Final project report

IMAGINE: Integrative Management of Green Infrastructures Multifunctionality, Ecosystem integrity and Ecosystem Services

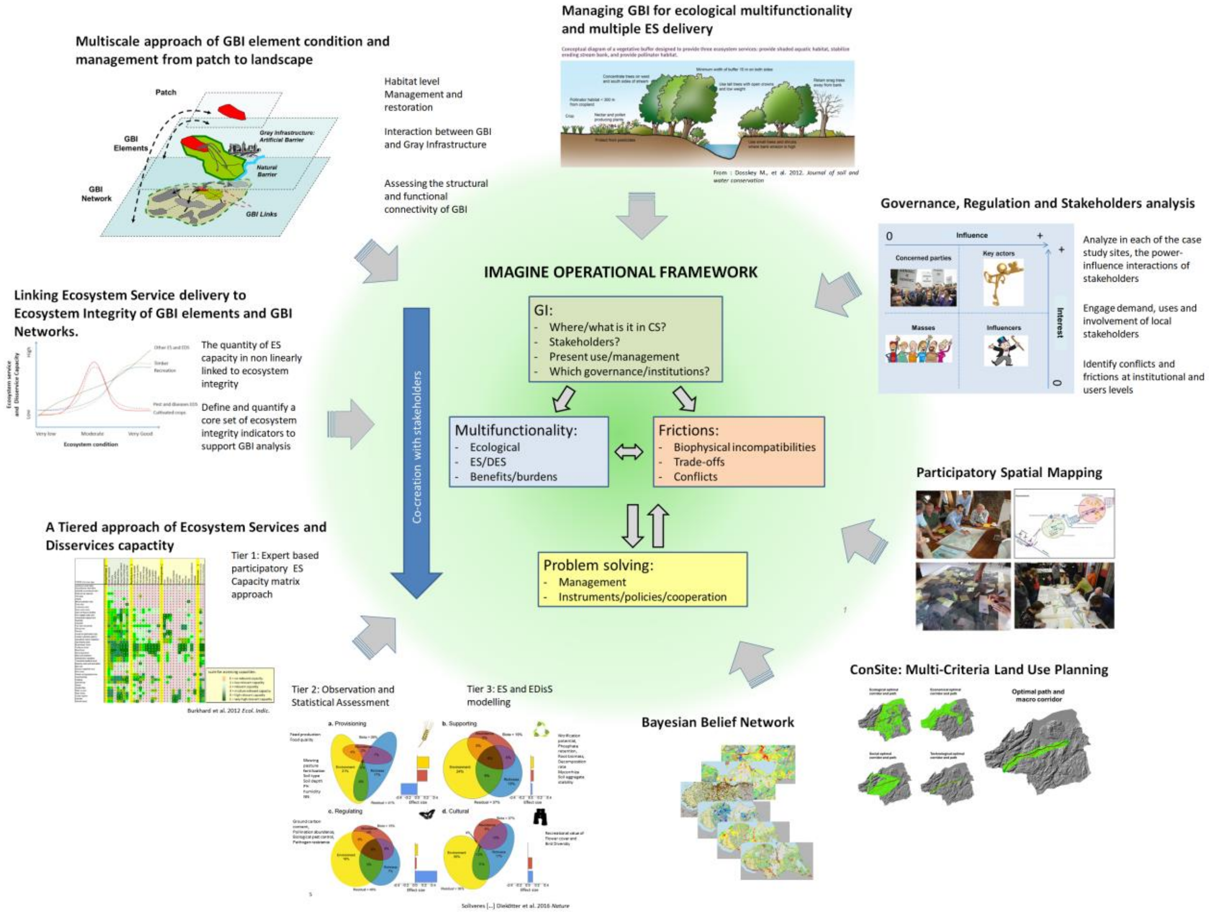
Project acronym		IMAGINE
Project title		Integrative Management of Green Infrastructures Multifunctionality, Ecosystem integrity and Ecosystem Services: From assessment to regulation in socio-ecological systems
Project coordinator	Person (Title, Full Name)	Dr. Philip K. Roche
	Entity (Company/organization)	INRAe, UMR RECOVER
Project period (Start date – End date)		01/02/2017 – 31/01/2020
Project website, if applicable		https://imagine.irstea.fr/the-project/

Author of this report	
Title, first name, surname	Dr. Philip K. Roche
Telephone	0442667931
E-mail	Philip.roche@irstea.fr
Date of writing	15 October 2018

List of partners involved in the project (company/organization and principal investigator). Please use partner numbers to specify the tasks, work packages and inputs of each partner in sections 4.3, 5 and 6.2 to 6.4.	Partner 1: INRAe, Philip K. Roche Partner 2: EMU, Mart Külvik Partner 3: INBO, Geert de Blust/Stien Heremans Partner 4: ISOE, Diana Hummel Partner 5: UniKiel, Tim Diekötter Partner 6: NINA, Roel May

1 Short description for publicity

The IMAGINE project aimed at quantifying the multiple functions, ecosystem services and benefits provided by Green Infrastructures (GI) in different contexts from rural to urban. The consortium led by INRAe (France) comprises 6 teams (EMU, INBO, INRAe, ISOE, NINA and UniKiel) from 5 European countries (Belgium, Estonia, France, Germany and Norway). Based on case study sites, we explored different state-of-the-art methods on the interaction between the environmental (abiotic characteristics of soil and water), structural (size, shape, spatial network configuration) and biological (species composition, structure, production) properties of the GI, which are necessary for the optimal provision of ecosystem services by the GI. In relation with GI ecological functions, we considered the societal values from different stakeholders and citizens as well as the policyscape addressing GI management in a set of case study sites. We observed that wild species connectivity is compatible with ecosystem services provision to people. GI have a capacity for different ES two times the average capacity of others habitats. The management and governance of green infrastructure is complex and requires participatory cooperation between institutions and stakeholders. Several different perceptions and wishes regarding the ES provided by green infrastructure may prevail. It is therefore important to define and specify the respective objective(s) for which a Green Infrastructure is implemented. Starting from common values related to the social elements and functions of green infrastructure will help to resolve frictions.
Our project not only generated new knowledge on the relationship between management, ecosystem integrity and multifunctionality of GI ecosystem services but also developed methods and technical guides that could be implemented by or in support to local stakeholders for sustainable landscape management.



Overview of IMAGINE project activities

4th IMAGINE Project Meeting, Talinn, Estonia, November 2018

2 Summary

Using a multidisciplinary approach in six case study sites covering a European north-south gradient from the boreal zone to the Mediterranean, the IMAGINE project assessed the multifunctionality and societal values of green infrastructure (GI) in different contexts at landscape level. An important objective of IMAGINE is to provide guidelines and develop ready-to-use methods for integrated management of GI's multifunctionalities. To stimulate and improve the performance of GI's ecosystem services. We explored different methods based on the most recent knowledge on the interaction between the environmental (abiotic characteristics of soil and water), structural (size, shape, spatial network configuration) and biological (species composition, structure, production) properties of the GI, which are necessary for the optimal provision of ecosystem services by the GI. In relation with GI ecological functions, we considered the societal values from different stakeholders and citizens as well as the policyscape addressing GI management in a set of case study sites.

Our project not only generated new knowledge on the relationship between management, ecosystem integrity and multifunctionality of GI ecosystem services but also provided local stakeholders with scientific and territorial arguments, regulation mechanisms and decision-making tools for sustainable landscape management.

3 Objectives of the research

Using a multidisciplinary approach across six case study sites spanning a European north-south gradient from the boreal zone to the Mediterranean, the proposed project IMAGINE aims at **quantifying the multiple functions, ecosystem services and benefits provided by Green Infrastructures (GI) in different contexts from rural to urban**. Within this quantification IMAGINE will explicitly consider ecosystem disservices, particularly in agricultural systems, facilitate strong participation of local stakeholders and site managers and focus on model-based exploration of alternative management options for designing multifunctional GI-networks. An important objective of IMAGINE is to **provide guidelines and elaborate ready-to-use methods for an integrative management of GI multifunctionality**. In order to stimulate and enhance ecosystem services performance of GI, a toolbox of management and restoration techniques will be prepared. These tools will be based on state-of-the-art knowledge regarding the interacting environmental (abiotic soil and water characteristics), structural (size, shape, spatial configuration of the network) and biological (species composition, structure, production) GI-properties that are required for the optimal provisioning of ecosystem services by GI. This way, our project will not only produce new knowledge on the relationship between the management, ecosystem integrity and ecosystem-service-based multifunctionality of GI, but also provide local stakeholders with science- and place-based arguments, regulatory mechanisms and decision tools for a sustainable landscape management.

To reach these project's aims, IMAGINE is structured into **six science work packages (WP1-6) and one management work package (WP7).** The science work packages will interactively address key research topics within a multifunctional framework based on state of the art knowledge (see project structure) and six case study sites (see Case Study Sites).

Key research topics of IMAGINE:

1. Relationships between biodiversity, ecosystem integrity and the capacity of GI to supply multiple ecosystem services.
2. Variation in ecosystem service and disservice provisioning by GI along rural to urban and simple to complex landscape gradients.
3. Management options to restore and design multifunctional GI networks.
4. Stakeholder-dependent demands and uses of GI-ecosystem services.
5. Complex interactions and regulatory mechanisms at different governance levels.
6. Propose models to evaluate alternative design and management options of GI at landscape level.

4 Project activities and achievements

4.1 *General description of activities over the duration of the project*

WP 1 was dedicated to landscape and connectivity analysis. INRAe from France led this work-package. The main tasks of this work-package were to provide with data layers to support the analysis of GI (notably a harmonised LULCs with WP3, NDVI, connectivity analysis, Ecological integrity analysis…). A global analysis of the 6 CSS structural connectivity was done using harmonised analyses of Green and Grey elements for the using high resolution EUGHLS 2.5 m data and the freeware GUIDOS. WP1 produced two IMAGINE cookbooks. One on Connectivity that cookbook presents and proposes methods for a finer analysis of connectivity based on graph theory (Conefor Sensinode) and the circuit theory (Circuitscape). The second is dedicated to the definition and assessment of ecological integrity of GI.

WP2 addressed the questions related to ecological functions and ecosystem services. This WP was led by the University of Kiel from Germany with a large contribution from INRAe. Regarding the ecological functions, it was decided to focus on pollination, pest predation and decomposition. The UniKiel team proposed a protocol and CSS Care Package with the sampling equipment needed for each CSS. They particularly focus on the ecological functions provided by small linear GI. This sampling protocol based on landscape analyses made in collaboration with INRAe was to be applied in late spring 2018. However, due to important drought, it was not possible to apply it with success. It was decided to postpone it to early spring 2019. Another aspect of WP2 is ecosystem services (ES) and ecosystem disservices (EDS) assessment, the method that was applied is to use expert-based assessment of ES capacities for each ecosystem type, the matrix approach (Campagne and Roche, 2018). A cookbook was produced and the ES capacity matrices have been produced for each CSS (Figure 2).

WP3 defined GI elements vulnerability and to propose options to manage/restore them. The INBO team from Belgium led this WP. They produced three cookbooks related to the assessment, management and vulnerability analysis of GI elements and link them to the structural state. WP3 team also contributed to the creation of a harmonised LULC's typology for all CSS. We used this typology with the ecosystem integrity analyses proposed in WP1, ES and EDS analysis in WP2, vulnerability in WP3 and modelling in WP5.

WP4 analysed societal values and preferences from the different group of stakeholders regarding different GI functions. The ISOE team from Germany led this WP in collaboration with INBO from Belgium. They also executed, with support of CSS teams, an analysis of policy coherence regarding GI regulation. They produced guidelines and support to CSS teams to conduct stakeholder network analysis, governance analyses and preference assessments. WP4 produced two cookbooks.
WP5 led by NINA from Norway is a modelling and synthesis work-package. This included mapping of the ES delivery chain as well as conservation concern at each CSS using a BBN modelling approach linking the stakeholder-derived outputs of the different WP. These ES maps provided input to the ConSite Urban toolbox enabling planners to assess spatial consequences of development scenarios on GI. WP5 produced one cookbook on this integrated modelling.

WP6 led by the Estonian Science University (EMU) from Estonia supported WP4 for stakeholder analyses and created and maintained the project website (https:// https://imagine.inrae.fr), project leaflets and edited the project cookbooks. The EMU team was also involved in stakeholder analysis.

4.2 *Deliverables and production*

Deliverables		Delivery date		
No.	**Title**	**Planned (Months)**	**Realised (Months)**	**Comment**
D1,2,3,5,6,7,9,111, 33,13,15,16, 20,23	Technical Report per Tasks	See Gantt Chart	24 and 44	IMAGINE Cookbook series
D4, D8, D10, D14, D18	Synthesis Report per WP	See Gantt Chart	24	Project Interim report
D21, D22,	Annual Project Report	12,24		
D24	Final Project Report	35	44	IMAGINE FINAL REPORT, shorter than initially planned. We put the emphasis on finishing the Cookbooks and Peer reviewed papers
D25	Guide How-To Management and Restoration of GI	26	44	3 cookbooks instead of 1 initially planned
D30	Guide How-To Ecological Integrity Assessment	26	44	1 Cookbook
D26	Guide How-To ES and EDS Assessment and Mapping for Local Stakeholders	27	12 - 44	1 Cookbook, drafted Jan2018, finalised Nov 2020
D28	Assessments of pilot studies: working paper for each pilot site	28	Cancelled	The format was not fitting with stakeholder needs. It appeared more interesting to make papers including several CSS.
D29	Policy Report Multifunctionality and Management of GI in Europe (4-6 pages)	30	To be done	To be extracted from the Final Report
D31	Synthesis Leaflet for General public (1 per WP, 1 recto-verso)	31	30, to be done	1 leaflet done and distributed at several european meetings, 1 synthesis leaflet to be extracted from final report.
D32	Adaptative GI Management ToolBox	33	40	Toolboox Consite Urban working. 1 cookbook.

The lists of project productions are in part 4.5 and 6 of this report.

4.3 *Scientific outcomes*

4.3.1 Project structure and case study sites

To reach its project's aims, IMAGINE was structured into six work packages that interactively addressed key research topics within a multifunctional framework based on the state of the art knowledge (Figure 1) and six case study sites (Figure 2).

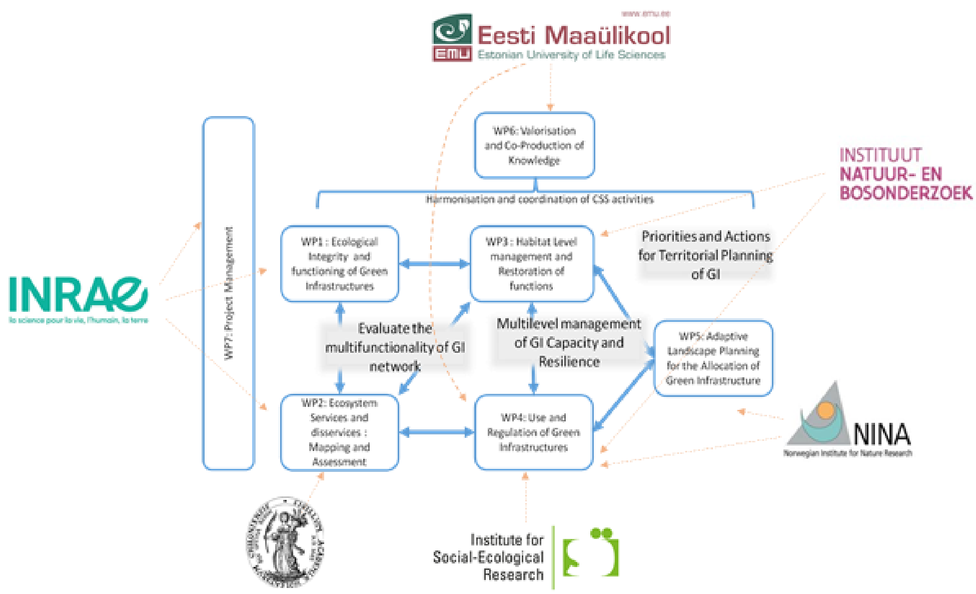


Figure 1: Overview of the IMAGINE project structures. Blue arrows represent the main interactions and fluxes of data between the work packages. The definition of a Core Set of Activities guarantees the availability of data flows between WPs. Orange arrows represent the main responsibilities of the different teams in the different work-packages. All teams contributed to the Core Set of Activities.

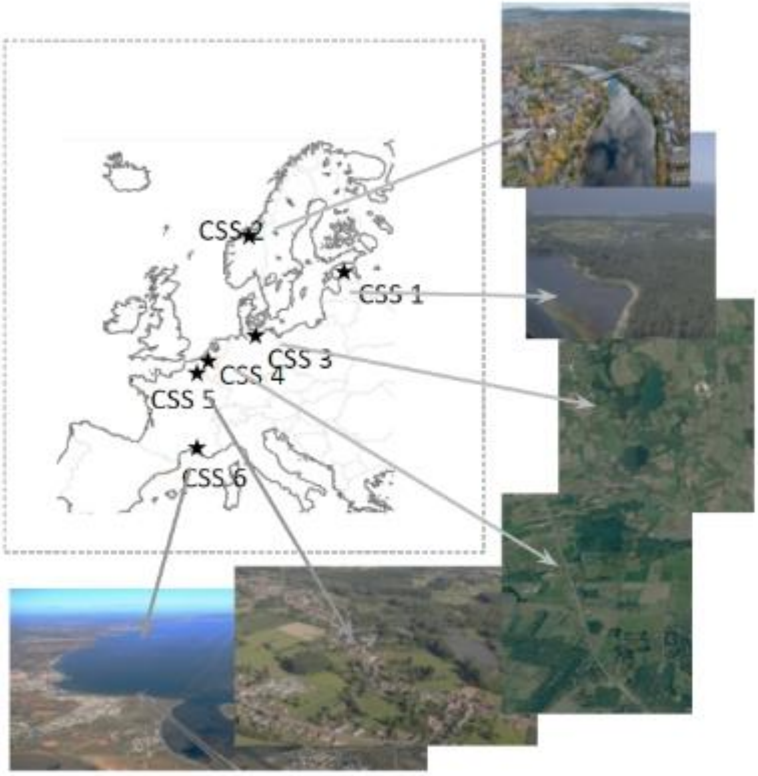


Figure 2: Map and illustration of the 6 Case Study Sites (CSS) where the project actions were developed. CSS1: Tallinn hinterland/Harku, CSS2: Trondheim region, CSS3: Bornhöved Lake District, CSS4: Grote Nete and Molse Nete area, CSS5: Natural Regional Park of Scarpe Escaut and CSS6: Thau lagoon and inland area.

4.3.2 Green infrastructure supporting biodiversity

Main contributor: WP1 team (INRAe)

4.3.2.1 Connectivity for wild species

Connectivity to support biodiversity is nowadays an important concern in any modern conservation plan around the globe. The challenge of these conservation plans is to identify the spatial scale(s) and key landscape elements needed to maintain or restore connectivity and the ecological processes that are promoted by it (Luque *et al.* 2012). While habitat loss and fragmentation have become major threats to biodiversity, conservation plans promoting connectivity implementation provide solutions to ecological restoration actions by crossing structures, zoning of areas for protection or management, and guidance for urban planning (Keeley *et al.* 2019).

To meet the final objective of favouring species viability and ecosystem diversity, landscape ecologists should convincingly demonstrate the effectiveness and benefits of connectivity investments compared to other competing conservation alternatives. Improving connectivity is fundamental to species resilience in the current context of land use and land cover change and of climate change leading to potential range shifts (Rudnick *et al.* 2012; Costanza and Terando 2019). Within the framework of IMAGINE we based landscape connectivity in terms of species dispersal ability, that is the threshold (i.e., the spatial scale) at which fragmentation starts to affect species survival in a fragmented landscape. Here the effective dispersal ability accounts for species behavioural response to various land cover types in terms of resistance to movement. We assessed the relevance of designing priority areas for conservation for a group of species with homogenous dispersal abilities against prioritisation based on species with both high and low dispersal ability (Preau *et al.* submitted).

We estimated connectivity importance by computing and merging current intensity based on the Circuitscape model using 2 complementary approaches. The first one implemented thy WP1, INRAe, Montpellier team and applied on Thau lagoon area (France), Grote Note (Belgium) and Trondheim region (Norway) used a combination of observation data, species distribution models and resistance layers. The second one was implemented by WP1, INRAe, Aix-en-Provence team and applied to all CSS used a combination of expert based habitat suitability maps, simulated pseudo-occurrence data and resistance layers (for more details see *Cookbook Connectivity and Habitat Suitability models*). The second method was used as data layers in the WP5 integrated modelling.

Multi-species distribution models (SDM's, Anderson *et al.*, 2006) allow considering the wide range of ecological requirements of the different species that are living in a particular geographical location. It **can be particularly useful** for landscape management to preserve the integrity of ecological networks **by highlighting the more important corridors and habitat patches** (Figure 3).

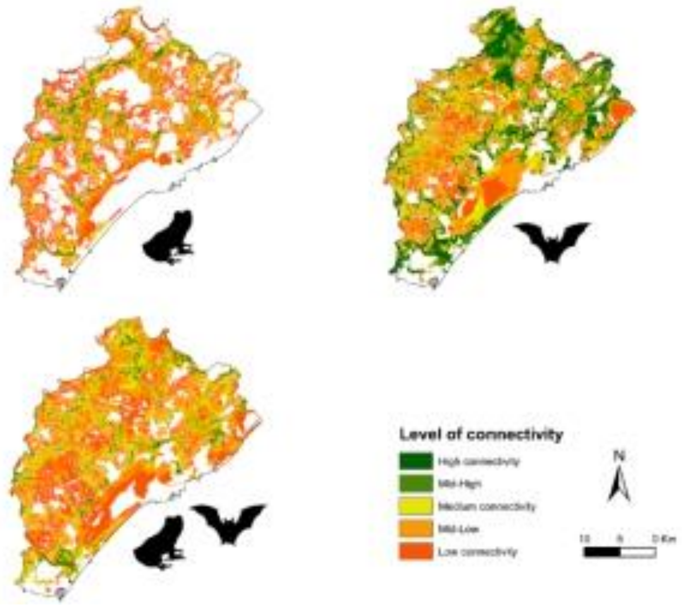


Figure 3: Average maps for three multi-species groups (CSS6:Thau lagoon region, France, Luque et al., INRAe).

Biodiversity open-source databases provide an important amount of data, but their use is limited by spatial biases. In particular, this important issue prevents building of reliable species distribution models (SDMs) and as a consequence jeopardizes the delivery of relevant recommendations for management. A sample bias correction can be performed, but the assessment of its effectiveness relies on independent data that are rarely available. **We tested a new method for assessing the effect of a correction technique in absence of independent data**, relying on a measure of spatial effect of correction relative to within-model stochasticity (Dubos *et al.* submitted). **This method was in better agreement with results obtained from virtual species with 'perfectly known' distribution and simulated sample bias than cross-validation performance metrics and absolute effects of correction.** Along with an investigation of the biological relevance of environmental variable selection, we advocate the use of a Relative overlap index to assess sample bias correction techniques and increase the potential use of biodiversity databases (Figure 4).

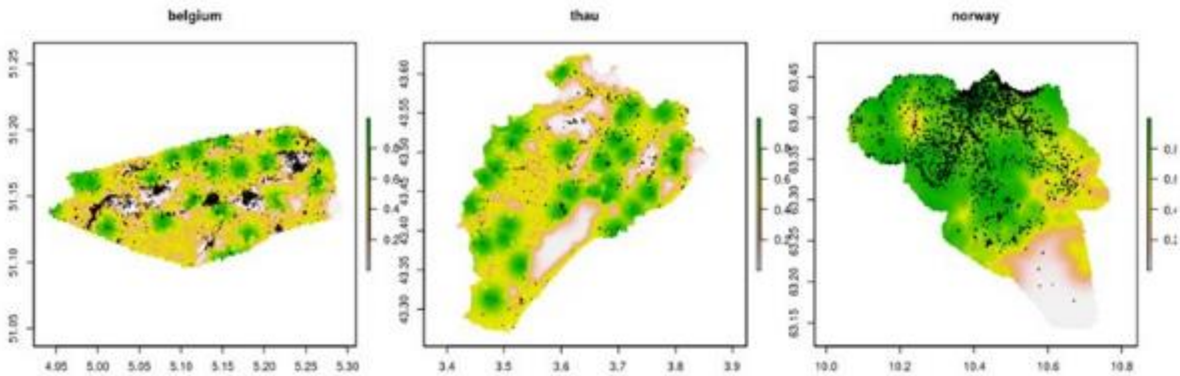
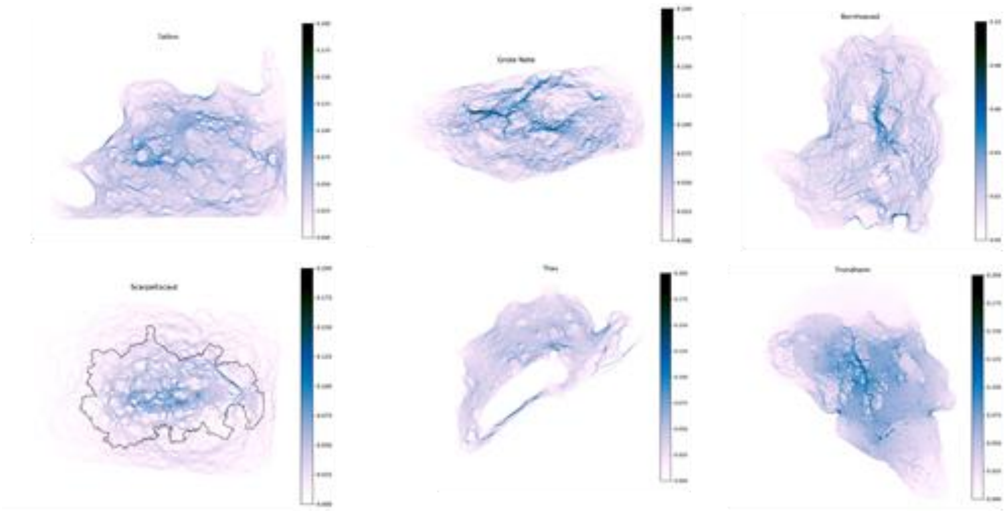


Figure 4: Relative overlap index maps computed for three sites in Europe. The small '+' represent occurrence data, all species pooled together (Dubos et al. in review, INRAe).

The pseudo-occurrence based on expert estimates of habitat suitability was used to be able to compute multi-species connectivity models in the absence of reliable or large enough species observation datasets (Figure 5). The method is described in the cookbook (*Connectivity and Habitat Suitability models).* The basic ideas are to generate randomly pseudo-occurrence points in the high suitability habitats and then to compute current modelling based on those pseudo-occurrence points. This method **allows to circumvent the lack of data and allow us to estimate the model robustness by applying data perturbation methods** (random change in the expert-based suitability and resistance data, as well as different number and methods of pseudo-occurrence generation). A paper is currently drafter for Landscape Ecology or Land Journals.

Figure 5: Pseudo-occurence multi-species connectivity models for all CSS. For each CSS a list of 8–10 important species was defined (E. Zakharova, P. Roche, INRAe)



4.3.3 Ecosystem condition and biodiversity support elements

Within the IMAGINE project, the ecological integrity was used belong other indicators related to biodiversity to evaluate biodiversity conservation potential of green infrastructures. Ecosystem condition can be defined as "*… The sum of biophysical properties that underpin services*" (Schröter *et al.*, 2016). This definition is used almost identically in the MAES report (Maes *et al.*, 2020), the ecosystem condition is defined as "*Ecosystem condition refers to the physical, chemical and biological conditions or quality of an ecosystem at a particular point in time. Pressure refers to a human induced process that alters the condition of ecosystems".* For Roche and Campagne, (2017) the "*notion of ecosystem condition (including ecosystem health and ecosystem quality) is used and related to an anthropocentric vision of nature, either as the state of the ecosystem in response to human pressures and disturbances or as the ability to continue to provide services to people*".

Considering the ecosystem condition as defined previously, potential indicators should refer to the biophysical aspects of the ecosystem and preferably relate to ecological function supporting various ecosystem services. As an example, the ecological functions that could be considered those most important ones to sustainably supporting the provision of ecosystem services will be related to productivity, energy fluxes and nutrient cycling.

Hemeroby (Greek: hémeros=cultivated, bios=living) is a term used in landscape ecology and literally expresses distance to nature. As such, it acts as the complementary term to the more common naturalness (Fehrenbach *et al.*, 2015). In IMAGINE, we used the same hemeroby scale as (Walz and Stein, 2018) and estimated for each LULC's class within the CSS a hemeroby value that could serve as the basis for ecosystem integrity mapping (Figure 6).

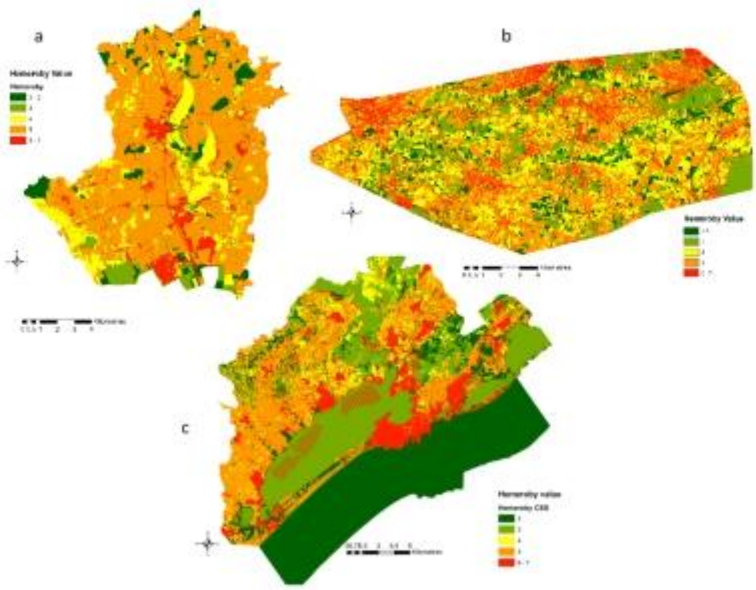


Figure 6: Hemeroby maps of 3 CSS: a. Bornhöved (Germany), b. Grote Note (Belgium) and c. Thau bassin (France).

4.3.3.1 Relations between ecosystem condition and ecosystem services capacity

Ecosystem condition as defined previously is an integrated proxy to ecosystem properties supporting ecosystem services. The relationships between ecosystem services capacity and ecosystem condition are expected to be different between the categories of ecosystem services. Braat and Brink (2008) proposed theoretical relationships between biodiversity/naturalness and ecosystem services values. Some services such as regulating services and cultural services (excluding recreation) will increase with the ecosystem condition, while others will peak at some level of ecosystem condition. Using the hemeroby as a pressure indicator, we adjusted the hemeroby to the ecosystem service capacity for each land use. We found that the **ES/EDS capacity is directly related to ecosystem condition as defined by the hemeroby indicator** (Figure 7). Agricultural based Provisioning services and disservices are peaking for low to moderate condition, Timber and recreation are peaking for good condition and regulation services and other EDS are increasing with condition (Figure 7).

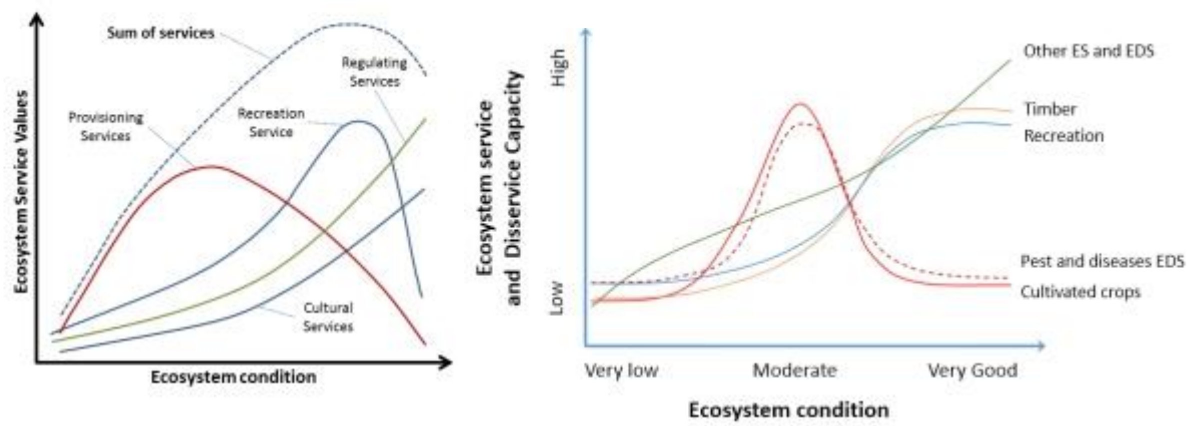


Figure 7: Left graph: Theoretical relationships between ecosystem condition and ecosystem service values (based on Braat and Brink 2008. Cost of Policy Inaction). Right graph: adjusted curves of ES scores (capacity matrix) and ecosystem condition (hemeroby) for CSS3 (Bornhöved, Germany).

4.3.3.2 Biodiversity support value

The hemeroby value was combined with the connectivity value issued from a Circuitscape current analysis for a set of selected species in each CSS (See Connectivity Cookbook) and the Nursery ES value issued from the capacity matrix assessment to compute a Biodiversity Support Value index (BSV).

Those 3 layers are related to a capacity of landscape to support dynamic and functioning biodiversity. Note that index is a direct biodiversity estimates, as measured by species numbers and abundance, but an index of biodiversity support capacity. It is why we called this indicator, «Biodiversity support value».

$$BSV_i = ((1 - Hemeroby_i) + Nursery_i + Connectivity_i)/3$$

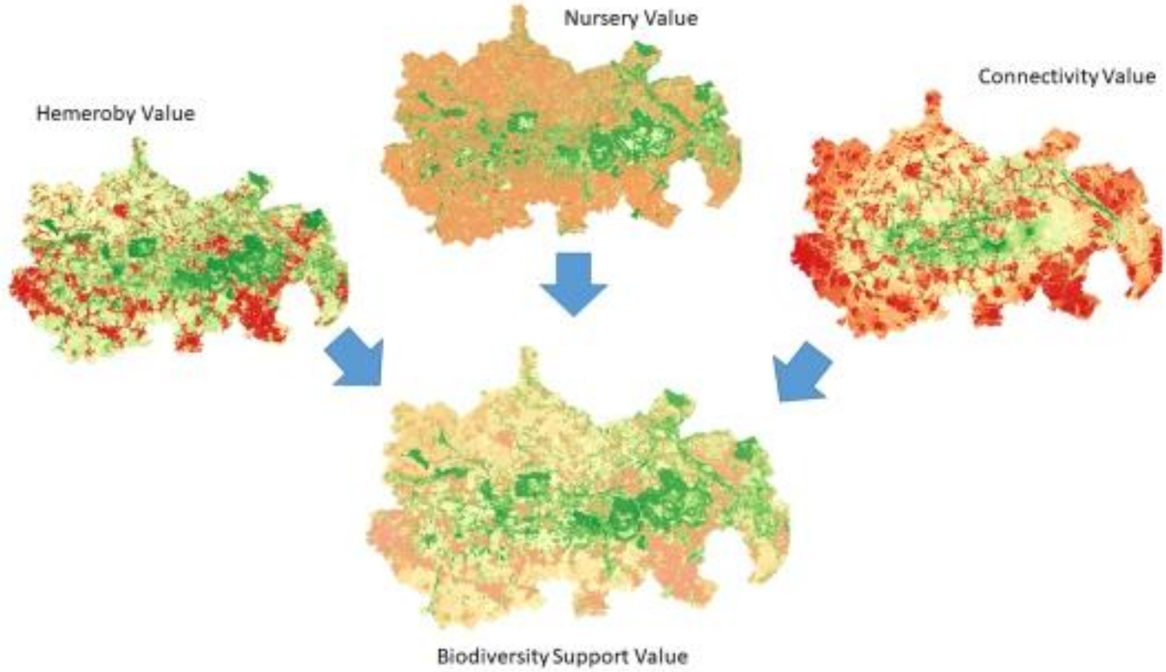


Figure 8: Illustration of the computation of Biodiversity support value for the Natural Regional Park of Scarpe-Escaut.

4.3.4 Green infrastructure providing benefits to people and society

Main contributor: WP2 Team (INRAe, UNIKIEL)

4.3.4.1 Participatory evaluation of ecosystem services and ecosystem disservices

Main contributor: WP2 Team (INRAe+ all CSS Teams)
The capacity matrix approach is a flexible semi-quantitative evaluation of the capacity of different ecosystem types or land cover types to provide ES or EDS. In IMAGINE, we used in all sites a panel of local experts following a precise methodological approach (see Campagne and Roche, 2018) to evaluate those capacities. We produced estimates for all CSS of Ecosystem services capacity at landscape level (Figure 9).

Based on the CSS capacity matrices, we observed that the expert estimated that **GI elements** (*woodlands, grasslands and other natural elements*) **have a capacity** to provide ecosystem services **between 1.5 et 2 times more than non-GI elements** (*Urban habitats and croplands*). Food and fibres usually produced in non-GI elements have lower capacity within GI. This implies that **the amount of GI in a landscape has a direct and positive impact on the ES available for people living in**.

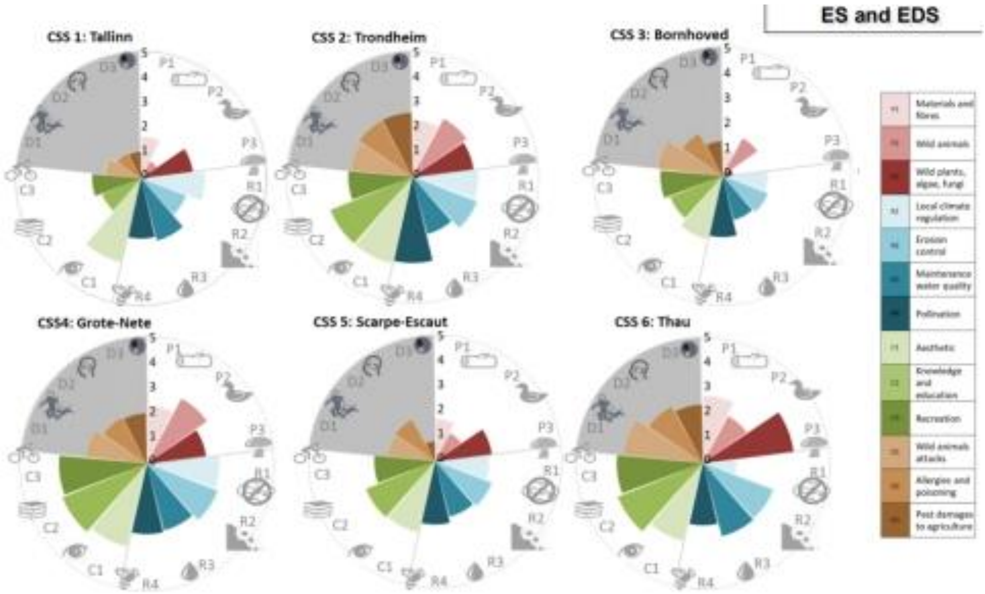


Figure 9: Overview of ecosystem services and ecosystem disservice for all IMAGINE CSS (C.S. Campgne, INRAe + All CSS teams)

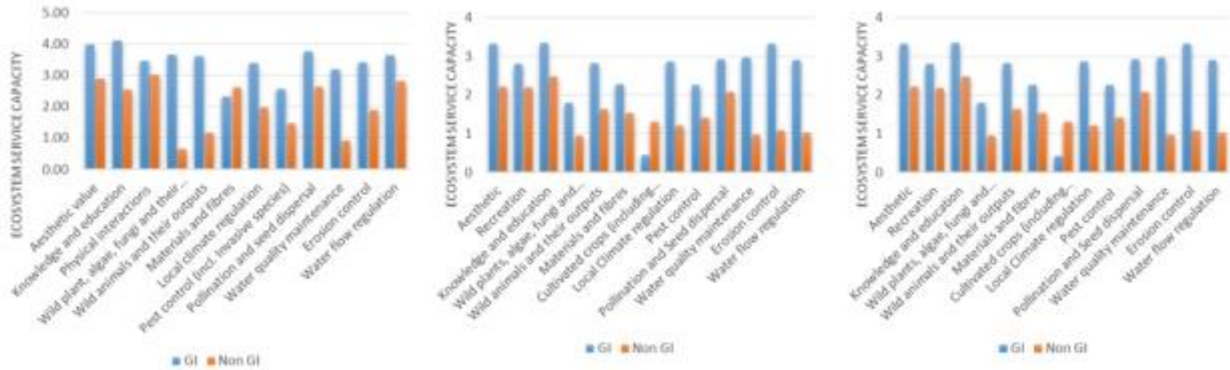


Figure 10: GI and non-GI habitat capacity to provide ecosystem services for 3 CSS. From left to right (Trondheim, Grote Nete and Scarpe-Escaut), presented during IALE World Meeting, Milano, 2019 (Roche et al.).

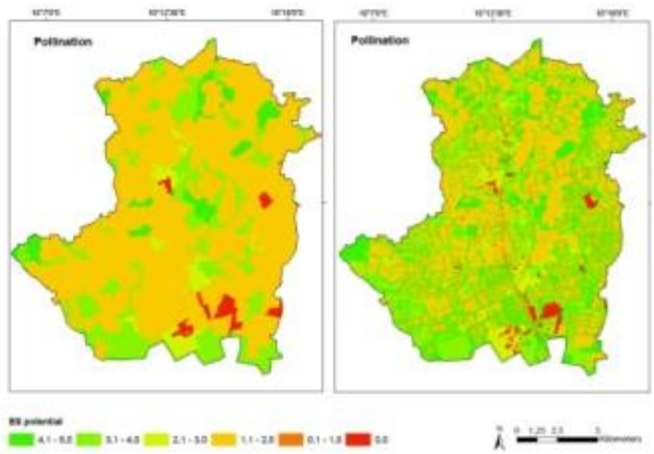
4.3.4.2 Ecological functions and ecosystem services provided by linear green infrastructure

Main contributor: WP2 (UNIKIEL)

Green infrastructure (GI) can generate a great variety of social, environmental and economic benefits (EEA 2014; EEA 2017). To fully realise this potential, elements constituting GI need to be clearly defined. So far, linear – in contrast to non-linear – semi-natural elements are rarely considered in the delineation of GI at the administrative planning level and thus a strategically planned network. This common approach may be questioned, as, particularly in agricultural landscapes, linear semi-natural elements provide habitat to many species (e.g. Diekötter *et al.* 2013). Thus, **functionality and the provisioning of ecosystem services (ES) in agroecosystems likely depend on linear semi-natural elements much more strongly than their current coverage in GI planning suggests**. In WP2, we (i) tested how land-use/land-cover data (LULC) of different thematic and spatial resolution (allowing also the inclusion of linear semi-natural elements) affect the prediction of ES potential using ES capacity matrices (Tier 1) or the InVEST tool (Tier 3), (ii) evaluated effects of GI amount and quality on ecosystem services potential or provisioning in a modelling or empirical approach (Tier 2) and (iii) modelled the pollination ecosystem service potential using a new hierarchical framework (Tier 3) in the rural case study site in Northern Germany.

The inclusion of linear semi-natural elements by using ATKIS/InVeKoS data as compared to relying on freely available but more coarse Corine Land Cover data in the capacity matrix approach (Tier 1) led to the predicted ES potentials to vary, but only slightly, in structural similarity (Figure 11), Perennes *et al.* 2020). These differences in the predicted ES potential became larger when the structural differences due to the inclusion of linear semi-natural elements were amplified by including distance decay in the ecosystem services originating from them in the InVEST tool (REFFigure 12, Bicking & Diekötter in prep.). While, on a scale from −1 to 1, the Structural Similarity (SSIM) Index ranged from 0.69 for nutrient regulation over 0.76–0.78 for erosion control and pollination to 0.84 for groundwater recharge between maps without and with **linear elements** in the ES capacity matrix approach (Perennes *et al.* 2020), this comparison **increased pollinator abundance and supply of approximately 8% and a reduction of the average nutrient export of approximately 18% at the landscape scale** (Tier 3; Bicking & Diekötter in prep.). Linear semi-natural elements in these approaches covered 5% of the area, which, in the models without these elements, were largely replaced by non-irrigated arable land (68%) or pasture (19%; Bicking & Diekötter in prep.).

Figure 11: Ecosystem service potential maps fo pollination using ATKIS (left) or ATKIS and InVeKoS (right land cover data and the ES potential matrix. 0.0: nc potential, 0.1–1.0: low potential, 1.1–2.0: low potential, 2.1–3.0: moderate potential, 3.1–4.0: high potential, 4.1-5.0: very high potential.



A second Tier 3 approach was applied, in which, in contrast to InVEST, information on the occurrence of pollinators is based on peer-reviewed knowledge rather than expert judgement and variation in the regional distribution of pollinator species (in our case species of the genus *Andrena*) was allowed by creating species distribution maps (SDM) based on occurrence data from the Global Biodiversity Information Facility (GIF) and its relation to five bioclimatic variables and eight land-use/land-cover (LULC) data. The model predicted bee diversity, thus pollination potential, related well to abundance ($p = 0.03$) and species richness ($p = 0.06$) of wild bees from the Genus *Andrena* that was observed at ten locations in the German Case Study Site (CSS3; Perennes *et al.* under revision). Based on the existing knowledge on the importance of linear semi-natural elements for biodiversity in agricultural landscapes (e.g. Diekötter *et al.* 2018, 2013) and modelling results of this work package (WP) that consider ecological knowledge on the service providing units (SPU) as well as distance decay functions that extent the service of linear semi-natural elements beyond their actual coverage, we conclude that linear semi-natural habitats increase the multifunctionality in agroecosystem and thus such be considered.

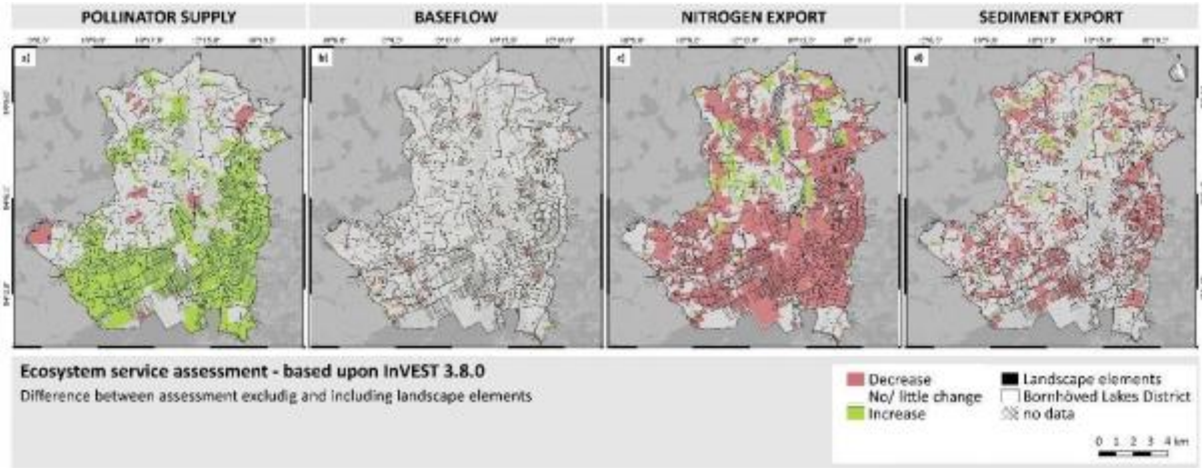


Figure 12: Difference between exclusion and including linear semi-natural landscape elements in the ecosystem services a) pollinator supply, b) base flow, c) nutrient export and d) sediment export as modelled with InVEST. The category "no/little change" refers to changes < 1% of the average values of the assessment excluding landscape elements (background: OpenStreetMap).

4.3.4.3 Green Infrastructure providing ecosystem disservice

Main contributor: WP2 (INRAe)

GI are important elements that can deliver a high number of ES and associated benefits, and through these benefits, the value of nature for a better quality of life is sought but also for maintaining biodiversity within managed and artificialised landscapes. Nevertheless, GI not only host beneficial ES providing species but also those with potential negative impacts, so called Ecosystem Disservices (EDS) (e.g. corridors for invasive species, refuges for pest and disease vectors), which are important to assess to arrive at a balanced assessment of GI multifunctionality. Considering both positive and negative effects of nature on human well-being are essential for local policy makers (e.g. municipalities) to implement an adaptive management for trade-offs in ecosystem services delivered by green infrastructure. Therefore, ecosystem disservices was also integrated into our analysis. Using the matrix approach (Burkhard *et al.*, 2012; Campagne and Roche, 2018) each CSS assessed the capacity of their ecosystems to provide ES and EDS jointly with a score 0 (strong capacity) to 5 (no or low capacity).

A total of 10 EDS were assessed with two EDS (wild animal attacks and Plants and their pollen can cause allergies or poisoning) **in all CSS** (Figure 13). Although more in total have been assessed if the CSS are considered.

The results show global lower capacity to provide EDS than ES like presented in figure X2 and more in detail in Campagne *et al.* (2018) for the CSS5 of Scarpe-Escaut. The capacities differ between EDS and for each EDS between the CSS (Figure 14). We can see a tendency for higher capacities for EDS linked to health impacts followed by EDS related to economic impacts compared with EDS linked to ecological impact considering that we have only one capacity score for each EDS related to ecological impact. Between the CCS, Bornhöved scored GI with lower EDS capacities than the other CSS, whereas Trondheim scored GI with the highest EDS capacities among the CSS. In conclusion, **GI provide more ES than EDS** and the EDS capacities vary among the CSS with a tendency for **high capacity to provide EDS related to health impact**.

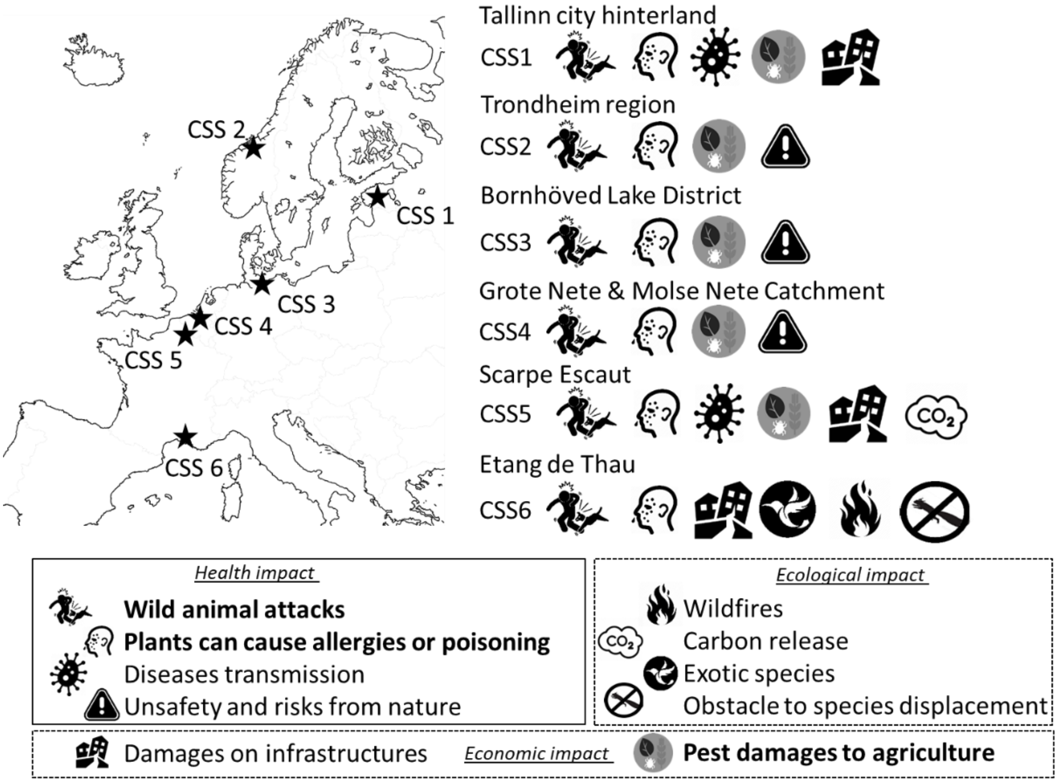


Figure 13: Ecosystem disservices assessed in the different Case Study Sites

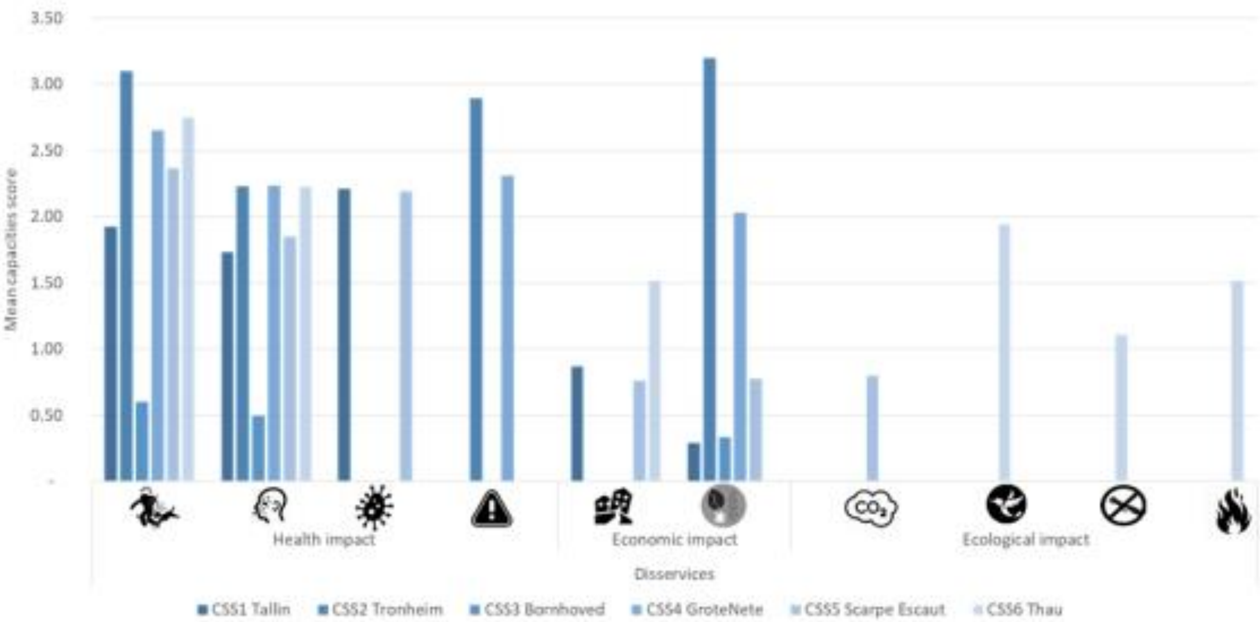


Figure 14: Mean scores of EDS provided by Green infrastructures

4.3.5 Social valuation of ecosystem services and green infrastructure

Main contributor: WP4 team (ISOE and INBO)

4.3.5.1 Use and desirability of ecosystem services and disservices

Research question: What is the current use of, demand for, access to and value of ecosystem services and disservices of the GI being studied by different stakeholder groups?

Social valuation and friction analysis of green infrastructure (GI):

We got a better idea how stakeholders value GI and how this can help better understand potential frictions related to GI. For this purpose, we applied stakeholder analysis and social valuation methods (individual scoring range between −3 and +3) in a deliberative workshop setting in six GI cases spread around Europe (including 4 in a rural context and 2 in an urban context).

Between 7 to 15 GI elements were identified per GI (median: 12), and the most common GI elements are hedgerows, green strips, forest, riparian zones, tree lines, stream and rivers. The GI deliver between 13 and 27 social functions each (median: 15), which cover all the main ecosystem service types (provisioning, regulatory and cultural ES). The most common social functions of GI are biodiversity, recreation, aesthetic landscapes, food and biomass fuel production, water quality maintenance and soil quality maintenance (including soil erosion control). Consequently, the number of involved stakeholder groups per GI is high and varies between 10 and 37 (median: 25), including (in declining frequency): government agencies, NGOs/CBOs/unions, companies, communities, and land-users/managers. The involved stakeholders have different levels of dependence, faced impact, interest and influence in relation to the GI.

Individual GI elements are very positively valued by different stakeholder groups (green dots in Figure 15, ranging between 1.5 and 2.8). The valuation of the social functions of GI is more diverse (Figure 15, ranging between −1.3 and 2.7). **Overall, the higher the value of the GI element or function, the higher consensus.** Three clusters can be identified related to the valuation of GI elements and functions:

Cluster 1 – High desirable GI elements and functions (desirability score: from 2 to 2.8): this concerns water-related elements and functions, forests and biodiversity, soft recreation/education and aesthetics, and air and soil quality. For all of these elements and functions, there is a relative high consensus (variance < 1.1).

Cluster 2 – Medium desirable GI elements and functions (desirability score: from 1.3 to 2.3): this includes green elements in the landscape (e.g., hedgerow, green strips), economic-related activities, hunting, and connectivity. The opinions between stakeholders are more variable related to these GI elements and functions (variance: 1.1 – 1.8).

Cluster 3 – Disservices or non-desired functions of the GI (desirability score: from 0 to −1.5). This includes less desired functions (e.g. motorised recreation) and many disservice caused by the GI (such as allergies, pests, invasive species). However, the high variance indicates that there are contrasting opinions on these functions.

The multi-stakeholder use of GI can result in (potential) frictions between stakeholders. As expected from the valuation exercise, frictions are more related with the GI functions then with The GI elements. Examples are use of hedgerows/tree lines (management for economic viability versus management for diverse landscapes, Grote Nete (BE) and Scarpe-Escaut (FR)), food production vs. biodiversity protection in agricultural areas Bornhöved (D).

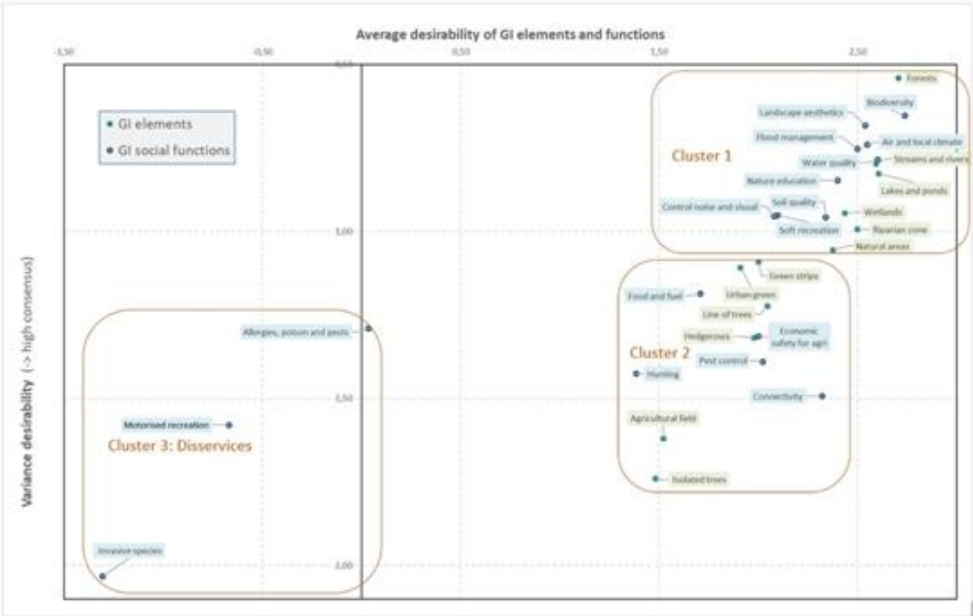


Figure 15: Social valuation of the elements and social functions 6 green infrastructures (GI) in Europe. The desirability scores were −3 (undesirable), -2 (undesirable), -1 (bit undesirable), 0 (neutral), 1 (bit desirable), 2 (desirable), 3 (very desirable). The dots below show the average and standard deviation of all individual scores of the 6 GI cases. Low variance indicates high consensus (high on the Y axis), high variance indicates low consensus (below on the Y axis).

4.3.5.2 Analysis of trade-offs in managing GI

Research questions: In which way does unequal access between interested users and imbalance between burdens and benefits of services (and disservices) generate (potential) conflicts and governance problems of GI?

Main results telephone survey:
Between April and September 2019, a standardised CATI (Computer Aided Telephone Interviews) survey was conducted in Germany, France, and Belgium. In total 500 interviews per country were conducted: 300 in rural communes, 200 in the urban areas each. The CATI partners were chosen according to the main criteria: living in the respective rural areas or urban town, and older than 18 years. Each interview lasted approximately 15 min. The questionnaire was structured into five parts: i) use of the landscape and reasons why participants visit the study site; ii) perception of the landscape and its elements; iii) desirability of landscape elements and societal demands in the near future; iv) preference regarding the trade-off of two management options: agricultural use or biodiversity protection; and v) socio-demographic parameters of the participants. For the analysis of this publication mainly part iv) and v) were considered. The mean value and t-test analysis were conducted using the software STATA.
Preference of management options: agricultural production versus biodiversity conservation
Figure 16 shows that **in all three countries there is a clear tendency towards the protection of biodiversity**. The preference towards biodiversity is clear with values above three indicating being clear or rather for the protection of biodiversity.

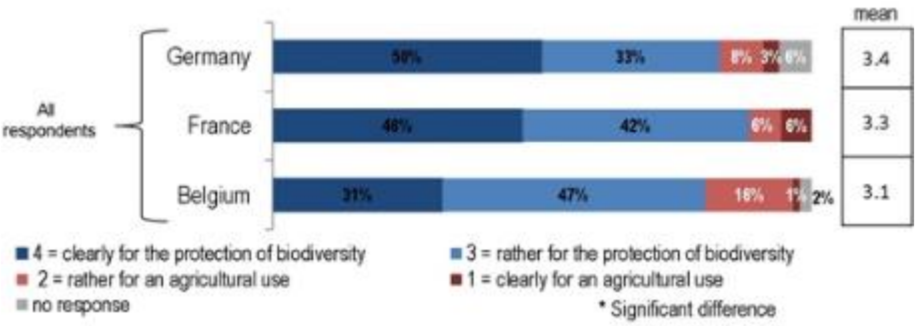


Figure 16: Preference of management options: agricultural production versus biodiversity conservation. Shown are all respondents, Germany: n = 471, France: n = 500, Belgium: n = 514. (T. Fickel et al., ISOE)

Rural-urban gradient

The rural-urban gradient (Figure 17) is only significantly expressed in Germany with higher values in urban areas (3.5) compared to rural areas (3.3). However, the difference between both groups is insignificant. Belgium and France did not show any significant difference.

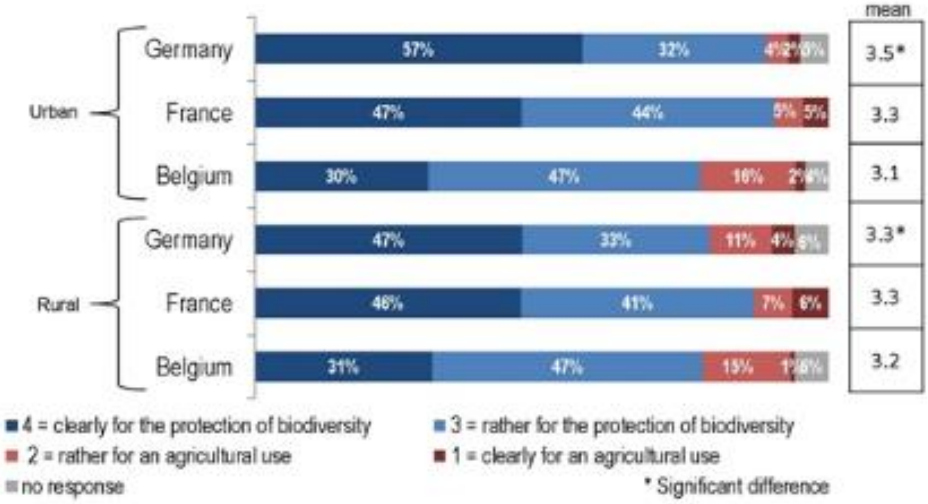


Figure 17: Preference of management options against the background of the rural-urban gradient; Urban: Germany n = 189, France: n = 200, Belgium: n = 204; Rural: Germany n = 282n=282, France: n=300, Belgium: n=283 (T. Fickel et al. ISOE)

Relevance of experience in agriculture or species protection

In Germany, there is a significant difference between respondents having experience in agriculture (2.9) versus species protection (3.1), respectively (Figure 18). In France and Belgium, we did not find such a significant difference. Similar to the other analysis, the values are highly indicating a preference towards biodiversity protection in all groups.

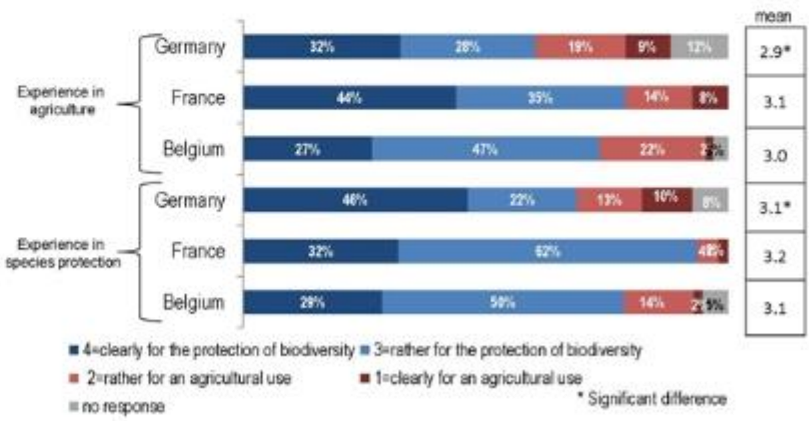


Figure 18: Preference of management options against the background of professional experience in agriculture or species protection, respectively; Experience in agriculture: Germany n = 95, France n = 80, Belgium n = 62; Experience in species protection: Germany n = 62, France n = 47, Belgium n=53) (T. Fickel et al. ISOE)

4.3.6 The policyscape of green infrastructure

Main contributor: WP4 (INBO)

4.3.6.1 Policy coherence analysis

Research question: Which regulation mechanisms and policy instruments, as well as informal institutions are currently defining GI governance? How successful are they in terms of efficiency, effectiveness, equity, etc.?

Member states have different definitions and interpretations of green infrastructure. Is it therefore not surprising that GI governance is characterised by an equivalent diversity of approaches and interpretations across member states.

There are nonetheless, a few noteworthy commonalities among the case studies analysed in the IMAGINE project:

The GI challenges identified by stakeholders in the respective member state all went beyond initial biodiversity and connectivity targets to also include ecosystem services and socio-economic functions. This reflects an ongoing paradigm shift in GI governance (Figure 19) but also the need to use a systemic approach for GI management. **The range of elements that are considered as GI is broad, going for example from forests (e.g. Estonia) to single trees (e.g. Belgium, France).** It reflects the resolution of the GI challenges addressed in each case study. The GI concept has been integrated within a mix of policy instruments, reflecting the transboundary and integrative nature of the concept. This policy mix also includes occasional private instruments (e.g. a wine certificate in France).

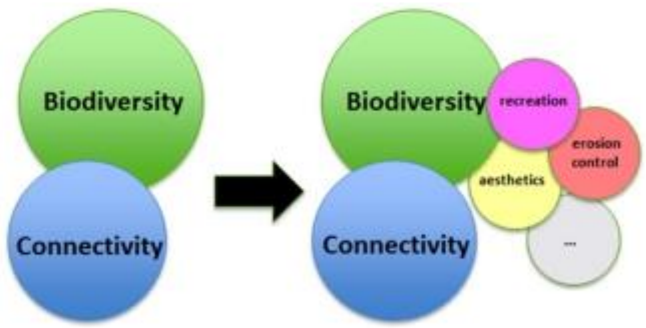


Figure 19: Paradigm shift in GI governance

GI governance across all case studies is defined by a combination of local (e.g. municipality level) and supralocal policy instruments. Overall, **the internal coherence and relevance of selected policy instruments impacting GI is rather positive across case studies with a few exceptions**. This however does not imply that their impact is sufficient to ensure sustainable management of GI but is a prerequisite for the latter objective to be achieved.

4.3.7 Maintaining functional green infrastructure

Main contributor: WP3 team (INBO)

4.3.7.1 Mapping the vulnerability of green infrastructure elements

An important objective of IMAGINE is to elaborate a rationale to identify the management and restoration needs of GI. The need for management and restoration depends on the impact of current and former disturbances on a GI patch. The impact disturbance has on the functioning of a GI element depends on the habitat types the GI is composed of. It relates to the capacity of the habitat to absorb changes in key attributes without considerably altering ecosystem functioning. **Whether a habitat patch is seriously impacted by a disturbance or not, also depends on its size of and the exposure to that disturbance.** To a certain extent, both relate to the spatial conditions of the habitat and the landscape matrix it is placed in. For general purposes, both the potential impact or sensitivity and the exposure can, thus be described using several landscape metrics. Finally, whether the changes brought about in a habitat patch are permanent or not, depends on its ability to recover. Again, this is (partially) a function of the spatial configuration of the surrounding landscape as isolated habitats have in general less chance to recover than habitats that are in one way or another connected to similar habitats.
To assess the general need for management and restoration of GI from the perspective of its actual state and hence degradation risk, we apply a methodology based on readily available spatial indices which are translated into a **vulnerability index.** Details about its calculation can be found in Heremans and De Blust (2020) and Heremans *et al.* (2020). A map of the vulnerability for the CSS of Grote Nete (Belgium) is provided in Figure 20.

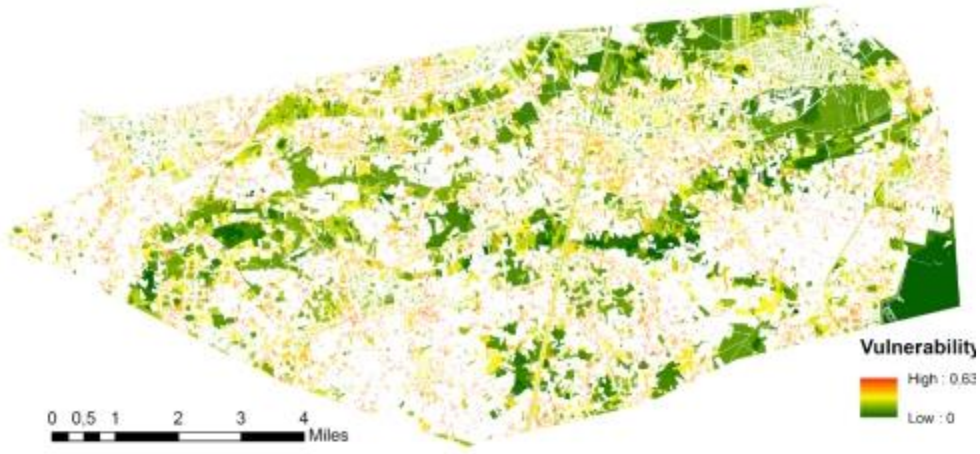


Figure 20: Map of GI vulnerability to ecological degradation for CSS Grote Notes. Non-GI is displayed in white.

From the vulnerability map of CSS Grote Nete shown above, the most prevalent patch is that of the military domain in the south-eastern corner. This area has the lowest vulnerability value mainly because it is the largest GI patch in the area and it is surrounded by other smaller GI patches that shelter it from external disturbances. The second distinct feature that we can identify on the map is the river valleys, which have markedly lower vulnerability than the surrounding upland areas. In these river valleys, nature has had to deal with fewer disturbances because the area is too wet for intensive agriculture or human settlement. Thus, relatively large patches of wetland forest remain. Moreover, they receive relative shelter from agricultural disturbances by wet grasslands that serve as a buffer between the forests in the valleys and intensive agriculture in the upland areas. In Grote Nete, extensively managed dry grasslands and urban green (parks, gardens etc.) are the parts of the GI most vulnerable to degradation because they are immersed in an agricultural or urban matrix, respectively. This is illustrated by numerous examples of extensive grasslands that are (being) converted into croplands or urban green patches that get paved.

4.3.7.2 Prioritisation of green infrastructure elements for restoration efforts

The vulnerability index can be used to identify those parts of the GI most prone to degradation, and are worth surveying up close. However, prioritizing efforts to maintain or improve GI performance regarding ES provision must be based on a more elaborated assessment of their status. In this respect, Hobbs *et al.* (2003) suggest combining (1) the degree of threat to a habitat with (2) the relative value of that habitat and (3) the likelihood of successful management interventions. We adapted this approach by combining the vulnerability of a habitat patch with the importance that habitat must deliver locally desired ES. The latter is estimated using a combination of the capacity of land cover types to deliver ES with the preferences of stakeholders for different ES.

Table 1 summarises the different possible responses in terms of intervention types. The result of this overlay can be used as a first attempt to localise - on a regional or landscape level - the areas most eligible for conservation and restoration efforts. The third criterion, the projected effectiveness of interventions, cannot be derived from a landscape-level spatial analysis. Explicit data are needed about (a) the type of disturbance acting on a habitat patch and (b) the actual state of those attributes that support the patch's provision of desired ES. Where the regional-scale estimates of vulnerability and capacity (Fig x) inform on *where to intervene*; these more detailed local inventories shed light on *how to intervene*. These specific management options that need to be tailored to (1) the desired ES, (2) the type and quality of the GI habitat and (3) its spatial configuration, while also considering the opportunity cost of management alternatives that were not chosen (see De Blust & Heremans, 2020).

		Patch vulnerability		
		Low	Medium	High
Preference-weighted ES capacity	High	Preservation (passive)	Conservation (active)	Restoration (proactive)
	Medium	Protection (threat avoidance)	Reclamation (threat reduction)	Remediation (threat reversal)
	Low	No action	Maintenance	Transformation

Table 1: Policy and management responses to maintain or improve ES provision by GI, given their actual vulnerability to ecosystem degradation (credits: Roel May, NINA)

4.3.8 Managing green infrastructure at landscape level

Main contributor: WP5 team (NINA)

Employing an integrated and interdisciplinary approach is essential to support the exploration of barriers, trade-offs and opportunities for GI design and management in urban and rural landscapes. The IMAGINE project studied the complex interactions of Green-Blue Infrastructures, and Ecosystem Services and Disservices dynamics within six Case Study Sites (CSS) across Europe. This forms the backbone to the ecosystem service bundle analysis when it comes to ES capacity to actual ES benefits. For the exploration of barriers, trade-offs and opportunities for GI design and management spatially-explicit tools enable understanding and support around land use planning, ecosystem-based management, and nature conservation and restoration initiatives.

4.3.8.1 From capacity to benefits, an ecosystem service bundles analysis

Mapping the ecosystem service delivery chain

To assess and map ecosystem services (ES), there is a need to enable the decomposition of the ecosystem service delivery chain into its multiple components and quantitative indicators (cf. Burkhard and Maes 2017). In IMAGINE, we defined the ecosystem service delivery chain as follows (Figure 21). The ecosystem's biophysical properties, represented by categories of land-use and land cover (LULC) and GI elements represent the ecological basis for the provision of ES.

IMAGINE, used a Capacity matrix approach (Burkhard et al. 2009) to link land cover data with expert judgements about different land cover types' capacity to provide ES. We then use NDVI as an indicator to account for the variation in ecological integrity (naturalness), and for biodiversity also connectedness of land cover types that can influence the potential provision of ES or ES supply within green patches. We then modelled the accessibility to green patches to get a spatial distribution measure of the potential use of ES, or ES flow. Finally, we used the Analytical Hierarchy Process (AHP, Saaty 2008) to obtain expert judgments on the perceived importance of ES, relative to other ES.

We applied these preference weights on ES flow maps to represent the spatial distribution of potentially used ES, weighted by their perceived importance, or the ES value. It measures the amount of ES that can be provided or used by society, particular stakeholder groups or individuals in a certain region.

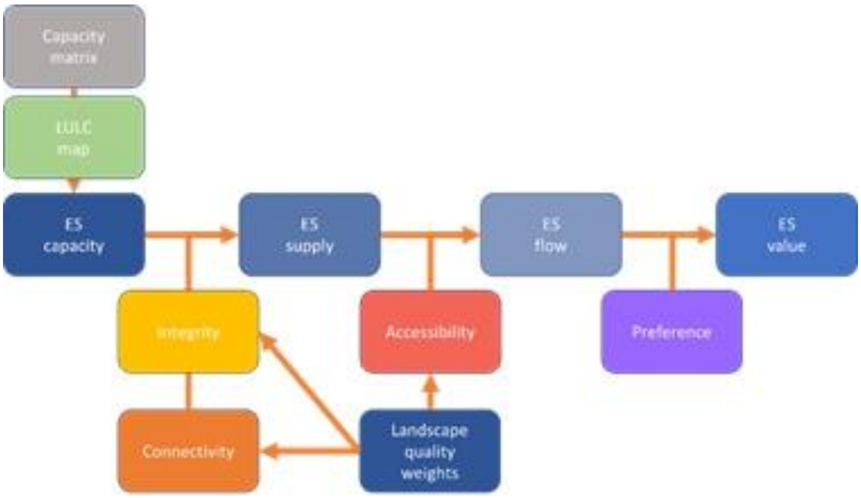


Figure 21: The Ecosystem service delivery chain.

Visualising ecosystem service bundles

For proper management of ES, it is important to be able to map ES bundles to visualise synergies and trade-offs , which arise between competing interests, both spatially (about differential land-use practise) and thematically (regarding demands for ES delivery). ES bundles can be defined as a set of associated ES that are linked to a given ecosystem and usually appear together repeatedly in time and space (Burkhard & Maes 2017). We assessed spatial bundling of Ecosystem Services (ES) within different land use and land cover (LULC) types, as well as thematic bundling of LULC for ES types. Both (inverse) assessments allow for increased insight into where management should be prioritised in terms of LULC to obtain specific ES bundles, and what would be gained within LULC bundles in terms of ES delivery. Lastly, a similar assessment was done to elucidate how policy plans may hamper, provide synergies for, or enhance the management of bundles of ES and LULC within Green-Blue Infrastructures. The bundle assessment was done for the entire ES delivery chain, and exemplified for the Trondheim CSS (Figure 22).

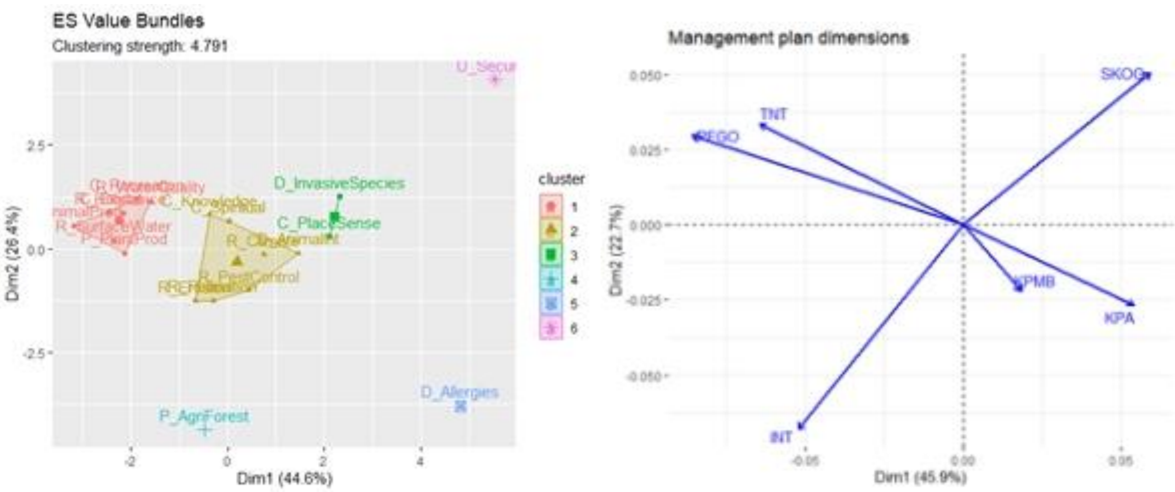


Figure 22: Principal Component Analysis and visualization of the six identified clusters of ES bundles (left-hand panel) and the six GI-relevant management plan coherence (right-hand panel), exemplified for the Trondheim CSS. ES included cultural (C_), provisioning (P_), regulating (R_) services, as well as disservices (D_). Relevant management plans included the municipality plans for the natural environment in Trondheim (TNT), for outdoor recreation and green areas (PEGO), for urban development (KPMB) and for its territories (KPA); the national forestry plan for sustainable forest production (SKOG) and the government expectations for municipalities regarding international agreements such as Bern convention, Water Framework Directive, Aichi targets, (INT).

4.3.8.2 Managing green infrastructure network planning

To support managers in the evaluation of alternative design and management options of GI at landscape level, we developed two spatially-explicit tools. The first is a Bayesian Belief Network (BBN) model to combine and integrate knowledge on biodiversity and ecosystem service capacity, landscape quality information and stakeholder valuation of different ES into a graphical social-ecological systems framework to map the ecosystem (dis) service provisioning of GI (Figure 23).

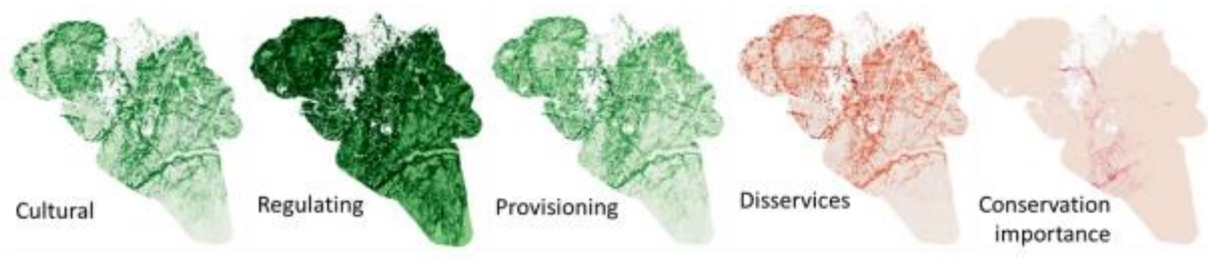


Figure 23: Mapped ecosystem (dis) services within the Trondheim CSS, based on the BBN model integrating stakeholder-derived knowledge and preference on ecosystem service capacity, landscape quality and valuation, and their functional relationships. (E. Strange, NINA)

This integrated model was made spatially-explicit across the case study sites. **The BBN model can be applied to visualise ecosystem service bundles as well as help address site-specific key management challenges.** Additional BBN inputs reflecting both green patches' importance for species movements between GI habitat (patch connectivity) and patches' size and the potential threat to expand non-GI land cover types (patch vulnerability) allow us to generate maps of both conservation *importance* and *concern*.

The mapped ecosystem (dis) services are after that used as input to the second tool, a GI design and decision-support toolbox. This toolbox, called ConSite Urban, supports the integration and management of GI in spatial planning. The built-in functions of the ConSite Urban toolbox enable visualising ecosystem (dis) services in the landscape, identifying socio-ecological bottlenecks, directing ecological restoration needs and predicting spatial effects of human impacts on GI. The tool helps assess and visualize the spatial consequences of various what-if scenarios, direct management actions for developing GI placement and design, and thereby provide decision-support for integration and management of GI in spatial planning (Figure 24). **The toolbox, which builds upon the ConSite Spatial multi-criteria decision Analysis Tool Suite (Hanssen *et al.* 2018), is useful for both land use/zonal planning, ecosystem-based management, area/green accounts and nature conservation and restoration purposes**. Both the BBN model and the ConSite Urban toolbox , therefore, provide analytical tools with the potential to improve GI planning and management.

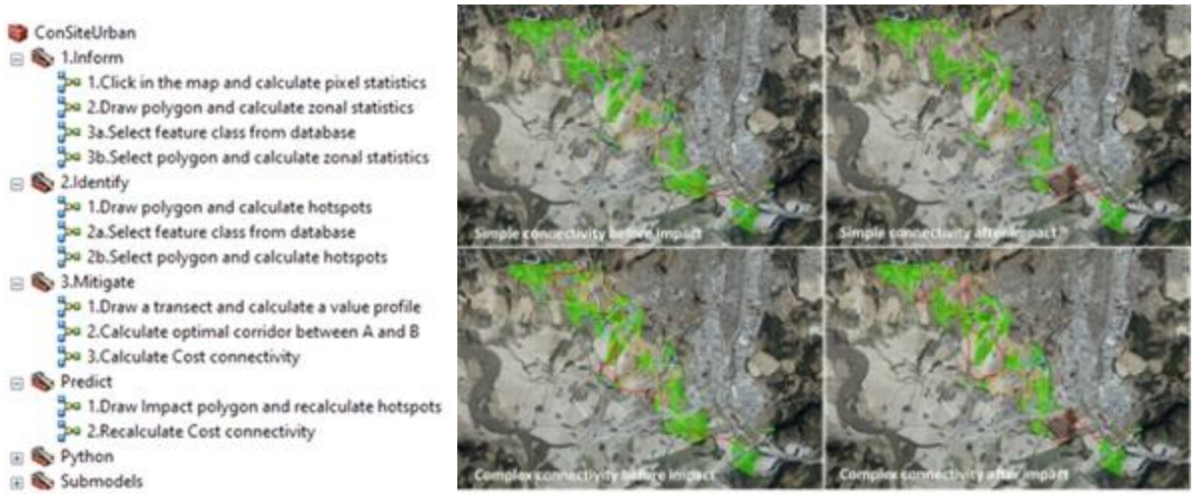


Figure 24: Visual output from the ConSite Urban toolbox (left) for predicting simple and complex connectivity network changes (right) before and after an imaginary development of an industrial area within the existing GI. The cost values range from 0 (blue) to 1 (red). (F. Hanssen, NINA)

4.3.8.3 Trade-offs between biodiversity and ecosystem service functions

Overlap analyses using results from both the BBN and the ConSite toolbox provide illustrations of the spatial relationships between areas that have high importance for the conservation of biodiversity, and ES that case study site residents deem important. In cases where the use of specific ES is compatible with biodiversity habitat conservation, areas with high overlapping values demonstrate the importance of synergy that strengthens arguments for preserving GI as well as prioritising sites for GI restoration. However, in instances where ES use is incompatible with conservation, or where the conversation entails areas with undesirable ES, overlapping areas illustrate trade-offs. Both sources of information that can be useful for landscape planning and environmental management by exploring the outcomes of alternative scenarios.

4.3.9 Conclusions and recommendations

The IMAGINE project implemented an operational framework that allowed us to replicate in 5 countries and 6 case study cases similar analysis regarding both ecological multifunctionalities, societal demands and regulations, resulting in the capacity to define flexible models that can be adapted to the different contexts and stakeholders demands. There is a series of short take home message for each topic we addressed in the project.

Species connectivity at the landscape level:

- When assessing the relationship between species and their environment, it is crucial that the input data correctly cover the ecological requirements of the species studied (necessary for modelling ecological niches).
- Bias in species observation data (localised over-observations for reasons of ease) must be taken into account when using data stored in open-access species databases (notably from citizen science).
- The generation of pseudo-occurrences (observation simulation) based on the species suitability of different habitats is an efficient approach to analyse potential corridors of species mobility at landscape level.
- Highlighting key cores and nodes enables managers and policymakers to target biodiversity management and conservation actions within territories.

Ecosystem services and ecosystem disservices:

- The capacity matrix approach is a flexible and efficient method for estimating capacity in Ecosystem Services and Disservices, as well as for engaging with local stakeholders and experts.
- Green and Blue Frame habitats provide 1.5 to 2 times more ES than non-GI habitats.
- Small GI linear elements are particularly important to ensure both the conservation of biodiversity and important ecological functions and services in agricultural landscapes (hedges, meadow strips, etc.).
- Wildlife connectivity and the capacity of ecosystem services are associated and not antagonistic. No trade-offs are needed between these two functions of the GI. It is therefore possible to promote both biodiversity and societal benefits.
- BTV elements provide ecosystem services associated with certain wild species with negative impacts (disservices, crop predators, disease vectors, attacks, etc.). They need to be taken into account in management options. However, GIs provide many more services than disservices.

Managing and restoring GI elements and networks:

- We have developed a hierarchical process to assess the management needs within each green infrastructure parcel.
- We have set up a system of "management blocks" that can be used to meet these needs and improve the quality of the green infrastructure plots to a level that allows for the required multifunctionality.
- Vulnerability analyses (a cartographic analysis that highlights the degree of vulnerability of natural habitats) allow us to identify the elements of green infrastructure that are particularly under pressure and thus help to prioritise management actions at the landscape level.

How can (existing) regulation mechanisms be further developed/improved?

- The broad and inclusive definition of green infrastructure leaves a lot of freedom and complexity in its management. There is no common understanding of what is a GI at the local level, despite EU and National definitions.
- Several different perceptions and preferences regarding ESs provided by green infrastructures may prevail. It is therefore important to define and specify the respective objective(s) for which a Green Infrastructure is implemented. This will help to manage the green infrastructures in the context of the different needs of society.
- A wide range of actors from different sectors are involved and have different interests regarding green infrastructures, which can lead to friction.
- The management and governance of green infrastructures is complex and requires participatory cooperation between institutions and stakeholders.
- Starting from common values related to the social elements and functions of green infrastructures will help to resolve frictions. For those elements and functions where opinions differ, it is important to understand why the opinions are contradictory. For the disadvantages brought about by green infrastructures, it is important to find ways to address them in integrated management.

Diverging, and conflicting societal demands:

- Local population and the citizens of neighbouring urban areas clearly prefer biodiversity conservation actions to agricultural intensification.
- Our results do not show a division of the population, i.e. farmers versus conservationists, but rather a huge overlap of preferences on this issue. Considering the different regional histories, contexts and policy mixes in the three countries, it is also surprising that the main conclusion is valid for all three case studies.
- From a policy perspective, our findings add to the broader and controversial discussion on the revision of the EU's Common Agricultural Policy (CAP). The results clearly show that society supports the fact that biodiversity should play a (more) important role in agricultural production.

- Our analysis leads us to conclude that future decisions should rather focus on overcoming current obstacles on how to better integrate biodiversity conservation into current agricultural production systems. In addition to the strong preference for biodiversity conservation, our study shows that there is a common understanding of the problem.

Integrated modelling of GI multifunctionality as decision-support tools:

- The design of common Core Set activities (harmonised set of indicators) for all study sites has made it possible to integrate site-specific characteristics into a common framework for the ecosystem services supply chain.
- The use of an integrated and interdisciplinary approach is essential to support the exploration of barriers, trade-offs and opportunities for the design and management of green infrastructure in diverse urban and rural landscapes.
- The tools developed capture the knowledge of experts and local people and provide geographical visualisations, such as information on the qualities of local landscapes providing ecosystem services, thus stimulating stakeholder and public engagement.
- Visual representations and scenarios have the power to cut through the complexity and vagueness often associated with policy or planning alternatives.
- Two models have been implemented in the project. On the one hand a BBN (Bayesian Belief Network) and on the other the ConSite multi-criteria model, useful for both land use/zoning planning, ecosystem-based management, area/green accounts and nature conservation and restoration objectives.

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4.4 *List of project meetings*

Project meetings and Stakeholders Workshops in study sites:
In each CSS at least 2 meetings were organised for participator evaluation of ecosystem services, preferences and policy coherence.

The project held 2 annual meetings each in one of the CSS site, except the PNR Scarpe-Escaut due to the COVID lockdown. **At each meeting, at least one person from each project meeting was present.**

- Thau Lagoon Area: IMAGINE Kick-Off meeting, 29-31 March 2017 - France CSS6
- Trondheim region: 2nd IMAGINE meeting, 22-24 November 2017 - Norway CSS2
- Turnhout: 3rd IMAGINE meeting, 24-26 March 2018 - Belgium CSS4
- Tallinn: 4th IMAGINE meeting, 24-28 November 2018 - Estonia CSS1
- Bornhöved: 5th IMAGINE meeting, Kiel, 18-21 March 2019 - Germany CSS3

We also organised a joint IMAGINE and URBANGAIA meeting : Ghent, 19-23 marche 2018.

Due to COVID Situation, the last IMAGINE meeting was replaced by an online WEBINAR, the 25th november 2020. 56 participants, all CSS Stakeholders were invited to join. The replay can be consulted at:https://app.livestorm.co/api/v1/event_types/73899de3-d4c3-4707-8a27-ab433c2cc8fa/replays/d9046aa1-d336-40b3-a0cb-70e6081e8277/download

4.5 *Follow up activities and plans for further exploitation of the results (Publication and meeting) - What next?*

Publications:

In preparation (to be submitted in 2021)

1. Campagne C.S. *et al.* 2021. Ecosystem services and ecosystem disservices capacity. Do green infrastructures provide more than other landscape elements? (journal to be decided).
2. Dubos Nicolas, Clémentine Preau, Maxime Lenormand, Guillaume Papuga, Sophie Monsarrat, Boris Leroy, Pierre Denelle, Marine Le Louarn, Stien Heremans, Frank Hanssen, Philip Roche, & Sandra Luque Assessing the effect of sample bias correction in species distribution models when independent data is unavailable (to be submitted MEE)
3. Hanssen *et al.* 2021. Preserving ecosystem services and GI in spatial planning of rural and urban landscapes. (Journal: “Journal of Environmental Assessment Policy and Management” or “Ecological Indicators”)
4. Heremans, S., De Blust, G., May, R.F., van Dijk, J.J, Campagne, C. S. & Roche, Ph. K. 2021. Management prioritization in Green Infrastructure by spatially combining stakeholder-weighted ES capacity with GIS-based degradation risk. (Journal: to be decided)
5. May, R. *et al.* 2021. Assessing ecosystem service bundles in multifunctional landscapes. (Journal: to be decided)
6. Mehring, M., Fickel, T., Hummel, D., Mortelmans, D., Roche, Ph.K., Turkelboom, F. 2021. Reconciling agricultural production and biodiversity conservation in rural landscapes: Perception and preference of local people in Europe. Research paper (Journal: to be decided)
7. Mehring, M., Fickel, T., NN. 2021. Challenges for the Implementation of the European Concept of Green Infrastructure - Insights from European Research. Opinion paper (Journal: to be decided)
8. Olivier Billaud, Sandra Luque, Clementine Preau, Samuel Alleaume, Pierre Maurel, Maxime Lenormand. 2021. Planning scenarios for urban expansion in coastal rural areas through ecosystem services assessment and trade-offs (to be submitted Geography and Sustainability (GeoSus) or Ecological Processes)
9. Preau, Clementine; Nicolas Dubos, Samuel Alleaume, Le Louarn, M., Lenormand, M, Luque, S. 2021. Hotspot prioritisation mismatch using dispersal-based connectivity assessment (submitted Landscape Ecology)
10. Roche, Ph. and Zakharova, E. 2021. Use of pseudo-occurence data and expert knowledge to model species connectivity. Journal (Ecological indicator, Landscape Ecology or One Ecosystem).
11. Roche, Ph. *et al.* 2021. Ecological condition and ecosystem services capacity in different european landscapes. To be submitted (Ecol. Indicator or Sustainability).

Sessions in International Meetings:

1. ESP 2021: Joint IMAGINE and URBANGAIA session: Recent advances in green and blue infrastructure ecosystem services and disservices. From rural to urban spaces. . June 2021, Tartu, Estonia. Co-lead of Session. Roche, Ph. K. and Pereira, P.

5 Stakeholder engagement in the project (WP6 with all WPLead)

5.1 *Stakeholder activities before the project*

We have worked with key stakeholders from early on, i.e. before this project and from the project application phase, as in many of our Case Study Sites (CSS), we have had long-term cooperation with the local/regional or relevant national stakeholders. These include, for instance, cooperation between stakeholders from water management, nature conservation and land-owners/managers (BE); or well-established cooperation between farmers, hunters, beekeepers, local communities, and NGOs (DE). Besides NGOs and different specific administrations (like Park managers, FR), very important stakeholders have been local and regional municipalities (e.g. Trondheim Municipality and County Governor Sør-Trøndelag (NO), Keila Rural Municipality (EE)) but also SMEs on participation and environmental planning (e.g. Vesterra Ltd (EE)). Those stakeholders were selected in the project for their helicopter view of the CSS and local stakeholders networks.

5.2 *Stakeholder activities during the project*

5.2.1 Nature of activities

The main stakeholder engagement forms and methods applied in IMAGINE are explained below (cf. also Table 1). A number of activities addressed what we called the **Green Infrastructure (GI) challenge**, which were defined in all CSS. They consisted of a) biophysical structures – relevant GI elements like hedge rows, forest patches, trails – and b) societal-desired functions of GI – stakeholder-identified ecosystem services (ES) and disservices (EDS).

Stakeholder analysis (1) supported all other stakeholder engagement in the CSS. Stakeholder analysis is a method identifying groups or organisations who are somehow related to the GI challenge ("affected by or can affect it"). Stakeholder analyses took place as desk studies and workshops/series of interviews with key informants in each CSS. This work was conducted in WP4 with WP6 support.

Social valuation of GI (2) detected with the stakeholders entry points needed to address the GI challenge, i.e. to identify social friction points (potential conflicts) but also opportunities (win-wins). Social valuation was carried out via 1-2 workshops (or series of interviews) with people identified via stakeholder analyses in all CSS. This work was conducted in WP4 with CSS teams support.

Analysis of GI uses, trade-offs (3) and **GI conflicts (4)** in-depth analysed the demand for, access to ES and EDS and potential conflicts thereof. Semi-structured interviews and scoring exercises were carried out in all CSS. Telephone surveys in selected CSS (Bornhöved (DE), Grote Nete (BE), Thau (FR)) zoomed in potential and existing conflicts between GI users'. This work was conducted by WP4 (ISOE) with support from CSS teams.

Policy coherence matrices (5) identified, which policy instruments are currently defining GI governance, to determine how successful they are in terms of effectiveness and equity. The matrices were filled in by policy experts in the field, either via individual interviews or small workshop, in all CSS. This work was conducted by WP4 (INBO) with support from CSS teams.

Certain other stakeholder activities investigated **specific GI problem-areas**. For instance, **ecosystem (dis)services' capacity matrix (6)** was a flexible semi-quantitative tool, to evaluate links between different ecosystem types or land cover types and the values for different ES or EDS. The matrix was filled in by different experts via workshops or individual/focus group interviews in all CSS.

Table 1: IMAGINE stakeholder activities: overview.

No.	Activity	What it does	Applied method	Involvement level(s)
1	Stakeholder mapping	identifies groups or organisations affected by or can affect GI challenge	interviews with key informants, workshop + stakeholder interviews	inform + consult + involve
2	Social valuation of GI	detects social friction points and opportunities of GI, as seen by the stakeholders	stakeholder workshop + interviews	inform + consult + involve
3	GI use and trade-offs analysis	in-depth analyses the demand for, access to ES and EDS and potential conflicts thereof	stakeholder interviews	inform + consult + involve
4	GI conflicts' analysis	zooms in conflicts between GI users', caused by e.g. side-effects, unequal access, and unfair division of burden of ES	stakeholder/lay people survey	inform + consult
5	Policy coherence matrix	identifies policy instruments defining GI governance, to determine their compliance with each other	policy experts' workshop/interviews	inform + consult
6	Ecosystem services' capacity matrix	evaluates links between different ecosystem types or land cover types and the values for different ES or EDS	(ecology) experts' workshop/interviews	inform + consult + involve
7	ES/EDS weighting via Analytical Hierarchy Processing	weighs ES/EDS relative importance, to standardize GI indicators and weighting functionality	stakeholder survey + workshop	inform + consult + involve
8	Management quality checks with stakeholders	a reality check with the stakeholders, if management measures foreseen are compatible with real CSS needs	structured interviews with stakeholders	inform + consult + involve

ES/EDS analytical Hierarchy Processing (AHP) (7) aimed to standardize GI indicators and weighting functionality. Different stakeholders valued and weighted the ES/EDS relative importance via a method called Analytic Hierarchy Process (AHP), via individual scoring exercises and deliberative workshops, done in selected CSS (Trondheim (NO), Grote Nete (BE), Scarpe-Escaut (FR)). This work was conducted by WP5 (NINA) with support from CSS teams.

Management quality checks with stakeholders (8) aimed to discuss with the local managers, how management of the GI elements may affect actual ES provision. Structured interviews with stakeholders in a number of CSS (Bornhöved (DE), Grote Nete (BE), Thau (FR)) yielded information that can be used as a reality check, to improve current management practices and/or restore different ecosystems. This work was conducted by WP4 (INBO) with support from CSS teams.

5.2.2 Brief reflection on these activities and lessons

We conducted a small survey in our consortium, to reflect on stakeholder activities' implementation and draw out lessons. The **most successful** stakeholder activities included: (6) **ecosystem services' capacity matrix**; (3) **social valuation of GI**; and (1) **stakeholder analysis**. The most **challenging** stakeholder activities included: (4) **policy coherence matrix**, and (7) **ES/EDS Analytical Hierarchy Processing**.

We asked project consortium members to think of and formulate general or important specific **lessons** learned from stakeholder interactions in the respective CSS in IMAGINE. Two main "clusters" of lessons emerged. The first lesson relates to establishing a **research-practice interface**. It was sometimes challenging to translate the different theoretical concepts (e.g. of the ES concept, conflict theory) to practice, and also to find the right match between stakeholder and researchers' needs (e.g. in case of applying the Policy Coherence Matrix). We learned that **proactivity** matters: it is better to integrate (or at least clarify) stakeholders' needs from the very beginning. We also learned that stakeholders are interested in contributing if they clearly understand **what is needed from them**, but also **potential benefits they might gain** from the project. However, academic timing is sometimes difficult to fit with timings of actual management decisions.

The second lesson relates to the **practical use** of **participatory methods**. The workshops were important arenas for stakeholders to meet and discuss issues, but also to share viewpoints and learn from each other in a non-conflictive setting. However, it was sometimes difficult to find a common ground between different interests (e.g. the viability of livestock agriculture and nature conservation (BE), or to get all key stakeholders represented (e.g. local authorities, Scarpe Escaut, FR; NO; EE cases). We learned that **choosing proper workshop methods,** e.g. tools to build consensus on GI challenges and solutions, is important. We also learned that **local coalitions** should be taken into account, and **some stakeholders (e.g. local opinion leaders) may help** the research team as **mediators**.

5.2.3 Dissemination to stakeholders

Dissemination took place as part of the above-mentioned participatory events. In addition, we also shared our results at international events, e.g. the ALTER-Net & EKLIPSE 2019 conference.

The CSS teams interacted regularly with local stakeholder regarding projects outcomes and potential application to their management challenges.

We also organized all our project meeting in the different CSS in order to be able to have a field visit with the whole project team and also to meet up local stakeholders.

The closing event initially planned to be held in the CSS5 (PNR Scarpe-Escaut, FR), was organized online due to the COVID lockdown constraints. All the key projects CSS were invited and many attended (We had 40 participants from outside the project team, including academics and stakeholders, Figure 1).

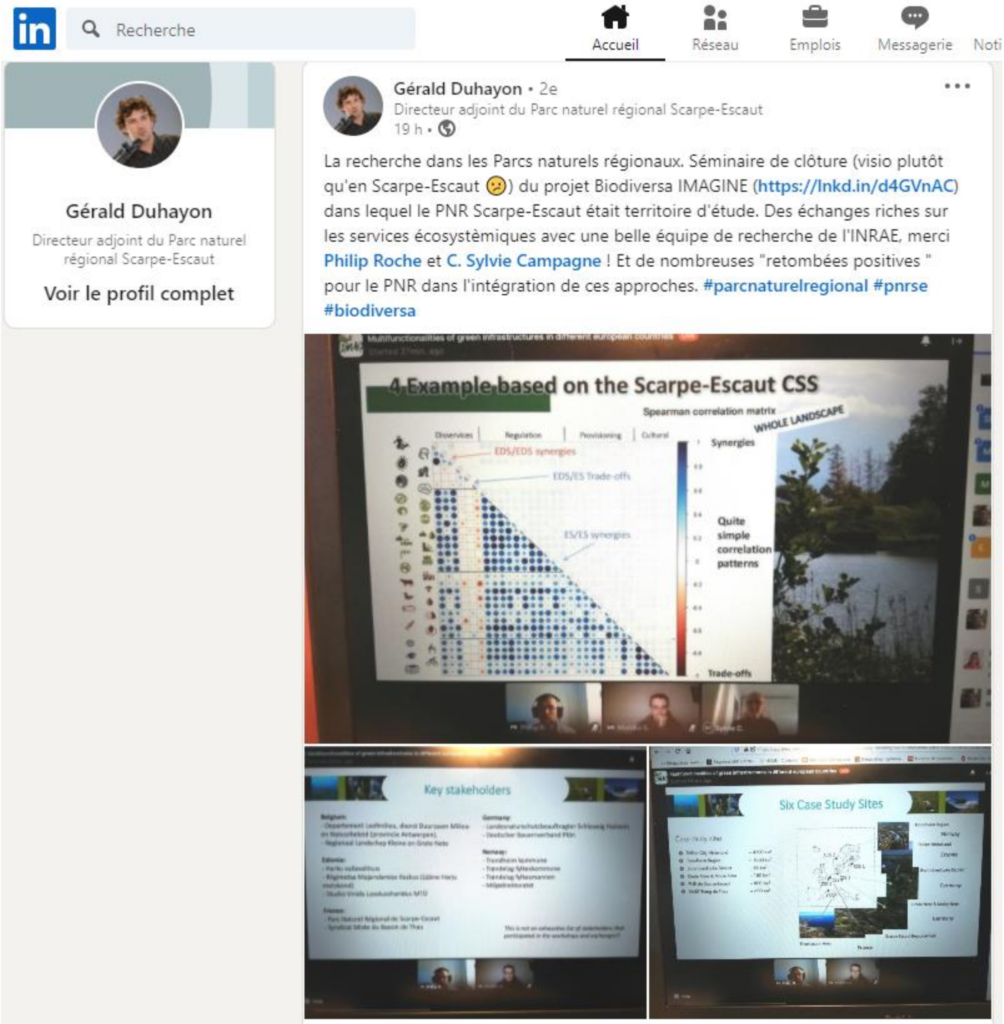

Figure 1: Acknowledgement of the closing IMAGINE Event by stakeholders on Linkedin. Translation: "Research in the Regional Nature Parks. Closing seminar (Visio rather than in Scarpe-Escaut 😕) of the BiodivERsa IMAGINE project (https://lnkd.in/d4GVnAC) in which the Scarpe-Escaut PNR was a study area. Rich exchanges on ecosystem services with a nice research team from INRAE, thanks Philip Roche and C. Sylvie Campagne! And many "positive spin-offs" for the PNR in the integration of these approaches. #parcnaturelregional #pnrse #biodiversa"

6 Dissemination of results

6.1 *List of scientific publications*

1. Campagne, C. S. and Roche P.K. (2018) May the matrix be with you! Guidelines for the application of expert-based matrix approach for ecosystem services assessment and mapping. *OneEcosystem. 3: e24134.* https://doi:10.3897/oneeco.3.e24134 8.
2. Campagne, C. S., Roche P. K., Gosselin F., Tschanz, L. and Tatoni, T. (2017) Expert-based ecosystem services capacity matrices:dealing with scoring variability. *Ecological Indicators*. 79, 63–72. http://dx.doi.org/10.1016/j.ecolind.2017.03.043
3. Campagne, C. S., Roche P.K., Müller, F. and Burkhard, B. (2020) 10 years of ecosystem services matrix: Review of a (r)evolution. *OneEcosystem*. 5: e51103. https://doi.org/10.3897/oneeco.5.e511035. (Acknowledgment to IMAGINE Missing, but partly supported by IMAGINE project)
4. Campagne, C. S., Roche P.K., Salles J-M. (2018) Looking into Pandora's Box: ecosystem disservices assessment and correlations with ecosystem services. *Ecosystem Services* 30, 126–136. https://doi:10.1016/j.ecoser.2018.02.005

5. Hanssen, F.O., May, R.F., van Dijk, J.J., Rød, J.K. 2018. Spatial multi-criteria decision analysis tool suite for consensus-based siting of renewable energy structures. *Journal of Environmental Assessment Policy and Management*, 20(3): 1-28. (Acknowledgment to IMAGINE Missing, but partly supported by IMAGINE project)
6. Karasov, O., Heremans, S., Külvik, M., Domnich, A., Chervanyov, I. 2020. On how crowdsourced data and landscape organisation metrics can facilitate the mapping of cultural ecosystem services: An Estonian case study. Land 9, 158. https://doi.org/10.3390/land9050158
7. Olivier Billaud, Maxence Soubeyrand, Sandra Luque, Maxime Lenormand. 2020. Comprehensive decision-strategy space exploration for efficient territorial planning strategies. *Computers, Environment and Urban Systems* Vol 83 https://doi.org/10.1016/j.compenvurbsys.2020.101516
8. Perennes, M., Campagne, C. S., Müller, F., Roche, P., & Burkhard, B. (2020). Refining the Tiered Approach for Mapping and Assessing Ecosystem Services at the Local Scale: A Case Study in a Rural Landscape in Northern Germany. Land, 9(348). https://doi.org/10.3390/land9100348
9. Roche P. K. and Campagne C. S. (2017) From ecosystem integrity to ecosystem condition: a continuity of notions supporting different aspects of ecosystems sustainability. *Current Opinion in Environmental Sustainability*. 29:63-68 https://doi.org/10.1016/j.cosust.2017.12.009
10. Roche, P. K and Campagne, C. S. (2019) Expert-based scoring provides reliable estimates of ecosystem service capacity. *Ecological Indicators*. 106, 105421. https://doi.org/10.1016/j.ecolind.2019.05.052 (Acknowledgment to IMAGINE Missing, but partly supported by IMAGINE project)
11. Suškevičs, M. (2019). Legitimate Planning Processes or Informed Decisions? Exploring Public Officials' Rationales for Participation in Regional Green Infrastructure Planning in Estonia. Environmental Policy and Governance, 29 (2), 132−143. https://doi.org/10.1002/eet.1836

6.2 *Dissemination of results to scientists and scientific organisations (1-page max)*

Sessions in International Meetings:

1. ESP9 World Meeting 2017 : Session: "Linking Green Infrastructure ecosystem condition and ecosystem services delivery: are Mediterranean systems different from others?". 11-15 december 2017, Shenzhen, China. Roche, Ph. K. and Campagne, C.S. co-hosts.
2. IALE World Congress - Symposium 59 Understanding the capacity of Landscape connectivity and ecosystem integrity to supply multiple ecosystem services: insights into sustainable landscapes. Coordinators Sandra Luque & Marc Lang Imagine Symposium, Milano 2019, Italy

Oral presentations (international conferences):

1. Campagne C. S., Callois J-M, Courtois P., Jacobs S., Lavorel S., Salles J-M, Turkelboom F. and Roche Ph. K. 2018. Sustainable use of ecosystem services at regional level. ESP9 EUROPE Regional Conference, San Sebastian, Spain, 15-19 October 2018.
2. Campagne C. S., Roche Ph.K., Burkhard B. and Salles J-M. (2019) Can we use ecosystem services capacity / flow balances to assess sustainable use? 10th IALE World Congress, Milano, Italy, July 1-5, 2019.
3. Campagne C.S and Roche Ph.K. 2017. Expert-based ecosystem services capacity matrices: Method and recommendations of application. Ecosystem Services for Eco-civilization: Restoring connections between people and landscapes through nature-based solutions, ESP8, 11-15 december 2017, Shenzhen, China
4. Campagne C.S and Roche Ph.K. 2017. Supply and demand assessment of ecosystem services based on expert knowledge: Mismatches at the habitat level. Ecosystem Services for Eco-

civilization: Restoring connections between people and landscapes through nature-based solutions, ESP8, 11-15 december 2017, Shenzhen, China

5. Campagne C.S, Roche Ph.K. and Salles J-M. 2017. Encompassing good and bad effects of nature: disservices assessment and correlations with ecosystem service. Ecosystem Services for Eco-civilization: Restoring connections between people and landscapes through nature-based solutions, ESP8, 11-15 december 2017, Shenzhen, China
6. Campagne, C.S., Roche, Ph. K. 2019. Risk of unsustainable use of ecosystem services through capacity/use assessment: current state and scenarios for support decision making. Ref. T_8882. 10th IALE World Congress, Milano, Italy, July 1-5, 2019.
7. Dijk, van; J., Hanssen, F., May, R. 2016. Incorporating ecosystem services together with the public goods approach in the consensus-based siting toolbox. ESP Conference Antwerp, Belgium.
8. Hanssen, F.O., May, R.F. 2017. ARCT Workshop. Consensus based siting (ConSite). ARCT Workshop
9. Hanssen, F.O., May, R.F., van Dijk, J.J., Stokke, B.G. 2017. Consensus based siting of renewable energy (ConSite). AlterNet Conference 2017, Ghent, Belgium, Policy, decision-making and social learning for conservation. AlterNet Conference.
10. Luque, S., Le Louarn, M. Lenormand, M. 2019. Combining connectivity and habitat suitability models as decision-making tools *IALE World Congress*, Milano 2019, Italy
11. Mehring, M. 2019 How to manage multifunctionality – The European concept of Green Infrastructure. Oral presentation: ALTER-Net and EKLIPSE Conference – The EU Biodiversity Strategy beyond 2020 (17.-19.6.2019)
12. Mortelmans, D. Turkelboom, F. Fickel, T. Mehring, M. 2019. Policy Coherence in Green Infrastructure management: insights from six European case studies. ESP 10 World conference – 10 years advancing ecosystem service science, policy and practice for a sustainable future (21.-25.10.2019)
13. Roche P. K. and Campagne C.S. 2018. Comparing expert based capacity matrices ecosystem services scores with biophysical quantitative indicators and models at regional level ESP9 EUROPE Regional Conference, San Sebastian, Spain, 15-19 October 2018.
14. Roche P., Campagne C. S. 2017. Eco* Integrity: What are we talking about? ESP meeting, Antwerp, 19-23 September 2017: oral presentation and co-host of this session.
15. Roche P., Campagne, C. S, Heremans, S., De Blust, G. and Van Dijk J. 2019. A Landscape level approach of green infrastructure multifunctionality from species conservation to ecosystem services producing areas, ref. T_0903. 10th IALE World Congress, Milano, Italy, July 1-5, 2019.
16. Suškevičs, M., Külvik, M., Lember, R., Schasmin, J. 2019. Social aspects of Green Infrastructure governance: role of stakeholder analysis and social valuation of ecosystem services. Paper presented at ALTER-Net & EKLIPSE conference “The EU Biodiversity Strategy Beyond 2020”, Gent, Belgium, 17-19 June 2019.
17. van Dijk, J.J., Hanssen, F.O., Köhler, B., Stange, E., May, R.F. 2018. Consistent valuation in a confusing world. ESP Conference 2018 San Sebastian, Spain.

Local presentations (National meeting, IMAGINE, local stakeholders, students):

1. Campagne, C.S and Roche Ph.K. 2017. Approche de concertation pour l’évaluation des services écosystémiques d’un territoire: exemple sur le Parc naturel régional Scarpe-Escaut. Colloque Valeurs et usage des zones humides, Bailleul, 26-30 Sept. 2017.
2. Hanssen, F.O. & May, R.F. 2018. Status report, Adaptive planning toolbox (ConSite Urban). IMAGINE consortium meeting Tallinn, Estonia.
3. Hanssen, F.O. 2020. ConSite Urban. Verktøy for analyse av grønne korridorer i arealplanleggingen. Trondheim CSS Stakeholder Meeting #3, Trondheim.
4. Hanssen, F.O., May, R.F. 2017. ConSite Wind- Konsensusbasert lokalisering av vindkraft. GIS-møte på Kungliga Tekniska Høgskolen.

5. Hanssen, F.O., van Dijk, J.J., May, R.F., Stange, E. 2019. Status report for WP5 in the IMAGINE project. IMAGINE consortium meeting Kiel, Germany.
6. Hanssen, F.O., van Dijk, J.J., Stange, E., May, R.F. 2017. IMAGINE: Integrative Management of Green Infrastructures' Multifunctionality, Ecosystem integrity and Ecosystem Services: From assessment to regulation in socio-ecological systems. Kick-off Meeting IMAGINE.
7. Le Louarn, M., Lenormand, M. & Luque, S. 2018. Sensitivity analysis of landscape metrics to human settlement data. GdR EcoStats, Grenoble, France, October 2018.
8. Le Louarn, M., Lenormand, M., Luque, S. 2018. Combining connectivity and habitat suitability models as decision-making tools: a case study in the south of France. International Conference on Ecological Science, French Society of Ecology, Rennes, France, October 2018.
9. Le Louarn, M., Lenormand, M., Luque, S. Assessing spatial priority of Green Infrastructures using morphological analysis: a European approach. International Conference on Ecological Science, French Society of Ecology, Rennes, France, October 2018.
10. Lenormand Maxime, Olivier Billaud, Maxence Soubeyrand 2019. Intégration des Services Ecosystémiques dans la Planification Territoriale : *Application au Bassin de Thau. LAMSADE :* Atelier ES et prise de décision *Montpellier Dec. 2019*
11. Lenormand Maxime. Stratégies de planification territoriale : Intégration des Services Ecosystémiques. Atelier de restitution, Bassin de Thau, SMBT Sept. 2020
12. May, R.F., Hanssen, F.O., van Dijk, J.J. 2016. IMAGINE: Integrative Management of Green Infrastructures' Multifunctionality, Ecosystem integrity and Ecosystem Services: From assessment to regulation in socio-ecological systems. NTNU Sustainability breakfast seminar, Trondheim.
13. May, R.F., van Dijk, J.J., Hanssen, F.O., Köhler, B., Stange, E. 2019. IMAGINE - Naturgode Kapasitet Kartlegging. Trondheim CSS Stakeholder Meeting #2, Trondheim.
14. Preau Clementine, Sandra Luque. Modèles spatiaux multi-espèces : hot spots de connectivité. Atelier de restitution, Bassin de Thau, SMBT Sept. 2020
15. Stange, E. 2018 Integrating and organizing IMAGINE Core Set outputs with Bayesian Belief Networks (BBN) as a Probabilistic Graphical Model. IMAGINE consortium meeting Tallinn, Estonia.
16. Stange, E. 2018. What can we realistically and meaningfully accomplish with a BBN common to all CSS? IMAGINE consortium meeting Tallinn, Estonia.
17. van Dijk, J.J. 2017. Biodiversitet, Økosystemtjenester og Arealplanlegging. AAR4845 – Landskapsanalyse. Guest lecture NTNU, Trondheim.
18. van Dijk, J.J. 2017. Fra Kulturelle økosytemtjenester, til kunnskaps- og opplevelsestjenester, til verdier av friluftsområder – har vi mistet noe på veien? SIS Urban Reference group meeting.
19. van Dijk, J.J. 2018. Biodiversitet, Økosystemtjenester og Arealplanlegging. AAR4845 – Landskapsanalyse. Guest lecture NTNU, Trondheim.
20. van Dijk, J.J. 2018. IMAGINE WP5: Hands-on AHP. IMAGINE consortium meeting Tallinn, Estonia.
21. van Dijk, J.J. 2018. Integrative management of green infrastructures multi-functionality, ecosystem integrity and ecosystem services - Experiences from Trondheim -. RFEL3082: Sustainable Management of Ecosystem Services**.** Guest lecture NTNU, Trondheim.
22. van Dijk, J.J. 2018. Stakeholder Analysis and Participatory identification of GI, ES and EDS, Trondheim CSS - Norway. IMAGINE consortium meeting Turnhout, Belgium.
23. van Dijk, J.J. 2019. Sosiale friksjoner og overenstemmelse Trondheim grønn infrastruktur. Trondheim CSS Stakeholder Meeting #2, Trondheim.
24. van Dijk, J.J., Hanssen, F.O., Köhler, B., Stange, E., May, R.F. 2020. IMAGINE - Trondheim: Kartlegging og verdsetting av grønn infrastruktur. Trondheim CSS Stakeholder Meeting #3, Trondheim.
25. van Dijk, J.J., May, R.F., Hanssen, F.O., Köhler, B. 2018. Bærekraftig flerbruk av Trondheim grønn infrastruktur. Trondheim CSS Stakeholder Meeting #1, Trondheim.
26. van Dijk, J.J., Stange, E., Hanssen, F.O., Köhler, B., May, R.F. 2018. IMAGINE …En Grønn By… …Fri Luft gir Liv… Trondheim CSS Stakeholder Meeting #1, Trondheim.

Poster presentations:

1. Campagne, C. S., Gosselin F., and Roche P. K. 2017. Expert's scores uncertainty and expert panel size in a participator scoring method. ALTER-Net Meeting, Ghent, 2-5 May 2017: poster presentation
2. Campagne, C. S., Salles J.-M. and Roche P. K. 2016. Assessing ecosystem services: sustainability of supply and demand at territory level. DOI: 10.13140/RG.2.2.18385.33122 EcoSummit, Montpellier, 29/08-1/09 2016: poster presentation
3. Campagne, C. S., Salles J.-M. and Roche P. K. 2017. Supply and demand assessment of ecosystem services based on expert knowledge: A bundle approach at ecosystem type level. ALTER-Net Meeting, Ghent, 2-5 May 2017: poster presentation - Winner of poster awards
4. De Blust, G. and Turkelboom, F. 2016. IMAGINE. Integrative management of green infrastructures multifunctionality, ecosystem integrity and ecosystem services. From assessment to regulation in socio-ecological systems. BELGIUM ECOSYSTEM SERVICES (BEES) meeting 2016. Poster.
5. Edward Ott: The role of institutions on the implementation of urban green infrastructure. 2. Conference of the Program on Ecosystem Change and Society, Oaxaca, Mexico (9.11.2017).
6. Roche Ph. K., 2017. The BIODIVERSA IMAGINE Project - Integrative Management of Green Infrastructures Multifunctionality, Ecosystem integrity and Ecosystem Services: From assessment to regulation in socio-ecological systems. Alternet International Conference, 2-5 may 2017 Gent, Belgium. Poster
7. Schasmin, J., Külvik, M., Suškevičs, M. 2019. Land cover scores-based ecosystem services supply assessment for green infrastructure planning: case of Harku rural municipality. Poster presented at ESP10: World Conference "10 years advancing ecosystem services science, policy and practice for a sustainable future" Hannover, Germany, 21-25 October 2019.

IMAGINE Cookbooks:

The Imagine cookbooks is a series of methodological documents that describes the methods used for the project analysis in order to be reproduced by others. The Imagine cookbooks would remain accessible online on the Imagine Website. An archiving solution will also be considered for long term accessibility.

1. De Blust, G., Heremans, S. 2020. Assessing detailed GI habitat quality for biodiversity and ecosystem services. IMAGINE COOKBOOK SERIES N°, Suškevičs, M. and Roche, Ph.K. Ed., 31 pp.
2. De Blust, G., Heremans, S. 2020. Green infrastructure management for ecosystem services. IMAGINE COOKBOOK SERIES N°, Suškevičs, M. and Roche, Ph.K. Ed., 47 pp.
3. Heremans, S., De Blust, G. 2020. Assessing GI vulnerability to ecosystem degradation at the landscape scale. IMAGINE COOKBOOKS SERIES N°, Suškevičs, M. and Roche, Ph.K. Ed., 13 pp.
4. May, R.F., van Dijk, J.J., Stange, E., Hanssen, F.O., Köhler, B. 2020. Developing adaptive landscape planning tools for the allocation of green infrastructure. IMAGINE COOKBOOK SERIES N°, Suškevičs, M. and Roche, Ph.K. Ed., 25 pp.
5. Mortelmans, D., Fickel, T., Ott, E., Mehring, M., Turkelboom, F. 2020. Policy Coherence Analysis. (PolCA) – Methodological approach. IMAGINE COOKBOOK SERIES N°, WP4, Suškevičs, M. and Roche, Ph.K. Ed., 17p.
6. Preau, C., Le Louarn, M., Luque, S., Roche, Ph.K. 2018. Connectivity and Habitat Suitability models. IMAGINE COOKBOOKS SERIES N°, WP1, Suškevičs, M. and Roche, Ph.K. Ed., 30p.
7. Roche, Ph.K., Campagne, C.S. 2020. Evaluating ecosystem services capacity: Guidelines and recommendations for cooking an ecosystem services and ecosystem disservices capacity matrix. IMAGINE COOKBOOKS SERIES N°, WP2, Suškevičs, M. and Roche, Ph.K. Ed., 20p.

8. Roche, Ph.K., Campagne, C.S. 2020.. Defining and evaluating ecosystem condition. IMAGINE COOKBOOKS SERIES, N°, WP1, Suškevičs, M. and Roche, Ph.K. Ed., 20p.
9. Turkelboom, F., Mehring, M., Ott, E., Mortelmans, D., *et al.* 2020. Stakeholder analysis, participatory identification of GI and ecosystem services. IMAGINE COOKBOOK SERIES N°, WP4, Suškevičs, M. and Roche, Ph.K. Ed., 20p.

Reports:

1. Campagne, C. S., Lefort, T. and Roche P.K. 2019. Approche participative de l'évaluation des services écosystémiques rendus par les habitats du Parc naturel régional Scarpe-Escaut. *Documents Phytosociologiques*
2. Campagne, C. S., Roche P.K. and Spinelli F. 2019. Services écosystémiques et évaluation participative : des outils pour l'aménagement du territoire et les évaluations environnementales. *Espaces Naturels*
3. Hanssen, F.O., May, R.F., van Dijk, J.J., Stokke, B.G., de Stefano, M. 2018. Spatial Multi-Criteria Decision Analysis (SMCDA) toolbox for Consensus-based Siting of Powerlines and Wind-power plants (ConSite). Trondheim: Norsk institutt for naturforskning, NINA rapport 1455: 42 pp.
4. Le Louarn, S. Luque 2018. Quantify the connectivity and the importance for connectivity of Green Infrastructures elements. IMAGINE WP 1 – Task 1.2 report. 10p.
5. Lindhjem, H., Navrud, S.,Magnussen, K., Westberg, N.B., Rasmussen, I., Hanssen, F.O., van Dijk, J.J. 2018. Tiltak i strømnettet og påvirkning på økosystemtjenester i samfunnsøkonomiske analyser. Oslo: Vista Analyse, Vista Analyse rapport 2018/2: 109 pp.
6. Suškevičs, M., Külvik, M. 2019. Social Frictions analysis: preliminary results from the Estonian Case Study Area (Harku municipality). Summary documentation on interviews. Report for WP4, 20.10.2019.
7. Suškevičs, M., Külvik, M., Tillemann, K. 2018. Participatory identification of Green Infrastructure, Ecosystem (Dis)services and Stakeholder Analysis. Case study: Harku municipality, Estonia. Report for WP4, 8.11.2018.

Others:

1. Plant, RA, Maurel, P & Ruoso, LE 2018, 'Utilisation du concept de Service Ecosystémique pour une évaluation participative du rôle des terres agricoles péri-urbaines dans le Sud de la France' in Plant, R, Maurel, P, Barbe, E & Brennan, J (eds), *Les terres agricoles face à l'urbanisation —De la donnée à l'action, quels rôles pour l'information ?*, Éditions Quae, Versailles.
2. Rey-Valette, H., Maurel, P., Jabbour, C., Cousin, C., Luque, S., Billaud, O., Salles, J.M., 2020. Apport de l'information géospatiale aux décisions d'aménagement du territoire : une expérimentation à partir de cartes d'occupation du sol à très haute résolution spatiale et de cartes de services écosystémiques. *Développement Durable et Territoires, France*.

7 Global Impact assessment indicators

7.1 *Impact statement*

7.2 *Synthetic figures for the project publications (including interactions with stakeholders)*

Peer reviewed Scientific Journal
Published: 12
In preparation for 2021: 11

International Conference presentations: 16
International Conference posters: 7
International Conference sessions: 3
Local conference: 26+ (some meetings were not noted)
Technical reports 7

Project meetings: 6 (1 webinar available online)
Joint Biodiversa meetings 3
Stakeholder meetings: 20+ (some stakeholders meetings were not noted)
Master and PhD thesis: 5

IMAGINE Cookbooks: 8

The Imagine cookbooks is a series of methodological documents that describes the methods used for the project analysis in order to be reproduced by others. The Imagine cookbooks would remain accessible online on the Imagine Website. An archiving solution could also be considered.

IMAGINE Closing Event Webinar:
To access the replay, it is necessary to register: https://app.livestorm.co/p/73899de3-d4c3-4707-8a27-ab433c2cc8fa

7.2.1 Analysis of the project publications

Scientific Journal	Number	Impact Factor (2019)	Scopus Cite Score (2019)
Computers, Environment and Urban Systems	1	4.66	7.50
Current Opinion in Environmental Sustainability	1	5.66	
Ecological Indicators	2	4.80	7.60
Ecosystem Services	1	6.33	10.80
Environmental Policy and Governance	1	2.13	3.90
Journal of Environmental Assessment Policy and Management	1		1.60
Land	2	2.43	
One Ecosystem	2		4.30
Sustainability	1	2.58	4.30

7.2.2 International dimension and multi-partnership for publications

Important: We considered only productions where Biodiversa was properly acknowledged.

	Nature of production	Published	In preparation
Multi-partner publications	Peer-reviewed journals	2	7
	Books or chapters in books		
	Communications (conferences)	4	
	IMAGINE Cookbooks	2	
Single-partner publications	Peer-reviewed journals	11	4
	Books or chapters in books		
	Communications (conferences)	13	
	IMAGINE Cookbooks	7	
Outreach initiatives including interactions with stakeholders	Popularization articles		
	Local Conferences/Workshops	26	
	Others		

7.3 *Assessment and follow-up of personnel recruited on fixed-term contracts (excluding interns)*

Identification			Before recruitment for the project			Recruitment for the project				After the project			
Surname and first name	Sex M/F	E-mail address	Last diploma obtained at time of recruitment	Country of studies	Prior professional experience, including post-docs (years)	Partner who hired the person (Organisation and Country)	Position in the project (1)	Duration of missions (months) (2)	End date of mission on project	Professional future (3)	Type of employer (4)	Type of employment (5)	Promotion of professional experience (6)
Campagne C. Sylvie	F	sylviecampagne@gmail.com	Master	France	1	Irstea, France	Doctoral student	24	30/10/2018	Post-doctoral abroad	Teaching and public research	researcher	Recruited based on acquired experience related to the project.
Chaurand Julie	F	julie.chaurand@latelescop.fr	PhD	France	1	Irstea, France	engineer	6	31/12/2018	Open-ended contract	SME/VSE		Current position in line with experience
Zakharova Elena	F	zavocado@gmail.co	PhD	Russia	26	Irstea, France	engineer	12	31/05/2019	Fixed-Term contract	research public institution	researcher	Current position in line with experience
Gourlet Laurie	F	laurie_2189@hotmail.fr	Licence	France	0	Irstea, France	Internship	3	31/08/2017	Fixed-Term contract	SME/VSE	engineer	No direct link
Tastayre Kévin	H	Kevin.tastayre@hotmail.fr	Licence	France	0	Irstea, France	Internship	3	31/08/2017	Open-ended contract	Other public	executive	No direct link
Furet Ugo	H		Licence	France	0	Irstea, France	Technician	3	30/09/2019	Unemployed	Other		No direct link
Ott, Edward	M	Edward.Ott@zalf.de	Master	Germany	0	ISOE, Germany	Doctoral student	17	juin-18	Fixed-term contract	Research public institution	Researcher	
Fickel, Thomas	M	fickel@isoe.de	Master	Germany	0	ISOE, Germany	Researcher	28	oct-20	Still working on the project	Research private institution	Researcher	
Mehring, Marion	F	mehring@isoe.de	PhD	Germany	6	ISOE, Germany	PI	46	oct-20	Open-ended contract	Research private institution	Researcher	
Hummel, Diana	F	hummel@isoe.de	PhD	Germany	18	ISOE, Germany	Post-Doc	46	oct-20	Open-ended contract	Research private institution	Researcher	
Marie Perennes	F	perennes@phygeo.uni-hannover.de	MSc	Germany	4	CAU, Kiel	Doctoral student	36	juil-20	Fixed-term contract	Research public institution	Researcher	
Sabine Bicking	F	sbicking@ecology.uni-kiel.de	PhD	Germany	0	CAU, Kiel	Post-Doc			Fixed-term contract	Research public institution	Researcher	
Marine Le Louarn	F	MarineLeLouarn@irstea.fr	PhD	France	1	Irstea, France	Post-doc	13	30/06/2019	Private consultant	Private	Project manag.	Current position in line with experience
Pierre Denelle	M	pierre.denelle@gmail.com	PhD	France	6	Irstea, France	Post-doc	5	31/01/2020	Research academia	public	Junior researcher abroad	Current position in line with experience
Nicolas Dubos	M	nicolas.dubos@inrae.fr	PhD	France	14	Inrae, France	Post-doc	2	30/04/2020	Research	Public	Post doc	Current position in line with experience
Olivier Billaud	M	olivier.billaud@agroparistech.fr	MSc	France	1	Irstea, France	Master student	6	15/09/2018	PhD fellowship	Public	PhD fellow	Current position in line with experience

7.4 *Data Management and timeline for open access*

Please list databases, and indicate timeline for open access

We plan to make accessible most of the data acquire during the project. The archiving solution is not yet defined.

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