Interreg
Alpine Space
AlpES

This project is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme

ECOSYSTEM SERVICES IN THE ALPS:

A SHORT REPORT

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1.1

The AlpES project

Ecosystem services provide the foundation upon which human societies are built. To better understand these services in the European Alps, the project "AlpES - Alpine Ecosystem Services - mapping, maintenance, management" was started in December 2015. The project aims to collect, analyse and distribute information about the ecosystem services (ES) provided by the unique yet threatened ecosystems of this famed region. The AlpES project is carried out by a group of ten partners from six Alpine countries (Austria, France, Germany, Italy, Liechtenstein and Slovenia), and is headed by Eurac Research of Bolzano/Bozen, Italy. Co-financed by the European Regional Development Fund through the Interreg Alpine Space programme, the project will end in December 2018.

AlpES target groups include public authorities, policy makers, NGOs, researchers and economic actors: in brief, everyone who is involved in the management and protection of ecosystems and their services. The AlpES project's overall objective is to introduce a common understanding of ecosystem services as a regional and transnational environmental governance framework and to train and support the AlpES target groups in understanding, valuing and managing them.

The specific steps to achieve this overarching goal are:

1. developing an Alpine ecosystem services concept,
2. mapping and assessing ecosystem services for the Alpine Space cooperation area including application in selected study regions across the Alpine Space,
3. providing stakeholders with the results through a dedicated wiki (WIKIAlps, 2018) and an interactive WebGIS (WebGIS, 2018),
4. ensuring a multi-level and cross-sectoral transfer of AlpES results to a maximum number of stakeholders via a suite of innovative, tailored and transferable learning tools and targeted activities.

This report summarizes the outputs of the "Mapping and Assessment" work package, for which Eurac Research, in close collaboration with the University of Innsbruck, was responsible. The mapping and assessment of multiple ES was carried out at the municipal scale for the entire Alpine Space cooperation area (Fig. 1.1). In total, 21 maps of different ES indicators were produced, which are made available to the reader in the third chapter of this report (and online in the dedicated WebGIS). Each map is accompanied by an individual description to ease its interpretation. Furthermore, the report also includes a brief overview of the basic concepts of ES and the methodologies used for their mapping and assessment.

Figure 1.1 The Alpine Space cooperation area is shown with green borders, and is further subdivided into its NUT2 regions.

1.2

Ecosystem services: what are they?

Ecosystems provide us with innumerable goods and services that support our personal well-being and the viability of our societies; these benefits are known as ecosystem services (ES). This term was first coined in 1981 (De Groot et al., 2017), but early references to the concept date back to the mid-1960's and early 1970's (De Groot et al., 2002). Over the past decade, the topic of ES has become extremely popular in research, resulting in a variety of definitions and terms. For example, ES are defined as "the benefits that people obtain from ecosystems" (Millennium Ecosystem Assessment, 2005) or as the "direct and indirect contributions of ecosystems to human well-being" (Sukhdev et al., 2010), among others. ES can refer to both goods (e.g. timber) and services (e.g. water filtration). The Common International Classification of Ecosystem Services (CICES) (EEA, n.d.) divides ES into three main categories:

- Provisioning services (that provide food, water, timber, etc.)
- Regulation and maintenance services (that maintain or mediate climate, water quality, floods, disease, and wastes [e.g. carbon sequestration, surface water filtration])
- Cultural services (that provide recreational, aesthetic, and spiritual benefits)

Each of these sections is further split into divisions (e.g. nutrition), groups (e.g. biomass, water) and classes (e.g. cultivated crops, surface water for drinking). The following report adheres to this classification system.

As our understanding of ES continues to grow, finding ways to explicitly identify and measure their condition, trends and rate of change is an important step to integrating ES in decision-making. To assess these different types of ES and efficiently communicate information about their characteristics and trends, indicators are used.

An indicator is a quantitative measure that represents a complex system or phenomenon. They are used to monitor the state and trends of ecosystems and ES delivery within a determined time interval (Vihervaara et al., 2017). Since ES provide many types of benefits to humans, indicators using biophysical, economic and social valuation methods can all be employed for their measurement (Vihervaara et al., 2017). Biophysical units are used to measure quantities or features directly connected to ecosystem structures, processes and functions. Some examples are the volume of water runoff from subcatchment areas or the amount of nitrogen filtered by the ecosystem. On the other hand, indicators with economic and social units are mainly used to quantify benefits and values that humans obtain from ecosystems, like the monetary value of a certain ecosystem for tourism or outdoor recreation (Vihervaara et al., 2017). These examples illustrate how indicators can simplify the evaluation of a complex system and enable its graphic or spatial representation. Through the calculation and analysis of ES indicators over time, we can understand trends in complex ecological processes and monitor sustainable development.

1.3

The Alpine space

The European Alps comprise an incredibly diverse and complex web of interconnected natural and human systems. They are the highest and most extensive inner-European mountains, spanning 8 countries (France, Switzerland, Liechtenstein, Italy, Germany, Monaco, Austria and Slovenia). With their considerable differences in altitude and climatic conditions, these mountains contain a dramatic variety of landscapes, ecosystems and species. Moreover, despite the relatively small amount of land that is available for settlement or agriculture, the Alps are densely populated and preserve an exceptionally rich cultural heritage. Unique traditions of mountain agriculture have emerged here, where grassland farming predominates over cereal, fruit, and vegetable agriculture, especially at higher altitudes (Tappeiner et al., 2008). These widespread alpine pastures and hay meadows are rich in species and contribute substantially to the biodiversity of the mountains, surrounding foothills and lowlands (Muheim & Meier, 2017).

The Alps are not, however, immune to the threats of recent global changes. Globalization has brought about new opportunities but also new challenges. Market changes have had severe social and economic effects and led to changes in land use. A rapidly changing climate has already begun to impact many facets of life for these mountain populations. Understanding these complex trends is a difficult process, but certain patterns are already apparent.

Political and economic processes, together with social changes, are altering many structures in the Alpine Space. For example, they have resulted in agglomeration processes in the valleys; the average size of farms is increasing, while their number and diversity are decreasing. Agriculture has slowly vanished from many hillsides and Alpine pastures, instead concentrating in extensive holdings found in the lowlands. This change is causing a loss in biodiversity, as species-rich Alpine pastures are overgrown by forests. Moreover, socio-economic trends such as marginalization and urbanization are changing the population distribution and land use across the Alps. Younger people are moving away from remote regions to urban settlements with greater education and work opportunities, leaving some areas to face ageing, depopulation and isolation. Areas where agricultural land has been abandoned, but neither tourism nor urbanization occurs, risk becoming more and more marginalized (Tappeiner, Borsdorf & Tasser [Eds.], 2008). On the other hand, regions that are easily accessible and rich in tourist and cultural attractions are experiencing growing populations, intensified commuter flows and high seasonal tourism. These trends bring a different set of problems to sustainable development, such as pollution, soil sealing and reduction of open spaces. These are only some of the general socio-economic trends and changes that the Alps currently face, the impacts of which vary greatly across the diverse countries, regions and communities found here.

Climate change is another major threat to Alpine ecosystems. One obvious outcome of climate change is that glaciers are melting at an ever-accelerating rate. This melting results in a cascade of downstream problems, such as dwindling glacier-fed rivers and the consequent lack of drinking water. Changes in precipitation, snow-cover patterns and glacier storage are expected to alter the Alpine water cycle. This could potentially lead to more droughts in summer, more floods and landslides in winter, and greater variability in the water supply throughout the year (EEA, 2010). Furthermore, the rising snowline poses a serious risk of upward migration of Alpine plants and the expansion of exotic species, thus substantially altering plant communities (Pauli, Gottfried & Grabherr, 2003). A warming world has major effects upon the natural systems of the Alps and every day new impacts are being uncovered.

These diverse processes have become more and more pronounced in recent years, challenging stakeholders in the region to ensure that development remains sustainable and further environmental and cultural degradation is avoided. By the late 1990's, it became clear that the effort to mitigate these impacts and to make better use of shared resources has to be coordinated between all Alpine countries. Accordingly, the first transnational EU cooperation programme for the Alps was launched in 2000. Since then, two more editions of the programme, each running for seven years, have been approved. The third, and current, Interreg VB Alpine Space Programme was launched in 2014. With an increasing number of project partners in each iteration, the Alpine Space programme now plays a pivotal role in ensuring cooperation between Alpine states. It is worth noting that the Alpine Space cooperation area (Fig. 1.1) covers not only the Alps, but also their surrounding lowlands, as these areas are inextricably linked.

1.4

Mapping and assessment of ES

Since the development of the Alpine Space program, institutions such as the United Nations, the European Union, the Alpine states and regions, and various NGOs have begun to pool their available capacities more effectively. In doing so, spatially explicit maps of different ES have been identified as a key requirement for their effective management. The European Union's Biodiversity Strategy to 2020 explicitly encourages member states to "map and assess the state and economic value of ecosystems and their services in the entire EU territory, and to promote the recognition of their economic worth into accounting and reporting systems across Europe" (EC, 2015).

A dedicated working group comprising member states, experts and relevant stakeholders, was specifically established to address this call: the EU initiative on Mapping and Assessment of Ecosystems and their Services (MAES) (BISE, n.d.). The MAES initiative produces and distributes annual reports with ES definitions and guidelines for their assessment, mapping and calculation via selected indicators. This initiative is an important model for the AlpES project, which strives to follow its directives and build on its framework at the Alpine level.

These concerted efforts aim to provide reliable and rigorous scientific and spatial information about ES that can be used to bolster sustainable, place-based decision making. Management of natural resources, planning of natural areas, and infrastructure and tourism development are deeply interconnected and dependent upon the provision of ES. By mapping ES, an important set of new tools is available to practitioners in each of these endeavours. Thanks to the growing body of research on ES, and as relationships between actions and outcomes become clearer, decision-makers will be more prepared to effectively address the issues they face.

2 Methods

The following section aims to inform readers about the methodological approach used to select, calculate and map the ES indicators, which are represented as maps in the third chapter of this report. The methodological chapter is intentionally kept short; further information for interested readers can be found in the metadata pages of the WebGIS.

2.1 Selecting ES indicators

In light of the myriad ES provided by the Alps, all participating AlpES partners first had to agree upon eight representative ES and their related indicators for mapping and assessment. To do so, one ES for each CICES division was selected (CICES, v4.3) considering its geographic, political and socio-ecological relevance. Then, ES indicators were chosen to describe the selected ES on the basis of data availability and the indicator's employability and comprehensibility for AlpES target groups. Each indicator needed to represent the related ES in a way that stakeholders could easily understand and use.

For each of the eight selected ES, the AlpES team calculated three different indicators, to describe their supply, flow and demand (see Fig. 2.1). The project defines the term supply as the amount of an ES that is delivered by an ecosystem in a specific time period, irrespective of its actual use. The flow is the de facto amount of an ES that is utilized from an ecosystem in a specific time period. The demand is the amount of a specific good or service consumed by society in a particular area over a given period, regardless of its origin (Syrbe et al., 2017). For further details, please refer to the AlpES project report "Alpine Ecosystem Services Concept".

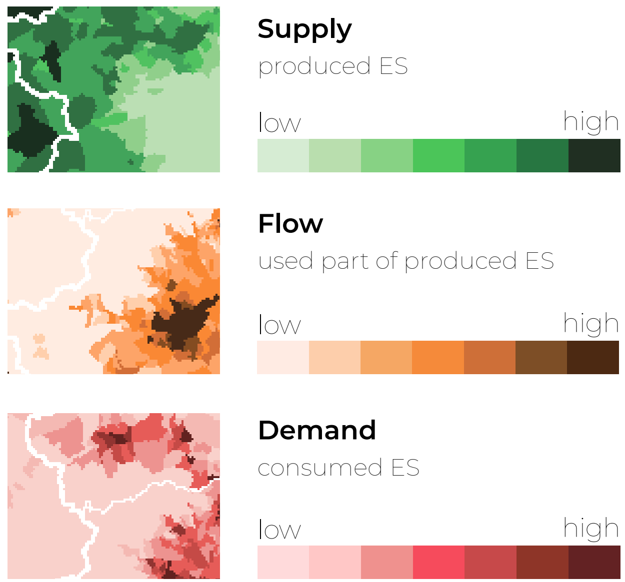


Figure 2.1 Example visualizations of ES indicators for supply, flow and demand.

2.2

Data sources and calculation methods

Once the ES indicators have been selected, the relevant data for their calculation have to be gathered. First, the temporal and spatial scales need to be carefully chosen. Ecological processes are heavily dependent on time (e.g. seasons) and space (e.g. global, national, municipal scale). The AlpES team mapped the spatial distribution of ES at the municipal level for over 16.000 municipalities throughout the Alpine Space cooperation area; this scale is the finest resolution that is possible across all selected indicators, while still being useful for management purposes. For the municipalities' boundaries we used the EuroBoundaryMap (v10) kindly provided by EuroGeographics. The selected time scale varied between indicators and is reported in the individual maps' descriptions.

Data requirements varied greatly from indicator to indicator, and encompassed land-cover and climate data, statistical information, protected area networks and digital elevation models, just to name a few. Detailed data sources for each individual ES indicator map (Chapter 3) can be found on the interactive WebGIS, using the link provided in its description. The datasets were obtained from a variety of sources, which are either nationally or internationally organized. For example, data has been acquired from the national statistical offices of Alpine countries, from European institutions like Eurostat and the European Environment Agency (EEA), and from global datasets, such as OpenStreetMap. If the definition or interpretation of a common concept varied between data sources, the collected data was harmonised, which may have led to minor inaccuracies. In general, it is important to remember that the characteristics of the input data (i.e. accuracy, scale, precision, etc.) will reflect in the output indicators. Therefore, the resulting indicator values are not absolute or "true" values, but have to be interpreted in the light of the available input data sources.

An important part of ES indicator development lies in finding appropriate methods and procedures for their measurement and calculation (Vihervaara et al., 2017). In the "Mapping and Assessment" work package of AlpES, the methods and instruments used for the indicators' calculation vary greatly between indicators. GIS-software tools were used to map and model ecosystem services and to perform analyses of remote sensing data. Depending on the nature of the indicator and the type of data used for its calculation, the models were based either on statistical data or on biophysical quantifications. Specific software (e.g. InVEST – a suite of free, open-source software models used to map and value ecosystem services) and guidelines from scientific papers and project reports were consulted for the development and calculation of indicators.

The AlpES partnership decided to apply a three-level "tier approach" to the mapping and assessment of ES, thus allowing for consistent but flexible methods. Tier 1, the most basic approach, uses existing, widely available (large-scale) datasets (e.g. CORINE databases for Europe) as a proxy for the provision of certain ES. For example, Corine Land Cover data can be used to quantify ES that are directly dependent on specific ecosystems. Tier 2 builds on the previous approach by linking different indicators with land use data to map ES. The output indicator will be more complex, depending on different datasets interlinked according to known relationships between, for example, land use and ES provision. Tier 3 is the most refined approach, and consists of modeling biophysical processes in GIS or other software instead of linking indicator data through simple relationships. The tier 1 approach is useful to estimate ES for which data are difficult to obtain. Tiers 2 and 3 deliver a higher resolution of results, however they require a higher degree of expert knowledge about modeling and ES provision.

2.3

Mapping ecosystem services

Ecosystem service mapping consists of creating cartographic representation of quantified ES indicators in geographic space and time (Burkhard & Maes [Eds.], 2017). It is therefore a method of making the information derived from the assessment process visually accessible and easily understandable, especially to those who are not familiar with the ES concept. For most of the eight selected ES, three different indicators were developed: the maps for ES supply, flow and demand are identified by a dedicated colour scale, as shown in Fig. 2.1, with darker colour tones meaning higher indicator values.

All maps were created in a uniform layout, with the external boundaries matching those of the Alpine Space cooperation area. National borders are also shown, to help viewers with orientation. The same projection and scale is applied to all maps. The spatial scale of the maps corresponds to the municipal level; that is, the ES indicator values are calculated for every municipality within the Alpine Space, and each municipality is depicted with a colour tone relative to this value. The temporal scale of each map is described in the related metadata.

The 22 ES indicators assessed by the AlpES project are listed in Table 2.2 and divided into groups relative to the ES that they describe. The unit of measure of the indicator is also shown. Each indicator has a direct link to the relative map in the AlpES WebGIS, from which the indicator's metadata can be consulted.

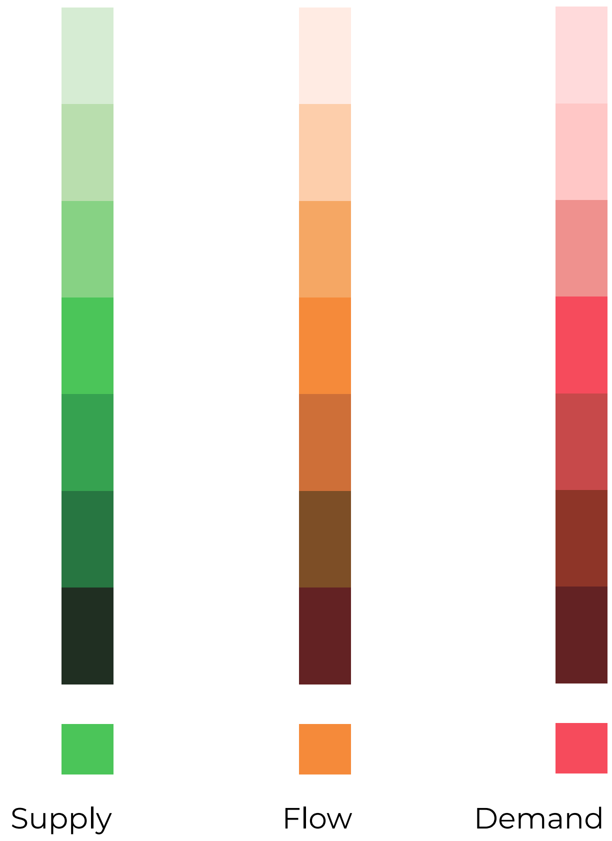


Figure 2.1 Colour scales used for the ES maps.

Ecosystem Service	Indicator type	Definition	Tier	Unit of measure
Surface water for drinking with minor or no treatments	Supply	Water availability	3	$m^3\ ha^{-1}\ y^{-1}$
	Flow	Water use	2	$m^3\ ha^{-1}\ y^{-1}$
	Demand	Water abstraction	2	$m^3\ ha^{-1}\ y^{-1}$
Biomass production from grassland	Supply	Gross fodder production	3	t DM $ha^{-1}\ y^{-1}$
	Flow	Net fodder energy content	3	MJ NEL $ha^{-1}\ y^{-1}$
	Demand	Feed energy requirements	2	MJ NEL $ha^{-1}\ y^{-1}$
Fuel wood	Supply	Forest biomass increment	3	$m^3\ ha^{-1}\ y^{-1}$
	Flow	Wood removals	3	$m^3\ ha^{-1}\ y^{-1}$
	Demand	Fuel wood requirements	2	$m^3\ y^{-1}$
Filtration of surface water by ecosystem types	Flow and Supply	Nitrogen removals	3	kg $ha^{-1}\ y^{-1}$
	Demand	Nitrogen loads	2	kg $ha^{-1}\ y^{-1}$
Protection of areas against avalanches, mudslides and rockfalls	Supply	Site-protecting forest	3	%
	Flow	Object-protecting forest	3	%
	Demand	Infrastructure in hazard zone	3	index
CO_2 sequestration by forests and bogs	Flow and supply	CO_2 sequestration by forests	3	t CO_2 $ha^{-1}\ y^{-1}$
	Demand	CO_2 emissions	2	t CO_2 $ha^{-1}\ y^{-1}$
Outdoor recreation activities	Supply	Outdoor recreation availability	3	index
	Flow	Visitation rate	3	index
	Demand	Beneficiaries	2	index
Symbolic alpine plants and animals, landscapes	Supply	Habitats of symbolic species	3	index
	Flow	Occurrence in hotel names	2	nr. of hotels
	Demand	Desired symbolic species and landscapes	1	index

Table 2.2 List of AlpES ES indicators, divided by their relative ES.

3 Ecosystem service indicator maps

Spatially explicit maps are perhaps the most direct, efficient and effective way to communicate with decision-makers about the state of ES in the Alpine Space. The EU Biodiversity Strategy to 2020 and the MAES Initiative both call on practitioners to generate such maps for use in advancing sustainable management. The following section includes the maps created through the course of the AlpES project. The selected ES are each represented by an indicator set comprised of a maximum of 3 indicators (supply, flow and demand). Every indicator that has been evaluated has a corresponding map included below. The different ES are described in a short introductory section preceding their respective maps, in the following order:

3.1 Surface water for drinking with minor or no treatments

3.2 Biomass Production from grassland

3.3 Fuel wood

3.4 Filtration of surface water by ecosystem types

3.5 Protection against avalanches, mudslides and rockfalls

3.6 CO_2 sequestration by forests and bogs

3.7 Outdoor recreation activities

3.8 Symbolic alpine plants, animals and landscapes

3.1 Surface water for drinking with minor or no treatments

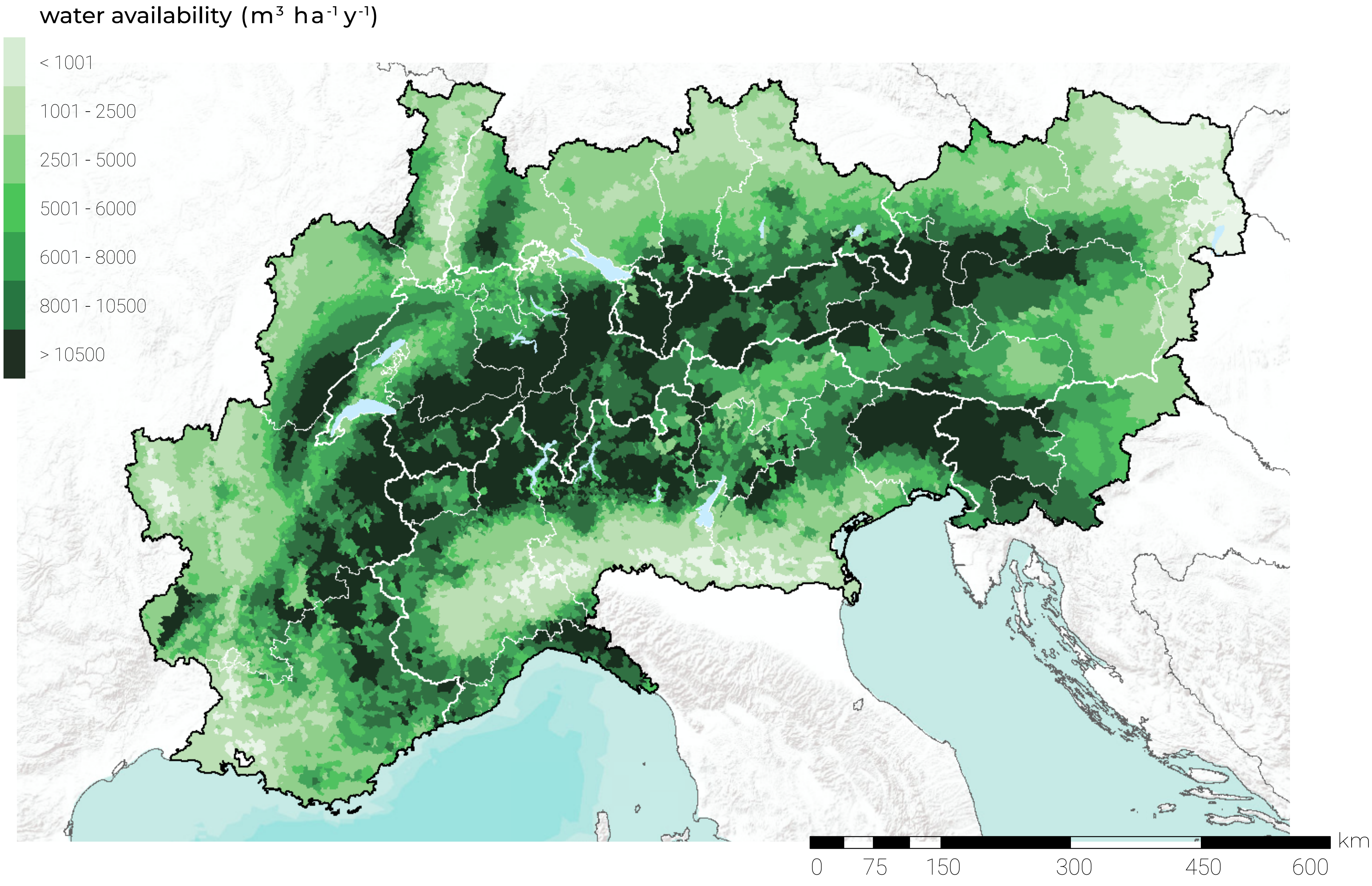
Clean water is a good that is so fundamental in our lives that we often take it for granted. Everyday we drink it, bathe in it, and eat crops grown with it. The Alps are a vital water source in the region, supporting life for millions of people across Europe. The iconic, high elevation mountains here store millions of cubic meters of water in natural and artificial lakes as snow and ice. They also provide a consistent flow of water downstream to the Danube, the Rhone, the Po, and the Rhine. It is for this reason that the Alps are sometimes referred to as Europe's "water tower".

Understanding just how much we rely on this water, and how much nature provides us with, is a vital undertaking in a changing world. We need this information in order to effectively manage and value Alpine resources as populations grow, technology develops, and climate changes.

"Surface water for drinking with minor or no treatments" is a set of indicators that measures exactly how much water with drinking quality is supplied for, demanded by and flows into Alpine communities. These three facets serve to inform adaptive, integrated natural resource decision-making. Descriptions of each facet can be found alongside its respective map in the following pages.

SUPPLY

surface water for drinking with minor or no treatments



Description

This indicator quantifies the annual average available water runoff with drinking water quality. The model estimates the water runoff from subcatchment areas based on gridded information on climatic, soil, topographic and land-cover characteristics.

Definition

Water availability (m^3 ha^{-1} y^{-1})

CICES section

Provisioning ecosystem service

CICES division

Nutrition

COMMENT

The Alps are widely known as the "water tower" of Europe, as their glaciers, soil, artificial and natural lakes are very important for the storage of water. The abundance of water is due to a combination of climatic and topographic characteristics: (1) the uplift and subsequent cooling of air which then turns into rain, (2) the low rate of net radiation, (3) lower temperatures and frequent snow cover and (4) shorter vegetation periods, which together result in lower evaporation and higher annual runoff (Permanent Secretariat of the Alpine Convention, 2009).

As a result, the supply indicator map delineates very clearly the Alpine mountain range, which scores high supply values, whereas the peripheral zones of the Alpine Space Cooperation Area, which are mainly flatlands, have a much lower water runoff. Surface water is not the only drinking water source in the Alpine countries; in some regions of the Alpine Space, ground water alone meets the demand for drinking water supply (Permanent Secretariat of the Alpine Convention, 2009). The overall high values of this indicator denote that there is little concern for surface drinking water supply in the Alpine Space, at least in the near future.

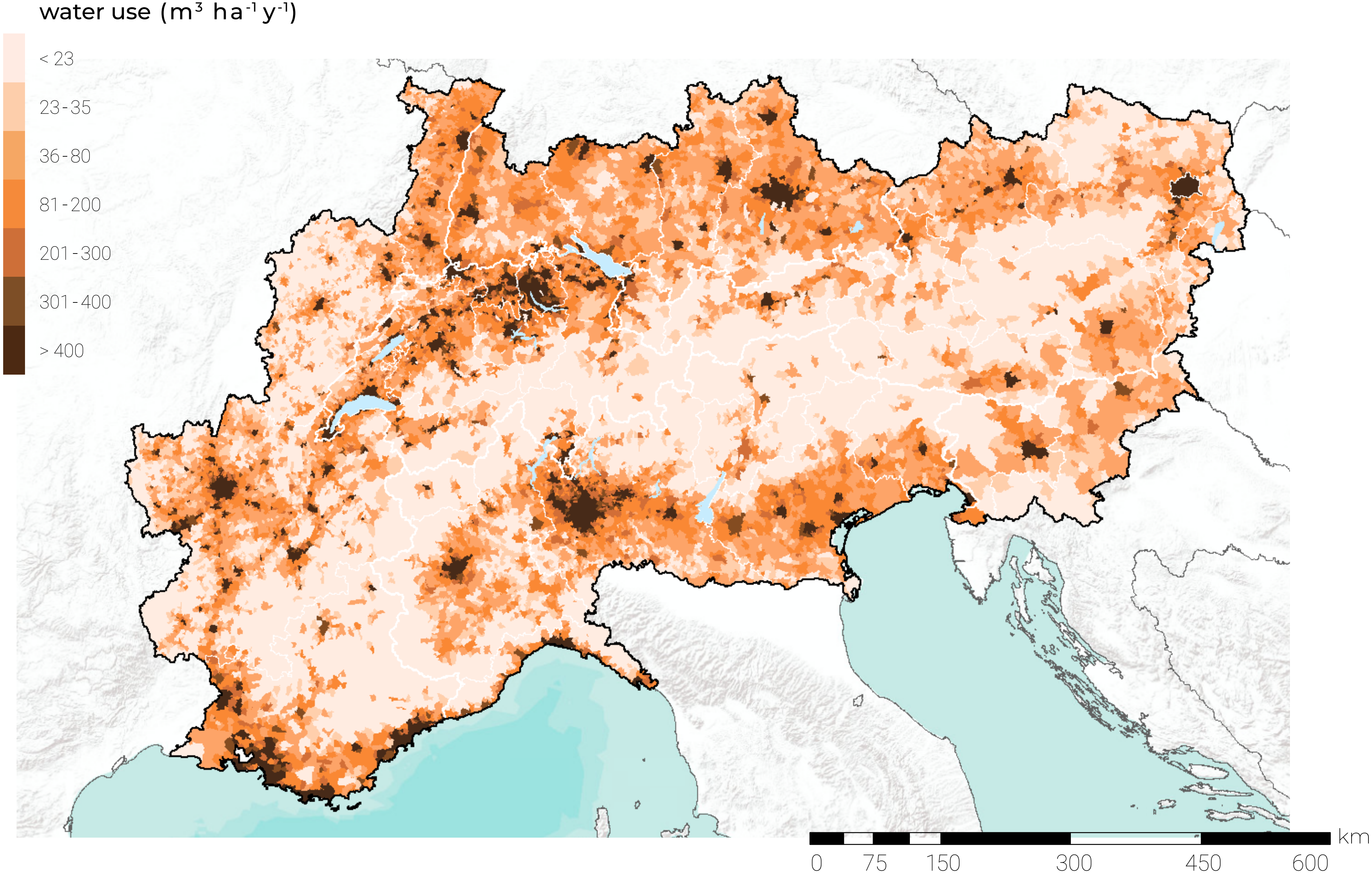
DID YOU KNOW ?

Freshwater accounts for only 2,5% of the total water on Earth, whereas the remaining 97,5% is seawater, unfit for human consumption. Earth's glaciers and ice caps lock away over 68% of this freshwater supply, but climate change accounts for their recent, rapid melting. The vast majority of glaciers in Europe are in retreat. Glaciers in the European Alps have lost approximately half of their volume since 1900, with clear acceleration since the 1980s. Glacier melting contributed to global sea level rise by about 0,8 mm per year in 2003–2009, and also affects freshwater supply and run-off regimes.

The European Environment Agency has been monitoring the state of European glaciers in the past decades and has published the data on the change in glacier mass, which are available here: Trends in mass and volume of glaciers across Europe (EEA, 2016).

FLOW

surface water for drinking with minor or no treatments



Description

The flow of drinking water is the annual amount of water that is withdrawn from the public water supply system. This indicator therefore displays the approximate total annual consumption of drinking water per municipality.

Definition

Water use (m^3 ha^{-1} y^{-1})

CICES section

Provisioning ecosystem service

CICES division

Nutrition

COMMENT

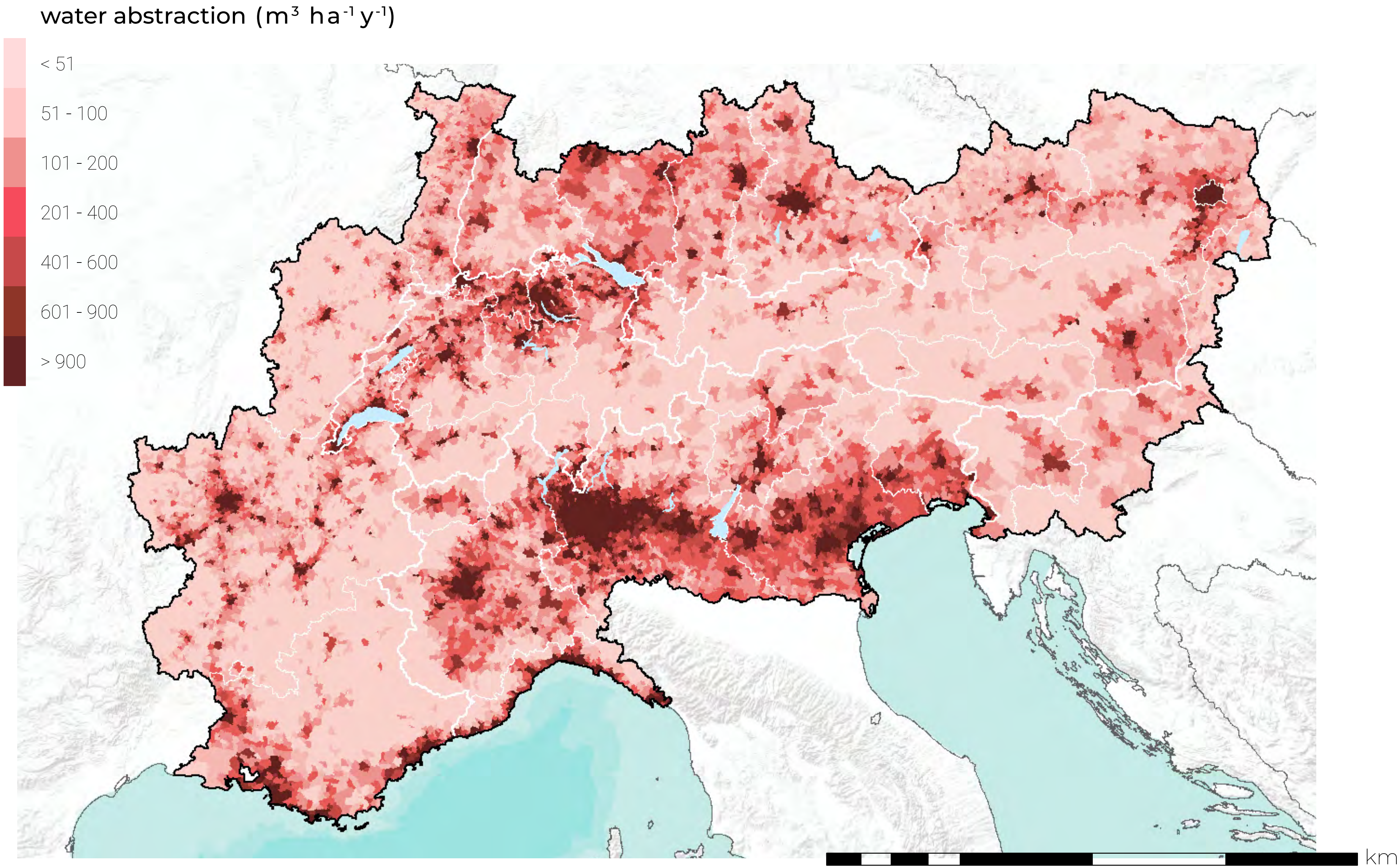
The flow indicator for the ES “Surface water for drinking with minor or no treatments” measures the total water utilization through the public water supply system at the point of delivery, i.e. taps and faucets. The Alps are a major provider of water for the whole Alpine Space, and the water quality of the Alpine springs is excellent. However, the rising number of residents in many cities in the Alpine Space is adding pressure on the drinking water resources. Furthermore, changes in precipitation (rain, snow and hail) and the concurrent melting of perennial glaciers due to climate change are threatening to alter the entire Alpine water cycle. The water supply and its water quality may be affected by such changes, potentially transforming the provision of drinking water into a long-term problem for the regions that depend primarily - or entirely - on Alpine water sources (EEA, 2010).

In this indicator, drinking water usage is assumed to be proportional to the population numbers, comprising both residents and tourists. In fact, when looking at the flow indicator map, the main cities of the Alpine region are highlighted; Zurich and Munich in the north, Vienna in the east and Milan in the south are easy to spot. On the other hand, the mountainous areas where the population is sparse score far lower values of water use.

High values of this indicator indicate a trend for elevated water consumption and potentially excessive water waste, and may become problematic in the future, putting a strain on the Alpine water sources.

DEMAND

surface water for drinking with minor or no treatments



Description

This indicator quantifies the demand for drinking water as the total annual abstraction of water for the public supply system. Water abstraction is understood as water removed directly from its source.

Definition

Water abstraction (m^3 ha^{-1} y^{-1})

CICES section

Provisioning ecosystem service

CICES division

Nutrition

COMMENT

The demand indicator for the ES "Surface water for drinking with minor or no treatments" represents the total abstraction of freshwater per municipality on an annual timescale. It is the amount of water that is removed from springs, reservoirs, and other sources every year to be used in the public water system, whether or not this water is then withdrawn at a tap or faucet. Similar to the previous map, the water abstraction and usage are elevated where population densities are higher; the municipalities with the highest demand are metropolitan areas, cities and other settlements. Nonetheless, the two maps also present interesting differences: the demand is relatively higher than the flow in areas like the Po valley, especially in the permanently irrigated areas surrounding Milan (see the CLC12 layer in the WebGIS), and in popular tourist destinations and ski resorts. Therefore, this high quality water is likely being used for irrigation, snow cover at ski resorts and tourist consumption. High values of this indicator may become unsustainable if they exceed the available supply, especially because the aforementioned uses are likely to increase with climate change (FAO).

The Eurostat data on total freshwater abstraction at European level in Figure 3.1 compares the Alpine area (which includes the Alps and other European mountain regions like the Pyrenees, the Dinaric Alps, the Carpathians and the Scandinavian Mountains) to its neighbouring biogeographical regions, most of which have much higher water demands. A seasonal difference in water abstraction rates is evident across all regions; this is due to increased water consumption for agriculture during the summer months, i.e. Q3 (Fig. 3.1).High values of this indicator indicate a trend for elevated water consumption and potentially excessive water waste, and may become problematic in the future, putting a strain on the Alpine water sources.

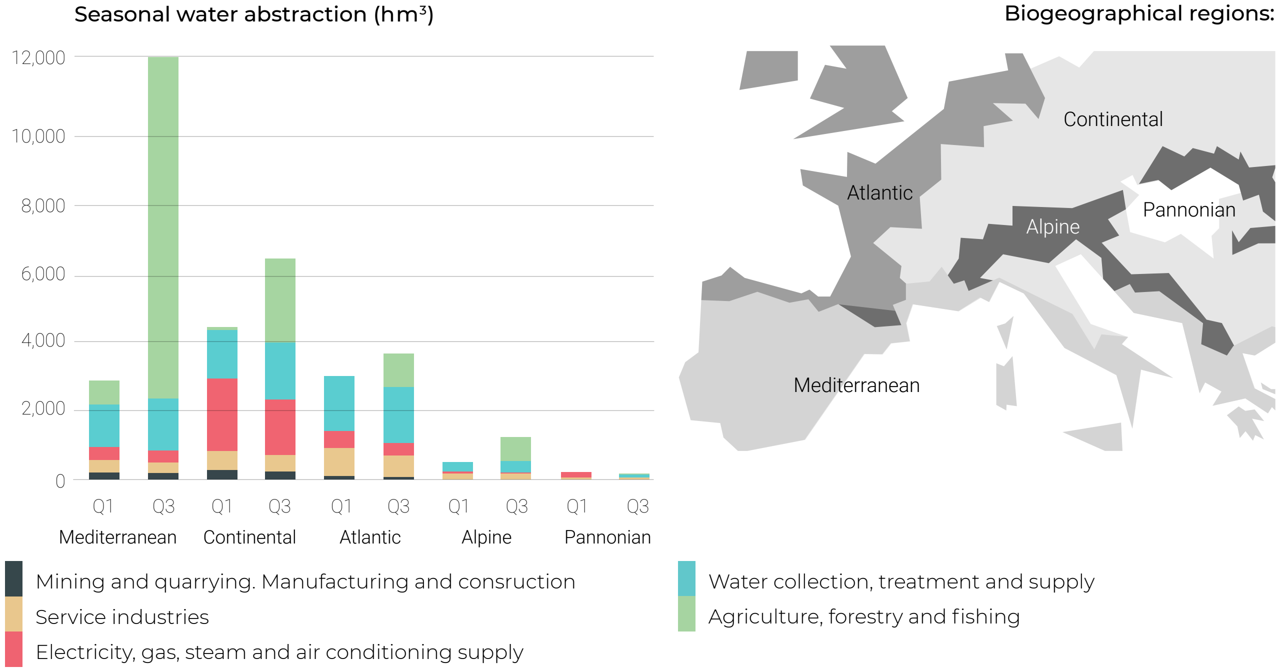


Figure 3.1 Seasonal water abstraction by economic sector, year quarters (Q1: January-March; Q3: June-September) and biogeographical regions relative to 2002-2012. Adapted from Bariamis et al, 2016.

3.2 Biomass production from grassland

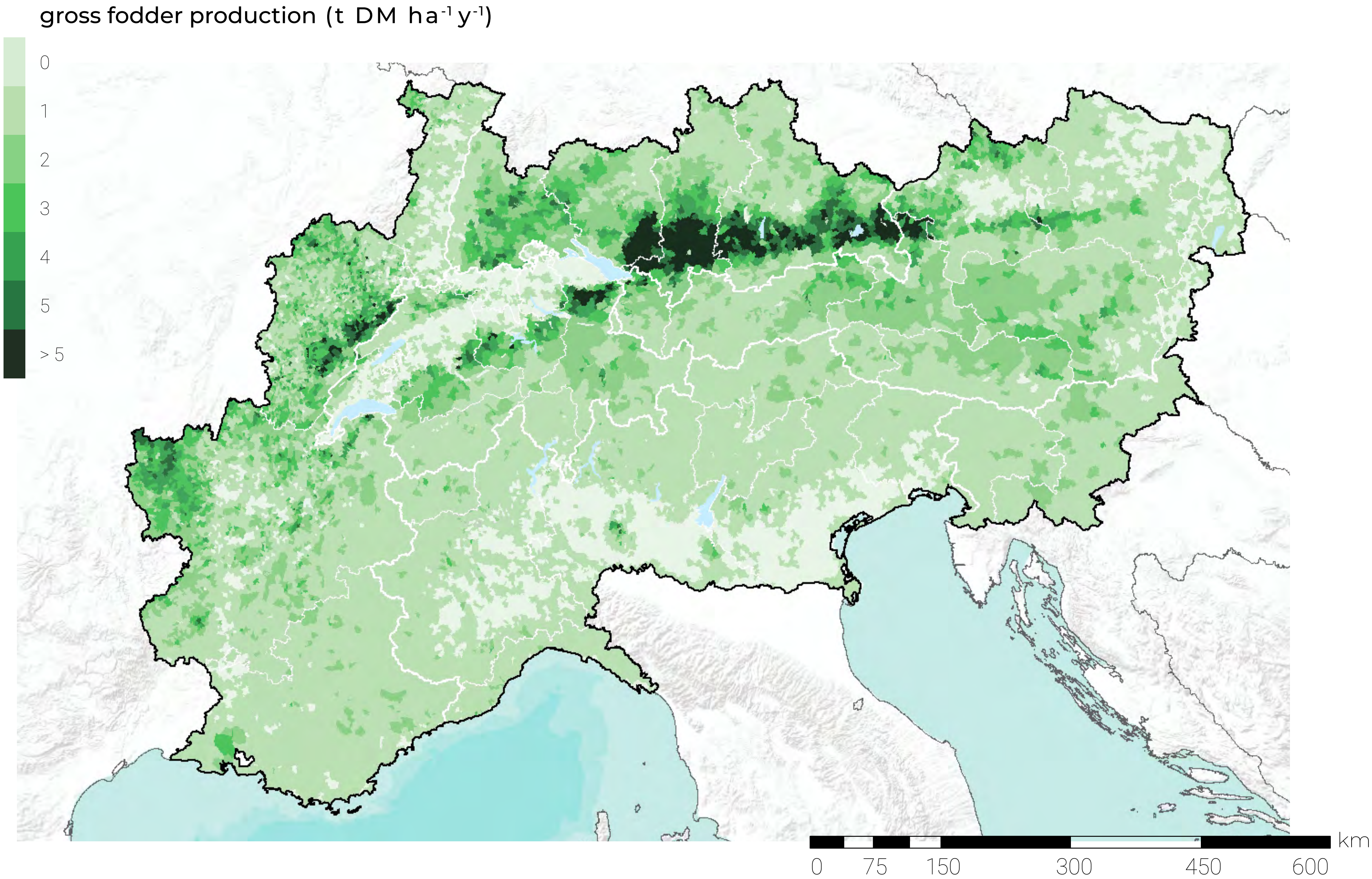
The Alpine Space has a long history of grassland production, a history that has shaped the many cultures across this range. In most corners of the Alps, one can still find traditional farms raising livestock such as cows, goats, horses and sheep on alpine pastures. These pastures are fairly common because the high altitudes and steep slopes of much of the Alps make most other means of agricultural production unfeasible in these areas.

The milk, meat, and local varieties of cheese that these operations produce are important for maintaining the cultural integrity of traditional rural ways of life and they all depend on a major ecosystem service: grassland biomass growth. Every year, alpine communities benefit from the fodder that grows freely in high elevation meadows as cows and other livestock transform this grassy material into valuable food products.

Assessing this service is done in three ways: by measuring the total amount of grassland biomass that is produced, by measuring the amount of grassland biomass that is actually consumed by livestock, and by measuring the total energetic needs of livestock farmers, to compare with what is provided. Understanding the supply, flow, and demand, on this ecosystem service will help to inform decisions made by natural resource managers, spatial planners, farmers, politicians, and scientists in the Alps. Ultimately, such informed decisions will be vital in protecting traditional ways of life and cultures across the Alpine Space.

SUPPLY

biomass production from grassland



Description

The supply of biomass production from permanent grasslands is calculated by first assessing the optimal yield of a municipality based on land use, climate data, and specific growth functions of the various plant types. Next, the actual local yield per year is estimated in tonnes of dry matter per hectare, based on the precipitation patterns and topographic conditions.

Definition

Gross fodder production ($t\ DM\ ha^{-1}\ y^{-1}$)

CICES section

Provisioning ecosystem service

CICES division

Materials

COMMENT

Grassland farming is a dominant factor in the agricultural landscape of the Alps. But not all meadows are the same: biomass supply depends firstly on the growth rate of all grassland types that are used as fodder. These can vary between extensive meadows, frequently cut pastures, and natural grassland found at high altitudes. Moreover, grasslands also differ in their plant composition, and in the use of fertilizers and management (cutting) levels. Finally, climatic parameters like the number of vegetation days, precipitation and energy budget of the grassland plot strongly influence the productivity of different grasslands.

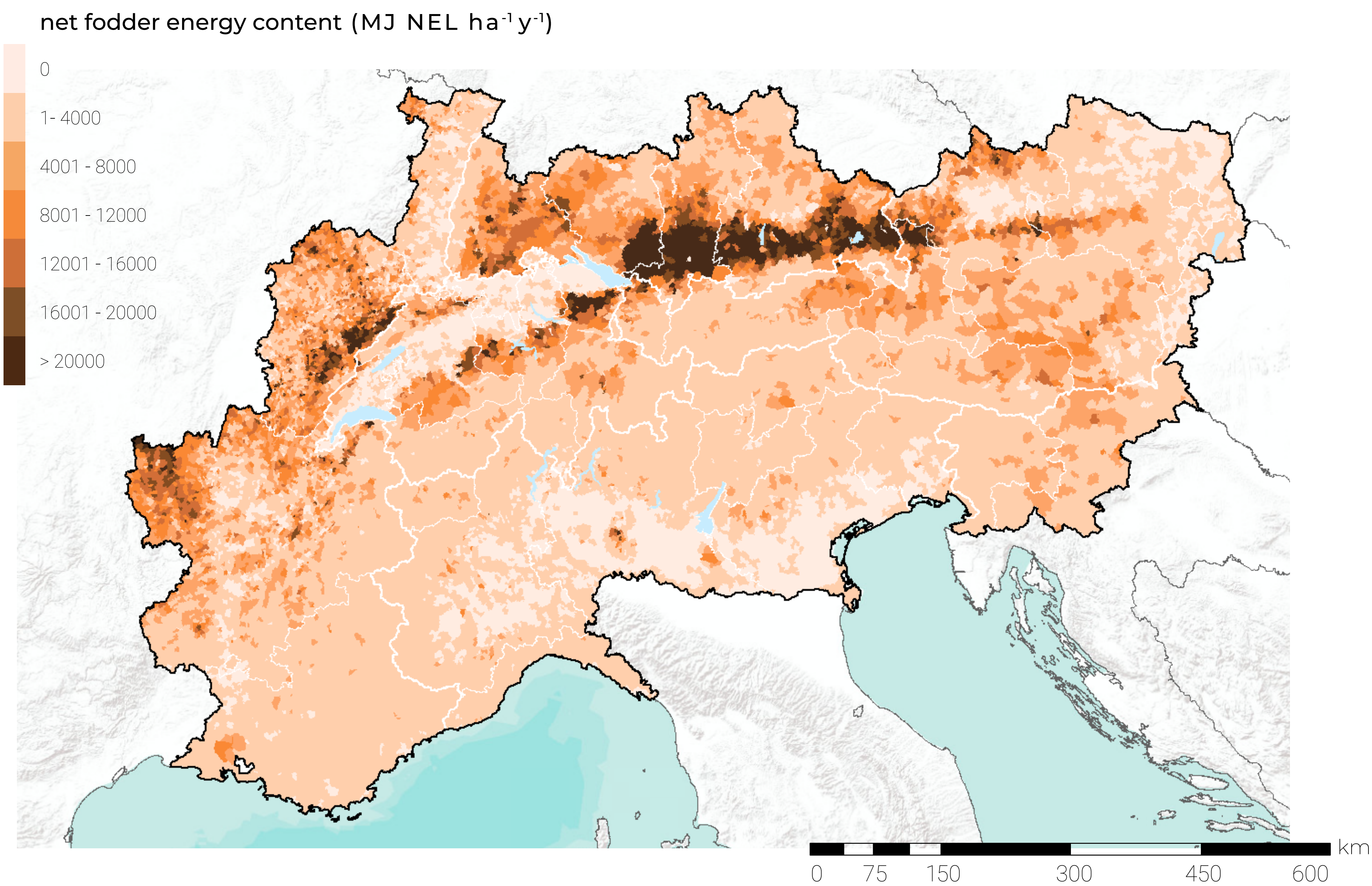
The map shows a hotspot of grassland biomass supply in lower Germany, namely the regions of Schwaben and Oberbayern, where the lower altitudes and abundant precipitation favour the growth of grassland. This area is indeed rich in pastures, as is observable in the CLC12 layer in the AlpES WebGIS. Other lowland areas, like the Po valley in Italy, the north of Switzerland and eastern Austria, have low values of this indicator, as the land is used for croplands, orchards, vineyards, arable lands and other cultivation types, and little space is dedicated to permanent grassland farming. High grassland biomass supply levels are important especially in areas where the agricultural and farming tradition is thriving.

Recent socio-economic trends saw a drop in the number of Alpine farmers, with about 20% of the agricultural land of the Alps being abandoned (Muheim & Meier, 2017). These plots of land previously managed for grassland farming are lost to scrub encroachment and reforestation, to the detriment of biodiversity and landscape diversity. Indeed, traditionally managed grasslands rank among the habitats with the highest species richness in Alpine regions, in terms of both plant diversity and animal species that use this habitat during their life cycle (Muheim & Meier, 2017).

Alpine grasslands are also subject to many threats. Livestock grazing, and in particular trampling and fertilization from accumulated excrement, can cause significant changes in the vegetation. Another major threat to Alpine grasslands is winter recreation and the related tourism flow. The establishment of ski resorts often affects the phenology of the underlying vegetation and promotes soil erosion, which may ultimately result in changed plant composition and a higher proportion of unvegetated ground.

FLOW

biomass production from grassland



Description

This indicator represents the de facto used amount of biomass from permanent grasslands in mega joules net-lactation (MJ NEL). This energy measure is obtained by estimating the energy content of each type of raw material used as fodder and the productivity of the areas dedicated to cultivating them in each municipality.

Definition

Net fodder energy content (MJ NEL $ha^{-1} y^{-1}$)

CICES section

Provisioning ecosystem service

CICES division

Materials

COMMENT

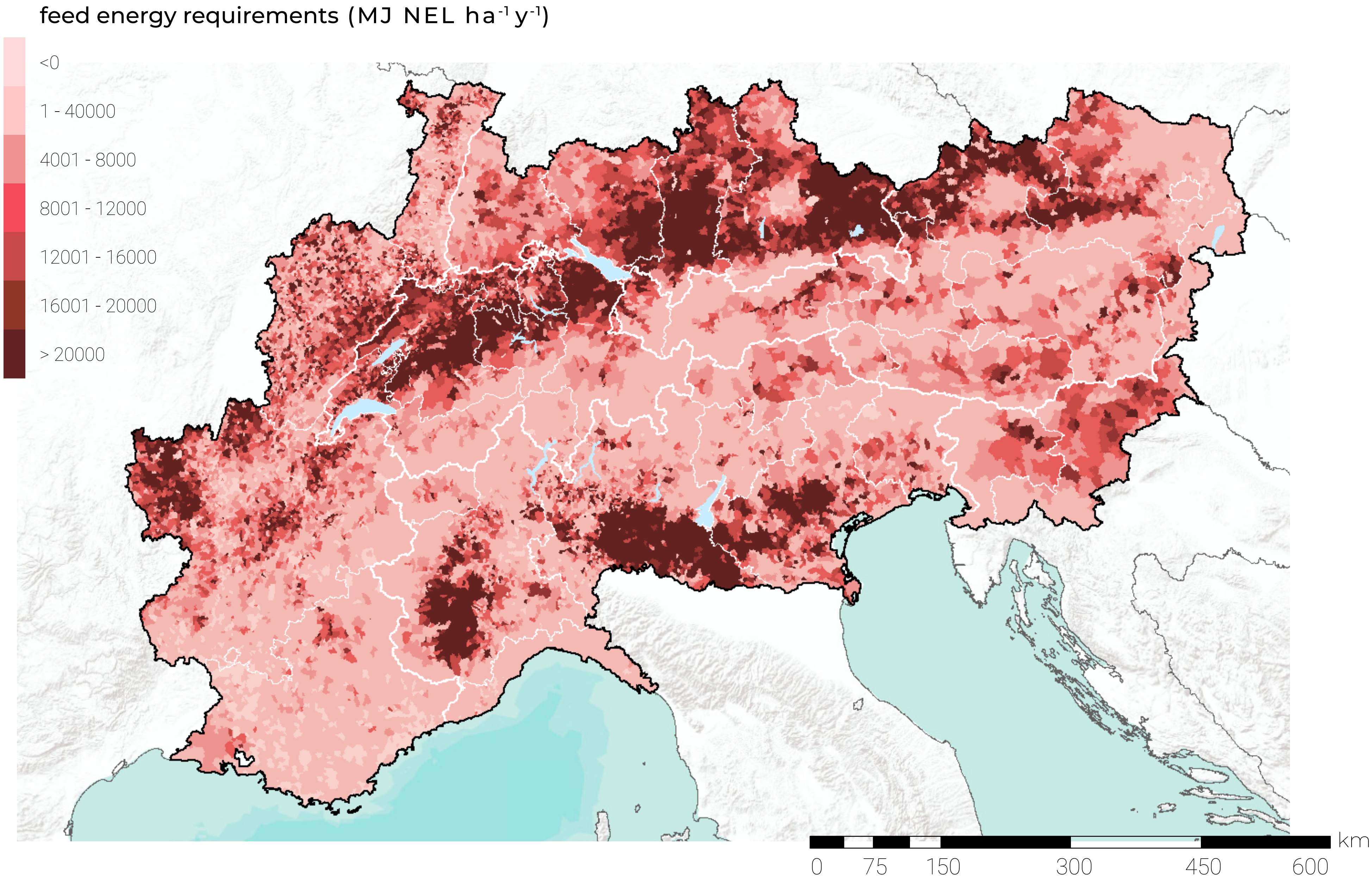
The consumed amount of grassland biomass depends on three factors: (1) the supply of grassland from the ecosystem, (2) the usage intensity, i.e. the cutting frequency of the pastures and (3) the loss of material during the harvesting and storage processes. The flow indicator is calculated as an energy measure, which takes into account the forage quality of the consumed biomass and its relative total energy content. Differences in the terrain, nutrient availability and use of fertilizers, also affect both the productivity of extensive grasslands and the quality of the end product.

The pattern of this map resembles the previous supply indicator map in that the highest flow rates are observed in Germany, whereas the lowest values appear again in the Italian and Swiss plains. Since this indicator is a measure of the used fraction of the local yield, the high similarity of the two maps should not come as a surprise.

In many mountain villages, the harvesting of hay from meadows that were too steep for grazing animals, and its transportation downhill, were fundamental parts of the farmer's work to sustain his animals during the wintertime, when they were kept inside the stable. Nowadays, the activity of "wild haymaking" is celebrated as a fascinating tradition, but is vanishing in favour of more time- and energy-efficient technologies (e.g. mowers and tractors).

DEMAND

biomass production from grassland



Description

The demand of biomass production from grassland is calculated by estimating the energy demanded by cattle, horses, and other forage feeding animals for their nourishment and for the production of desired animal products, such as milk.

Definition

Feed energy requirements ($MJ\ NEL\ ha^{-1}\ y^{-1}$)

CICES section

Provisioning ecosystem service

CICES division

Materials

COMMENT

As most cultivation types are difficult to maintain in the rough Alpine environment, with its steep terrain and harsh climate, farmers have instead focused on the production of animal-derived products like milk, cheese and meat. Dairy and beef cows have therefore become common in the Alpine landscape, along with equine species, sheep and goats.

The demand for grassland-derived forage varies greatly with the composition of the herd and the age and gender of the animals. The energetic costs required by animals for milk production were also included in the calculations, based on the average amount of milk produced per municipality. Nowadays, such energetic requirements are largely satisfied with the consumption of additional fodder and nutritional supplements, as local grassland farming alone is often insufficient.

The resulting map shows that the largest demand is located in the northern foothills of the Alps and in the Po valley, where great numbers of cattle are present. In these areas, the high demand for fodder is satisfied through multiple sources: concentrated feed, biomass from local grasslands and imported biomass, transported from other production zones. The steepness and ruggedness of the central mountains preclude the management of large herds of animals.

Did you know that: With the general increase in the demand of high-quality meat and dairy products versus those supplied by intensive animal farming, there has been a growing desire to recognize and reward the quality of animal products from Alpine farms. One such product that is getting considerable attention is the so-called “hay-milk”, i.e. milk derived from cows that feed predominantly on fresh grass or hay.

3.3 Fuel wood

Large swaths of forested land are one of the defining features of the Alps. These numerous forests provide for many social and economic benefits: one of the most significant being timber. Timber can be processed in numerous ways and serves a variety of purposes: from constructing buildings to being burned as fuel. Traditionally, fuel wood was used in homes all across the Alps. Today, the use of fuel wood is less consistent, and varies dramatically by region. However, as alternative and sustainable energy sources become more sought after, fuel wood is once again becoming a vital energy source across the region.

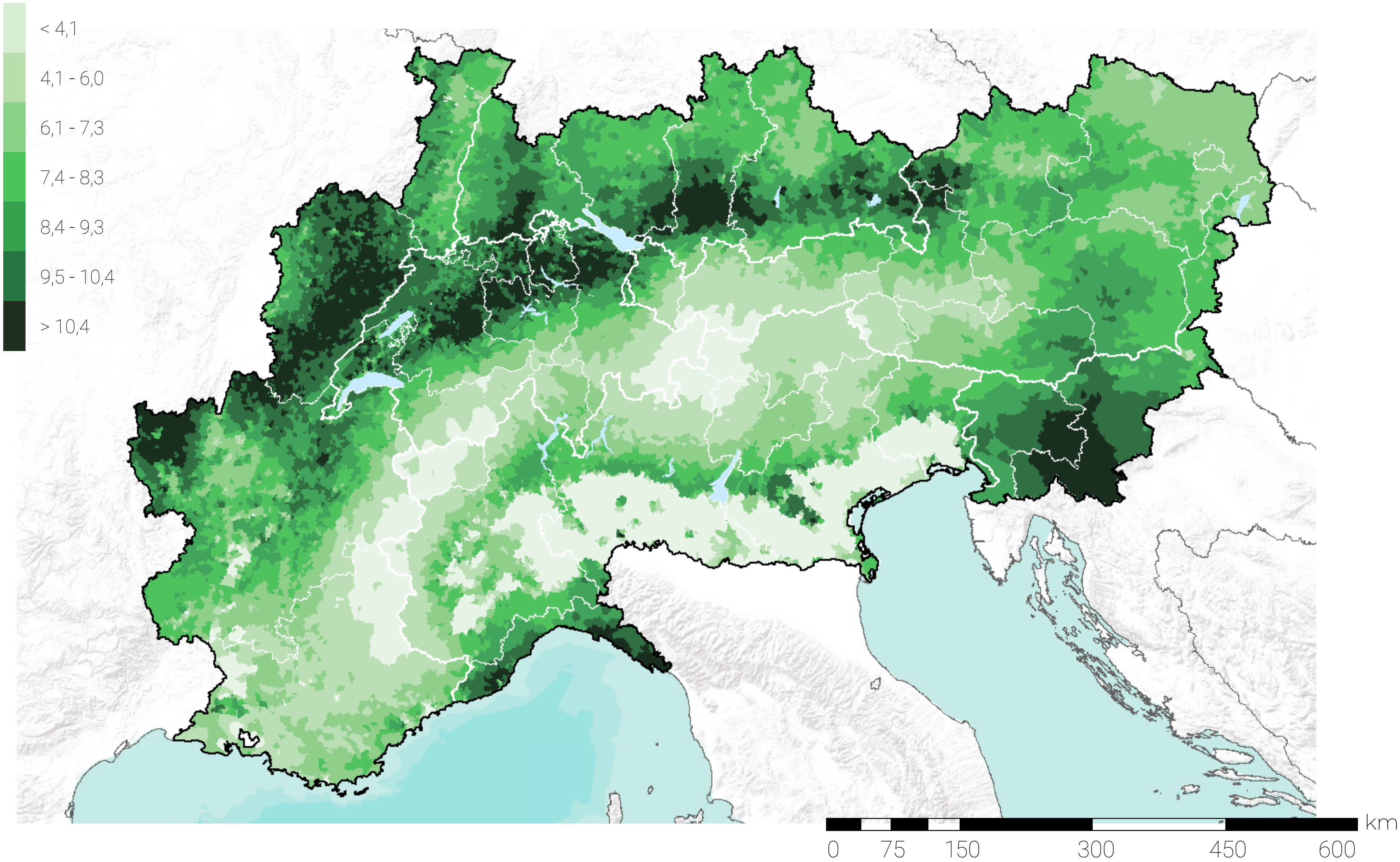
In order to better understand the benefits humans derive from fuel wood, it is important to identify how much wood ecosystems supply, how much wood humans take from these systems, and finally how much demand exists for heating that could be met by this source. Many factors affect these values, such as the rate at which a forest grows, how accessible wood resources are for extraction, and the caloric content of wood used for heating.

This suite of indicators evaluates these three components and maps them across the Alpine Space. By doing so, this ecosystem service can be included in adaptive management that meets the heating and energy needs of the present and the future.

SUPPLY

fuel wood

forest biomass increment (m³ ha⁻¹ y⁻¹)



Description

This indicator quantifies the net annual increment of wood biomass in Alpine forests, measured as cubic meters per hectares per year.

Definition

Wood biomass increment ($m^3\ ha^{-1}\ y^{-1}$)

CICES section

Provisioning ecosystem service

CICES division

Energy

COMMENT

Forests are one of the formative landscapes of the Alps, covering over 41% of the Alpine Space and providing essential goods, like wood. To keep forest inventories stable, the harvested timber should not exceed the net biomass increment of the forest that supplies it. Sustainable Forest Management (SFM), as defined by the European Commission, should maintain the forests' productivity, biodiversity, regeneration capacity and its potential to fulfil relevant ecological, economic and social functions now and in the future.

The supply for fuel wood is therefore limited to the regrowth rate of the forests, which depends on the climate and altitude of the location. This is apparent when looking at the map, as the areas with highest elevation have a low biomass increment rate, whereas mid- to lower altitude zones fare better. High supply levels allow for proportionally higher timber harvesting levels.

Figure 3.2 provides an overview of the growing stock in forests (i.e. the stem volume of living trees) at the regional scale across Europe, providing basic information for the assessment of the sustainability of forest management and harvesting possibilities.

DID YOU KNOW ?

Forests cover 33% of Europe's territory (excluding the Russian Federation) and their area continues to expand. Indeed, in 2015 forests occupied an area of 215 million hectares, about 4 million ha more than in 2011. However, it is estimated that about 3,7 million ha of Europe's forests are affected by forest damage, most often caused by biotic agents, and a further 0,5 million ha are damaged by fire (Forest Europe, 2011 and 2015). Climate change accounts for new risks for Alpine forests: the temperature rise stimulates the growth and proliferation of pathogens and parasites while also disrupting the development phases of trees (e.g. early sprouts, longer vegetation periods) (Zebisch et al., 2018).

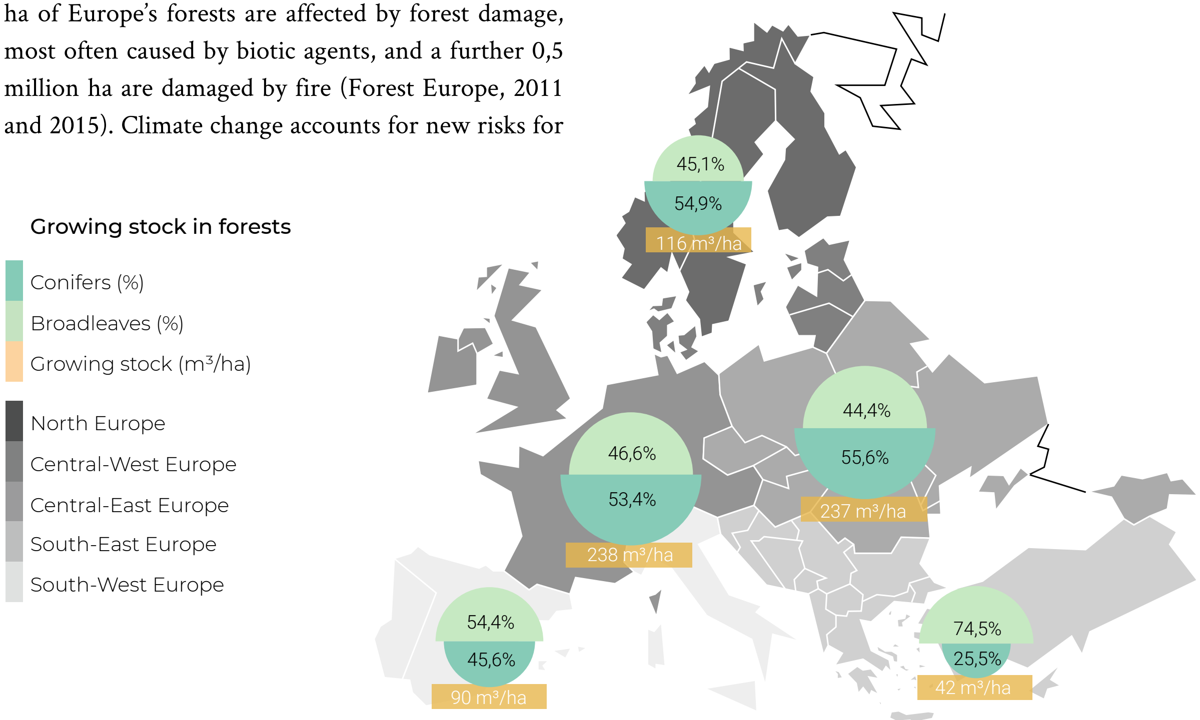
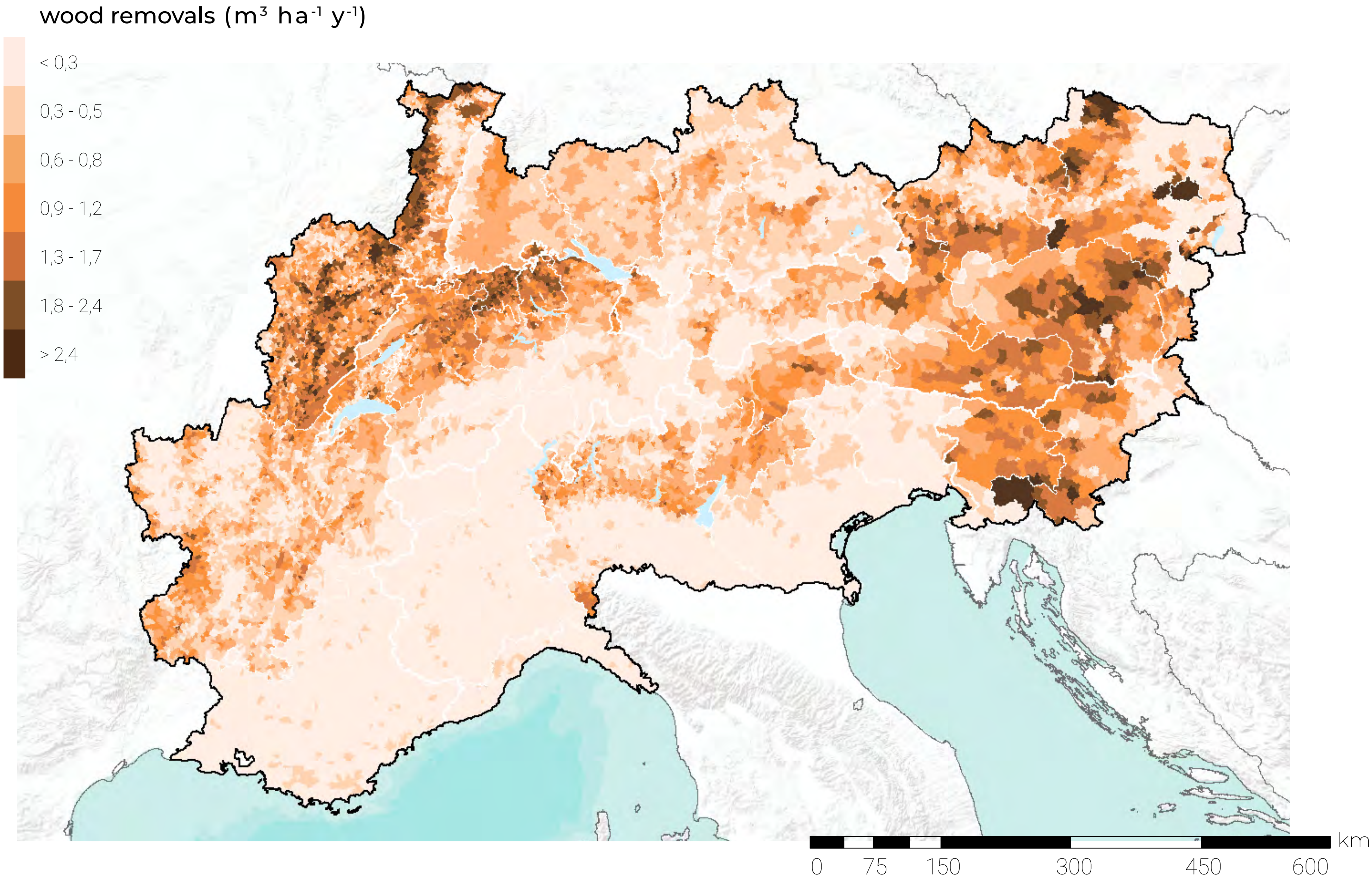


Figure 3.2 The growing stock in forests, subdivided into conifers and broadleaves, by region, 2015 (m³/ha). Adapted from Forest Europe, 2015.

FLOW

fuel wood



Description

This indicator measures the total annual wood removals - based on national inventories - for fuel wood production, considering also the forest accessibility and the technical feasibility of harvesting due to topographical site conditions.

Definition

Wood removals
($m^3\ ha^{-1}\ y^{-1}$)

CICES section

Provisioning ecosystem service

CICES division

Energy

COMMENT

Forest management is only possible if there is viable infrastructure to reach the felling sites. Moreover, topographical site conditions affect the technical feasibility of the tree felling activities and the subsequent collection and transportation of the timber. All these factors, together with data on the forests available for wood supply, were utilized to develop the flow indicator for fuel wood.

The resulting map shows a heterogeneous distribution of the flow rates for fuel wood; high values can be observed in the eastern (Slovenia and east Austria) and the northwestern (upper Switzerland and France) parts of the Alpine Space. Such areas present the most accessible and workable forests, which also have a reasonably high supply. The southern areas of the Alpine Space and the central mountain ridge score low levels of fuel wood flow, partly due to already low wood supply rates, and partly because of the remoteness and ruggedness of these areas.

DID YOU KNOW ?

While forest stocks are stable or even growing in most of the northern hemisphere, deforestation remains a major threat to the preservation of the tropical rainforests of Central and South America, Central Africa and Southeast Asia, collectively known as the Earth's lungs (Fig. 3.3). The loss of these pristine forests contributes to biodiversity loss, soil erosion, disrupted water cycle and the release of greenhouse gases. Indeed, between 1990 and 2015, the world lost some 129 million ha of forest, an area the size of South Africa. (WWF).

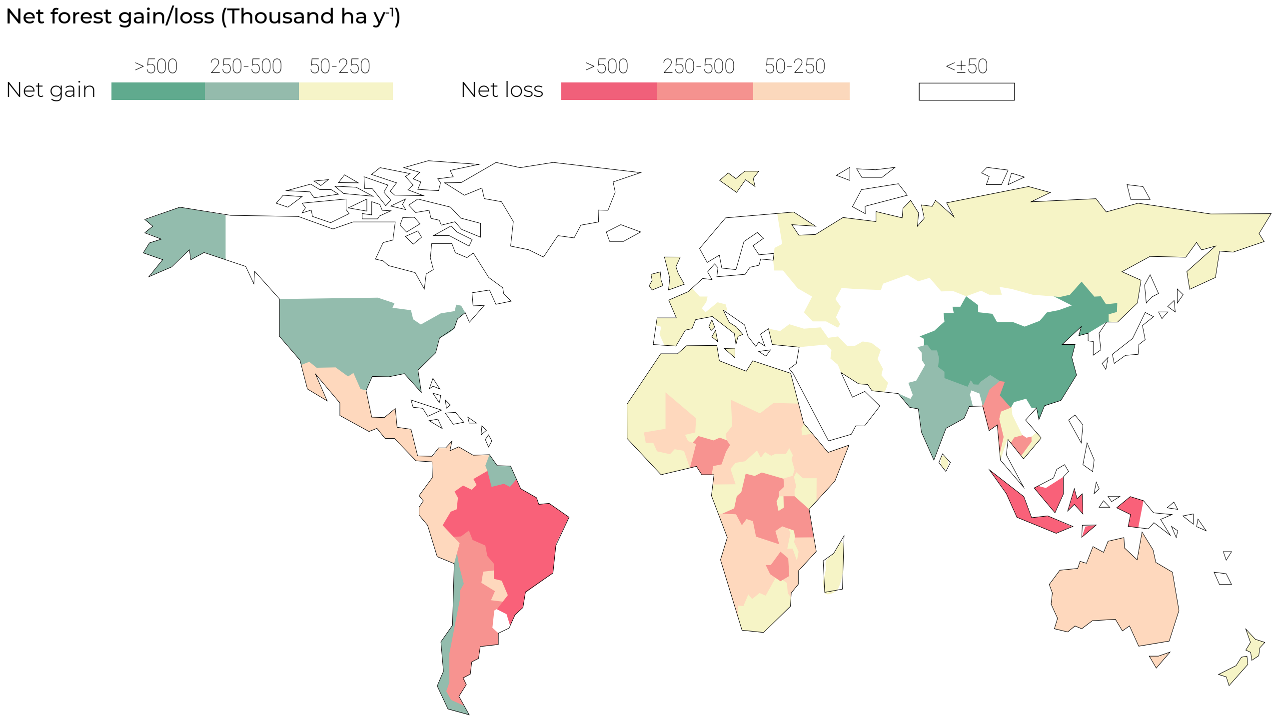
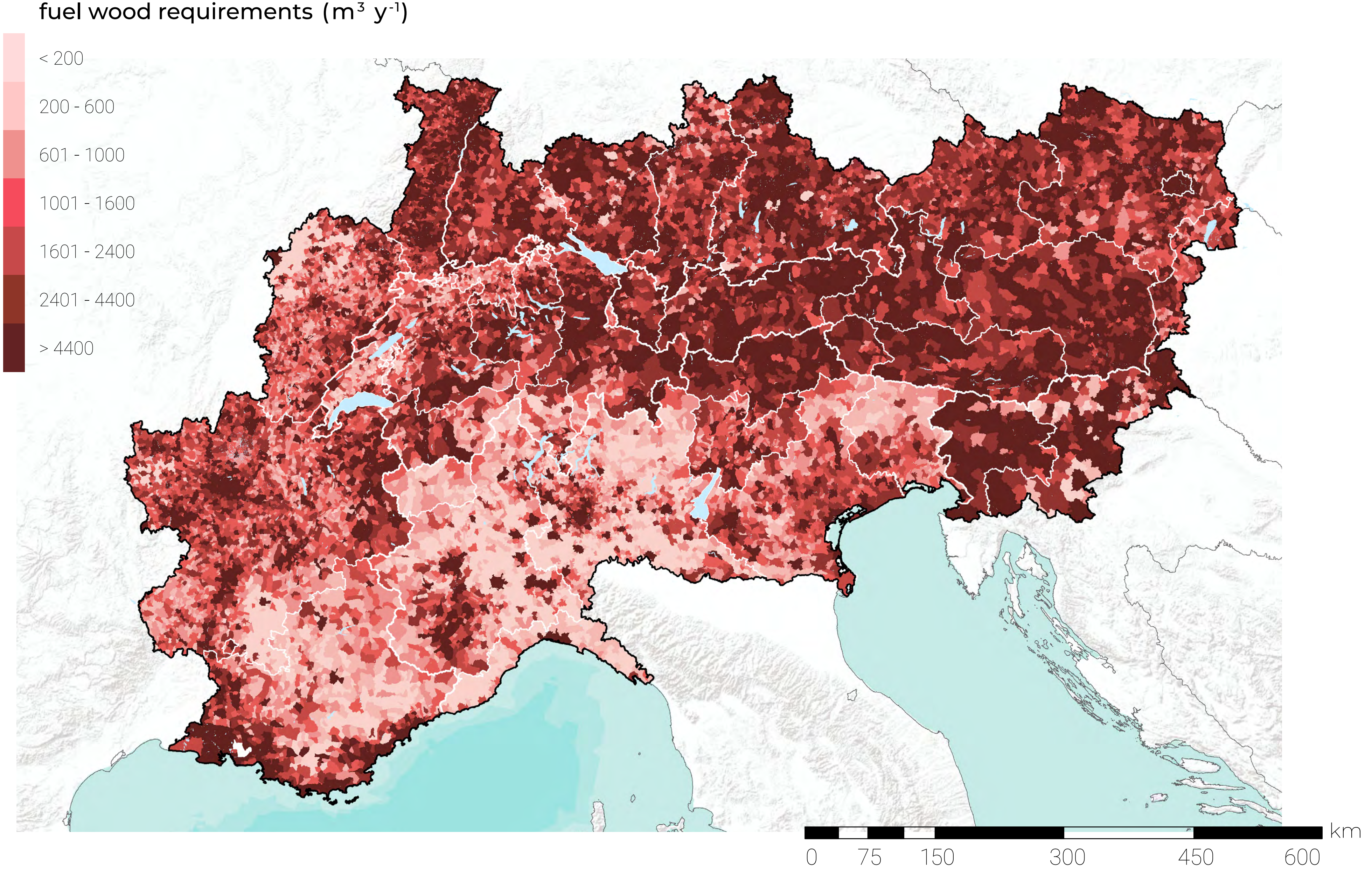


Figure 3.3 Annual net forest gain/loss by country, 1990–2015. Adapted from FAO, 2016.

DEMAND

fuel wood



Description

This indicator quantifies the municipal demand for fuel wood on the basis of the average energy requirements for heating and the average calorific value of fuel wood.

Definition

Potential fuel wood requirements (m^3 y^{-1})

CICES section

Provisioning ecosystem service

CICES division

Energy

COMMENT

The demand for fuel wood as an energy source is highly variable across the Alps and high-resolution data on energy consumption is scarce. Hence, this indicator estimates the hypothetical fuel wood requirements for heating purposes per municipality. The resulting map has a mosaic pattern, yet most big cities are easily recognizable due to their large population numbers, and consequently high energy demand.

Figure 3.4 compares the different heating and cooling systems used in different European countries: fuel wood is the predominant heating system only in Sweden, Latvia and Finland, whereas in the Alpine countries the favored heating source is natural gas. Nonetheless, biomass is currently the most widely used renewable energy source for heating, representing some 90% of all renewable heating as of 2012.

With the 2020 Energy Strategy, the EU aims to reduce its greenhouse gas emissions by at least 20% and increase the share of renewable energy to at least 20% of consumption by 2020, while also achieving energy savings of 20% or more.

Biomass is considered to be carbon neutral under EU legislation, based on the assumption that carbon released during combustion will be re-absorbed during tree growth. Therefore, EU policies provide incentives to use biomass for heating and power generation. However, several environmental NGOs are challenging the assumption of biomass carbon neutrality, as burning fuel wood releases more CO2 per unit of energy generated than fossil fuels. Furthermore, the emission of particulate matter, benzene, benzo[a]pyrene and other substances into the air can have significant effects on human health, increasing the risk of asthma and respiratory diseases. Lastly, the sustainability of woodcutting has to be continuously reassessed to avoid forest loss (Bourguignon, 2015)

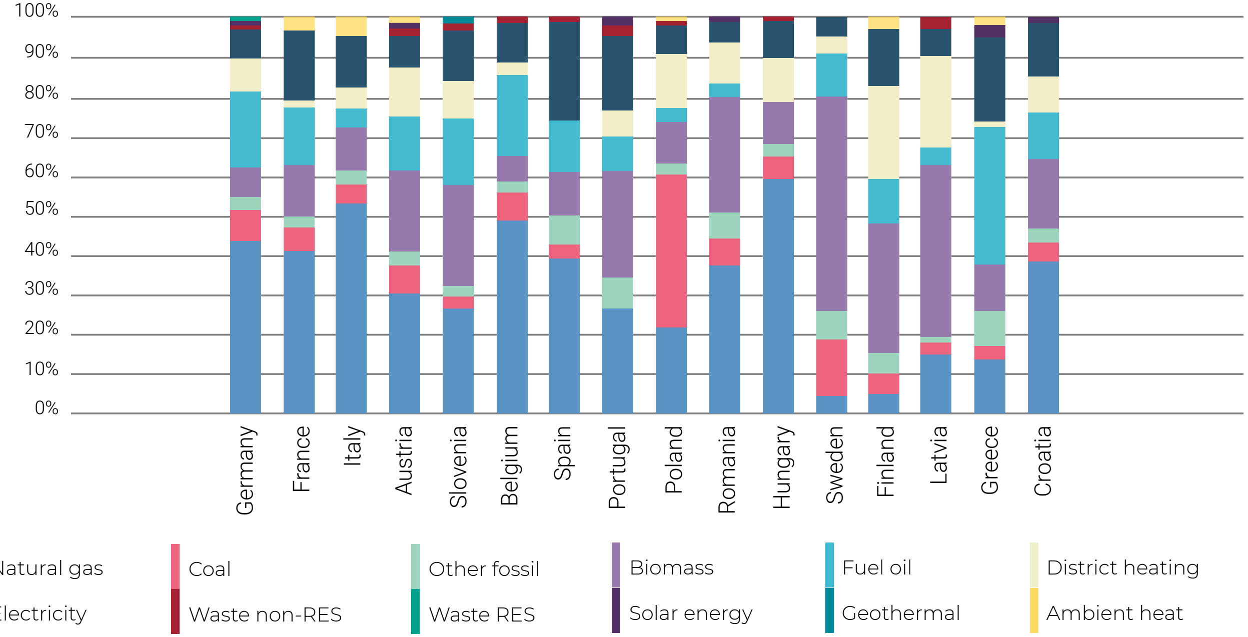


Figure 3.4 Energy consumption for heating and cooling by country and type of heating system, 2012. Adapted from Innovation Union (2014) "An EU Strategy on Heating and Cooling".

3.4 Filtration of surface water by ecosystem types

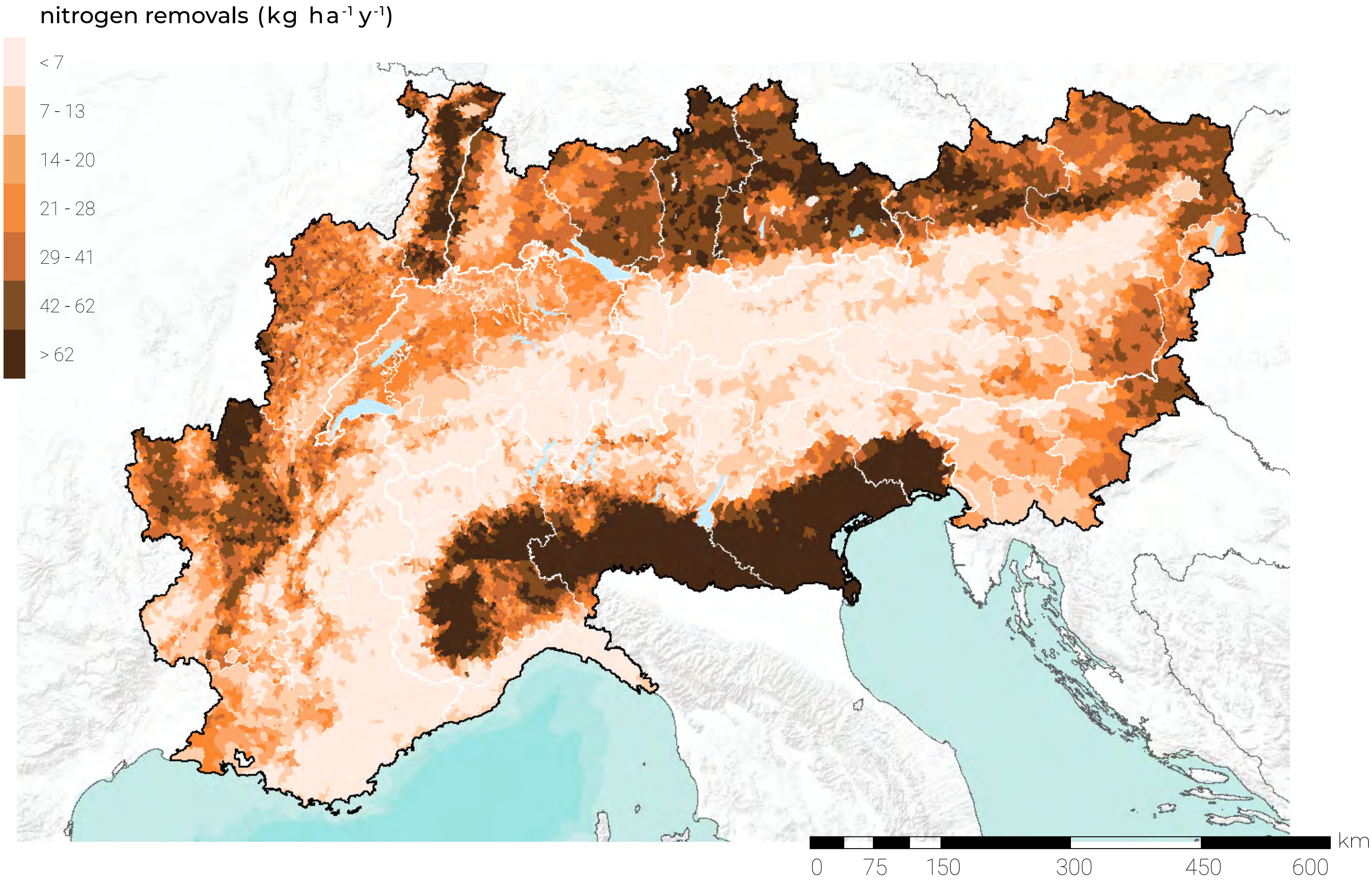
Water purification is one of the many regulating services provided by ecosystems. Pollutants such as metals, oils, excess nutrients and sediment are processed and filtered out as water moves through wetland areas, forests, and riparian zones. Water purification depends on filtration and absorption by soil particles and living organisms in the water and soil. As Europe's "Water Tower", this regulating function is especially pertinent in the Alps.

Nutrient pollution, and especially nitrogen, can have deleterious ecological and biogeochemical effects on the environment. For example, high nitrogen levels are a leading cause of eutrophication of surface waters, as they can induce excessive algal growth. The major causes of nutrient pollution are anthropogenic fertilizers, sewage, and industrial wastewater discharged into the environment. Thus, nitrogen is the focus of this set of indicators: "Filtration of surface water by ecosystem types".

Clearly, we would hope that the areas where nitrogen pollution is highest are also the areas where nature can most effectively filter it out. However, this is not always the case. It is thus important to examine how the two indicators in this set compare with one another.

FLOW / SUPPLY

filtration of surface water by ecosystem types



Description

This indicator measures the amount of filtered nitrogen from surface waters, and therefore describes both the flow and the supply of the ES, as the potential filtration of nitrogen by ecosystems and the de facto filtered nitrogen are identical.

Definition

Nitrogen removals ($kg\ ha^{-1}\ y^{-1}$)

CICES section

Regulation & maintenance ecosystem service

CICES division

Mediation of waste, toxics and other nuisances

COMMENT

This indicator focuses on the filtration of nitrogen from surface waters like rivers, lakes and wetlands. The major causes of nutrient pollution are the anthropogenic input of fertilizers, sewage and industrial wastewater discharges into the environment. The filtration of pollutants that reach the surface water occurs in several ways: vegetation can remove nutrients from water by storing them in tissues, soil can filter and store them, and riparian vegetation may act as a barrier and prevent pollutants from reaching a stream.

The map highlights efficient nitrogen filtering areas in the Po valley in Italy, and in some lowland municipalities of France and Germany. These areas are highly exploited for agricultural purposes, and therefore retain higher nitrogen loads compared to mountain or hilly areas. Moreover, as water is the nutrients' main vector, its presence and flow are crucial for the filtration of nitrogen: flat areas allow the water to flow more slowly than on steeper terrain, ensuring more effective filtration by the ecosystem. Land use, water presence and topography influence the values of this indicator, making its interpretation difficult. In fact, although high filtration rates are good, as they mitigate nutrient pollution of waters, they can only occur where the nitrogen loads are already high.

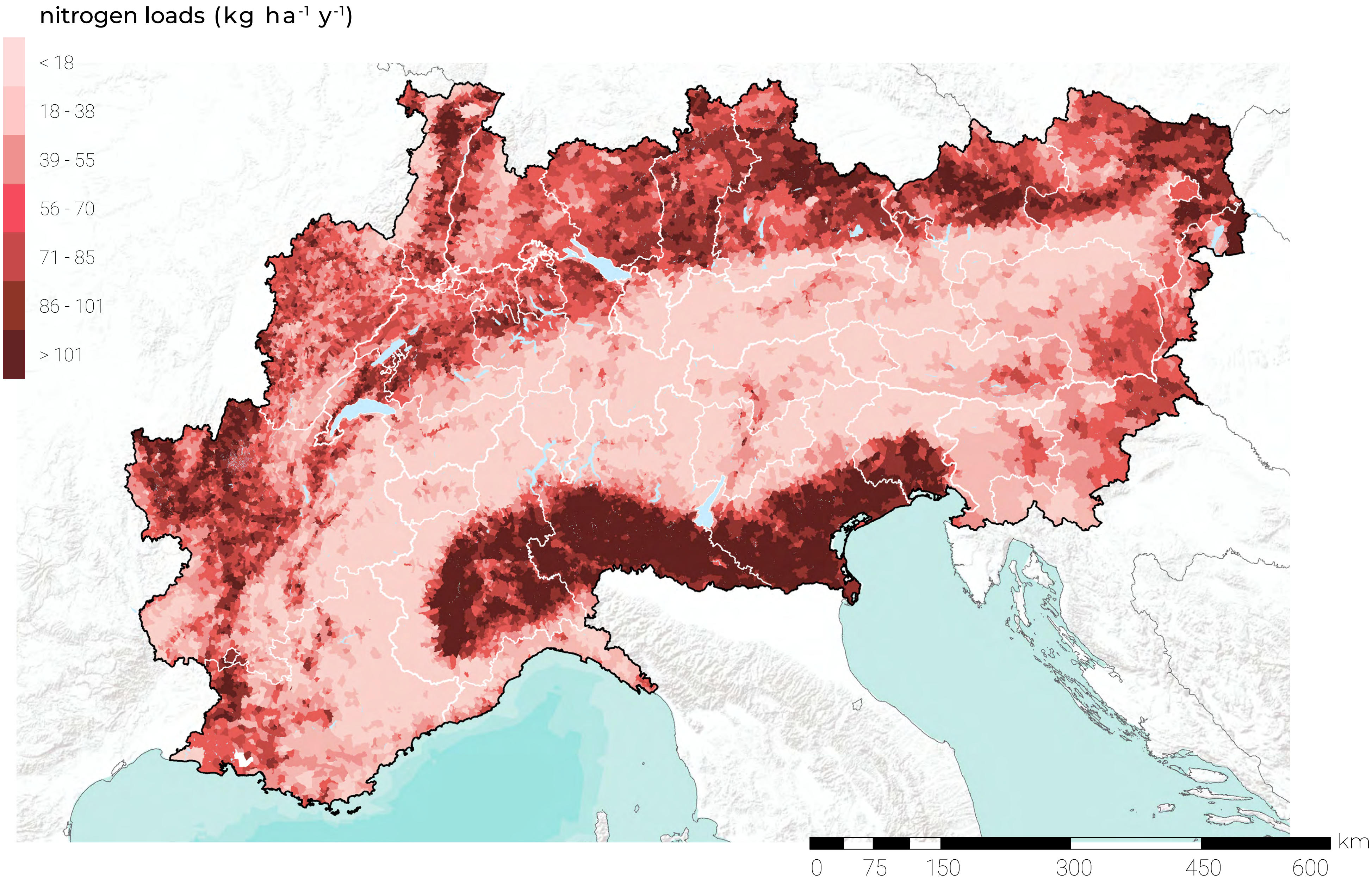
As the amount of ES delivered and the de facto utilized amount are equal, ES flow and supply are represented in the same map.

DID YOU KNOW ?

Nutrient pollution has already contributed to species extinction in the European Alps. Vonlanthen et al. (2012) showed that eutrophication caused a rapid loss in populations of whitefish, a member of the salmon family (Coregonus spp.), from a number of Swiss lakes. Low levels of oxygen at the bottom of eutrophied lakes reduce the number of whitefish eggs that survive to hatching, leading to a substantial decrease in population sizes and diversity among whitefish species.

DEMAND

filtration of surface water by ecosystem types



Description

The demand indicator for "Filtration of surface water by ecosystem types" represents the actual annual loads of nitrogen in kg per hectare that are emitted into the environment, regardless of the current levels of ecosystem filtration.

Definition

Nitrogen loads ($kg\ ha^{-1}\ y^{-1}$)

CICES section

Regulation & maintenance ecosystem service

CICES division

Mediation of waste, toxics and other nuisances

COMMENT

The demand indicator for this regulating ES gives an impression of where nitrogen loads are highest across the Alpine Space. Although Nitrate pollution has several sources: agriculture, transports, industry, and energy, land use is the factor that contributes most substantially, as recognized in the EU Nitrates Directive (EC, 1991). For this reason, the demand indicator scores high values in the plains, where croplands and other arable land plots are located. The map looks therefore quite similar to the supply-flow map: montane areas score low values for both indicators, whereas valleys and flat zones, where agricultural use of the land prevails, experience a greater level of nutrient pollution, and therefore have higher demand rates.

The European Commission has selected 50 mg/l of nitrate as the threshold above which water is considered to have excessive nutrients i.e. to be polluted. The values of this indicator should therefore be kept as low as possible – and ideally below the aforementioned concentration – to preserve a healthy ecosystem.

Figure 3.5 shows the exceedance of nutrient critical loads across Europe for the year 2010. The Po valley is highlighted once again as a critical spot for nutrient pollution, with serious risk of eutrophication.

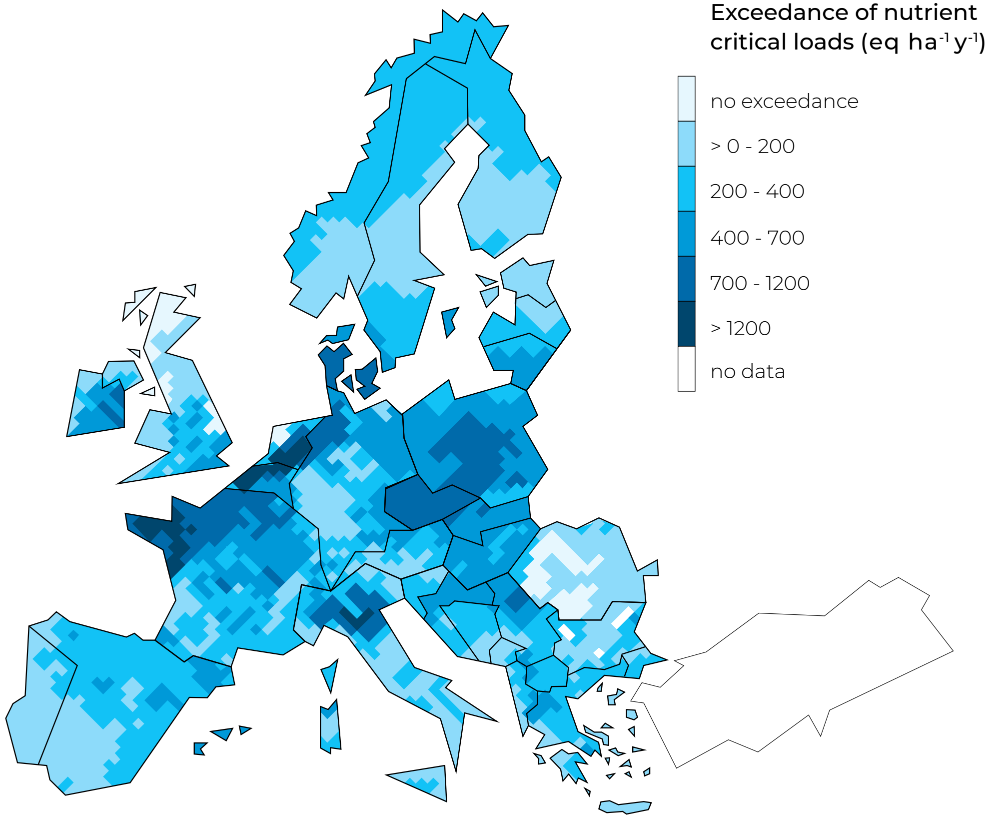


Figure 3.5 Exceedance of critical loads for eutrophication due to the deposition of nutrient nitrogen in 2010. Adapted from EEA 2010, "EU 2010 biodiversity baseline".

3.5 Protection against avalanches, mudslides and rockfalls

In mountainous areas characterised by considerable topographic variation and abundant ice, snow and water, one of the most important functions of forests is helping to prevent and mitigate rockfalls, mudslides, and avalanches.

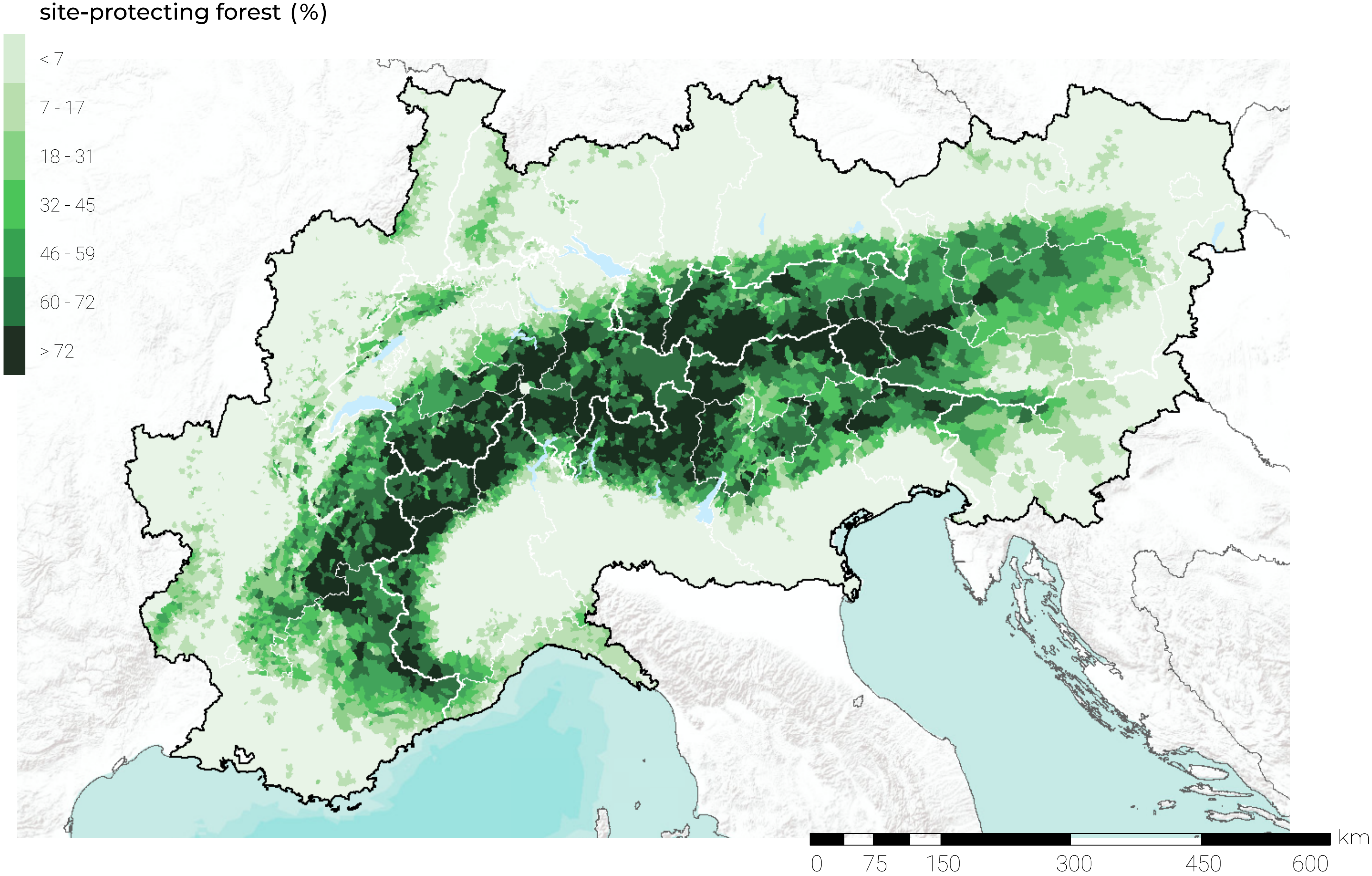
The Alps rank amongst the most forested areas in Europe, with about half of their area covered by woodlands. However, not all forests have a protective function to people and human infrastructures. According to Brang et al. (2001), protective forests are identified by the simultaneous presence of (1) people or assets that may be damaged, (2) a natural hazard or a potentially adverse climate that may cause damage and (3) a forest that has the potential to prevent or mitigate this potential damage. This ES is of particular importance in many municipalities of the Alpine Space, where the topographic, geomorphologic and climatic conditions account for an elevated potential for natural hazard events.

Accounting for this ecosystem service entails first defining all forests that have a mitigating function in natural hazards, whether or not there are “people or assets that may be damaged”. This way, total potential protection forests are accounted for. Next, only those forests that fully meet Brang et al’s requirements are considered, in other words, object protecting forests. Finally, calculations are performed to determine exactly how much area of human infrastructure exists in danger zones, and thus requires some form of protection (whether or not it comes from forests). As climatic changes continue to ripple through the Alps, it is necessary for decision-makers to understand trends in these natural hazards and the role of forests in their mitigation.

In this indicator set, only protection against avalanches and rockfalls, but not mudslides, was modeled. This is due to the complexity of this natural process, and the lack of suitable datasets for its modeling.

SUPPLY

protection against avalanches, mudslides and rockfalls



Description

This indicator quantifies the amount of forests with a potential protective function. Site protecting forests reduce the impact of natural hazards and erosion processes, regardless of the presence of human infrastructure.

Definition

Site-protecting forest (%)

CICES section

Regulation & maintenance ecosystem service

CICES division

Mediation of flows

COMMENT

Protection forests are one of the most inexpensive and environmentally friendly mitigation approaches for natural hazards such as avalanches, rockfalls and mudslides. In fact, forests are cheap and self-sustaining, they require little or no management and they do not disrupt the landscape, unlike artificial barriers and protection systems.

The map shows that the protection forest coverage is highest in the Alpine mountain range. This is explained by the very definition of protection forest, as those are the areas with the highest potential for gravitational hazards and mass movements, due to the slope of the terrain. Flat areas have a very limited potential for such types of natural threats, and therefore have little to no protection forest cover.

Even in areas where there is no human infrastructure to protect, protection forests can be beneficial to counteract soil erosion, soften the impact of rain and reduce run off by water, thus contributing to the preservation of an intact and functional ecosystem.

DID YOU KNOW ?

Forests cover 63% of Slovenia, but only 13,5% of these forests have a protective function (Copernicus High Resolution Layers: Forest Type & Tree Cover Density 2012). Figure 3.6 presents the share of forest cover per municipality. The comparison between this map and the protection forest supply map enables the identification of other highly forested areas that are non-protective. This leads to a better understanding of what topographic features (i.e. slope steepness) determine whether or not a forest is protective.

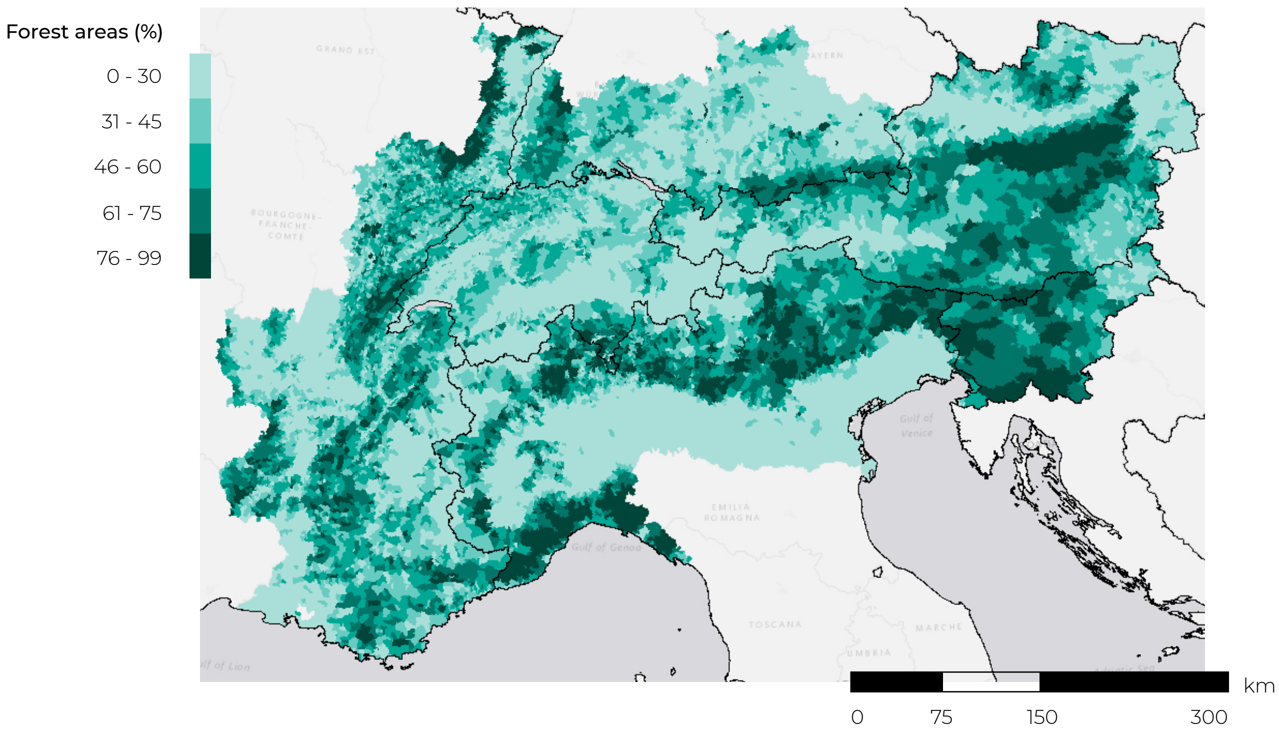
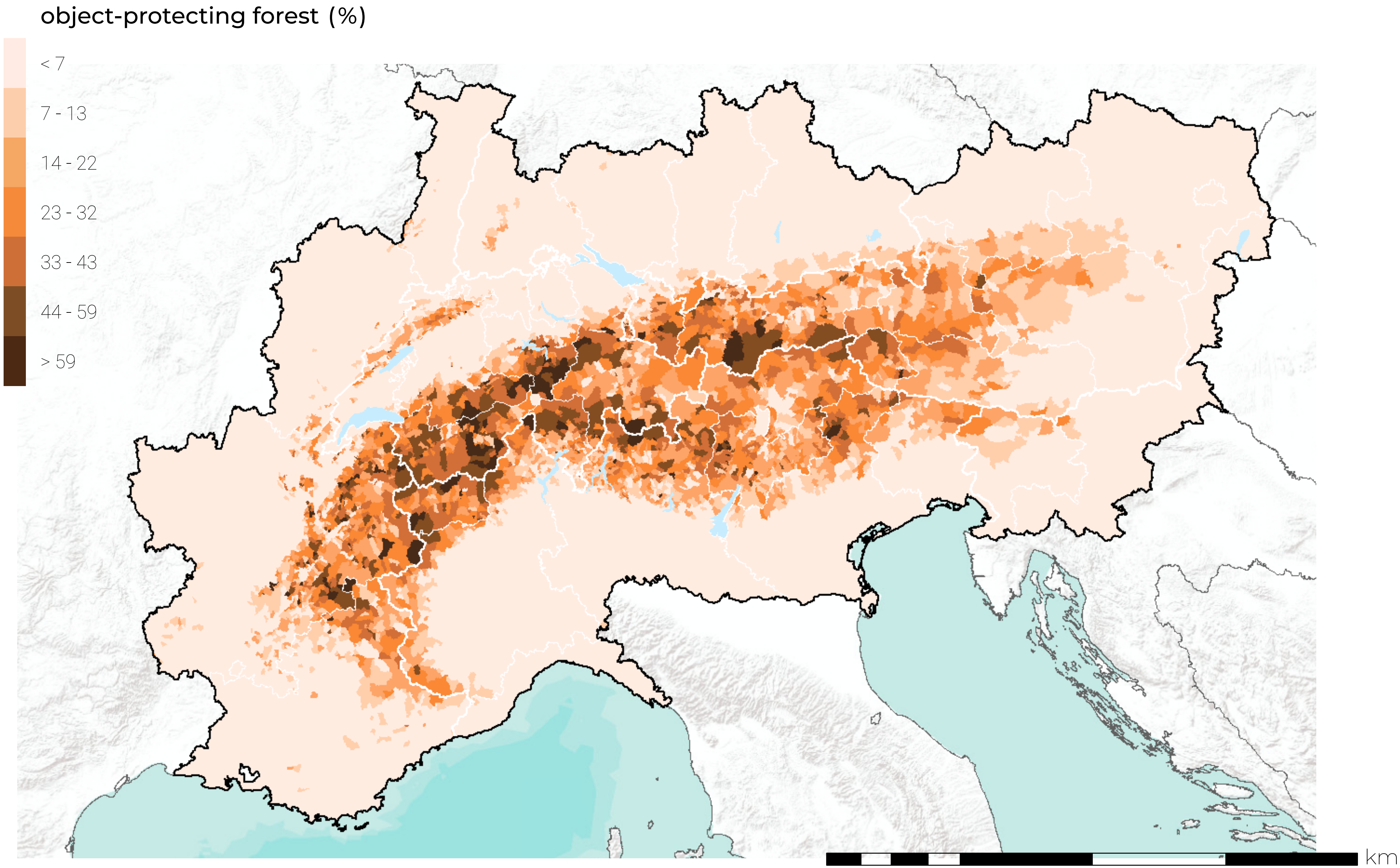


Figure 3.6 The percentage of each municipality that is covered by forests, as of 2012. Copyright 2018 AlpES

FLOW

protection against avalanches, mudslides and rockfalls



Description

This indicator quantifies the share of object-protecting forests only. These are the forests located in areas where potential hazard events could impact human infrastructure directly.

Definition

Object-protecting forest (%)

CICES section

Regulation & maintenance ecosystem service

CICES division

Mediation of flows

COMMENT

Of all the potential protection forests mapped through the supply indicator, the flow indicator considers only those that have a direct protective function for human infrastructure, like buildings, road networks and urban settlements. That is why the flow map shows a similar trend to that of the supply indicator. The hotspots in the map coincide with the municipalities where villages have developed on or between mountainsides, nestled among the Alps. In these locations, forests play a key role in protecting municipalities from the steep slopes that surround, and threaten, them.

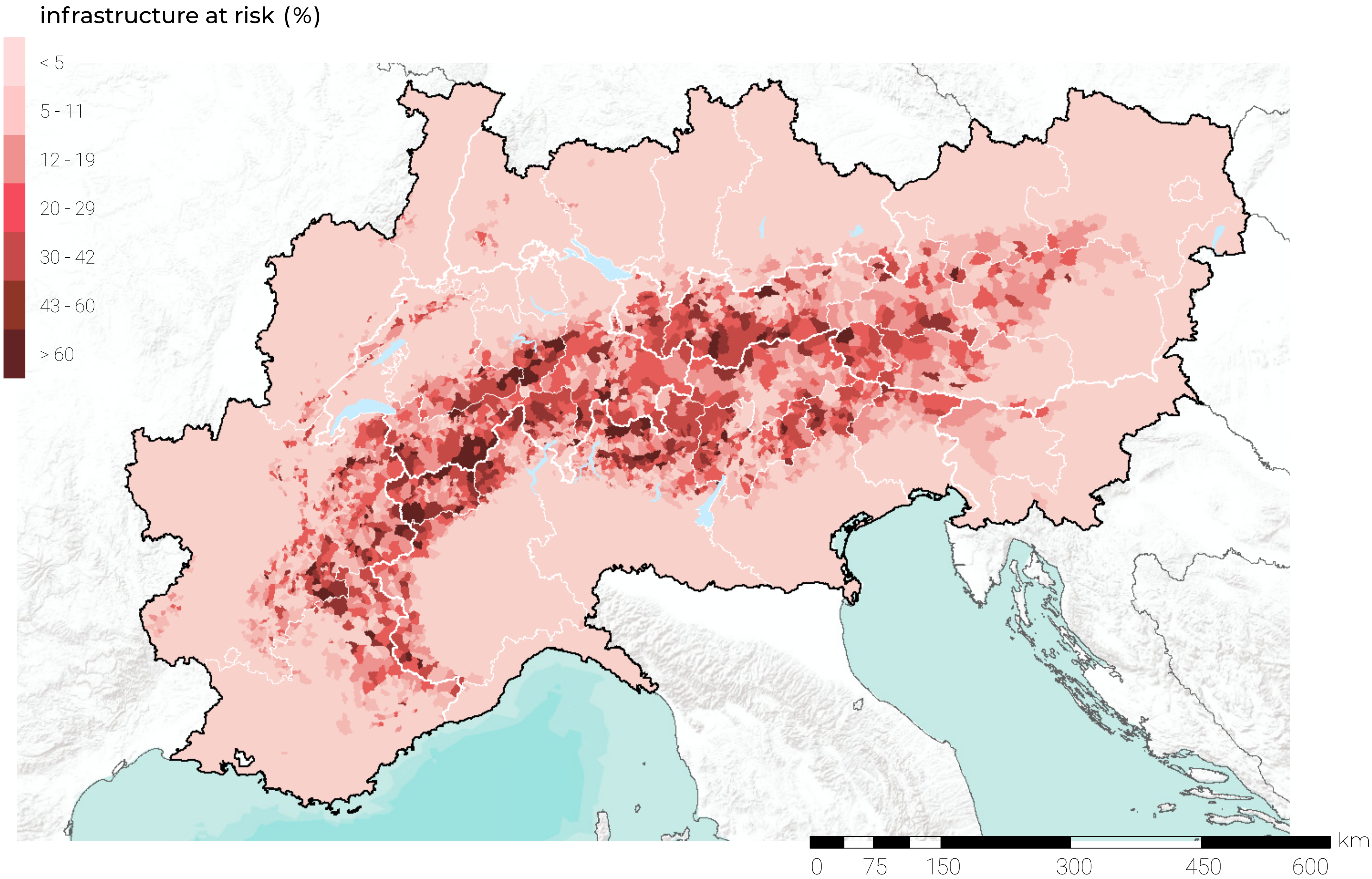
The protective function of forests in the Alps has been recognized for centuries, as evident from logging bans declared from the 1350s onwards. The more recent Mountain Forest Protocol of the Alpine Convention of 1996 states that "mountain forests …provide the most effective, the least expensive and the most aesthetic protection against natural hazards". As forest cover is constantly evolving, targeted silvicultural management strategies are needed to maintain or increase forests' protective role (Berger et al., 2013).

DID YOU KNOW ?

Annual landslide costs in Italy, Austria, Switzerland and France are estimated at $1-5 billion, or € 0,8-4 billion (Kjekstad & Highland, 2009). Landslides and rockfalls may become even more frequent in the Alpine Space due to the degradation of permafrost in steep slopes. Increased precipitation might also lead to more frequent and extended slope instabilities in the future (EEA, 2017).

DEMAND

protection against avalanches, mudslides and rockfalls



Description

The demand indicator for the ES “Protection of areas against avalanches, mudslides and rockfalls” quantifies the need for protection from natural hazards by showing the percentage of human infrastructure in potential danger zones.

Definition

Infrastructure in hazard zones (%)

CICES section

Regulation & maintenance ecosystem service

CICES division

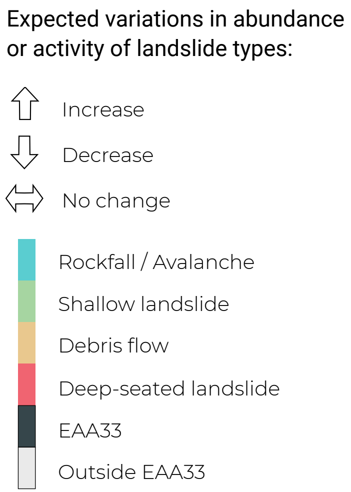
Mediation of flows

COMMENT

The demand indicator for protection forests is calculated by considering two main factors: (1) the natural hazard potential, based on avalanche and rock-fall transition zones, and (2) the damage potential, which considers all human infrastructure (i.e. settlement areas, buildings, roads and railways). The intersection zones between these two areas identify all infrastructure that is located in potential hazard zones, and therefore is in need of protection.

The map shows higher levels of demand in the Alpine mountain chain, where the natural hazard potential is high. In comparing the three maps for this ES, there is great consistency between the supply, flow and demand for protection forests. Indeed, there are only a few municipalities with high demand and low supply values, such as Saint-Martin-de-la-Porte or Hallstatt. These communities may receive high return on investment for planting protection forests in their jurisdiction. This relatively small amount of municipalities with a demand exceeding their supply does not necessarily imply that all potential danger zones are completely protected; protection forests may not offer absolute protection from every rockfall and avalanche event, and mudslides were not included in these calculations.

Climate change affects the stability of natural and engineered slopes; thus, it has important consequences on the frequency of rockfalls, erosion events and landslides. Recent research suggests that the increasing temperatures will lead to more frequent natural hazard events. Figure 3.7 shows the expected variations in abundance of landslides due to climate change; these changes entail mostly increases of landslide activities across the Alpine Space and the rest of Europe. Furthermore, avalanches, storms, typhoons and other abnormal climate events are also likely to become more common, as a result of a rapidly changing climate.



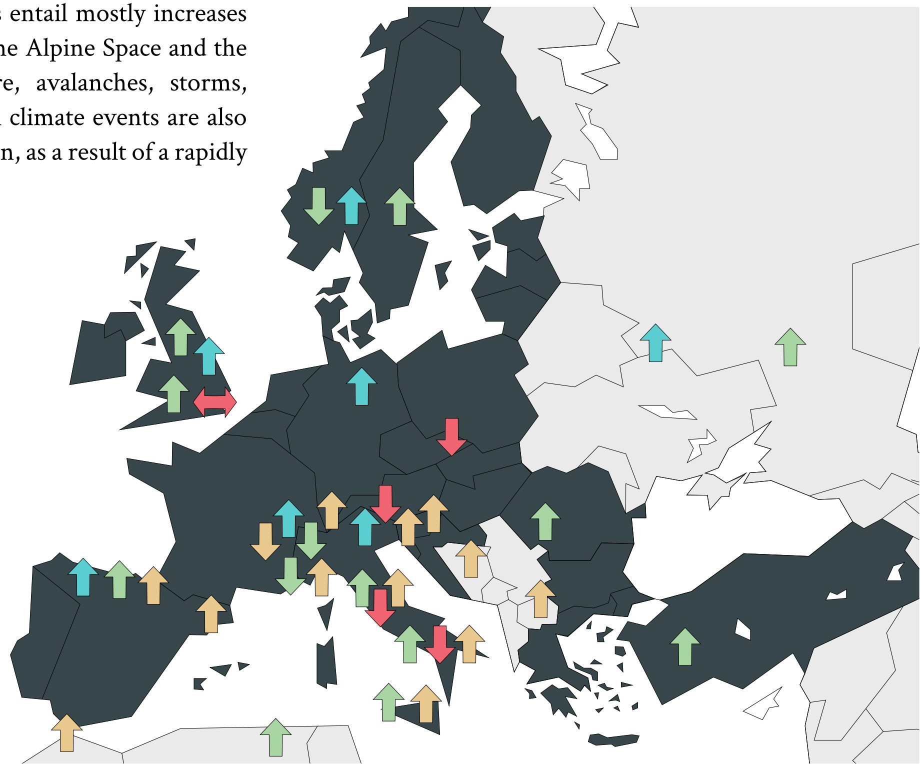


Figure 3.7 Expected variations in the abundance of natural hazards due to climate change. Adapted from EEA 2017 “Climate Change adaptation and disaster risk reduction in Europe”.

3.6 CO_2 sequestration by forests and bogs

The vast amounts of fossil fuels being burned around the globe mean that carbon dioxide (CO_2) is one of the most powerful drivers of global climate change. As no major reductions in CO_2 pollution are occurring at a global scale, the capacity of natural environments to sequester CO_2 is becoming more and more vital. Thus, any large-scale CO_2 sinks have a positive regulating effect not just locally, but globally as well.

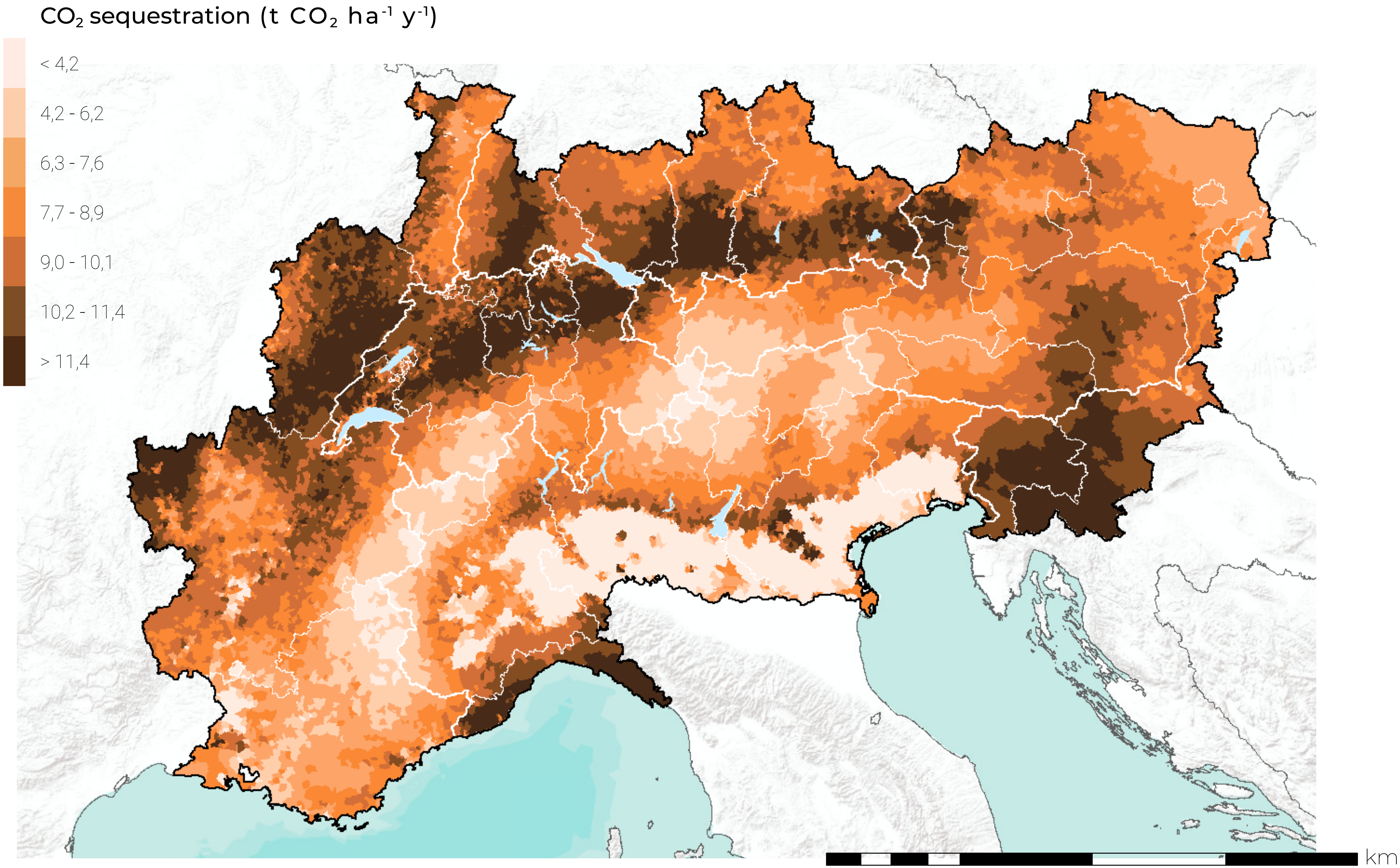
In the Alpine Space, the ecosystems with the largest sequestration capacity are forests and bogs. Every year, these ecosystems sequester CO_2 by storing it in biomass that is created as plants and trees grow. This yearly growth is known as “biomass increment” and is calculated using Intergovernmental Panel on Climate Change equations. These equations allow for the prediction of above- and below-ground changes in the amount of biomass, expressed in tonnes of carbon per year.

The supply and flow indicators for sequestration are mapped together, because the supply is equal to the flow in this case; all the carbon that these environments can sequester every year is in fact being sequestered. The demand indicator is calculated by assessing how much CO_2 each alpine municipality is emitting. Understanding the alpine contribution to CO_2 emission and sequestration is an important facet in coordinated action at local, regional, and global scales in the effort to mitigate global climate change.

In this indicator set, only CO_2 sequestration from forests was modelled. This is due to the lack of suitable knowledge about carbon cycling processes in bogs.

FLOW / SUPPLY

CO_2 sequestration by forests and bogs



Description

This indicator quantifies the tonnes of CO2 sequestered annually by Alpine forests in a municipality. As the potential and the de facto CO2 sequestration are identical, this indicator describes both flow and supply of the ES.

Definition

CO_2 sequestration by forests ($t\ CO_2\ ha^{-1}\ y^{-1}$)

CICES section

Regulation & maintenance ecosystem service

CICES division

Maintenance of physical, chemical, biological conditions

COMMENT

This indicator measures the amount of CO_2 sequestered by Alpine forests, the effects of which are not only of benefit to the Alpine population, but represent the contribution of the Alpine area to global climate protection. As the amount of ES delivered and the de facto utilized amount are equal, ES flow and supply are represented in the same map.

The map shows that the highest values of CO_2 sequestration occur in Slovenia, Germany, and northern France and Switzerland. In these areas, the increase in biomass carbon stock due to biomass increment is the highest, thanks to the optimal altitudinal and climatic conditions and the extended woodland areas. Carbon is absorbed by growing trees and is only released back to the environment through decomposition and burning. Thus, forests act as one of the most effective and sizeable carbon sinks. Indeed, recent studies have shown that the world's forests have absorbed as much as 30% of annual global anthropogenic CO_2 emissions in the past few decades (Bellassen & Luyssaert, 2014).

Peters et al. (2012) reported an increase in CO_2 sequestration levels by forests and other types of vegetation per hectare of land in the past 50 years (Fig. 3.8), despite a decrease of 2% in forest cover globally since 1990. These findings reaffirm the importance of sustainable and far-sighted management plans for the world's forests.

The contribution of bogs was not evaluated in this indicator, due to a lack of data on their distribution and CO2 sequestration potential. However, recent studies indicate that they play a key role in carbon storage and that their preservation may be one of the most cost-effective climate protection measures (WWF, 2010).

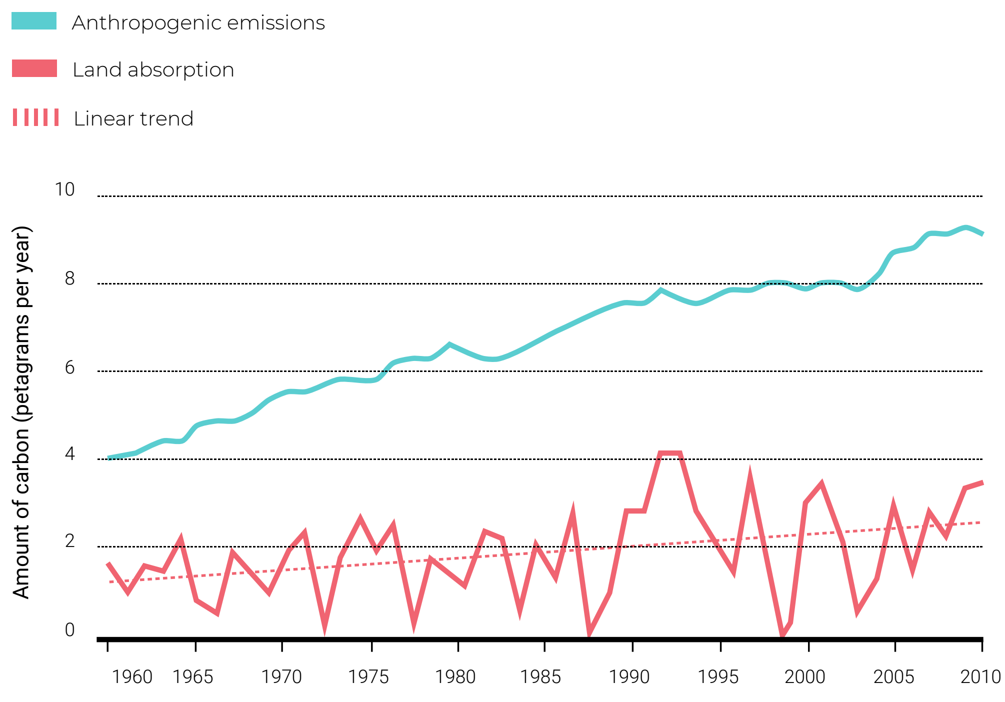
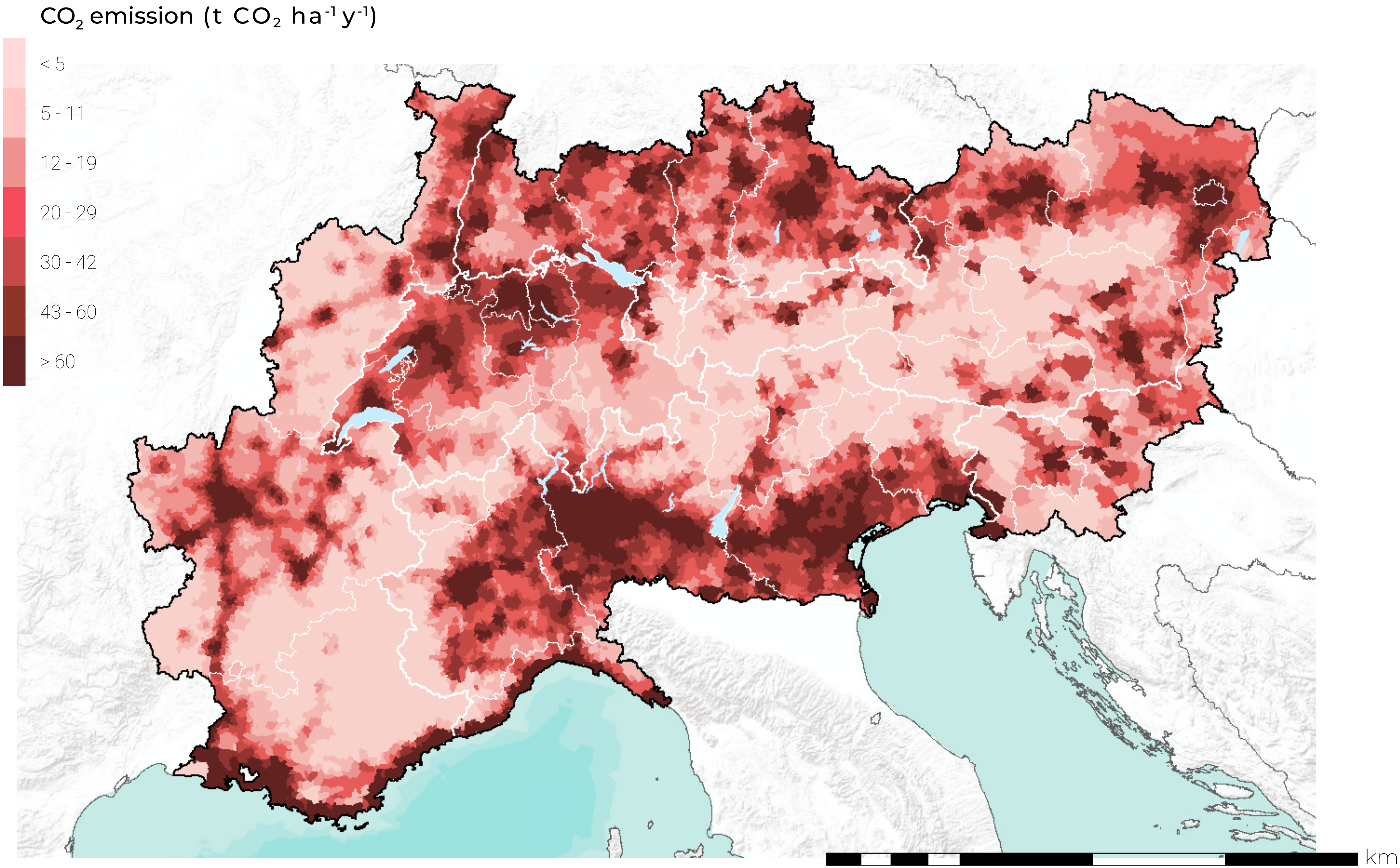


Figure 3.8 Global land CO_2 sink compared to anthropogenic emissions. Adapted from G. P. Peters et al. Nature Clim. Change 2, 2–4 (2012).

DEMAND

CO_2 sequestration by forests and bogs



Description

The demand indicator for the ES "CO2 sequestration by forests and bogs" represents the CO2 emissions per municipality for the year of 2010, measured in tonnes of CO2 per hectare.

Definition

CO_2 emission (t CO_2 $ha^{-1} y^{-1}$)

CICES section

Regulation & maintenance ecosystem service

CICES division

Maintenance of physical, chemical, biological conditions

COMMENT

The demand indicator for CO_2 sequestration provides an overview of the rate of CO_2 emissions across the Alpine Space. Unsurprisingly, the values are elevated in and around industrialized and urbanized areas, and the biggest cities are particularly apparent in the map (e.g. Milan, Zurich, Lyon, Munich, Vienna, etc.). The valleys of the Adige and the Inn are also evident, as they cut through the Alpine range, which otherwise has low emission rates.

The levels of atmospheric CO_2 are increasing at an unprecedented rate worldwide. This trend is effectively described in Figure 3.9, in which the increase in CO_2 levels in the last 22.000 years is compared to that registered in the last decades. Over the past 70 years, the rate of increase of atmospheric CO_2 is nearly 100 times larger than that at the end of the last ice age, accounting for a vertiginous spike in CO_2 concentrations. In an attempt to stop this deleterious trend, the international debate on this matter has become more serious, and binding environmental commitments to cut CO_2 emissions were taken – most notably the Paris Agreement within the United Nations Framework Convention on Climate Change.

Coordinated action at global and regional scales is essential to counteract the effects of these anthropogenic influences on climate. International commitment is needed for the effective preservation of forests and other ecosystems that provide regulation and maintenance services of atmospheric conditions. By comparing the Flow & Supply and the Demand indicators for carbon sequestration, important local and regional sources and sinks become evident. It is vital that the role certain regions play in carbon sequestration are acknowledged and leveraged in such coordinated action.

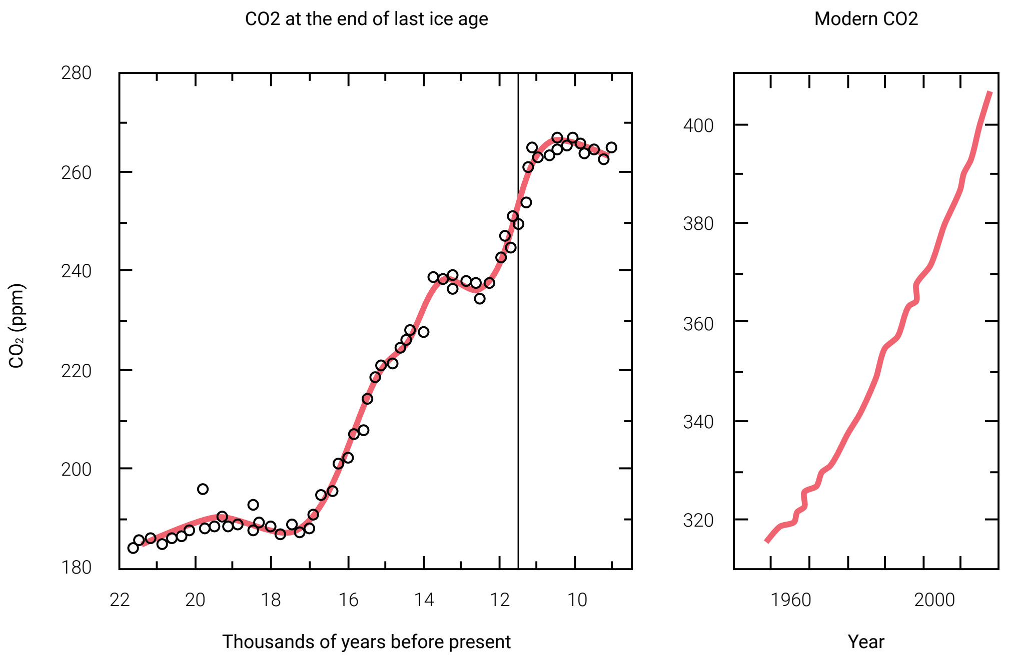


Figure 3.9 Atmospheric CO2 increase in the last 22.000 years (left) and in the last 50 years (right). The vertical line in the left graph indicates the end of the last ice age, 11,5 thousand years ago. Adapted from World Meteorological Organization

3.7 Outdoor rectration activities

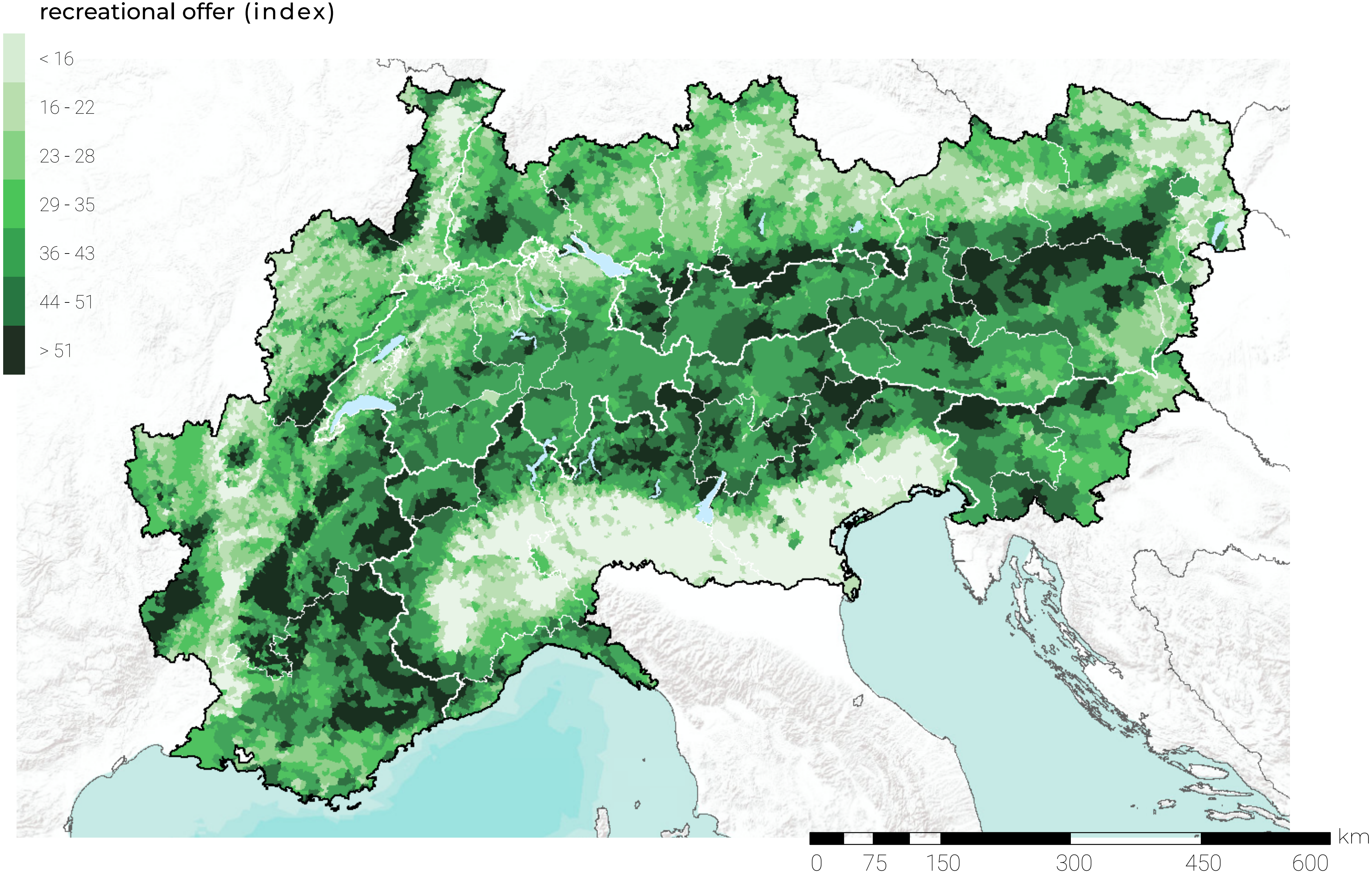
When discussing ecosystem services, most people imagine the material benefits humans receive from nature, such as clean drinking water, wood, and pollination of crops. However, there exists a whole category of ecosystem services concerned with non-material benefits, entitled cultural ecosystem services. This category includes aesthetic appreciation and inspiration, cultural identity, sense of home, and spiritual experience related to the natural environment. Typically, opportunities for recreation are considered within this category.

Nature-based opportunities for recreation (e.g. walking and playing sports in parks and urban green spaces or hiking in the mountains) play an important role in maintaining mental and physical health, as many studies have demonstrated (Stigsdotter et al., 2010; Barton & Pretty, 2010). Measuring the potential benefit of outdoor recreation is an important piece in the Alpine Space puzzle.

The three indicators for outdoor recreation activities assess the supply, flow, and demand of this service. In other words, they demonstrate how much open, natural, and accessible space exists for recreation, how many people are actually using these spaces, and the potential beneficiaries of outdoor recreation opportunities. In a landscape as beautiful as the Alps, the opportunities for outdoor recreation for both local and visiting populations comprise an enormous benefit.

SUPPLY

outdoor recreation activities



Description

This indicator measures the outdoor recreation potential of a municipality, taking into account the natural conditions and accessibility of such recreation opportunities.

Definition

Outdoor recreation availability (index)

CICES section

Cultural ecosystem service

CICES division

Physical and intellectual interactions with biota, ecosystems and land-/seascapes [environmental settings]

COMMENT

Many factors contribute to the nature-related recreation potential of a place; the naturalness of the environment, its ruggedness and a diverse composition of the landscape are all characteristics that increase this potential. Moreover, national parks and nature reserves often attract visitors and can provide many outdoor opportunities and sometimes even wildlife-watching experiences.

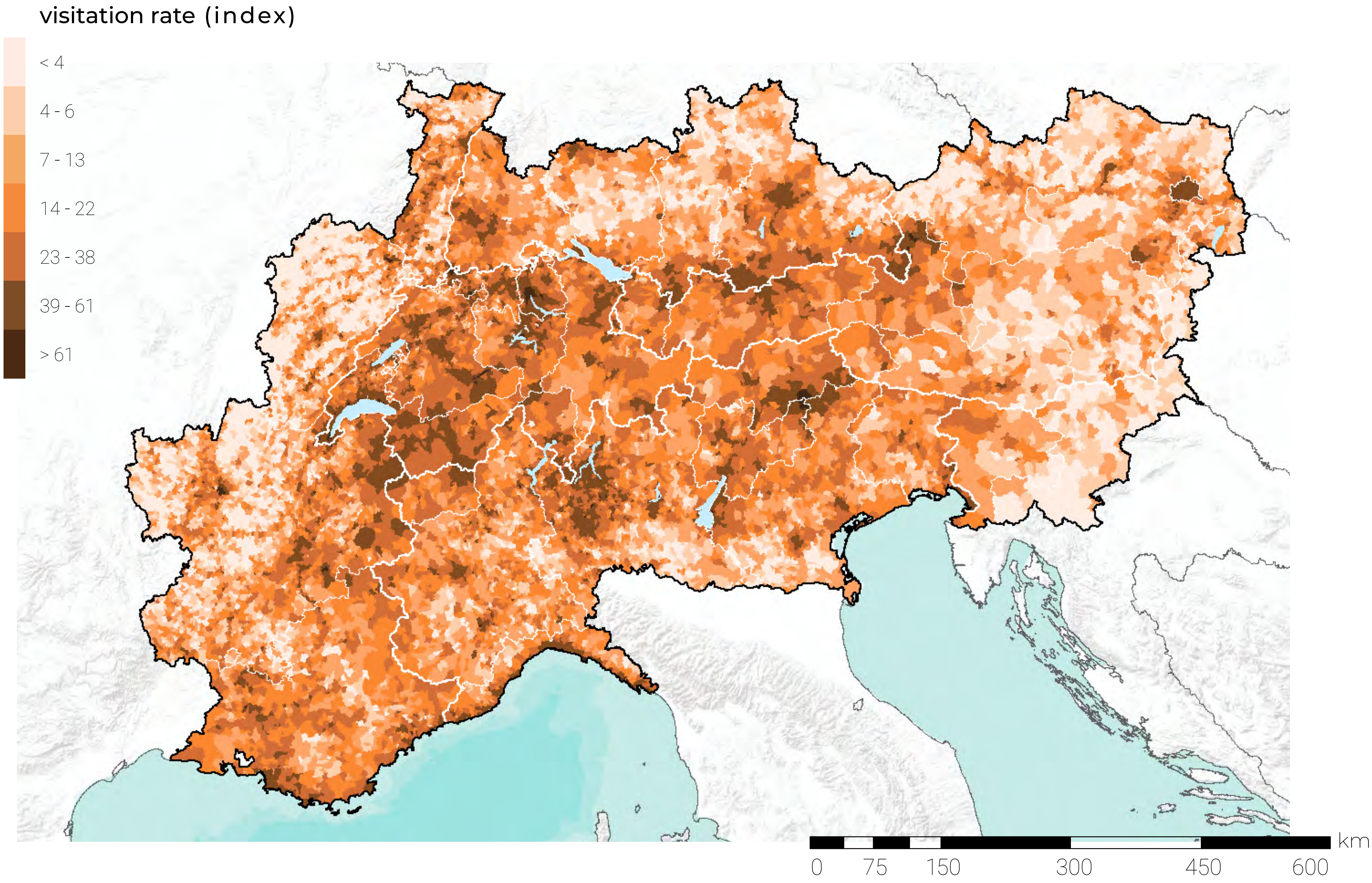
This indicator is a measure of the naturalness and diversity of the landscape, which add to its recreation potential, and of the accessibility of such outdoor recreational spots. Low values of supply are often related to a strong anthropogenic impact on the territory.

The map shows a heterogeneous spatial distribution of the outdoor recreational areas; nevertheless, the mountains score medium to high values in their entire range. High supply rates are apparent in renowned mountain areas like, Styria (AT), the ski-town of Garmisch (DE) and the Dolomites (IT). Lakes are also very attractive in terms of recreation activities; this is particularly evident in the case of lake Garda (the largest lake in Italy and a popular holiday destination) and its surrounding municipalities.

The accurate assessment of cultural ES remains challenging because they are strongly interconnected, depend on human perceptions and preferences, and are not directly linked to measurable ecosystem processes (Schirpke et al., 2017).

FLOW

outdoor recreation activities



Description

The flow indicator for the ES "Outdoor recreation activities" estimates the visitation rates of outdoor recreationists in a municipality, relying on metadata linked to photographs uploaded on social media.

Definition

Visitation rate (index)

CICES section

Cultural ecosystem service

CICES division

Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]

COMMENT

The flow indicator for "Outdoor recreation activities" aims to give an idea of the utilization of the recreational opportunities offered by the ecosystem, i.e. how frequently these spots are visited by residents and tourists. The visitation rates have been estimated on the basis of metadata linked to the photo-sharing social media platform Flickr, where location, time and date of the shared picture are saved.

The map highlights hotspots that are popular for outdoor recreation activities: (1) the municipalities located on the seaside, like those along the Ligurian Riviera, or near lakes, such as the communes around Lac Léman, Lake Garda, or Chiemsee; (2) emblematic mountain locations, like the Dolomites, Chamonix-Mont Blanc, and famous ski areas such as Garmisch and Huez. High values are also observable in cities - particularly in big metropolitan ones like Zurich, Munich and Vienna, which form a cluster of "urban recreational areas". This is due to high population numbers and tourist visitation rates, which account for a proportionally large number of photos shared on social media, for example in green areas and parks, despite the relatively low naturalness of the environment.

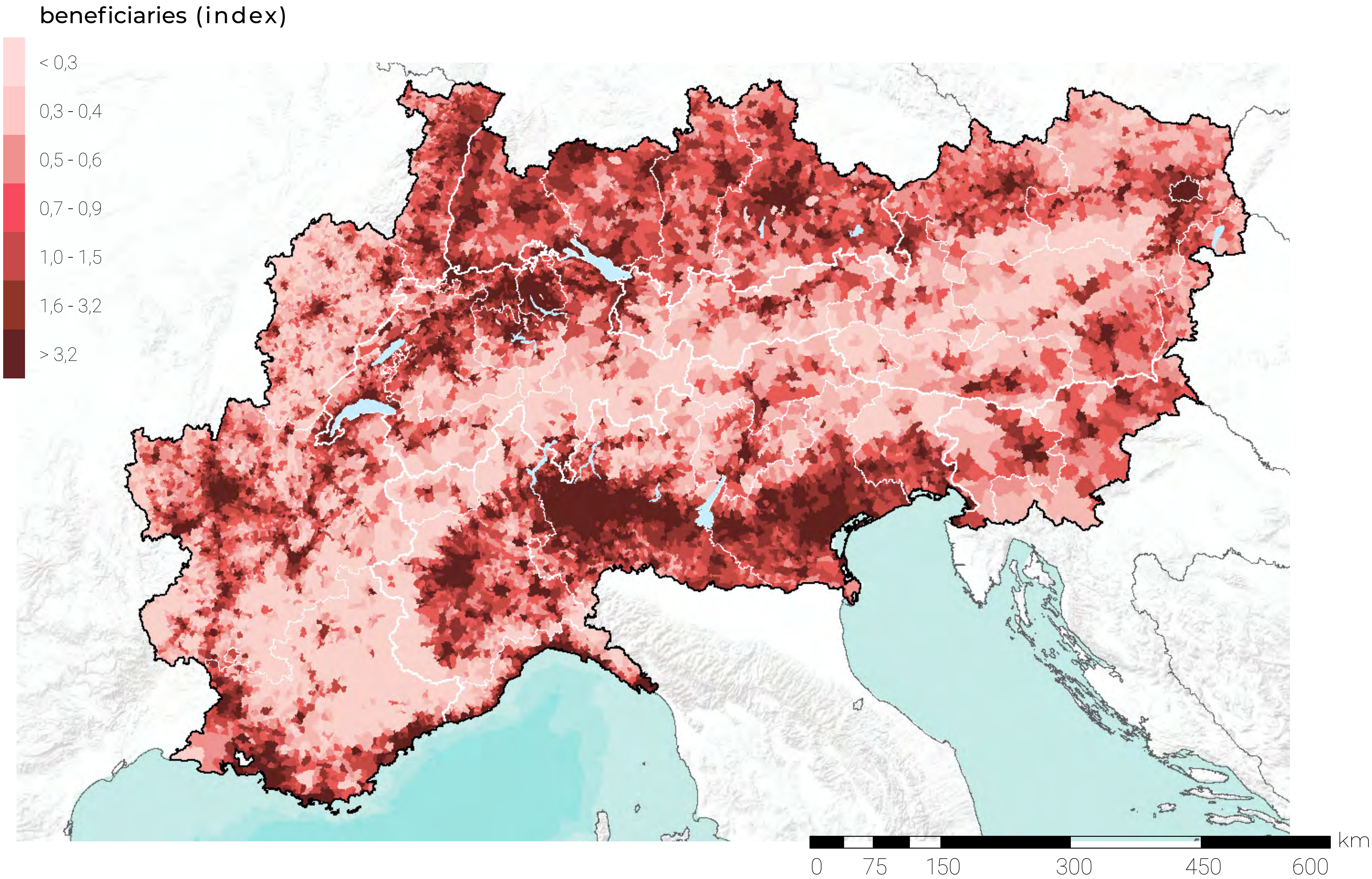
Elevated visitation rates can be beneficial for the local economy, boosting the tourism industry. But they may also have negative effects for the environment, like increased pollution levels, human disturbance to animal species, infrastructure development (e.g. ski resorts and mountain huts), and more.

DID YOU KNOW ?

In Langnau am Albis, Switzerland, a "forest kindergarten" lets children spend most of their time in the woods, where they learn to start fires, build dens and explore the outdoors. The program is thought to foster self-confidence and an independent spirit, and has been featured in a dedicated short film. The concept of forest kindergartens originated in Scandinavia in the 1950s, and is spreading throughout Europe, also becoming popular in the Alpine Space, where nature offers plentiful outdoor activities. The spread of these schools demonstrates their success and the powerful ways in which nature can teach us and improve our well-being. Outdoor recreation can offer so much to our societies, and it is important to account these benefits as accurately as possible.

DEMAND

outdoor recreation activities



Description

The demand indicator for the ES "Outdoor recreation activities" estimates the demand for outdoor recreational opportunities as an index that is proportional to the number of potential beneficiaries, i.e. residents and tourists.

Definition

Beneficiaries (index)

CICES section

Cultural ecosystem service

CICES division

Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]

COMMENT

The demand for nature-based outdoor recreation opportunities is directly proportional to the size of local populations and visiting tourists. Therefore, the demand indicator calculates the mean population density of each municipality, including both permanent residents and visitors.

The indicator's highest values correspond to the cities, whereas the lowest values are in the remote and sparsely populated mountainous areas of the Alpine range. However, there are some exceptions: high visitation rates in certain zones of the eastern Alps and in the northern municipalities of France account for a relatively high value of the indicator, despite small resident numbers. On the other hand, the lowest demand rates are found in the southwestern Alps, at the border between France and Italy, and in southern Switzerland.

Figure 3.10 lists the European regions with the most overnight stays in accommodation establishments in rural areas. Alpine regions like Tirol, the Rhône-Alpes, the Autonomous Province of Bolzano/Bozen, and Veneto rank among the most visited rural locations for holidays: proof that the Alps are a very attractive holiday destination both in the summer- and wintertime. The growing popularity of winter sports and of "white weeks", i.e. winter holidays on the snow, has contributed to a significant rise in visitation rates of the Alpine region. It is unclear what will happen to this trend as the effects of climate change reduce snow-cover and season length in many areas of the Alps.

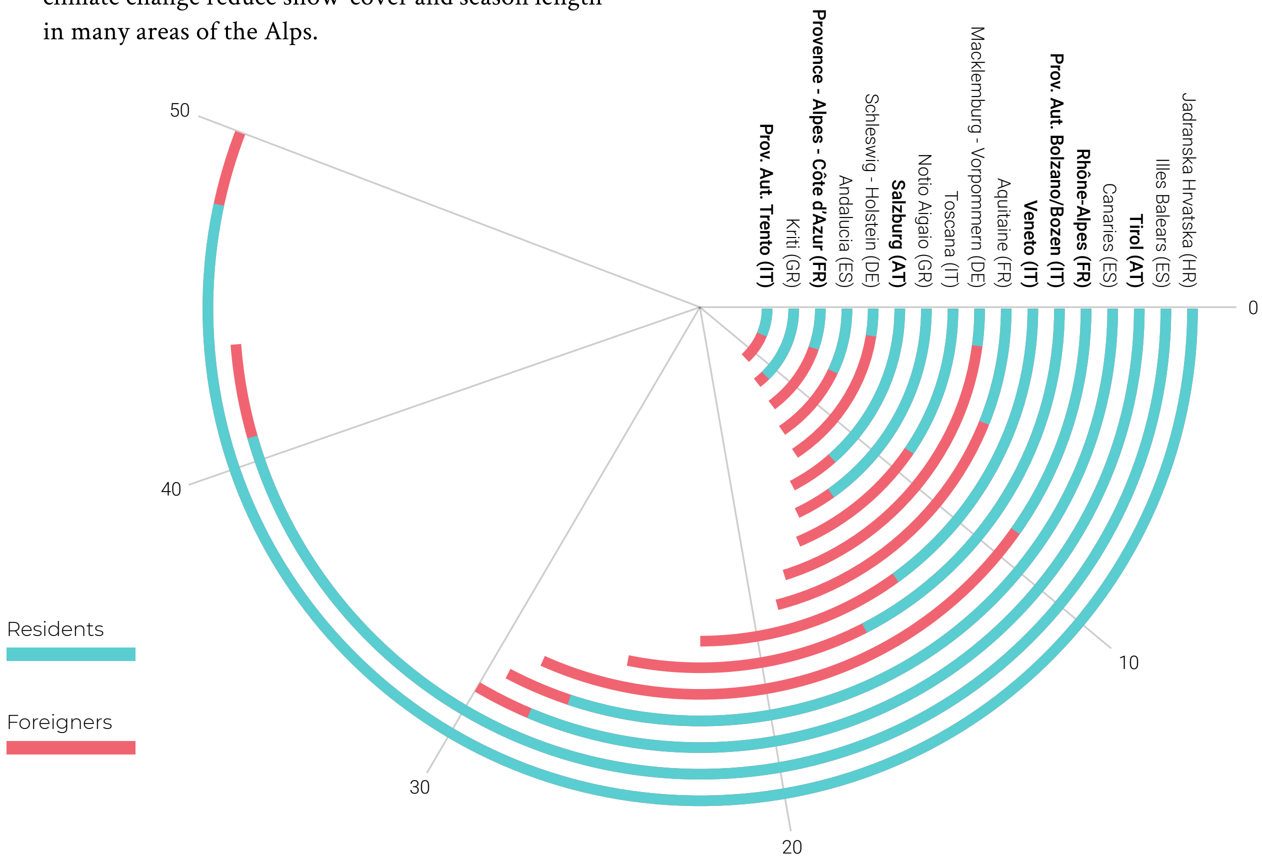


Figure 3.10 Number of nights (in millions) spent in tourist accommodation establishments in rural areas in the top 17 EU-28 tourist regions, by NUTS 2 regions, in 2016. Adapted from Eurostat.

3.8 Symbolic alpine plants, animals and landscapes

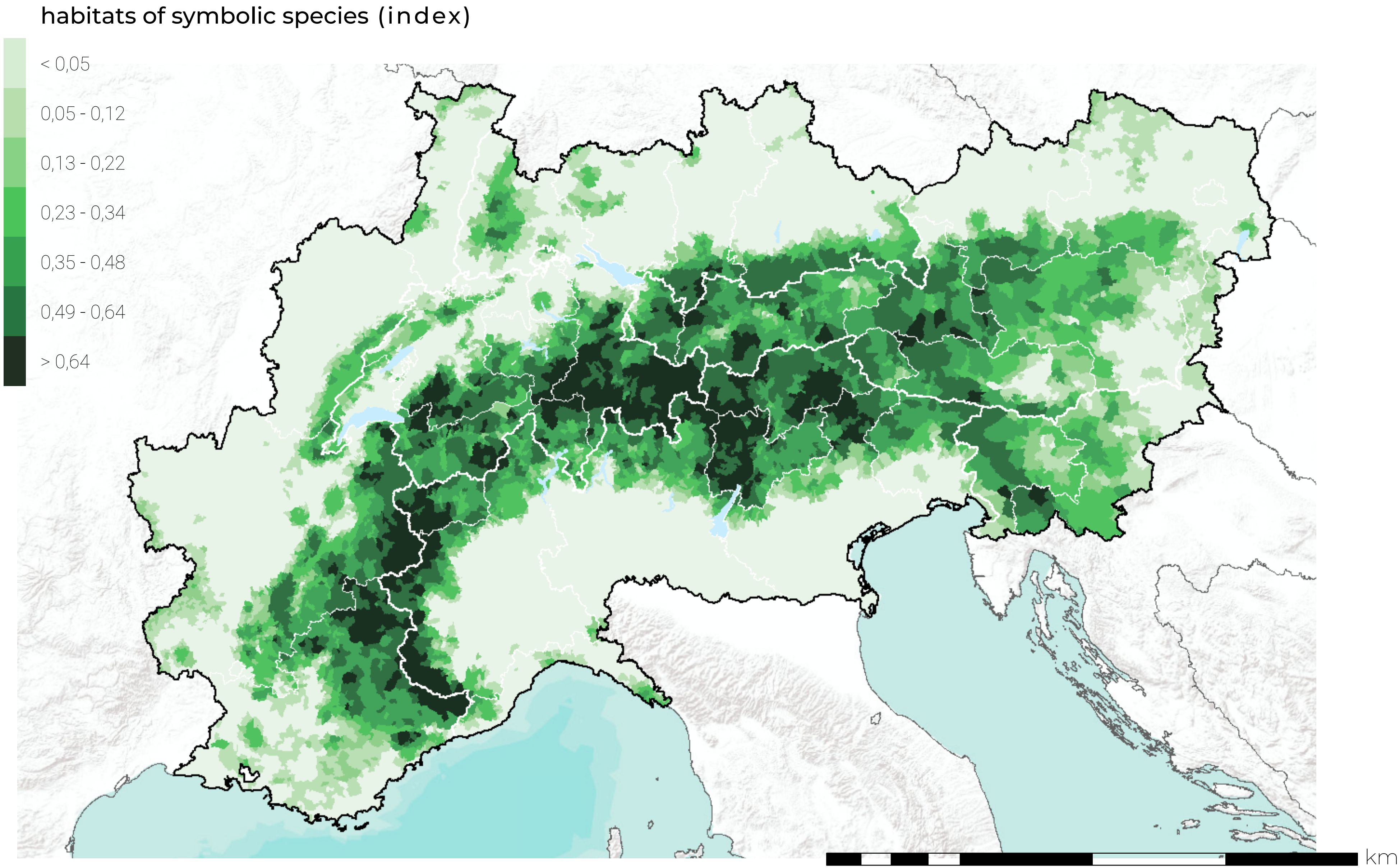
The Alps are one of the richest biodiversity hotspots in Europe and are home to many endemic plant and animal species. These species have become intertwined with the many cultures that have developed here; they have symbolic meaning to people who call the Alps home. A well-known example is the edelweiss, a beautiful, diminutive white flower found high in rocky mountain environs. The edelweiss has been a symbol for different alpine militaries, represented intrepidness in the mountains, and even been a part of many songs from the region. Many other species have symbolic meaning in the Alps, including ibex, chamois, golden eagle, alpenrose, larch, and more.

Calculating the impacts of ecosystem services with such non-material benefits as symbolic plants, animals and landscapes is no easy task. The intangible nature of symbols, especially their value, use, and extent, render traditional spatial analysis methods exceedingly difficult. This set of indicators thus develops novel methodologies to assess this service. Supply of this service is evaluated by examining the geographic ranges of the selected culturally important plant and animal species. By tracking the use of these species in hotel names per municipality, the flow of this service is mapped. Given the personal, qualitative nature of symbols and their importance, no demand indicator has been mapped for this ecosystem service, although a qualitative evaluation of the population's demand has been carried out through an online questionnaire.

Appraising the value of these symbols proves to be challenging, but is vital in a deeper understanding of the benefits we draw from the environment around us. This is especially true as land-use and climate changes threaten many of the species that are most important to the cultures found in the Alpine Space.

SUPPLY

symbolic alpine plants, animals and landscapes



Description

This indicator estimates the range of selected species that have a symbolic value in the Alpine Space, such as emblematic animals and plants.

Definition

Habitats of symbolic species (index)

CICES section

Cultural ecosystem service

CICES division

Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]

COMMENT

The Alps are one of the richest biodiversity hotspots in Europe and are home to many endemic plant and animal species. Many of these species are so characteristic of the Alps that they have become a symbol of Alpine culture and traditions. This indicator is based on the geographic range of 10 Alpine species, polled by the AlpES partners, to estimate an index of symbolic species richness. The selected animal species include ungulates like the Alpine ibex and the chamois; charismatic predators, such as brown bear and golden eagle; and one of the most abundant mountain rodents, the marmot. The plant species comprise symbolic flowers like edelweiss, alpenrose and gentian, and conifers like the European larch and several pine species.

All these species are essential components of the Alpine landscape. Nonetheless, many of them are now threatened, and some have almost completely vanished from the Alpine Space. The brown bear, for example, has been extirpated from most of its historic range, which covered the entire Alps. Today, the only extant breeding populations are in Slovenia and in the province of Trentino, Italy, where a reintroduction program saved the local population from extinction. Alpine ibexes had also been eradicated from the Alps in the early 19th century, except for the population in Gran Paradiso National Park. Since then, reintroduction programs

National Park. Since then, reintroduction programs have repopulated the Alpine peaks with these elusive creatures. Plant species too have been subject to serious and continuous threats: flowers like the edelweiss and the gentian were all too frequently collected in the wild for ornamental or medicinal purposes. Now, legislation in many Alpine countries prohibits the picking of such species in the wild (IUCN, n.d.).

Most of these species live at high altitudes, as the resulting map shows. The central and southwestern Alps are the richest in symbolic Alpine species. High values of this indicator relate to a higher species richness and diversity of the ecosystem, which are important features of a healthy ecosystem.

DID YOU KNOW ?

Symbolic species have been widely used in traditional medicine. For example, the edelweiss was used in the past for its astringent and antimicrobial properties, whereas the oil obtained from marmot fat is the principal ingredient of marmot ointment, a natural remedy against joint inflammation and rheumatism.

FLOW

symbolic alpine plants, animals and landscapes

Description	Definition	CICES section	CICES division
The flow indicator for the ES "Symbolic Alpine plants and animals, landscapes" represents the number of hotels holding symbolic species in their names per municipality.	Occurrence in hotel names (nr. of hotels)	Cultural ecosystem service	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]

COMMENT

Iconic animal and plant species are not only important components of the Alpine ecosystem; they have become part of the cultural heritage of local communities. They appear on traditional dresses, on logos of Alpine associations and in the coat of arms of municipalities. The edelweiss is even represented on the backside of the Austrian two-cent Euro coin. These examples reflect how deeply rooted these species are in Alpine identities. Symbolic species are also well represented in the names of hotels, guesthouses, restaurants and the like. The flow indicator evaluates this specific usage of the symbolic value of Alpine species. For its calculation, we searched the official registries and used automatic routines to scrape online databases (e.g. booking sites) to find all tourist accommodation facilities which had symbolic Alpine plants or animals in their names.

However, as the data pool was too scarce to create a pan-Alpine map, this indicator was mapped on an exemplary basis for the Alpine regions of Tyrol and South Tyrol (Fig. 3.11). When looking at this map, it becomes clear that the habit of naming hotels after symbolic species is particularly common for many of tourism-prone municipalities in the central Alps. Here, mountain huts are scattered along the network of hiking trails, providing refreshment and shelter to the visitors.

Valley bottom municipalities have fewer such hotels, and hotels with symbolic species in their name occur only sporadically outside the main mountain range.

In general, it seems that the representation of symbolic Alpine species is not so strongly correlated

to their actual presence in the area, but rather that it is used to reaffirm the sense of belonging to a specific region or cultural identity, even in places where such species are not present. Indeed, in many cases the symbolic value of an animal or plant can persist in case of extinction (Schirpke et al., 2018).In general, it seems that the representation of symbolic Alpine species is not so strongly correlated to their actual presence in the area, but rather that it is used to reaffirm the sense of belonging to a specific country or cultural identity, even in places where such species are not present. Indeed, in many cases the symbolic value of an animal or plant can persist in case of extinction (Schirpke et al., 2018).

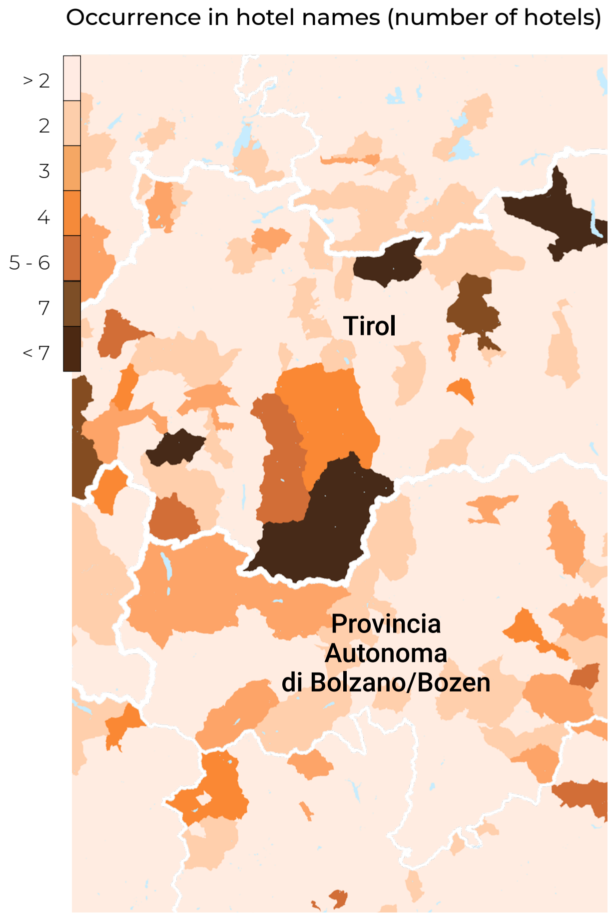


Figure 3.11 Number of hotels holding symbolic species in their names in the central Alpine regions of Tyrol and South Tyrol.

DEMAND

symbolic alpine plants, animals and landscapes

Description

A questionnaire is used to assess symbolic and emblematic use of Alpine plants, animals and landscapes by society. This includes its characteristics (e.g. preferences for certain species or species types), its different fields of application (tourism, emblems, etc.), and the linkages between the occurrence of entities in nature and their symbolic use.

Definition

Symbolic and emblematic species and landscapes desired by society

CICES section

Cultural ecosystem service

CICES division

Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]

COMMENT

The importance and value of symbolic Alpine animals, plants and landscapes are highly subjective and therefore not easy to assess. Their demand and use are often detached from their occurrence in natural systems and do not necessarily require their presence in the environmental setting. For these reasons, spatially mapping the demand was not appropriate for this ES. However, the characteristics of demand for symbolic Alpine entities were assessed through a multilingual questionnaire. This online survey about perception and preferences for symbolic entities had more than 500 respondents in all project partners' countries. Participants were asked which animals, plants and landscapes they consider to be symbolic for the Alpine Space, which landscape elements have the strongest symbolic character, and in which context they are used (e.g. outdoor activities, cultural ecosystem services [CES]). Answers are analysed and discussed considering the personal context of respondents, such as residence, birthplace, as well as personal, cultural and socio-demographic characteristics. The results of the questionnaire are still in processing, but will likely be published by Seppi et al. and Rüdisser, Schirpke, Rampl & Tappeiner (in preparation). Despite the different format of measurement and the absence of an indicator map, these findings will be useful for a comparison between the distributions of the ES demand with its supply and flow.

4

Conclusions

As a global society, we are beginning to understand just how much we rely on the natural systems around us. Perhaps one of the best ways to expand this understanding and integrate it into our decision-making is the ecosystem services concept. This concept is widely accepted and has gained momentum in the past decades, as proven by its inclusion in important European directives and programs, such as the Biodiversity Strategy to 2020, the MAES initiative and the TEEB studies (The Economics of Ecosystems and Biodiversity). Mapping ES indicators aids decision-makers in understanding trends in complex ecological processes and can provide them with policy performance metrics. Their use is now more important than ever. Indeed, we are experiencing societal, economic, environmental and climatic changes at a markedly fast pace. ES indicators are useful tools to interpret these changes and act proactively to manage their consequences. This is especially relevant in areas like the Alpine Space, which can be more severely impacted by such changes.

The results of the AlpES "Mapping and Assessment" work package offer a comprehensive overview of the state of some of the ES from which Alpine Space communities benefit. The maps provide detailed information to estimate the resources and potential of the Alps and the human pressure to which they are subject. In general, our results show that Alpine ecosystems are capable of supplying a number of services at a level that meets the local demand without needing to draw upon external sources. However, high tourism flow, agricultural land exploitation and bourgeoning populations in many cities of the Alpine Space are putting strain on the natural capital of the Alps and their surrounding regions. Mapping and assessing ES can also serve to shed light on services and benefits that are currently unused or overlooked, which could open up new opportunities to managers and policy-makers.

Many finer-scale insights are also available to those managers who explore the AlpES results in the WebGIS. For example, natural resource managers in Hallstatt might examine the difference between flow and demand for protection forests and invest in relatively cheap protection forest mitigation solutions based upon this information. International carbon strategists could evaluate the differences in the Flow & Supply and Demand indicators for CO2 Sequestration, and incorporate this information in the development of regional or international plans for carbon neutrality. The information presented in this report is only the beginning; we have barely begun to scratch the surface of the tangible policy and management outcomes this resource can inform.

Future opportunities in this field include the modelling of projected changes and trends in the state of ES; scientifically sound forecasts of the state of ES would be a major boon to managers. Furthermore, as much research has thus far focussed on single ES supplied by an ecosystem, future studies should aim to investigate how different ES are interconnected. For decision-making and management purposes, it is critically important to analyse the relationships between all ES, i.e. their trade-offs and synergies (OpenNESS).

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A dedicated glossary of terms and concepts relative to Ecosystem Services is available in the Glossary page of WIKIAlps.

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