset does not allow the tracing of the full dynamics of changes at farm scale and at practice case scale.

On a more conceptual level, a recent milestone from PLUS Change highlighted the lack of insight and indicators of wellbeing and how wellbeing is influenced by land use change. While we are, based on the conceptual understanding emerging from the project so far, as well as the discussions in the practice cases, able to provide a broad synthesis of these effects, more indicators are needed that are better targeted to the land dynamics that will be simulated later in the PLUS Change project in order to fully trace the impacts of land use and land cover change on wellbeing. Finally, the analysis of novel land use in Europe highlights the gaps in the thematic resolution of land cover monitoring in Europe and its potential consequences for the insights in the effects of land use and land cover change on wellbeing.

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Annex 1: Corine Land Use reclassification

CLC	**Explanation**	**Group**	**Group code**
1	Continuous urban fabric	Urban and infrastructure	1
2	Discontinuous urban fabric	Urban and infrastructure	1
3	Industrial or commercial units	Urban and infrastructure	1
4	Roads, rail networks and associated land	Urban and infrastructure	1
5	Port areas	Urban and infrastructure	1
6	Airports	Urban and infrastructure	1
7	Mineral extraction sites	Extraction, dump, construction	2
8	Dump sites	Extraction, dump, construction	2
9	Construction sites	Extraction, dump, construction	2
10	Green urban areas	Urban and infrastructure	1
11	Sport and leisure facilities	Urban and infrastructure	1
12	Non-irrigated arable land	Arable land	3
13	Permanently irrigated arable land	Arable land	3
14	Rice fields	Arable land	3
15	Vineyards	Permanent crops	4
16	Fruit trees and berry plantations	Permanent crops	4
17	Olive groves	Permanent crops	4
18	Pastures	Pastures	5
19	Annual crops associated with permanent crops	Complex vegetation patterns	6
20	Complex cultivation patterns	Complex vegetation patterns	6

21	Land principally occupied by agriculture, with significant areas of natural vegetation	Complex vegetation patterns	6
22	Agro-forestry areas	Complex vegetation patterns	6
23	Broad-leaved forest	Forests	7
24	Coniferous forest	Forests	7
25	Mixed forest	Forests	7
26	Natural grasslands	Nature	8
27	Moors and heathland	Nature	8
28	Sclerophyllous vegetation	Nature	8
29	Transitional woodland-shrub	Nature	8
30	Beaches, dunes, sands	Nature	8
31	Bare rocks	Nature	8
32	Sparsely vegetated areas	Nature	8
33	Burnt areas	Nature	8
34	Glaciers and perpetual snow	Nature	8
35	Inland marshes	Nature	8
36	Peat bogs	Nature	8
37	Salt marshes	Nature	8
38	Salines	Nature	8
39	Intertidal flats	Nature	8
40	Water courses	Water	9
41	Water bodies	Water	9
42	Coastal lagoons	Water	9
43	Estuaries	Water	9
44	Sea and ocean	Water	9