JRC TECHNICAL REPORTS

Ecosystem services accounting

Part I Outdoor recreation and crop pollination

KIP INCA Report *- contribution to the* ***K****nowledge and* ***I****nnovation* ***P****roject on an* ***I****ntegrated system of* ***N****atural* ***C****apital and ecosystem services* ***A****ccounting in the EU*

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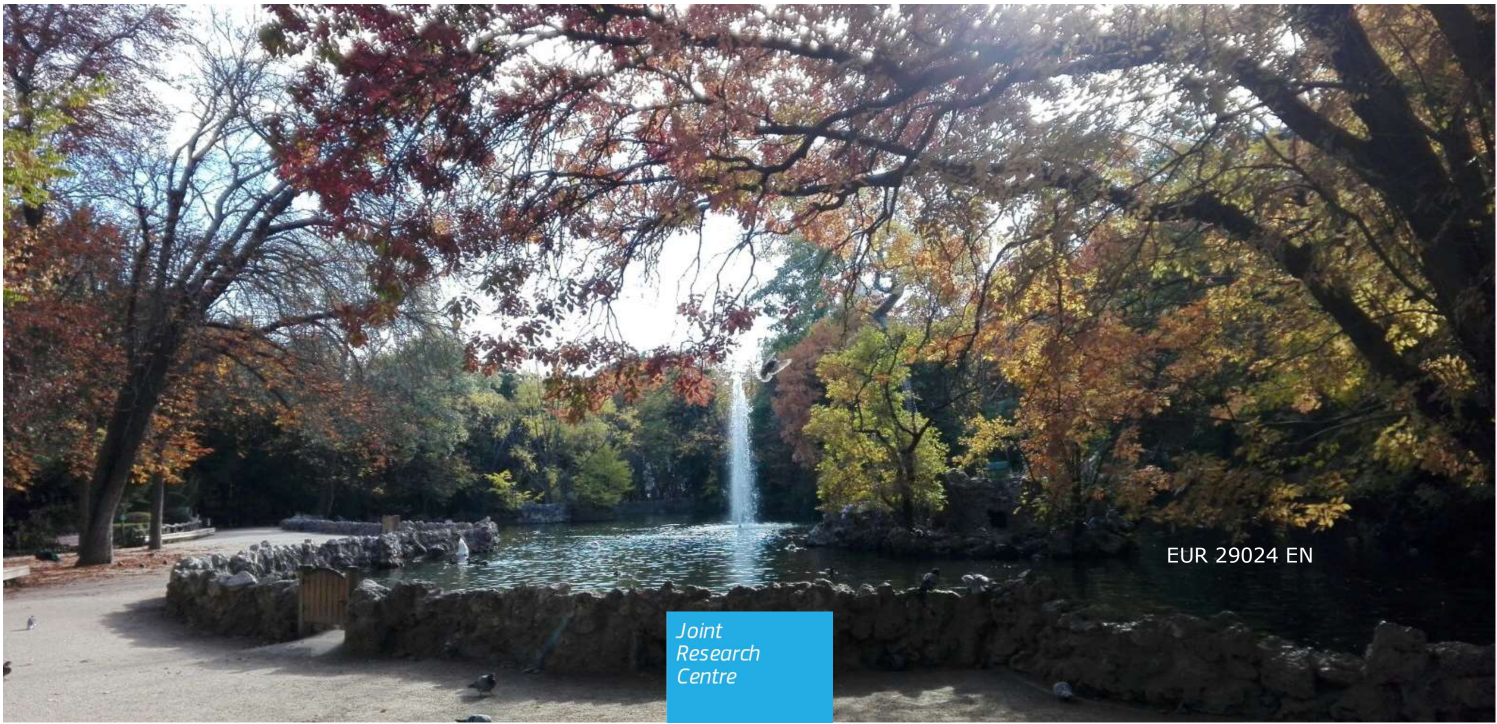

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Abstract

The Knowledge Innovation Project on an Integrated system of Natural Capital and ecosystem services Accounting (KIP INCA) aims to develop a set of experimental accounts at the EU level, following the United Nations System of Environmental-Economic Accounting- Experimental Ecosystem Accounts (SEEA-EEA). The application of the SEEA-EEA framework is useful to illustrate ecosystem accounts with clear examples, to further develop the methodology outlined in the Technical Recommendations, and to give guidance for Natural Capital Accounting.

This report assesses and accounts for two ecosystem services: outdoor recreation (on a daily basis) and crop pollination. Each service is assessed biophysically using the ESTIMAP toolbox, allowing us to quantify different service components: the service potential that ecosystems can deliver; the demand for each service; and the actual flow of the service, which is used by people based on the spatial relationship between the service potential and the demand. The results of the biophysical assessment are then translated into monetary units using valuation methods consistent with the System of National Accounts. Valuation methods require the integration of the key variables of the biophysical model to quantify the actual service flow. This way, changes in the value of the service are strictly linked to changes in biophysical assessment, which includes potential, demand and their spatial relationship determining the actual flow.

Accounting of outdoor recreation focuses on locations offering high opportunities for outdoor recreation that are close to urban areas and roads, being therefore, suitable for a daily use. Outdoor recreation accounts show that at the EU level, forest ecosystems have the highest contribution to the outdoor recreation flow, although this varies across countries. Households are the users of the service, with Germany being the country with the largest share of population whose demand for daily recreation is sufficiently covered. Countries with a larger share of population living within 4 km of the areas for daily recreation considered for the accounting present a higher level of satisfaction with recreational and green spaces. The accounts show an overall increase in the use of the service between 2000 and 2012 (26%), mainly due to the enhancement of the recreation potential, and, to a lesser extent, to an increase in the demand (population). These results are useful to support policy decisions related to land planning, aiming at guaranteeing equitable access to outdoor recreation opportunities (citizen rights): 38% of the population at the EU has limited access to recreational areas (unmet demand). We estimated for 2012 an actual flow of 40 million potential visits to recreational areas per year, with a conservative total annual value of 50 billion euro.

Crop pollination accounts in 2006 show that 13 million tonne of food production in the EU is derived from crop pollination, which represents 15% of the total yield of pollinator-dependent crops. The value of crop pollination as ecosystem service is 3 billion euro. Fresh fruits show the largest value of the actual flow (2.1 billion euro in 2006). There is an overall increase in the actual flow of the service, mainly due to the increase in pollinator-dependent

crops. Crop pollination assessment and accounts provides useful results to support prioritization of Green Infrastructure deployment and, importantly, the EU Pollinators Initiative.

The work presented in this report highlights the importance of the spatial relationship between ecosystem service potential and demand. The changes in the use of the service cannot be explained solely by changes in the potential and demand, but also by their spatial relationship. When dealing with ecosystem services the spatial component is a key driver that needs to be integrated within the accounting framework for a consistent assessment. The spatial relationship between potential and demand is different for each service. Crop pollination requires the spatial overlap between potential and demand, whereas proximity is the key spatial feature for outdoor recreation.

As shown by the two examples, ecosystem service accounts significantly differ depending on the service being assessed, both conceptually and methodologically. Hence, further examples of ecosystem service accounting are needed to produce accounting tables for a representative number of service. Ultimately, the availability of this information represents a key input for the analysis of synergies and trade-offs between ecosystem services.

1 Introduction

The 7th Environment Action Programme and the EU Biodiversity Strategy to 2020 include objectives to develop natural capital accounting in the EU, with a focus on ecosystems and their services. More concretely, the Action 5 of the EU Biodiversity Strategy to 2020 requires Member States, with the assistance of the European Commission, to map and assess the state of ecosystems and their services. They must also assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020.

Ecosystem services (ES) are the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). ES as flows are understood as a measure of the amount of ES that are actually mobilized (used) in a specific area and time: actual flow (Maes et al., 2013). Ecosystem services accounts focus on the actual flow of the service, considered as a 'transaction' from the ecosystem to the socio-economic system.

Different components of ES play a role in the use of the service. All these components are fundamental to understand changes in the actual flow of the service (Figure 1.1). The amount of service that ecosystems provide (i.e. ES potential) is usually assessed based on the ecosystem properties and conditions that are recognised to be relevant to the service considered (Figure 1.1); this assessment is often referred to as 'biophysical assessment'. For instance, quality of the water bodies is an important determinant of outdoor recreation potential, but not of pollination potential. Therefore, the assessment of all these components, and their inter-connection, is essential to quantify the actual flow of the service (i.e. use) and its integration into an accounting system.

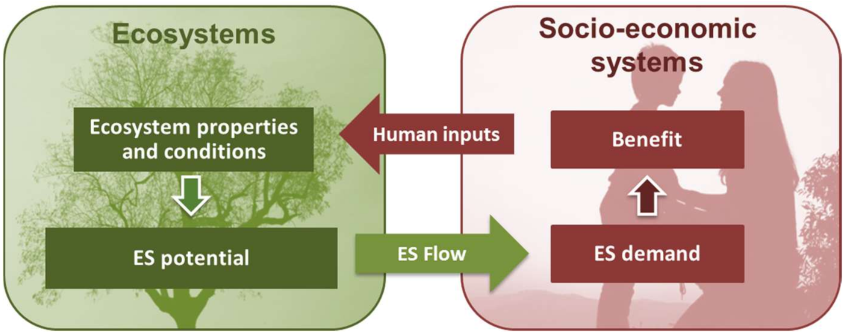

Figure 1.1. Mapping aspects of ecosystem services (modified from Syrbe et al. 2017)

An ES flow is a fraction of this potential steered by the demand for the service. This fraction can also be higher than the potential, if the service is overused. Socio-economic agents (such as economic sectors and households) demand ecosystem services to obtain the benefit they generate within the socio-economic system. It is important to stress that service flow is only generated if these three conditions are met:

1. There is an ecosystem potential to generate service (in the service providing areas);
2. There is demand for it (by the socio-economic system);
3. There is spatial connection between the demand and the service providing areas.

Consequently, an ES flow connects ecosystems to socio-economic systems to ultimately generate benefits. However, human inputs derived from socio-economic systems also act on ecosystems by modifying their properties and conditions (Figure 1.1). Some of these human inputs are land use and land cover changes, pressures on the environment, but also land management and protection measures. All of them act on the ecosystems modifying the ES potential and affecting, therefore the actual flow of the service.

In this context, ecosystem services accounting proves a very useful tool to assess the role of ecosystems and socio-economics systems determining the ES flow, to assess changes arising from the interaction of the different components in Figure 1.1, and to assess the importance of the service in monetary terms (see also Box 1). The accounting tool provides the advantage of clearly presenting the service flow as ecosystem potential on the one hand, and the service demand on the other hand. Ecosystem potential and demand generate together the actual flow of the service. This procedure is undertaken by employing the mechanism and rules of the System of National Accounts (SNA) and this approach allows the integration with traditional economic accounts to undertake environmental-economic assessments and analyses.

Once the ecosystem service is assessed in biophysical terms, the accounting workflow continues with the translation of the output in monetary units, by choosing the appropriate valuation technique. To ensure consistency, the valuation method is applied to the final output of the biophysical assessment, but it also integrates some of the key variables used for the service mapping (model).

Box 1. What does ecosystem services accounting show us?

- The contribution of different ecosystem types to the actual flow of the service,
- The socio-economic agents (economic sectors and households) that use and/or benefit from the service,
- The value of the service used: in biophysical and monetary terms,
- Changes over time in the actual flow of the services,
- Complementary information to give policy support in terms of ecosystems management and sustainability

The main outputs of accounting are the supply and use tables. While the supply table shows the contribution of each ecosystem type to the actual flow, the use table reports who is using and benefiting from the service (see section 2 for further details).

This report presents one of the first EU wide ecosystem services accounts. It is the first release of a series of reports presenting ecosystem service accounts service by service. This report introduces first the general JRC approach adopted for the accounting of ecosystem services (section 2); it then summarises the state-of-the-art for the accounting of outdoor recreation, a cultural service, and for crop pollination as an example of a regulating service. The outdoor recreation and crop pollination accounts are presented in section 3 and 4, respectively, covering the biophysical assessment and the changes over time, a description of the valuation method, the accounting tables and, ultimately, the model limitations and the potential applications of ecosystem service accounts. The last section presents the main conclusions derived from this work.

2 JRC proposal for the accounting approach

The framework several actors are currently experimenting with is the System of integrated Environmental and Economic Accounting – Experimental Ecosystem Accounts (SEEA-EEA). This framework, and in particular the supply and use tables, are explained in a previous JRC report (La Notte et al., 2017), including a discussion about the limitations of this framework and potential issues to be addressed in future updates of the framework.

The approach currently experimented at the JRC starts by considering individual flows of ecosystem services. This ecosystem services based approach is not contradicting an asset-based approach because they both feed the same (external satellite) accounting framework. We briefly describe how the ecosystem services approach fits within the ecosystem asset perspective.

The main task is to build supply and use tables for ecosystem services, first in biophysical and, then, in monetary terms. Through the supply table it is possible to track from which ecosystem assets each of the services does flow; through the use table it is possible to track to which economic sectors and/or households each of the services does flow (Figure 2.1[1]).

In building the supply table, the flow of each ecosystem service is allocated to the specific ecosystem asset it comes from. The allocation itself depends on the technique employed for the biophysical assessment. For instance, in the case of crop-pollination the ecosystem assets mainly belong to croplands, in the case of outdoor recreation the ecosystem assets are almost all (with few exception). Once a fair number of ecosystem services is calculated and translated in a common monetary unit, it is possible to sum those flows and estimate the value of each ecosystem type (Figure 2.2).

Ideally, whether practitioners start from ecosystem assets and assess the services, or whether they start from each service and allocate ex post the flow to the ecosystem assets, the outcome should not change: the internal consistency is explained through by the frame presented in Figure 2.2.

[1] In grey are the cell where no flow is possible.

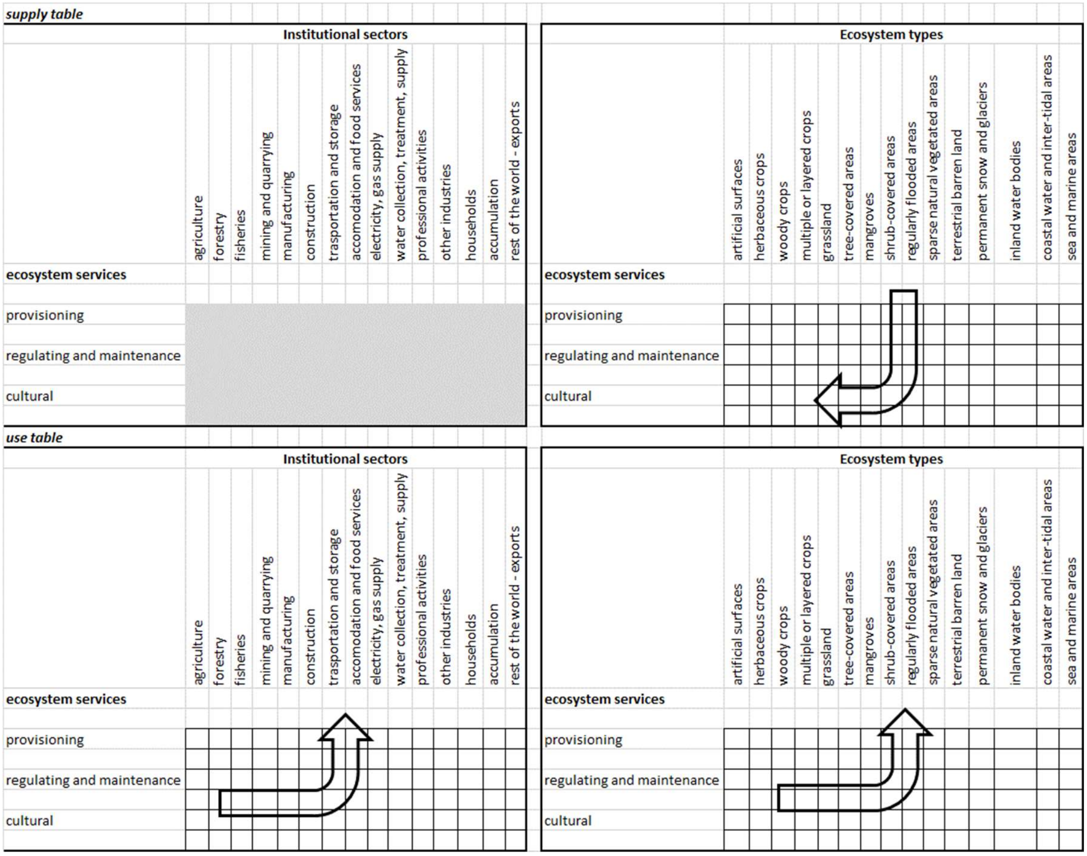

Figure 2.1. General presentation of supply and use tables

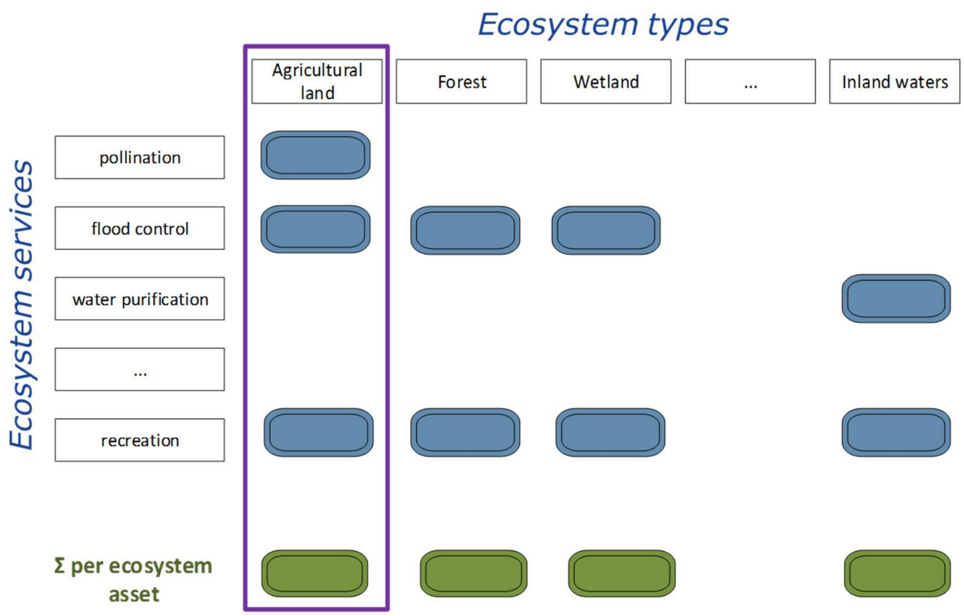

Figure 2.2. The relationship between ecosystem services and ecosystem types

3 Nature-based outdoor recreation

3.1 Assessment of outdoor recreation

Outdoor recreation is a cultural ecosystem service that includes all physical and intellectual interactions with biota, ecosystems, land-/seascapes. For the purpose of this report, outdoor recreation comprises the biophysical characteristics or qualities of ecosystems that are viewed, observed, experienced or enjoyed in a passive, or active, way by people on a daily basis. Currently, KIP INCA has developed a short-distance recreation account, which estimates the value of ecosystems with a high recreation potential for daily use recreation.

Why outdoor recreation on a daily basis?

ACCOUNTING FOR OUTDOOR RECREATION ON A DAILY BASIS MAY CONTRIBUTE TO GIVE POLICY SUPPORT TO GUARANTEE EQUITABLE ACCESS TO GREEN AND RECREATIONAL AREAS. OFFERING CITIZENS THE POSSIBILITY TO RECREATE IN NEARBY URBAN AND RURAL GREEN SPACE REQUIRES AN AVAILABLE AND DENSE, WELL-CONNECTED AND HIGH QUALITY AREAS, MANAGED AT MUNICIPAL OR REGIONAL LEVEL.

It includes a wide variety of practices ranging from walking, jogging or running in the closest green urban area or at the river/lake/sea shore, bike riding in nature after work, picnicking, observing flora and fauna, enjoying the surrounding beauty of the landscape, among a myriad of other possibilities. The benefit society gets from this service is the enhancement of the human well-being, as demonstrated in a number of studies (Bowler et al., 2010).

Ideally, the use of the service could be assessed by quantifying the number of people that for a daily recreation uses 'green' areas. Given the lack of data at the EU level on outdoor recreational use, the ecosystem service has been modelled using an adapted version of the outdoor recreation model implemented in the ESTIMAP toolbox (Paracchini et al., 2014; Zulian et al., 2017). Technical details are presented in Appendix I.

As highlighted in the introduction, the actual flow, required to fill in the accounting tables, is driven by different components of the service: service potential, service demand, and the spatial relationship between them (Figure 3.1). Therefore, to model the actual flow, it is necessary to assess first the recreation potential and demand.

The outdoor recreation potential quantifies what ecosystems offer in terms of recreation opportunities. Areas with higher recreation opportunities are more attractive to people and have, therefore, higher potential to be used. However, the use of the service is, in the last instance, determined by the demand, which in this case is population. Our estimates have individual as observational unit and thus as users of the service, getting as benefit the enhancement of their well-being.

The actual flow of outdoor recreation for a daily use depends, therefore, on the proximity of recreational areas to people. In this sense, we first assess the spatial distribution of the demand (i.e. people) based on different buffer distances from areas for daily recreation. Since not all people actively recreate outdoor on a daily basis, we applied a function to derive the number of potential visits, called mobility function (see technical details in Appendix I).

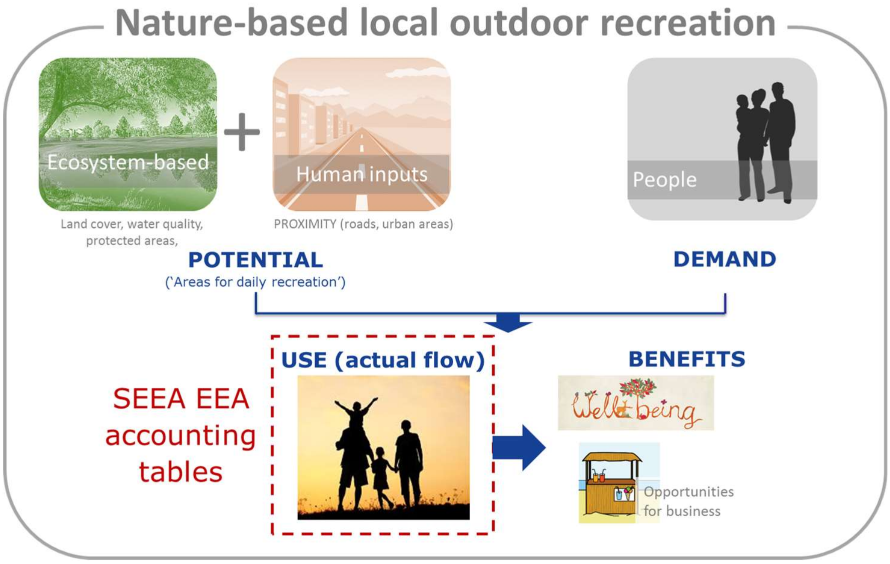

Figure 3.1. Scheme of the components required for the accounting of outdoor recreation

Since accounting aims to report changes over time, we tried to cover a representative time series. We took as reference years 2000, 2006 and 2012, matching the years in which ecosystem extent accounts, based on the CORINE Land Cover map, are available (EEA report). The years assessed for each component of outdoor recreation depends on data availability (Table 3.1). Recreation potential was assessed for all three years. However, the actual flow of outdoor recreation can only be estimated for 2000 and 2012, given that spatially resolved population data, derived from census, are not available for 2006.

Table 3.1. Components of outdoor recreation and overview of the temporal availability

Outdoor recreation		Years assessed		
Potential	Extent of service providing areas: 'areas for daily recreation' (high opportunities for recreation and close to urban areas and roads, ha)	2000	2006	2012
Demand	Population (inhabitants)	2000	NA	2015
Actual flow	Potential visits to the 'areas for daily recreation' (number of visits)	2000	NA	2012

Appendix II presents a factsheet for outdoor recreation summarizing the main components of the service accounts.

3.1.1 Outdoor recreation potential

Outdoor recreation potential is assessed based on the contribution of ecosystems to offer recreation opportunities (ecosystem-based potential) but also on other human inputs (Figure 3.1). The ecosystem-based potential depends on the ecosystem properties and conditions at ecosystem level. It includes a suitability score to support recreation for each land cover type (i.e. zero/very low for artificial areas, close to one for semi-natural areas), quality and distance to water bodies and the presence of protected areas. However, the ecosystem-based potential is largely supplemented by human inputs such as roads and residential areas. Recreational areas close to infrastructure have higher potential for outdoor recreation. This spatial component related to built infrastructure is especially important for the assessment of outdoor recreation on a daily basis (see Appendix I for further technical details).

The ESTIMAP recreation model gives as main output the recreation opportunities spectrum, which represents a whole range of recreation opportunities categorized as a function of the level of provision of recreation opportunities and the distance to roads and residential areas (Figure 3.2). There is a widespread distribution of areas with low and medium recreation opportunities near or proximal to human settlements. Areas with the highest recreation opportunities are mainly in mountain areas and close or within natural protected areas.

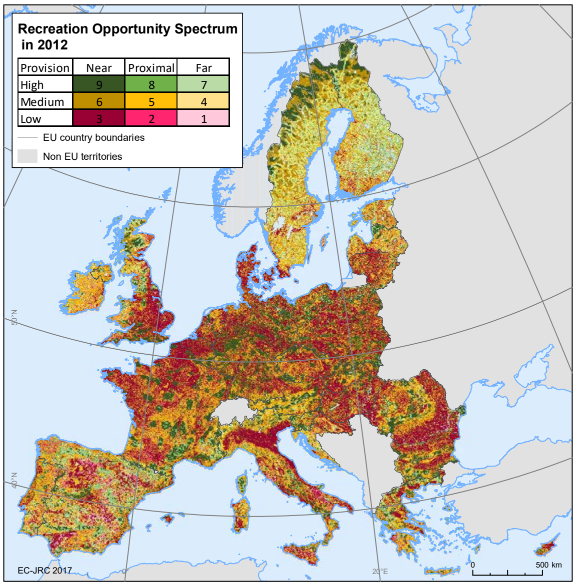

Figure 3.2. Recreation opportunities spectrum in 2012

The accounting of outdoor recreation on a daily basis requires the quantification of the service in physical units to be able to derive the service flow (actual use of the service). With this goal, we focused the accounting of outdoor recreation in those locations with high quality for recreation, with high recreation opportunities close to urban areas and roads, and suitable, therefore for a daily use. It corresponds to category 9 in Figure 3.2. We refer to this category as '**areas for daily recreation**' and they are considered in this application as the Service Providing Area (SPA). In this context, the ecosystem service potential in this accounting exercise is quantified as the extent of 'areas for daily recreation'.

The share of 'areas for daily recreation' per Local Administrative Unit (LAU) is depicted in Figure 3.3. Countries like Slovenia and Germany show the highest share values, while Ireland and Croatia present the lowest recreation potential for a daily use in relative terms.

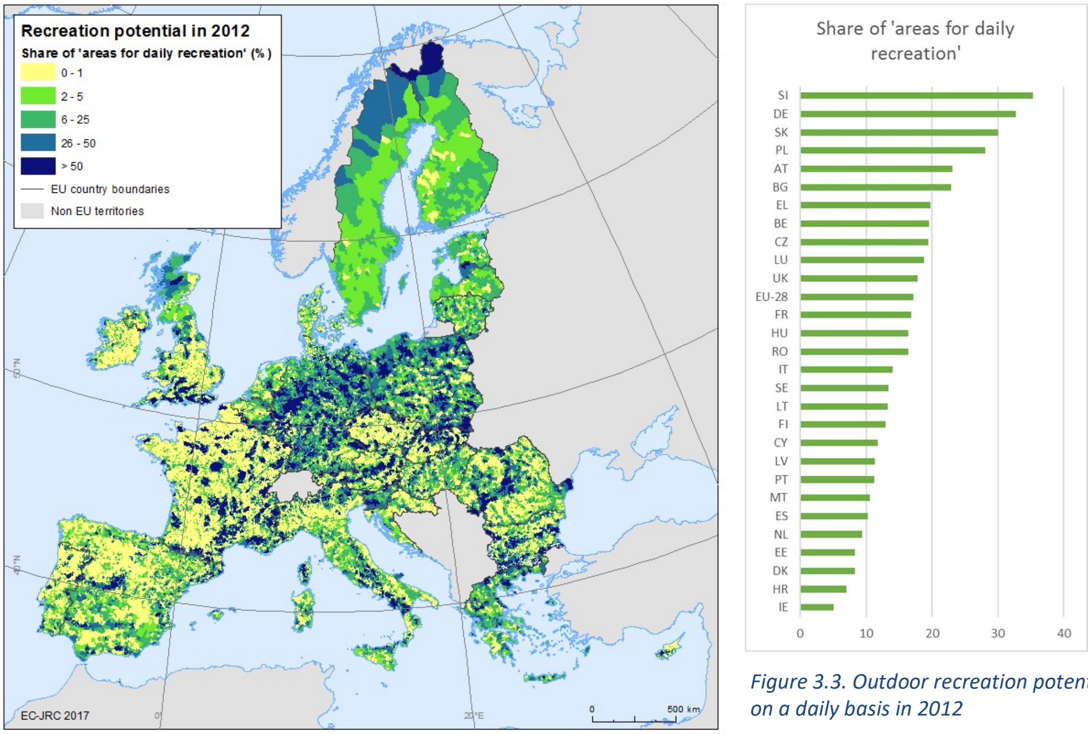

Figure 3.3. Outdoor recreation potential on a daily basis in 2012

3.1.2 Demand for outdoor recreation

Households are considered as user of the service; therefore, to quantify the demand for outdoor recreation we used the population data from the Global Human Settlement (GHS) model (European Commission-Joint Research Centre (JRC) et al., 2015). For comparative purposes, we estimated the population density at LAU region as the ratio between the total population and the area of the region (persons per square kilometre). Regions in central Europe, but also capital cities of each country show the largest demand for outdoor recreation because of the high population density of those areas (Figure 3.4). The presence of areas with high recreation opportunities for daily use in those regions would contribute to the well-being of more population, increasing therefore the benefit generated by the service.

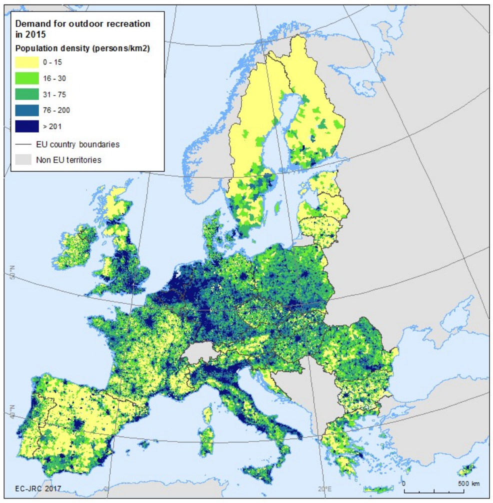

Figure 3.4. Demand for outdoor recreation in 2015

3.1.2.1 Spatial analysis of outdoor recreation demand

Before calculating the actual flow of the service, it is necessary to assess first the spatial relationship between the SPA (i.e. 'areas for daily recreation') and the demand (i.e. people) steering the service flow. This will allow us to distinguish the share of population with their need for outdoor recreation on a daily basis covered ('met demand') from the share for which the accessibility to 'areas for daily recreation' is not guaranteed ('unmet demand').

Hereto, we quantified the number of inhabitants living at different distances from the 'areas for daily recreation' (see Appendix I for further technical details). The applied distance buffers are:

1. Within 1 km: considered as a regular walking distance. People living in these areas can easily reach the recreation area by a short walk,
2. 3 distance buffers (from 1-2 km, from 2-3 km and from 3-4 km): at these distances recreational areas may be reached by long walks or by using a recreational / standard bicycle,
3. Beyond 4 km: we took an intermediate value between the average cycling journey of 3 and the 5 km threshold beyond which bicycles are generally not used, according to research in the United Kingdom (Hugh & Catherine, 2013). We considered people living beyond this distance as an unmet demand, since they may need to take a car to reach the 'recreational area for a daily use' or might use recreational areas with lower opportunities or quality for outdoor recreation, generating therefore a lower benefit.

In 2015, 62% of the population in the EU live within 4 km from 'areas for daily recreation'. This share is considered as the 'met demand', since they may satisfy their need for recreational areas in a relatively easy way: by foot or by bike[2]. From this share, about 29 million people live within a walking distance (i.e. within 1 km) from 'areas for daily recreation', while a total of 255 million inhabitants need a long walk or a bicycle to reach them (between 1 and 4 km) as shown in Figure 3.5.

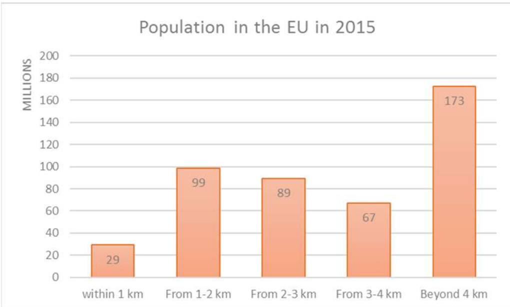

Figure 3.5. Inhabitants at different distance buffers from recreational areas

In contrast, 173 million inhabitants (38% of the total population of the EU-28) live more than 4 km from recreational areas. This share is considered as an 'unmet demand' and follows an uneven distribution across the EU (Figure 3.6). Countries like Romania and

[2] For consistency with the SNA, in the monetary estimate we used as proxy the cost of short car journeys.

Bulgaria show a large share of unmet demand across the whole territory. Both, Figure 3.5 and Figure 3.6 show an unequitable access to recreational areas.

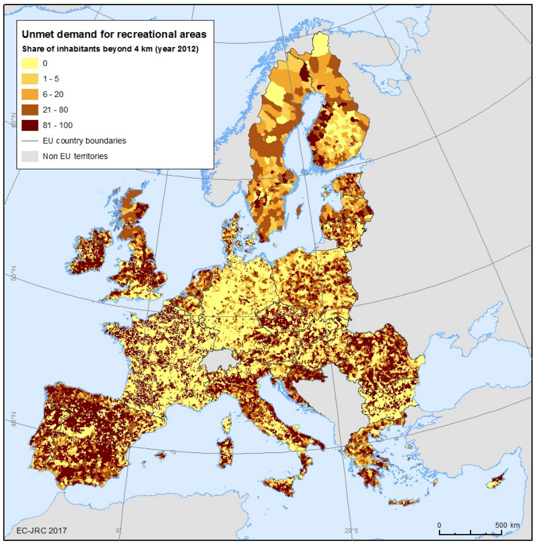

Figure 3.6. Map of unmet demand for outdoor recreation on a daily basis

Policy application

ANALYSIS OF THE SPATIAL DISTRIBUTION OF POPULATION IN RELATION TO THE RECREATIONAL AREAS FOR A DAILY USE MAY GIVE SUPPORT TO THE PLANNING OF MEASURES TO GUARANTEE THE EQUITABLE ACCESS TO OUTDOOR RECREATION OPPORTUNITIES (CITIZEN RIGHT)

For the assessment of the actual flow of outdoor recreation for a daily use, only the share of population considered as 'met demand' is accounted for.

3.1.3 Actual flow of outdoor recreation: the use

The assessment of the actual flow requires an intermediate step determined by the valuation technique that will be used. Our valuation application is based on travel cost technique that relies on the number of visits. We thus need to move from the number of inhabitants considered as the 'met demand' to the number of potential visits that inhabitants will do depending on the distance to the 'areas for daily recreation'.

The number of potential visits is calculated through a mobility function calibrated on a recent survey undertaken in the UK: the Monitor of Engagement with the Natural Environment (MENE) survey, funded by Natural England, with support from Defra and the Forestry Commission. Appendix I describes in detail how the mobility function calculation took place. From the outcomes obtained, we can report that on average in the EU, 28% of people living within 1 km from the 'areas for daily recreation' visit them. Moving away from the natural attraction will strongly decrease this rate of visits to 14% (Figure 3.7). In other words, there is a loss of half visitors when distance to 'areas for daily recreation' is about 1-4 km.

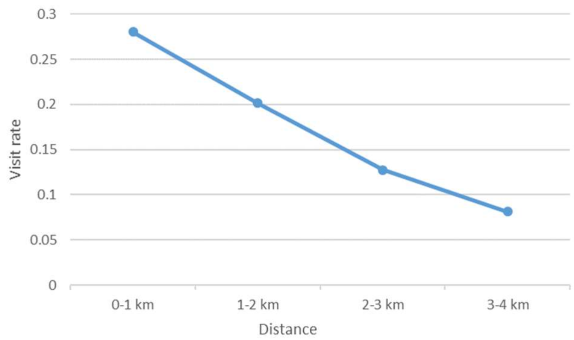

Figure 3.7. Rate of visits in relation to the population at different distances from the 'areas for daily recreation' (Average at the EU level)

For policy makers willing to guarantee the provision of this service to their citizens this is important information: areas for daily recreation should be where people live: out-of-reach involves a drop in daily usage. Recreation as daily service provided to citizens only represents the lower boundary of the total potential users, who might come from longer distances. However, this specific feature of outdoor recreation is meant to measure how the possibility to enjoy natural amenities lies in the daily activities of citizens just as other daily activities do (e.g. work, school, and shopping).

Once we assess the number of potential visits through the mobility function, we can map the actual flow per year in physical terms at LAU level. Figure 3.8 represents the actual flow in relative terms to the extent of the local administrative unit.

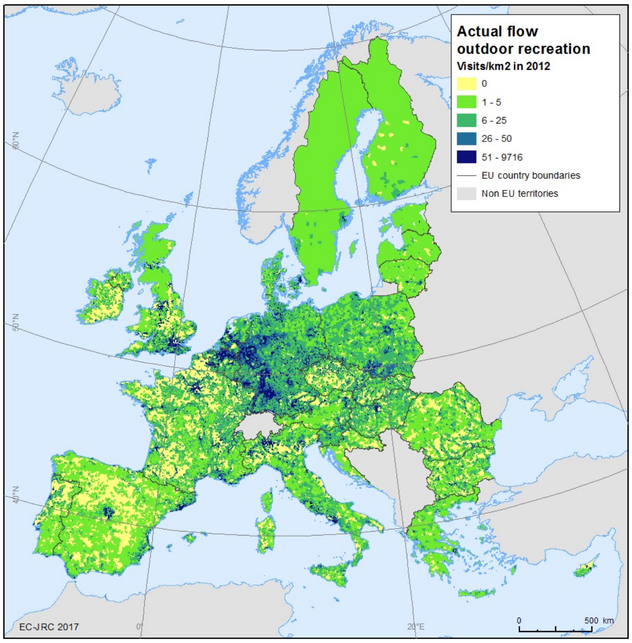

Figure 3.8. Map of the actual flow of outdoor recreation in 2012

Comparison of the actual flow of outdoor recreation in 2012 at country level clearly shows that countries with the highest population have the largest actual flow, as measured by the potential number of visits in 2012 (Figure 3.9, A). Therefore, for a more meaningful comparison of the actual flow across countries, the actual flow needs to be expressed in relative terms. Figure 3.9, B shows the rate of potential visits per inhabitants, with

Denmark and Luxembourg as the countries with the highest rate of visits per capita. This can be explained by the low share of population considered as 'unmet demand', with 22% in Denmark and 10% in Luxembourg. However, it is also to a higher share of the population living very close (less than 2 km) from 'areas for daily recreation', where the rate of visits is higher, as shown in Figure 3.7.

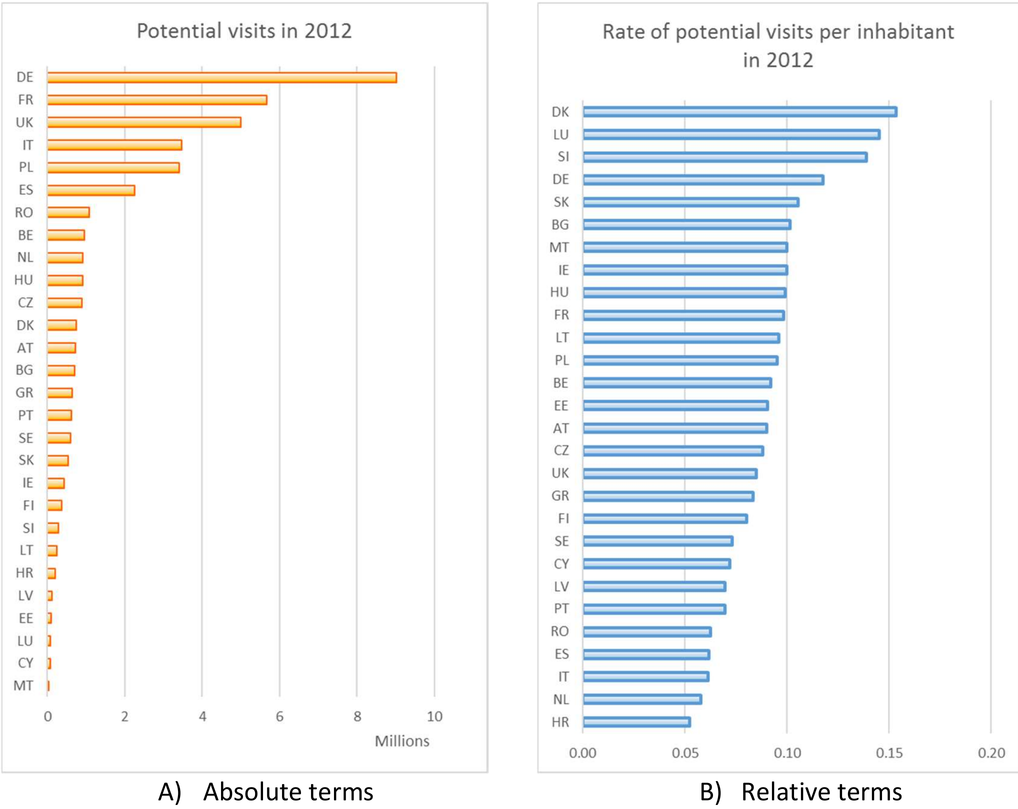

Figure 3.9. Actual flow of outdoor recreation at country level in 2012

Relationship between the recreation potential and the demand

When dealing with ecosystem services the relationship between the service potential and the demand is not always straightforward. At country level, higher ecosystem service potential and higher demand does not necessarily imply a higher actual flow of the service. As illustrated before, there is also a large share of the population considered as 'unmet demand', which is not accounted for the assessment of the actual flow. For ecosystem services, the spatial component linking the service potential and the demand is a key factor to be considered. In this context, the comparison between the recreation potential and the demand across countries is useful to understand the role of the spatial component, in this case the proximity between the areas for daily recreation and the population.

Figure 3.10 shows the relative importance of the service potential (share of areas for daily recreation) and the demand (population density) at country level. This allows us to make comparisons across countries. For instance, Finland and Sweden show a very high recreation potential that, ideally, should completely satisfy the demand for outdoor recreation given the low population density in these countries. However, these countries show higher unmet demand than countries with a lower relative recreation potential like Germany, Slovenia and Luxembourg. This is due to the role of the spatial component. In Finland and Sweden, there are many recreational areas to be used on a daily basis, however around 30% of the population lives more than 4 km away from these areas requiring therefore the use of a car to reach areas for daily recreation or, alternatively, visit areas with lower recreation opportunities. On the other hand, countries like Germany and Luxembourg have not as much recreation potential when compared to the demand, but they are located very close to the places where people live, showing only about 10% of the total population living further than 4 km from areas for daily recreation, being therefore considered as the unmet demand. In these countries, the important role of the demand, when compared to the recreation potential in relative terms may suggest that there could be situations of congestion of 'areas for daily recreation' that should be considered in future assessments.

Figure 3.10 also shows that Malta, followed by the Netherlands, has the lowest relative recreation potential when compared to the relative importance of the demand for recreation. In these countries, the enhancement of 'areas for daily recreation' would contribute to satisfy the demand, and improve the well-being.

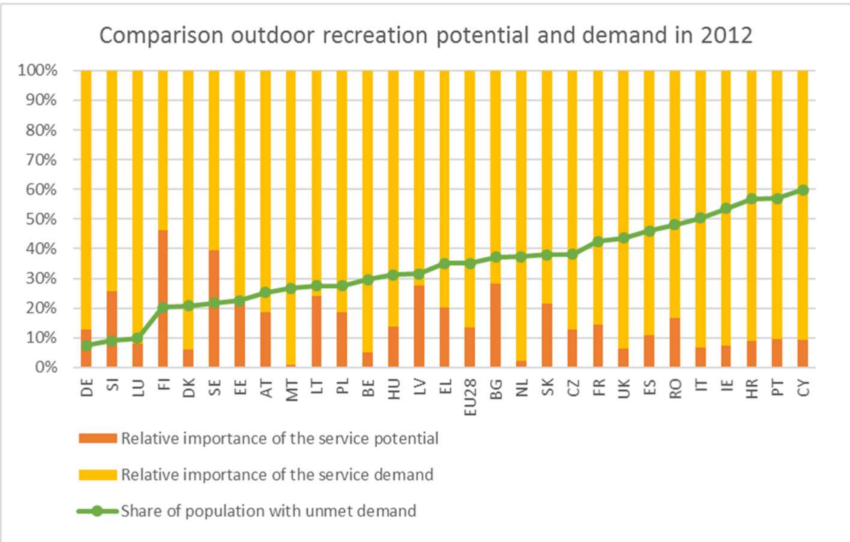

Figure 3.10. Relative importance of the recreation potential and demand compared to the unmet demand at country level

3.1.4 Towards a benefit assessment of outdoor recreation

One of the socio-economic benefits of outdoor recreation most frequently acknowledged in the literature is contribution and enhancement to the human well-being (Bowler et al., 2010). However, so far, we have not properly assessed the benefit for the outdoor recreation account here.

The only EU wide data available related to well-being is the indicator of life satisfaction at country level for 2013. This indicator includes, among other domains, the satisfaction with recreational and green areas (GREENSAT, Eurostat [ilc_pw05]). GREENSAT indicates the percentage of the population rating their satisfaction with recreational and green areas as high, medium or low. Figure 3.11 shows a significant positive correlation of 0.60 (n=28; R^2=0.36; $p<0.05$) between the share of population considered as 'met demand'[3] and the share of the population with high rating of satisfaction with recreational and green areas. This demonstrates that countries with higher recreation potential within 4 km from residential areas, as assessed in this report, have higher satisfaction with recreational and green areas as measured by the statistical indicator relevant to the personal well-being. Measurements to reduce the unmet demand (population living beyond 4 km from recreational areas) may significantly contribute to increase the level of satisfaction in relation to recreational and green areas.

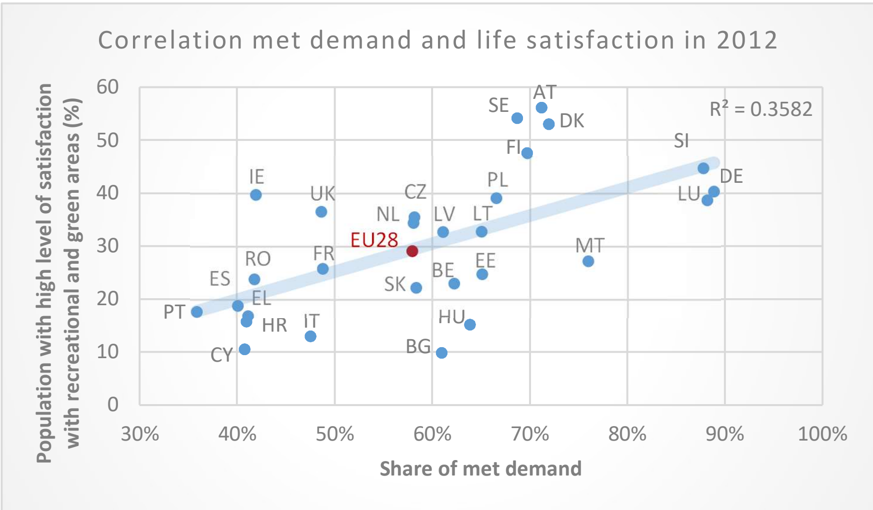

Figure 3.11. Correlation between the share of met demand and the share of the population with a high level of satisfaction with green and recreational areas

The comparison of the outdoor recreation assessment with external and completely independent indicators may be interpreted as an ex-post validation of the assumptions made in the assessment, such as those taken for the delineation of 'areas for daily recreation' or the distances considered to distinguish between the met and unmet demand.

However, it is important to take into account that for a more accurate assessment of the benefits derived from outdoor recreation, congestion of recreational areas should be to some extent considered. Areas with a very high density of visits may have a lower contribution to the well-being.

[3] Inhabitants within a distance of 4 km, easily reaching 'recreational areas for daily use'

3.1.5 EU trends of outdoor recreation

Analysis of trends at the EU level can only be done for countries that were member states of the EU in 2000[4] (EU-15). Unfortunately, for the rest of the countries there are not enough accurate data on protected areas to make sound comparisons of outdoor recreation potential.

Between 2000 and 2012, all countries show a significant increase of the **recreation potential**, as shown by the increase in the share of 'areas for daily recreation' (Figure 3.12). At the EU-15, recreation potential increased by 23%, with Belgium as the country with the most significant improvement of the recreation potential between 2000 and 2012, mainly because of the designation of new Natura 2000 sites. After this increase, in 2012 Belgium becomes the third country with the largest share of 'areas for daily recreation' after Germany and Austria.

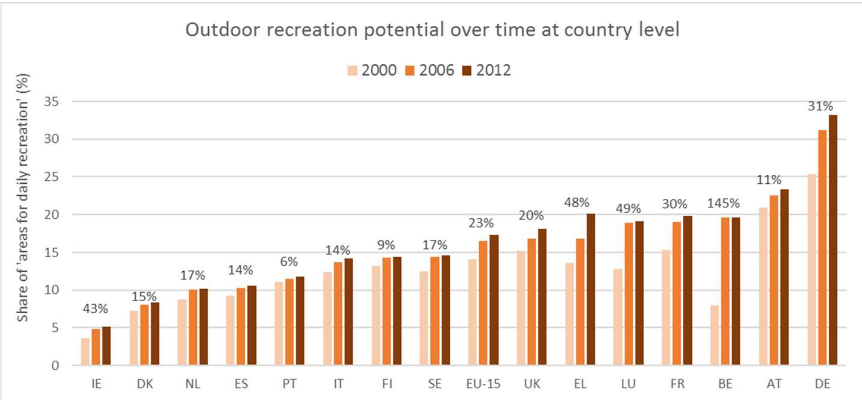

Figure 3.12. Areas for daily recreation over time at country level
(Values on the top of bars indicate the percentage increase between 2000 and 2012)

Although the designation of new Natura 2000 sites does not necessarily imply an improvement of the physical suitability of the ecosystems supporting recreation, it usually involves the improvement of recreation services and facilities, such as walking path and informative signs about the designated areas with high natural value, contributing therefore to increase the recreation potential.

Other important driver of changes in the outdoor recreation potential is land cover. In this sense, ecosystem extent accounts developed at country level would provide the necessary data to make an accurate interpretation of the role of land cover changes on the increase of ecosystem service potential undergone in all countries. According to the model used to assess outdoor recreation, an increase in forest and semi-natural areas would increase the service potential. In some cases, urban sprawl may also have a key role if recreation hot spots become closer to the residential areas.

[4] AT, BE, DE, DK, ES, FI, FR, GR, IE, IT, LU, NL, PT, SE, UK

In the EU-15, the **demand for recreation** as measured by the population density has increased about 6% between 2000 and 2012. Countries like Luxembourg and Ireland show the largest increase in population density over the period of 12 years, while Germany shows a reduction of about 1% (Figure 3.13).

For all countries in the EU-15, the increase of the recreation potential was significantly larger than the increase of the demand, improving the situation to potentially satisfy the demand for recreation.

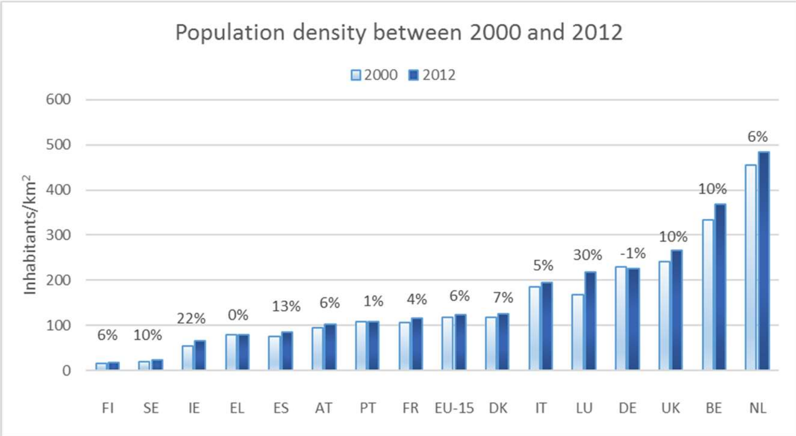

Figure 3.13. Population density between 2000 and 2012
(Percentages indicate the increase)

The **actual flow of outdoor recreation** has increased in the EU-15 with around 26%. Belgium and Ireland are the countries showing the largest increase in the actual flow of the service (Figure 3.14). However, while in Belgium the main driver of change in the use of the service was due to an expansion of recreational areas, in Ireland this expansion was not as important. Instead, the increase in the actual flow is also driven by higher demand.

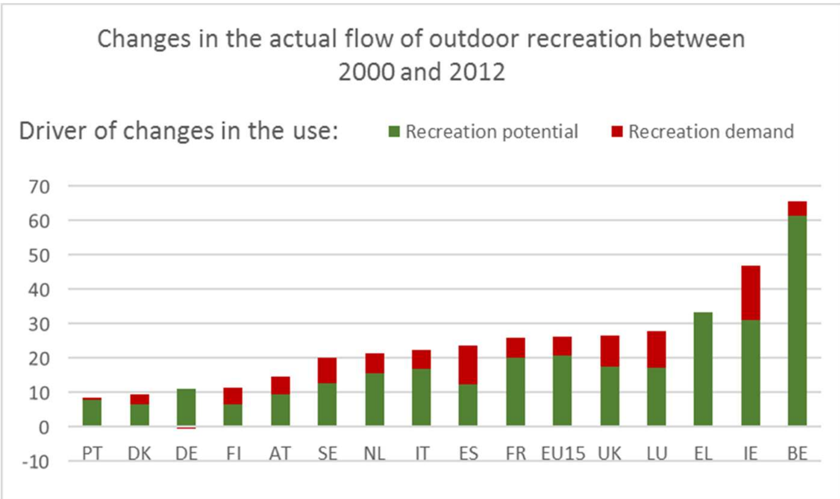

Figure 3.14. Changes in the actual flow of outdoor recreation 2000-2012

3.2 Monetary valuation of outdoor recreation

The actual flow assessed in biophysical terms as the potential visits to the 'areas for daily recreation' is then valued in monetary terms. It is important to remark here, that the actual flow of outdoor recreation only considers the share of population that lives within 4 km from 'areas for daily recreation'. Citizens do not need to use motor transport to enjoy nature-based recreation if they live in a place providing high recreation opportunities for a daily basis. There may be visits from people living further away: this still is part of recreation as a whole but overlaps with tourism and needs to be treated separately (see section 3.4 for further discussion). This distinction is needed in order to avoid confusion between local outdoor recreation (and its implication) and tourism, whose users will not only be households but also the tourism sector.

The valuation technique applied belongs to the family of 'revealed preference techniques'. The technique is the Travel Cost Method (TCM) and it is considered a 'revealed preference technique' because consumers' preferences are disclosed by consumers' purchasing habits. For TCM consumers' purchasing habits are estimated based on the number of trips that they make at different travel costs. This technique is applied by using the cost of fuel[5] in order to be consistent with the transaction price approach that characterise the SNA of which ecosystem services are external satellite accounts. In the future, it might be useful to think about a methodology that includes the cost of time rather than the cost of fuel.

The development of the TCM dates back to 1959 (Clawson M., 1959) and experienced a wide range of applications since then (further references in: https://www.es-partnership.org/services/data-knowledge-sharing/ecosystem-service-valuation-database/). This technique belongs to the revealed preference techniques because it infers the values placed by users on amenity/recreational services from the costs they afford for enjoying these services.

Two approaches of TCM can be applied: individual and zonal. Individual TCM requires a very detailed survey of visitors since it calculates travel costs for each category of individuals. To apply zonal TCM it is necessary to divide the area surrounding the 'areas for daily recreation', and then to count the number of visits from each zone. In our application, we are going to apply the zonal travel cost.

The methodological steps that describe TCM can be exemplified as follows:

- Stratification of relevant zones: this set-up has been undertaken when identifying inhabitants at different buffer distances;
- Assessment of potential visits from each zone: this process takes place when applying the mobility function;
- Calculation of visitation rate: intermediate step where the number of potential visits is divided by the number of inhabitants for each zone;

[5] For this application we consider an average cost for all Europe, kept constant for the two reported years

- Multiplication of the average travel cost per trip for each zone: in our application, we consider the cost of fuel as reported by the UK Automobile Association and validated for the rest of Europe by the European Road Information Centre;
- Finalization of a 'Trip Generation Function', which constitutes a model of the use for the analysed site: a regression is undertaken against travel costs from each zone.

The outcomes of the monetary valuation are currently expressed in absolute terms and include roundtrips. This implies that a higher number of inhabitants will lead to higher number of potential visits that in turn will be translated in a higher monetary value. The current representation does not include an analysis in terms of congestion, which should be further developed in future applications. One possible way of considering congestion may be to assess the number of visits for squared meter of area for daily recreation: the area size on its own cannot provide a measurement for congestion unless considered together with visiting ratio of the population. Where there are many inhabitants, larger size areas or many areas of smaller size would be required to meet the demand for daily recreation in social sustainable way.

3.3 SEEA-EEA accounts: outdoor recreation

The actual flow of outdoor recreation for a daily use quantified in physical and monetary terms is used to fill in the SEEA-EEA accounting tables. For illustrative purposes, we only show in this section the accounting tables in monetary terms, however, the same tables could be filled in with the number of potential visits. The supply table assigns the contribution of each ecosystem type to the actual flow of outdoor recreation as measured by the number of potential visits to 'areas for daily recreation' per year. For the classification of ecosystem types, we have employed the MAES ecosystem typology (Maes et al., 2013), disaggregating into the CORINE land cover classes when more detailed information is required. Then, the use table allocates the service flow to the users, which in this case are households.

From the two supply and use tables (Table 3.2 for 2000 and Table 3.3 for 2012) it is possible to check that different countries record higher outdoor recreation for different ecosystem types. For example, in UK a high actual flow is recorded for grassland while in other countries such as Germany, Italy and Poland, it is woodland and forest that provide the highest actual flow.

It is interesting to check country by country how the actual flow of outdoor recreation changes over time. A higher number of inhabitants in the proximity to 'areas for daily recreation', and/or a larger number/extent of 'areas for daily recreation' will determine higher potential visits that, in turn, will affect the monetary value attributed to this ecosystem service.

Table 3.2. Supply (a) and use (b) tables for outdoor recreation (year 2000)

Type of economic unit						Type of ecosystem unit								
outdoor recreation *mlln euro year 2000*	Primary sector	Secondary sector	Tertiary sector	Households	Rest of the world - exports	Green urban areas	Cropland	Grassland	Heatland and shrub	Woodland and forest	Sparsely vegetated land	Wetlands	Rivers and lakes	Coastal and intertidal areas
AT						0.74	24.43	68.44	25.95	336.23	77.63	5.80	-	-
BE						2.67	71.68	65.39	23.47	404.24	2.72	18.04	0.91	2.39
BG						0.19	5.61	24.14	10.12	179.06	10.18	1.75	0.14	0.02
CY						0.22	0.45	0.22	3.74	34.74	1.11	0.12	0.47	-
CZ						0.48	78.38	60.56	0.84	490.42	0.14	4.31	-	-
DE						37.40	1,033.7	1,973.66	87.87	9,027.35	32.25	125.86	22.19	7.50
DK						12.16	125.57	92.26	106.28	457.36	17.66	134.57	52.67	2.27
EE						0.30	2.03	8.72	1.47	84.97	1.09	38.60	0.37	0.11
EL						0.07	76.14	129.13	212.65	551.05	39.85	9.82	15.22	1.31
ES						0.68	232.18	269.92	502.01	1,228.37	94.40	14.89	21.28	3.63
FI						0.02	1.34	2.47	88.40	440.52	21.08	128.33	0.46	-
FR						1.37	371.85	714.20	131.85	2,295.20	182.88	37.22	29.08	8.16
HR						0.31	11.91	19.68	6.05	157.86	3.10	7.98	0.24	0.02
HU						0.89	51.68	201.91	-	678.91	2.34	66.89	-	-
IE						0.08	3.53	13.21	8.26	14.19	9.98	89.47	0.88	1.70
IT						2.53	260.97	422.71	258.79	2,531.47	286.98	13.18	11.57	2.72
LT						0.31	20.48	5.63	0.44	114.06	0.36	7.82	-	0.01
LU						0.09	3.75	3.57	-	92.35	-	-	-	-
LV						0.25	11.56	7.01	-	88.17	0.22	10.47	0.00	-
MT						0.27	2.26	-	3.85	0.34	0.49	-	0.12	-
NL						10.64	34.69	350.94	184.75	954.32	58.04	230.43	50.03	3.75
PL						1.52	386.94	360.06	1.94	3,544.38	5.90	58.09	-	0.02
PT						0.27	255.81	52.25	200.09	747.24	40.75	1.51	31.78	16.55
RO						0.20	10.25	33.60	8.47	211.96	4.48	94.18	1.60	0.27
SE						1.00	3.03	22.23	248.59	629.85	85.82	138.71	0.12	0.19
SI						0.12	7.85	3.31	6.76	69.60	8.96	0.21	0.49	-
SK						0.15	56.75	58.67	9.17	856.04	7.66	2.80	-	-
UK						7.84	319.00	1,257.23	486.60	715.79	152.11	777.60	37.04	12.45
EU						82.78	3,463.9	6,221.13	2,618.40	26,936.03	1,148.2	2,018.66	276.66	63.05

(a) Supply table

outdoor recreation *mlln euro year 2000*	Type of economic unit					Type of ecosystem unit								
	Primary sector	Secondary sector	Tertiary sector	Households	Rest of the world - exports	Green urban areas	Cropland	Grassland	Heatland and shrub	Woodland and forest	Sparsely vegetated land	Wetlands	Rivers and lakes	Coastal and intertidal areas
AT				539.22										
BE				591.51										
BG				231.21										
CY				41.07										
CZ				635.13										
DE				12,347.81										
DK				1,000.79										
EE				137.67										
EL				1,035.25										
ES				2,367.35										
FI				682.62										
FR				3,771.81										
HR				207.15										
HU				1,002.62										
IE				141.30										
IT				3,790.91										
LT				149.10										
LU				99.75										
LV				117.67										
MT				7.32										
NL				1,877.60										
PL				4,358.84										
PT				1,346.25										
RO				365.01										
SE				1,129.54										
SI				97.30										
SK				991.25										
UK				3,765.67										
EU				42,828.74										

(b) Use table

Table 3.3. Supply (a) and use (b) tables for outdoor recreation (year 2012)

Type of economic unit						Type of ecosystem unit								
outdoor recreation *mlln euro year 2012*	Primary sector	Secondary sector	Tertiary sector	Households	rest of the world - exports	Green urban areas	Cropland	Grassland	Heatland and shrub	Woodland and forest	Sparsely vegetated land	Wetlands	Rivers and lakes	Coastal and intertidal areas
AT						1.00	32.96	92.34	35.01	453.62	104.73	7.82	-	-
BE						4.06	109.19	99.61	35.75	615.76	4.15	27.48	1.39	3.63
BG						0.85	24.61	105.87	44.39	785.37	44.63	7.69	0.62	0.09
CY						0.33	0.67	0.33	5.61	52.09	1.66	0.18	0.70	-
CZ						0.55	89.39	69.07	0.96	559.29	0.16	4.91	-	-
DE						32.51	898.37	1,715.23	76.36	7,845.29	28.03	109.38	19.28	6.51
DK						10.53	108.77	79.91	92.06	396.17	15.29	116.57	45.62	1.97
EE						0.47	3.20	13.74	2.32	133.91	1.73	60.83	0.59	0.18
EL						0.05	52.96	89.83	147.93	383.33	27.72	6.83	10.59	0.91
ES						1.05	358.29	416.53	774.69	1,895.60	145.68	22.98	32.84	5.60
FI						0.02	1.18	2.18	77.87	388.06	18.57	113.05	0.41	-
FR						2.10	568.54	1,091.97	201.60	3,509.21	279.61	56.91	44.47	12.47
HR						0.29	11.28	18.64	5.73	149.52	2.94	7.56	0.23	0.02
HU						1.74	100.85	393.99	-	1,324.78	4.58	130.52	-	-
IE						0.17	7.72	28.90	18.07	31.03	21.82	195.68	1.93	3.71
IT						3.50	361.32	585.24	358.29	3,504.82	397.32	18.24	16.02	3.76
LT						0.75	49.88	13.70	1.06	277.76	0.87	19.05	-	0.03
LU						0.05	2.34	2.23	-	57.78	-	-	-	-
LV						0.24	11.20	6.79	-	85.44	0.21	10.15	0.00	-
MT						0.56	4.79	-	8.15	0.72	1.04	-	0.24	-
NL						6.64	21.64	218.93	115.25	595.34	36.21	143.75	31.21	2.34
PL						1.25	318.58	296.44	1.59	2,918.14	4.85	47.82	-	0.01
PT						0.29	272.96	55.76	213.50	797.33	43.48	1.61	33.91	17.66
RO						0.95	47.91	157.12	39.62	991.11	20.95	440.36	7.47	1.27
SE						1.04	3.14	23.05	257.72	652.98	88.97	143.81	0.12	0.20
SI						0.24	15.69	6.62	13.51	139.16	17.90	0.43	0.98	-
SK						0.21	79.14	81.82	12.79	1,193.77	10.69	3.91	-	-
UK						11.44	465.21	1,833.44	709.62	1,043.85	221.83	1,133.99	54.01	18.16
EU						82.89	4,021.79	7,499.27	3,249.44	30,781.22	1,545.6	2,831.51	302.63	78.53

(a) Supply table

outdoor recreation *mlln euro year 2012*	Type of economic unit					Type of ecosystem unit								
	Primary sector	Secondary sector	Tertiary sector	Households	Rest of the world - exports	Green urban areas	Cropland	Grassland	Heat land and shrub	Woodland and forest	Sparsely vegetated land	Wetlands	Rivers and lakes	Coastal and intertidal areas
AT				727.48										
BE				901.03										
BG				1,014.13										
CY				61.58										
CZ				724.33										
DE				10,730.96										
DK				866.89										
EE				216.95										
EL				720.15										
ES				3,653.25										
FI				601.33										
FR				5,766.85										
HR				196.21										
HU				1,956.46										
IE				309.04										
IT				5,248.52										
LT				363.10										
LU				62.41										
LV				114.03										
MT				15.51										
NL				1,171.32										
PL				3,588.69										
PT				1,436.49										
RO				1,706.77										
SE				1,171.02										
SI				194.53										
SK				1,382.32										
UK				5,491.55										
EU				50,392.90										

(b) Use table

Table 3.2 and Table 3.3 report data in absolute terms. If we consider data expressed in relative terms, the ranking of countries changes remarkably as shown in Figure 3.15.

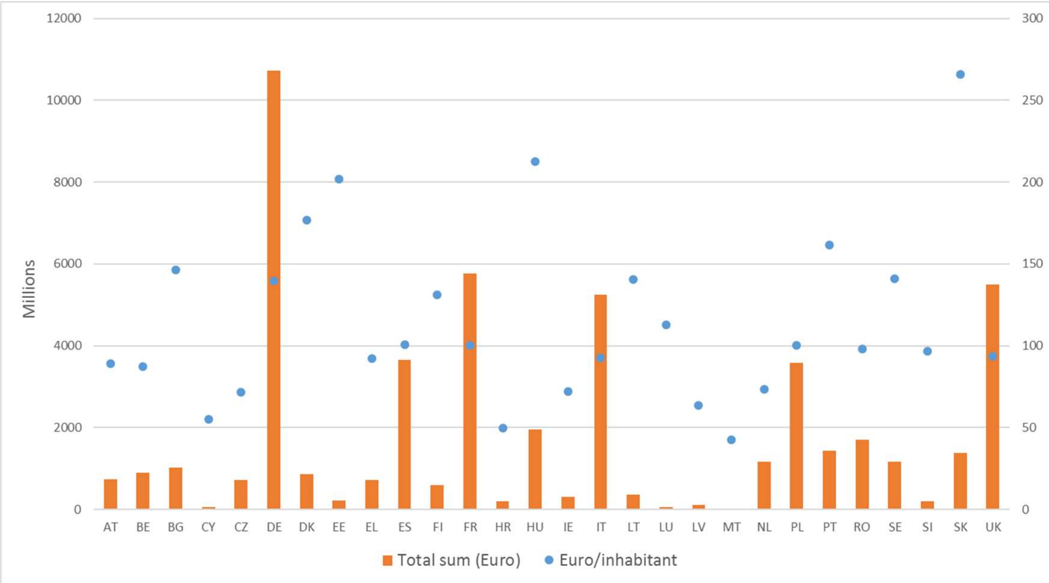

Figure 3.15. Comparison between absolute and relative values for outdoor recreation (year 2012)

Germany is the most populated country in Europe and it records the highest value for outdoor recreation in absolute terms. If we consider the value of recreation per total inhabitants, then Slovakia, Hungary and Estonia record the highest values; Germany ranks 9th. The message provided to policy makers is that more natural attractions should be where people live and should be made accessible: more inhabitants needs more nature-based recreation to improve their well-being. The relative values of outdoor recreation result more meaningful from a policy perspective.

Considering relative values is important but not enough: a congestion factor should be assessed in order to better represent the value of the service integrated with the level of satisfaction of citizen.

3.4 Limitations and further developments of outdoor recreation accounts

All modelling approaches present a number of **LIMITATIONS** derived from the assumptions adopted, that are required when building the models. In this section, we discuss about the main limitations of the approach applied for the outdoor recreation accounts that should be considered when interpreting the results and using them for policy support.

In the experimental application described in this report, we focused only on the assessment of **nature-based recreation on a daily basis**, without accounting for the visits to natural areas that require motor transport to reach them. Therefore, what we present here is only one part of the whole range of outdoor recreation possibilities and results should be interpreted only in terms of what is being measured.

Modelling at European scale imposes as one of the most important limitation the **availability of spatially explicit data for a representative time series**. As mentioned in Appendix I, the ESTIMAP model was simplified for accounting purposes, because of the lack of data for key natural features important for outdoor recreation potential such as: 1) Semi-natural vegetation areas and natural riparian zones. 2) Leisure and recreation related infrastructures (especially local trails and paths).

The number of visits to 'areas for daily recreation' was necessarily derived from models because of the **lack of data on the real use related to daily recreation activity**. This information would be useful to validate the model and relate the real use data with the ecosystem potential we modelled here. Availability of only data on the real use related to daily recreation activity would not be suitable for ecosystem service accounts. Although this data could be taken as a measure of the actual flow, they would lack in the linkage with the ecosystem service potential failing in capturing the importance of the drivers of changes in ecosystem service flow: service potential and demand. In other words, we might find an increase in the number of users of green areas just because population has increased. However, the green area could have been reduced in extent or quality, reducing ecosystem service potential without really addressing it by looking only at the real use as actual flow.

The actual flow here presented has been quantified using a **mobility function** using MENA, a survey undertaken in the UK. Therefore, it **only considers data based on preferences in the UK**, without capturing the cultural behaviour in relation to outdoor recreation in other countries. For future development, it would be recommended to have this kind of survey for most of European countries in order to provide a calibration that reflects different cultural behaviours and routines.

Finally, the **valuation method** used is based on travel costs, when the outdoor recreation assessed considers only users of the service as those living within 4 km from 'areas for daily recreation'. This method was chosen among other valuation techniques, which could be more suitable for this purpose, such as hedonic pricing because of the **lack of data at the EU level on housing pricing** hindered the application of this alternative valuation method.

This first exercise of outdoor recreation accounts provides useful information to highlight key issues that could be addressed in **FURTHER DEVELOPMENTS**. The accounting of outdoor recreation could be enhanced by integrating:

- The **flow of long-distance visitors**, by taking care of the overlap between recreation as ecosystem service and nature-based tourism as an economic activity;
- **Congestion** of areas for daily recreation as a **social sustainability** issue to be integrated in the monetary valuation. Areas for recreation which are crowded would

contribute to a lower contribution of the well-being, decreasing therefore the benefit generated by the service and in consequence, its value;

- **Alternative valuation methods** could be also tested, such as hedonic pricing, once datasets become available. However, attention should be paid to harmonize this technique with SNA by avoiding double counting;
- Establish **linkages between the actual flow of the service with indicators of human well-being** to build combined presentations of the accounting tables. Although we have done some tests (see section 3.1.4); this should be further explored by using the actual flow with other possible indicators.

3.5 Potential applications of outdoor recreation accounts

Accounting of outdoor recreation has a number of applications to support policy-decisions in relation to land planning. The main outcomes of outdoor recreation accounting are summarized in Box 2.

Box 2. What does outdoor recreation accounting show us?

- At the EU level the ecosystem with a higher value of outdoor recreation are forest, having therefore a higher contribution to human well-being,

- Households are the user of the service, with Germany as the country with the largest actual flow: about 9 million potential visits to 'recreational areas for a daily use' in 2012 (absolute terms),

- The highest actual flow per capita is found in Denmark, where 18% of the total population visit 'recreational areas for a daily use' in 2012 (relative terms),

- At the EU level in 2012, there are 40 million potential visits to 'recreational areas for a daily use', with a total value of 50 billion euro,

- There is an overall increase in the use of the service, mainly due to the increase of the recreation potential, but also, although at lower extent, to an increase of the demand (population),

- Spatial maps and accounting tables can be used to support policy decisions related to land planning to guarantee the equitable accessibility to outdoor recreation opportunities (citizen right): 38% of the population at the EU have limited accessibility to recreational areas (unmet demand)

The actual flow of the service in 2012 is 40 million visits per year. This number may look relatively low if we consider the 450 million EU citizens. However, in our approach there are different factors explaining the low number of visits in relation to the total population (sorted by level of importance):

- The assessment of the actual flow is based only on the share of population considered as 'met demand' (i.e. living within 4 km from 'areas for daily recreation). At the EU level is 62% of the total population (Figure 3.5);
- The rate of visits used to calculate the actual flow as the potential visits to an 'area for daily recreation' is based on a calibrated mobility function showing that, on average, 17% of the 'met demand' visits 'areas for daily recreation' (Figure 3.7);

- The outdoor recreation potential only includes high quality areas, with high outdoor recreation opportunities that are close to settlements and roads. Therefore, it only covers the recreation needs on a daily basis (see section 3.4 on limitations for further discussion).

More in detail, the spatial analysis required for the accounting of outdoor recreation are a useful tool to identify priority areas for ecosystem restoration. An enhancement of the recreation potential in those areas where there is high unmet demand should be prioritized for the deployment of Green Infrastructure. As described before, this kind of measures would contribute to increase the equitable accessibility to outdoor recreation areas. Ultimately, the potential conflict between nature conservation and recreation activities should be considered in the management strategies.

Improving proximity/accessibility to recreational areas will have a direct effect on the level of satisfaction with recreational and green areas (Figure 3.11), contributing therefore to the increase of the human well-being.

The recreational use of protected area may compromise the conservation management of those areas. Unfortunately, at the EU level it is difficult to establish a threshold for the number of visits above which the species and habitat conservation could be compromised. These thresholds should be defined at local level, based on the species and habitat vulnerability by the likely pressures generated by the visits. However, it is important to notice, than in the model used for outdoor recreation 'strict nature reserves' have been not considered given that access to these reserves is not permitted (see Appendix I for further details).

4 Crop pollination by wild insect pollinators

4.1 Assessment of crop pollination

Crop pollination is a regulating ecosystem service defined as the fertilisation of crops by insects and other animals that maintains or increases the crop production. Concretely, insect pollination benefits more than 80% of crops grown in Europe (Williams, 1994), with an estimated value greater than 14 billion euro annually (Leonhardt, 2013). Hence, there is growing concern that observed declines in insect pollinators may affect production and revenues from pollinator-dependent crops. Knowing the distribution of pollinators, therefore, is crucial to estimate their availability to pollinate crops. This information, in turn, can be used to ensure the maintenance of habitats that support insect pollinators, ultimately safeguarding the long-term provision of crop pollination services.

Ideally, crop pollination should be assessed by counting the number of bees and/or other insects effectively pollinating the flowers of the pollinator-dependent crops. Since this method is unfeasible and unrealistic at the EU level, the use of models is required. Technical details of the crop pollination model are provided within the Appendix III.

Accounting for crop pollination requires the assessment of the ecosystem potential to support wild insect pollinators (pollination potential) and the demand for pollination, which, in this case, is defined as the extent of pollinator-dependent crops. Then, the spatial overlap between the pollination potential and the demand for pollination is used to estimate the actual flow of the service. Lastly, the service flow will be integrated into the SEEA-EEA accounting tables (Figure 4.1).

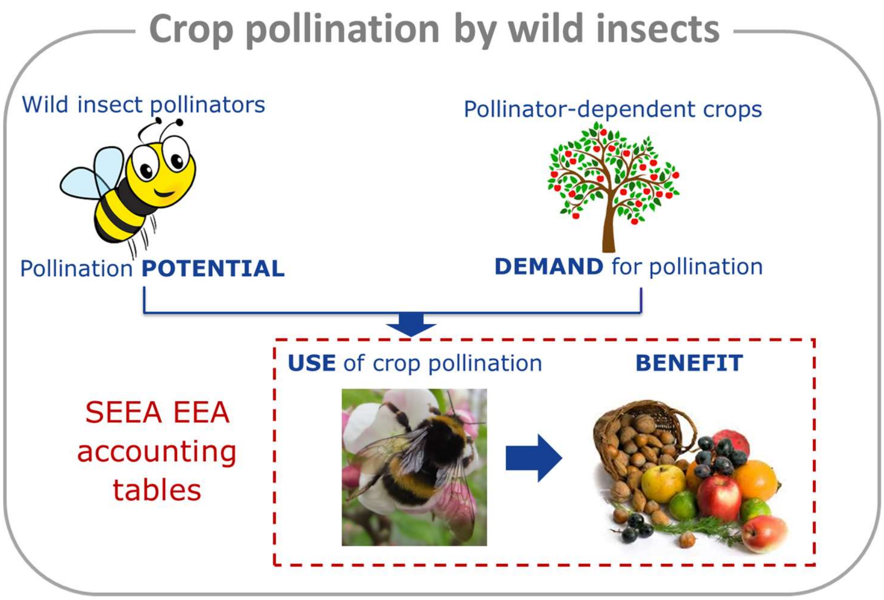

Figure 4.1. Scheme of the components required for crop pollination accounting

Appendix IV presents a factsheet for crop pollination summarizing the main components of the service accounts.

The different components of crop pollination accounting are assessed depending on the data availability. As such, given the temporal mismatch between the pollination potential data and the demand data, the use of the service (actual flow) can only be assessed for 2000 and 2006 (Table 4.1). The reference years for the assessment are those for which the CORINE Land Cover map series are available.

Table 4.1. Components of crop pollination and overview of the temporal availability

Crop pollination		Years assessed		
Potential	Extent of service providing areas with different pollination potential (ha)	2000	2006	2012
Demand	Extent of pollinator-dependent crops (ha)	2004	2008	NA
Actual flow	Yield production attributable to pollination in overlapping areas between pollination potential and demand (ton)	2000	2006	NA

4.1.1 Crop pollination potential

The assessment of pollination potential is based on an indicator of the environmental suitability to support wild insect pollinators. The environmental suitability is, then, used to delineate service providing areas (SPA) showing different level of pollination potential: high, medium, low and none (see Appendix III for further technical details).

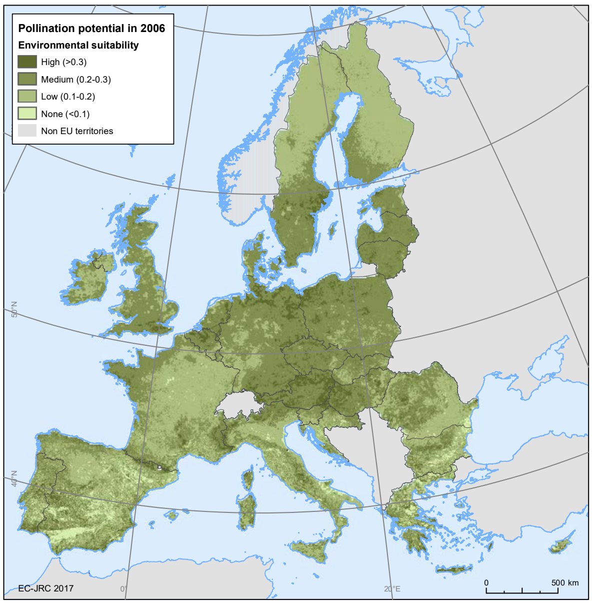

Figure 4.2. Pollination potential in 2006

In this report, pollination potential integrates two different models: an Expert-Based Model for solitary bees (computed with ESTIMAP toolbox, Zulian et al. (2013)) and a Species Distribution Model for bumblebees, predicted with observed species records. Both models are based on land cover, climate data, and on the distance to semi-natural areas (see Appendix III for further details).

Figure 4.2 depicts the spatial variation in the pollination potential over the SPA for 2006. The map shows spatial differences through Europe. Large areas of medium to high pollination potential can be found in the central-eastern part of Europe, and, occasionally, in the southern part of the northern most countries.

From the environmental variables available to assess the pollination potential, climate is the most important driver of the large-scale occurrence of the groups of pollinators considered here. This finding agrees with the results published during the EU-funded project 'Status and Trends of European Pollinators' (STEP), where it has also been show that, according to the predicted changes in climatic patterns, some species of wild pollinators will move towards northern ranges and the vast majority of bumblebees will suffer from range contractions (Potts et al., 2015). Land cover is the second most important driver, but its relative importance differs among the taxonomic groups, reflecting their ecological requirements. However, given its importance, there is a large potential of well-designed land management strategies to mitigate the increasingly negative effects of climate change (Potts et al., 2015).

For simplicity in this first experimental account of crop pollination, we focussed on those SPAs with high and medium pollination potential as service areas (Figure 4.2). In this application, we assume pollinators are present only under medium and high pollination potential. Pollinators are considered as absent under none and low pollination potential since environmental suitability in these areas may not be enough to maintain pollinators population.

4.1.2 Demand for crop pollination

The demand for crop pollination was quantified as the extent of pollinator-dependent crops, following the methodology described in Zulian et al. (2013).

We used the spatial data derived from the CAPRI model (Britz & Witzke, 2014; Leip et al., 2008) to quantify the demand as the number of hectares per square kilometer. We considered ten crop types benefitting from insect pollination to different extent as shown by the level of dependency (Table 4.2). CAPRI data were only available for 2004 and 2008 (Table 4.1). Data were not available for Croatia, Malta and Cyprus, and some specific regions for which the model used for the data disaggregation was not appropriate.

Table 4.2. Crop types according to the dependency on insect pollination (in %)

Crop type	Dependency (%)
Apples, pears and peaches	65
Other fruits	40
Rapeseed	25
Sunflower	25
Soya	25
Other oilseeds	17.5
Pulses	5
Flax and hemp	5
Tomatoes	5
Citrus	5

Source: Klein et al. (2007)

The demand is reported as the number of hectares for the sum of all crops dependent on pollinators. Figure 4.3 shows the pollination demand at the country level in 2008 across the EU[6]. France and Spain are the countries with the largest extent of pollinator-dependent crops. However, in Spain a large share of this extent comes from crops such as pulses, flax and hemp, tomatoes and citrus. For these crop types, the contribution of pollination constitutes only 5% of the crop production.

On the other hand, the largest extent of crops highly dependent on pollinators (apples, pears and peaches with a level of dependency of 65%) are found in Poland and Italy. In these countries, the likely contribution of pollination to generate the benefit would be higher, since 65% of the production of these crops is attributable to the role of pollination.

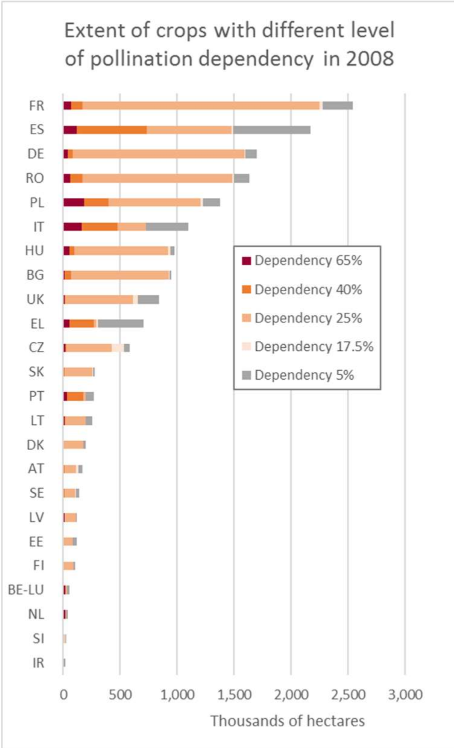

Figure 4.3. Pollination demand in 2008

4.1.3 Actual flow of crop pollination

The overlap between the pollination potential and demand for pollination is used to quantify the area generating the actual flow of service[7]: the use area. In this way, the use area is defined as the extent of pollinator-dependent crops benefitting from the SPA with different pollination potentials.

The use area can be quantified as the number of hectares of pollinator-dependent crops covered by the SPA with different potential to support pollinators. Results are provided for the total extent of pollinator-dependent crops in Figure 4.4. In 2006, about 50% of the crop extent was covered by low and none pollination potential that has been considered in terms of unmet demand in this accounting exercise. In these areas, environmental suitability may be not enough to maintain pollinator's population, generating the lack of the service, even when there was demand for it. This may generate a situation where crop production is not benefitting from pollination. At the other extreme, there is about 6% of the crop demand covered by SPA with high pollination potential. In these areas with high pollination potential, measures such as the regulation of the use of harmful pesticides

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[6] CAPRI data are available for the whole EU, except for Croatia, Malta and Cyprus. Other regions present also no data due to methodological issues in the downscaling model (i.e. surroundings of Paris). Note that the assessment of pollination demand and the actual flow of crop pollination is only based in the common spatial data available for both years: 2004 and 2008.

[7] Actual flow can only be assessed for 25 Member States for which data on demand were available

might be implemented to guarantee the maintenance of the service. Most of the met demand (44%) is covered by SPA with medium pollination potential. In these areas, restoration action targeting the creation of pollinator-friendly habitats might enhance the use of the service, increasing therefore the benefit derived from it. These results are in line with those reported by (Schulp et al., 2014) showing that half of demand area is covered by a high-medium pollination potential.

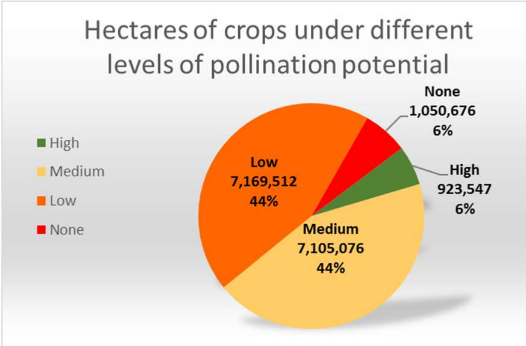


Figure 4.4. Use area of crop pollination in 2006 for all pollinator-dependent crops

A detailed spatial analysis of the spatial relationship between different levels of pollination potential and demand is useful to identify, for instance, hotspots of high potential and high demand, or low potential and high demand. A map derived from the cross-tabulation of the levels of pollination potential and demand is presented in Figure 4.5. This map has multiple applications to improve land management and enhance the use of the service. For instance, areas mapped in dark brown should be prioritized for the enhancement of habitats capable of supporting insect pollinators (pollinator-friendly habitats). A more suitable environment, in fact, is expected to increase the pollination potential and, ultimately, crop productions. Areas in red and blue (Figure 4.5) are of special interest from the point of view of the 'unmet demand': the absence of suitable conditions for pollinators in these areas, in fact, are related to the lack of the service flow even when there is a high demand for it.

For simplicity in this first experimental account of crop pollination, we focused in use areas with only medium and high pollination potential. In this way, considered as met demand the crop extent covered by pollination (i.e. medium and high pollination potential) as an unmet demand, the extent not covered by pollination (i.e. low and none pollination potential). We quantified for each crop type, the extent of met and unmet demand as shown in Figure 4.6.

This assessment shows that some crop types such as flax and hemp, and sunflowers have a very large share of unmet demand. On the contrary, other oilseeds, rapeseed, apple, pears and peaches have a share of met demand above 60%. Increase of the share of the met demand may contribute to increase the benefit generated by pollinators, especially in those areas where crops with high level of pollinator-dependency are found.

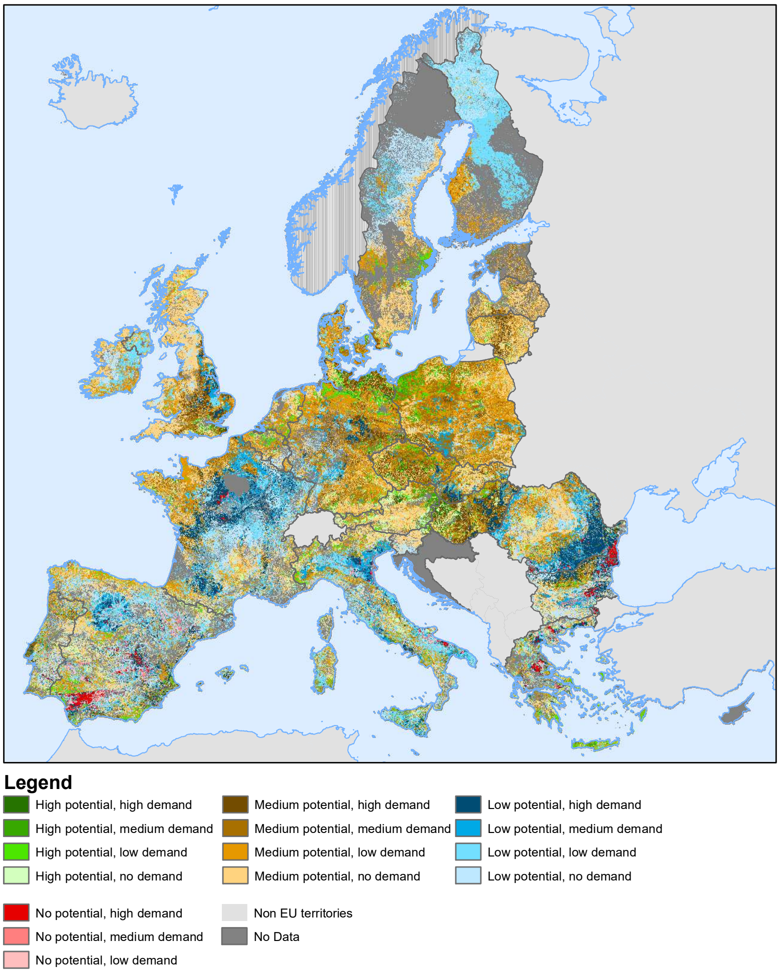


Figure 4.5. Map of the use areas of crop pollination for all pollinator-dependent crops. Colours indicate different levels of pollination potential; shading from light to dark shows increasing demand.

The assessment of the use area is a necessary preliminary step to the calculation of the actual flow. The actual flow of crop pollination is quantified as the yield production attributable to pollination according to the level of pollinator-dependency of different crop types (Table 4.2). Therefore, the actual flow of crop pollination necessarily needs to be assessed in areas with suitable environment for pollinators.

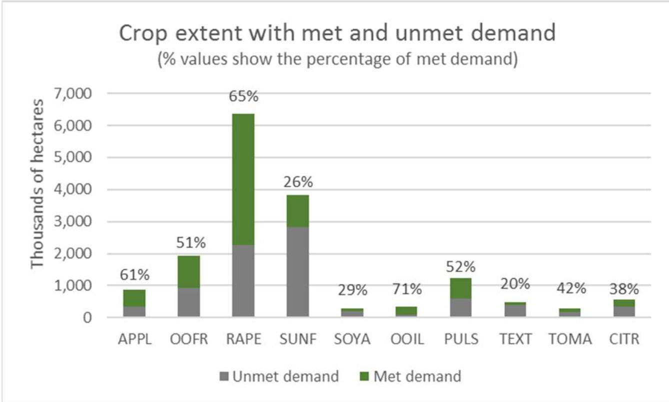


Figure 4.6. Crop extent with met and unmet demand in 2006

For simplicity in this first experimental account of crop pollination, we focussed on those SPAs with high and medium pollination potential, based on the pollination potential map (Figure 4.2), deriving a simplified binary map of pollination showing area with potential presence of pollinators. Subsequently, we estimated the service flow within the areas of pollinator's presence according to the following equation:

$$Flow = Yield * Dependency/100$$

where 'yield' is the production of each crop type in areas with potential pollinator's presence and 'dependency' is the level of pollination dependency of each crop type. Spatial yield data were taken from CAPRI. The service flow is quantified as total kilogram of yield production per year as depicted in Figure 4.7.

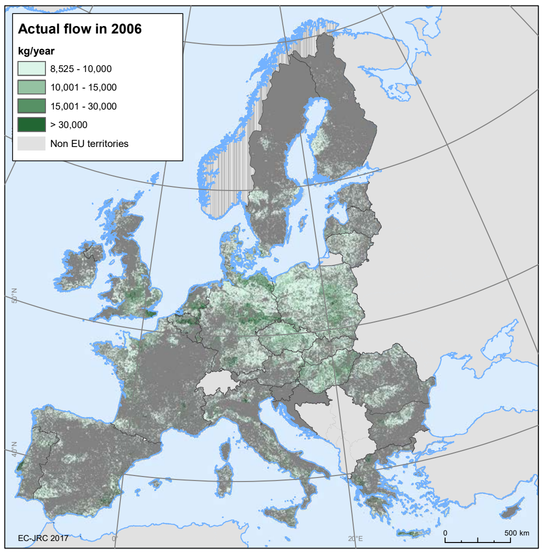


Figure 4.7. Actual flow in 2006

4.1.4 EU trends of crop pollination

The **pollination potential** was assessed for 2000, 2006 and 2012. However, since the demand is only available for 2000 and 2006, we focus the analysis on these two years. Figure 4.8 shows a dominant trend at the EU-28 of expansion of SPA with high pollination potential between 2000 and 2006. For the assessment of the actual flow of crop pollination, we just considered areas with medium and high pollination potential, as the areas where the presence of pollinators may contribute to the actual flow.

At the EU level, pollination potential increased only about 0.7%. Portugal is the country showing the highest increase of pollination potential, followed by Luxembourg; while Bulgaria and Romania present the highest reduction.

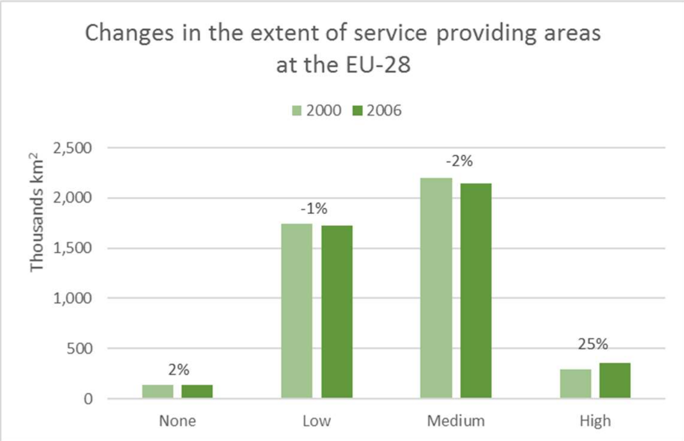
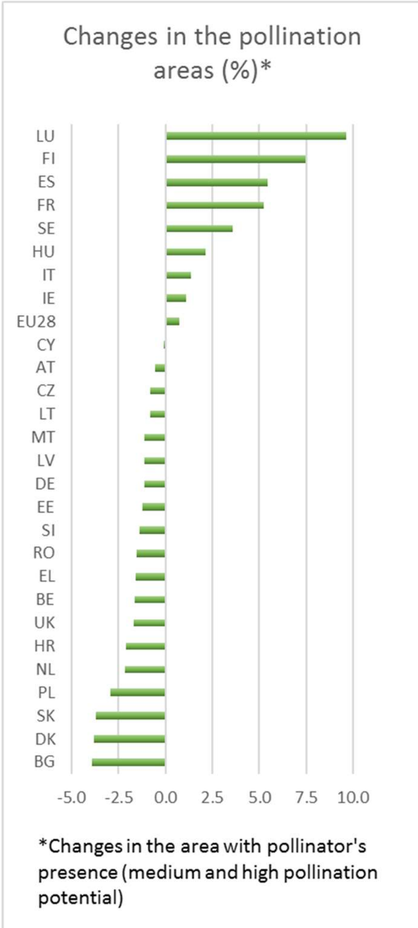
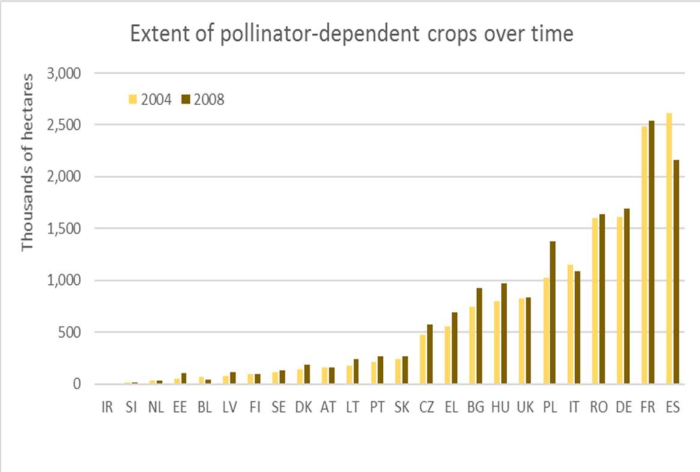


Figure 4.8. Pollination potential over time



At the EU level, the **demand for crop pollination**, as measured by the total extent of pollinator-dependent crops, increased with about 6% between 2004 and 2008; however, this increase is mainly due to the expansion of crops with medium level of dependency (i.e. rapeseed, sunflower, soya, other fruits and other oilseeds). On the other hand, crops with high and low pollinator-dependency show negative trends between 2004 and 2008, i.e. their extents are generally decreasing across the EU (Figure 4.9).



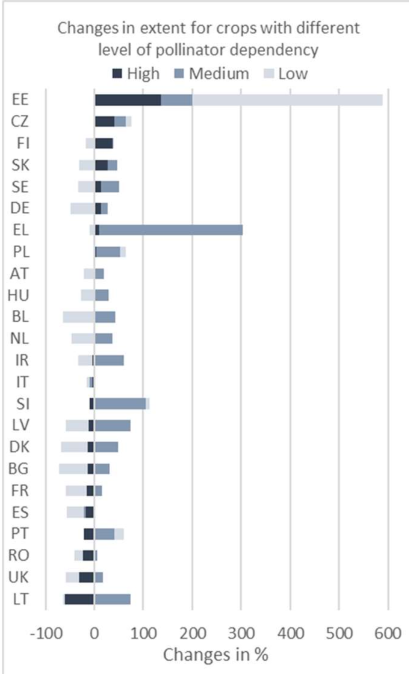


Figure 4.9. Pollination demand over time

(Total demand, left, and separately for crops with different level of pollinator dependency, right)

The changes in the **actual flow of crop pollination** should be assessed by quantifying the difference of the actual flow between 2000 and 2006, as measured by the tonne of yield per year (Figure 4.7). However, yield production is affected by many other factors not related to pollination, such as climate condition of the year assessed, or management practices, which were not included in the pollination model. Therefore, we could find situations in which there are no changes in the pollination potential nor in the demand, but there are changes in the actual flow as a consequence of changes in total production.

Strictly speaking, changes in the actual flow can only be explained by changes in the pollination potential, changes in the demand, or their spatial relationship. Therefore, a consistent analysis of changes in the use of crop pollination benefits from assessing changes in the use area, in spite of the actual flow, where changes in the total yield may give as results a misleading message in relation to the service flow.

Changes in the **use area of the crop pollination**, as measured by the hectares of all pollinator-dependent crops, show an overall increase between 2000 and 2006 at the EU level (Figure 4.10). Crop extent covered by areas with high pollination potential increased about 50%. The expansion of the areas with high use of pollination potential are due to several factors: an increase within the demand (~6%), a very slight increase in the potential (by about 0.7%), and an increase in their spatial overlap. On the contrary, areas with no pollination potential decreased about 4%.

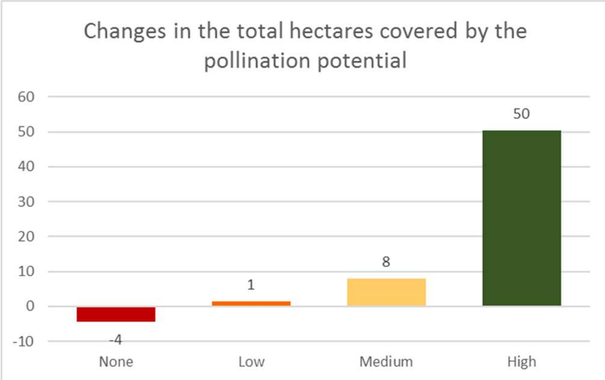


Figure 4.10. Changes in the use of crop pollination at the EU between 2000 and 2006

4.2 Monetary valuation of crop pollination

Crop pollination is a regulating service, as reported in many ecosystem services classifications (e.g. CICES, TEEB). However, this service shares with the provisioning services one peculiar feature: it contributes to a good that is already in the SNA, i.e. pollinator-dependent crops. As it may happen for the provisioning services, the procedure followed in monetary terms considers disentangling SNA products in those components, which are relevant from an ecosystem service perspective. This practically involves that we use agricultural economic accounts and disentangle what is due to the ecosystem contribution. The initial dataset downloaded from ESTAT is "Economic accounts for agriculture - values at n-1 prices" [ref. aact_eaa02]. The three years around the target year are averaged in order to avoid odd fluctuations. The reason to consider constant values (i.e. values at n-1 prices) rather than current prices can be justified by the need to focus on changes generated by the biophysical side and not by external factors such as inflation.

CAPRI classification of crops differs from ESTAT classification. An intermediate harmonization step is required. Its outcome is reported in Table 4.3.

Table 4.3. Equivalence between ESTAT and CAPRI codes

CAPRI code	Description	ESTAT code	Description
RAPE	Rapeseed	02110	Rape and turnip rape seed
SUNF	Sunflower	02120	Sunflower
SOYA	Soya	02130	Soya
OOIL	Other oilseeds	02190	Other oleaginous products
PULS	Pulses	02200	Protein crops
TEXT	Flax and hemp	02910	Fibre plants
TOMA	Tomatoes	04120	Tomatoes
APPL	Apples, pears and peaches	06110 06120 06130	Apples Pears Peaches
CITR	Citrus Fruits	06200	Citrus fruits
OFRU	Other fruits	06190	Other fresh fruits

The starting point for the monetary valuation of crop pollination is the economic account reported for agriculture within the SNA (Table 4.4). From the total production expressed in constant monetary values, we estimate the contribution of the ecosystem service (pollination) (i) by separating the pollinator-dependent crop production covered by pollination service from the pollinator-dependent crop production not covered by pollination service, and (ii) by disentangling the contribution of the ecosystem service from the former.

In order to use consistently the official agricultural statistics made available by ESTAT, we first need to move from the actual flow processed using CAPRI data to the actual flow expressed in ESTAT data. There are two sets of information we withdraw from the data processed using the CAPRI model as source: (i) the actual flow, i.e. the tonnes of met demand multiplied by the dependency coefficients (Klein et al., 2007), (ii) the total production including both met and unmet demand. We obtain a pollination ratio whose amount depends on the way the biophysical side was undertaken (because of the actual flow).

$$Pollination\ Contribution = \frac{CAPRI\ Actual\ Flow}{CAPRI\ Total\ Production}$$

Table 4.4. The total SNA products supplied by the agriculture sector

	Type of economic unit															
	Agriculture															
SNA product *mlln euro year 2006*	Apple,pear and peaches	Other fruits	Citrus	Protein crops	Oilseeds	Rape and rape seeds	Soya	Sunflower	Fibre plants	Tomatos	Forestry	Fisheries	Secondary sector	Tertiary sector	Households	Rest of the world - exports
AT	22.32	83.96		13.36	29.26	27.88	13.61	15.89	0.19	25.61						
BE	94.87	107.31		0.83	2.67	8.26		0.00	18.99	167.43						
BG	16.65	50.73		9.01	9.46	9.27	0.10	175.51	0.860	63.17						
CZ	11.45	13.22		11.04	38.06	193.17	5.14	18.38	1.34	6.93						
DE	208.08	256.88		66.80		1187.06		14.44	0.00	27.79						
DK	5.99	11.71		7.13	0.16	115.65			0.00	22.76						
EE	0.52	3.82		1.67	0.05	26.84			0.00	5.49						
EL	125.10	363.74	258.64	9.32	1.81			4.25	741.39	490.34						
ES	375.83	1410.72	1639.47	69.56	0.16	4.14	0.46	249.68	178.11	1817.20						
FI	1.59	39.70		1.90	0.90	43.70			0.20	51.33						
FR	373.88	1002.03	11.77	279.30	8.80	1280.40	36.97	472.27	168.70	542.60						
HR	10.69	47.78		4.69	0.96	9.95	37.97	23.79	0.00	23.16						
HU	29.82	78.84		14.07	11.85	88.95	19.25	269.90		48.41						
IE	0.91	32.01				2.55			0.23	8.42						
IT	468.46	921.28	1223.05	80.82	1.39	2.69	120.58	69.64	0.59	1100.17						
LT		8.77		8.20	0.30	63.40			1.23							
LU	0.52	1.94		0.18		3.56			0.00	0.26						
LV	1.63	6.44		0.45	0.15	34.96			0.43	6.83						
NL	104.03	174.89		25.13	3.36	2.97			17.40	659.09						
PL	122.62	244.34		54.15	13.80	396.22			2.29	230.35						
PT	95.99	182.87	105.44	18.16	0.08	0.09	0.02	2.38	1.38	134.89						
RO	103.36	369.34		24.91	0.59	41.56	49.57	229.25	0.27	361.21						
SE	4.33	43.55		13.35	3.48	58.46			0.000	20.35						
SI	10.63	19.70		1.94	6.27	2.17	0.17	0.12	0.00	2.63						
SK	4.31	6.59		5.43	1.89	60.66	3.34	39.46	0.11	5.53						
UK	47.00	441.14		162.24	19.65	512.56			1.303	106.40						
EU	2240.58	5923.31	3238.37	883.62	155.10	4177.13	287.19	1584.96	1135.03	5928.34						

The pollination contribution expresses how much of the total production depends on pollination: it is not only necessary to have the dependency coefficients, it is also necessary to know how much of the crop demand for pollination is actually met. In fact when looking at the outcomes obtained by applying the pollination contribution, it becomes clear that the application of the dependency ratio on all production might in some cases results an overestimation of the service that hides sustainability issues (Table 4.5).

Table 4.5. Pollination contribution and dependency ratio

	Agriculture									
	Apple, pear and peaches	Other fruits	Citrus	Protein crops	Oilseeds	Rape and rape seeds	Soya	Sunflower	Fibre plants	Tomatoes
AT	0.65	0.40		0.05	0.17	0.25	0.25	0.25	0.05	0.05
BE	0.64	0.39		0.04	0.16	0.23		0.07	0.05	0.05
BG	0.28	0.17		0.01	0.06	0.11	0.18	0.06	0	0.02
CZ	0.60	0.37		0.05	0.16	0.24	0.22	0.20	0.04	0.04
DE	0.57	0.35		0.04	0.15	0.21	0.25	0.23	0.04	0.04
DK	0.57	0.35		0.04	0.14	0.19			0.04	0.04
EE	0.63	0.39		0.05	0.17	0.24			0.05	0.05
EL	0.30	0.18	0.03	0.01	0.00	0.09	0.06	0.01		0.02
ES	0.26	0.16	0.02	0.00	0.01	0.03	0.08	0.01		0.02
FI	0.29	0.18		0.04	0.11	0.14		0.09	0.03	0.03
FR	0.29	0.17	0.03	0.02	0.05	0.05	0.04	0.05	0.03	0.03
HU	0.53	0.32		0.04	0.14	0.20	0.21	0.18	0.04	0.04
IE	0.26	0.16		0.03	0.13	0.10				0.04
IT	0.13	0.08	0.02	0.01	0.04	0.05	0.01	0.06	0.02	0.02
LT	0.64	0.39		0.05	0.17	0.24			0.05	0.05
LU	0.53	0.33		0.04	0.16	0.19	0.25	0.12		0.05
LV	0.65	0.40		0.05	0.17	0.25			0.05	0.05
NL	0.55	0.34		0.04	0.14	0.24		0.24	0.04	0.05
PL	0.59	0.36		0.04	0.16	0.22	0.22	0.22	0.05	0.04
PT	0.42	0.26	0.03	0.03	0.02	0.15	0.21	0.04		0.03
RO	0.47	0.29		0.02	0.06	0.05	0.06	0.04	0.02	0.02
SE	0.45	0.27		0.05	0.17	0.24		0.00	0.05	0.04
SI	0.58	0.36		0.04	0.15	0.20	0.20	0.12	0.05	0.04
SK	0.53	0.32		0.03	0.10	0.17	0.15	0.12	0.03	0.03
UK	0.55	0.34		0.04	0.13	0.17		0.19	0.04	0.04
EU	0.48	0.30	0.02	0.03	0.12	0.17	0.16	0.12	0.04	0.04
Dependency ratio according to the literature (Klein et al., 2007)										
	0.65	0.40	0.05	0.05	0.175	0.25	0.25	0.25	0.05	0.05

Once the pollination contribution is available, it is multiplied by the agricultural statistics provided by ESTAT in order to estimate the part of met demand, which depends on the action of wild pollinators:

$$ESTAT\ Actual\ Flow = Pollination\ contribution * ESTAT\ Total\ Production$$

ESTAT total production can be calculated in physical terms when tons of yields are considered. In that case, the following step is to multiply the flow by euro/tonne. In this application, we directly consider ESTAT total production expressed in monetary terms at basic price, for the sake of simplicity.

4.3 SEEA-EEA accounts: crop pollination

The actual flow of crop pollination can be quantified in physical and monetary terms and is used to fill in the SEEA-EEA accounting tables. As previously explained, we only show in this section the accounting tables in monetary terms; the same tables in physical terms would be filled with tons yield. As already done for outdoor recreation, we have employed the MAES ecosystem classification for ecosystem types (Maes et al., 2013) in the supply table. We further disaggregated the economic sector "Agriculture" according to ESTAT crop classification in the use table.

In Table 4.5, we report the supply (a) and use (b) tables for crop pollination. In the use table, we did not report the SNA section as this is already part of the SNA (i.e. the intermediate consumption used by the other economic sectors for transformation).

In the supply table (Table 4.6 (a)) we read the contribution of cropland in terms of pollination. This estimate is disentangled from the total economic aggregate, reported in Table 4.4 by using the contribution coefficients reported in Table 4.5. In the use table (Table 4.6 (b)); the pollination service is allocated to the different crops whose production takes advantage of this ecosystem service. The logic behind this approach is that cropland provides farmers with a production input they do not pay for. With this first application, we use basic prices that measure the amount retained by the producer (what actually drives producers' decision taking). For future applications, fine-tuning of basic prices should take place in order to make sure that only net profit value is considered in this specific calculation.

Compared to Table 4.4, although the total sum remains the same (i.e. 25.5 billion euro) we are able to disentangle the contribution of crop pollination (i.e. 3.1 billion euro) from the SNA product. Fresh fruits (that according to ESTAT classification includes apples, pears, peaches, citrus and other fruits) show the largest value of the actual flow with 2.1 billion euro.

Table 4.6. Supply (a) and use (b) table for crop pollination (2006)

	Type of economic unit																Type of ecosystem unit								
	Agriculture																								
	Apple,pear and peaches	Other fruits	Citrus	Protein crops	Oilseeds	Rape and rape seeds	Soya	Sunflower	Fibre plants	Tomatos	Forestry	Fisheries	Secondary sector	Tertiary sector	Households	Rest of the world - exports	Green urban areas	Cropland	Grassland	Heatland and shrub	Woodland and forest	Sparsely vegetated land	Wetlands	Rivers and lakes	Coastal and intertidal areas
crop pollination																									
mlln euro year 2006																									
AT																		69.38							
BE																		114.58							
BG																		26.44							
CZ																		70.36							
DE																		479.70							
DK																		31.77							
EE																		8.78							
EL																		120.39							
ES																		390.92							
FI																		14.44							
FR																		404.49							
HR																		35.80							
HU																		117.67							
IE																		6.04							
IT																		158.60							
LT																		19.56							
LU																		1.70							
LV																		12.76							
NL																		153.38							
PL																		268.63							
PT																		96.25							
RO																		177.46							
SE																		29.77							
SI																		14.76							
SK																		21.05							
UK																		284.94							
EU																		3129.6							

SNA met demand

AT	7.82	50.36		12.62	24.05	20.86	10.20	11.87	0.18	24.30
BE	33.44	64.16		0.72	2.11	5.85			17.11	146.73
BG	5.07	17.61		1.92	3.07	3.48		40.38	0.06	20.51
CZ	4.23	7.69		9.91	29.60	141.70	3.58	11.77	1.16	6.12
DE	77.77	147.70		54.67		809.29		10.15		23.41
DK	2.24	6.75		5.62	0.11	72.98				19.83
EE	0.19	2.27		1.56	0.04	19.89				5.21
EL	39.84	132.69	129.59	2.13	0.05			0.19	16.68	226.53
ES	110.67	475.55	639.49	5.31	0.01			13.09	8.94	600.62
FI	0.48	13.39		1.35	0.49	20.90			0.13	27.19
FR	118.15	360.15	6.39	85.18	2.14	219.40	5.24	79.74	91.52	270.42
HR	4.02	27.65		2.13	0.44	5.55	17.72	13.64		22.00
HU	11.42	43.38		10.02	8.46	58.08	12.92	161.56	0.19	36.98
IE	0.27	10.90				0.78				7.16
IT	80.61	166.06	376.71	14.02	0.32	0.54	4.58	14.66	0.25	395.45
LT		5.24		7.69	0.25	46.99			1.16	
LU	0.20	1.09		0.13		2.31				0.23
LV	0.57	3.86		0.43	0.13	26.16			0.41	6.49
NL	39.35	99.19		19.87	2.50	2.20			13.76	587.82
PL	45.36	142.05		45.60	10.64	278.71			2.03	200.43
PT	36.06	88.14	64.38	10.33	0.01	0.05		0.35	0.13	75.92
RO	39.65	190.86		7.25	0.20	8.04	10.26	35.37	0.09	121.50
SE	1.66	21.56		12.57	2.77	42.12				17.15
SI	3.99	11.27		1.64	4.56	1.40		0.05		2.34
SK	1.65	3.59		3.19	1.01	34.95	1.79	17.45	0.08	3.70
UK	17.77	250.03		120.12	12.70	301.70			1.02	83.63
EU	682.49	2343.19	1216.55	435.98	105.68	2123.94	66.29	410.28	154.90	2931.67

SNA unmet demand

AT	0.01	0.05		0.08	0.11	0.07	0.01	0.08	0.00	0.04
BE	0.29	0.68		0.08	0.11	0.52			0.98	13.01
BG	7.04	24.68		6.99	5.82	4.81	0.02	124.38	0.80	41.61
CZ	0.37	0.67		0.61	2.27	4.74	0.41	2.93	0.12	0.49
DE	8.78	17.08		9.28		119.06		1.01		3.16
DK	0.25	0.75		1.22	0.03	19.97				1.89
EE	0.004	0.05		0.03	0.001	0.35				
EL	48.64	166.52	122.40	7.08	1.75			4.01	723.87	252.21
ES	168.21	708.54	967.36	63.98	0.14	3.62	0.30	233.27	168.72	1186.03
FI	0.69	19.93		0.48	0.31	16.74			0.07	22.75
FR	147.74	467.46	5.05	189.79	6.27	1003.57	30.36	371.67	72.47	258.30
HR	0.52	2.74		2.45	0.44	2.73	15.12	6.02		
HU	2.53	9.68		3.52	1.65	12.60	2.23	58.89	0.03	9.50
IE	0.39	15.90				1.56				0.89
IT	327.73	683.16	827.21	66.09	1.00	2.02	114.85	51.10	0.33	684.58
LT		0.06		0.11	0.00	0.83			0.01	
LU	0.04	0.19		0.04		0.52				0.02
LV	0.001	0.01		0.00	0.00	0.08			0.001	
NL	5.98	14.85		4.22	0.35	0.05			2.93	40.44
PL	3.96	12.39		6.16	0.94	27.29			0.15	19.42
PT	19.26	47.04	37.74	7.29	0.07	0.03	0.01	1.94	1.25	55.05
RO	14.71	70.67		17.29	0.35	31.40	36.59	184.66	0.17	233.53
SE	0.66	10.15		0.12	0.13	2.56				2.31
SI	0.51	1.44		0.21	0.77	0.33	0.01	0.05		0.17
SK	0.38	0.89		2.08	0.68	15.12	1.03	17.01	0.03	1.64
UK	2.66	37.86		35.87	4.39	118.96			0.22	18.41
EU	761.37	2313.44	1959.76	425.07	27.58	1389.54	200.94	1057.02	972.16	2845.43

a) Supply table

	Type of economic unit																Type of ecosystem unit								
	Agriculture																								
	Apple,pear and peaches	Other fruits	Citrus	Protein crops	Oilseeds	Rape and rape seeds	Soya	Sunflower	Fibre plants	Tomatos	Forestry	Fisheries	Secondary sector	Tertiary sector	Households	Rest of the world - exports	Green urban areas	Cropland	Grassland	Heatland and shrub	Woodland and forest	Sparsely vegetated land	Wetlands	Rivers and lakes	Coastal and intertidal areas
crop pollination *mlln euro year 2006*																									
AT	14.49	33.55		0.66	5.10	6.95	3.40	3.95	0.01	1.28															
BE	61.14	42.47		0.04	0.44	1.90			0.90	7.69															
BG	4.53	8.45		0.10	0.57	0.97	0.02	10.75		1.04															
CZ	6.85	4.86		0.52	6.19	46.73	1.15	3.68	0.06	0.32															
DE	121.53	92.10		2.86		258.70		3.28		1.22															
DK	3.50	4.21		0.29	0.02	22.70				1.04															
EE	0.33	1.49		0.08	0.01	6.59				0.27															
EL	36.62	64.52	6.65	0.11	0.01			0.05	0.84	11.60															
ES	96.95	226.63	32.62	0.27	0.002	0.11	0.04	3.32	0.45	30.54															
FI	0.42	6.38		0.07	0.10	6.07			0.01	1.40															
FR	107.99	174.42	19.13	4.33	0.39	57.43	1.36	20.86	4.71	13.88															
HR	6.15	17.39		0.11	0.08	1.67	5.12	4.13		1.16															
HU	15.87	25.78		0.52	1.73	18.27	4.11	49.45	0.01	1.93															
IE	0.24	5.21				0.21				0.37															
IT	60.11	72.06	0.33	0.71	0.06	0.14	1.15	3.88	0.01	20.14															
LT		3.47		0.40	0.05	15.57			0.06																
LU	0.29	0.66		0.01		0.73				0.01															
LV	1.06	2.57		0.02	0.03	8.71			0.02	0.34															
NL	58.70	60.85		1.04	0.52	0.73			0.72	30.83															
PL	73.30	89.89		2.39	2.22	90.22			0.11	10.50															
PT	40.67	47.69	3.32	0.53	0.002	0.01	0.00	0.09	0.01	3.91															
RO	49.00	107.82		0.37	0.04	2.12	2.71	9.21	0.005	6.18															
SE	2.01	11.84		0.66	0.58	13.78				0.90															
SI	6.13	6.99		0.09	0.94	0.44	0.04	0.02		0.12															
SK	2.27	2.11		0.16	0.20	10.59	0.53	5.00	0.004	0.19															
UK	26.57	153.25		6.25	2.56	91.90			0.05	4.36															
EU	796.72	1266.69	62.06	22.57	21.84	663.24	19.64	117.66	7.96	151.24															

b) Use table

We are also able to distinguish between the SNA met production which represents met demand (i.e. overlapped by the presence of pollination service, with medium and high pollination potential) from the SNA unmet production which represents the unmet demand (i.e. not overlapped by the pollination service), according to the applied biophysical model. The use table (Table 4.6 (b)) shows that a remarkable part of SNA production is not benefitted from pollination.

The unmet demand of crop-pollination highlights that there is room to enhance crop pollination. This could generate i) higher production and/or (ii) more sustainable production practices in countries where pollinator-dependent crops do not receive enough crop pollination service. To invest in creating habitat suitability for crop-pollination could in fact: (i) increase crop production and/or (ii) reduce the human factors (especially chemical fertilizers) in the production process by keeping the same amount of production.

The two options vary according to the characteristics of different areas and to the current management practices currently in place. This analysis remains an interesting issue to be explored, especially when coupled with the provisioning service "crop production" and the intensity versus extensive agricultural management practices.

The actual flow of crop pollination is 3.1 billion euro for the EU-28 in 2006. This value is not as high as reported by other studies (e.g. Breeze et al., 2016; Gallai et al., 2009). These studies apply the dependency ratio to the market value (as suggested by (Gallai & Vaissière, 2009), assuming that the whole extent of crops (i.e. demand) is covered by the pollination potential. Our application shows that for pollinator-dependent crops, about 66% of production depends on the service of crop pollination. The actual flow is then only processed for the 66% of the production rather than the 100% of production. Therefore, practitioners should keep in mind that:

1) Different crops have different dependence on pollination and different prices on the market. Any aggregation undertaken disregarding those peculiarities could be misleading;
2) Different crops record different pollination contribution across countries (Table 4.5). Any spatial aggregation aiming at averaging values for the EU would hide these differences and not allow highlighting the role of this service for those countries that have a production specialization in pollinator-dependent crops.

When it comes to valuation, we experiment a fast-track approach that starts from the current SNA production and attempts to disentangle from it the contribution of ecosystem service. In this case, the role of the biophysical assessment is crucial to estimate the pollination contribution that defines the "amount" of the ecosystem service itself. In this way, we are able to not only attribute what is provided by ecosystem (as services) but also what of the current production is covered by the ecosystem service and what remain uncovered.

For what concerns this specific application, many limitations could be easily overcome when more detailed datasets on agricultural production might become available.

4.4 Limitations and further developments of crop pollination accounts

As mentioned for the outdoor recreation approach, all models present a number of **LIMITATIONS**. Some of the limitations are intrinsic to the fact that a model is a simplification of the reality, with the aim of making a particular feature (e.g. a phenomenon, a part of the world, a problem, etc.) easier to study, simulate, quantify, understand, and represent. Therefore, modelling requires the adoption of different assumptions.

In this section, we discuss the main limitations of the modelling approach adopted for the crop pollination accounts. All this limitations should be considered to ensure that the outputs of ecosystem service accounts are correctly interpreted and used to inform policy.

The most important limitation of the model used to assess **pollination potential** is the **lack of local data on pollinators' presence and abundance**. We have used records on bumblebees' presence to assess the capacity of the environment to provide a suitable habitat (i.e. the environmental suitability) across the EU-28. While their spatial resolution is acceptable for a continental-scale investigation, it is too coarse to capture the influence of local features (e.g. environmental elements) on the resulting suitability. As in any assessment, therefore, also the model predicting pollination potential would significantly benefit from additional observations gathered on the field, following consistent protocols throughout the whole EU-28, and made available to the modellers at their original resolution (i.e. sampling unit, field level).

A different issue is pollinator abundance. Notwithstanding the importance of numbers of individuals versus simple presence of a species, we believe that gathering information on abundance across the extent of EU-28 would be extremely difficult, and possibly not cost-effective. Data on abundance would require an enormous amount of resources (e.g. surveyors, time, skills, and money), including the possibility to repeat the data collection at different intervals (e.g. to distinguish noise within the data from real differences). For these reasons, they can only be gathered over limited extents, making any upscaling very difficult, if not impossible or poorly supported by evidence. In addition, we have only partial knowledge to quantify the relations between number of insect pollinators and effective pollination (and, ultimately, seed set and resulting yield). This knowledge comes from experiments under controlled environments (be that field or lab), which must necessarily consider only a limited number of variables (and only consider a few species at the time). For these reasons, again, inferring patterns that can be transferred to conditions very different from the experiment can be extremely challenging, and highly risky.

We strove to include the best available information (e.g. pollinator and environmental data, established relations) and expert knowledge to assess the environmental suitability at the basis of the pollination potential. The results, bound between 0 and 1, are an indicator of the relative capacity of the environment to support insect pollinators and, hence, of the pollination potential. The continuous numbers from 0 to 1, however, had to be necessarily converted into a binary outcome (either presence or absence) to allow us produce a map identifying the Service Providing Areas (i.e. where pollinators are considered to be present). Unfortunately, there is **no scientific evidence to take a sound decision on the threshold distinguishing presence from absence**. This is a well-known issue, common to many different research fields and addressed by a vast body of literature (Jiménez-Valverde & Lobo, 2007; Liu et al., 2005; Liu et al., 2016; Schulp et al., 2014).

Another limitation we faced while assessing pollination potential is the **lack of data on some of the environmental pressures** affecting pollinators, due to the scarcity of spatial information on these pressures. One of the pressures for which we only have partial information, for instance, is the pesticide load.

The assessment of the **demand** (pollinator-dependent crops) also presents some limitations, such as the **lack of official statistics on the distribution and yield of different crop types at a detailed spatial resolution**. For this purpose, we used data derived from CAPRI model; however, official data are likely to improve the consistency of the results and the regular update as new release of official statistics become available.

The **actual flow**, ideally, **should be calculated based on the effective pollination** (i.e. number of visits by pollinators to the flowers of pollinator-dependent crops). However, data availability hinders the assessment of the actual flow in these terms, making the assessment in these terms practically impossible at continental scale.

In relation to the **valuation technique**, we have applied a **'fast-track' approach** that disentangles the contribution of pollination from agriculture economic accounts. It presents the advantage of avoiding the issue of double counting, and of using data sources that are fully harmonized with the System of National Accounts. The drawback is the current lack of disaggregated data that allows us collecting at the same time information on specific crops (with the level of details provided in Table 4.4) and on the costs incurred by farmers during the production process. Alternative valuation methods available (Allsopp et al., 2008; Breeze et al., 2016; Hanley et al., 2015) could also be tested. In this case the valuation would need to be adapted and harmonized in order to (i) avoid overlapping with SNA product and (ii) be consistent with SNA transaction price approach. Few references on applicable valuation techniques are available in the "Crop pollination" factsheet (La Notte et al., 2017).

Since the main limitations of our approach are derived from scarcity of data, further developments could be undertaken once the data for the modelling approach here proposed become available.

4.5 Potential applications of crop pollination accounting

Accounting of crop pollination has a number of applications to support policy-decisions in relation to land planning and ecosystem restoration. The main outcomes of crop pollination accounting are summarized in Box 3.

Box 3. What does crop pollination accounting show us?

- At the EU level, there is an actual flow of 13 million tonne of food production attributable to crop pollination, with a value of 3.1 billion euro in 2006,
- Agriculture is the user of the service: fresh fruits show the largest value of the actual flow (2.1 billion euro in 2006),
- There is an overall increase in the use of the service, mainly due to the increase of the demand, but also to an increase of the overlap between pollination potential and demand,
- Spatial maps can be used to support policy decisions in the prioritization of ecosystem restoration: increase the extent of the unmet crop demand (50%) can contribute to increase the service flow and the benefit generated.

As mentioned in previous sections, the spatial analysis required for the accounting of crop pollination is a useful tool to identify priority areas for ecosystem restoration. An enhancement of the pollination potential in those areas where there is high unmet demand should be prioritized for the deployment of Green Infrastructure. As described before, this kind of measures would contribute to increase the benefit generated by the service; mainly food products.

Importantly, the Commission published on 1 December 2017 a Roadmap[8] for the EU Pollinators Initiative. In spite of the limitations that our approach presents (as described above), it constitutes one of the first applications of crop pollination assessment and accounting, grounded on the best available scientific knowledge and data at the EU level. In this sense, accounting of crop pollination could contribute to the following specific objectives:

- Improving knowledge on pollinators: using the best available data and methods we provide a scientifically sound assessment of the pollination potential (based on environmental suitability for pollinator), the demand for crop pollination and the actual flow (both, in quantitative and qualitative terms);
- Tackling the causes of the decline of pollinators: spatial maps depicting the use of crop pollination (Figure 4.7) can support the planning of maintenance and restoration of diverse pollinator habitats. Similarly, these maps can also be used to prioritize areas where pesticide use should be reduced, to decrease the risks of negative impacts on pollinators;

[8] http://ec.europa.eu/environment/nature/pdf/roadmap-for-the-eu-pollinators-initiative.pdf

- Raising awareness and improving collaboration and knowledge sharing: the translation of the biophysical service model into monetary terms is a useful tool to raise awareness about the importance of crop pollination.

5 Conclusion

This report presents the current state-of-the art for the EU-wide accounting of outdoor recreation and crop pollination. The accounts showed clearly illustrate all different steps required for ecosystem service accounting:

1) Biophysical models quantify the service potential and demand, which are then used to estimate the actual flow;

2) The monetary valuation of the actual flow by applying a suitable valuation technique for the translation of the ES flow into monetary terms;

3) The accounting tables, reporting biophysical or/and monetary units (for illustrative purposes, we only showed monetary units).

Appendix V presents the main maps used for the ecosystem service accounts, in which ecosystem service potential, demand and actual flow is presented for outdoor recreation and crop pollination.

It is important to notice that ecosystem service potential, as shown in this report, is usually assessed using a dimensionless indicator. However, this indicator needs to be transformed to delineate the service providing areas, as illustrated for recreation with the 'areas for daily recreation' and for crop pollination with 'areas with different level of pollination potential'. To make this possible, some assumptions and decisions need to be taken, for instance in relation to the choice of thresholds adopted. In absence of better evidence, we used our knowledge of the systems to guide our choices.

The assessment of the actual flow of the service is an area that requires further research. In the field of ecosystem services, the service potential is assessed more frequently than the actual flow. The estimation of the actual flow involves a higher level of complexity arising from the integration of the socio-economic system (the demand) and the complex spatial relationships between the demand and the service providing areas. For outdoor recreation, proximity between recreational areas and population (users) is a key parameter to estimate the service flow; while in the case of pollination there must be spatial overlap between pollination potential and demand for pollination; in other words, pollinators need to be where pollinator-dependent crops are grown. In this sense, biophysical models for the ecosystem services are essential to understand changes over time and develop policy measures targeting the enhancement of ecosystem services, and the benefits they provide.

Another level of complexity arises from the fact that the use of the service is a measure of flows, and, as such, needs to be quantified in biophysical units per year. This conversion into biophysical units is usually determined by the chosen valuation method. For instance, for outdoor recreation, the actual flow was measured as the number of potential visits in a year, because the valuation method was travel cost (see Appendix I).

This report presents one of the first stages needed to develop a full ecosystem service accounts for a representative number of services. However, services vary among them, as illustrated in this report for outdoor recreation and crop pollination. Therefore, the standard methods described to perform ecosystem service accounts need to be adjusted for the particularities of each service.

Finally, further development of accounting applications for ecosystem services is required. The accounting tables filled for a representative number of ecosystem services may become a useful tool to aid the analysis of bundles of ecosystem services including provisioning, regulating and maintenance, and cultural ecosystem services; and to look at potential synergies and trade-offs among them. Consistent application of the same accounting methodology across the different EU member states will enable sound comparisons between countries and over time.

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List of abbreviations

(Alphabetically ordered)

ES - Ecosystem services

EU - European Union

KIP INCA - Knowledge Innovation Project on an Integrated system of Natural Capital and ecosystem services Accounting

LAU – Local Administrative Unit

NPV – Net Present Value

SEEA-AFF - System of Environmental-Economic Accounting -Agriculture, Forestry and Fisheries

SEEA-CF - System of Environmental-Economic Accounting Central Framework

SEEA-EEA – United Nations System of Environmental-Economic Accounting- Experimental Ecosystem Accounts

SPA - Service Providing Area

TCM - Travel Cost Method

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Appendices

Appendix I: Outdoor recreation assessment

Potential to support outdoor recreation

The ESTIMAP model for recreation (Zulian et al. 2013; Paracchini et al. 2014) is based on "Advanced multiple layers LookUp Tables" (Advanced LUT) method. Advanced LUT assign ecosystem service scores to land units based on cross tabulation and spatial composition derived from the overlay of different thematic maps. ES scores for each input layer are derived from literature and from an expert-based approach (Zulian et al. 2017).

The model provides a spatially explicit assessment of the ecosystems potential to provide nature-based outdoor recreational and leisure opportunities. It consists of two basic sections:

(1) The Ecosystem-Based potential Map (EB Potential), which estimates the potential capacity of ecosystems to support nature-based recreation activities;

(2) The human inputs map, which integrates a proximity-remoteness concept in relation to the road network and residential areas

Both, the EB potential and the human inputs are combined for the assessment of daily recreation opportunities as a measure of the recreation potential.

Appendix-Figure 1 presents the model adapted for the account. This configuration is slightly simplified, compared to the original one. In order to assess a time series, all input data with no time series available were excluded. The original terminology of the model has also been changed for consistency with the terminology used in accounting.

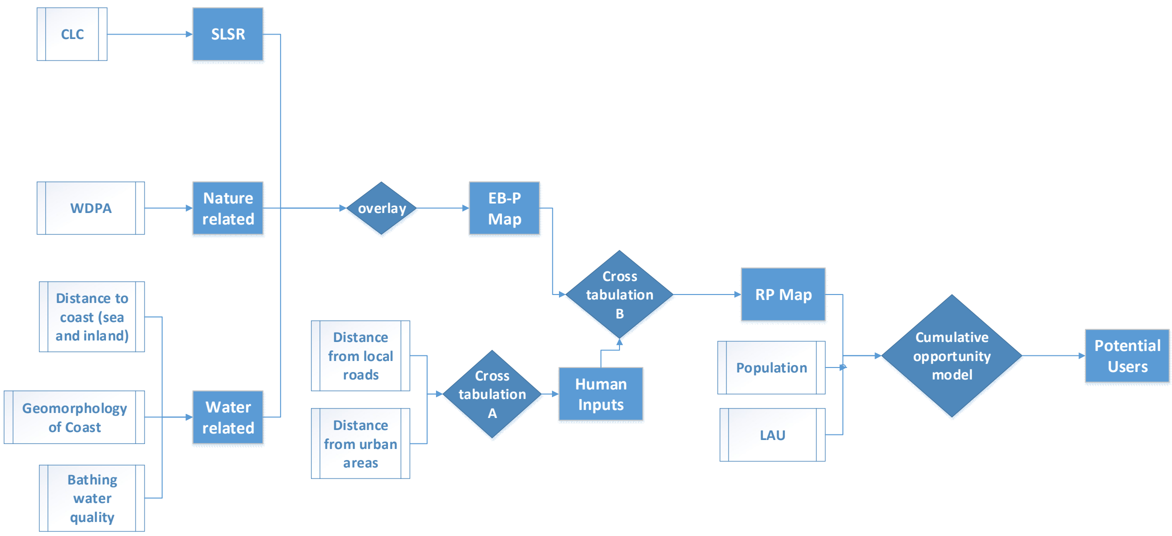
The Ecosystem-Based Potential Map (EB-P Map in Appendix-Figure 1) depends on three components:

1. Suitability of land to support recreation (SLSR in Appendix-Figure 1): land use types contribute differently to the provision of recreation opportunities [very low or close to 0 in industrial or high urbanised areas or potentially very high in semi-natural areas];
2. Inland natural elements (Nature-related in Appendix-Figure 1): this component includes other features that play a role in the provision of nature-based opportunities9, such as the presence of natural protected areas. Natural protected areas are scored according to the IUNC management categories for protected areas10, the score matrix has been derived from the analysis of management objectives, see
3. Appendix - Table 1.
4. Water related elements (Water related block in Appendix-Figure 1): the presence of water represents a key element for nature based leisure and recreation practices

[9] In the complete version of the model, we consider also the presence of semi-natural vegetation and the presence of natural riparian zones.

[10] http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/

(Jennings 2007; Ghermandi 2015). As proxies for this component, we consider sea coastal and inland elements. The first group is represented by geomorphology of coast, proximity to sea coast and presence of marine protected areas. The second group is represented by the proximity to lakes. Bathing water quality compliant with the EU Bathing Water Directive11 is also considered.



Appendix-Figure 1. Structure of ESTIMAP-recreation model.

Appendix - Table 1. Cross tabulation between management objectives and IUNC categories and related score for the recreation potential map; table derived and modified from Eagles et al. 2002.

Management objective	IUNC categories						
	Ia	Ib	II	III	IV	V	VI
Scientific research	1	3	2	2	2	2	3
Wilderness protection	2	1	2	3	3	–	2
Preservation of species and genetic diversity (biodiversity)	1	2	1	1	1	2	1
Maintenance of environmental services	2	1	1	–	1	2	1
Protection of specific natural/ cultural features	–	–	2	**1**	3	**1**	3
Tourism and recreation*	**–**	**2**	**1**	**1**	**3**	**1**	**3**
Education	–	–	2	2	2	2	3
Sustainable use of resources from natural ecosystems	–	3	3	–	2	2	**1**

[11] The EU Bathing Waters Directive requires Member States to identify popular bathing places in fresh and coastal waters and monitor them for indicators of microbiological pollution (and other substances) throughout the bathing season which runs from May to September

Management objective	IUNC categories						
	Ia	Ib	II	III	IV	V	VI
Maintenance of cultural/traditional attributes	–	–	–	–	–	**1**	2
score for the recreation potential map	**0.0**	**0.6**	**0.8**	**0.6**	**0.6**	**1.0**	**0.8**
Key: 1 = Primary objective; 2 = Secondary objective; 3 = Potentially applicable objective; – = not applicable.							

The Human Inputs Map depends on the distance from local roads and distance from residential areas. The Recreation Potential Map (RP Map in Appendix-Figure 1) depends on two components:

- Human Inputs Map, reclassified in near, proximal, far (Appendix-Figure 2, A)
- The Ecosystem-Based Map, reclassified in very high, high, low, very low potential (see Appendix-Figure 2, B)

A

Distance from urban (km)	Distance from roads (km): <0.5	0.5-1	1-5	5-10	> 10
<0.5	1	1	2	3	4
0.5-1	1	1	2	3	4
1-5	2	2	2	4	5
5-10	3	3	4	5	5
> 10	3	4	4	5	5

Human Inputs	
near	1
	2
proximal	3
far	4
	5

B

Himan Inputs classes	EB-P classes: very low 1	low 2	high 3	very high 4
5	1	1	4	7
4	1	4	4	7
3	2	2	8	8
2	3	5	5	9
1	3	6	6	9

RP categories		
low provision	far	1
	proximal	2
	near	3
medium	far	4
	proximal	5
	near	6
high	far	7
	proximal	8
	near	9

Appendix-Figure 2. Cross tabulation models to derive A: the Human Inputs map and B: the Recreation Potential Map.

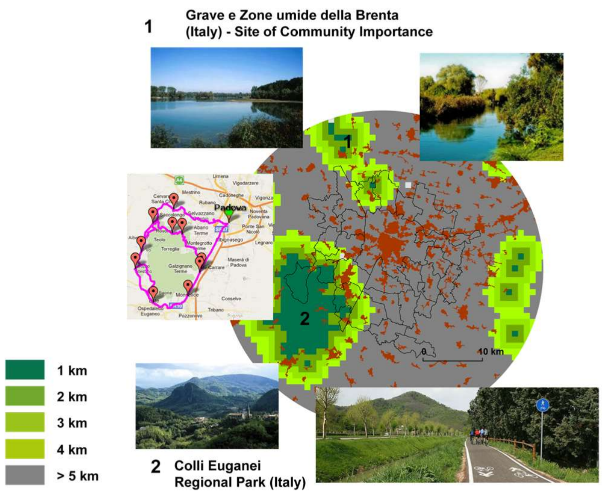
Spatial analysis of outdoor recreation demand

For the spatial analysis of the demand we used a cumulative opportunity model (Vale et al. 2015). This model assess the share (percentage) of population within each Local Administrative Unit (LAU) that lives at different distances from the 'areas for daily recreation'. 'Areas for daily recreation' were extracted from the Recreation potential map (class 9 of the Recreation Potential Map, see Appendix-Figure 2, B). Population data were taken from the global human settlement dataset. This spatial raster depicts the distribution and density of population, expressed as the number of people per 1 km cell[12].

The cumulative opportunity model was structured as follow:

- Create 5-distance buffers: from 1 to 4 km and beyond 4 km see Appendix-Figure 3;
- Extract at LAU level the inhabitants that live within the 5-distance buffers. Inhabitants within 4 km from the 'areas for daily recreation' were considered in terms of 'met demand' and considered for the assessment of the actual flow and those beyond 4 km as the 'unmet demand'.

Appendix-Figure 3 provides an illustration of the distance buffers from 'recreation areas for daily use' in the surroundings of an urban area in Padova, Italy.



Appendix-Figure 3. Schematic representation of the distance buffers from 'areas for daily recreation'

[12] Residential population estimates for target years 1975, 1990, 2000 and 2015 provided by CIESIN GPWv4 were disaggregated from census or administrative units to grid cells, informed by the distribution and density of built-up as mapped in the Global Human Settlement Layer (GHSL) global layer per corresponding epoch.

Actual flow of the service: mobility model

The proportion of visits (i.e. portion of population that makes visits) to outdoor green areas is the key component that defines the economic value of outdoor recreation as ecosystem service. This value is rarely known to policy makers to be able to properly account for this ES although some Member States have recently started collecting outdoor recreation data (e.g. Netherlands, Great Britain).

An established approach to value outdoor recreation is to estimate a trip generating function (e.g. Sen et al 2013) and using this information we can infer the economic value of outdoor recreation via, e.g., travel cost method. The trip generation function estimates a quantified relationship between number of outdoor visits and explanatory variables, such as population, outdoor recreational spaces and distance to these spaces. Alternative approaches have been used in the mobility literature to derive accessibility (or number of visits) to shopping centre, jobs or stations. These approaches derive statistical functions like:

1. gravity or opportunities approach,
2. constraints-based approach,
3. utility-based surplus approach, and
4. composite approach

With the final objective of defining whether two locations of interest (e.g. housing area to jobs locations) are connected and generate visits.[13]

Example of this approach is (Zulian et al., 2013) who employ a log-logistic function originally derived by Geurs and Ritsema (2001) to determine the accessibility to coastal areas and outdoor recreation visits. In a template case study where you have a single recreational site and 2 outsets locations at 5 km and 10 km distance, the access rate (or number of visits) is defined as a function of distance to the site and population in each sub-zone (respectively 1500 and 800).

$$(1)\quad N_{visits} = P_{area1} * \frac{(1+K)}{(k+\mathrm{e}\quad(\alpha * Dist_{area1})} + P_{area} \quad * \frac{(1+K)}{(k+\exp(\alpha * Dist_{are}\quad)}$$

$$= 1500 * f(d\_5) + 800 * f(d\_10)$$

According to distance, the $f(d\_i)$ function can get different values. For a long distance, alfa is 1.13E-03 and K 450, for closer distance alpha is equal to 3.50E-03 and K to 150. Therefore the equation (1) assumes different values accordingly to distance buffers as better described in Geurs and Ritsema (2001).

[13] A reference for accessibility model is: https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/journal_of_transportation_and_statistics/volume_04_number_23/paper_03/index.html

One option to value the outdoor recreation in context of EU NCA project is to use these values; however, they might not be adequate as they were estimate in different geographical and temporal context.

We explore the possibility to re-calibrate the parameters k and alfa from above equation (1) using observational data from recreational visits collected in England in the period 2009-2013. England collects every year roughly 40k observation of natural based visits to local amenities recording weekly diary of visits.

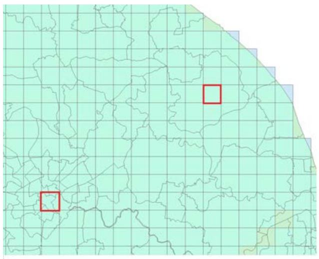
Alternatively, the England dataset can be used to develop a new functional form altogether for the trip generation function.

Although there is a concern about the representativeness of the English dataset for the whole Europe, it still represents the best available dataset for the first attempt to derive outdoor recreational values for the EU NCA. Further, it is possible to adopt similar approach when further, perhaps EU-wide, data of this type will be available in the future.

Data preparation

The observational units for this exercise are the Local Aministrative Units (LAU) or UK-Wards for which observational recreational visits are available and consequently can be produced for other EU MS. The data preparation has been carried out with the support of JRC ArcGIS team.

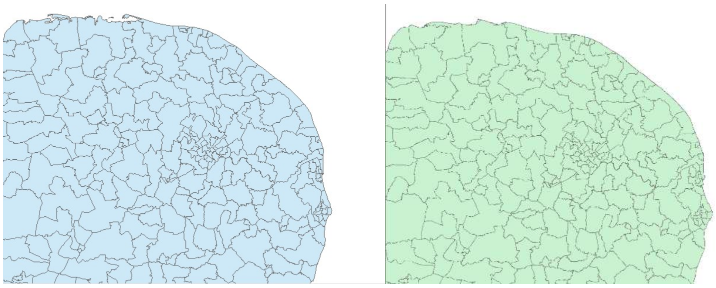
The original England recreational dataset (MENE) reports finer spatial zones (LSOA) or 2 km grid squares. Therefore, the first attempt was to merge England cells with EU LAU cells. The figure on the right describes the overlay of England grid cells and LAU.



Appendix-Figure 4. Overlay of UK LSOA with EU LAU

In many cells, several LAUs correspond to a single grid cell (max 66 LAU for a grid cell), in many other the opposite is true (see the two red squares in figure above). This poses some challenges on how to process the data.

The second attempt was to overlay the LSOA revealed preference data (the MENE dataset) with the JRC recreational biophysical model for ROS type 1-3. UK-ONS arranges LSOA in Wards and they are equivalent to EU LAUs (see Appendix-Figure 5).



Appendix-Figure 5. England Wards (left side) and EU LAU (right side)

This correspondence guarantees that we can aggregate LSOAs in Wards and produce estimates applicable at EU LAU level.

In order to prepare the data for deriving the outdoor recreational visits LSOA areas and the areas for daily recreation have been overlaid in ArcGIS and 5 distance buffers were created between green amenities and population. In this procedure, we refer to the RP categories shown in Appendix-Figure 2 as follows: (i) we always consider the closest distance from recreational areas, (ii) we do not only consider the recreational areas with the highest ecosystem-based potential but also the areas with medium and low ecosystem-based potential. The Recreation Opportunity Spectrum (ROS) is named as follows:

- ROS1: high ecosystem-based potential and high accessibility (RP 9 in Appendix-Figure 2);
- ROS2: medium ecosystem-based potential and high accessibility (RP 6 in Appendix-Figure 2);
- ROS3: low ecosystem-based potential and high accessibility (RP 3 in Appendix-Figure 2).

The distance was calculated as the straight-line distance from a centre of LSOA to a centre of ROS-type 1-3 and classified in 1-5 as follows:

1 = from 0 to 1 km

2 = from 1 to 2 km

3 = from 2 to 3 km

4 = from 3 to 4 km

5 = more than 4 km

<u>MENE and ROSs Data analysis</u>

For any LSOA: the MENE data provides the total number of visits per week for given LSOA and the JRC model provides the proportion of ROSs areas in the LSOA (% of land in hectares).

Analysing the MENE data we examine whether the number of visits might be influenced by the extent of land under ROS1, ROS2 and ROS3 from the biophysical model. Summarizing the percentage of each ROSs, we observe that the main ROS type is ROS1 with a median percentage greater than 0 (see Appendix - Table 2).

Appendix - Table 2. ROS extent statistics.

	ROS_1	ROS_2	ROS_3
%_average	33.60	19.44	6.89
%_median	22.2	0	0
%_st.dev	33.68	27.29	16.71
CV (Coef_var)14	1.002	1.40	2.42

On average 33% of Land is ROS1, 19% ROS 2 and 7% ROS3 across sampled LSOAs in England.

Per each surveyed LSOA we can further consider the probability of recreational visits as the ratio between weekly total visits and population in the area. The main stats – reported below- suggest on average a 2.3% visitation rate and a median of 1.3% visitation rate per week in sampled LSOAs.

Appendix - Table 3. Probability of recreational visits.

	ProB visits
%_average	0.023
%_median	0.013
%_st.dev	0.028
CV_Coef_variation	0.82

From the CV (coefficient of variability; between 0 and 1) it is clear that the variability of visits is quite high and the average number of visits differs significantly from the median.

Classifying the proportion of visits in quartiles, as in table below, we can observe whether the extent of ROSs might influence on average probability of outdoor visits (independently of the distance).

The table above shows that the average probability of visits can be explained by the extent of ROS. Especially for ROS1 the probability of visits increases with the extent of ROS (1-2 quartile present a similar extent of ROS1 which is significantly smaller than extent of ROS1 for quartile 3 and 4). For ROS2 and ROS3 we can observe a significant increase in probability of visits from quartile 1 and 2 whereas quartile 3 and 4 present a less clear impact on probability of visits.

Overall, the Pearson chi squared test of the two-way tables above shows a significant association between probability of visits and ROSs extent. This positive result suggests that we might proceed to establish a parametric correspondence between visits and ROS.

[14] Coefficient of variation measures the relative variability of data. It is standard deviation/mean.

Appendix - Table 4. Probability of recreational visits in relation with ROS extend.

Quartile	%_probability of visits	ROS1		ROS2		ROS3	
		mean	St.dev	mean	St.dev	mean	St.dev
1.00	<0.004	32.78	33.10	21.22	27.86	7.73	17.42
2.00	0.004-0.013	32.18	31.80	22.63	27.73	9.34	18.91
3.00	0.013-0.03	35.24	33.48	20.23	27.38	7.41	17.54
4.00	>0.03	34.22	36.17	13.71	25.31	3.10	11.31

We estimate the following regression analysis, number of visits as a function of IROSs extent:

$$(2) \qquad N_{visits} = I_{ros1} * \beta_1 + I_{ros2} * \beta_2 + I_{ros3} * \beta_3 + \varepsilon$$

Setting ROS2 as baseline, we derive the Beta parameters for ROS1 and 3. Both parameters are significant and with expected signs. ROS 1 increases by 11% the probability of visits comparing to ROS2 and ROS3 decreases this probability by 7% [15].

Considering an initial uniform distribution of visits among the three ROSs we can conclude that ROS1 attracts 44% of visits, ROS2 33% and ROS3 26%.[16]

Appendix - Table 5. Derivation of Beta parameters for ROS1.

Number of visits	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
Beta_ROS1	10.56996	1.64972	6.41	0	7.335658	13.80426
Beta_ROS2	0	(omitted)				
Beta_ROS3	-7.1168	2.641698	-2.69	0.007	-12.2959	-1.93771

<u>Models deriving number of visits for EU LAUs</u>

Using the MENE data we can derive alternative approaches to predict number of recreational visits to EU_LAU. The England dataset was arranged in WARD units to facilitate transferability of model results.

The first approach is a trip generation function, which employs a count model (Quasi Poisson). In the Poisson model, we aim to estimate the mean of the distribution as:

$$(3) \qquad N_{visits} = \exp(Pop\_d_1 * \alpha_1 + \cdots + Pop\_d_5 * \alpha_5 + Subs_{d1} * \gamma_1 + \cdots . + Subsd_5 * \gamma_5)$$

where "Pop_x" refers to the population living in buffer "x", with x=1,…5, representing the distance buffers and "Subs_x" takes value 1 whether in buffer x just one type of ROS is

[15] The ROS_outside the LSOA was include in the model when it presents 100% of extent and its parameter value was very small and was removed from the model exercise.

[16] This probability distribution is based on MENE data and is crucial for results. Sensitivity of results to this assumption should be tested.

available, 2 whether 2 ROSs are available and 3 if all ROSs are present. These variables aim to capture a sort of substitution effect of other recreational areas comparing to the centroid (ROS1).

Once the total number of visits per LAU is obtained, we can distribute the visits per ROS type using the proportion of ROS available and weighting for the higher attraction of ROS1 44%, lower for ROS2 33% and ROS 3 (26%) derived from the calculations above (see page 4).

Once the number of visits is predicted, the economic valuation can progress using the zonal travel cost model previously reported in the template file "TGF with EU distance Equation_example".

The trip generation function approach has been validated by using the MENE data to compared observed and predicted visits. Predicted estimates are lower than observed and we believe that this is a strength of the model as it presents conservative estimates of recreational values.

As an alternative, we estimate a statistical approach, which aims to derive the Number of visits following the equation (1) similarly to Geurs and Ritsema (2001). The log-logistic function has been specified as in equation 4:

$$(4)\ N_{visits} = \frac{(1+K)}{(k+\exp(\alpha * Pop\_d1)} + \ldots. + P_{area2} * \frac{(1+K)}{(k+\exp(\alpha * Pop\_d5)}$$

Where Pop_dx represents the population in distance x. The parameters of interest are k and alfa and estimates are reported below:

Appendix - Table 6. Parameters of the mobility function.

	k	alfa
DIST_1	0.0132500	0.001547
DIST_2	0.02677	0.00115
DIST_3	5.18E-02	9.82E-04
DIST_4	0.10670	0.00067
DIST_5	0.07424	0.00059

Applying these estimates at EU_LAU, we can derive the number of recreational visits using the accessibility approach. Contrary to previous approach, the only information needed for this approach is the population in the 5 distance buffers from the centroid recreational site. To apply this approach it is necessary to follow this calculation given as example in the following equation and table (Appendix-Table 7):

N_{visits}=*(1+0.0132500)/(0.0132500+exp(-0.001547*3007))+*
*(1+0.02677)/(0.02677+exp(-0.00115*3320))+*
*(1+5.18E-02)/(5.18E-02+exp(-9.82E-04*2153))+*
*(1+0.10670)/(0.10670+exp(-0.00067*2153))+*

*(1+0.07424)/(0.07424+exp(-0.00059*2153))= 78*

Appendix - Table 7. Probability of recreational visits in relation with ROS extend.

LAU	pop_d1	pop_d2	pop_d3	pop_d4	pop_d5	Predicted visits
1	3007	3320	2153	2153	2153	78
2	2041	2041	2041	2041	3459	40
3	3366	2272	2272	2272	2272	78
4	2003	3256	2003	2003	2003	49

Input data

Model	Variable	Temporal Coverage	Data source
Ecosystem-based potential	Land use (CLC)	2000, 2006, 2012	Corine Land Cover (CLC) from EEA (http://www.eea.europa.eu/data-and-maps)
	Protected areas (PA)	2000, 2006, 2012	World database of Protected areas https://www.iucn.org/theme/protected-areas/our-work/world-database-protected-areas
	Bathing Water Quality (BWQ)	2000, 2006, 2012	State of Bathing water https://www.eea.europa.eu/themes/water/status-and-monitoring/state-of-bathing-water/state/state-of-bathing-water-3
	Distance to Coast (sea and inland water bodies) (DC)	2000, 2006, 2012	CLC 1990, 2000, 2006 and 2012 from EEA (http://www.eea.europa.eu/data-and-maps)
	Coastal geomorphology (CG)	2000, 2010	EUROSION Coastal Erosion Layer (Eurosion 2005)
Human inputs	Tele atlas (RN)	2013	"Tele Atlas Map Insight". Tele Atlas. Retrieved 2013.
	Residential areas (RA)	2000, 2006, 2012	Corine Land Cover (CLC) from EEA (http://www.eea.europa.eu/data-and-maps)
Spatial analysis of the demand	Local administrative units (LAU)	2015	http://ec.europa.eu/eurostat/web/nuts/local-administrative-units
	Population (POP)	2000, 2015	Global Human Settlement Layer http://ghsl.jrc.ec.europa.eu/ghs_pop.php

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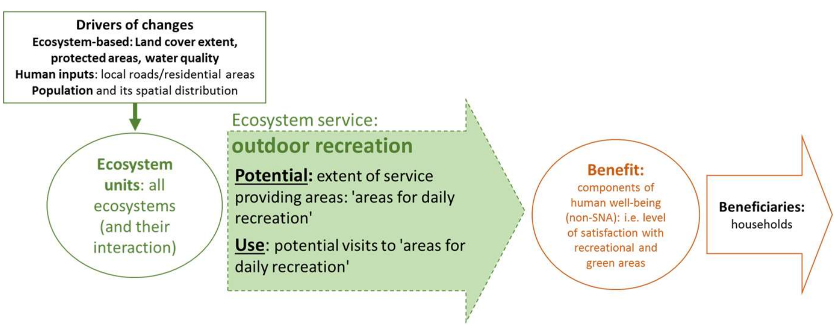
Appendix II: Factsheet outdoor recreation

OUTDOOR RECREATION ON A DAILY BASIS

Definition	The biophysical characteristics or qualities of ecosystems that are viewed, observed, experienced or enjoyed in a passive or active way by people on a daily basis (modified from CICES V5)	
Ecosystem types	All ecosystem types. Interaction among different ecosystem types may be translated in a positive effect in terms of ecosystem-based potential offering opportunities for recreation	
Economic unit	Users of the service	Households
	Beneficiaries	Households, sports activities and amusement and recreation activities, tourism related services (food and beverage), public health system
SEEA-EEA ecosystem accounting model		

CONCEPTUAL DEFINITION OF INDICATORS

ECOSYSTEM SERVICE

Potential	Ecosystems potential to provide outdoor/nature-based recreation opportunities for a daily basis measured as the hectares of 'areas for daily recreation' (i.e. high quality for recreation and close to human settlements and roads (ESTIMAP toolbox)
Use	Actual flow of outdoor recreation is assessed as the potential number of visits to 'areas for daily recreation' in a one-day trip (annual values)

SOCIO-ECONOMIC SYSTEM

Demand	Population
Unmet demand	Population living beyond 4 km from 'areas for daily recreation'
Benefit	Components of human well-being (non-SNA benefit): level of satisfaction with recreational and green areas

DRIVERS OF CHANGES IN THE MODELLING FRAMEWORK

Dynamic variables: land cover extent, protected areas, geomorphology of coast, marine water clarity, road network, population

VALUATION METHODS

Two steps are needed to calculate and value the actual flow:

1. Building a mobility function in order to assess the number of potential visits from local population, different parameters are calibrated for different distances
2. Attributing a travel cost (roundtrip) to each visit according to the Zonal Travel cost approach; increasing distances will (i) increase the cost of travelling, but (ii) dramatically decrease the number of visits.

Appendix III: Crop pollination assessment

Potential to support insect pollinators

A spatial indicator for the 'pollination potential by wild insect pollinators' across the European Union is estimated through an assessment of the *suitability of the environment to support wild insect pollinators*, using two complementary approaches: an Expert-based Model (EBM) and a Species Distribution Model (SDM) (Appendix-Figure 6). More specifically, we build upon previous work undertaken by JRC staff, which has resulted in an EBM with a spatial resolution of 1 ha (100 x 100 m grid-cell) (Zulian *et al.*, 2013), and a SDM based on bumblebee records, with a spatial resolution of 100 km^2 (10 x 10 km) (Polce *et al.*, 2013). Each of these approaches has some strengths and weaknesses: the EBM for instance, has the advantage of being able to account for the effect of detailed local information, such as the presence of wild flower edges between crop-fields, or other small patches of habitat suitable for pollinators. The EBM, however, might fail to reflect the environmental suitability for poorly known species, or to capture environmental characteristics that can modify the expected suitability (e.g. climatic differences) or, again, it might not be able to predict species richness. The SDM, on the other hand, has the advantage of being informed by actual species records, but it is constrained by the spatial and temporal resolution of these records. Hence, the SDM might fail to capture the effect of local landscape elements, if their accuracy is greater than what is available for the species records. By integrating the EBM and the SDM approach, therefore, we should be able to reflect better the environmental suitability to support wild insect pollinators (and, hence, the pollination potential).

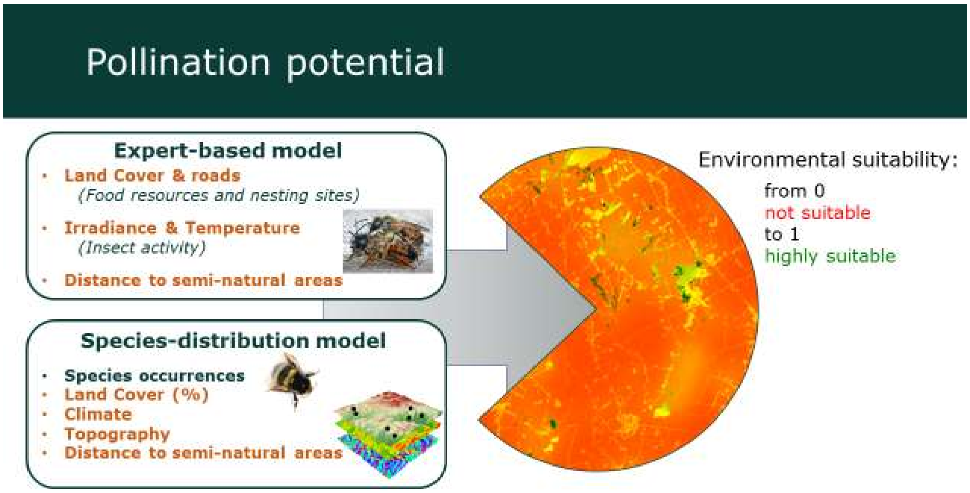
Both models provide a 'suitability score' between 0 and 1 for each grid-cell. The 'suitability' is often interpreted as the '*capacity of the environment to support insect pollinators*' (EBM) or the '*probability of occurrence of insect pollinator*' (SDM).

The EBM-suitability is based on experts' knowledge of the species ecology, solitary bees in our case. The SDM-suitability on the other hand, is derived through, e.g., statistics or machine learning techniques, which are used to characterise the 'quality' of the environment where species are recorded. In simple words, within a SDM, the relations between the environmental variables characterising the species' sightings, bumblebees in our case, are used to predict the environmental suitability across the area of interest.

Since the SDM is informed by the sightings of species, it can capture complex relations among the different variables characterising the environment (e.g. land use and land cover, climate, etc.) where species are found. Environmental suitability is interpreted as a proxy for the 'probability of occurrence' for a species, therefore, by defining a threshold it is able to distinguish potential presence from absence (Liu *et al.*, 2005).

The JRC has produced individual SDMs for 47 bumblebee species, as well as a SDM resulting from aggregating all single SDMs. The score of the aggregated SDM is the mean of the single species' model for all species predicted to be present in a given cell, with equal weights across species (weight =1/N, where N is the number of species present in a given cell).

The original models by Zulian *et al.* (2013) and Polce *et al.* (2013) were adapted to meet the requirements of the accounting, such as the need to rely on datasets regularly updated. The outputs of the updated models were then averaged to estimate the potential availability of wild insect pollinators to relevant crop groups: the ***pollination potential*** (Appendix-Figure 6).



Appendix-Figure 6. Schematic representation of the models used to assess pollination potential.

We know that agrochemicals like fertilisers and pesticides have also a negative impact on pollinators, but since the distribution and application of these products is not available over time and throughout the whole Europe, we cannot account for it, at this stage.

Input data: overview

The main features considered to estimate the environmental suitability to support wild insect pollinators are land use and land cover (LULC) elements providing food resources and nesting sites. At this stage, the most suitable candidate for LULC are the CORINE data; in particular, the accounting layers made available from the EEA, which allow us to make comparisons over time.

In addition to these datasets, we also include the major roads from TeleAtlas® Maps, to identify areas that cannot provide floral resources or nesting sites to insect pollinators (suitability = 0 for road categories 0, 1 and 2, which identify major roads).

Lastly, we include climatic variables characterising the environment. Additional details are provided in

Appendix - Table 8. Additional resources (e.g. the Pan European High Resolution Layers from Copernicus) were examined but excluded for the time being, mainly due to their lack of temporal series.

Appendix - Table 8. Input data for the spatial indicator of 'Pollination potential' (indicator of potential supply of wild insect pollinators).

Theme	Year		
	2000	2006	2012
LULC – Dynamic dataset	CORINE Accounting Layer 2000	CORINE Accounting Layer 2006	CORINE Accounting Layer 2012
Roads – Static dataset	Road network from TeleAtlas 2006 version (major roads only, corresponding to road category 0, 1 and 2); if a more recent version becomes available, it can be used from 2012 onward.		
Climate data – Dynamic dataset	Gridded Meteorological data from Agri4Cast[17] (Mean air temperature and total global radiation used for the Expert-Based model) and E-OBS[18] (minimum and maximum air temperature, sum of precipitation are used to compute the bio-climatic variables used for the Species-Distribution model - These variables were already computed and during the model calibration phase, and the most relevant one were selected.		
Species records – Static dataset	Bumblebee records from Atlas Hymenoptera[19]: • 47 species selected from ca. 60 (excluded species with very few records) • 10 x 10 km grid • 1991 to 2014		

Expert-based suitability model: scoring and model elements

The scores for the suitability of different LULC elements to provide foraging resources and nesting sites are given in Zulian *et al.* (2013).

The presence of major roads in agricultural areas has a negative effect on the capacity to support insect pollinators. Major roads are given a score of 0.

Local roads: positive effects of certain types of margin managements are documented in literature. However, the presence of a margin does not ensure, in itself, a positive effect on crop pollination services; hence, *in absence of information on the type of margin*, this evidence cannot be used.

Forest edges: a 100 m edge is computed for each forest patch; edges are then assigned the corresponding expert score for forage availability (FA) and nesting sites (NS), as described in Zulian *et al.* (2013). The rest of the forest patch is assigned FA and NS scores of 0. Forest edge can be extracted using different techniques: first, a binary raster showing 1 for Forest (CORINE LC classes 23, 24, 25, corresponding to: Broad-leaved forest, Coniferous forest and Mixed forest respectively) and 0 for other classes is generated. Next, edges are identified, using, for instance, Morphological Spatial Pattern Analysis (MSPA)

[17] Agri4Cast: http://agri4cast.jrc.ec.europa.eu/DataPortal/SignIn.aspx?idResource=7&o=d
[18] E-OBS: http://www.ecad.eu/download/ensembles/download.php
[19] Atlas Hymenoptera: http://www.atlashymenoptera.net/

with the GUIDOS Toolbox[20] (but file size can be a limiting factor), or Focal Statistics in ArcGIS (window size = 3 x 3, statistics = "variety", or "maximum" or "range", according to the software used), or the function 'boundaries' in R (type = 'inner', classes = TRUE, directions = 8, asNA = FALSE). After extracting the edges, some post-processing might be needed, such as masking out non-forest areas.

An activity index is computed, to reflect the influence of temperature and solar irradiance on insects' activity. The activity index was computed using total global radiation (KJ/m^2/day) and minimum air temperature (°C), from Agri4Cast.

The approach described in Zulian *et al.* (2013) was used to convert the radiation data to the units needed for the activity index (W/m^2). The method takes into account the latitude and the day of the year, to estimate the hours of daylight. After inspecting the formulas, I adopted the function [daylength] available within the R package geosphere v1.5-5 by Robert Hijmans (https://www.rdocumentation.org/packages/geosphere/versions/1.5-5). The function is based on the work of Forsythe *et al.* (1995).

Three temporal slots were considered:

- 1999-2001, to extract average values for 2000 LULC input year,
- 2005-2007 for the 2006 LULC input year, and
- 2011-2013 for the 2012 LULC input year.

The activity index (AI) was computed using the parameters estimated by Corbet *et al.* (1993). Monthly AI were computed using monthly radiation and temperature averages with parameters for honeybees; they were used as an indication of the activity of insects having size similar to honeybees. An overall average AI was then computed limited to the months from April to September included, for each 25 x 25 km cell of the Agri4Cast grid. This period was chosen to (i) cover the sampling period considered by Corbet *et al.* (1993) within the northern Hemisphere (April to July), and (ii) cover the typical period where crop pollinators are visiting flower, on the northern Hemisphere.

A raster with an extent matching input maps (FA, NS, CORINE LULC) was derived from the AI points (roughly 25 x 25 km spatial resolution). The raster was then resampled to 100 x 100 m using bilinear interpolation with 4 neighbouring cells.

The average between 'Floral availability' and 'Nesting suitability' was computed (rather than their multiplication, done in Zulian *et al.* (2013).

A new module that accounts for the effect of (semi-)natural areas in agricultural landscape is included: the review by Garibaldi *et al.* (2011) shows that the stability of pollination services decreases with isolation from natural areas despite honeybee visits, with greater effects for pollinators exhibiting short flight ranges. In addition, they found a 34% decrease in mean richness at 1 km distance from natural areas (semi-natural and natural). Ricketts

[20] GUIDOS Toolbox: http://forest.jrc.ec.europa.eu/download/software/guidos/

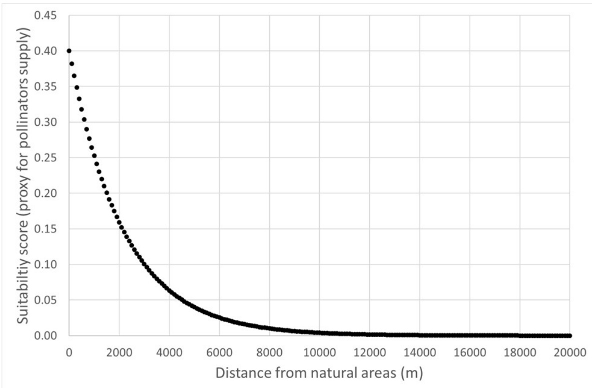
et al. (2008) found strong exponential declines in both pollinator richness and visitation rates, with distance from natural or semi-natural areas (23 studies from 5 continents). They found mean decay rate = -0.00046 and a 50% reduction in species richness at 1507 m from natural areas (50% decay).

The exponential decay model is: $Y_{ij} = \exp^{(\alpha_i + \beta_j D_{ij})} + \varepsilon_{ij}$
Where:

1. Y_{ij} = observed pollination datum in the i^{th} study;
2. D_{ij} = associated distance from the nearest natural habitat, in meters;
3. α_i=study specific intercept (the suitability score, in our case);
4. β_i = rate of change;
5. ε_{ij} = fitted error term.

Hence, for a class with score = 0.4, the model becomes. The distance decay function describes the relation between suitability score and distance from natural areas (Appendix-Figure 7). The suitability score is used as a proxy for the potential pollinators supply (and, ultimately, pollination service). The model is based on Ricketts et al. (2008).

$Y_{ij} = \exp^{(\ln(0.4) - 0.00046 D_{ij})} + \varepsilon_{ij}$



Appendix-Figure 7. Distance decay function.

Informed by Garibaldi *et al.* (2011), the following CORINE classes were considered semi-natural (Appendix-Table 3):

Appendix - Table 9. CORINE Land Cover classes defining semi-natural areas.

Code	Class
3.1.1	Broad-leaved forest
3.1.2	Coniferous forest
3.1.3	Mixed forest
3.2.1	Natural grasslands
3.2.2	Moors and heathland
3.2.3	Sclerophyllous vegetation
3.2.4	Transitional woodland-shrub
3.3.1	Beaches, dunes, sands
3.3.3	Sparsely vegetated areas

The distance map from the edge of the semi-natural areas was computed using Euclidean distance, setting a threshold of 20,000 m (i.e. maximum distance from natural areas). This large threshold was chosen to ensure to capture the effects over a sufficiently wide area.

Species-based suitability model: main model elements

Species data: x and y locations of species sightings on a 10 x 10 km grid (Coordinates of the cell center, projected to the Spatial Reference System 'Lambert Azimuthal Equal Area'). Species having the same 'prevalence' (see Maxent[21] and Polce *et al.* 2013) are grouped within the same table (saved as *.csv).

Environmental predictors:

LULC classes from the 'Corine Accounting layers' were converted to percentage cover within 10 x 10 km grid (the resolution of the species data). Some of them were discarded and others aggregated (

Appendix - Table 10).

E-OBS gridded data from 1991 to 2012: monthly averages were computed from daily minimum and maximum temperature, and daily total precipitation (taking into account of leap years). These data were used to derive the 19 bioclimatic variables (see for instance Bioclimatic Variables with R[22] and WorldClim[23]).

Average, mode and standard deviation of elevation within 10 x 10 km grid, were obtained from the Global digital elevation data based on the NASA Shuttle Radar Topographic Mission (SRTM) of 3 arc-second resolution (ca. 90 m) (Farr *et al.*, 2007, post-processed by Jarvis *et al.* 2008). This layer has been previously used within other JRC studies (e.g. Liquete *et al.*, 2013)).

An additional variable was included: the average distance from natural and semi-natural areas, as defined in Appendix-Figure 7 and Appendix - Table 9 (following Garibaldi *et al.* 2011), within a 10 x 10 km grid, rounded to the nearest meter and then converted to kilometre. The new variable is named "snd_km" (Distance from semi-natural areas), and may contain decimal values.

Following Polce *et al.* (2013), the 19 bioclimatic variables and 3 topographic layers were reduced to a set of non-collinear variables, from which the following were retained:

- bio04 Temperature seasonality (standard deviation *100)
- bio05 Max temperature of warmest month
- bio08 Mean temperature of the wettest quarter
- bio15 Precipitation seasonality (coefficient of variation)

[21] Maxent:https://biodiversityinformatics.amnh.org/open_source/maxent/
[22] Bioclimatic Variables with R: https://rforge.net/doc/packages/climates/bioclim.html
[23] WorldClim: http://www.worldclim.org/bioclim

- elmode Mode of elevations in the 10-km grid, from the original ca. 90-m spatial resolution DEM

Appendix - Table 10. Rules to aggregate and/or rename the original Corine LC 'Level 3'. 'SDM_code' identified as 'RM' were not used within the SDM (RM = 'Removed'). Classes with the same code (e.g. 'lu_GUS') were aggregated.

CLC-Level3	Level3_Label	Grid-code	SDM-Code	SDM-Included
111	Continuous urban fabric	1	RM	no
112	Discontinuous urban fabric	2	lu_DUF	yes
121	Industrial or commercial units	3	RM	no
122	Road and rail networks and associated land	4	RM	no
123	Port areas	5	RM	no
124	Airports	6	RM	no
131	Mineral extraction sites	7	RM	no
132	Dump sites	8	RM	no
133	Construction sites	9	RM	no
141	Green urban areas	10	lu_GUS	yes
142	Sport and leisure facilities	11	lu_GUS	yes
211	Non-irrigated arable land	12	lu_AL	yes
212	Permanently irrigated land	13	lu_AL	yes
213	Rice fields	14	lu_AL	yes
221	Vineyards	15	lu_PC	yes
222	Fruit trees and berry plantations	16	lu_PC	yes
223	Olive groves	17	lu_PC	yes
231	Pastures	18	lu_PA	yes
241	Annual crops associated with permanent crops	19	lu_HAG	yes
242	Complex cultivation patterns	20	lu_HAG	yes
243	Land principally occupied by agriculture, with significant areas of natural vegetation	21	lu_AGNV	yes
244	Agro-forestry areas	22	lu_HAG	yes
311	Broad-leaved forest	23	lu_BF	yes
312	Coniferous forest	24	lu_CF	yes
313	Mixed forest	25	lu_MF	yes
321	Natural grasslands	26	lu_NG	yes
322	Moors and heathland	27	lu_SMH	yes
323	Sclerophyllous vegetation	28	lu_SMH	yes
324	Transitional woodland-shrub	29	lu_SMH	yes
331	Beaches, dunes, sands	30	lu_BDSV	yes
332	Bare rocks	31	RM	no
333	Sparsely vegetated areas	32	lu_BDSV	yes
334	Burnt areas	33	RM	no
335	Glaciers and perpetual snow	34	RM	no
411	Inland marshes	35	lu_IW	yes
412	Peat bogs	36	lu_IW	yes

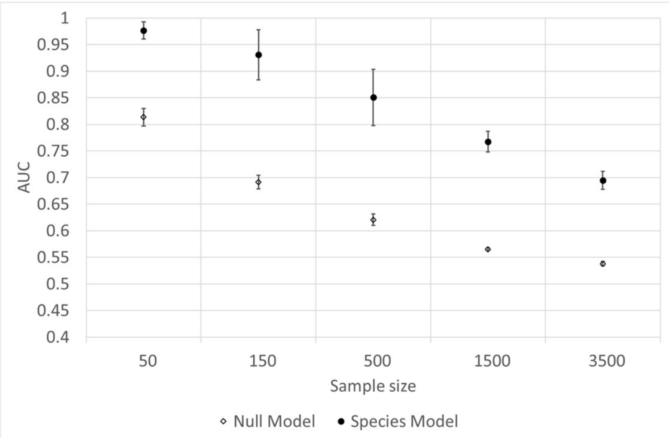
CLC-Level3	Level3_Label	Grid-code	SDM-Code	SDM-Included
421	Salt marshes	37	lu_BW	yes
422	Salines	38	RM	no
423	Intertidal flats	39	RM	no
511	Water courses	40	lu_IWB	yes
512	Water bodies	41	lu_IWB	yes
521	Coastal lagoons	42	RM	no
522	Estuaries	43	RM	no
523	Sea and ocean	44	RM	no

General model settings: Maxent 3.4.0 was used to predict the environmental suitability for each species. After model calibration, 'Hinge feature' only was used; for each species, prevalence was set to either 0.1, 0.2, 0.3, 0.4 or 0.5 according to the method described in Polce et al. (2013). Other Maxent settings were set as: `maximumbackground=10000`, `replicates=5`, `replicatetype = crossvalidate`, `outputformat = Cloglog`, `applyThresholdRule = Minimum training presence`.

At last, the predictions are interpreted as 'probability of occurrence'.

Target group background (TGB): target group background is used by Maxent to account for any spatial or environmental bias occurring within the species records (for instance, when they provide only a partial sample of the environmental and/or geographic conditions found within the study area). Bias was found within our records, and hence a TGB was created (Phillips *et al.*, 2009). The TGB corresponded to all grid cells where bumblebee records were found, before removing species with too little records.

Model performance: we used null models to test whether the resulting SDMs provided a significantly better fit than expected by chance alone. With presence-only data the maximum achievable AUC (Area Under the Curve of the Receiver Operating Characteristic) is <1 (Wiley *et al.*, 2003) namely, it is 1-a/2, with a being the true fraction of the study area occupied by a species, typically unknown when absence data are not available (Phillips *et al.*, 2006). To assess SDM accuracy, therefore, we compared the average AUC value of each species SDM (AUC_{SDM}) with the average AUC value of a set of null models (AUC_{NM}) where species records were replaced by randomly chosen locations (Raes & ter Steege, 2007). We expected $AUC_{SDM} > AUC_{NM}$.



Appendix-Figure 8. Average ± 1 SD for the (model testing) AUC, for Null Model (open diamonds) and the SDM (black circles).

Appendix-Figure 8 shows the performance of the SDMs compared to that of the Null Models, as measured by the AUC. The results highlight that the SDM performance is significantly better than that of the Null Models.

Model outputs: for each species, two main model outputs were generated:

1. The average 'Probability of occurrence' ($P_{(occ)}$)across the area of interest, from each of the 5 model runs.
2. The average threshold indicating, for each model run, the species 'Minimum training presence' - this threshold was used to convert the average probability of occurrence to presence / absence across the study area: if $P_{(occ)}$ >= Threshold, presence = 1, else presence = 0.

These outputs were used to derive an average 'Probability of occurrence' from the aggregated set of 47 species. First, a 'Species richness' map was computed by summing up each species 'Presence/Absence' map. Second, single species $P_{(occ)}$ maps were summed up, and their average extracted by dividing it by the 'Species Richness' map. Hence, for each grid cell, the average $P_{(occ)}$ was based on the number species likely to be present.

Merged model

The EBM and SDM were resampled to the same spatial resolution:

1. EBM: aggregation from 100 m^2 to 1 km^2 (cell factor = 10, statistics: 'mean')
2. SDM: resampling from 100 km^2 to 1 km^2 (bilinear interpolation)

Then, their average was computed and used as an indicator of 'Pollination potential'. The indicator was computed for the year 2000, 2006, and 2012 using the datasets listed in Appendix - Table 2.

The final model output is a dimensionless indicator of environmental suitability that is used to delineate service providing areas (SPA) with different suitability for pollinators:

1. High: environmental suitability above 0.3
2. Medium: environmental suitability between 0.3 and 0.2
3. Low: environmental suitability between 0.2 and 0.1
4. None: environmental suitability below 0.1

The criteria on the thresholds chosen to define the different categories of pollination potential was based initially on quantiles; rounding the values to one decimal point.

Demand

For the demand for crop pollination different data sources at the EU level were considered at the initial stage of this study. Appendix - Table 11 presents a summary of the main advantages and disadvantages of the different data sources with available data on the extent of pollinator-dependent crops.

Appendix - Table 11. Alternative data sources for the demand for pollination.

Source	Advantages	Disadvantages
CORINE Land Cover	- Spatially explicit (100 m resolution)	- Lack of yield data (for monetary valuation) - Only data for fruit trees
Eurostat + LUCAS	- Official statistics - Ground-truth data	- Limited spatial coverage - Lack of yield data - Trends: only for 11 countries, between 2006 and 2012
CAPRI data	- Spatially explicit data (HSMU > ~ 1 km) - Consistent with Eurostat statistics - Yield data: required for monetary valuation	- Derived from a modelling exercise - Only 2004 and 2008 available

In this report, we present the crop pollination accounts based on data derived from the Common Agricultural Policy Regionalised Impact model (CAPRI) because the advantages this data set present were more suitable for the accounting purposes: crop extent data at the fines spatial resolution available and yield production for different crop categories.

CAPRI data are reported at level of Homogeneous Spatial Mapping Units (HSMU). Crop extent was then disaggregated at 1 km^2, assuming an homgenous distribution of the crop extent over the HSMU. A similar approach to assess the pollination demand has been applied in (Zulian et al., 2013; Schulp et al., 2014). In this way, pollination demand is defined as the hectares per 1 km^2 grid-cell for nine by nine crop groups benefitting from insect pollination.

Finally, the demand is reported as the total number of hectares per square kilometre (or share) for crops dependent on pollinators and disaggregated by level of dependency as described before.

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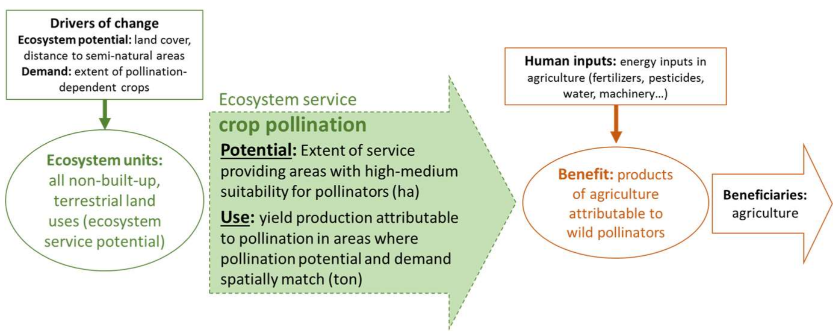
Appendix IV: Factsheet crop pollination

CROP POLLINATION

Definition	The fertilisation of crops by insects and other animals that maintains or increases the crop production (modified from CICES V5)	
Ecosystem types	All non-built-up, terrestrial land covers (ecosystem service potential) Cropland (actual flow)	
Economic unit	Users of the service	Agriculture (pollinator-dependent crops)
	Beneficiaries	Agriculture (pollinator-dependent crops)
SEEA-EEA ecosystem accounting model		

CONCEPTUAL DEFINITION OF INDICATORS

ECOSYSTEM SERVICE	
Potential	Extent of service providing areas with high-medium suitability for pollinators (ha)
Use	Share of yield production of pollinator-dependent crops attributable to pollination (ton). The use takes only place where pollination potential and demand spatially match
SOCIO-ECONOMIC SYSTEM	
Demand	Extent of pollinator-dependent crops (ha)
Unmet demand	Extent of pollinator-dependent crops not covered by the service providing areas (ha); with low environmental suitability for pollinators
Benefit	Share of the yield production attributable to the pollination flow (ton)

VALUATION METHODS

Crop pollination affects a product that is already in the SNA. In monetary terms it is possible to disentangle the contribution of crop pollination directly from the economic accounts already reported in the SNA by using the outcomes from the biophysical model:

(i) calculating the pollination contribution (actual flow/total production) as much detailed as possible (i.e. per crop and per country);

(ii) multiplying the pollination contribution by the total production per crop and per country;

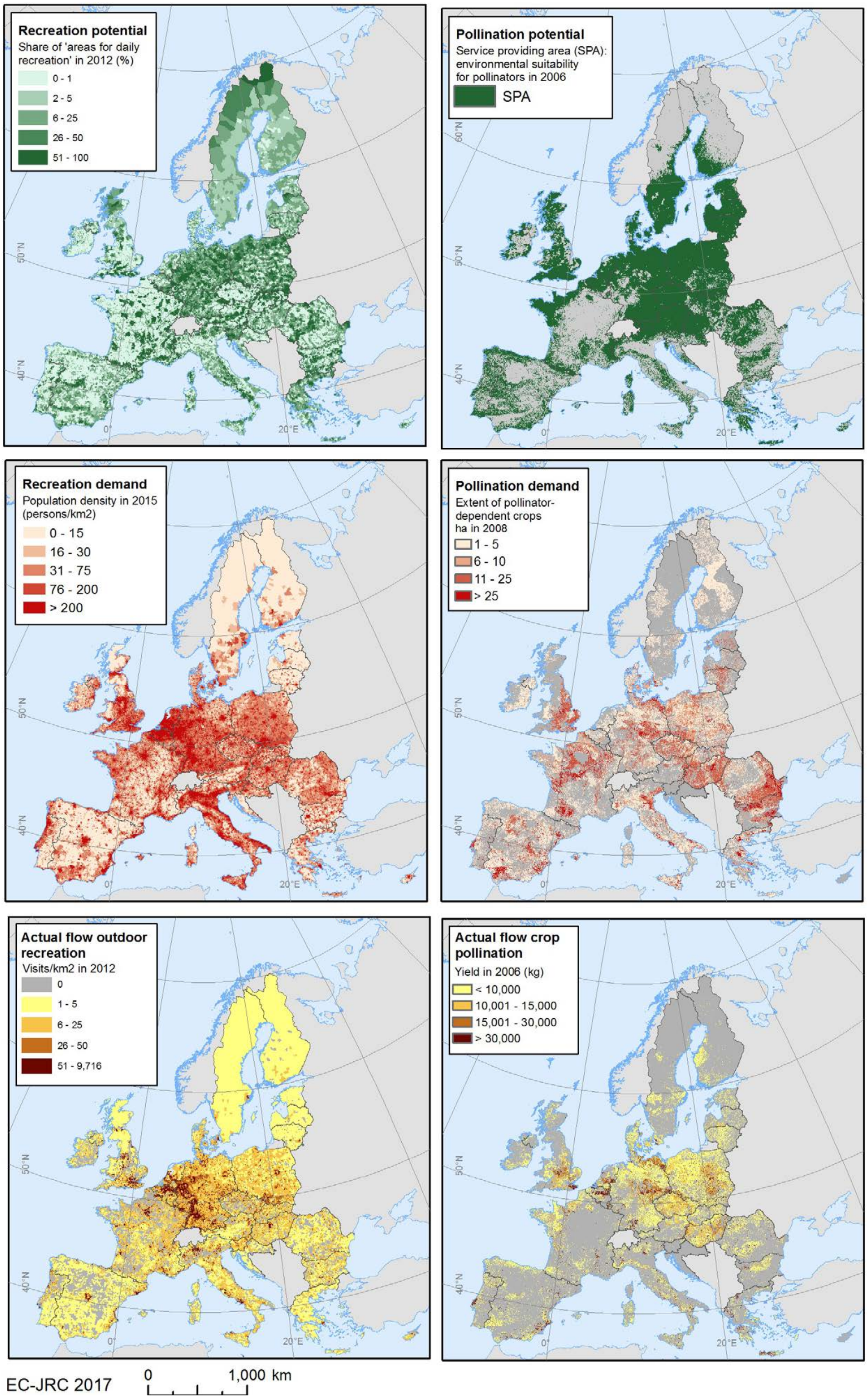
(iii) deriving as residual part the unmet demand of pollinator-dependent crops.

This procedure will allow identifying for the SNA product the share of yield due to pollination (i.e. where pollination potential and demand overlap: met demand).

DRIVERS OF CHANGES IN THE MODELLING FRAMEWORK

Dynamic variables: land cover extent and configuration, distance to semi-natural areas, extent and spatial distribution of pollinator-dependent crops.

Appendix V: Maps of the biophysical assessment



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