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1. Introduction and aim

The purpose of this deliverable is to apply existing tools and datasets to examine multi-hazard risk in across Europe and for key demo basins within it, using existing spatial methods to better understand the spatial patterns of exposure to the risks mapped in D2.1. This is done with the Co$tingNature platform and globally available remote sensing datasets at 1km spatial resolution. Further we review the research and data to better characterise exposed assets within the demo basins in order to better understand on what basis an Eco:Actuary system can be designed and applied to the demo basins, in collaboration with partners.

NAIAD has combined hazard potential maps with information on socio-economic exposure to hazards based on agriculture, infrastructure, population and urban exposure, with their vulnerability, to highlight areas at risk at the European scale and in detail for four demo basin case study areas (Thames basin in the UK, the Lower Danube basin in Romania, Brague basin and surrounding watersheds on the French Mediterranean coast and the Ljubljanica basin in Slovenia) using Co$tingNature methods (Mulligan 2015) as a starting point. This includes an investigation of relevant exposure to hazards and recent trends for specific assets in specific basins.

2. Methods: Co$ting Nature

This report should be read alongside D2.1 and D2.3. Co$tingNature is primarily a conservation prioritisation tool that assesses the value of an area on a relative scale (lowest to highest, 0 to 1) based on its provision of ecosystem services, its importance for biodiversity and the anthropogenic pressure and threat that it is under. One of the ecosystem services covered is that of hazard mitigation. To calculate hazard mitigation one must first calculation the hazard potential (see D2.1) then the exposure of people and assets to hazard, then the mitigation services provided. Co$ting Nature calculates all hazard and all exposure in relative terms (lowest 0 to highest 1) which can scale locally to the area of study, or globally as relative indices. In this report, indices are scaled locally within the study areas shown in order to examine variation within those study areas rather than consider pixels in a global context.

In Co$tingNature, exposure to hazards is considered to scale with relative human population, relative infrastructure, relative agriculture and relative GDP indices. In this way we examine permanent exposure of assets (including population) rather than the transient exposure that may occur, for example, by a single car passing through an area

with potential for rockfall. The original data are of course in different units but in order to combine them we scale each between low and high (1st to 99th percentile to avoid issues with outliers) and combine them without weighting. An overall high exposure can thus represent a high exposure of any combination of inputs. In addition to the magnitude of exposure calculated in this way, we also show the greatest exposure per pixel (i.e. the component of exposure, which has the greatest relative value). Exposed assets include: presence of mines, presence of oil and gas wells, roads, pastures, croplands, population, GDP. Hazard exposure is therefore the product of hazard potential and exposure. Vulnerability is assumed to scale inversely with combined GDP and infrastructure such that high GDP and infrastructure lead to lower vulnerability. Risk is then the product of exposure to hazard and vulnerability. This is further described in Figure 1. The resulting relative indices allow identification and visualisation of hotspots of hazard potential (D2.1), hazard exposure (D2.2) and risk (D2.3).

Co$ting Nature is a global system, parameterised from remote sensing based datasets. These vary in resolution but generally have a resolution of 1km down to 1ha. For local scale studies (individual cities, small local administrative regions) this means that results are prone to data limitations and local data should be sourced for application (though this has its own problems). For basin, national or international scale work the 1km resolution earth observation data provides significant detail (often more than would be possible from ground based data sources). The tool is thus most applicable at the regional scale and for the catchment and upslope areas that deliver threats to cities rather than to the city scale itself. More detail is provided in appendix 1 and online with with Co$tingNature at www.policysupport.org/costingnature

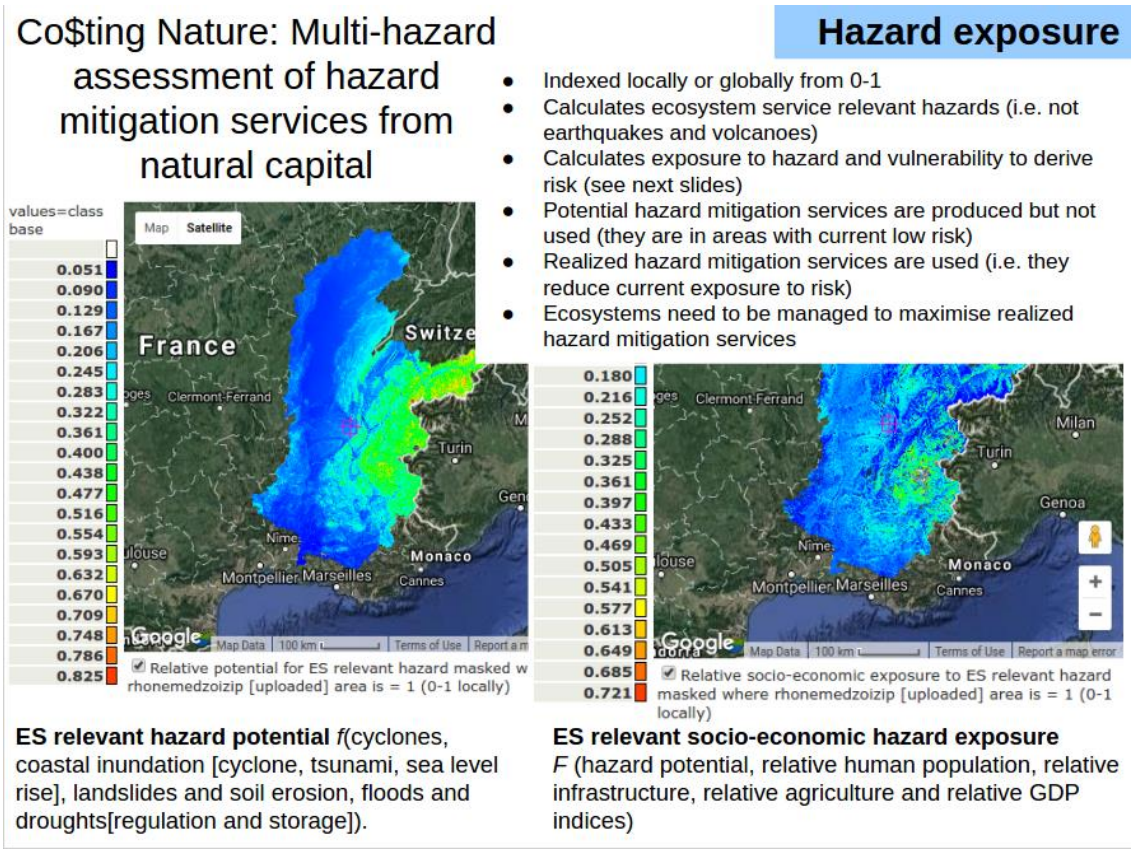


Figure 1. Multi-hazard hazard exposure as defined by Co$tingNature. Hazard potential index (left), exposure index (right).

3. Demo basin datasets

This section provides an analysis of data, literature and methods available that are suitable for understanding exposed assets and their characteristics in the demo basin areas and, for those demos who wish to apply the Eco:Actuary tool for their basin, the potential for improvement of data used in Co$tingNature.

3.1 Thames Basin: UK DEMO site

Demo Focus and proposed methods

The main insurance relevant risk in the Thames basin comes from fluvial, tidal and cloudburst flooding. Thames basin demo will **focus on fluvial flooding** as the key

hazard but will also look at the multi-hazard metrics of Co$tingNature. We will focus on **direct impacts as**: disruption to transport, commuting and thus economic activity and destruction of infrastructure and indirect impacts as loss of economic production, tax receipts and jobs, disruption to decision-making structures and risk to health and safety. The **following sectors are key**: finance, education, government, insurance, retail. **Physical and social characteristics defining vulnerability** in the Thames includes: the fact that it is low lying, has a high concentration of population, GDP and infrastructure, includes large urbanisation with limited natural storage and drainage, much commuting and pressured transport systems.

We will focus on **NBS as a means of reducing** the hazard potential and reducing exposure (in some cases). There are of course barriers to the development of NBS in the Thames including lack of space and high land prices in the urban environment, resistance from landowners in the rural environment, lack of funding, reliance on grey solutions. Also of relevance is Brexit and potential loss of CAP subsidies for set aside and conservation agriculture. Our work will focus exclusively on the development and application of **robust spatial information and scenario tools**, alongside economic trade-off analysis to support the development of **financial instruments for supporting NBS**. This will be achieved through the development and application of the Eco:Actuary Policy Support System to **simulate multi-hazard and flood hazard baselines and scenarios under land use and climate change**, alongside impact analysis for different types and scale of relevant NBS. The key NBS on the hazard potential side will focus on increasing storage, infiltration in the rural and urban environment. On the exposure side, NBS can help in reducing assets exposed in hazard prone areas. There is a wide range of existing initiatives looking at green/grey for the Thames catchment but our contribution is currently at an early stage. We are working with stakeholders on problem definition. The last day of the London workshop (2018) will bring together an array of local stakeholders around the beta version of the EcoActuary tool.

Table 1: Data on exposure of assets in the Thames demo

Key asset class exposed	**Sources for exposure data**	**Characteristics of exposure data (timescale, extent, spatial resolution)**

Agriculture	Natural England Agricultural Land Classification: Centre for Ecology and Hydrology land cover map	2012, UK wide, shapefile 2007, UK wide, raster 1-km
GDP	Office for national statistics GDP per head: Eurostat GDP at regional level:	2012-2016, UK, CSV 2014 GDP at NUTS 2 level, EU 28, CSV
Population	Eurostat population density at regional level: CDRC population density	2014 population density at NUTS 2 level, UK28, CSV 2011 (latest UK census), UK wide, CSV
Infrastructure	Ordnance Survey open roads Ordnance Survey Edina Digimap local data London infrastructure map - planning tool for future planned infrastructure 2015 - 2050	2017, UK wide, shapefile 2016, Tiles for Thames basin, shapefiles (buildings, motorways, roads, junctions, stations, tunnels etc.). Online interactive vector map downloadable. Energy, education, medical health, residential, transport, water, Crossrail.

3.2 Lower Danube section, Romania DEMO site

Demo Focus and proposed methods

The main focus in this demo is pluvial flooding and riverbank erosion which leads to collapse. Secondly, during the low water period the Lower Danube sector is facing numerous problems for navigation.

A number of urban areas have been developed on the banks of the Danube, very close to the water, and these are very susceptible to floods and riverbank collapse, particularly where no engineering works (riverbank stability) have been performed.

Desertification is important in some areas, even in areas close to Danube. Ideally, the solutions to this will include a mixture of grey engineering works combined with green solutions, developed according to local needs, although the general risk characteristics of the demo site need to be considered. The mixed grey green solutions include strategic reed planting, drainage canals, smarter sewage systems, pluvial water collection and river bank consolidation.

The main challenge is to identify, with the help of the local stakeholders, the areas, which are more appropriate to green interventions so maximum level of impact can be achieved. The reed planting solution should provide a sustainable method for lowering erosion – riverbank protection and also will help preserve the local ecosystem with regard to the different aquatic species. Another possible NBS could be the reforestation of the exposed riverbanks.

Within the large area covered by the demo site the risk of catastrophic damage to the local communities is extremely high, due to the lack of development plans for sustainable economic friendly solutions, the high number of urban areas, accumulation lakes, old/nonexistent drainage infrastructure, and riverbank consolidation works. Much of the damage risk involves local infrastructure and (in case of extreme drought) quality of life is lowered consistently.

Most of the damaged localities are close to the riverbank. The systems that have high socio economic importance that are most affected by flooding and riverbank collapse are infrastructure elements (roads, sewage systems, settlements, pumping stations, water drainage systems).

Table 2: Data on exposure of assets in the Lower Danube section demo

Key asset class exposed	Sources for exposure data	Characteristics of exposure data (timescale, extent, spatial resolution)
Infrastructure	National institute of hydrology and water management National administration “Romanian water”	Archived datasheets, daily updates, full Danube coverage. CSV Datasheets, maps, pdf Maps, csv, flood model, daily update

	Lower Danube fluvial administration "R.A.Galati" Flooding emergency action plan Management plan for floods risk on the Danube river. Ministry of environment GIS Maps – online community	Fluvial transport infrastructure, navigation data, water level csv, different maps, daily update. Full document with index, gov. reglementation. National reglementation for floods, national synthesis. GIS Maps, data tables, data sheets.
Agriculture and other land use	General agricultural land use report, Ministry of regional development and public administration National research institute for agriculture	Report pdf, value tables, yearly update. Different publications, archived data.
Population	Consulting committee for territorial cohesion Development of the Romanian Danube territory	Detailed information, statistic sheets, pdf.
GDP	National statistics EU site	Detailed information on every region, charts, csv values, maps.
Natura 2000 site	Danube Delta Biosphere Reservation	National legislative reglementation, different data, maps.

3.3 Brague Basin, France DEMO site

Demo Focus and proposed methods

The Brague catchment is located in the South East of France on the Mediterranean coast. The region experiences the so-called Mediterranean climate, which is characterized by rainy winters and dry, warm to hot summers. The Brague catchment, as with all the French Mediterranean coast, is regularly subject to extreme rainfall events triggering damaging flash flood events. The work developed in this DEMO site will mostly focus on torrential flood risks with particular attention to:

- the flashiness of the events,
- the aggravation of flooding due to large wood transport and jamming in bottleneck river sections,
- the aggravation of flooding related to erosion and sediment deposition, partially obstructing river bed,
- the eventual aggravation of the hydrological and hydraulic response of the catchment after wildfires, another threat to the catchment and its ecosystem under the local climate.

The Brague catchment regularly experiences floods. The CCR damage database has, for instance, gathered so far the following data:

- The geographical distribution of flood damage varies greatly within the catchment with less than 1M€ of cumulated damage for the headwater municipalities (06038 Chateauneuf-Grasse et 06084 Mouans-Sartoux) while the lowlands' municipalities (Biot and Antibes) have more than 50 M€ of cumulated damages.
- Within the 5,500 damage data points, 4,200 are geolocalised with sufficient accuracy (street or even house accuracy), enabling detailed mapping, although the data are confidential, they can be presented but only when aggregated to bigger scales.
- 65.9% of the registered damages are related to the 2015 event. Other less extreme floods occurred in Nov. 2011 and Sept. 2005, accounting for another 10.5 % and 5.6% of registered damages, respectively.

These data and events will be used to calibrate a flood risk assessment tool that will probably be based on a suite of models coupled or in series:

- Hydrological model estimating discharges from rainfall data,

- Hydraulics model estimating flood hydrograph propagation within the catchment river network and mapping flooded areas,
- Large-wood transport and jamming module estimating the aggravation related to large wood presence in rivers,
- Bedload sediment transport module estimating erosions and depositions, as well as the resulting changes in the flood hazards,
- GIS analysis of assets (building, bridges, roads) enabling a mapping and inventory of potentially damage assets,
- Vulnerability analysis at the asset scale depending on flood hazard and asset type (housing, commercial, industry, number of level, building material),
- Financial cumulated estimation of damages summing asset value multiplied by their local damage ration.

This model suite should be calibrated on one or two events and validated on the other measured events.

Secondly, the model suite will be used to explore damages resulting from events of low to high frequency in order to estimate probability density functions of flood damage in the current situation.

Finally, the models will be tuned to account for the ecosystems' effects. The tuning definition will be based on literature results, expert assessment and additional analysis, e.g., on wildfire influence on hydrology. The same low-to-high frequency event-related damages will be modeled.

The difference between the current situation and the tuned model should highlight the insurance value of ecosystems.

Within this work, we expect to gain a good comprehension of flash flood processes in this 68 km² basin. It will help use to define the more relevant nature based solutions to compare to classical grey solutions currently mostly used. As a first approximation, the NBS that may be studied are:

- Forest best-adjusted management for wildfire prevention and fauna & fish-oriented potential,
- Light, integrated large wood trapping facilities concentrated upstream of sensible bridges and structures,
- Bio-engineering erosion protection on banks,
- Floodplain – river bed reconnection to store water at acceptable frequency in mixed-used areas (low vulnerability areas, parks, agricultural areas, etc.).

These NBS will be compared to the current grey solutions that are usually implemented, such as:

- Heavy forest management, removing all large wood debris and old trees on banks, thereby strongly decreasing fish potential. This is profoundly debatable from a risk mitigation perspective as demonstrated in 2015 (Préfécture des Alpes-Maritimes 2016, RTM06 2016),
- Absence of sediment and large woods trapping upstream of sensible structures,
- Riprap and concrete bank protections,
- Fully channelized and disconnected river system.

Stakeholders have already implemented flood mitigations plans and early warning systems (PAPI CASA 2013, Ville d'Antibes 2013). It has not been sufficient to prevent more than 50M€ of damages and 4 casualties in 2015, although the event was a dramatic extreme at the regional scale between Cannes and Nice (twenty people died, 550-650M€ of losses).

Interviews will be performed to assess the risk perception of a wide range of stakeholders in order to understand the risk and perception of NBS. Public meetings will be organized during the whole project and an assessment will be done again at the end to understand the interest and knowledge gained during the project and the remaining challenges and issues.

Table 3: Data on exposure of assets in the Brague basin and surrounding watersheds in France. These data can also be used in the Lez demo study area in France

Key asset class exposed	**Sources for exposure data**	**Characteristics of exposure data (timescale, extent, spatial resolution)**

Agriculture	CORINE land cover data base Adapted version of CORINE land cover for the PACA region (south east of France) : BDOCSOL-PACA 2014 RPG (référentiel parcellaire graphique) AGRESTE RICA database	1990, 2000, 2006, 2012, French nation scale, shapefiles or raster 2006, 2014, PACA Region, shapefiles Principal agricultural plots (parcel level) Principal agricultural plots (communal level) Sample of farmers (agricultural exploitation level)
Buildings	Mapping of legal plots and buildings	Available under convention for research purposes, updating on a 3-years frequency, shapefiles
Roads, railways, train stations	IGN BD ROUTE 500®, regional scale road network IGN BD Carto, 10-m precise mapping of roads, building, rivers, etc. IGN BD TOPO®: meter precise mapping of roads, building, river, etc.	Free, bi-annual updating, shapefiles Available under convention for research purposes, updating on a yearly to 5-years frequency, shapefiles Available under convention for research purposes, updating on a yearly to 5-years frequency, shapefiles

Population	INSEE inventory of populations on 200m-side squares (ages and number) Same data on 1km-side squares National inventory on population evolution at the municipality scale INSEE database INSEE IRIS IGN France 2050 INSEE population projection	2010, shapefiles, national 2010, shapefiles, national 2013, tables,, National Communal and Cresta level population (statistics and trends for 2040) infra communal population data (2013) infra IRIS population data in 2050 (50m meshes) General trends
Assets -Large waste water stations (>2000 EH) - Polluting factories (établissements IPPC) -Patrimonial assets (historical, cultural, religion.) -Areas of economic activity Detailed information on professional risks	Asset assessment done within the TRI (Flood risk territories) study within the Flood EU directive SIRENE database	2013, shapefiles, flood hotspot region limited to the floodplain near the sea Monthly update, tables, municipal level.
GDP	INSEE database	Country & Department level

Insurance	Policies and claims databases from insurers (i.e. CCR database)	Detailed information on the policy location, risk type and premiums *NOTA: These data are not shared at a detailed level but will be used in the project Demo for damage assessment*

3.4 Copenhagen area, Denmark DEMO site

Demo Focus and proposed methods

The focus in the Copenhagen demo area is on pluvial and groundwater flooding. Climate adaptation to avoid damage due to flooding is achieved by combining grey and blue/green solutions. Where there is space, excess rainwater is decoupled from the sewer system and diverted to blue pathways, which transport excess water via surface canals to open water, such as the harbour area. Green solutions include retention areas that delay water discharge for evaporation or infiltration to groundwater. Focus is therefore also to identify suitable locations for both blue and green solutions, to avoid e.g. local groundwater level rise (affecting the sewer system) and water quality issues.

Proposed methods include use of Bayesian Belief Network (BBN) to analyze the influence of climate change, sea level rise and climate adaptation measures on urban flooding, and to evaluate damage costs, both direct and indirect. A dedicated hydrologic model is set up and applied to simulate flooding depth in Copenhagen and the effect of mitigation measures, grey and blue/green solutions. The hydrologic model outputs into the BBN.

Unsustainable groundwater extraction in Metropolitan Copenhagen which includes aquifers adjacent to and including the Copenhagen Demo area may affect the green/blue solutions considered as the near surface groundwater level and the groundwater quality is affected. Modelling of the extended area by means of both the Copenhagen hydrological model and eco:actuary tools is compared and inspected for added value and synergy.

Table 4: Data on exposure of assets in the Copenhagen demo area in Denmark.

Key asset class exposed	Sources for exposure data	Characteristics of exposure data (timescale, extent, spatial resolution)
Built environment	Damage data provided by insurance umbrella company; model simulated data	Insurance data: on dates where damage occurred; model data for 10-100-1000 yrs. Flooding Spatial resolution: 10 m, 100 m, 500 m
Infrastructure (trains, metro, roads)	model	model data for 10-100-1000 yrs. Flooding Spatial resolution: 10 m, 100 m, 500 m

3.5 Spangen Area, Rotterdam, The Netherlands DEMO site

Demo Focus and proposed methods

The focus of this demo is on pluvial flooding and its consequent social, economic and environmental impact. Climate adaptation to avoid damage due flooding hazard is achieved by designing and implementing unique combinations of grey and green/blue infrastructures (GBI). Nature-based solutions to be implemented include retention systems to retain excess rainwater, bio-filtration systems to purify runoff to be infiltrated and Aquifer Storage & Recovery of rainwater for later use.

In the demo site, Sparta Stadium and surrounding, rainwater is decoupled from the sewer system and temporarily stored in the underground retention area. From there water is distributed to a biofiltration system, which intends to filter water for underground storage via infiltration wells (ASR). The focus hereby is to identify the effect and potential scalability of this solution, known as 'Urban Water buffer', to potentially increase buffer capacity, avoid damage to the sewer system, improve quality of surface and groundwater, and to increase the availability of sustainable, safe and reliable freshwater for other uses, i.e. urban use.

Due to the fine scale of this demo, the deployment of EO supported data is limited. Proposed method will include a dedicated tool based on parametric modelling, which will be developed based on the beta version of the Visual Water Canvas (VWC) to assess the social, economic and environmental impact of pluvial flooding in the Demo site, and to model the effect of the implemented GBI solutions. As input existing models and available GIS datasets will be used. This model can be compared with the model of the Copenhagen Demo to gather relevant insights.

Table 5: Data on exposure of assets in the Rotterdam demo site, The Netherlands

Key asset class exposed	**Sources for exposure data**	**Characteristics of exposure data (timescale, extent, spatial resolution)**
Buildings	Data of damage and claims provided by insurance company and municipality of Rotterdam (if available), AHN (National elevation maps)	Data of pluvial flooding events; model data for 10-100 yrs. Spatial resolution: 10m - 500 m
Infrastructure: transportation (roads, rails);	AHN (National elevation maps), Open data Municipality of Rotterdam	Data of pluvial flooding events; model data for 10-100 yrs. Spatial resolution: 10m - 500 m
Utilities (sewage, water supply, energy)	AHN (National elevation maps), Open data Municipality of Rotterdam	Data of pluvial flooding events; model data for 10-100 yrs. Spatial resolution: 10m - 500 m
Green infrastructure	AHN (National elevation maps), Open data Municipality of Rotterdam	Data of pluvial flooding events; model data for 10-100 yrs. Spatial resolution: 10m - 500 m

3.6 Glinščica catchment, Slovenian DEMO site

Demo Focus and proposed methods

The main insurance relevant risk in the Glinščica catchment is torrential flooding, but we will also look at the multi-hazard metrics of Co$tingNature for the wider Ljubljanica catchment, to get an overview and relation of the demo in the larger catchment. We will focus on **direct impacts**: destruction of private property and risk to health and safety, effects on agricultural lands, disruption to transport, commuting and thus economic activity and destruction of infrastructure as well as indirect impacts as the loss of economic production. The **following sectors are key**: finance, education, government, insurance, retail. **Physical and social characteristics defining vulnerability** in the Glinščica catchment include: its torrential character and highly urbanized areas on its floodplains, a high concentration of population in the lower reaches, GDP and infrastructure, including relatively large urbanisation with limited natural storage and drainage capacity.

Table 6: Data on exposure of assets in the Glinščica catchment, Slovenia

Key asset class exposed	Sources for exposure data	Characteristics of exposure data (timescale, extent, spatial resolution)
Land use	Slovenian Environment Agency	Slovenian wide, shapefiles (agglomerations)
Land use	Ministry of Environment and Spatial planning	Slovenian wide, shapefile, different types of spatial data
Agriculture	Ministry of Agriculture, Forestry and Food	Slovenian wide, shapefiles (land use, change in land use from 2006 to 2012 etc.)

Infrastructure	Ministry of Environment and Spatial planning	Various, Slovenian wide, shapefiles (buildings, motorways, roads, junctions, stations, tunnels etc.)
Population	Republic of Slovenia, Statistical office	2011 - 2017, population density on Slovenian, municipality and settlement levels, CSV
GDP	Republic of Slovenia, Statistical office	GDP per capita per statistical region, 2000 - 2015, CSV
Protected areas/Natura2000	Slovenian Environment Agency	Protected areas, Natura2000, shapefile, Slovenian level

3.7 Medina Del Campo, Spain DEMO site

The insurance sector in Spain with regard to Natural Hazards is mainly governed by the Insurance Compensation Consortium, a private entity of the Ministry Of Economy, Industry and Competitiveness. Their prime is based on compensation concept, so a small amount of prime (0.7%) is charged to all private insurance taken by any stakeholder to any insurance company, no matter if it is a compulsory insurance (e.g. third party vehicle insurance) or a free insurance (e.g. full vehicle coverage insurance). This model takes no consideration for the type of insurance involved (fire, crash, burglary) as long as an owner has insured something against whatever issue, it will automatically be covered against natural hazards. The success of this model is that the fee charged to insurance takers is so small it goes unnoticed, practically speaking, and it guarantees the broadest coverage possible to the overall population, reaching insurance indexes as high as 70 to 80% and growing. The insurance covers not only the value of the object at stake and life, it also includes loss of profit.

However, given the entry into force of SOLVENCY II Directive, the Spanish Insurance Compensation Consortium is requiring a scientifically and physically (hazard specific) based approach to better understand the compensation they would have to face in case an event takes place. The Spanish Geological Survey is the research body providing

such assessments. Natural hazards covered by this model include: low frequency floods, earthquakes, tsunamis, volcanic eruptions, storms, meteorites and aerolites.

Demo Focus and Proposed Methods

The Medina del Campo area is subject to three main sources of damage: floods, droughts and water toxicity. Floods might be derived after three possible mechanisms: overflow, in situ precipitation and groundwater table rises. Drought is a complex hazard felt by the population as a water supply scarcity, which might not be related to actual precipitation patterns. However, understanding natural driven droughts will aid decision makers to point out the best NBS model to take into consideration along with other green or gray measures. Water toxicity in the Medina del Campo area is linked to the presence of Arsenic (As) in high concentration coming from groundwater sources. The source of the As in the groundwater body is under discussion, so a better understanding of the aquifer system will help in the process of recovering the water body healthy status. The Medina del Campo will hence focus on physical modeling of hazards following a combined probabilistic and evidence based approach, providing Inspire Directive Annex III (Natural Risk Zones) compliant coverages and hence not compatible with Co$ting Nature models or data. The data source for exposed elements will be obtained after cadastral parcels, so physical property will be the main focus, including both agricultural lands (loss of profit) and urban areas (properties and people). Hazard and vulnerability assessments will be specifically compiled for the problem at stake.

Table 7: Data for Medina del Campo

What data	Availability	Contact point or source
DEM@ 1 metre, 5metre, Spanish aerial imagery and more	Free to download and WMS	http://centrodedescargas.cnig.es/CentroDescargas
Geology, hydrogeological and geothematical information	On demand and WMS	WMS: http://mapas.igme.es/Servicios/default.aspx Spatial data inventory: http://info.igme.es/BDcartografia/ Geoscientific data and projects http://www.igme.es/actividadesIGME/lineas/cartoGeo.htm
Hydrological information (such as Flood prone zones, flood risk,	Free to download and WMS	http://www.mapama.gob.es/es/cartografia-y-sig/ide/descargas/agua/default.aspx or

groundwater bodies, and much more)		http://www.mapama.gob.es/ide/inspire/atom/CategAgua/downloadservice.xml
Weather information (temperature, humidity, precipitation, etc.)	On demand	http://www.aemet.es (may be obtained through IGME)
Cadastral information	WFS, WMS	http://www.catastro.meh.es/webinspire/index.html http://www.catastro.meh.es/esp/productos.asp#prod8
Demography and other national statistics	WMS and downloads	http://www.ine.es/welcome.shtml http://www.ine.es/censos2011/visor/

3.8 The Lodz Region, Poland DEMO site

Demo Focus and proposed methods

The City of Lodz is located on the border between the first order watersheds of the largest Polish rivers, the Vistula and the Oder. Its 19 rivers flow in a star-shaped structure to the north to supply the Bzura, then the Wisła (8 rivers), and to the south to supply the Ner and the Oder (11 rivers). All the rivers have been, at least partially, channelized in 19th century and incorporated into one stormwater and combined sewage system. That creates unusual conditions of the City suffering mostly from fluvial flooding originating from excessive rainwater combined with rivers peak flows.

The direct impacts include: destruction of infrastructure, disruption of transport, and health risk related to water quality and infrastructure status, indirectly it affects city economy in twofold way – by handicapping the production / commuting, and by raising costs of city maintenance and restoration. The most exposed areas are those of historical and cultural value, located in the city centre, being a hub of stormwater /river network, as well as housing located on floodplains. It characterises also with high socio-economic vulnerability being densely populated, especially by low income communities and older people, and having a high concentration of vital infrastructure and GDP.

The general solution to the problem would be decentralization of stormwater system - water harvesting and temporal storage, and rehabilitation of rivers and floodplains towards high water storage capacity. Considering other burning problems of the city, such as heat island effect, high air pollution and poor quality of water, partially caused

by incidences of sewage treatment plant overload, the only multifunctional solution is green infrastructure and regulatory ecosystem services, which it can deliver. Simultaneously river network can sustain flow and transfer of those services across the city and between the watersheds.

Nature Based Solutions can be also helpful with solving problem of severe city droughts that affect green infrastructure and its regulatory functions, and currently amplify due to climate change, but also water drainage following land development.

The city focus is on identification the areas particularly exposed to flooding and heat island effect, and on development of blue-green solutions originating from the whole range of NBS-technology hybrid implementations. It is assumed that they allow lowering or elimination of risks to people, wildlife and infrastructure by re-location of water surplus in space and time.

Green solutions, however, are not a prioritized approach so far, neither by political-governing system nor by citizens, mostly due to limited trust in their efficiency and the adopted procedures, e.g. for public procurement.

Proposed methods include use of Bayesian Belief Network (BBN) to analyse synergistic risk mitigation effect of different NBS and their locations against the attitudes of main actors (citizens, decision makers, insurance companies). Due to complexity of dynamics of the combined river-stormwater system and strong social and economic gradients, the more detailed studies will be conducted in the second biggest catchment of Lodz – the Jasień River. The options of de-canalizing the river will be also explored together with the city green ring protection plan.

The stakeholder platform of the City of Łódź is engaged in the process of co-design of solutions and knowledge co-production. In order to secure broader societal support for actions, ensure meeting citizens' demand for greens, and to bundle ecosystem services delivered by the blue-green infrastructure, an extended surveys as well as workshops with focus groups will be carried.

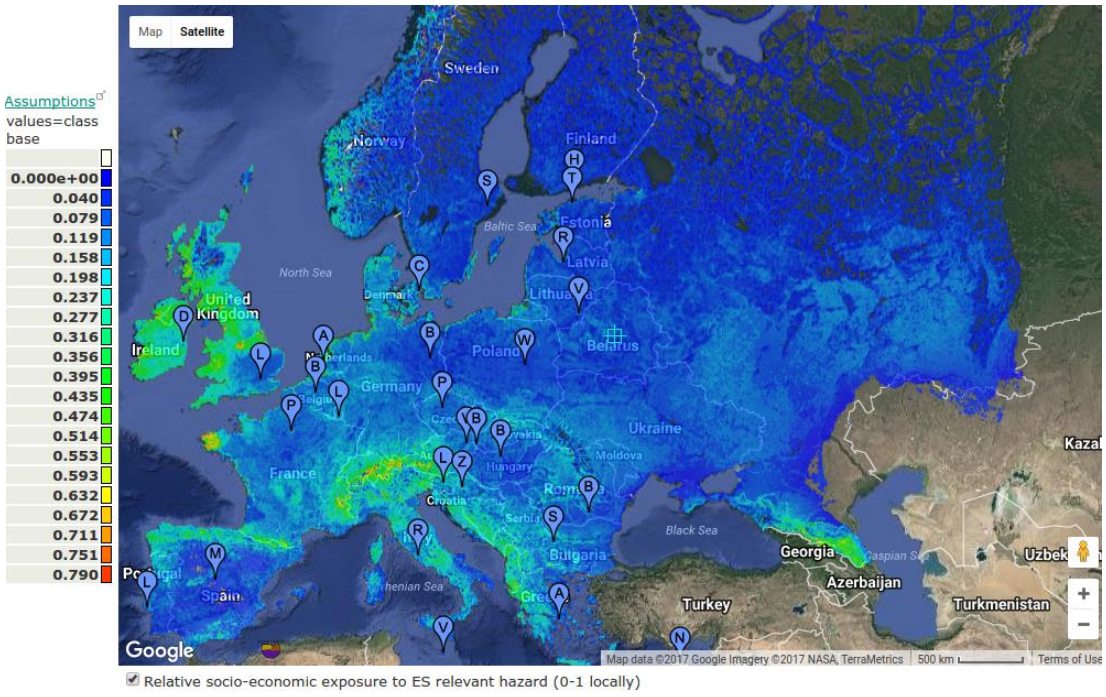
Modelling of the extended metropolitan area with eco:actuary tools could be an added value to provide a context for the city.

4. European analysis with Co$tingNature

4.1 Relative socio-economic exposure

Socio - economic exposure is defined by Co$ting Nature (Mulligan 2015) as normalised GDP (CIESIN, 2002), population (Landscan, 2007), agriculture (cropland and pasture fractional areas from Ramankutty, 2008). and infrastructure. Infrastructural exposure is calculated as the sum of the presence of dams (Mulligan et al., 2011), mines (Mulligan, 2010a), oil and gas (Mulligan, 2010b), urban areas (Schneider et al., 2009) and roads (FAO, 2010).

The Co$ting Nature hazard exposure maps for Europe are shown in Figure 2. Risk Exposure is multiplied by hazard potential to produce the index of exposure to hazards. The index is scaled locally (rather than globally) to highlight the risks across Europe. The exposure index has high values where hazard potential is high and multiple assets are exposed i.e. in populated, agriculturalised and infrastructure-rich areas, particularly in Western and Southern Europe, and along coasts. By basin, those in Ireland, UK, SE France, Switzerland, Austria and Southern Germany show particularly high values. By country Switzerland has the highest combination of hazard and exposure, followed by Ireland. A typical profile for Switzerland indicates the importance of pastures, croplands, roads, population and GDP in hazard prone areas on hazard exposure.



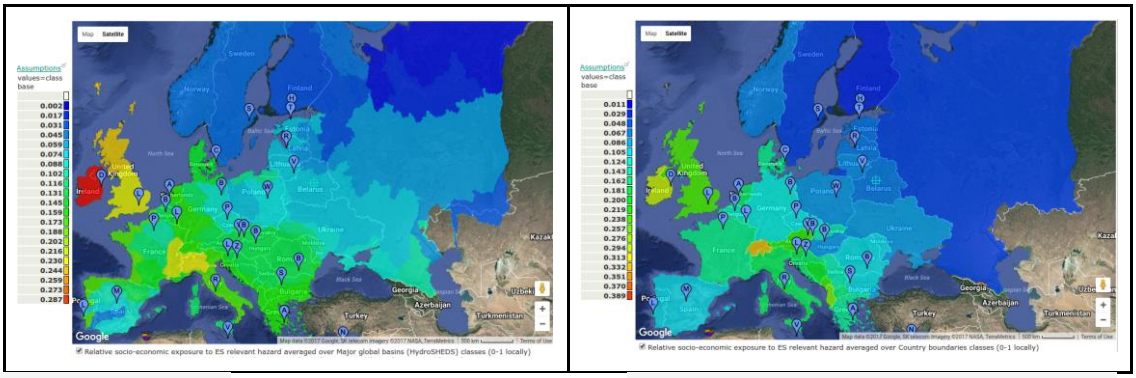
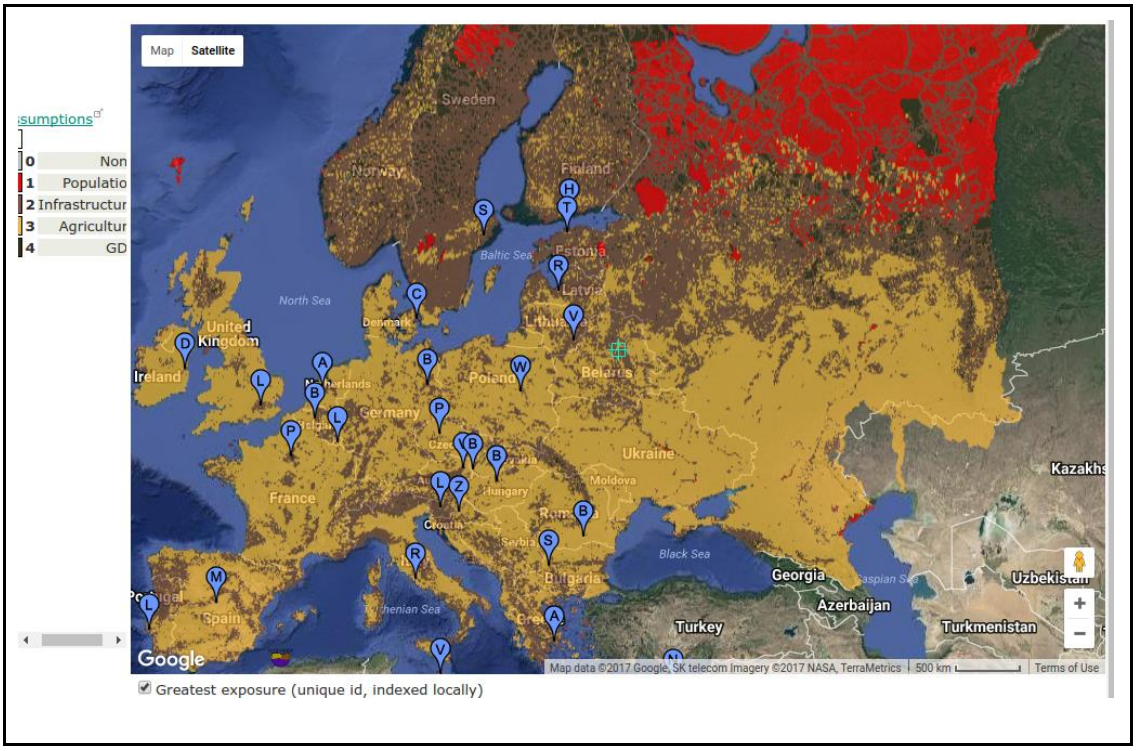


Figure 2 Relative socio-economic exposure to ecosystem service relevant hazard for Europe by pixel, major global basin and country. The normalisation is for Europe from 1st to 99th percentile. The map shows hotspots of exposure which combine hazard potential with assets exposed to that hazard. Low values indicate low hazard potential or low exposure. High values mean both hazard potential and assets exposed to that potential.

4.2 Greatest hazard exposure

The assets most exposed vary from infrastructure where agriculture, GDP and population are low to GDP (major cities), agriculture for much of Europe grading to infrastructure in the less agriculturalised north and population (outside of roads) in the north east. By basin agriculture dominates as the most exposed asset over space. By country agriculture is the most exposed asset outside Norway, Sweden, Finland, Greece, Portugal and a few others.



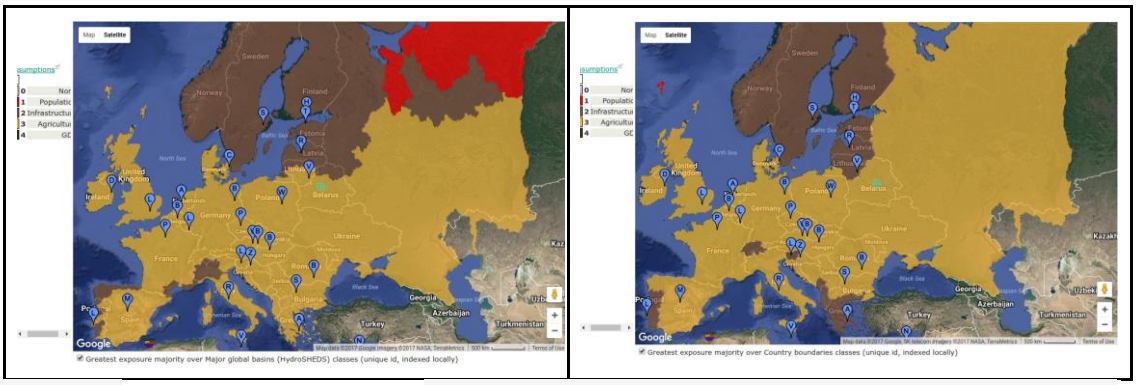


Figure 3: Greatest exposure of ecosystem service relevant hazard for Europe by pixel, and majority by major basin and country. The colour indicates the asset thatis most exposed. This depends upon the magnitude of the assets and the distribution of hazard potential in relation to the assets.

4.3 Hazard exposure and assets greatest exposed for European capital cities

Examining values at the locations of European capitals we see the highest multi-hazard exposure is for Amsterdam (dominated by exposed infrastructure), followed by Ljubljana, Dublin, Paris. The capital cities with lowest assets exposed are Madrid, Bucharest, Athens, Warsaw.

Table 8: EU capital cities ranked by Co$ting Nature hazard exposure with indicator of assets most exposed in the urban area

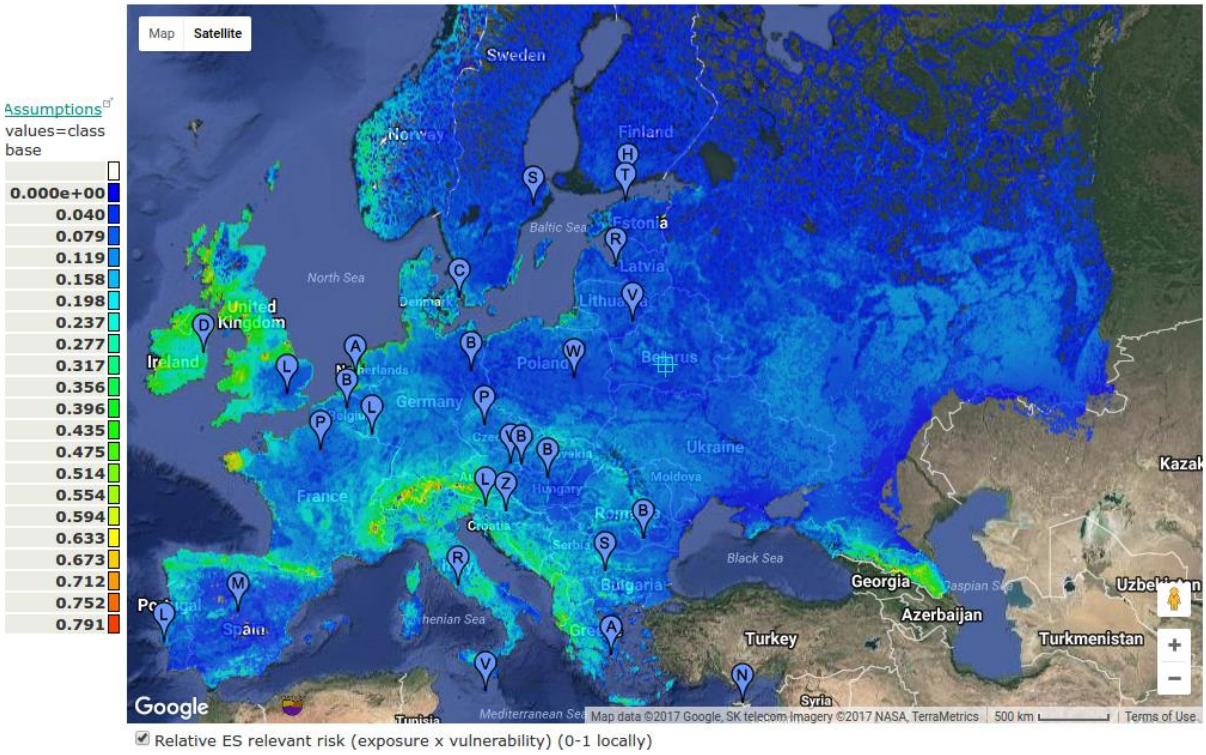
EU Capital	Relative socio-economic exposure to ES relevant hazard (0-1 locally) Mean	Greatest exposure (unique id, indexed locally)
Nicosia	Outside study area	Outside study area
Amsterdam	0.30	Infrastructure
Ljubljana	0.26	Infrastructure
Dublin	0.19	Infrastructure
Paris	0.15	GDP
Zagreb	0.14	Infrastructure
Tallinn	0.12	Infrastructure
Luxembourg	0.11	Infrastructure
Brussels	0.10	Infrastructure

Sofia	0.09	Infrastructure
Rome	0.09	Infrastructure
Bratislava	0.08	Infrastructure
Valletta	0.08	Infrastructure
Vienna	0.06	Infrastructure
Budapest	0.06	Infrastructure
Vilnius	0.06	Infrastructure
London	0.06	Infrastructure
Prague	0.05	Infrastructure
Lisbon	0.05	Infrastructure
Helsinki	0.05	Infrastructure
Copenhagen	0.05	Infrastructure
Berlin	0.04	Infrastructure
Stockholm	0.04	Infrastructure
Riga	0.04	Infrastructure
Madrid	0.04	Infrastructure
Bucharest	0.03	Infrastructure
Athens	0.03	Infrastructure
Warsaw	0.02	Infrastructure

4.4 Relative ES relevant risk (exposure x vulnerability)

The Co$ting Nature risk maps for Europe are shown in Figure 4 and indicate high values where hazard potential is high and multiple assets are exposed i.e. in populated, agriculturalised and infrastructure-rich areas, particularly in Western and Southern Europe, and along coasts, but especially where remoteness and thus vulnerability may also be high. Risk is defined as exposure x vulnerability.

By basin, those in Ireland, UK, SE France, Switzerland, Austria and Southern Germany show particularly high values. By country, Switzerland has the highest concentration of hazard exposure, followed by Ireland.



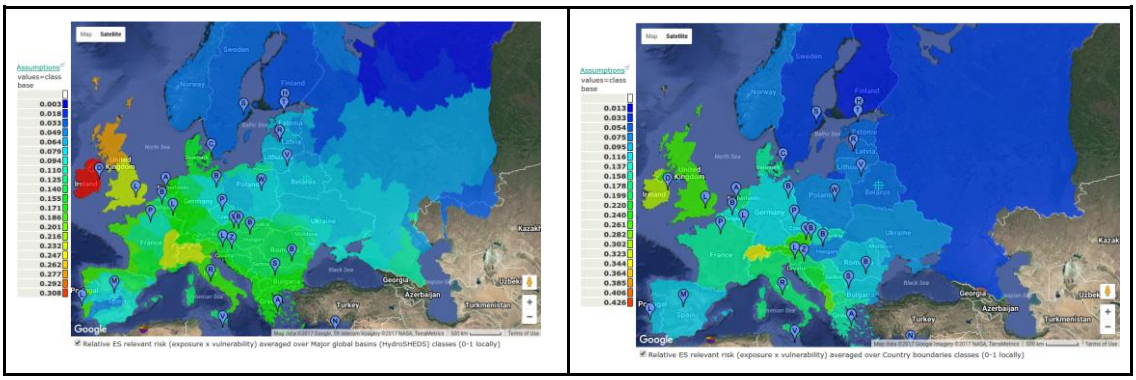


Figure 4: Co$tingNature risk maps for Europe by pixel, major global basin and country

5. Basin analysis with Co$tingNature

5.1 Thames Basin, UK DEMO site

5.1.1 Relative socio-economic exposure to hazard

The relative socio-economic exposure to hazard in the Thames basin (Figure 5) is very heterogeneous throughout the basin. Higher values are found for London and towards the south of London due to the higher hazard potential and multiple asset exposure.

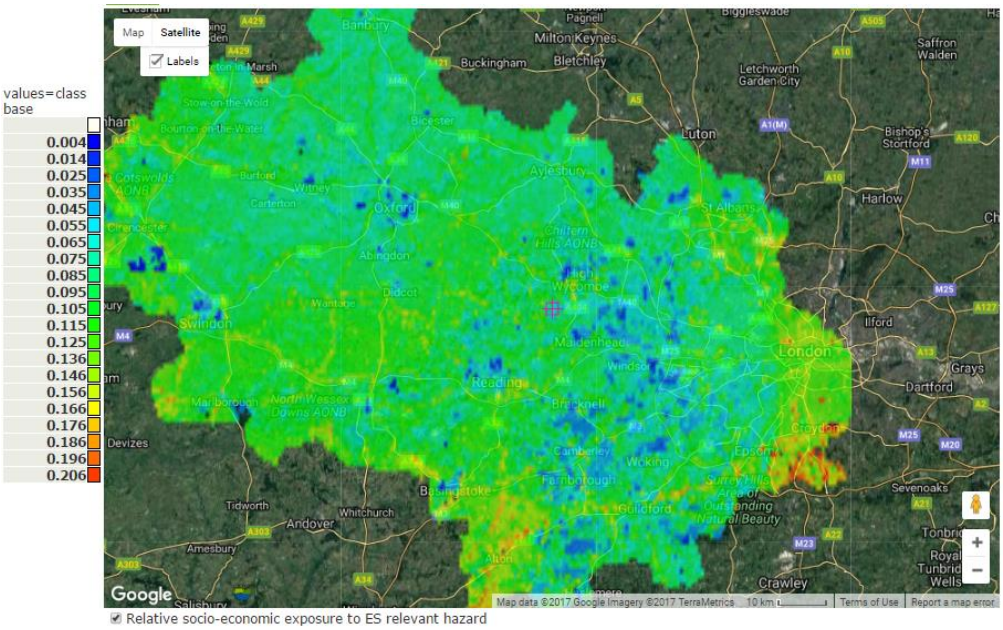


Figure 5: relative socio-economic exposure to hazard in the Thames basin

5.1.2 Assets with greatest exposure to hazard

For most of the Thames basin upstream of the urban extent of London, agriculture is the most exposed asset (Figure 6). GDP is most at risk for London while other cities such as Reading and Oxford are mostly at risk of damage to infrastructure.

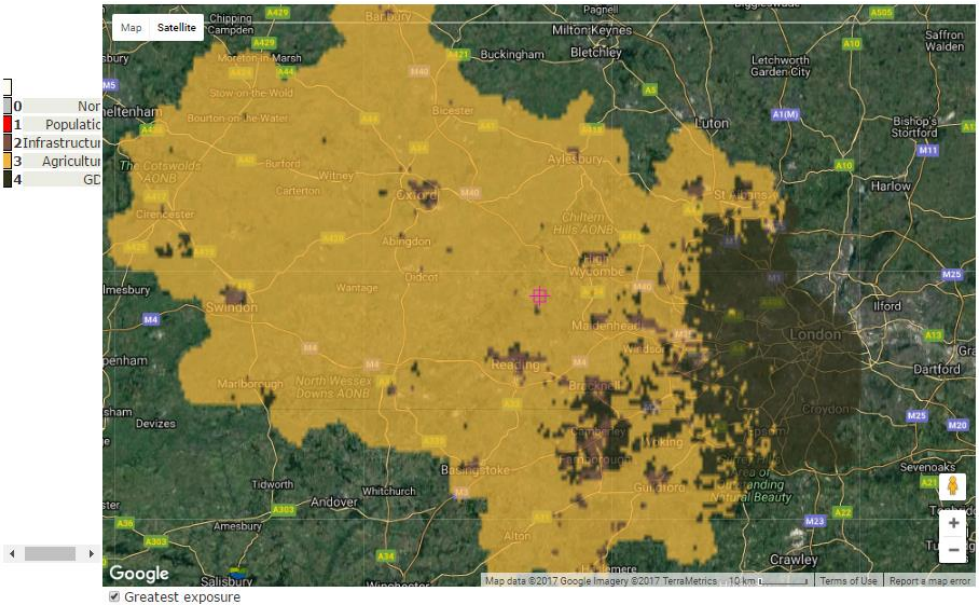


Figure 6: Greatest hazard exposure in the Thames basin

5.2 Lower Danube section (GeoEcoMar), Romania DEMO site

5.2.1 Relative socio-economic exposure to hazard

The relative socio-economic exposure in the Lower Danube basin (Figure 7) is generally low as the population density is relatively low as well as the number of infrastructural assets.

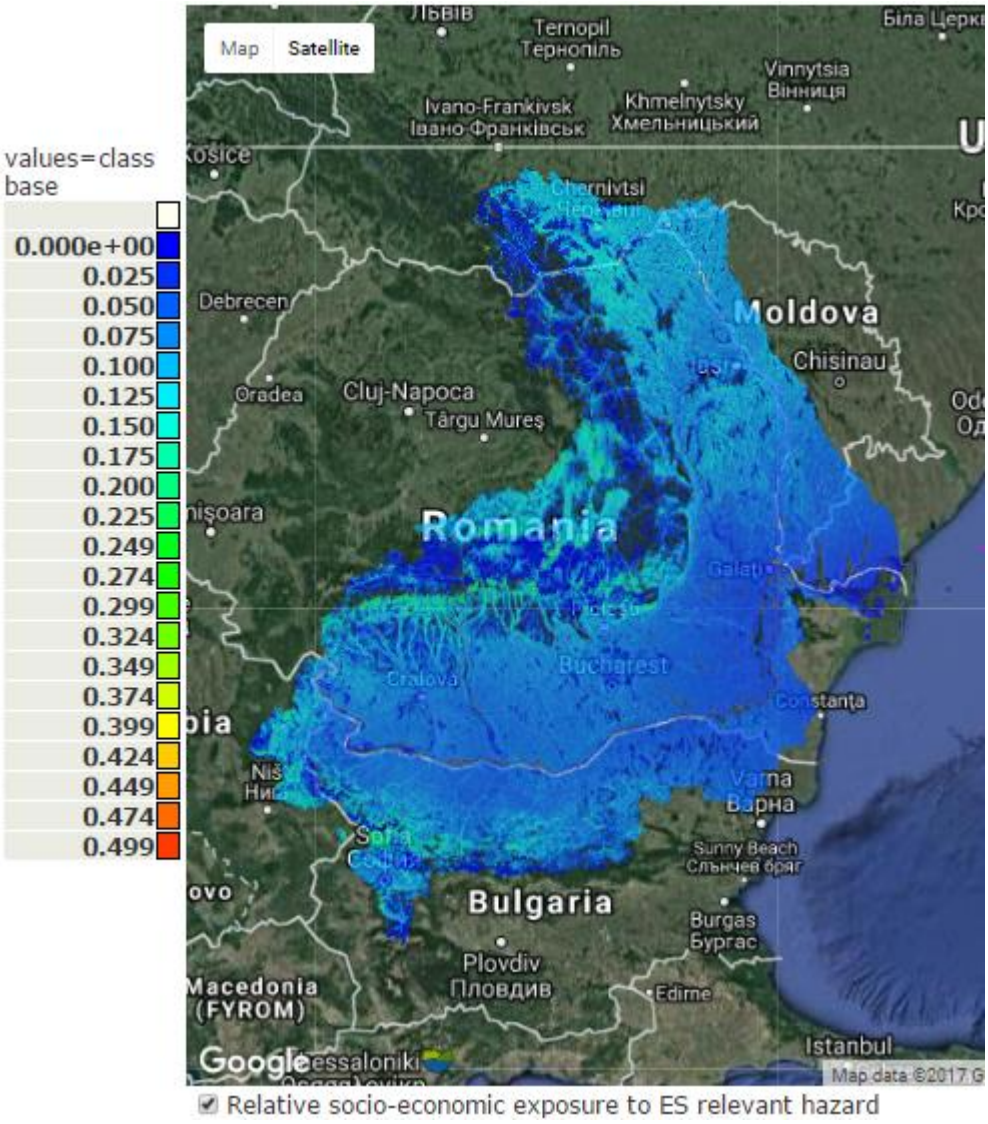


Figure 7: relative socio-economic exposure to hazard in the lower Danube basin

5.2.2 Assets with greatest exposure to hazard

Assets most exposed to natural hazard are agriculture in the lower lying areas in the basin and GDP in the mountains. Towards the delta of the Danube, population is most at risk.

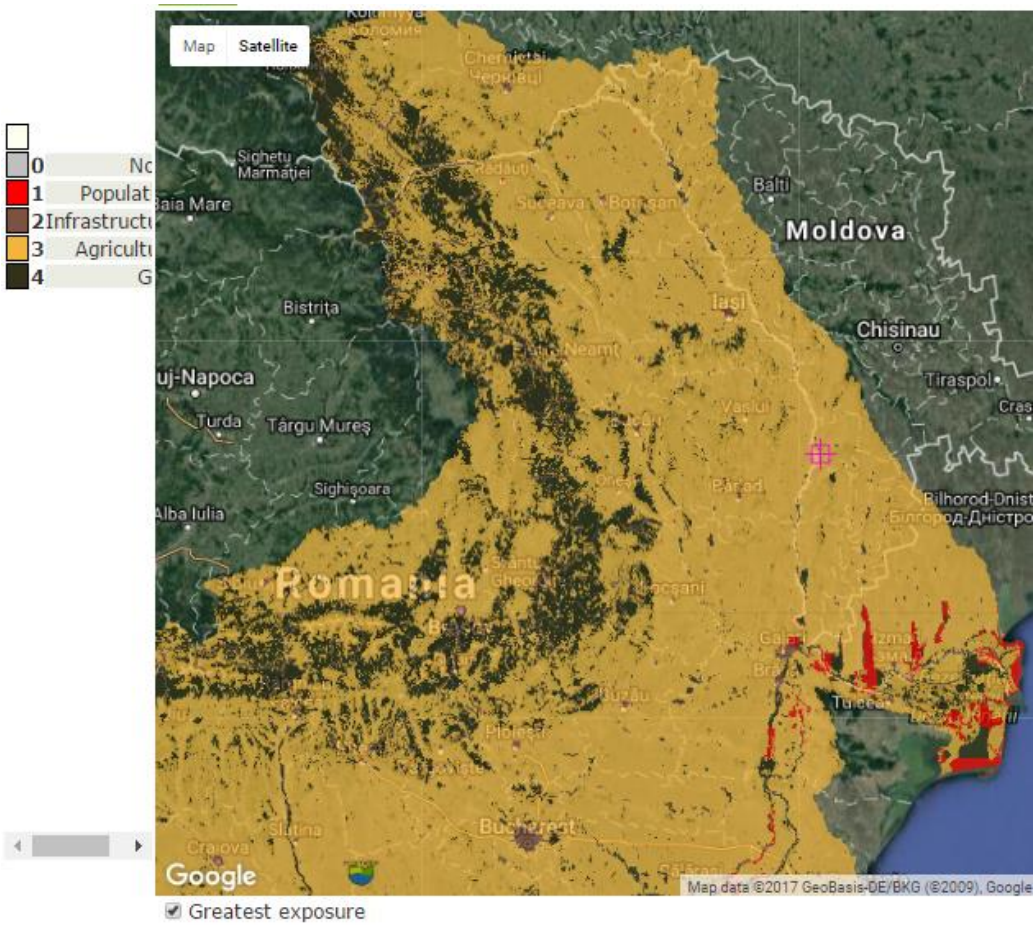


Figure 8: Greatest hazard exposure in the lower Danube basin

5.3 Bragues and surrounding watersheds, France DEMO site

5.3.1 Relative socio-economic exposure to hazard

The relative socio-economic exposure in the French mediterranean demo is highly variable although in general higher values are found towards the north in the mountains.

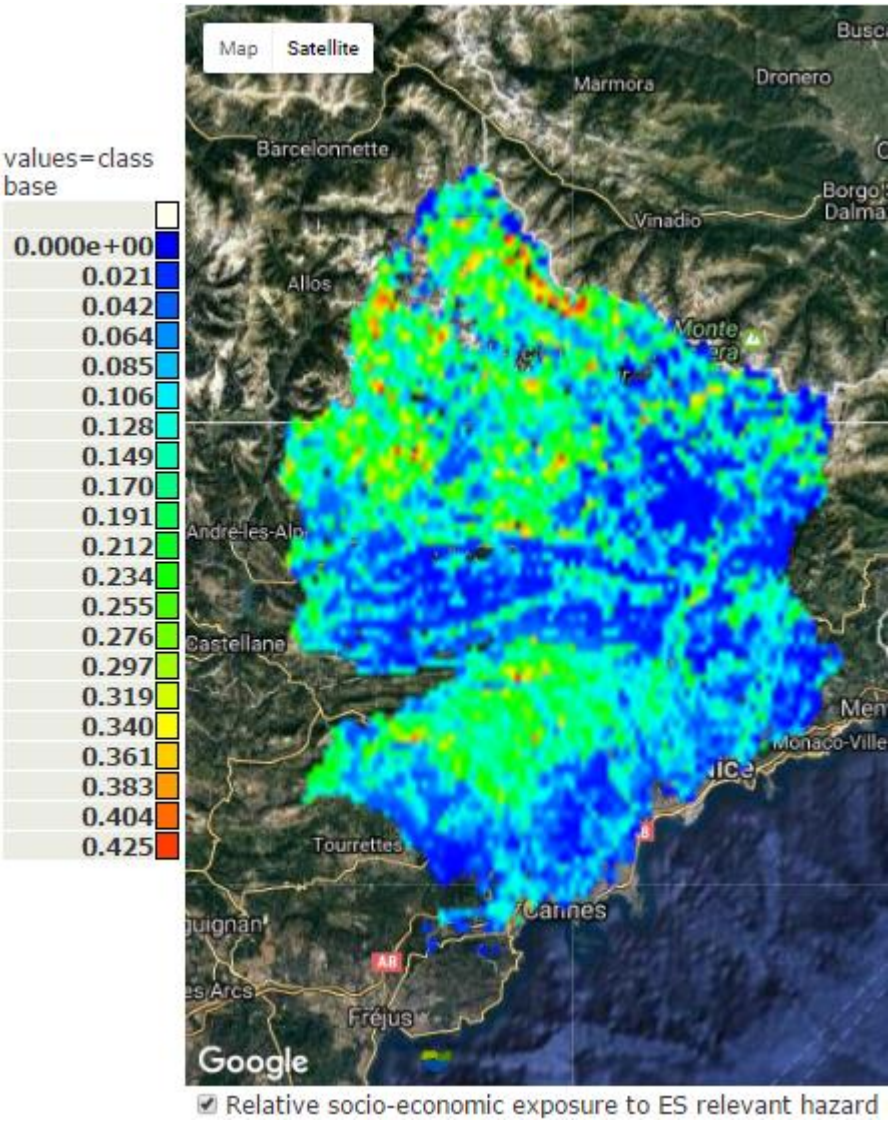


Figure 9: relative socio-economic exposure to hazard in the Brague and surrounding watersheds

5.3.2 Assets with greatest exposure to hazard

The assets most exposed to natural hazards in this demo are agriculture and population along the densely populated coastline as well as infrastructure, particularly around the cities of Nice and Antibes and along some major highways.

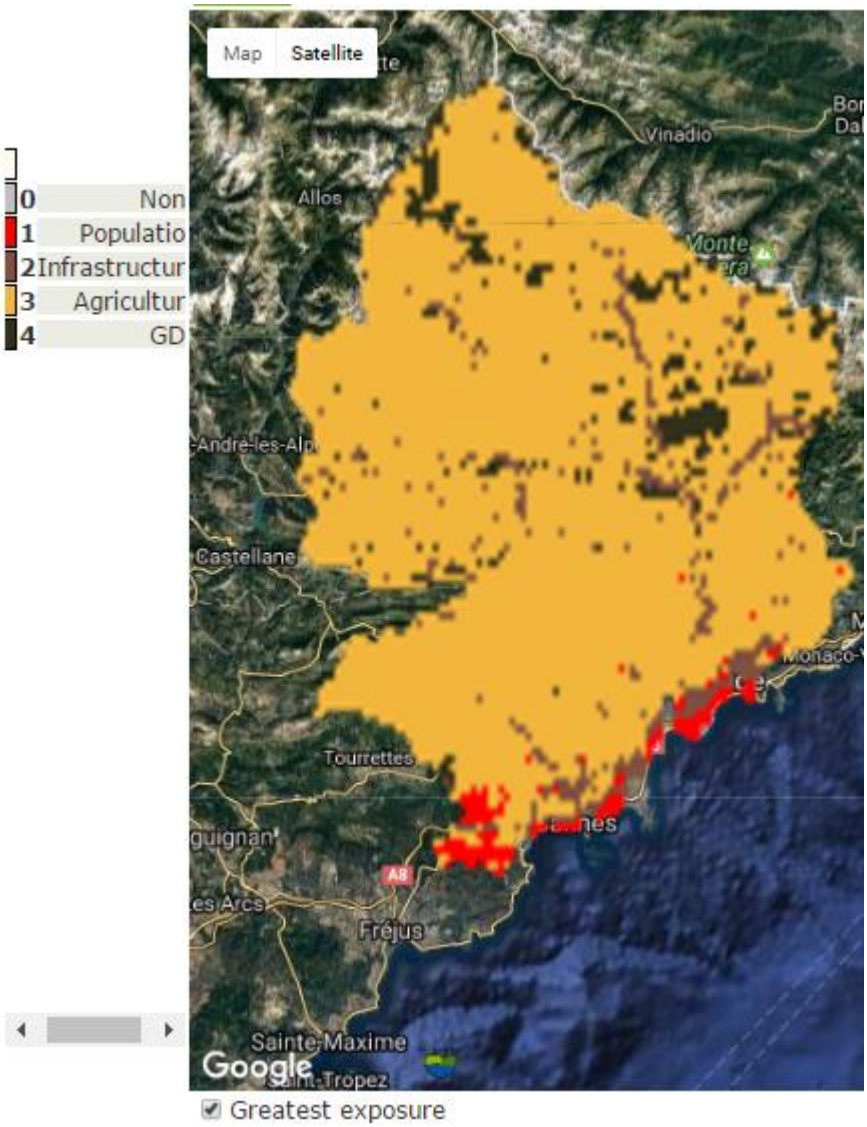


Figure 10: Greatest hazard exposure in the Brague and surrounding watersheds

5.4 Ljubljanica basin-Glinščica catchment, Slovenian DEMO site

5.4.1 Relative socio-economic exposure to hazard

The greatest socio-economic exposure in the Ljubljanica basin is found just upstream from the city of Ljubljana, particularly along the major transport networks.

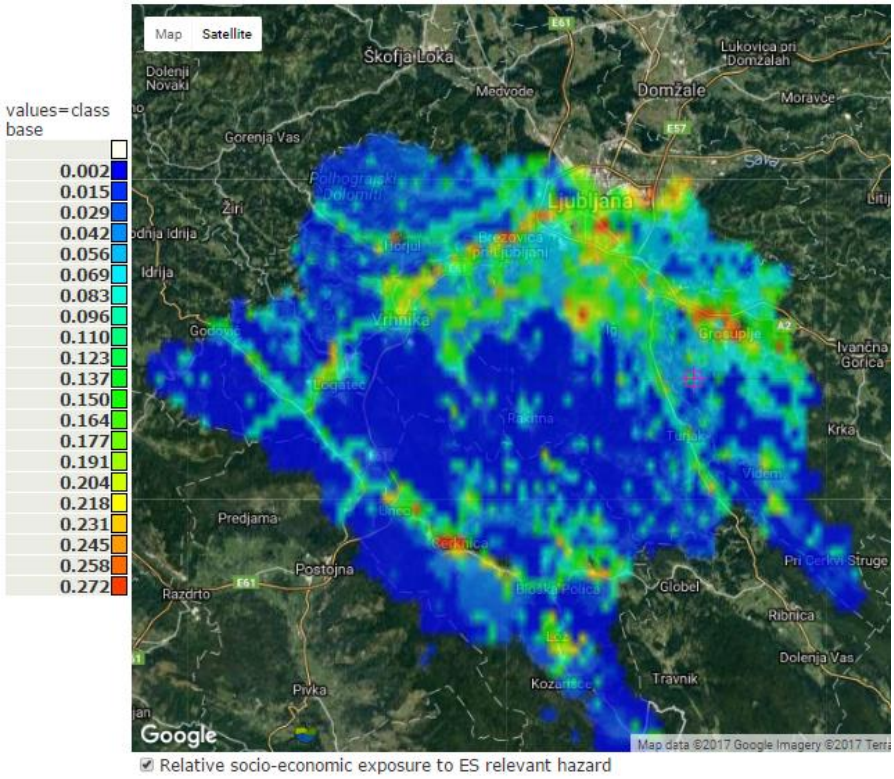


Figure 11: relative socio-economic exposure to hazard in the Ljubljanica basin

5.4.2 Areas with greatest exposure to hazard

Asset exposure to natural hazards in this demo is varied. The assets most exposed are agriculture and GDP but the infrastructure along the major transport routes and around the city of Ljubljana are also at risk, as is the population of the Ljubljana itself.

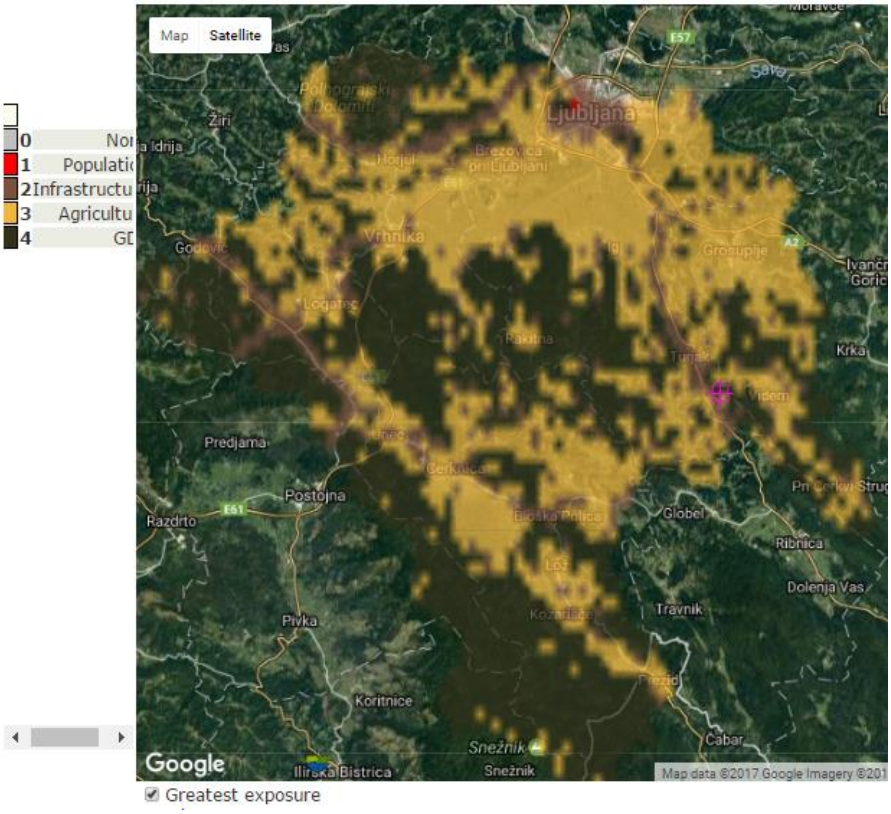


Figure 12: Greatest hazard exposure in the Ljubljanica basin

6. Basin analyses with local data

This section lists for each demo basin any existing or new key studies for hazard exposure and analyses of change over time.

6.1 Thames Basin UK, exposure and recent trends

Table 9: Key publications on hazard exposure and recent trends in the Thames basin

Key asset class exposed	Published studies on exposure	Published studies on exposure change over time
Infrastructure	Schaller, N., Kay, A. L., Lamb, R., Massey, N. R., Van Oldenborgh, G. J., Otto, F. E., ... & Bowery, A. (2016). Human influence on climate in the 2014 southern England winter floods and their impacts. *Nature Climate Change*, *6*(6), 627-634. Environment Agency (2009) Flooding in England: A National Assessment of Flood Risk Dawson, R.J., Thompson, D., Johns, D., Gosling, S., Chapman, L., Darch, G., Watson, G., Powrie, W., Bell, S., Paulson, K., Hughes, P., and Wood, R. (2016) UK Climate Change Risk Assessment Evidence Report: Chapter 4, Infrastructure. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London London Regional Flood Risk Appraisal 2014 The London Strategic Flood Framework 2015: National Landslide Database. Many are ancient landslides which are now stable and happened under very different	Nicholas S Reynard, Alison L Kay, Molly Anderson, Bill Donovan and Caroline Duckworth, 'The evolution of climate change guidance for fluvial flood risk management in England,' Progress in Physical Geography, SAGE Publishing, published 13 April 2017. Doi: 10.1177/0309133317702566 Marsh, T. and Harvey, C.L., 2012. The Thames flood series: a lack of trend in flood magnitude and a decline in maximum levels. *Hydrology Research*, *43*(3), pp.203-214. Bell, V.A., Kay, A.L., Cole, S.J., Jones, R.G., Moore, R.J. and Reynard, N.S., 2012. How might climate change affect river flows across the Thames Basin? An area-wide analysis using the UKCP09 Regional

	climatic conditions to today; these are worth noting for planned development. Also recorded earthquakes. Geohazards in the Thames Lloyds city risk	Climate Model ensemble. *Journal of Hydrology, 442*, pp.89-104.
Agriculture	Thorne, C. (2014). Geographies of UK flooding in 2013/4. *The Geographical Journal*, *180*(4), 297-309. Marsh, T.J.; Hannaford, J.. 2007 *The summer 2007 floods in England and Wales – a hydrological appraisal.* Wallingford, NERC/Centre for Ecology & Hydrology, 30pp. Marsh, T. J. (2004), The January 2003 flood on the Thames. Weather, 59: 59–62. doi: 10.1256/wea.212.03	

6.2 Lower Danube section, Romania; exposure and recent trends

Table 10: Key publications on hazard exposure and recent trends in the Lower Danube basin

Key asset class exposed	Published studies on exposure	Published studies on exposure change over time
Infrastructure and general situation	1. Comitetul Judetean pentru Situatii de Urgenta (County Commettee for Emergency Situations) 2. General situation on natural hazards, budget for recovery and statistical data.	

	Ministerul Dezvoltarii Regionale, Administratiei Publice si Fondurilor Europene; (Ministry of Regional Development, Public administration and European Funds); Public version of situational awareness (short version)	
Flood management and identification of high risk areas	Vasile Crăciunescu."Satellite Based Service for Flood Monitoring in Romania", Simpozionul Internațional "Sisteme Informaționale Geografice" - Ediția a XXII-a, Chișinău, Academia de Științe a Moldovei, 24-25 octombrie 2014.	Gheorghe Stăncălie, Vasile Crăciunescu, Iulia Dana Negula, Ion Nedelcu."Meteo Romania Contribution to the Creation of an Satellite Based Service for Flood Monitoring in Romania", seminarul național "Soluții libere open source pentru prelucrarea și reprezentarea datelor geospațiale", 14-15 noiembrie 2014, Timișoara, Facultatea de Chimie, Biologie, Geografie - Universitatea de Vest din Timișoara.
Damage assessment using new technology	A. Radutu, D.Bratasanu, I.Nedelcu, "Damage assessment of affected areas using satellite imagery during the floods in Romania, June-July, 2010", TIEMS 18th Annual Conference, Bucharest, Romania, 2011, ISBN-978-9-49-029704-6, Published in the conference Proceedings by: The International Emergency Management Society, TIEMS Romanian Chapter, Volume:18, Year: 2011, pp.273-282	

	I. Gavat, D. Faur, M. I. Piso, F. Serban, M. Datcu, "Knowledge Based Image Information Mining System – KIM used for flooding and other risk assessments", PV 2007 International Conference, executed October 9-11, 2007 at DLR, Oberpfaffenhofen/Munich, Germany.	

6.3 Bragues Basin, France, exposure and recent trends

Table 11: Key publications on hazard exposure and recent trends in the Bragues basin and surrounding watersheds. These studies also apply to the Lez demo basin in France

Key asset class exposed	Published studies on exposure	Published studies on exposure change over time
Global view on flood risk in the south of France	Vinet, F. Diagnostic et enjeux de la gestion du risque inondation en France méditerranéenne La Houille Blanche, EDP Sciences, 2004, 76-82 JULIAN, M. (1989). Les risques naturels dans l'intérieur des Alpes-Maritimes: permanences et variations historiques. Recherches Régionales, oct.-déc, (4).	Neppel, L.; Bouvier, C.; Vinet, F. & Desbordes, M. A possible origin for the increase in floods in the Mediterranean region Revue des Sciences de l'Eau/Journal of Water Science, 2003, 16, 475-494

Fatalities during flood	Boissier, L. La mortalité liée aux crus torrentielles dans le sud de la France: un approche de la vulnérabilité humaine face à l'inondation Univ. Paul Valéry - Montpellier 3, Univ. PhD thesis, 2013 Antoine, J.-M.; Desailly, B. & Gazelle, F. Les crues meurtrières, du Roussillon aux Cévennes/Casualty-causing flood: from the Roussillon region to the Cevennes country Annales de géographie, 2001, 597-623	Vinet, F., Boissier, L., & Saint-Martin, C. (2016). Flashflood-related mortality in southern France: first results from a new database. In E3S Web of Conferences (Vol. 7, p. 06001). EDP Sciences.
Building exposure	Saint-Martin, C., Fouchier, C., Javelle, P., Douvinet, J., & Vinet, F. (2016). Assessing the exposure to floods to estimate the risk of flood-related damage in French Mediterranean basins. In E3S Web of Conferences (Vol. 7, p. 04013). EDP Sciences.	

6.4 Glinščica catchment, Slovenian, exposure and recent trends

Table 12: Key publications on hazard exposure and recent trends in the Glinščica catchment

Key asset class exposed	Published studies on exposure	Published studies on exposure change over time
Infrastructure/ urban areas	Mina Dobravc. 2009. Ocena ogroženosti Mestne občine Ljubljana zaradi poplav. Mestna občina Ljubljana, Mestna uprava, Oddelek za zaščito, reševanje in civilno obrambo, str.44.: (Threat Assessment of the Municipality of Ljubljana due to flooding)	
Urban	Vrednotenje poplavnih škod	Ferlan M. 1995. Analiza

areas/Infrastructure/nature	ter analiza preventivnih ukrepov, Končno poročilo; Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo Jamova 2, 1000 Ljubljana: (Evaluation of flood damage and analysis of preventive measures, final report).	vodnih ujm v Sloveniji od 1990 do 1999. Diplomsko delo. UL-FGG, Ljubljana 2002. (Analysis of water disasters in Slovenia from 1990 to 1999).
Buildings	Dostal G. 1995. Merila za ocenjevanje škode na gradbenih objektih na podlagi obstoječih veljavnih metodologij za vrednotenje nepremičnin. Diplomsko delo. Ljubljana. (Criteria for assessment the damage of buildings on the basis of existing methodologies for valuation of real estate).	
Urban areas/Infrastructure/nature	Ušeničnik B. in sod. 1996. Odpravljanje posledic naravnih in drugih nesreč . RS-Ministrstvo za obrambo, Uprava RS za zaš čito in reševanje, Ljubljana. (Eliminating the consequences of natural and other disasters).	
Urban areas/Infrastructure/ agriculture		Tušar P. Zgodovinska analiza poplav v Sloveniji.Dipl. projekt (UN). Ljubljana, Univ. v Ljubljani, Biotehniška fakulteta, Oddelek za agronomijo, 2012. (Historical analysis of floods in Slovenia)

6.5 Łódź demo area, Poland, exposure and recent trends

Table 13: Key publications on hazard exposure and recent trends in the greater Łódź catchment.

Key asset class exposed	Sources for exposure data	Characteristics of exposure data (timescale, extent, spatial resolution)
City built environment	The Municipal Department and City Treasure Department of the City of Lódź	Flooding occurrence data Spatial resolution: 10 m
City greens	The Lodz Geodetic Branch	Maps, multispectral ortophotomaps (2-20m)
Economic loss – city scale	The Municipal Department and City Treasure Department of the City of Łódź	Data for properties / districts,
Population	City statistics	Long-term changes, age structure, distribution, average income distribution data
Agriculture	The Marshall Office, The Regional Water Management Authority Warsaw	GIS: land use, statistical data, probability of flood occurrence,
Road infrastructure	Regional Department of Roads and Transportation	Flooding occurrence data, costs of infrastructure disruption

7. Conclusions and next steps (KCL)

This study has highlighted areas at risk of natural hazards at the European scale and in detail for four demo basin case study areas (Thames basin in the UK, the Lower Danube basin in Romania, Bragues basin and surrounding watersheds on the French Mediterranean coast and the Ljubljanica basin in Slovenia) using the Co$tingNature methods as a starting point.

At the European scale, the relative socio-economic exposure to hazard is high in populated, agriculturalised and infrastructure-rich areas, particularly in Western and Southern Europe, and along coasts. Assets that are most at risk tend to be GDP in major cities and agriculture in areas where GDP and population are low.

For the four demo basins analysed in more detail, the socio-economic exposure tends to be spatially variable while the key hazard exposed over large areas (in most cases) is agriculture with the exception of densely populated places such as London (high GDP) in the Thames and the South Mediterranean coast (population and infrastructure).

Analysis of available data that can potentially be used to improve datasets in the Co$ting Nature PSS or the Eco: Actuary system under development revealed a relatively large range of available spatial datasets for the Thames basin, the French Mediterranean demo basins and the Glinščica – Ljubljanica basin but less (accessible) data available for the Lower Danube demo basin. High resolution (modelled) data for the city demos of Copenhagen and Rotterdam was also identified although only it was concluded that the Rotterdam demo is not suitable for modelling with the Eco:actuary tool, while in the case of Copenhagen, modelling will be carried out for the larger hazardshed around the city.

As a next step the data identified for each demo basin area will be reviewed for its usefulness and applicability within the Eco:Actuary system relative to the existing and new global datasets that are already used by the EcoEngine platform. The next deliverable focuses on European insurance-relevant natural capital and co-benefits and will examine the distribution of natural capital and co-benefits and will review datasets for in-demo characterisation of these in greater detail than is possible from the global datasets. Following that deliverable we will be in a position to finalise the design for Eco:Actuary applications in demo basins and to move forward in building the system.

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Appendix 1 Hazard Mitigation Services Methodology of Co$tingNature

Ecosystems have a role to play in the mitigation of natural hazards. In Costing Nature we first calculate the environmental potential for hazards as an index varying from 0 to

1. We then calculate human socio-economic exposure to this hazard potential and combine this with a measure of vulnerability to hazard in order to calculate risk where risk is the product of exposure to hazard and vulnerability. Potential hazard mitigation services provided by nature for coastal inundation, floods, regulation services (e.g. drought) and landslides/soil erosion. These are then combined with risk to calculate realised hazard mitigation services as the minimum of the risk and potential hazard mitigation services indices.

We calculate an index of potential hazards taking into account cyclones, coastal inundation, landslides and soil erosion, floods and droughts. The potential cyclone hazard is calculated as the relative cyclone hazard frequency of Dilley et al. (2005). Potential flood hazard is calculated as proportional to the available water in each pixel (downstream cumulated rainfall minus actual evapotranspiration). Coastal inundation hazard is considered to be inversely proportional to elevation in the range 0-30 masl and in coastal areas (that is to say within 2000m of the coast). The coastal inundation hazard index (0-1) is comprised of sea level rise hazard (assumed to be uniform globally but clearly relating with terrain elevation, global relative Tsunami hazard (mapped by Mulligan, 2011 based on NGDC data) and global relative cyclone frequency as above. Potential hazards from landslides are assumed to scale with relative global mean upstream slope gradient. Hazard potential is then the mean of the cyclone hazard index, coastal inundation hazard index, landslide hazard index and flood hazard index.

Exposure to hazards is considered to scale with the relative human population, relative infrastructure, relative agriculture and relative GDP indices. Hazard exposure is then the product of hazard potential and hazard exposure. Vulnerability is assumed to scale inversely with combined GDP and infrastructure such that high GDP and infrastructure leads to lower vulnerability (even though they may also contribute to higher exposure). Risk is then the product of exposure and vulnerability.

Ecosystems provide a range of potential hazard mitigation services. These can derive from ecosystem processes in situ or elsewhere (e.g. upstream). The hazard mitigation services currently considered are landslide/erosion control, coastal protection, flood storage/mitigation, flow regulation). Landslide/erosion control is considered to be provided by the presence of vegetation, especially trees. Therefore, the erosion control service is assumed to scale with the proportion of upstream land that is tree-covered. This tree cover index is also assumed to control the flow regulation service at a point. Flood control is assumed to be provided by water bodies, wetlands and floodplains, all of which provide storage capacity for flood waters. Thus, the flood protection services

provided to a particular point are assumed to scale with the upstream cover of water bodies, wetlands and floodplains. Coastal protection is assumed to be provided is coastal (within 2000m of the coast and from 0-30m above mean sea level) by mangroves and by wetlands in those areas. Total potential hazard mitigation services is thus the sum of coastal protection, flood protection, flow regulation and soil erosion/landslide control services. Of course, not all potential hazard mitigation services are realised since in many places the potential hazard or the actual risk are low. This the realised hazard mitigation services are calculates as the minimum of the potential hazard mitigation services and the actual risk.

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An analysis of exposure to natural hazards in Europe towards an Eco:actuary system

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