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"NAture Insurance value: Assessment and Demonstration"

NAIAD

SC5-09-2016 Operationalising insurance value of ecosystems

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Deliverable 2.3

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Edition information

Table 1

VERSION	EDITION DATE	MODIFICATION	WRITTEN BY	CONTROLLED BY
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1 Introduction and aim

In this deliverable, NAIAD will map insurance-relevant nature based capital at the European scale based on earth observation (EO) and other routinely available data. We work with each demo to define the most robust nature-based capital, urban infrastructure, and mitigation infrastructure data throughout the case study areas and elsewhere in Europe. We focus on rural green infrastructure (forests, wetlands, floodplains) as well as green areas, soils and groundwater, rivers in the urban environment. The biophysical co-benefits of insurance-relevant natural capital for other ecosystem services (carbon, water quality and quantity and biodiversity) are also analysed at the European scale using Co$tingNature. The purpose is to set the context for the development of the Eco:actuary tool and its application across Europe and in the demo areas. We also begin the process of further refining the Co$tingNature algorithms to begin the development of an Eco:actuary. An actuary compiles and analyses statistics and uses them to calculate insurance risks and premiums. In order to calculate the insurance value of ecosystems and of nature based solutions, the Eco:actuary will need to calculate:

a) The ecosystem-service-relevant multi-hazard potential (D2.1)

b) The insured (asset) exposure to these potential hazards (D2.2 and D2.3)

c) The vulnerability to this exposure and thus risk

d) Potential and realised hazard mitigation services provided by existing and planned nature-based capital

1.1 Defining nature-based and natural capital

Natural capital can be defined as the world's stocks of natural assets, which include geology, soil, air, water and all living things. It is from this natural capital that humans derive a wide range of services, often called ecosystem services, which make human life possible.

Nature based capital is defined here within the context on nature based solutions (NBS), as any existing or newly developed green infrastructure whether purely 'natural' (rare in Europe) or managed (more common), including all nature based solutions. As we transition from natural, through nature based to build systems, we traverse a continuum of potential ecosystem service (or dis-service) provision, depending on the degree of (mis)management of these systems.

Nature based (green infrastructure) solutions involve nature-based capital as distinct from grey infrastructure solutions, which are derived from built capital or grey assets. Most risks are mitigated through a combination of green and grey infrastructure, most green infrastructure also includes elements of grey and vice versa. The boundary between natural and nature-based is indistinct and clearly depends on the management by people. See Comiti (2012) in Alpine

rivers (his analysis of Italian rivers can be extended to French, Austrian and Swiss rivers) which he considers as only partially natural. This is in line with the old but very interesting vision of Marsh (1864) who compared American and European forests and considered the latter as "gardens" even in remote areas, compared to the wilderness of American forests. The impact of management is realised through changes in land cover and land use (including resulting management) see Andreassian (2004), Cosandey et al. (2005). From here, forward natural capital will refer to both natural and nature-based capital since the two are effectively indistinguishable.

This deliverable focuses on the biophysical characterisation of natural and nature-based capital and their ecosystem service co-benefits. We do not carry out economic valuation since this work will be addresses in WP4.

1.2 Defining "insurance-relevant" nature-based capital

We define "insurance relevant" and green and grey infrastructure of relevance (i.e. providing hazard mitigation services to) at risk insured or insurable assets downstream. For flooding this includes all natural capital providing flood storage upstream of insurable assets.

1.3 Defining ecosystem service "co-benefits"

We define ecosystem service co-benefits as benefits of natural and nature-based capital beyond the primary benefit and primary beneficiary. For example, water regulation is a co-benefit of plantation forests for which timber is the primary benefit (to the timber company) but downstream populations benefit from enhanced water regulation as a result of the forest's existence.

2 Data for natural capitals and ecosystem services calculated by Co$ting Nature V3

Here we define a series of insurance-relevant natural capitals and calculable ecosystem services and examine their relevance, previous work and potential data sources for each of the demo basins.

Appendix 1 lists key elements of insurance relevant natural capital, their relevance and a series of published references to the mapping or assessment of the service in the demo study areas.

Appendix 2 lists the key ecosystem services calculated by Co$ting Nature - and thus calculable by the Eco:actuary. For each DEMO the table indicates their relevance and a series of published references to the mapping or assessment of the service in the DEMO study areas. Co$ting

Nature V3 calculates the following ecosystem services: Timber (softwood, hardwood), Fuelwood (softwood, hardwood),Grazing/fodder, non-wood forest products, water provisioning (quantity, quality), fish catch, carbon, natural hazard mitigation (flood, drought, landslide, coastal inundation), culture-based tourism, nature-based tourism services, environmental and aesthetic quality services, wildlife services (pollination, pest control), wildlife dis-services (crop raiding, pests).

3 Methods to be applied in each DEMO

3.1 Thames Basin: UK DEMO site

The Thames basin DEMO will use the Co$tingNature and Eco:actuary platforms only, using some of the datasets outlined in this deliverable as alternative inputs to the global datasets.

3.2 Lower Danube section, Romania

In the lower Danube DEMO, the Eco:actuary platform will be used using some of the datasets outlined in this deliverable where possible.

3.3 Brague Basin, France

In the Brague catchment, new 2D hydraulic numerical modelling will be performed with a specific module accounting for large wood transport and jamming in bridges to enter the full detail of the specific torrential flood risk of the region. The Eco:actuary platform will be used on a larger area comprising other coastal rivers of the Alpe Maritime department.

3.4 Lez Basin, France

The main objective of the Lez DEMO is to analyse and value the role of nature-based solutions (NBS) for flood hazard mitigation in the Lez catchment. In particular, this DEMO will explore the role of groundwater-related ecosystem services for flood and drought hazard mitigation. The management of the aquifer consists in managing actively water abstraction at the source to lower groundwater levels before the rainy season, and in maintaining natural and agricultural ecosystems in the recharge area. Four models will be coupled to simulate the role of groundwater to mitigate flood hazard: a hydrogeological model of the karst system, a hydrological model of the Lez river, a hydraulic model of the Lez river and a risk model of the Montpellier city. Co-benefits will be assessed at the local scale, based on literature review and interviews with local stakeholders to (i) describe ecosystem services provided by the NBS, and

(ii) collect local data to assess them in economic terms. The Eco:actuary platform will be tested for this DEMO basin to assess some co-benefits of the NBS.

3.5 Greater Copenhagen area, Denmark

GEUS will model subsurface processes (groundwater) using a modified version of the Danish national model, adapted for a high resolution modelling of the Østerbro subcatchment in the city where NB solutions are being and will be implemented. The Eco:actuary platform will be applied to the larger Copenhagen catchment surrounding and embedding the Østerbro catchment. This extended area is challenged by unsustainable water extraction from groundwater well fields which affects both the hydrology in this area as well as the shallow groundwater in the urban Østerbro catchment and ultimately has an impact on the feasibility and implementability of NBS solutions

3.6 Spangen Area, Rotterdam DEMO Site, The Netherlands

There will be no role for Eco:actuary in this DEMO. Other techniques will be used and thus will be identified in other of the project deliverables.

3.7 Glinščica catchment - Slovenian DEMO site

The Eco:actuary framework will be applied to the wider Ljubljanica catchment, to get an overview and relation of the DEMO in the larger catchment.

3.8 Medina Del Campo DEMO Site, Spain DEMO

There are three physical issues to deal with in the Medina del Campo DEMO Site. On the one hand, a part of the aquifer will be studied, on the other hand, floods will be addressed and finally droughts will be taken into account. All three physical issues will be dealt by the use of different modelling approaches, including average trending and aquifer recharge, modelling extreme weather related to precipitations, both as the excess of rainfall and the lack of it. While the aquifer model is clearly deterministic, trying to reproduce its behaviour and then model future scenarios, floods and droughts will be clearly probabilistic. Hydraulic modeling will take place both for groundwater and for surface water in different software platforms. Rainfall probability will be dealt alone as the most likely triggering factor for floods, and the chances for abnormally large dry periods will establish the basic starting point in order to assess droughts.

3.9 The Lodz Region, Poland DEMO

Surveys and focus group workshops will be used to assess the ecosystem services delivered by the blue-green infrastructure Modelling of the extended metropolitan area with Eco:actuary framework.

4 From Co$ting Nature to Eco:actuary

This section provides results of analysis of hazard potential and greatest hazard potential for four DEMO basin regions.

4.1 Mapping absolute insurable asset value per pixel

An actuary compiles and analyses statistics and uses them to calculate insurance risks and premiums. In order to calculate the insurance value of ecosystems and of nature based solutions, the Eco:actuary will need to calculate:

a) The ecosystem-service-relevant multi-hazard potential

b) The insured (asset) exposure to these potential hazards

c) The vulnerability to this exposure and thus risk

d) Potential and realised hazard mitigation services provided by existing and planned nature-based capital

Much of this already exists in the Co$tingNature platform. The key developments required in moving from the Co$tingNature platform to an Eco:actuary will be in the following key areas:

Flood hydrology and NBS:

a) Improved modelling of flood risk to incorporate extreme events both in rural and urban settings

b) Improved modelling of the role of urban drainage systems

c) Improved representation of policy options for a variety of nature based solutions

d) Improved representation of policy options for a variety of built capital solutions

Insurance relevance:

a) Improved modelling of risk to insurable assets and their relative replacement value when damaged

b) Improved modelling of risk to the disruption to economic productivity

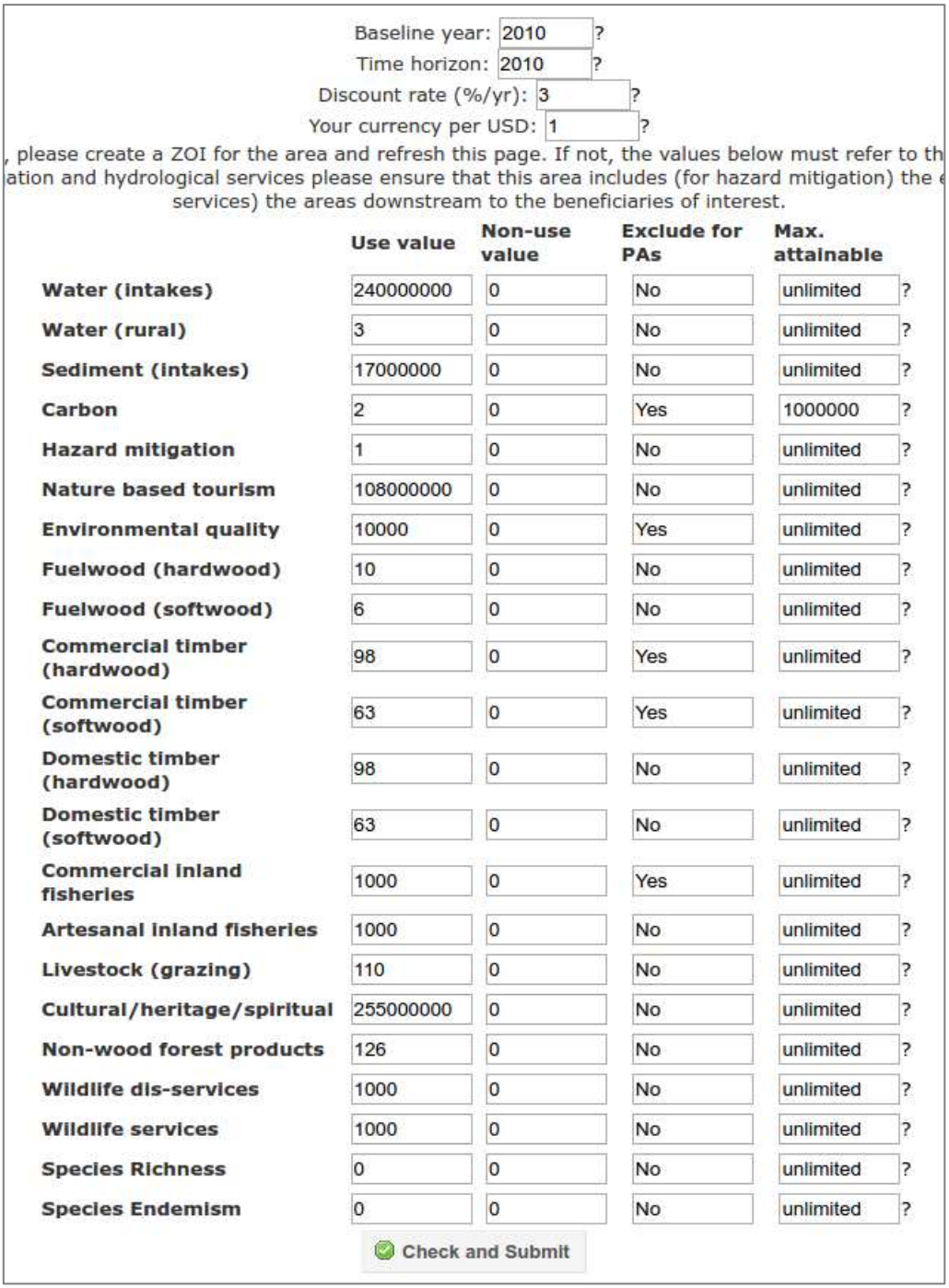
c) Improved modelling of risk to nationally important infrastructure and consequences for disruption

d) Improved modelling of risks to travel times

e) Improved modelling of risk to supply chains

The current deliverable focuses on insurance relevance, in particular to improve the treatment of asset exposure from Co$tingNature. Currently Co$tingNature calculates socio-economic exposure as relative human population, relative infrastructure, relative agriculture and relative GDP indices based on coarse global datasets. For the Eco:actuary we will focus on improving the representation of first order assets at risk (e) but also of second order impacts (f-i).

This valuation (as everything in Co$tingNature) will be relative (not economic) but Co$tingNature provides, and the Eco:actuary will provide, the interface for those (within and outside of NAIAD) with expertise in economic valuation to enter economic and insurance values. These will then be used to map economic asset value alongside economic risk and economic mitigation values. The current valuation interface for Co$tingNature V3 is as Figure 1 below. This will need to be modified in collaboration with WP4 and with insurers and risk assessors as part of our stakeholder process so that it is relevant to the valuation of: insurable assets, risk and mitigation by green and grey infrastructure.



Baseline year: 2010 ?
Time horizon: 2010 ?
Discount rate (%/yr): 3 ?
Your currency per USD: 1 ?

, please create a ZOI for the area and refresh this page. If not, the values below must refer to th
ation and hydrological services please ensure that this area includes (for hazard mitigation) the e
services) the areas downstream to the beneficiaries of interest.

	Use value	Non-use value	Exclude for PAs	Max. attainable	
Water (intakes)	240000000	0	No	unlimited	?
Water (rural)	3	0	No	unlimited	?
Sediment (intakes)	17000000	0	No	unlimited	?
Carbon	2	0	Yes	1000000	?
Hazard mitigation	1	0	No	unlimited	?
Nature based tourism	108000000	0	No	unlimited	?
Environmental quality	10000	0	Yes	unlimited	?
Fuelwood (hardwood)	10	0	No	unlimited	?
Fuelwood (softwood)	6	0	No	unlimited	?
Commercial timber (hardwood)	98	0	Yes	unlimited	?
Commercial timber (softwood)	63	0	Yes	unlimited	?
Domestic timber (hardwood)	98	0	No	unlimited	?
Domestic timber (softwood)	63	0	No	unlimited	?
Commercial inland fisheries	1000	0	Yes	unlimited	?
Artesanal inland fisheries	1000	0	No	unlimited	?
Livestock (grazing)	110	0	No	unlimited	?
Cultural/heritage/spiritual	255000000	0	No	unlimited	?
Non-wood forest products	126	0	No	unlimited	?
Wildlife dis-services	1000	0	No	unlimited	?
Wildlife services	1000	0	No	unlimited	?
Species Richness	0	0	No	unlimited	?
Species Endemism	0	0	No	unlimited	?

Check and Submit

Figure 1 Co$tingNature V3 Economic valuation of ecosystem services interface.

4.2 First order built infrastructure replacement value

Co$tingNature considers infrastructure as the presence of urban, dams, mines, oil and gas, roads using global datasets. Here we develop more sophisticated approaches that are capable of differentiating exposed assets within urban areas. We bring together remote sensing and crowdsourced data.

Remote sensing

Asset value is assumed to scale with night-time brightness from light pollution and building height. Clear-sky night-time light intensity is shown for London in Figure 2 (a), with red areas indicating highest intensity and transparent indicating zero. These remotely sensed data from NASA's VIIRS (Visible Infrared Imaging Radiometer Suite on the Joint Polar Satellite System) are available globally at <500m resolution. These data provide some distinction of different densities of urbanisation, but not sufficient. By combining these data with a 30m resolution globally available digital surface model developed from JAXA's ALOS (Advanced Land Observation Satellite) PALSAR (Phased Array type L-band Synthetic Aperture Radar) data we can better differentiate the scale of value of within urban assets. Height difference on a 9 by 9 cell (1 hectare) grid is calculated from the PALSAR data as shown in Figure 2 (b) and shows a clear concentration of high buildings in the east (the City of London and docklands), the far South (central Croydon) and the West (central Slough, Maidenhead and Reading).

By combining the night-time brightness and height data in a normalised, coupled index we obtain the *Eco:actuary Urban asset index,* Figure 2 (c) in which the high value assets of the City of London, Westminster, Docklands, the Olympic Park, Heathrow and central Croydon can be clearly distinguished.

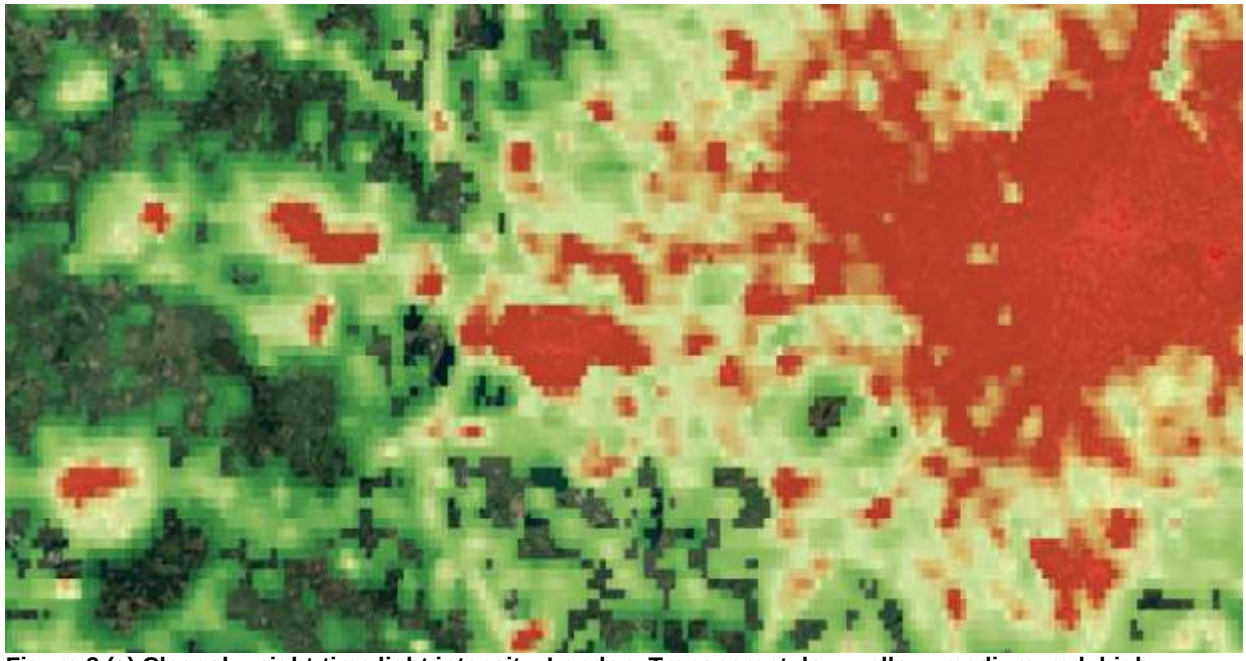


Figure 2 (a) Clear sky night-time light intensity, London. Transparent=low, yellow=medium, red=high.

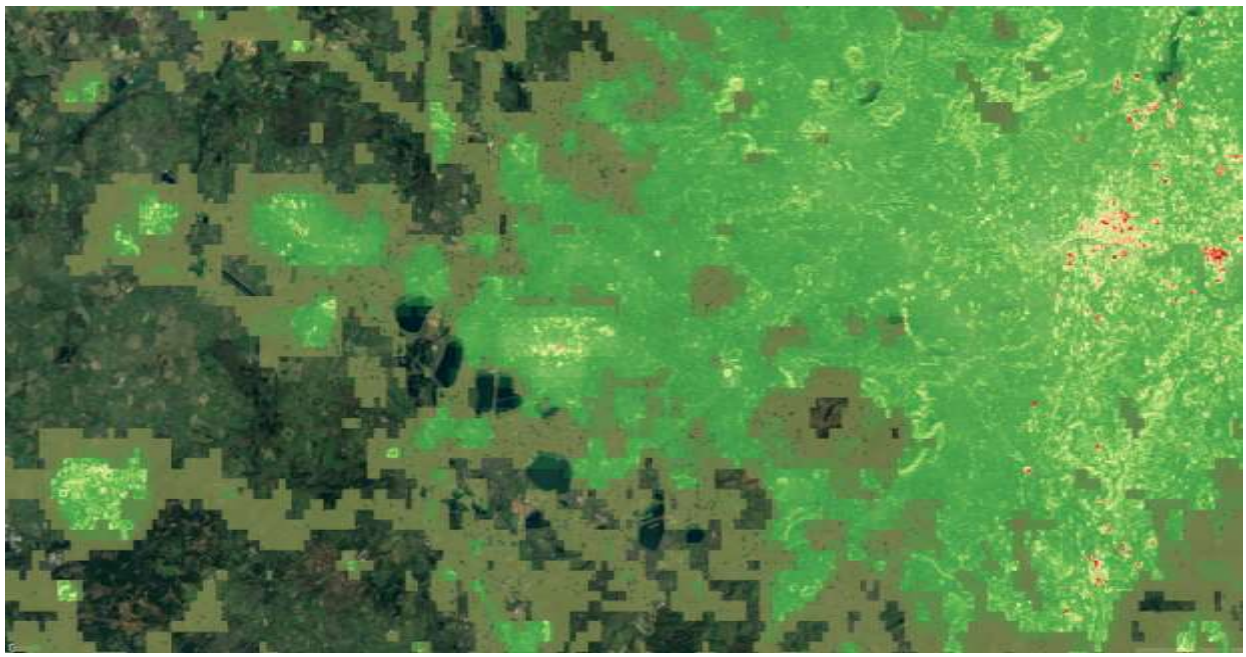


Figure 2 (b) One-hectare average building height range, London (scale 0-42m). Transparent=low, yellow=medium, red=high.

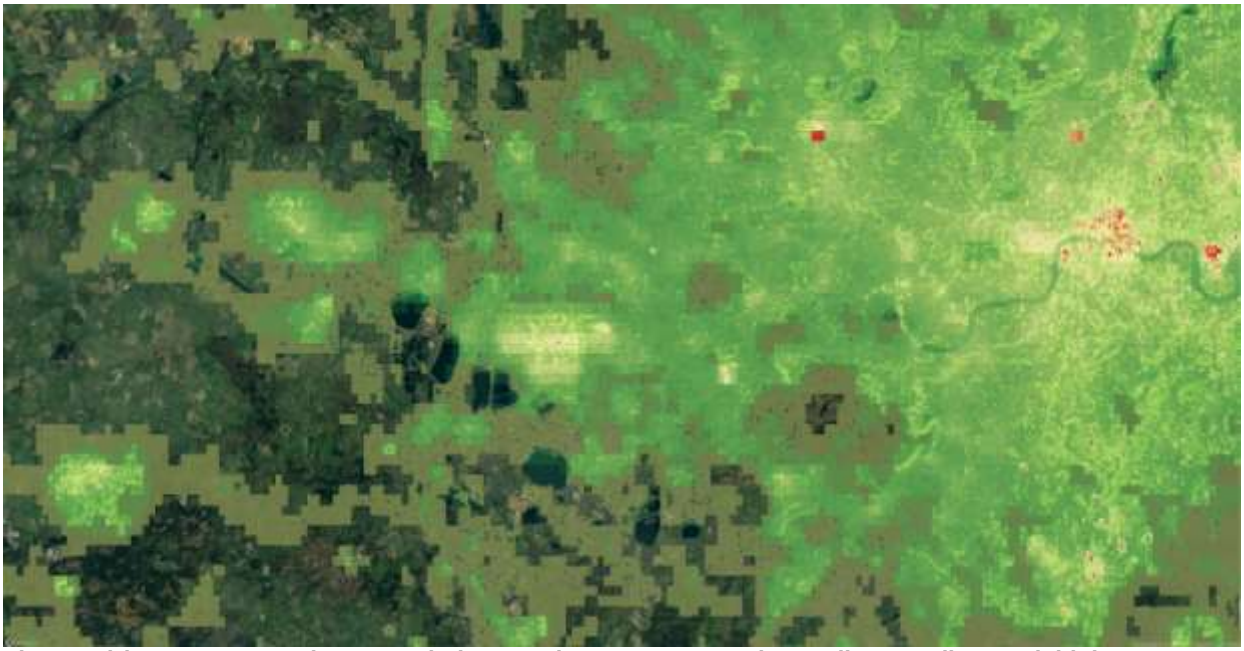


Figure 2 (c) Eco:actuary Urban asset index, London. Transparent=low, yellow=medium, red=high.

The same two data sources can be used to determine different types of urban asset (financial, commercial, and residential). In Figure 3 residential assets (brown) are defined as height<20m, brightness index>5, commercial assets (yellow) as height 5-20m, brightness index >100 and financial assets (red) as height >20 and brightness index >100.

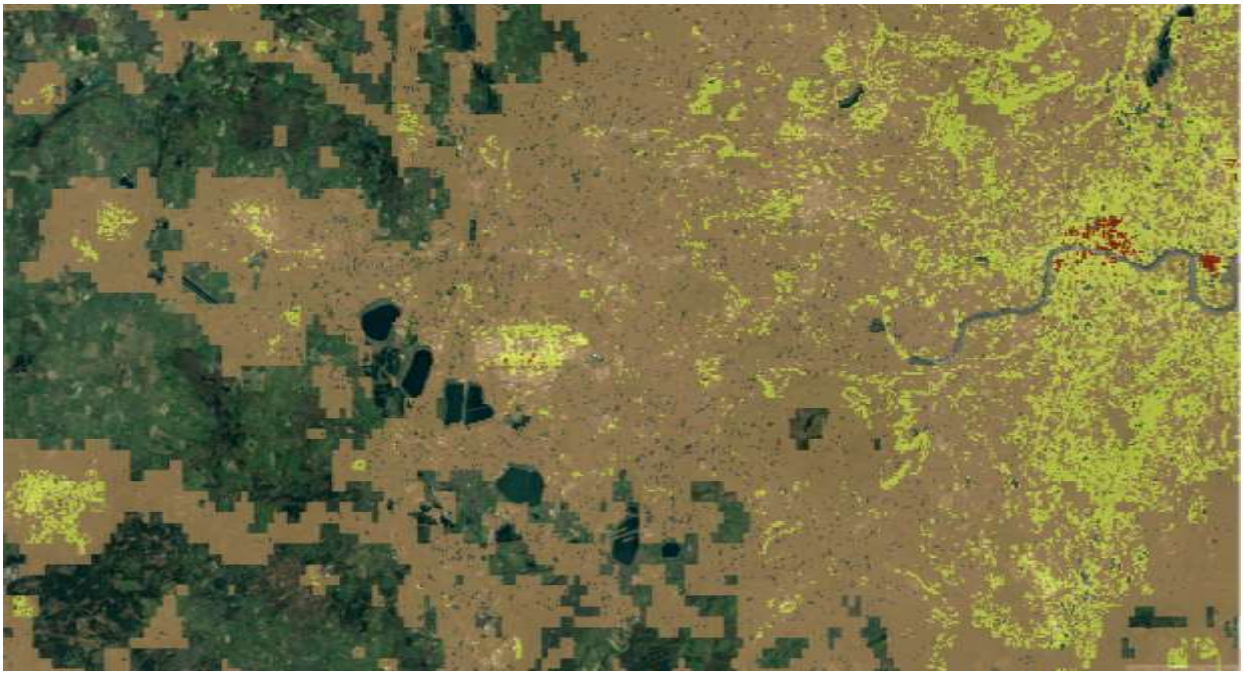
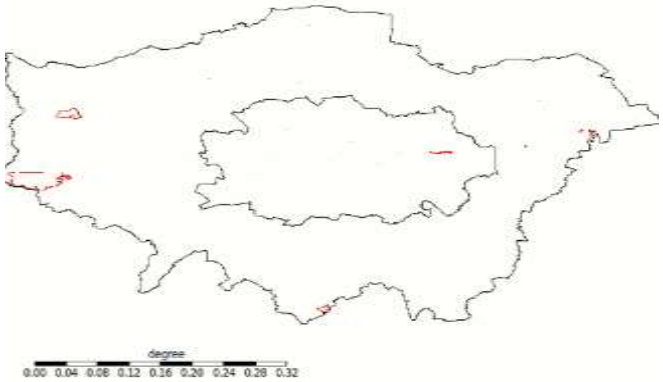


Figure 3 Eco:actuary asset type. Dense residential (brown), low commercial (yellow) and high financial assets (red), London.

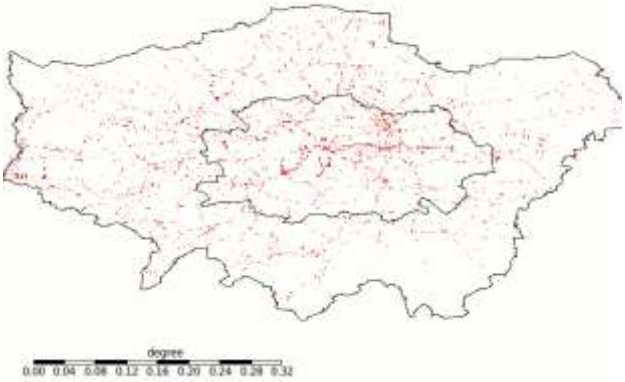
Crowdsourcing

Remote sensing can provide surrogates for asset value but more detailed information on the types of asset are not possible through remote sensing. Of course, each insurance context may have detailed local datasets available. If so, they can be used within the Eco:actuary platform. If not then a fall back option of routinely available data is necessary so the tool can be applied to any city in the world. Here we use the dataset of OpenStreetMap (OSM), again available throughout the world, to characterise different types of assets. OSM has more than 4.25 million users having uploaded 5.9 billion GPS points and having edited (digitised) around 4.1 billion points and 444 million lines globally. Where OSM data is not of sufficient quality for an evaluation using Eco:actuary then these data can be further developed by anyone in the OSM interface.

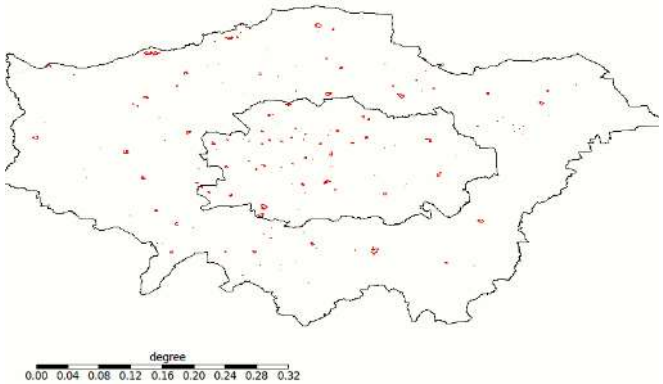
Here we define a series of insurance relevant assets and derive maps of their presence within Greater London as an indicator of how crowdsourcing can be used in the Eco:actuary.



Airports

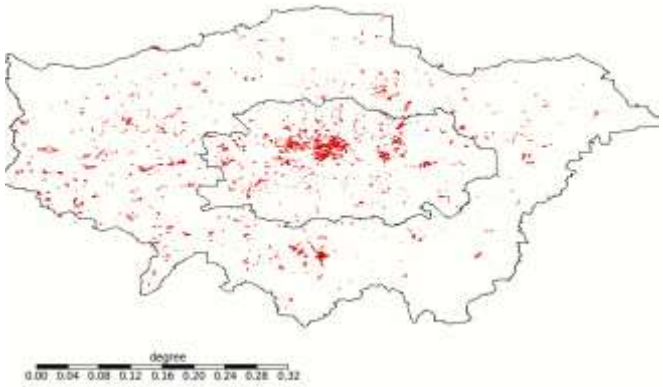


Bridges

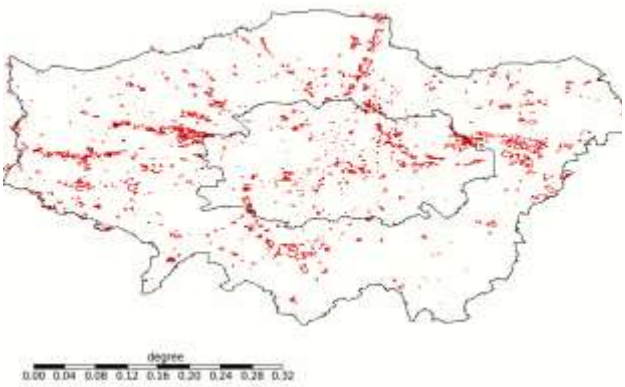


Hospitals

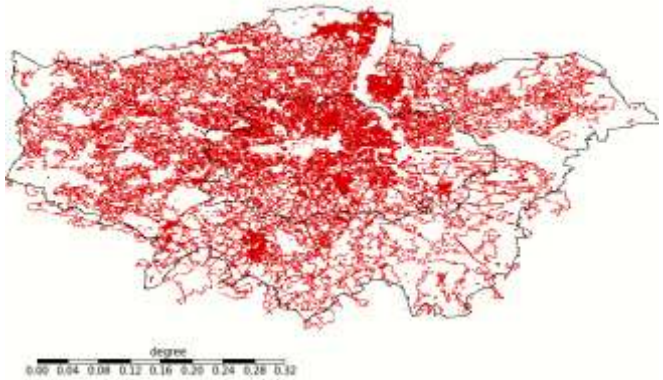
Highways



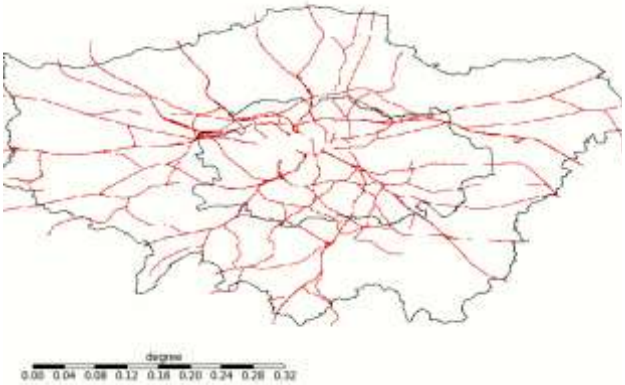
Commercial



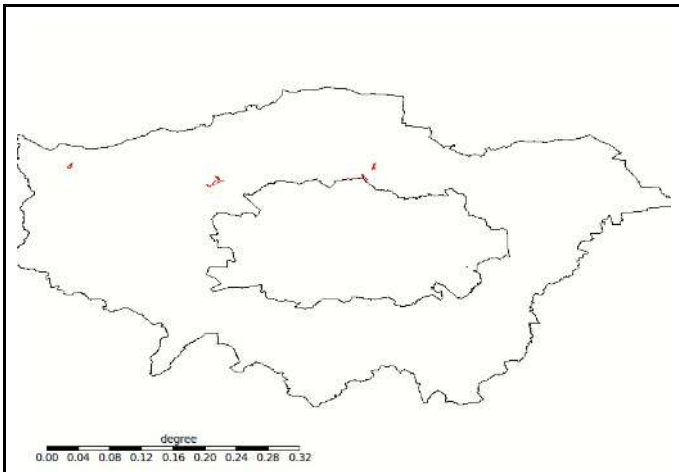
Industrial



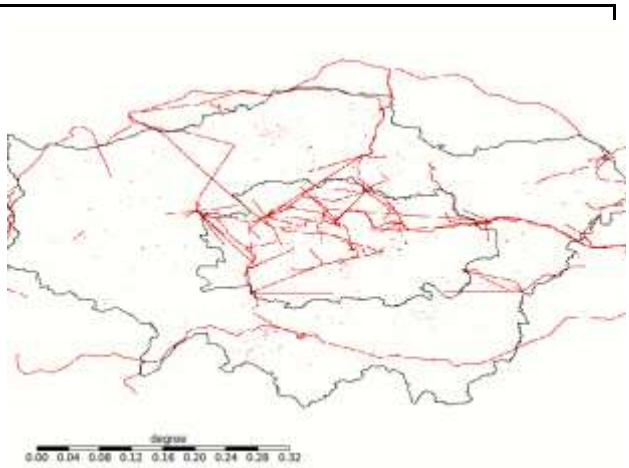
Residential



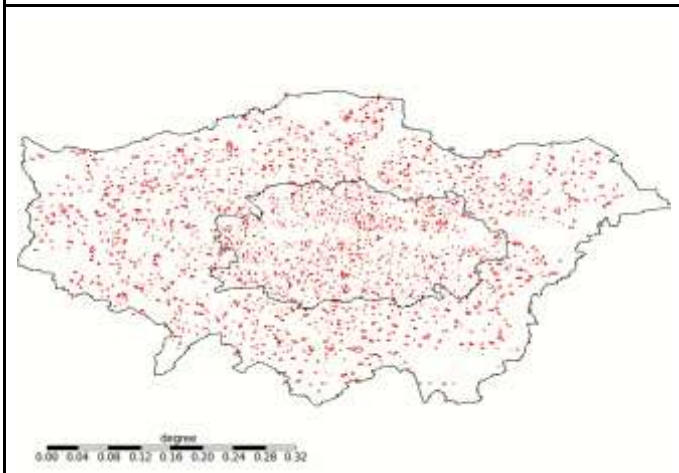
Railways



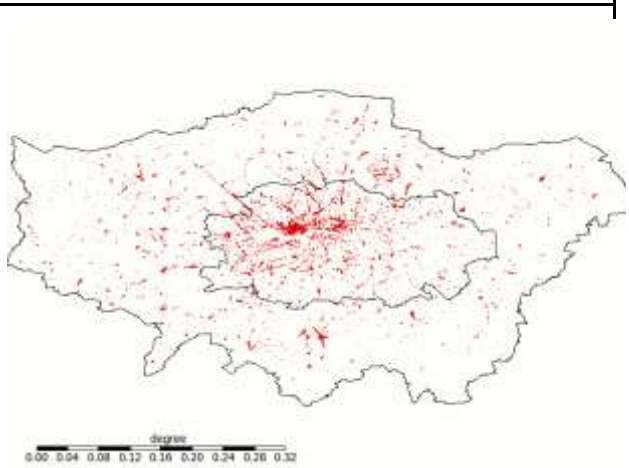
Reservoirs



Power infrastructure



Schools



Retail

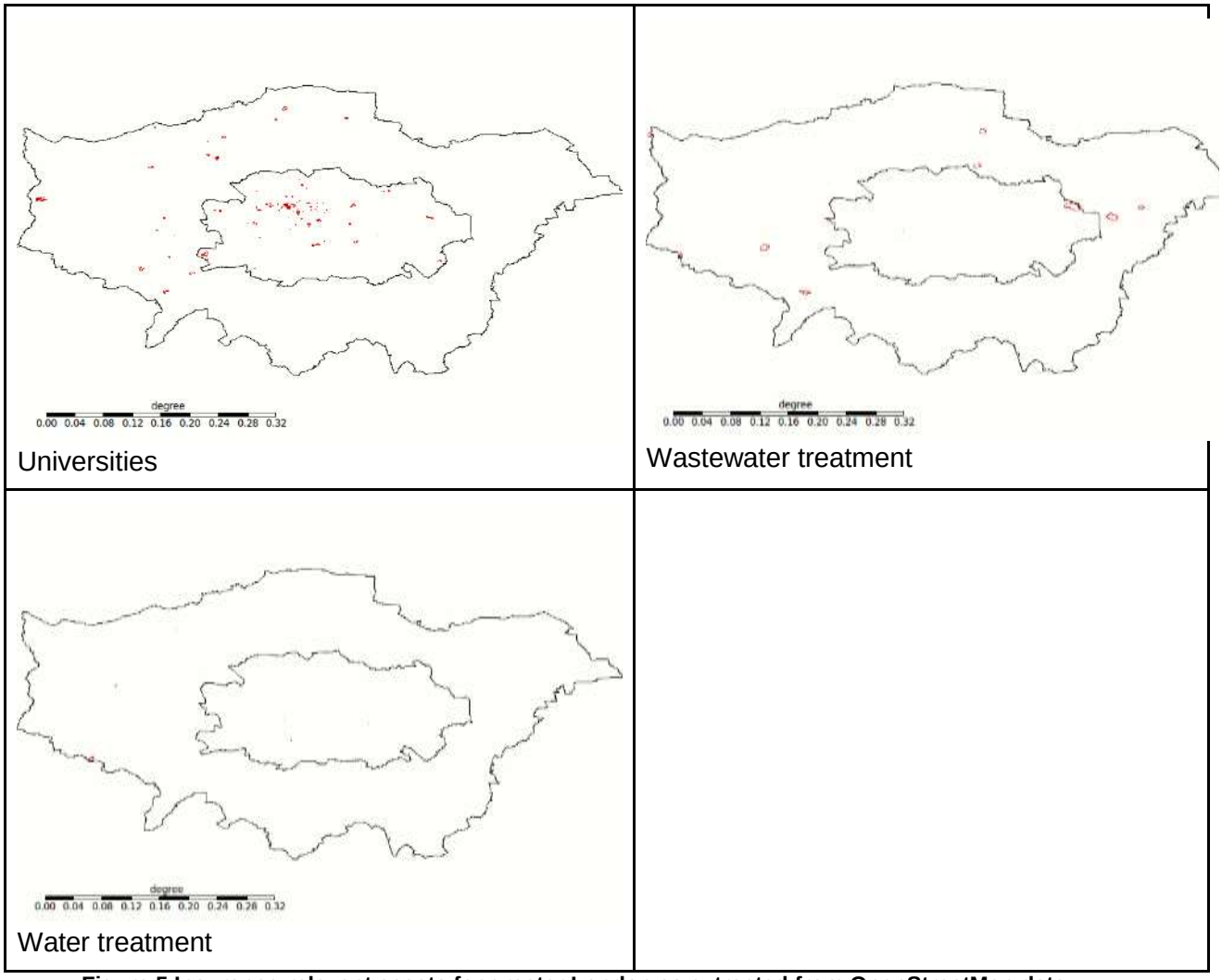


Figure 5 Insurance-relevant assets for greater London as extracted from OpenStreetMap data.

Clearly these data provide a useful basis for the mapping and valuation of different asset classes in order to better understand spatial risk to insured assets. By coupling these data on asset types with remotely sensed data on asset intensity global high resolution mapping of normalised asset value is possible.

The data is not of equal intensity throughout the world but perhaps the mapped river density of http://osm-analytics.org/ (Figure 6) provides the best overview of mapped areas. Europe is clearly well covered.

Figure 6 Mapped density of rivers as a surrogate for OSM coverage (source: http://osm-analytics.org/)

4.3 Second order disruption value

In addition to the value of assets themselves (replacement costs), we must also factor in the disruption costs associated with (a) the loss of function of assets themselves (e.g. machinery, processes) and (b) the loss of accessibility to the asset holders (e.g. the workforce). These can both be considered as different for each type of asset and to scale with the intensity (value, size) of the asset and the intensity of damage to the asset in the case of (a) and to the transport infrastructure in case (b). A potential interface allowing the parameterisation of (a) asset replacement costs, (b) asset loss of function costs and (c) asset inaccessibility costs is given in Figure 7. Normally data would be expected to vary between asset types, dummy values are present for now. This schema will be negotiated with insurance and risk assessment stakeholders at the London co-design workshop in January 2018.

Baseline year	2017					
Time horizon	2017					
Discount rate (%)	3					
Your currency per USD	1					
	Asset replacement costs		**Asset loss of function costs**			**Asset inaccessibility cost**
Asset type	**Lowest asset full replacement cost in area (million USD) L**	**Highest asset full replacement cost in area (million USD) H**	**Shortest asset loss of function period in area (days from full loss)**	**Longest asset "loss of function" period in area (days from full loss)**	**Productivity "loss of function" fraction. (Fraction of local asset related GDP lost for total loss of asset function)**	**Inaccessibility disruption fraction. (Fraction of local asset related GDP lost asa result of total loss of accessibility)**
Urban commercial asset class	0	10	1	10	0.75	0.5
Urban financial asset class	0	10	1	10	0.75	0.5
Urban residential asset class	0	10	1	10	0.75	0.5
Rural residential asset class	0	10	1	10	0.75	0.5
Industrial asset class	0	10	1	10	0.75	0.5
Cropland asset class	0	10	1	10	0.75	0.5
Pasture asset class	0	10	1	10	0.75	0.5
Airport asset	0	10	1	10	0.75	0.5
Aquaculture asset replacement cost	0	10	1	10	0.75	0.5
Bridge asset	0	10	1	10	0.75	0.5
Dam asset	0	10	1	10	0.75	0.5
Dyke asset	0	10	1	10	0.75	0.5
Highway/road asset	0	10	1	10	0.75	0.5
Hospital asset	0	10	1	10	0.75	0.5
Hydropower plant assets	0	10	1	10	0.75	0.5
Pipeline asset	0	10	1	10	0.75	0.5
Power utility asset	0	10	1	10	0.75	0.5
Railway asset	0	10	1	10	0.75	0.5
Reservoir asset	0	10	1	10	0.75	0.5
Retail asset	0	10	1	10	0.75	0.5
School asset	0	10	1	10	0.75	0.5
Telecoms asset	0	10	1	10	0.75	0.5
University asset	0	10	1	10	0.75	0.5
Waste water plant asset	0	10	1	10	0.75	0.5
Water treatment plant asset	0	10	1	10	0.75	0.5
Weir asset	0	10	1	10	0.75	0.5

Figure 7 Potential asset replacement and disruption valuation interface connecting the work of WP2 with WP4 towards the development of an Eco:actuary.

5. Mapping insurance relevant natural and nature-based capital

5.1 European distributions of "insurance relevant" natural capital

Our study area is Europe (hydrologically defined) since we must consider all areas upstream of the area of study. Though Co$tingNature is a multi-hazard platform, we focus on this pan-European analysis on flooding as a key European hazard. Other hazards are mapped at the European scale in NAIAD D2.1 and D2.2. For the purposes of a pan-European analysis we define insurance-relevant as any natural capital providing flood storage upstream of urban areas. Our

focus is on urban areas and any natural capital providing a flood storage service upstream of these is considered to be providing an insurance-relevant service. Clearly there are non-urban insurable assets that will also be considered in Eco:actuary but for this pan-European exercise we will focus on urban areas as key concentrators of high value insured assets. Areas upstream of urban areas in Europe are shown in figure 8. These are calculated in WaterWorld (Mulligan, 2013) as the areas upstream of where rivers enter the urban areas. Urban areas are defined from a remote sensing analysis and the red areas in Figure 8 are the (urban and rural) areas upstream of these. The catchments for the pan-European analysis do not include the urban areas themselves (except where those urban areas are part of a catchment of a downstream urban area). The map shows that some 76% of the study area drains into urban areas, with most areas that do not being either remote Arctic areas or coastal basins.

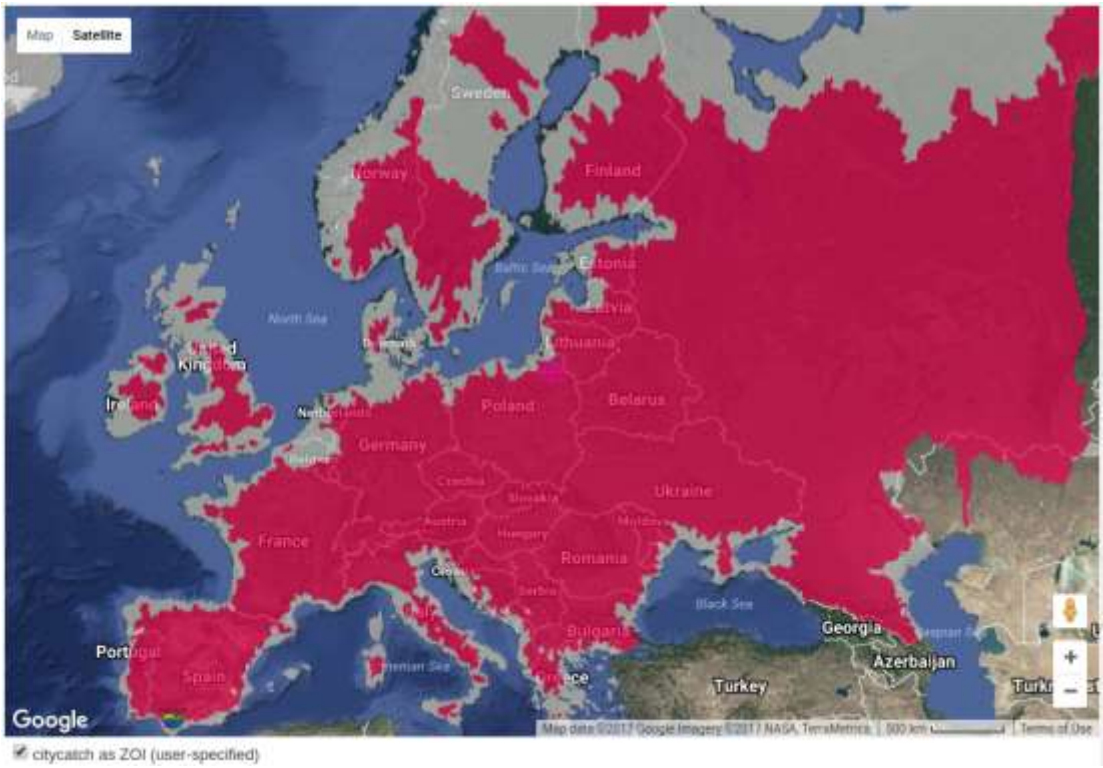


Figure 8 Hydrological catchments of urban areas in the European (hydrological) study area.

5.2 Natural capital providing flood mitigation services

We now present a series of flood storage services provided by natural capital in all areas upstream of urban areas and in areas with protected status (with protected areas covering some 31% of the region). In each case, the volume of flood storage available per year and in total,

upstream of urban areas and in protected areas upstream of urban areas, is shown. The analysis was performed using the WaterWorld Natural infrastructure tool that uses a range of remotely sensed datasets to define the different elements of storage as described below.

Floodplain storage capacity

Floodplains are defined here as pixels in which a connected downstream pixel has a Strahler stream order of greater than or equal to 3 (i.e. can be considered a permanent river rather than a hillslope or ephemeral stream) and the difference in elevation between the land pixel and its downstream neighbour (the river) is less than the (cellsize/20.0) i.e 5m @100m resolution, 50m @1km resolution, 500m @10km resolution (inter-cell differences greater than this are considered to define slopes rather than floodplain). Stream orders are calculated from the drainage direction map of Lehner et al., (2008) and elevations are calculated from the corresponding conditioned elevation map based on SRTM data (Farr and Kobrick, 2000). The average depth of water storage capacity on a floodplain is considered to be 0.5m (after Li et al, 2013).

Water body storage capacity

Water body storage is calculated based on the full pixel surface water frequency dataset of Mulligan (2017). Water bodies are assumed to include all pixels with a surface water frequency >0. The area of each water body is calculated, together with the volume, based on the empirical relationship of Lehner et al. (GRAND technical documentation, 2011). Water body volume is then converted to a per-pixel volume and scaled linearly to the long term frequency of observed wetness, such that storage that is frequently with water is considered to have lower (available) storage capacity (since capacity is filled already) than storage which are rarely wet.

Canopy storage capacity

Canopy storage capacity is calculated on the basis of the percentage tree cover in each pixel (Sexton, 2013) and a canopy storage capacity per rain-day set to 5mm. Davies-Barnard et al. (2014) present values for trees varying from 0.1-9.1mm across arid, temperate and tropical regions. 5mm is thus considered a representative average for a closed canopy. Values will then scale with per pixel tree cover such that in more arid environments, with more sparsely distributed trees, values will be lower. In this global analysis we do not consider canopy storage by grasses and shrubs since our focus is on tree canopies as green infrastructure. In order to account for interception losses to the atmosphere (i.e. evaporation from leaf surfaces) from this store, a rain per rain-day metric is calculated from the precipitation and rain-days datasets. Where rain per rain-day is greater than the canopy storage capacity of a pixel, the storage capacity defines the available storage, otherwise the available rain per rain day defines it. This gives a metric of the storage capacity available for a given rainfall event. The metric is multiplied

by the number of rain-days available per year to give the total annual storage capacity, on the basis that the store empties to the atmosphere (evaporates) between each rain-day.

Wetland storage capacity

Wetland storage capacity is based on the part-pixel surface water frequency dataset of Mulligan (2017) that uses a long term MODIS analysis over 12 years to identify the frequency of wetness per pixel, globally. The volume of storage per pixel is calculated from the surface wetness frequency multiplied by a mean maximum wetland depth of 5m, approximating therefore that the permanent (deepest) wetlands have a depth of 5m with temporary wetlands grading linearly from 5m to 0 by frequency. This captures water storage capacity at the edges of permanent water bodies and in seasonally drying wetlands.

Soil storage capacity

Soil storage capacity is based on a topographic index scaled soil depth for all non-impervious surfaces. It thus represents porous soil storage capacity. Soil storage is scaled linearly between 0 and a maximum accessible soil storage of 2m (representing a maximum accessible soil thickness of 4m given 50% porosity), according to the calculated topographic wetness index (TWI) (Beven and Kirkby, 1979). TWI is ln(A/tan[b]) where A is upstream area and b is local slope Maximum accessible soil storage (2m) is assumed to apply at a global topographic wetness index of 40 and the scaling thus operates between wetness indices of 0 and 40. In addition to the topographic effect, vegetation is also considered to influence soil storage, by adding 1mm of storage per per-cent of tree cover (i.e. adding 10cm soil storage at 100% tree cover). Finally, where water bodies, urban areas or roads occur, soil storage is considered inaccessible. For water bodies, soil storage is simply set to zero; for roads, the fraction of the pixel occupied by the road is considered inaccessible; and for urban areas, 90% of the soil storage is considered inaccessible (the remaining 10% representing green surfaces within the urban matrix).

Total storage capacity

Total storage capacity is calculated for both green and blue storage, and for total storage by all natural flood infrastructure, as simply the sum of all relevant stores.

The parameterisation of storage depths for each store are shown in Figure 9:

Figure 4 Parameterisation of storage depths (default) for the WaterWorld natural infrastructure tool.
The weight parameters are used to include or exclude storage from the analysis.

Soil storage

Soil storage occurs throughout the insurance-relevant areas of Europe, with around 35% falling in protected areas. Values are least in the built up areas of central Europe and in the rocky slopes of the Alps and Pyrenees and highest in the large sedimentary valleys of Russia and eastern Europe.

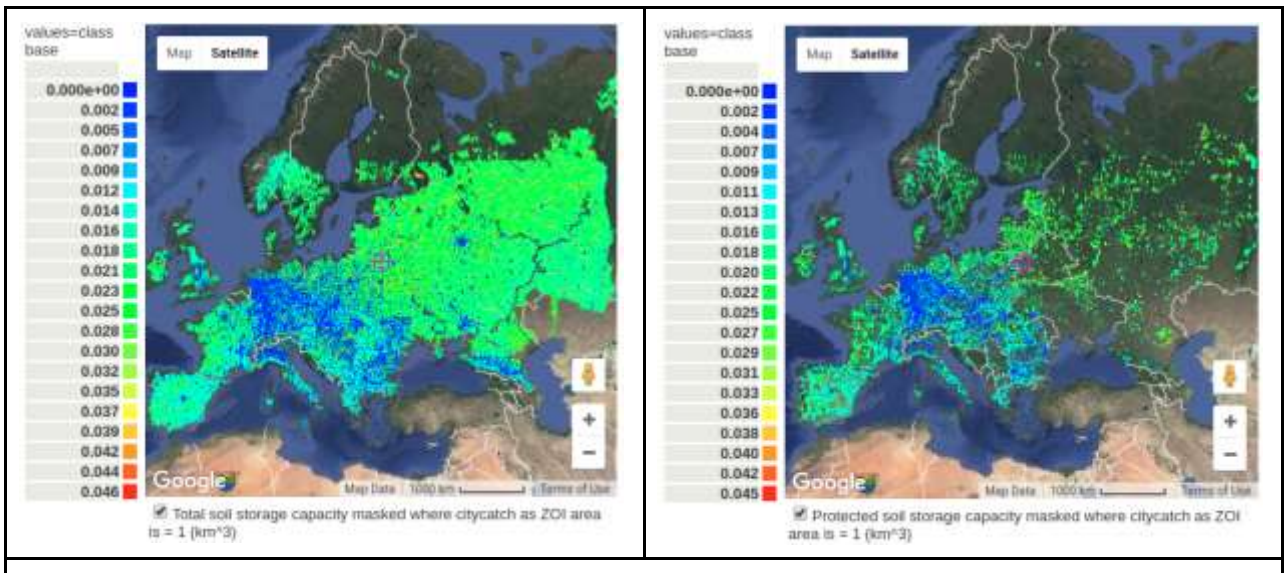


Figure 10 Soil storage volumes upstream of urban areas and in protected areas upstream of urban areas

All: 76,743 km^3

Upstream of urban areas: 66,421 km^3

Protected upstream of urban areas: 23,420 km^3

Canopy storage

Canopy storage occurs throughout the insurance-relevant areas of Europe, with around 39% falling in protected areas. Values are least in areas of climatically-driven low tree cover in South and East Europe and in the rocky slopes of the Alps and Pyrenees and highest in the frequency rainfall and high tree cover areas of Western UK, Scandinavia, Eastern Europe and Russia.

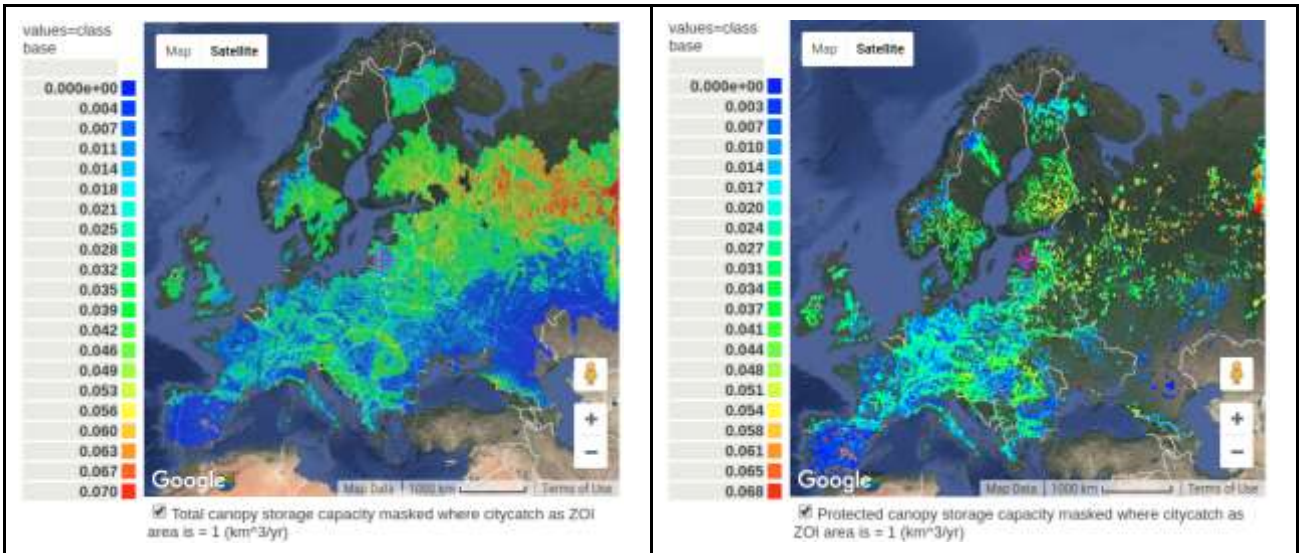


Figure 11 Canopy storage volumes upstream of urban areas and in protected areas upstream of urban areas

All: 107,630 km^3/yr

Upstream of urban areas: 87,283 km^3/yr

Protected upstream of urban areas: 34,941 km^3/yr

Wetland storage

Wetland storage is intermittent in the insurance-relevant areas of Europe, with around 42% falling in protected areas. Values are least in dry southern Europe and are highest in the rocky slopes of the Alps and Pyrenees, Scandinavia, Eastern Europe and Siberia since wetland storage also incorporates water storage in shallow depressions and snow held in topographic depressions and stored over long periods.

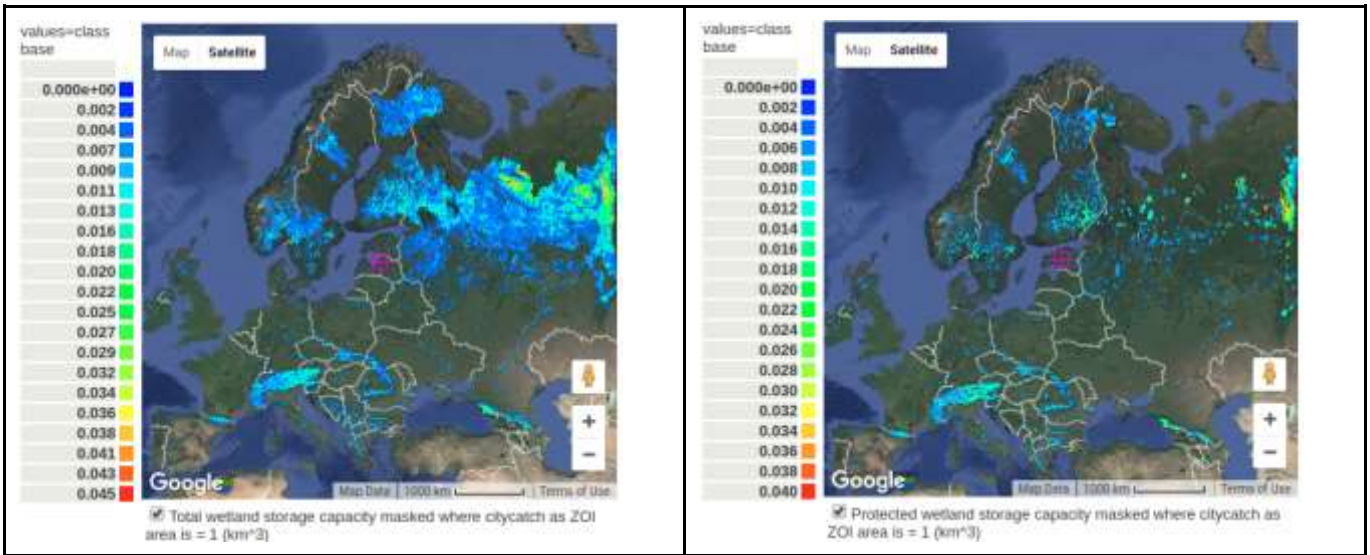


Figure 12 Wetland storage volumes upstream of urban areas and in protected areas upstream of urban areas

All: 12,534 km^3

Upstream of urban areas: 7,938 km^3

Protected upstream of urban areas: 3,324 km^3

Water body storage

Water body storage is highly intermittent in the insurance-relevant areas of Europe, with around 45% falling in protected areas. Values are concentrated in a few areas with many water bodies: Scandinavia, the Alps, Pyrenees and Northern Ireland.

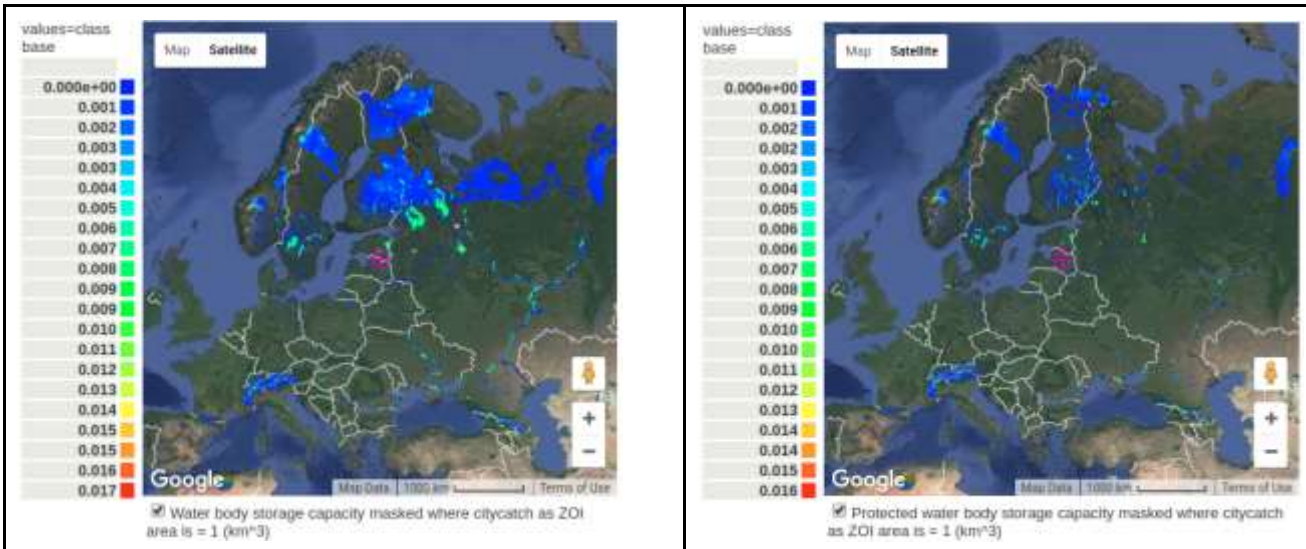


Figure 13 Water body storage volumes upstream of urban areas and in protected areas upstream of urban areas

All: 1,920 km^3

Upstream of urban areas: 625 km^3

Protected upstream of urban areas: 281 km^3

Floodplain storage

Floodplain storage occurs throughout the insurance-relevant areas of Europe, with around 40% falling in protected areas. Values are concentrated is a few areas with major European rivers.

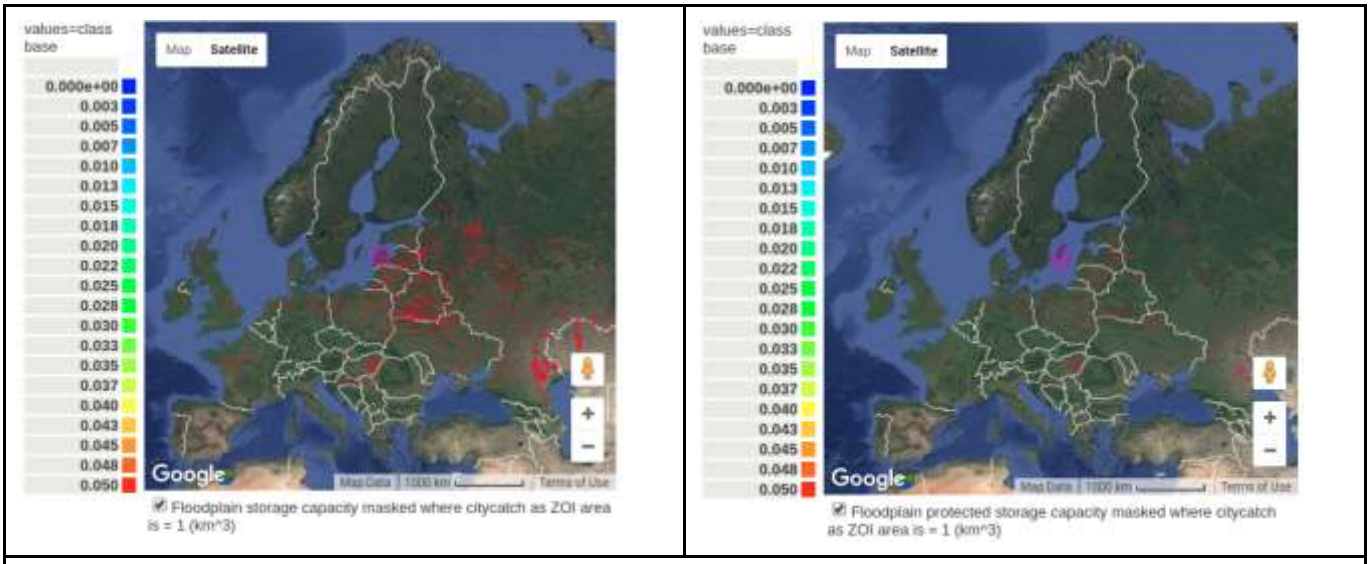


Figure14 Floodplain storage volumes upstream of urban areas and in protected areas upstream of urban areas

All: 13,971 km^3

Upstream of urban areas: 12,576 km^3

Protected upstream of urban areas: 4,600 km^3

Total storage

Total storage combines the values for soil storage, canopy storage, wetland storage, water body and channel storage, floodplain storage and total storage. It shows that values tend to be much higher in wet environments such as those in Scandinavia, Eastern Europe, Russia and the Baltic States with lower values throughout densely populated Western Europe (in part because of urbanisation). The lowest values tend to be in mountainous areas. Some 38% of total storage occurs within protected areas (with protected areas covering some 31% of the region). Table 2 indicates the total storage in each element of natural capital for the whole study area, upstream of urban areas and in protected areas upstream of urban areas. Note that a rainfall event of 1mm over the whole study area would be equivalent to 189.6 km^3 so the soil storage alone could store 404mm of rainfall when empty.

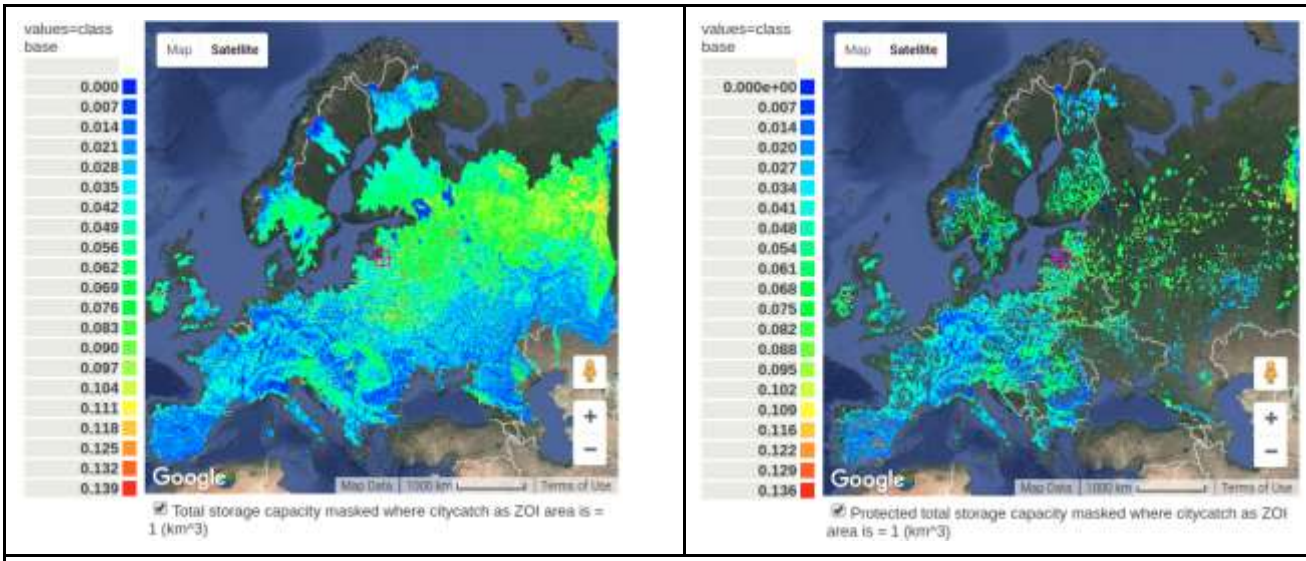


Figure 15 Total storage volumes upstream of urban areas and in protected areas upstream of urban areas

All: 212,804 km^3

Upstream of urban areas: 174,847 km^3

Protected upstream of urban areas: 66,567 km^3

Table 2 Flood storage volumes in the European (hydrological) study area.

Storage type	All (km^3)	Upstream of urban areas (km^3)	In protected areas upstream of urban areas (km^3)
Soil storage	76,743	66,421	23,420
Canopy storage	107,630	87,283	34,941
Wetland storage	12,534	7,938	3,324
Water body and channel storage	1,920	625	281
Floodplain storage	13,971	12,576	4,600
Total storage	212,804	174,847	66,567

Figure 16 shows the distribution between different storage types across the study area and indicates that the vast majority of storage falls between canopy and soil storage, since these are distributed throughout the landscape. The more sparsely distributed storages (floodplain, water body and wetland), even though they may be greater storage capacities at a point, make up a much smaller proportion of the total available flood storage because of their sparse distribution. This indicates the importance of managing farmland (soil) and forest (canopy) storages.

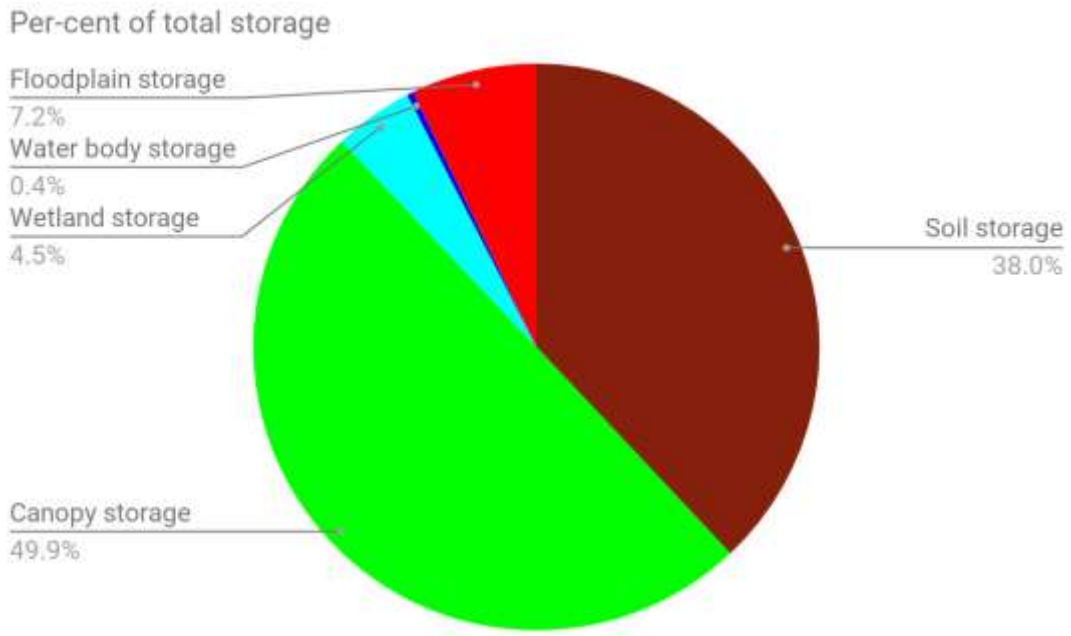


Figure 16 Elements of flood storage in the European study area.

Greatest storage

Figure 17 (a) shows the greatest storage per pixel across the study area and clearly shows the wide spatial distribution of areas in which canopy or soil are the dominant (or only) storage, with only very small areas dominated by wetland, floodplain and water body. In the protected insurance-relevant areas (Figure 17 (b)) the canopy storage is the dominant protected storage, as is to be expected, though this makes careful management of the significant areas of soil upstream of cities, all the more important. The dominant storage per country and per upstream catchment of urban area are shown in Figure 17 (c) and (d) respectively. On a country basis canopy storage is the most significant for much of northern Europe (except Denmark), whereas soil storage dominates in southern Europe and the Baltic states. By upstream catchment of urban areas the same pattern is apparent though a few urban areas have their upstream

catchments dominated by other storages: Floodplain (Peterborough, UK), Wetlands (Turin, Italy), Water Bodies (Visp Switzerland).

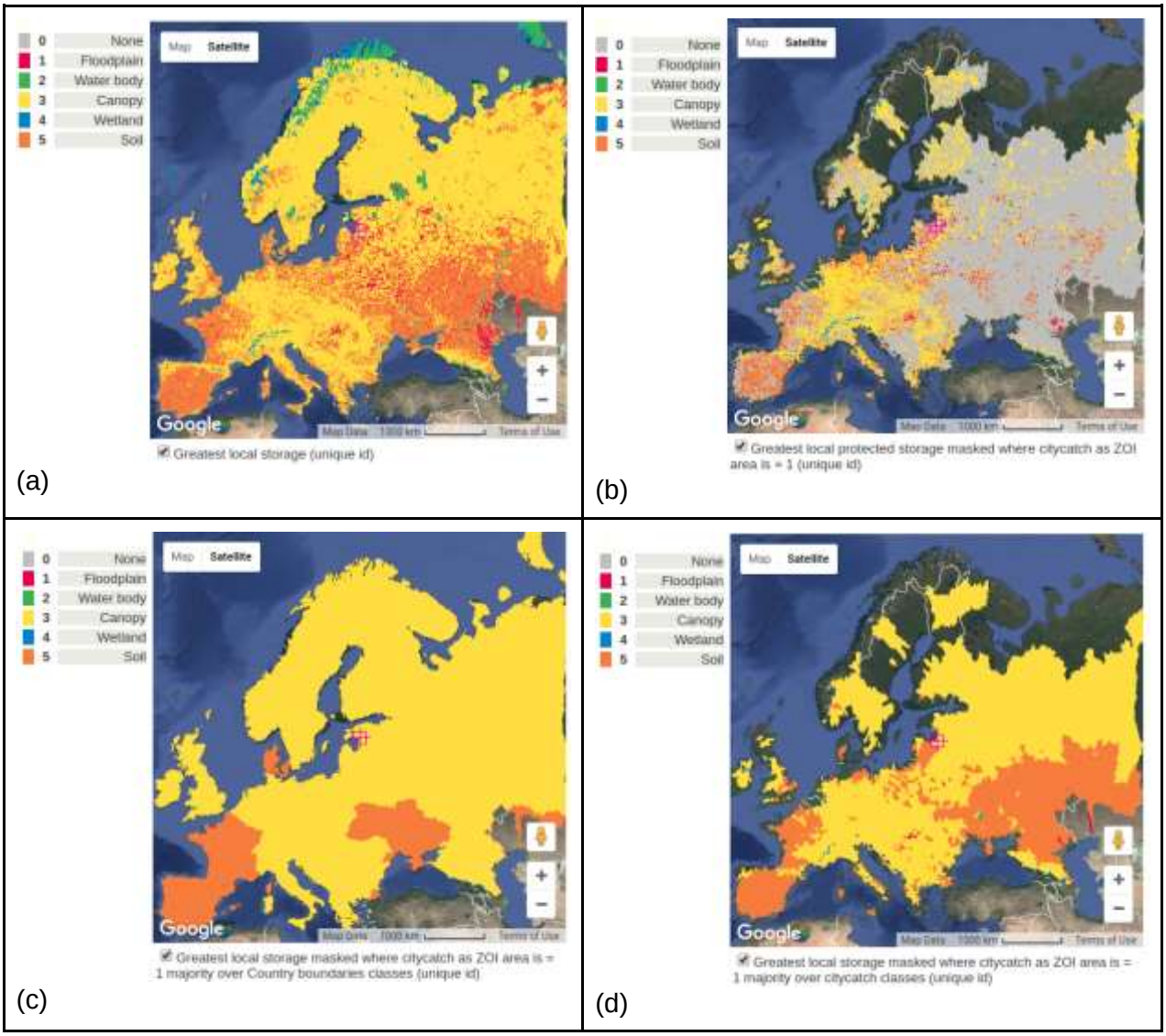
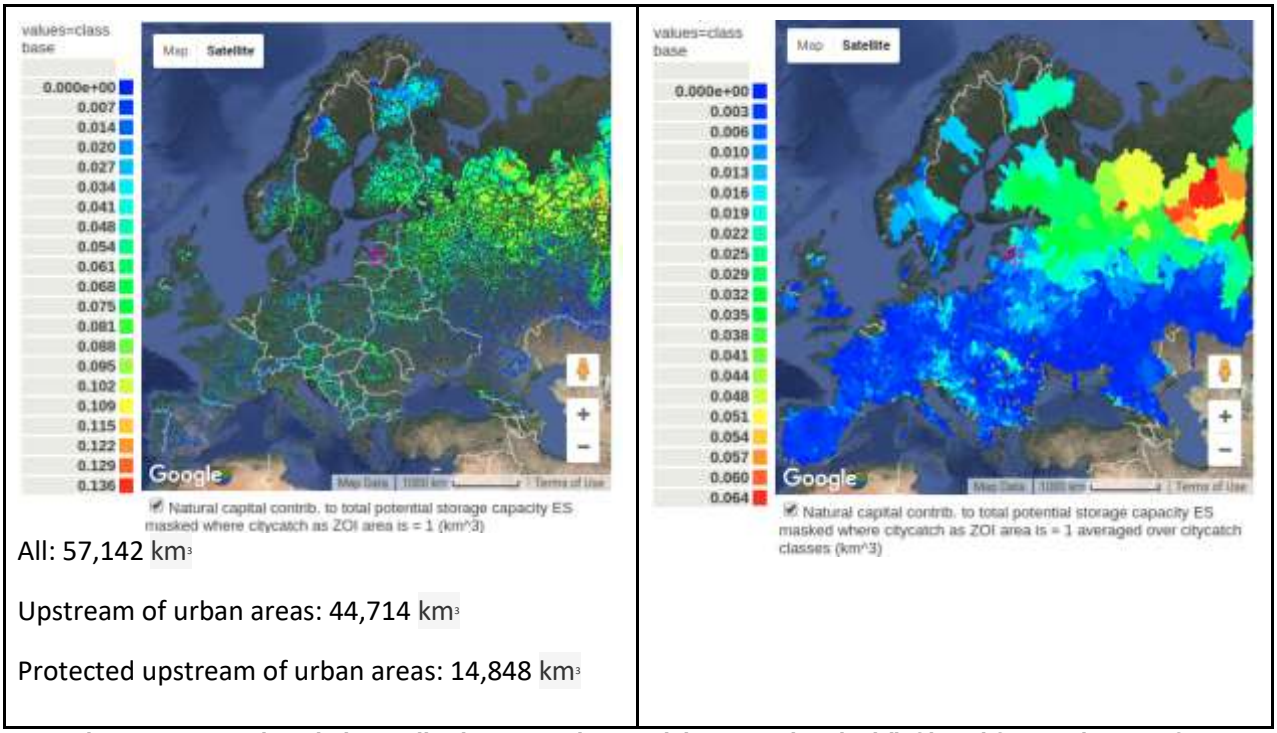


Figure 17 The greatest flood storage per 10-square-km for (a) all of the study area, (b) upstream catchments of urban areas (c) majority greatest flood storage type by country and (d) majority greatest flood storage type by upstream catchment of urban area

Natural capital contribution

The Natural capital contribution to this storage service is difficult to separate from the nature-based (or managed) capital contribution. In Figure 18 below we exclude all human land uses (cropland, pasture, roads, urban, extractives) from the storage calculation to show the more fully natural capital contribution. This is clearly removed from much of southern and western Europe (dominantly agricultural landscapes) and shows the remaining natural capital contribution upstream of urban areas to occur largely in Scandinavia and Siberia with isolated patches of contributing natural capital elsewhere in the study area. Overall some 27% of total nature-based storage capacity upstream of urban areas is contributed by non-managed natural capital under this metric. 26% of this natural capital is protected.



All: 57,142 km³

Upstream of urban areas: 44,714 km³

Protected upstream of urban areas: 14,848 km³

Figure 18 Natural capital contribution to total potential storage by pixel (left) and for catchmets of large cities in Europe

5.3 Use of this storage capacity under normal annual flow conditions

'Potential' and 'realized' flood storage services

Storage capacity as derived above can be considered a *potential* ecosystem service (Georgiou and Turner, 2012) since it does not factor in the use of the service. The *realized* ecosystem service provided depends upon the relationship between the supply of the service (the storage

capacity) and the demand for the service (the amount of water that needs to be stored in order to reduce flood risk to exposed populations downstream). The latter in particular is challenging to quantify. We therefore introduce a novel metric for estimating riverine flood risk in an attempt to overcome some of these challenges. We calculate the realized service as the ratio of the annual mean runoff (downstream accumulated precipitation excess as calculated by the web-based policy support system WaterWorld (Mulligan, 2013)) to total upstream green and blue storage capacity. Where this ratio is greater than one there is, on an annual basis, more water in a given pixel than the storage capacity to store it, and hence the excess water (runoff) may represent an increased flood risk. Where the ratio is less than one there is greater storage capacity than required to store the annual runoff passing through the pixel, indicating a reduced (though not zero) flood risk. We calculate these service ratios separately for total storage capacity, green storage capacity and blue storage capacity, together with the separate components of green (canopies, wetlands, soil) and brown (water bodies, floodplains) storage, in order to understand the flood mitigation contribution of each type of store.

Figure 19 shows the ratio of downstream accumulated mean annual water balance to downstream accumulated total storage capacity for the study area. This annual flow ratio is an estimate of use of the available storage capacity by long term mean annual flows. In dry environments, available storage capacity may not be used and the ratio will be less than 1, whilst in wet environments there may routinely be more runoff than storage capacity, leading to high levels of storage and vulnerability to high rainfall events. The ratio shows high values (>1) in rivers draining the Scandes and the Alps (where rainfall is high) as well as in the western Iberian peninsula (where storage capacity is low).

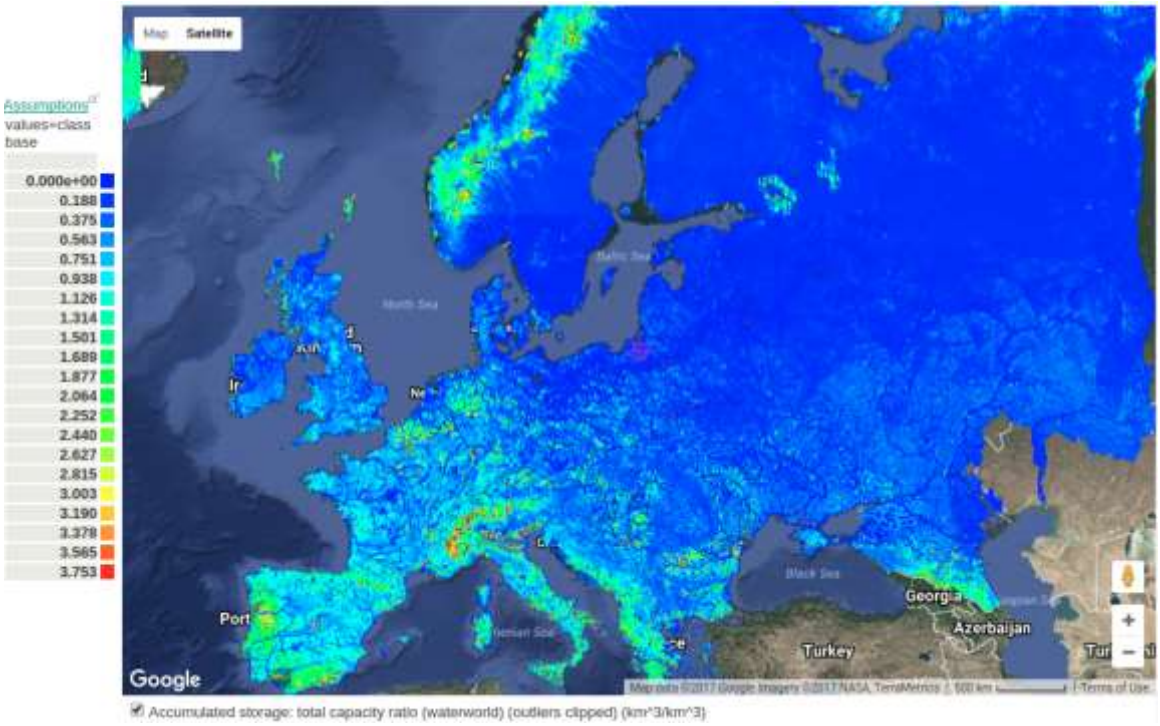


Figure 19 Ratio of downstream accumulated mean annual water balance to downstream accumulated total storage capacity for the study area.

However only part of this annual flow ratio can be managed through NBS - the so called green storage (canopies, soils, wetlands) whose management can expand or reduce the available storage capacity. Whereas for blue storage (floodplain, water body) management of land use cannot expand the available storage (though it is sensible not to put infrastructure into floodplains). Figure 20 is thus the ratio of accumulated water balance to accumulated green storage capacity but averaged over the catchments of urban areas. The NBS-manageable green infrastructure is only sufficient to capture annual flows in most continental (large) catchments of urban areas but is >1 throughout much of the Scandinavian countries and small coastal basins throughout Europe. In these areas, better management of the dominant soil and canopy storages through natural flood management (NFM) could yield reduced impacts of at least the usual annual floods and make a contribution to the mitigation of any flood greater than those.

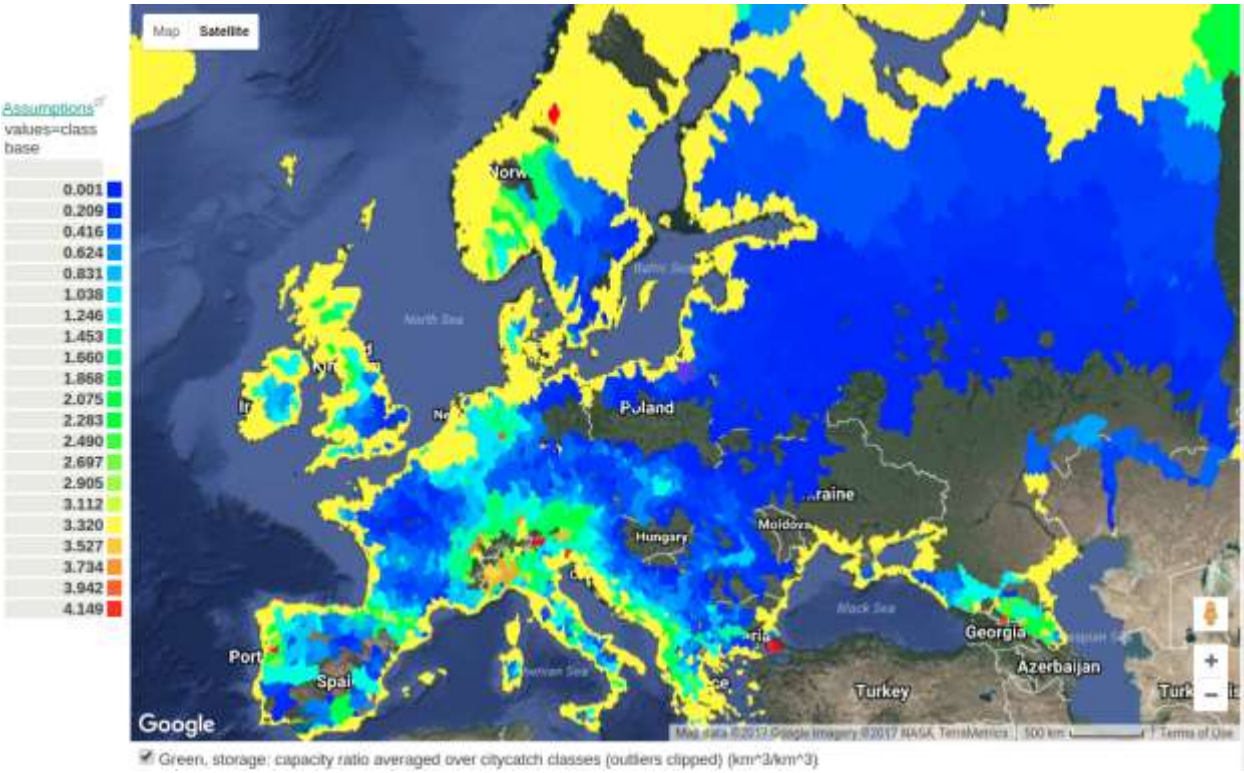


Figure 20 Ratio of downstream accumulated mean annual water balance to downstream accumulated green storage capacity for the study area, averaged over upstream catchments of urban areas.

5.4 Protected used storage capacity

Figure 21 shows the proportion of the used green storage capacity (the annual flow ratio) within each urban area catchment that is protected and thus indicates the scope for NBS. Interestingly for many of the coastal basins identified as in need of NBS in the previous figure, these have no land protected (transparent) in Figure 21.

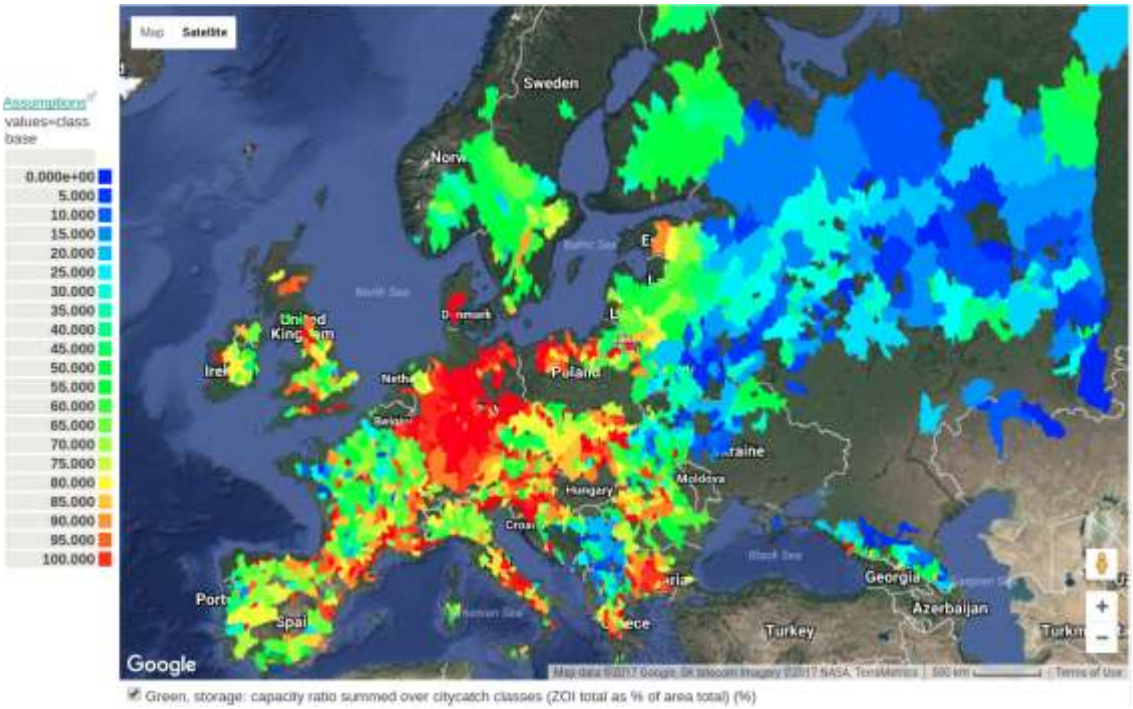


Figure 21 Proportion of total storage capacity upstream of urban areas that is protected (%)

5.5 Greatest 50% of Flood storage, by country

Whether flood storage is manageable or not, it still provides a flood storage. This service is provided irrespective of whether the annual flow ratio >1 since even where the ratio <1, individual extreme rainfall events can more than fill the available storage. Thus, for the definition of co-benefits we focus on the areas potential providing flood storage benefits (the total storage capacity upstream of urban areas). Rather than examine co-benefits for all areas providing flood storage upstream of urban areas, we look at the top 50% of values by country for their total flood storage, as shown in Figure 22 below. These areas are used as a mask to examine co-benefits provided by the ecosystems in these areas. These areas represent 37% of the study area.

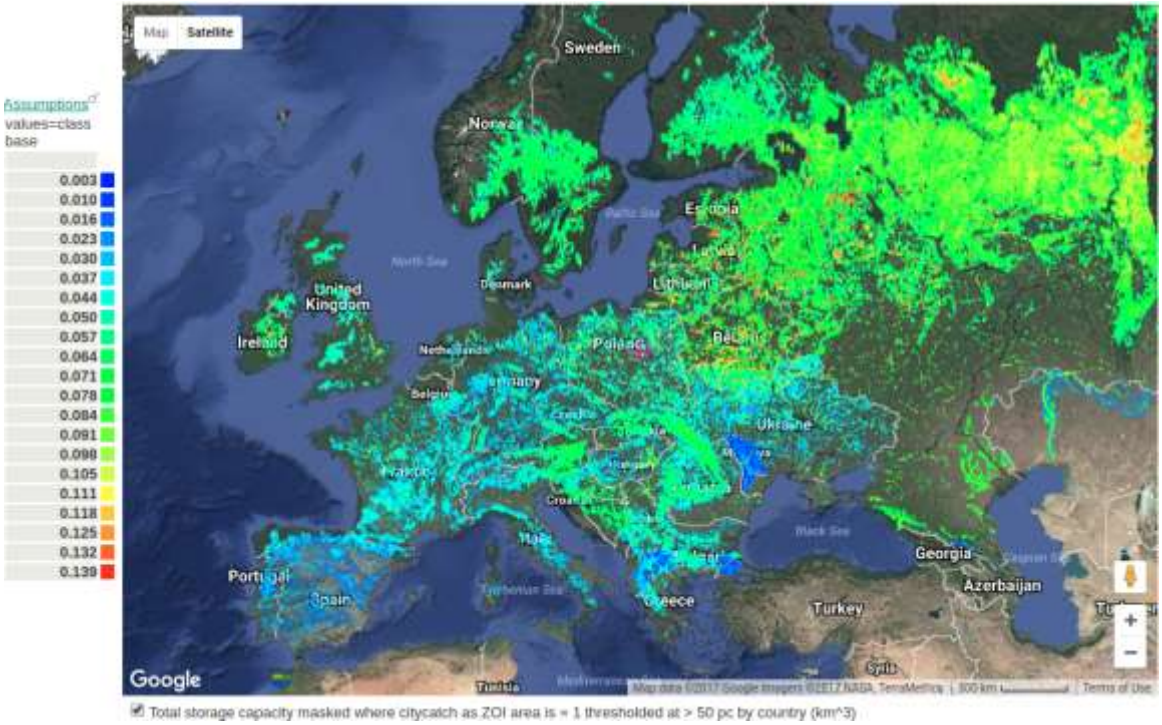


Figure 22 Greatest 50% of total storage capacity upstream of urban areas, by country.

6 Mapping ecosystem service co-benefits

The total realised bundled services index of Co$ting Nature V3 shows the normalised total for the following services: Timber (softwood, hardwood), Fuelwood (softwood, hardwood),Grazing/fodder, non-wood forest products, water provisioning(quantity, quality), fish catch, carbon, natural hazard mitigation (flood, drought, landslide, coastal inundation),culture-based tourism, nature-based tourism services, environmental and aesthetic quality services, wildlife services (pollination, pest control), wildlife dis-services (crop raiding, pests).

Figure 23 shows, for the whole study area, that the service bundle is greatest in the more populated areas of Europe but also those with mountains, forests and less intensive agriculture since these underpin many of the services listed above.

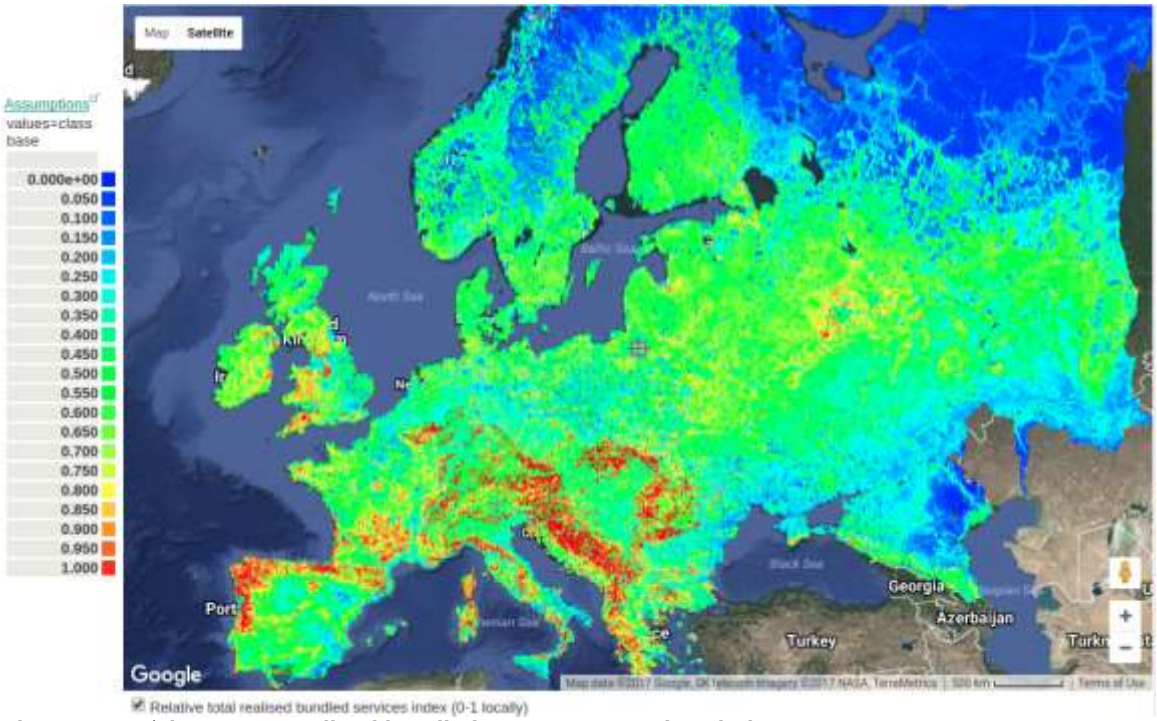


Figure 23 Co$tingNature realised bundled ecosystem services index.

Figure 24 shows the bundled ecosystem service index for the 50% highest flood storage service areas only (i.e. the co-benefits of this flood storage), indicating that these are many and significant, especially in the Mediterranean and Baltic countries.

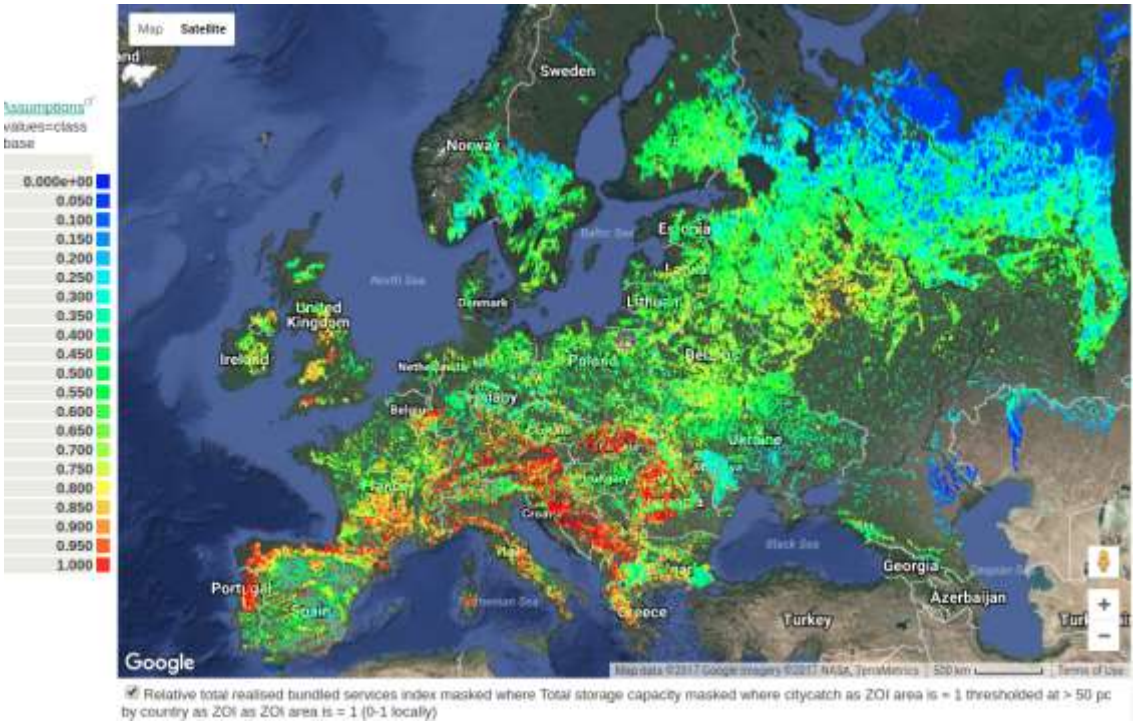


Figure 24 Co$tingNature realised bundled ecosystem services index masked for greatest 50% of total storage capacity upstream of urban areas, by country, with protected areas excluded.

Different areas have different bundles of service and different services are at their greatest. Throughout much of rural Europe, the greatest service is Carbon because all other services require proximity for significant numbers of people to benefit. Culture-based tourism is greatest in some of the more urbanised areas. Grazing in remote mountains with significant livestock headcounts, water in dry, continental interiors like Spain, Timber in Scandinavia and the Boreal forests and others elsewhere.

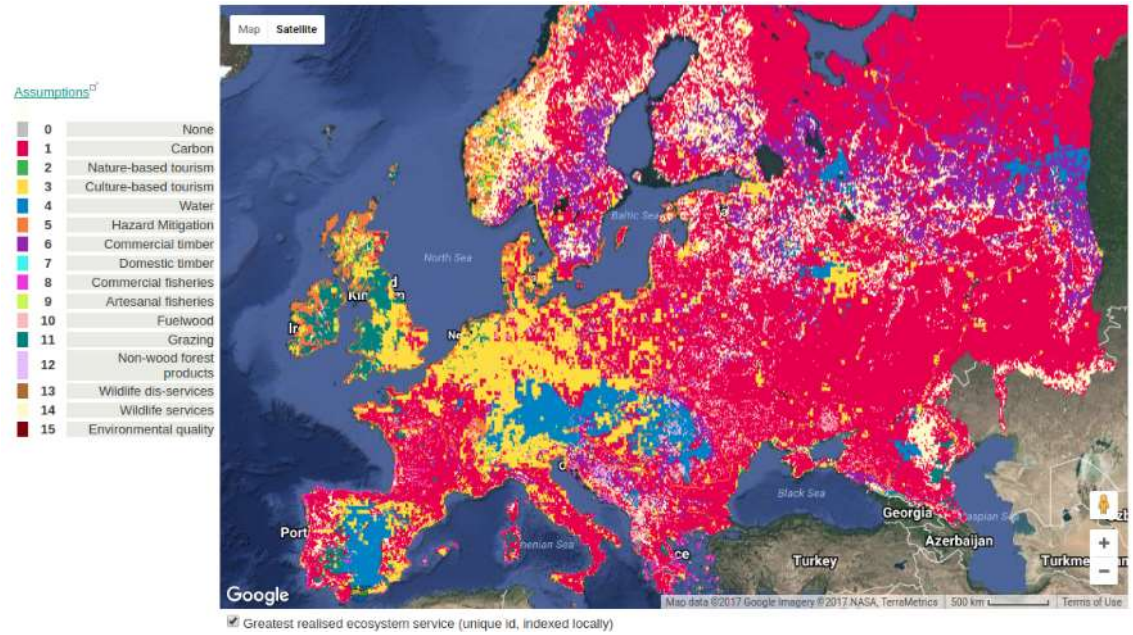


Figure 25 Greatest realised service (on a European scale) for each 10-square-km

For the insurance-relevant areas a range of services are the dominant co-benefit of areas also providing significant flood storage to urban populations downstream. In each case a mix of co-benefits will be provided, only one of which is the greatest co-benefit.

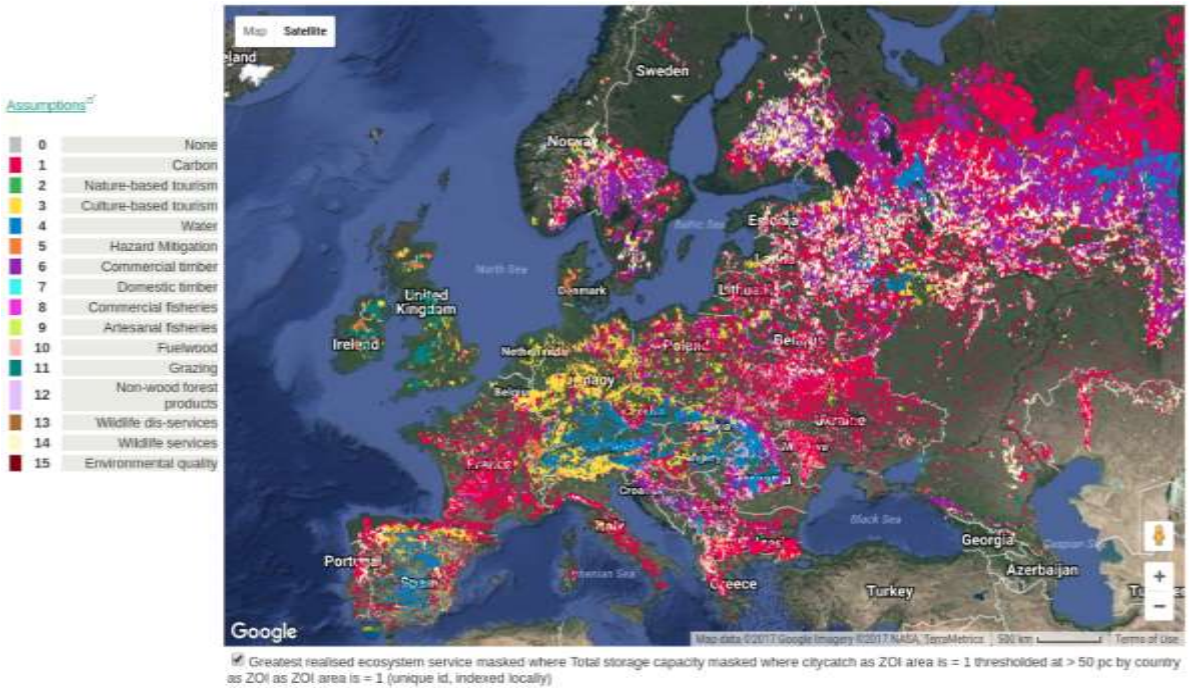


Figure 26 Greatest realised service (on a European scale) for each 10-square-km, masked for greatest 50% of total storage capacity upstream of urban areas, by country, with protected areas excluded

7 Implications for NBS and Conservation Priority

Where NBS represent one form of conservation management action we examine here the conservation implications of defining flood insurance relevant areas and we calculate their co-benefits beyong Natural flood Mitigation. Co$tingNature is a conservation prioritisation tool and does so on the basis of mapping areas with the highest provision across 12 ecosystem services, the highest species richness and endemism, the highest threat of land conversion and the lowest current human pressure on land. Co$tingNature's *Relative aggregate nature conservation priority index (realised services)* maps threatened conservation priority areas with high realised service provision. Equal weighting is given to the three components: threat, conservation priority and ecosystem service provision. Figure 27 shows the Co$tingNature conservation priority metric masked for the 50% highest priority flood storage zones upstream of urban areas and with existing protected areas cut out. It thus indicates the overall conservation priority of areas providing flood storage services and not already protected and

forms the basis for targeting NBS at the European scale that would also have significant co-benefits for other ecosystem services and for biodiversity protection.

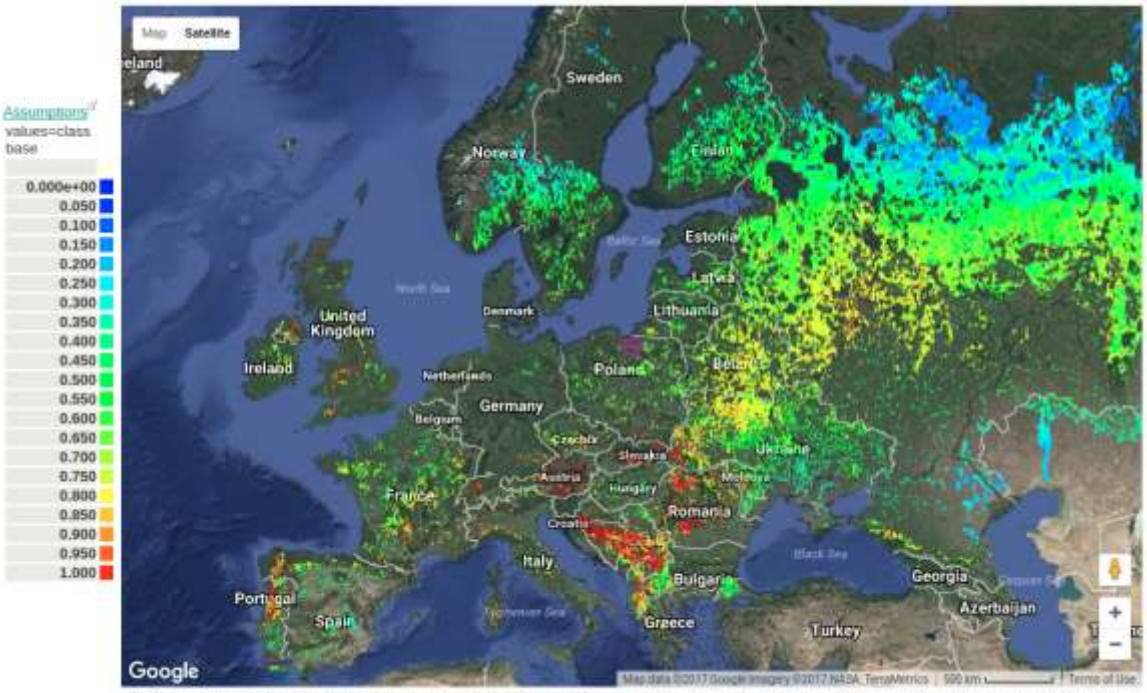


Figure 27 Co$tingNature conservation priority index, masked for greatest 50% of total storage capacity upstream of urban areas, by country, with protected areas excluded

8 Conclusions and next steps

Co$tingNature has been used here at the European scale to examine insurance relevant natural capital and its benefits for other forms of ecosystem service provision of relevance to local communities. Insurance-relevant is considered to be natural capital providing flood storage that is upstream of urban areas. New datasets and techniques were also applied to developing globally relevant and high resolution spatial metrics for relative insurance value of different forms of infrastructure such as the Eco:actuary urban asset index. A method for coupling these with valuation data is proposed to enable valuation of first order replacement and second order disruption costs for specific damage scenarios. Asset values are shown to be highly

heterogeneous with significant concentration of high value assets with significant potential for disruption costs, in a few places.

At the European scale, most of the land surface drains into an urban area and the distribution of different forms of flood storage in these areas is highly spatially heterogeneous. Flood storage tends to be higher in northern and mountainous Europe compared with the drier South and East. Canopy storage is the largest component of flood storage, followed by soil storage with wetlands, water bodies and floodplains contributing very little at the European scale. Where wetlands, water bodies and floodplains exist nearby upstream of urban areas they may be important but by far the most important contributions to natural flood storage are canopies and soils, where present and properly managed. Little natural capital remains in western Europe as most land is some form of agriculture or plantation (thus nature-based capital). In NE Europe, significant areas of natural capital remain.

This storage capacity is particularly strongly realised (used) in the Mediterranean and in mountainous areas of NW Europe, especially in the smaller coastal basins. The greatest 50% of this storage capacity for each European country was mapped and used to assess co-benefits using Co$tingNature version 3. These areas are shown to provide a wealth of ecosystem services, with different services being most significant in different parts of Europe: carbon dominating in the least populated areas, water in parts of the Mediterranean and eastern Europe, grazing in the highlands of western Europe and nature/culture based tourism dominant in highly populous zones. On the basis of flood storage and ecosystem service provision a series of conservation priority areas are defined for the protection and further development of NBS.

A review of available research and data on each type of natural capital that is of insurance relevance for each DEMO revealed that good regional/national data exists for the Thames, Brague and Copenhagen DEMOs while the lower Danube and Glinščica DEMOs are more dependent on European scale data such as CORINE land cover. The literature study shows that co-benefits of forests, wetlands, floodplains and green urban areas are particularly important in most of the DEMO sites. In terms of ecosystem services of relevance to the DEMOs, only a few studies were identified, mostly for the Thames and Glinščica DEMOs. Data for the Lez basin will be collected as part of the project.

The next phase of the project will see final decisions on which DEMOs Eco:actuary will be applied and on the co-design of the system with insurers for application globally and detailed comparison with other methods and datasets in some of the NAIAD DEMOs. Eco Actuary will map ecosystem-service-relevant multi-hazard potential, relative, economic and insurance exposure to these potential hazards, potential damage and disruption losses (replacement value, productivity disruption value, utilities disruption value, travel time disruption value, supply chain disruption value) and potential and realised hazard mitigation services provided by

existing and planned nature-based capital and their relative and (in combination with WP4) economic value as well as the relative and (in combination with WP4) economic value of co-benefits of nature-based capital. It will do this for data-poor areas globally, to answer questions like:

What is the financial exposure to risk at the catchment to national scale?

How is this exposure affected by new built-infrastructure?

How is this exposure mitigated by (existing or planned) green-grey mitigation strategies and what are their co-benefits/co-disbenefits?

What are the potential losses to extreme weather events?

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Appendix 1

DEMO basin distributions of natural capital

The tables below list the available research and data on each type of natural capital that is of insurance relevance for each DEMO. In each case the relevance of the natural capital is given alongside the relevant whole-DEMO accessible spatial datasets and key publications.

Insurance-relevant Forests

DEMO	**Relevant spatial dataset on insurance relevant green infrastructure and narrative on importance of this infrastructure in the DEMO with key citations**
Thames Basin: UK DEMO site	CEH Land cover map 2015 Trees never use less water than other vegetation, and usually use more water, leaving less water for surface runoff and groundwater recharge. Any land use/management intervention that promotes tree growth will use more water. Mature forests use less water than growing forests, and plantation forestry goes through stages, some of which (drainage and felling) can increase runoff and recharge: **Houghton-Carr, H.A.**; **Boorman, D.B.**; **Heuser, K.**. 2013 *Land use, climate change and water availability: Phase 2a. Rapid Evidence Assessment: Results and synthesis.* Wallingford, UK, NERC/Centre for Ecology & Hydrology, 45pp
Lower Danube section, Romania	Land cover / Land use data presented in an international communication that highlights the current situation in the Romanian DEMO site; http://lucc.zrc-sazu.si/Portals/31/Conferences/KELMORAJN/19_Balteanu.pdf
Bragues Basin, France	Adapted version of CORINE land cover for the PACA region (south east of France) : BD OCSOL-PACA 2014 http://www.crige-paca.org/geoportail/geocatalogue.html?id_lot_donnee_carto=681 code: 244 (Agro-forestry space), 311 (deciduous forest), 312 (coniferous forest) & 313 (mixed forest) scale: PACA Region, precision : forest unit

	WFS link & WMS link #French Forest mapping – PACA REGION - 2003 Scale: PACA region, precision : 1/25 000, Data: forest type, details: http://geocatalogue.crige-paca.org/geonetwork/srv/en/resources.get?id=159&fname=Descriptif_Cartographie_forestiere_IFN_v1.pdf&access=private Access: free for research but on demand. #National forest inventory: http://inventaire-forestier.ign.fr/spip/spip.php?rubrique159 -scale:France, precision: forest plots (fuzzy location) - data: forest type, forest cover, forest age, type of species, type of soil, etc. details: http://inventaire-forestier.ign.fr/edb/pdf/Manuel_Utilisateur.pdf Raw data: http://inventaire-forestier.ign.fr/spip.php?rubrique153 #PACA region web platform on forest: http://www.ofme.org/cartotheque/ Extension: PACA region, precision: municipality, - data: forest type, % forest cover, forest fragmentation index, forest surface, details: http://www.ofme.org/cartotheque/collections.php #Forest fires database for Mediterranean area in France: http://www.promethee.com/en/default/incendies (1973-2016) - scale: Mediterranean area, precision: forest plots. - data: date, area, kind of cause.

Lez basin, France	Corine Land Cover data More detailed data will soon be collected locally (note that this DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure)
Greater Copenhagen area (CPH), Denmark	Land cover data for the area surrounding CPH including forest patches and parks can be extracted from the DK National Model: www.vandmodel.dk Key reference is Højberg et al. (2015) and annexes
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Land cover CORINE 1995, 2000, 2006, 2012 and Change in land cover between 2006 -2012, 2000-2006, 1995-2000: http://gis.arso.gov.si/wfs_web/faces/WFSLayersList.jspx Land use for several years: http://rkg.gov.si/GERK/ All data is for non commercial use!
Medina Del Campo DEMO Site, Spain DEMO	http://centrodedescargas.cnig.es/CentroDescargas http://www.mapama.gob.es/es/cartografia-y-sig/ide/descargas/agua/default.aspx http://www.catastro.meh.es/webinspire/index.html

The Lodz Region, Poland DEMO	No information provided

Insurance-relevant Wetlands

DEMO	**Relevant spatial dataset on insurance relevant green infrastructure and narrative on importance of this infrastructure in the DEMO with key citations**
Thames Basin: UK DEMO site	Natural England open data Floodplain wetlands generally reduce or delay floods. However, headwater wetlands can increase the immediate response of rivers to rainfall generating higher volumes of flood flow: Bullock, Andy, and Mike Acreman. "The role of wetlands in the hydrological cycle." *Hydrology and Earth System Sciences Discussions* 7.3 (2003): 358-389.
Lower Danube section, Romania	Wetlands issues: https://www.icpdr.org/main/issues/wetlands
Brague Basin, France	Adapted version of CORINE land cover for the PACA region (south east of France) : BD OCSOL-PACA 2014 http://www.crige-paca.org/geoportail/geocatalogue.html?id_lot_donnee_carto=681 code: 411 (Interior marshes and rosieres), 412 (Tourbiere), 413(Other wetland), 421 (maritime marshes), 422 (salt marshes) scale PACA Region, precision : forest unit WFS link & WMS link #Wetlands and lakes

	http://carmen.developpement-durable.gouv.fr/25/environnement.map scale: PACA region, precision: wetland extend - data: mapping of wetland extension The inventory of wetlands in the Alpes-Maritimes area is available at: - http://www.pnrpaca.org/index.php?cont=login It is a territorial information system focusing on available wetlands.
Lez basin, France	Corine Land Cover data More detailed data will soon be collected locally (note that this DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure)
Greater Copenhagen area, Denmark	Land cover data for the area surrounding CPH including forest patches and parks can be extracted from the DK National Model: www.vandmodel.dk Key reference is Højberg et al. (2015) and annexes And from SDFE / Water Management Plans
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment -	Wetlands: http://nfp-si.eionet.europa.eu/Dokumenti/GIS/splosno

Slovenian DEMO site	Land use for several years: http://rkg.gov.si/GERK/ All data is for non commercial use!
Medina Del Campo DEMO Site, Spain DEMO	Home Natural Spaces Wetland Conservation Catalog of Wetlands of Castilla y León: https://goo.gl/ykn8Md Wetlands included in the RAMSAR Convention List (RamsarES): https://goo.gl/AuhV9M
The Lodz Region, Poland DEMO	No information provided

Insurance-relevant Floodplains

DEMO	**Relevant spatial dataset on insurance relevant green infrastructure and narrative on importance of this infrastructure in the DEMO with key citations**
Thames Basin: UK DEMO site	Environment Agency data Storage of floodwater on floodplains can reduce flood magnitude downstream. A study in upper Thames basin found that restoring river channel through floodplain can reduce peak flows by 10-15%: Acreman, M. C., R. Riddington, and D. J. Booker. "Hydrological impacts of floodplain restoration: a case study of the River Cherwell, UK." *Hydrology and Earth System Sciences Discussions* 7.1 (2003): 75-85.
Lower Danube section, Romania	The former Danube's floodplains have been used for agriculture in the last 30 years. Because of this, most of the floods have a catastrophic impact on the local community. The old floodplains were meant to reduce the impact and the speed of the floodwaters.

	https://www.icpdr.org/main/issues/floods http://www.icpdr.org/main/files/drbmp2015-map11-wetfloodreconnection.pdf
Brague Basin, France	#Geomorphological flood plain extension GIS and presentation note on a general flood plan mapping from a geomorphologica l method (Atlas des zones inondables (AZI)) edited 2006, scale: PACA Region; precision:1/25,000 https://goo.gl/J6wXEy http://www.paca.developpement-durable.gouv.fr/IMG/pdf/plaquetteAZI_cle7c3ebf.pdf
Lez basin, France	Detailed data will soon be collected locally (note that this DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure)Insurance relevant floodplains in CPH surrounding catchment for mitigating flooding is not relevant.
Greater Copenhagen area, Denmark	Insurance relevant floodplains in CPH surrounding catchment for mitigating flooding is not relevant.
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Several flood maps: https://goo.gl/DRQQ5t All data is for non commercial use!

Medina Del Campo DEMO Site, Spain DEMO	Floods Directive Flood hazard and risk maps: http://cdr.eionet.europa.eu/es/eu/fhrm
The Lodz Region, Poland DEMO	No information provided

Insurance-relevant Green urban areas

DEMO	**Relevant spatial dataset on insurance relevant green infrastructure and narrative on importance of this infrastructure in the DEMO with key citations**
Thames Basin: UK DEMO site	OS Open greenspace data https://data.london.gov.uk/dataset Urban flood risk can be reduced sustainably through wider use of green infrastructure that makes the urban hydrological cycle more like the natural hydrological cycle, by reducing impervious areas, enhancing evaporation, transpiration and infiltration, and inundating flood suitable, green spaces and corridors: Thorne, Colin. "Geographies of UK flooding in 2013/4." The Geographical Journal 180.4 (2014): 297-309. http://www.bluegreencities.ac.uk/
Lower Danube section, Romania	Most of the human interaction issues that arise in the DEMO site area are susceptible to change, towards green solutions; https://www.icpdr.org/main/issues/municipalities http://www.icpdr.org/main/files/drbmp2015-map05-uwwt-ref.pdf
Brague Basin, France	#Adapted version of CORINE land cover for the PACA region (south east of France) : BD OCSOL-PACA 2014 http://www.crige-paca.org/geoportail/geocatalogue.html?id_lot_donnee_carto=681

	Code: 141 (urban open space) & 142 (sport facilities and urban parks) scale PACA Region, precision : forest unit WFS link & WMS link
Lez basin, France	Detailed data will soon be collected locally (note that this DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure)
Greater Copenhagen area, Denmark	Green areas of relevance for NBS solutions are stored in the mapping web service of CPH: http://data.kk.dk/dataset?groups=geografi&page=2 And maps / data for the built environment in CPH to be extracted from the DK National Model: www.vandmodel.dk Key reference is Højberg et al. (2015) and annexes And data from the National Cadaster Registry
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Land use for several years: http://rkg.gov.si/GERK/ No other data. All data is for non commercial use!
Medina Del Campo DEMO Site, Spain DEMO	No information provided

The Lodz Region, Poland DEMO	No information provided

Insurance-relevant Soils

DEMO	Relevant spatial dataset on insurance relevant green infrastructure and narrative on importance of this infrastructure in the DEMO with key citations
Thames Basin: UK DEMO site	NATMAP national soil map Different soils respond differently to drainage. Impermeable (clay) soils reduce peak flows when drained but peak flows may increase when draining more permeable soils. Soil compaction under arable and livestock agriculture increases surface run-off.
Lower Danube section, Romania	At the moment, no current data is available. Floodplains rich soil are currently used for agriculture (see land coverage); https://www.icpdr.org/main/sites/default/files/MONERIS_MANUAL_CHAPTER_II.PDF (page 107,108)
Brague Basin, France	#French soil GIS portal: https://www.gissol.fr/donnees/cartes Gather several data set on soil Scale: either on plots or regions Data: e.g.: type of soil, carbon stock, pH, chemical features, soil humidiy, etc. https://www.gissol.fr/donnees #French geological maps from the French geological survey: http://geoservices.brgm.fr/wms-c.html

	- scale: France, precision 1/25 000 List of data accessible by WMS: http://www.geocatalogue.fr/Detail.do?id=8958
Lez basin, France	Soil is not considered as an insurance-relevant infrastructure in this DEMO.
Greater Copenhagen area, Denmark	The Danish soil type classification data and maps can be found here Key reference is Greve et al. (2007): Greve, M.H., Greve, M.B., Bøcher, P.K., Balstrøm, T., Breuning-Madsen, H. & Krogh, L. (2007). Generating a Danish raster-based topsoil property map combining choropleth maps and point information. Geografisk Tidsskrift 107, 1-12 And Levin et al. (2012)
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Soil map: http://rkg.gov.si/GERK/ All data is for non commercial use!
Medina Del Campo DEMO Site, Spain DEMO	Castile and Leon soil type classification data and maps: https://www.jcyl.es/web/jcyl/AdministracionPublica/es/Plantilla100/1284531763609/_/_/_

The Lodz Region, Poland DEMO	No information provided

Insurance-relevant urban groundwater

DEMO	**Relevant spatial dataset on insurance relevant green infrastructure and narrative on importance of this infrastructure in the DEMO with key citations**
Thames Basin: UK DEMO site	BGS Hydrogeology map Macdonald, D., Dixon, A., Newell, A. and Hallaways, A., 2012. Groundwater flooding within an urbanised flood plain. Journal of Flood Risk Management, 5(1), pp.68-80.
Lower Danube section, Romania	Groundwater situation report and maps; https://www.icpdr.org/main/issues/groundwater
Brague Basin, France	#French database on groundwater: ADES http://www.ades.eaufrance.fr/ Scale: France, precision : local data on drilling site Data: water quality and watertable level Restricted access, on demand http://www.geocatalogue.fr/Detail.do;jsessionid=17A8270FC100357C983A796D9A5ACBE1? fileIdentifier=BR_EAU_CAA

Lez basin, France	The active management of the karstic aquifer located upstream the Lez catchment plays a key role to mitigate the first autumnal flooding events. The recharge area of the Lez karstic aquifer corresponds to the groundwater safeguard zone delimitation and study report (34-Hérault : Système karstique du Lez) http://www.rhone-mediterranee.eaufrance.fr/traitements-eau/eau-potable/ressources-majeures/index.php
Greater Copenhagen area, Denmark	NBS relevant data for urban groundwater can be retrieved from the CPH model or the Danish national model (DK-model). The DK model has been used to model groundwater for various climate scenarios: http://en.klimatilpasning.dk/tools.aspx http://mst.dk/service/miljoegis/
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Hydrogeologic map, groundwater: https://goo.gl/dNSoSy All data is for non commercial use!
Medina Del Campo DEMO Site, Spain DEMO	Castile and Leon Goundwater maps: file:///C:/Users/vayde/Downloads/mapa+aguas+subterraneas.pdf National monitoring system for ground water, data and maps: http://sig.mapama.es/redes-seguimiento/

The Lodz Region, Poland DEMO	No information provided

Insurance-relevant rivers

DEMO	**Relevant spatial dataset on insurance relevant green infrastructure and narrative on importance of this infrastructure in the DEMO with key citations**
Thames Basin: UK DEMO site	OS Open rivers
Lower Danube section, Romania	http://www.riversnetwork.org/rbo/index.php/river-blogs/east-europe/itemlist/category/1016-lower-danube
Brague Basin, France	# BD Carthage database: French river and stream network Scale: France, precision: 1/25 000 http://www.sandre.eaufrance.fr/notice-doc/r%C3%A9f%C3%A9rentiel-hydrographique
Lez basin, France	Rivers are not considered as a insurance-relevant infrastructure in this DEMO
Greater Copenhagen area, Denmark	Refer to the National DK model http://Hydroinform.dk/DKModel.html (IE only)

Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	River network: https://goo.gl/9BTZfm
Medina Del Campo DEMO Site, Spain DEMO	Duero Water Management Authority VISOR: alphanumeric information system and cartography (data and maps of the Duero Basin): http://www.mirame.chduero.es/DMADuero_09/index.faces
The Lodz Region, Poland DEMO	No information provided

Co-benefits of insurance relevant Green Infrastructure

The tables below list the co-benefits that are relevant to each DEMO for each class of insurance relevant green infrastructure and supporting literature

Forests

DEMO	**Key co-benefits defined and supporting literature**
Thames Basin: UK DEMO site	Thames basin lowlands: Maintain and restore the natural functions of the rivers Wey, Mole, Hogsmill and Wandle at a landscape scale, providing improvements in water quality and water availability and helping to regulate water flow while reducing pollution and the risk of flooding to benefit biodiversity, geodiversity and enhance a sense of place.http://publications.naturalengland.org.uk/file/6531226517110784

Lower Danube section, Romania	Forests restoration of the Lower Danube section can restore some natural habitats as well as provide a "filter" for the current floods. Riverbank forests can become a green solution as long as they provide good riverbank stability as well as mitigating some of the flood effects in the area; https://www.icpdr.org/main/issues/nature-protection
Brague Basin, France	(Brague basin mid-lands) Help to regulate water flow and the risk of flooding while: improving water availability, improving biodiversity and recreational, aesthetic and economic functions. Special attention will be paid to potential disservices (see Francisco J. Escobedo, Timm Kroege, and John E. Wagner, 2011, Urban forests and pollution mitigation: Analyzing ecosystem services and disservices, Environmental Pollution, 159, 2078-2087, http://esanalysis.colmex.mx/Sorted%20Papers/2011/2011%20USA%20-CO2%20Interd.pdf and Kai M. A. Chan, Lara Hoshizaki and Brian Klinkenberg Ecosystem Services in Conservation Planning: Targeted Benefits vs. Co-Benefits or Costs?, PlosOne, 6(9). http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0024378) #Wood economy PACA region web platform on forest: http://www.ofme.org/cartotheque/ - Extension: PACA region, precision: municipality, - data: Number of company working in the wood sector, number of jobs, volume of wood harvested, importation and exportaiton, details: http://www.ofme.org/cartotheque/collections.php # Tourism in forests (recreational, aesthetic and economic functions) PACA region web platform on forest: http://www.ofme.org/cartotheque/ - Extension: PACA region, precision: municipality, - data: Number of touristic activity in forests, pedestrian paths, number of hunter, details: http://www.ofme.org/cartotheque/collections.php #Forest protection against rockfalls:

	# Biodiversity improvement: - http://www.observatoire-biodiversite-paca.org/environnement/fiches-indicateurs/services-rendus-par-la-biodiversite_47.html - https://inpn.mnhn.fr/docs/ZNIEFF/znieffpdf/930020153.pdf - Data on fauna: CEN PACA (Admin.). V2017. SILENE-Faune [en ligne]. http://faune.silene.eu. - Data on flora: CBNMed & CBNA (Admin.). V2017. SILENE-Flore [en ligne]. http://flore.silene.eu. - Data on natural habitats: CBNMed & CBNA (Admin.). V2017. SILENE-Habitats [en ligne]. http://habitats.silene.eu. Global view of Silene-PACA): CBNA, CBNMed, CEN PACA, DREAL PACA, Région PACA V2017, SILENE-Paca [en ligne]. http://silene.eu.
Lez basin, France	This DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure → see table urban groundwater
Copenhagen area, Denmark	An overview of Copenhagen's green economy and assess some of the major challenges: https://international.kk.dk/sites/international.kk.dk/files/uploaded-files/Green%20Economy%20Leader%20Report%20-%20Copenhagen.pdf CPH climate adaptation plan and co-benefits https://international.kk.dk/artikel/climate-adaptation
Spangen Area, Rotterdam DEMO Site, The	No information provided

Netherlands	
Glinščica catchment - Slovenian DEMO site	Urban forest around Ljubljana (including Glinščica catchment) has several protective functions. It regulates water flow, reduce water and air pollution, prevents erosion, increases biodiversity, regulate wind speed, air temperature and humidity etc. Moreover it has recreational, touristic, social, economical and aesthetic functions. -http://www.digitalna-knjiznica.bf.uni-lj.si/md_robert_hostnik.pdf -https://repozitorij.uni-lj.si/IzpisGradiva.php?id=15889 -http://www.bf.uni-lj.si/fileadmin/groups/2708/Zbornik_final.pdf
Medina Del Campo DEMO Site, Spain DEMO	Planning of the natural environment:Forestry planning in Castile and Leon: https://medioambiente.jcyl.es/web/jcyl/MedioAmbiente/es/Plantilla100/1132926921318/_/_/_
The Lodz Region, Poland DEMO	No information provided

Wetlands

DEMO	Key co-benefits defined and supporting literature
Thames Basin: UK	Wetland management can have benefits for flood storage, aquifer recharge, water quality and low flow water demand, as well as for biodiversity (Department for Environment, Food and Rural Affairs (Defra) (2002). Directing the Flow: Priorities

DEMO site	for Future Water Policy. Department for Environment, Food and Rural Affairs, Defra Publications (http://www.defra.gov.uk)
Lower Danube section, Romania	The local flood wetlands provide a good filter for groundwater pollution as well as a high natural value considering the high biodiversity; In the drought periods they can act as reservoirs for groundwater and also providing a clean source of nutrients.
Brague Basin, France	(cf. K.-S. Peh et al. 2014, "Benefits and costs of ecological restoration: Rapid assessment of changing ecosystem service values at a U.K. wetland", Ecology and Evolution, 4(20), 3875–3886) Expected co-benefits are related to the maintenance of a better surface and underground water quality and quantity, provide water retention (sponge system) and contribute to the flood safety.
Lez basin, France	This DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure → see table urban groundwater
Greater Copenhagen area, Denmark	Wetland of potential relevance to insurance value and co-benefits can be found from the environmental data platform, here, here, and here, and from the water management plans, here
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided

Glinščica catchment - Slovenian DEMO site	Wetlands, besides their natural value and high biodiversity, provide numerous ecosystem services. They mitigate pollution from the land, are source and consumer of nutrients. They provide and maintain a better surface and underground water quality and quantity, provide water retention (sponge system) and contribute to the flood safety. Because of several benefits wetlands are known as natural water treatment plants. -http://www.mvd20.com/LETO2008/R11.pdf -http://www.wetman.si/?lang=en
Medina Del Campo DEMO Site, Spain DEMO	Wetlands in Castile and Leon Catalogue: http://www.ayto-medinadelcampo.es/images/AytoMedina/MedioAmbiente/Catlogozonahumedasvalladolid.pdf Mapas: REDNATURE 2000 (ZEPA and LIC) in Valladolid: http://rednatura.jcyl.es/natura2000/Mapas%20generales/MAPAvalladolid2.pdf Identification and characterization of interrelation that occurs between waters underground, river courses, downloads by springs, wet areas and others natural ecosystems of special water interest: http://info.igme.es/SidPDF/146000/851/146851_0000001.pdf Study and Analysis of hydromorphological indicators to establish the reference conditions of lagoon systems in the province of Valladolid: https://www.orbemapa.com/wp-content/uploads/2012/04/Estudio-y-An%C3%A1lisis-de-indicadores-hidromorfol%C3%B3gicos-para-establecer-las-condiciones-de.pdf Report on Medina del Campo Wetlands “Humedales de Los Arenales” Protected Area: http://www.chduero.es/acciona5/fotos/RECORRIDOS%20DE%20CAMPO%20Humedales%20de%20los%20Arenales.pdf
The Lodz	No information provided

Region, Poland DEMO	

Floodplains

DEMO	Key co-benefits defined and supporting literature
Thames Basin: UK DEMO site	Floodplains can deliver flood management and biodiversity benefits: Morris et al. (2004) Integrated Washland Management for Flood Defence and Biodiversity
Lower Danube section, Romania	The local floodplains restoration can help to restore the balance in the area. Most of the issues that arise today are to the fact that human intervention has had a large influence in the area, along the Lower Danube region. https://www.icpdr.org/main/issues/floods
Brague Basin, France	These areas (cf. the recent agreement between CEN PACA and the Antibes Juan-les-Pins municipality about 2.8. ha of floodplains in the Brague basin) will help to: - conservation of specific flora - absorbing water surplus (see: Carolyn Kousky and Margaret Walls, 2014, Floodplain conservation as a flood mitigation strategy: Examining costs and benefits, Ecological Economics, 104: 119-128, https://pdfs.semanticscholar.org/19a3/bf300ada1bd99b94c0fec7a8732f740f3ae1.pdf; Oana Iacob, John S. Rowan, Iain Brown, Chris Ellis, 2014, Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective, Hydrology Research, 45(6): 774-787.)

Lez basin, France	This DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure → see table urban groundwater
Greater Copenhagen area, Denmark	Floodplains of potential relevance to insurance value and co-benefits can be found from the environmental data platform, here, here, and here, and from the water management plans, here
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Floodplains have important role in mitigation of flood peaks, floodwater storage (water retention), recharging underground water quantity and rich biodiversity. Besides that floodplains offer several other services such as nutrient retention, support for sustainable agriculture, forestry and fisheries, recreation and tourism. -http://d2ouvy59p0dg6k.cloudfront.net/downloads/ livingwithfloodswwfpolicybriefingfinal.pdf -http://www.digitalna-knjiznica.bf.uni-lj.si/dn_rogelj_dasa.pdf
Medina Del Campo DEMO Site, Spain DEMO	No relevant
The Lodz Region,	No information provided

Poland DEMO	

Green urban areas

DEMO	Key co-benefits defined and supporting literature
Thames Basin: UK DEMO site	Biodiversity in green infrastructure is key to maintain ecosystem services, making the urban ecosystem more resilient to disturbances (London Assembly Environment Committee 2005; Mayor of London 2011) Green, T. L., Kronenberg, J., Andersson, E., Elmqvist, T., & Gómez-Baggethun, E. (2016). Insurance value of green infrastructure in and around cities. Ecosystems, 19(6), 1051-1063. Green infrastructure also helps to reduce ambient temperatures in cities: Hardin, PJ and Jensen, RR. 2007. The effect of urban leaf area on summertime urban surface kinetic temperatures: a Terre Haute case study. Urban Forest Urban Green., 6: 63–72
Lower Danube section, Romania	The need for green solutions is very important at the moment. The human impact has had a negative outcome on the local environment. A transition from grey to green solutions is anticipated considering the current grey infrastructure limitation in time. https://www.icpdr.org/main/issues/human-impacts
Brague Basin, France	A social demand in the Brague context is to build a "green" bicycle path along the Brague river. Expected co-benefits are related to recreation, eco-tourism and water flow improvements. (Cf. Sara Meerow and Joshua P. Newell, 2017, Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit, Landscape and Urban Planning, 159: 62-75,

	http://urbansustainability.snre.umich.edu/wp-content/uploads/2017/01/Spatial_planning_for_multifunctional_gre.pdf Aleksandar Rankovic, Chantal Pacteau et Luc Abbadie, 2012, « Services écosystémiques et adaptation urbaine interscalaire au changement climatique : un essai d'articulation », Vertigo, Hors-série 12, mai, https://vertigo.revues.org/11851.)
Lez basin, France	This DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure → see table urban groundwater
Copenhagen area, Denmark	CPH climate adaptation plan and co-benefits https://international.kk.dk/artikel/climate-adaptation Data sets provided for Copenhagen http://data.kk.dk/dataset?tags=Klimatilpasning&tags=Klima
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Green urban areas have several positive impacts on urban environment and population. They reduce the air temperature in the summer months. Vegetation filters pollutants and CO^2 from the air, alleviates the impacts of climate changes, increases rain absorption and biodiversity. Besides that green urban areas provide various benefits to human health, social and mental well-being as well to economy. -http://www.interreg-central.eu/Content.Node/UGB/Baseline-Study-28-04-2017.pdf

Medina Del Campo DEMO Site, Spain DEMO	This DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure
The Lodz Region, Poland DEMO	No information provided

Soils

DEMO	**Key co-benefits defined and supporting literature**
Thames Basin: UK DEMO site	Agricultural landscape management using methods and crops that retain and improve soil quality also leads to increased food production, water availability and biodiversity: natural england character area profile Northern Thames basin
Lower Danube section, Romania	The local population uses the old floodplains mainly for agricultural purposes. The rich soils provide an excellent yield for any crops planted in the region. The fact that most of the area is very close to the riverbank also provides a good source of water during drought seasons.
Brague Basin, France	[Related to agriculture?] Beyond usual functions related to water and nutrient retention and water filtration, in the Brague basin, it is expected that agricultural areas play a role of "floodplain". (cf. Felipe-Lucia, M. R., F. A. Comín, and E. M. Bennett. 2014. Interactions Among Ecosystem Services Across Land Uses in a Floodplain Agroecosystem, Ecology and Society, 19(1): article 20. https://www.ecologyandsociety.org/vol19/iss1/art20/

Lez basin, France	This DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure → see table urban groundwater
Copenhagen area, Denmark	Not applicable in Copenhagen area.
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Soils have important role in water and nutrient retention and water filtration. They are known as important natural water treatment plants. The soils determine the type of vegetation in certain areas, biodiversity and food production. -http://www.digitalna-knjiznica.bf.uni-lj.si/dn_sijanec_mihael.pdf -Brady N. C., Weil R. R. 2002. The nature and properties of soils. Stephen H (Ed.). Pearson education, Upper Saddle River, New Jersey: 960 str.
Medina Del Campo DEMO Site, Spain DEMO	No information provided
The Lodz Region, Poland DEMO	No information provided

Urban groundwater

DEMO	**Key co-benefits defined and supporting literature**
Thames Basin: UK DEMO site	N/A
Lower Danube section, Romania	Urban groundwater pollution due to the overuse of the agricultural area alongside the riverbank is a very important issue to take into consideration. https://www.icpdr.org/main/issues/groundwater
Bragues Basin, France	Most of considered co-benefits associated to urban groundwater can be considered as "joint" products of the measures and options generally implemented to preserve urban groundwater (i.e. agroecology, implementation of floodplains, conservation of vegetal covering, agricultural practices fostering the conservation of water stocks). The expected related co-benefits are: - the development of a brand image and attractivity - the quality of food production - the global improvement of the quality of life - recreational activities cf. http://infoterre.brgm.fr/rapports/RP-63859-FR.pdf
Lez basin, France	The active groundwater management (AGWM) enables to benefit from the natural stocking capacity of GW to reduce the risks of floods, to distribute drinking water which is naturally of good-quality to Montpellier citizens, and to sustain the Lez river flow during the summer season. Maintaining natural and agricultural ecosystems in the groundwater recharge area delivers a wide range of ecosystem services, among others water regulation services (quantity and quality), provisioning services (e.g., food, timber, fuelwood) and cultural services (e.g. recreational activities). The groundwater recharge area is mostly covered by Mediterranean forests and agricultural areas that contribute to the production of ecosystem services. See an example of such an analysis in Hérivaux and Grémont (2017):

	http://www.set-revue.fr/implications-economiques-des-choix-de-protection-des-eaux-souterraines-pour-lalimentation-en-eau. SCOT PADD du Pic Saint Loup Haute Vallée de l'Hérault: http://www.scot-picsaintloup.fr/index.php?option=com_phocadownload&view=category&id=6:dossiers-scot&Itemid=44
Copenhagen area, Denmark	Protection of pole based infrastructure and built environment foundations, groundwater level management. This is further described here
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Groundwater provides numerous ecosystem services such as drinking water, water retention/storage, water filtration (pollutants, harmful microorganisms etc.), control erosion and floods by absorbing runoff and drought prevention. Groundwater maintains and sustains river flows, springs and wetlands as well provides biodiversity and genetic resources, specifically in the form of organisms that are able to breakdown contaminants. Moreover it has significant impact on settling and economy, which can have negative impact on groundwater. -http://aguas.igme.es/igme/isgwas/Ponencias%20ISGWAS/13-Bergkamp.pdf - https://www.researchgate.net/profile/Mihael_Brencic/publication/316464329_ Podzemne_vode_-_med_naravoslovjem_tehniko_druzbenim_in_politicnim_Groundwater_-_between_natural_sciences_technics_society_and_politics.pdf

Medina Del Campo DEMO Site, Spain DEMO	No information provided
The Lodz Region, Poland DEMO	No information provided

Rivers

DEMO	**Key co-benefits defined and supporting literature**
Thames Basin: UK DEMO site	Adopting environmental flows in IWRM in rivers leads to better ecological quality: Overton, I. C., D. M. Smith, J. Dalton, S. Barchiesi, M. C. Acreman, J. C. Stromberg, and J. M. Kirby. "Implementing environmental flows in integrated water resources management and the ecosystem approach." Hydrological Sciences Journal 59, no. 3-4 (2014): 860-877. River restoration leads to better water quality: Wharton, G., & Gilvear, D. J. (2007). River restoration in the UK: Meeting the dual needs of the European Union Water Framework Directive and flood defence?. International Journal of River Basin Management, 5(2), 143-154
Lower Danube section, Romania	The rivers as a natural resource are mainly used for generating energy and navigation. Most of the tributary rivers have an important economical background as well as a national utility. https://www.icpdr.org/main/issues/dams-structures

Brague Basin, France	Performing heavy dead wood and riparian ecosystem management degrade water and especially fish habitat and nutrient quality: Lassettre, N. S. & Kondolf, G. M. Large woody debris in urban stream channels: redefining the problem *River Research and Applications, Wiley-Blackwell,* **2011***, 28*, 1477-1487 Rinaldi, M.; Surian, N.; Comiti, F. & Bussettini, M. A method for the assessment and analysis of the hydromorphological condition of Italian streams: The Morphological Quality Index (MQI) *Geomorphology,* **2013***, 180-181*, 96-108
Lez basin, France	This DEMO site will firstly specifically focus on groundwater as an insurance-relevant infrastructure → see table urban groundwater
Copenhagen area, Denmark	This is primarily for restoration of urban rivers, Which for Harrestrup River is described here For the extended CPH area including the aquifer with well field for drinking water supply it concerns maintaining ecological flow. Refer to Vandmodel.dk and http://Hydroinform.dk/DKModel.html
Spangen Area, Rotterdam DEMO Site, The Netherlands	No information provided
Glinščica catchment - Slovenian DEMO site	Rusjan, S. et al.: Možnosti za revitalizacijo urbaniziranih vodotokov na primeru Glinščice v Ljubljani – River Rehabilitation of Urban Watercourses on the Example of the Glinščica River in Ljubljana, Acta hydrotechnica 21/34 (2003), 1–22, Ljubljana

	-http://ksh.fgg.uni-lj.si/acta/a34sr.pdf
Medina Del Campo DEMO Site, Spain DEMO	No information provided
The Lodz Region, Poland DEMO	No information provided

Appendix 2

Ecosystem services of relevance to the DEMO areas, previous research and data available.

Co$ting Nature index **Provisioning**	**Relevance to DEMO and references to previous research on mapping this service in your DEMO area**	**Ecosystem service represented**
Relative realised fisheries services index	**Thames Basin: UK DEMO site** *Atlantic Salmon Stocking area mapping* Griffiths AM, Ellis JS, Clifton-Dey D, Machado-Schiaffino G, Bright D, Garcia-Vazquez E, Stevens JR (2011) Restoration versus recolonisation: the origin of Atlantic salmon (Salmo salarL.) currently in the River Thames. Biol Conserv 144:2733–2738 Thames fishing map: map of angling points, some of which has species information Environment Agency: ToolHab DSS contains maps of Thames fisheries **Lower Danube section, Romania**: no information provided **Brague Basin, France**: no information provided **Lez basin, France:** Relevant data will be collected locally. **Greater Copenhagen area, Denmark**: N/A **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site** Šumer S., Povž M., Brilly M. 2004. Vpliv regulacije na ribe reke Glinščice. Aktualni projekti s področja urejanja voda. Mišičev vodarski dan 2004: 171 - 181 URL: http://mvd20.com/LETO2004/R23.pdf (17.10.2017)	Fish provision

	In river Glinščica fishing is not allowed. **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	
Relative realised timber services index	**Thames Basin: UK DEMO site** Felling Licenses - forestry commission open GIS data for felling licenses. National Forest Inventory England 2016 (367MB) This file contains 2016 Forestry Commission National Forest Inventory spatial data and associated metadata for England. Felling rates research: Levy, P.E. and Milne, R., 2004. Estimation of deforestation rates in Great Britain. *Forestry*, *77*(1), pp.9-16. **Lower Danube section, Romania**: no information provided **Brague Basin, France:** no information provided **Lez basin, France**: Relevant data will be collected locally. **Copenhagen area, Denmark**: N/A **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site** Forest accounts: http://pxweb.stat.si/pxweb/Database/Environment/16_forestry_hunting/ 01_16227_forestry_account/01_16227_forestry_account.asp Forest data - general: http://pxweb.stat.si/pxweb/Database/Environment/16_forestry_hunting/	Timber provision

	03_16731_forestry_general/03_16731_forestry_general.asp Purchase of wood: http://pxweb.stat.si/pxweb/Database/Environment/16_forestry_hunting/ 05_16564_wood/05_16564_wood.asp **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	
Relative realised fuelwood provision services index	**Thames Basin: UK DEMO site** The Forestry Commission has estimated that the potential woodfuel resource from woodland management arising in the South East England is around 500,000 tonnes per year. This could provide approximately 900 GWh of renewable heat, or enough energy to heat around 45,000 homes. - Data for south east England from: Forestry Commission England **Lower Danube section, Romania**: no information provided **Brague Basin, France:** no information provided **Lez basin, France:** Relevant data will be collected locally. **Copenhagen area, Denmark:** N/A **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site**: no information provided **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	Fuelwood provision

Relative realised grazing and fodder services index	**Thames Basin: UK DEMO site** Natural England - DEFRA Wood-Pasture and Parkland BAP Priority Habitat Inventory for England 2017 Provisional wood-pasture and parkland inventory created during the Natural England Wood-pasture and Parkland Inventory update. Typically large, open-grown or high forest trees in a matrix of grazed grassland and heathland. **Lower Danube section, Romania**: no information provided **Brague Basin, France**: no information provided **Lez basin, France:** Relevant data will be collected locally. **Greater Copenhagen area, Denmark:** N/A **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site**: no information provided **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	Grazing provision (on non agricultural land)
Relative realised non-wood forest product services index	**Thames Basin: UK DEMO site** Wild food is vital for the survival of the UK's wildlife. Foraging wild food by humans is mainly limited to elderflower, blackberries, sloes and fungi. Woodland Trust - UK trees, shrubs, flowers, grasses, fungi **Lower Danube section, Romania**: no information provided **Brague Basin, France**: no information provided **Lez basin, France**: Relevant data will be collected locally. **Greater Copenhagen area, Denmark**: no information provided	Fruits, berries, fungi provision (global data - fallingfruit.org)

	Spangen Area, Rotterdam DEMO Site, The Netherlands: no information provided **Glinščica catchment - Slovenian DEMO site**: no information provided **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	
Relative realised water provisioning services index	**Thames Basin: UK DEMO site** Thames Water provides a public water supply to around 8.5 million customers in London and the Thames Valley, an area largely covering the River Thames catchment. On average, around 2,600 million litres per day of potable water are put into supply, 35% groundwater and 65% from river water (Jones, M.A., Hughes, A.G., Jackson, C.R. and Van Wonderen, J.J., 2012. Groundwater resource modelling for public water supply management in London. *Geological Society, London, Special Publications*, *364*(1), pp.99-111.) The Environment Agency has an online Catchment Data Explorer (CDE) to download information about the water environment (groundwater and surface water rivers and lakes. It supports and builds upon the data in the river basin management plan. Asset location plan Thames Water (Permission needed) Thames water land and properties (STW, RES) Water quality: Whitehead, P.G., Crossman, J., Balana, B.B., Futter, M.N., Comber, S., Jin, L., Skuras, D., Wade, A.J., Bowes, M.J. and Read, D.S., 2013. A cost-effectiveness analysis of water security and water quality: impacts of climate and land-use change on the River Thames system. *Phil. Trans. R. Soc. A*, *371*(2002), p.20120413.	Water quantity, quality and regulation

	Water Quality: Surveys show that water quality in the Thames is stable. However 92% of samples reveal a significant presence of coliform bacteria. These findings point to storm-water sewage pollution entering the Thames and impacting the river's water quality. London has a combined sewage system – meaning that rainwater and waste water flow together in the same pipes. Currently to avoid rainwater and sewage from flooding our homes, the mix is discharged during large rainfall events into the Thames and is known as storm-sewage pollution. The Thames Tideway Tunnel is addressing this issue. Outside of these storm events, effluent is treated to a high standard, discharged into the river and is then abstracted further downstream for the part of the water supply to a downstream town. This is called indirect reuse. Thus London's supply comes partly from the effluent treatment works of Swindon, Oxford, Reading and Maidenhead. **Lower Danube section, Romania**: no information provided **Brague Basin, France**: no information provided **Lez basin, France:** Relevant data will be collected locally. **Greater Copenhagen area, Denmark**: no information provided **Spangen Area, Rotterdam DEMO Site**, The Netherlands: no information provided **Glinščica catchment - Slovenian DEMO site**: no information provided **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	

Regulating		
Relative potential and realised carbon services index	**Thames Basin: UK DEMO site** Natural England assessment Carbon at 1km 2016: Natural England have a 1km resolution map of mean estimates of carbon stocks, in tonnes per hectare, stored in above-ground vegetation. This is based on current published literature. Soil carbon is known to be the biosphere's largest carbon reservoir, but forests and other vegetation can also make up large proportions of the total carbon pool. Changes in size and productivity of the above-ground carbon pool may act as a sink or source for carbon dioxide. As such, the carbon stored in vegetation plays a vital role in climate regulation. Topsoil carbon stock SOIL: Gregory, A.S., Kirk, G.J.D., Keay, C.A., Rawlins, B.G., Wallace, P. and Whitmore, A.P., 2014. An assessment of subsoil organic carbon stocks in England and Wales. *Soil use and management*, *30*(1), pp.10-22. GRASS: Manning, P., Vries, F.T., Tallowin, J.R., Smith, R., Mortimer, S.R., Pilgrim, E.S., Harrison, K.A., Wright, D.G., Quirk, H., Benson, J. and Shipley, B., 2015. Simple measures of climate, soil properties and plant traits predict national-scale grassland soil carbon stocks. *Journal of applied ecology*, *52*(5), pp.1188-1196. **Lower Danube section, Romania:** no information provided **Brague Basin, France**: no information provided **Lez basin, France:** Relevant data will be collected locally. **Greater Copenhagen area, Denmark**: no information provided **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site**: no information provided	Climate mitigation

	Medina Del Campo DEMO Site, Spain DEMO: no information provided **The Lodz Region, Poland DEMO**: no information provided	
Relative realised natural hazard mitigation index	**Thames Basin: UK DEMO site** We are in the planning phase of a Thames flood management project in the lower Thames (between Datchet and Teddington) and outlined here. Map detail here. The scheme consists of: A large-scale engineering work to construct a new flood channel between 30 to 60 metres wide and 17 kilometres long, built in 3 sections: Datchet to Hythe End flood channel; Egham Hythe to Chertsey flood channel; Laleham to Shepperton flood channel. improvements to 3 of the existing weirs on the River Thames improved flood incident response plans creation of over 40 hectares of biodiversity action plan habitat working with communities to raise flood awareness and support them in flood preparedness, response and recovery providing community resilience measures to homes and communities to make them more resistant to flooding Construction is planned from 2019 to 2027. In 2010 a strategy appraisal report outlined some of the environmental benefits of some of these plans - however green infrastructure does not feature highly in the plans. It is hoped that the diversion channels will provide significant environmental enhancements, with benefits to the local landscape and biodiversity. Herne Hill & Dulwich Case Study Sustainable Urban Drainage Systems: Southwark Council, Thames Water & Environment	Floods, drought, erosion landslide, coastal inundation mitigation

	Agency • £4.2m flood alleviation scheme – sub surface storage, drainage channels, wetland/meadows. Enfield Suds - construction and maintenance of wetlands SUDS in public spaces as flood storage. For example, Firs Farm wetlands has been developed from an underground river under parkland. Firs Farm wetlands now stores 30,000m3 of flood water, helping to protect more than 100 properties from flooding, as well as the A10 Great Cambridge Road. Drought: In 2010 Thames Water opened the first municipal desalination plant in the UK (Beckton on the Thames Estuary). The economic regulator agreed with Thames Water's assessment that they had a supply demand deficit under sustained dry conditions and that there was little alternative but to develop a desalination scheme. Thames have spent £250m building the plant and pipes which will only be turned on at times of drought and can supply 1 million people with water. Further upstream, over abstraction of groundwater has seasonal effects on river flow in tributaries such as the Misbourne, Pang, Wey near Alton Hampshire, The Ver in St Albans, and Letcombe Brook near Abingdon. **EROSION** Bank erosion due to navigation and riparian land use, which increase sediment yield. Bussi et al (2016) suggest that a soil erosion mitigation scenario consisting in afforestation and the implementation of optimal agricultural practices and riparian buffer strips could be a robust adaptation strategy, as it was found to reduce sediment transport under different climate scenarios. **LANDSLIDE - not applicable** **COASTAL FLOODING NOT CONSIDERED IN THAMES DEMO** **Brague Basin, France**: no information provided	

	Lez basin, France: Relevant data will be collected locally. **Lower Danube section, Romania**: no information provided **Greater Copenhagen area, Denmark**: no information provided **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site** Municipality of Ljubljana has a plan with several actions for better flood protections, including actions in Glinščica catchment where dry retention areas are planned. https://www.ljubljana.si/assets/Seje/15445/5.-toka---poplavna-varnost-mol.pdf **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	
Cultural, Aesthetic		
Relative realised culture-based tourism services index	**Thames Basin: UK DEMO site** Britain is recognised as a world class destination for culture and heritage and the Thames valley is no exception. NBS are linked to a number of culture based tourism services, for example parks and gardens, historic places such as castles such as Highclere Castle, and local food and drink tourism services such as breweries and vineyards. **http://www.chilternsaonb.org/explore-enjoy/interactive-map.html** **Lower Danube section, Romania**: no information provided **Brague Basin, France:** no information provided **Lez basin, France:** Relevant data will be collected locally.	Recreation opportunities provided by non-urban cultural sites

	Greater Copenhagen area, Denmark: no information provided **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site** Lower part of Glinščica catchment is used as green urban area mainly for recreation. Main tourist activity is connected with a ZOO, which is located in lower part of catchment. Other tourism and activities are located in Ljubljana city center. **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO:** no information provided	
Relative realised nature-based tourism services index	**Thames Basin: UK DEMO site** In the Thames basin there are a two areas of natural beauty (AONB): the Chilterns and North Wessex Downs. There are a number of walks and cycle rides for recreation, such as the Thames Path national trail Continuing the example of the Firs Farm, Enfield: Apart from the wetland transformation, amenities include a cycleway and network of footpaths, an outdoor classroom, dipping platform, an open bird hide, broadwalks, stepping stones and several seating areas have been created for the public to enjoy. **Lower Danube section, Romania**: no information provided **Brague Basin, France**: no information provided **Lez basin, France:** Relevant data will be collected locally. **Greater Copenhagen area, Denmark**: no information provided **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site**	Recreation opportunities provided by non-urban natural sites

	Lower part of Glinščica catchment is used as green urban area mainly for recreation. **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	
Relative realised environmental and aesthetic quality services index	**Thames Basin: UK DEMO site** The Thames Basin has a number of nature reserves to visit, including attractive seasonal 'bluebell woods' For example, the River Ray is a tributary river catchment that has recently undergone changes to develop of a more natural landscape that will sustainably support wildlife typical of the area, is resilient to future pressures and is an attractive place for people to work, live and visit. These NBS have improved water quality, increased recreational opportunities, flood alleviation and reduced problems associated with low summer water flows. Similarly Loddon catchment has developed a Natural Flood Risk Management plan with local stakeholders. These include flood retention areas to slow the floodwaters, with environmental co- benefits for biodiversity and water quality. **Lower Danube section, Romania**: no information provided **Brague Basin, France**: no information provided **Lez basin, France:** Relevant data will be collected locally. **Greater Copenhagen area, Denmark:** no information provided **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site:** no information provided **Medina Del Campo DEMO Site, Spain DEMO**: no information provided	Environmental and aesthetic quality

	The Lodz Region, Poland DEMO: no information provided	
Other		
Relative realised wildlife services index	**Thames Basin: UK DEMO site** **Lower Danube section, Romania**: no information provided **Brague Basin, France**: no information provided **Lez basin, France:** Relevant data will be collected locally. Copenhagen area, **Denmark**: no information provided **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided **Glinščica catchment - Slovenian DEMO site**: no information provided **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO**: no information provided	Pollination and pest control
Relative realised cost of wildlife dis-services index	**Thames Basin: UK DEMO site** With environmental change, there is a risk of the spread of pests for trees and crops. There is a growing risk of new pests and plant diseases because of the increasing pace of change in trade, travel and climate and the cost to farmers and horticulture of millions of pounds every year, according to a report by the National Audit Office (2003) **Lower Danube section, Romania**: no information provided **Brague Basin, France**: no information provided **Lez basin, France**: Relevant data will be collected locally. **Greater Copenhagen area, Denmark**: no information provided **Spangen Area, Rotterdam DEMO Site, The Netherlands**: no information provided	Pests and crop raiding (Global pest data from CABI https://goo.gl/mCftKV)

	Glinščica catchment - Slovenian DEMO site: no information provided **Medina Del Campo DEMO Site, Spain DEMO**: no information provided **The Lodz Region, Poland DEMO:** no information provided	