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EXECUTIVE SUMMARY

A spatial analysis using the Policy Support System Co$ting Nature shows that greatest hazard potential for most of Europe and for major cities is hydrological flood, followed by landslides. The results show a clear distinction between flood risk dominating in northern Europe and landslide in mountainous southern Europe.

The report includes an analysis of available data that can potentially be used to improve the global datasets already provided by the Co$ting Nature PSS, or the Eco:Actuary system that is to be developed. A wide range of spatial datasets are described for the Thames and the French Mediterranean demo basins but there are less (accessible) data available for the Lower Danube demo basin. This highlights the importance of data availability at the European or Global scale for improvement and use in the Eco:actuary system in order to be able to consistently map hazard potential and risk for all areas.

1. Introduction and aim

NAIAD has used Earth Observation (EO) data to map hazard potential for flood, inundation, drought, soil erosion and landslides at the European scale for cities and their hazard-sheds (areas contributing to hydrological hazards), and in more detail for tree demo basins case study areas: Thames basin in the UK, Brague basin and surrounding watersheds on the French Mediterranean coast and the Lower Danube basin in Romania.

Relative hazard potential and greatest hazard potential at the European scale and for the demo basins was mapped using the Co$ting Nature Policy Support System which will be the basis for the Eco: actuary system that is to be developed in the NAIAD project. For each demo basin, a separate analysis was done on identifying the key potential hazards and characteristics and (spatial) data availability that can potentially be used in the Eco: actuary system. Furthermore, an investigation of relevant hazards and recent trends for specific hazards in specific basins was carried out through an extensive literature review.

2. Methods: Co$ting Nature modelling

Ecosystems have a role to play in the mitigation of natural hazards. In Co$ting Nature we first calculate the environmental potential for hazards as an index varying from 0 to 1 globally. We then calculate human socio-economic exposure to this hazard and combine this with a measure of vulnerability to hazard in order to calculate risk where risk is the product of hazard exposure 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, 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. Thus the realised hazard mitigation services are calculated as the minimum of the potential hazard mitigation services and the actual risk as described in figures 1-3 below.

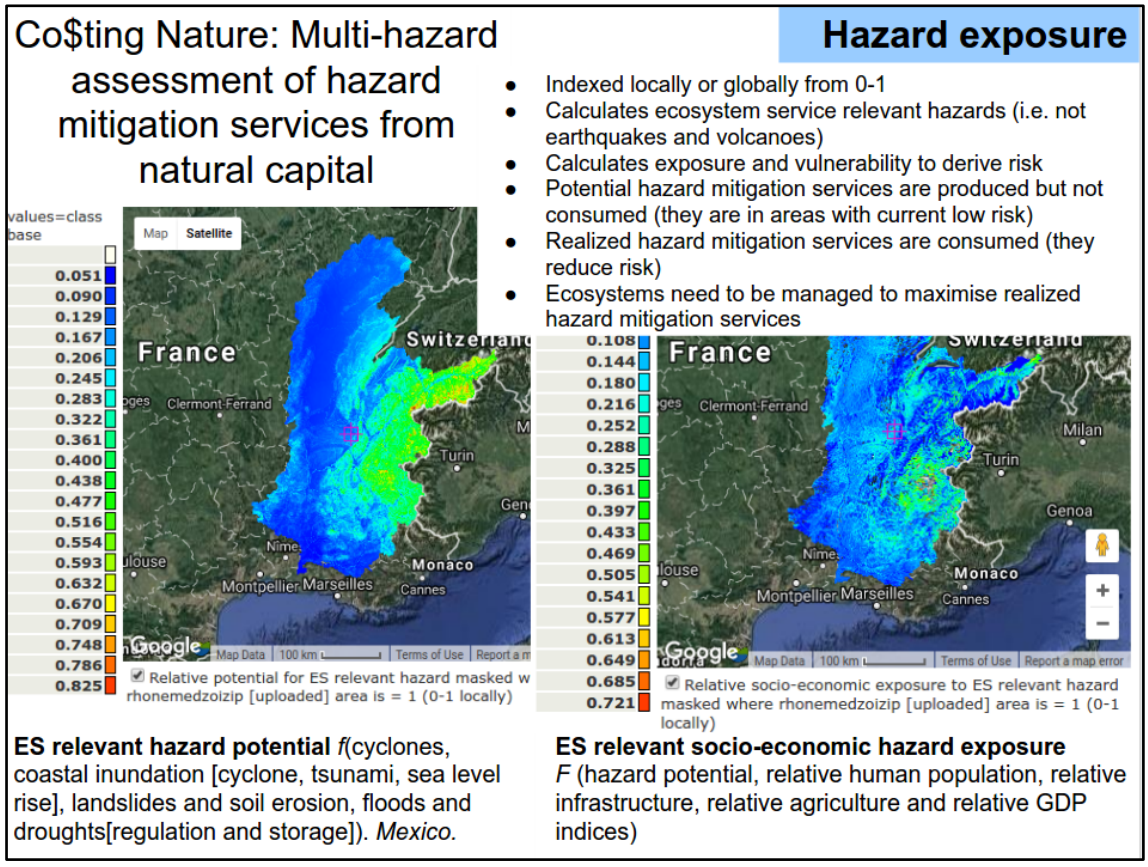

Figure 1. Hazard exposure as defined in Co$ting Nature.

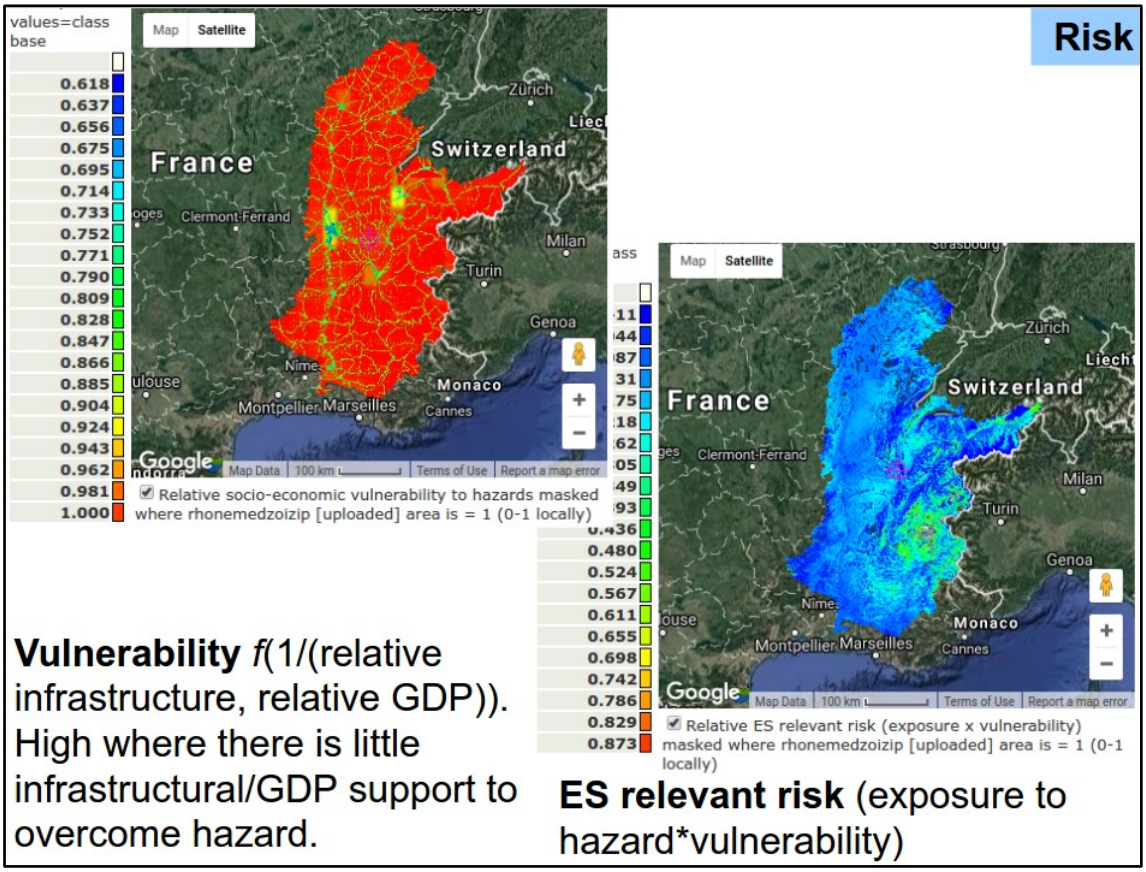

Figure 2. Risk as defined in Co$ting Nature.

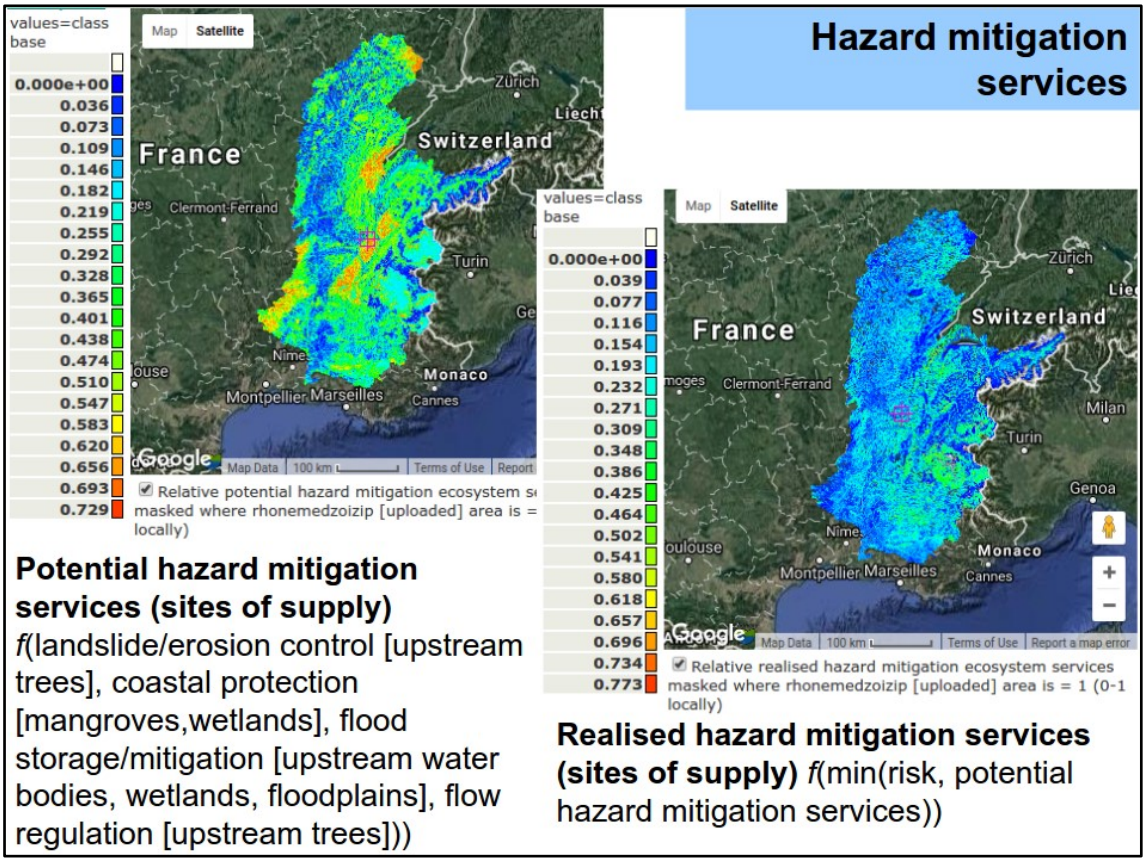

Figure 3. Hazard mitigation services as defined in Co$ting Nature.

3. Methods: demo basin datasets

This section provides an analysis of data available on potential hazards and its characteristics for each demo basin which can potentially be used for improvement of data used in the Co$ting Nature Policy Support tool and the Eco: actuary tool to be developed. An overview of the datasets currently used in Co$ting Nature to calculate hazard mitigation provided by nature is provided in table 2. We hope that some of these can be improved on from the global datasets by access to demo basin data.

Table 1. Datasets used in Co$tingNature Policy Support System.

Name	Unit
Total annual precipitation	mm/year
Carbon stock	tonnes C/km^2

Dams	Unique id
FAO irrigation percentage	%
Population (2007, Landscan)	persons/km cell
Urban Areas	Unique ID
Croplands (2005)	%
Pastures (2005)	%
Protected areas (UNEP-WCMC WCPA) 2016	unique ID
Presence of mines	unique id
Presence of oil and gas wells	unique id
Water balance (WorldClim rainfall - CPWF AET)	mm/yr
Rainfall accumlated down flow lines (Hydro1k)	Mm^3/yr
Accessibility	seconds to nearest town of 50K popn
Frequency of fire burn events	% of observations
Wetlands including lakes, rivers and reservoirs	unique ID
Mangroves (1997, UNEP-WCMC/ISME)	unique id
Relative cyclone hazard frequency index (CHRR)	0-10
Number of observed tsunami since 2000BC(NGDC)	frequency
Number of dams upstream (GOOD)	scalar
Area of water bodies upstream	Km^2
Mean slope upstream (>10 deg)	degrees
Area of wetlands upstream	Km^2
Number of dams downstream	number
Upstream relative cyclone hazard frequency index (CHRR)	number
Upstream land area	Km^2
Downstream land area	Km^2
Upstream irrigated area	Km^2
Downstream irrigated area	Km^2
Upstream cropland	Km^2
Downstream cropland	Km^2
Upstream population	sum p/ Km^2
Downstream population	sum p/ Km^2
Upstream population considered poor (<$2 per day)	persons
Downstream population considered poor (<$2 per day)	persons
Water bodies (SWBD lakes)	Unique ID
Coastline (SWBD)	Unique ID

Protected areas upstream (WDPA)	Km^2
Protected areas downstream (WDPA)	Km^2
Total tree cover upstream	%
Total tree cover downstream	%
Floodplain area upstream	%
Floodplain area downstream	%
Protected floodplain area upstream	%
Protected floodplain area downstream	%
Soil carbon	t/km2
Oil and gas concessions	Unique ID
Planned transportation routes	Unique ID
Mining concessions	Unique ID
Rural populated places	Unique ID
Cropland 2005 [IIASA-IFPRI]	percentage
Roads (2010, groads)	Nominal (class)

Thames

The key potential hazard in the Thames basin is fluvial flooding and a wide range of spatial data exist which are freely available (Table 3). The most relevant data is available from government organisations such as the Environment Agency. These data in most cases are available for the whole of the UK.

Table 2. Data on the Thames demo, UK.

Key potential hazard	Sources for hazard data.	Characteristics of hazard data (timescale, extent, spatial resolution)
Fluvial Flooding	Environment Agency: http://environment.data.gov.uk/ds/catalogue/index.jsp#/catalogue	Various GIS data for the whole of the UK, mostly shapefiles
Fluvial Flooding	National River Flow Archive: https://nrfa.ceh.ac.uk/	Various GIS data for the whole of the UK, point data
Fluvial Flooding	Centre for Ecology and Hydrology: https://catalogue.ceh.ac.uk/eidc/documents	Various GIS data for the whole of the UK, point data as shapefiles and CSV

Brague and surrounding watersheds

The French Mediterranean coast demo region is subject to a number of potential hazards (Table 4) including flooding, landslides, wildfires and avalanches. There is generally good (spatial) data availability for this region.

Table 3. Data on the Brague and surrounding watersheds demo.

Key potential hazard	Sources for hazard data.	Characteristics of hazard data (timescale, extent, spatial resolution)
Multi hazards	Alpes-Maritime Préfécture http://www.alpes-maritimes.gouv.fr/Politiques-publiques/Environnement-risques-naturels-et-technologiques/Les-risques-naturels-et-technologiques/Dossier-departemental-des-risques-majeurs/Dossier-des-risques-majeurs	Communication document for citizens on flood, landslide, wildfire, avalanche and storm risks (edited: 2013, scale: Alpes-Maritime department; spatial resolution: municipalities)
Fluvial and Torrential flooding	DIREN PACA http://carmen.developpement-durable.gouv.fr/25/environnement.map&group=Atlas%20des%20zones%20inondables http://www.paca.developpement-durable.gouv.fr/IMG/pdf/plaquetteAZI_cle7c3ebf.pdf	GIS and presentation note on a general flood plan mapping from a geomorphological method (Atlas des zones inondables (AZI)) (edited 2006, scale: Alpes-Maritime department; spatial resolution: relatively detailed – 1/25,000)
Torrential flooding	DREAL de bassin Rhône-Méditerranée http://www.rhone-mediterranee.eaufrance.fr/gestion/inondations/cartes/nice.php	DREAL PACA (2013): GIS of consistent flood study (frequent, mean and extreme magnitude, i.e. return period 10-30; 100-300 and ~1000 years) of the coastal urban belt of most vulnerable areas (Territoires à Risques Important d'inondation (TRI) (scale: key municipalities of the Alpes-Maritime department (90 000 peoples for the extreme event); spatial resolution: relatively detailed – 1/25,000)
Fluvial and Torrential flooding	DDTM Alpes-Maritimes https://www.data.gouv.fr/en/datasets/ddtm-06-plans-de-prevention-des-risques-naturels-dinondation-zonage/	GIS risk mapping on selected municipalities (edited: last version 2017 but globally older documents, scale: selected municipalities of the Alpes-Maritime department; spatial resolution: detailed – 1/5,000)
Landslides	DDTM Alpes-Maritimes https://www.data.gouv.fr/en/datasets/ddtm-06-plans-de-prevention-des-risques-	idem

	naturels-de-mouvements-de-terrain-zonage/	
Wildfires	DDTM Alpes-Maritimes https://www.data.gouv.fr/en/datasets/ddtm-06-plans-de-prevention-des-risques-naturels-dincendies-de-forets-zonage/	Idem
Avalanches	DDTM Alpes-Maritimes https://www.data.gouv.fr/en/datasets/ddtm-06-plans-de-prevention-des-risques-naturels-davalanches-zonage/	idem
Fluvial and Torrential flooding	MEED – national Platform on flood marks https://www.reperesdecrues.developpement-durable.gouv.fr/	GIS point data on flood marks (edited: ~500 data points form the last event of 2015, scale: French territory; spatial resolution: GPS coordinate)
Torrential flooding	DDTM Alpes-Maritimes http://www.riviere-brague.fr/media/flash/carte_ppri/ppri_antibes.pdf http://www.biot.fr/wp-content/uploads/2016/09/ppri_rapportdepresentation.pdf	PPRi de Antibes (1998) and PPRi de Biot (1998): Reports of the flood risk mapping in the Brague catchment (scale: Biot and Antibes municipalities; spatial resolution: Detailed)
Torrential flooding	Préfécture des Alpes-Maritimes http://observatoire-regional-risques-paca.fr/evenement/rex-inondation-des-3-et-4-octobre-2015-alpes-maritimes	Préfécture des Alpes-Maritimes (2016): Specific report on the October 3rd and 4th, 2015 flood disaster: 550-600 M€ of damage 22 fatalities (edited: 2015, scale: coastal belt of the Alpes Maritimes department; spatial resolution: Detailed)

Lower Danube

Key potential hazards identified in the Lower Danube demo region are fluvial flooding, desertification and water pollution (Table 5). The analysis has identified a number of relevant datasets although some of the datasets may not be as easily accessible as digital spatial data.

Table 4. Data on the Lower Danube demo.

Key potential hazard	Sources for hazard data.	Characteristics of hazard data (timescale, extent, spatial resolution)
Fluvial Flooding	Lower Danube River Administration http://www.afdj.ro/en/content/danube-water-level	Different types of data
Fluvial Flooding	http://www.danube-floodrisk.eu/	Danube Atlas Hazard and Risk Maps

Problems for navigation	Lower Danube River Administration http://www.afdj.ro/en/content/bottlenecks	Different types of data
Fluvial Flooding	INHGA https://goo.gl/8AAFKt	Daily water levels
Desertification	http://eprints.whiterose.ac.uk/80375/7/Romania%20paper%20combined_LDD%20revised%20LS_CLEAN%20R5.docx	Different types of data
Desertification	https://jehse.biomedcentral.com/articles/10.1186/2052-336X-11-5	Different types of data
Fluvial Flooding	ICPDR http://www.icpdr.org/main/publications/maps-danube-flood-risk-management-plan-2015	Danube Risk Management Plan 2015
Water pollution	https://www.icpdr.org/main/issues/water-pollution	

Glinščica catchment

The key potential hazard in the Glinščica catchment in Slovenia is torrential flooding. A wide range of spatial data exist which are freely available (Table 6). The most relevant data is available from governmental organisations like different ministries and their institutes. These data in most cases are available for the whole of Slovenia. All data can be extracted to the Glinščica demo site area.

Table 5. Data on the Glinščica catchment.

Key potential hazard	Sources for hazard data.	Characteristics of hazard data (timescale, extent, spatial resolution)
Torrential Flooding	Slovenian Environment Agency: http://gis.arso.gov.si/geoportal/catalog/main/home.page	Various, Slovenian wide, shapefiles (past flood maps, flood risk maps for different return periods, precipitations maps for different return periods, snowfall, underground water maps, LIDAR, etc.)
Water pollution	Slovenian Environment Agency: http://gis.arso.gov.si/geoportal/catalog/main/home.page	Various, Slovenia wide, shape files

Torrential Flooding	Slovenian Environment Agency: http://www.arso.gov.si/vode/	Slovenia wide, water levels, excel data (daily, monthly, yearly basis)
Torrential Flooding	Slovenian Environment Agency: http://www.arso.gov.si/vode/	Slovenia wide, precipitations, excel data (daily, monthly, yearly basis)
Erosion	Slovenian Environment Agency: http://gis.arso.gov.si/geoportal/catalog/main/home.page	Slovenian wide, shapefiles (erosion warning map)
Torrential Flooding	Ministry of Environment and Spatial planning: http://www.e-prostor.gov.si/si/	Slovenian wide, shapefiles,(Lakes, rivers and reservoirs)

Lez watershed

The French Mediterranean coastal demo region is subject to fluvial flooding hazards (Table 7). There is generally good (spatial) data availability for this region.

Table 6. Data on the Lez watershed demo.

Key potential hazard	Sources for hazard data.	Characteristics of hazard data (timescale, extent, spatial resolution)
Fluvial flooding	DREAL Languedoc-Roussillon https://www.google.fr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0ahUKEwjKr8WqofzTAhXF2xoKHYXcAwkQFggvMAI&url=http%3A%2F%2Fwww.occitanie.developpement-durable.gouv.fr%2FIMG%2Fpdf%2Fpresentation_ADZI34_cle02bc37.pdf&usg=AFQjCNFjzwlkhuCoCLRU0Oj8ZWWBPd7YFQ&cad=rja	GIS and presentation note on a general flood plan mapping from a geomorphological method (Atlas des zones inondables (AZI) (edited 2006, scale: Occitanie region; spatial resolution: relatively detailed – 1/25,000)
Fluvial flooding	SYBLE www.gesteau.fr/sites/default/files/syble-atlas.pd	Atlas of maps of Lez-Mosson watersheds

Fluvial flooding	MEED – national Platform on flood marks https://www.reperesdecrues.developpement-durable.gouv.fr/	GIS point data on flood marks (edited: ~500 data points form the last event of 2015, scale: French territory; spatial resolution: GPS coordinate)
Flooding	DREAL http://www.rhone-mediterranee.eaufrance.fr/gestion/inondations/cartes/montpellier.php#docs http://carmen.developpement-durable.gouv.fr/115/TRI_MONTPELLIER.map	TRI : territoire à risque important d'inondation GIS of consistent flood study (frequent, mean and extreme magnitude, i.e. return period 10-30; 100-300 and ~1000 years) of the coastal urban belt of most vulnerable areas (Territoires à Risques Important d'inondation (TRI) (scale: key municipalities of the Alpes-Maritime department (90 000 peoples for the extreme event); spatial resolution: relatively detailed – 1/25,000)
Fluvial flooding	DDE Hérault http://www.montpellier.fr/2310-v-7-plan-de-prevention-des-risques-d-inondation.htm	PPRi de Montpellier (2004) Reports on the flood risk mapping in Montpellier city (scale: Montpellier municipalities; spatial resolution: Detailed)

4. European analysis with Co$ting Nature

The Co$ting Nature hazard potential maps for Europe are shown in Figure 4 and indicate high values around coasts, low-lying areas and in mountainous areas as well as along major rivers. By basin, those in Ireland, Scotland and the Alps show particularly high values. By country Switzerland has the highest hazard potential, followed by some other North-western and South-western European countries.

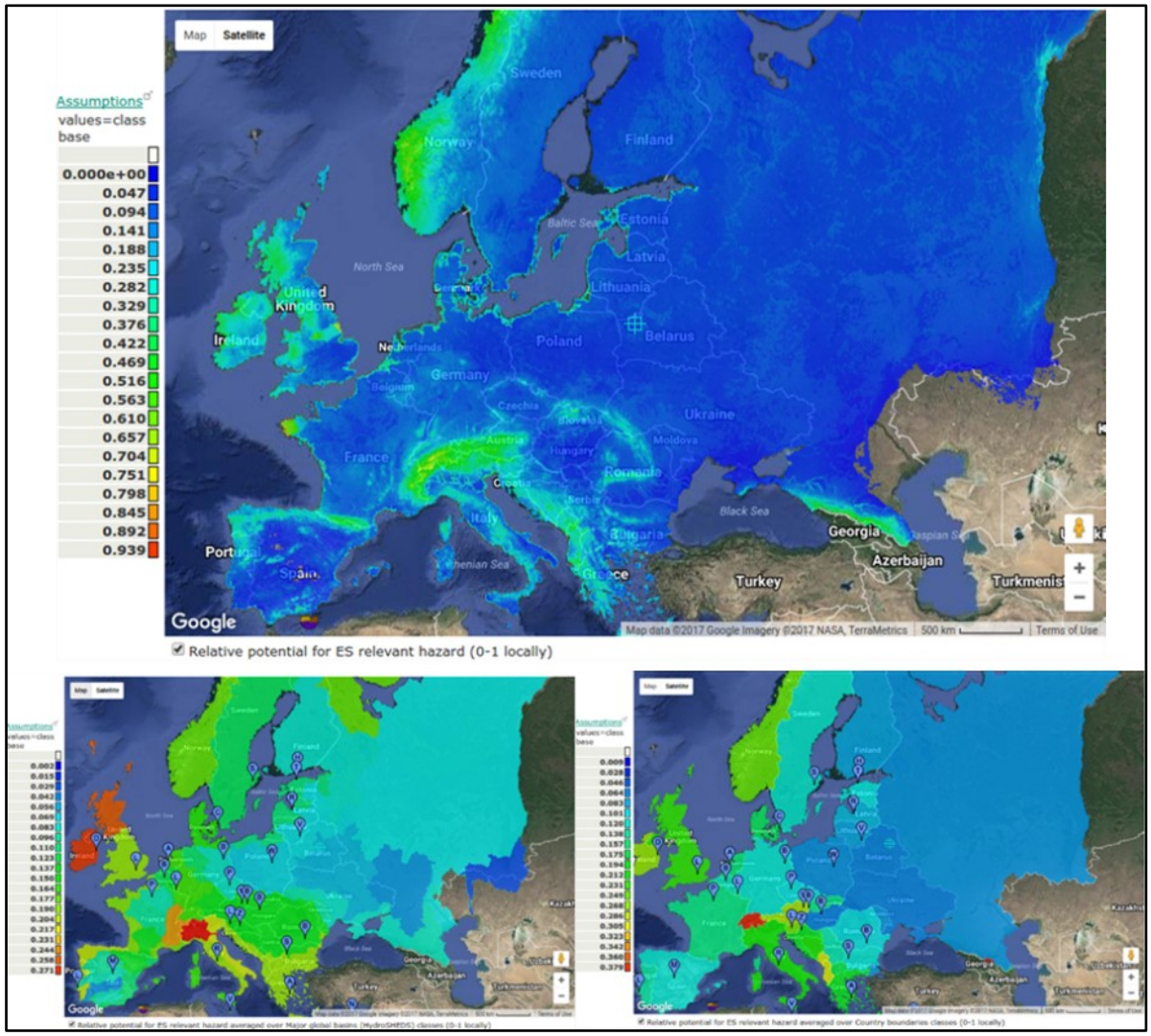

Figure 4. Relative potential for ecosystem service relevant hazard for Europe by pixel, major global basin and country.

Greatest hazard potential

The per-pixel greatest hazard potential for most of Europe is hydrological flood, followed by landslide with some coastal areas subject to inundation and a few small patches having been subject to cyclonic hazards. Averaged by basin and by country there is a clear distinction between flood risk dominating in northern Europe and landslide in mountainous southern Europe

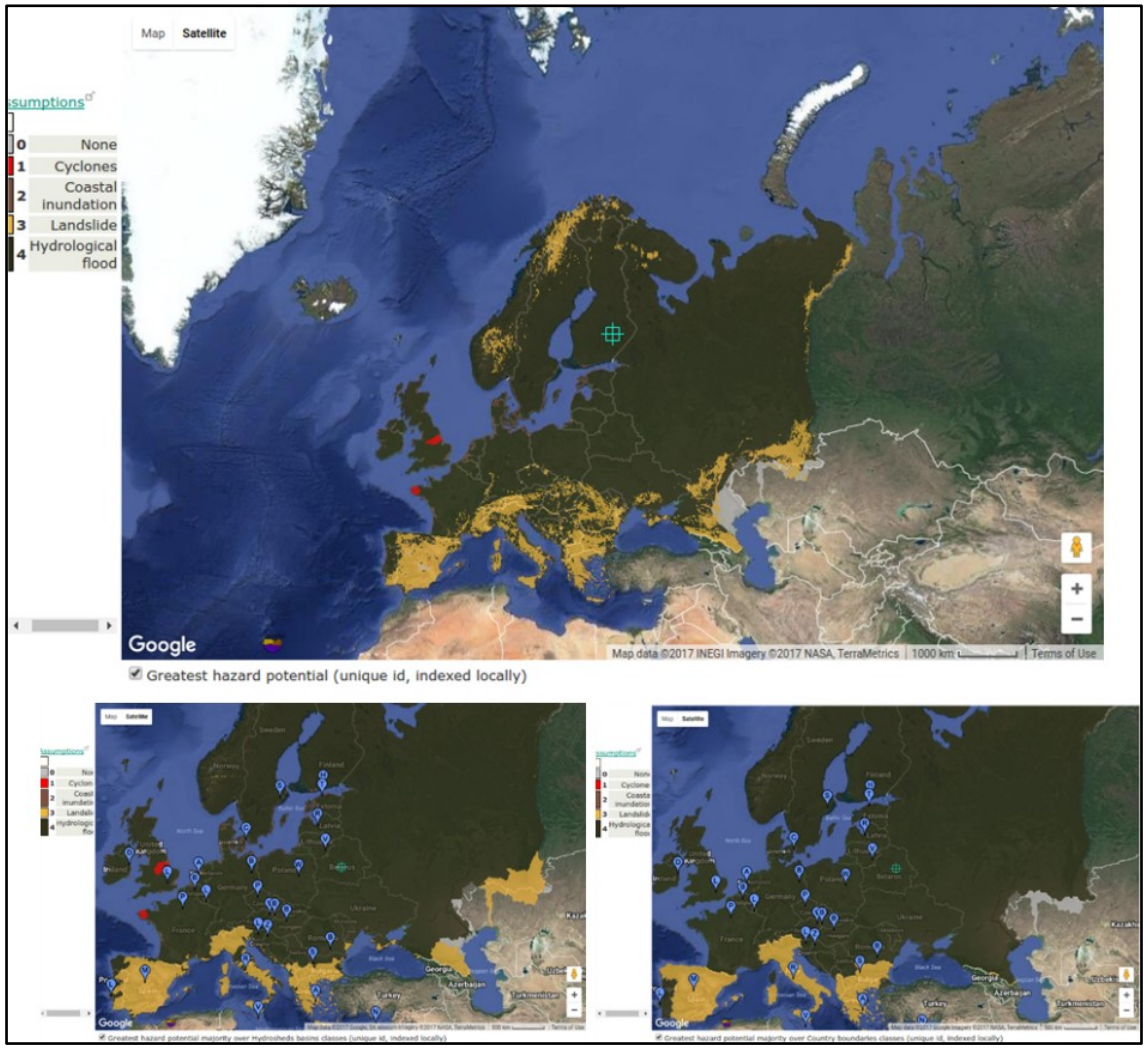

Figure 5. Greatest hazard potential ecosystem service relevant hazard for Europe by pixel, major global basin and country.

Hazard potential and greatest hazard potential for European capital cities

Examining values at the locations of European capitals (Table 8) we see the highest multi-hazard potential for Amsterdam (dominated by coastal inundation), followed by Ljubljana, Tallinn, Dublin, Zagreb (flood and coastal inundation). The capital cities with lowest hazard potentials are Berlin, Madrid, Warsaw, Bucharest, dominated by flood and landslide.

Table 7. EU capital cities ranked by Co$ting Nature hazard potential with indicator of greatest potential hazard potential in the urban area.

EU Capital	Relative potential for ES relevant hazard (0-1 locally) Mean	Greatest hazard potential (unique id, indexed locally) Mean
Nicosia	Outside study area	Outside study area
Amsterdam	0.29	Coastal inundation
Ljubljana	0.27	Flood
Tallinn	0.23	Coastal inundation
Dublin	0.22	Flood
Zagreb	0.16	Flood
Sofia	0.13	Landslide
Rome	0.13	Landslide
Luxembourg	0.12	Flood
Brussels	0.11	Flood
Valletta	0.11	Coastal inundation
Budapest	0.10	Landslide
Vilnius	0.09	Flood
Bratislava	0.09	Flood
Paris	0.08	Flood
Lisbon	0.08	Flood
Vienna	0.08	Flood
Helsinki	0.07	Flood
Riga	0.07	Flood
Copenhagen	0.06	Flood
Prague	0.06	Flood
London	0.06	Flood
Stockholm	0.05	Flood
Athens	0.05	Landslide
Berlin	0.05	Flood
Madrid	0.04	Landslide
Warsaw	0.04	Flood
Bucharest	0.04	Flood

5. Demo basin analysis with Co$ting Nature

This section provides results of analysis of hazard potential and greatest hazard potential for four demo basin regions with the Co$ting Nature policy support system. Since Co$ting Nature operates at larger policy relevant scales, some demo regions are too small to model with this policy support system (e.g. Brague and Lez catchments in France and Glinščica catchment in Slovenia). In those cases, the larger surrounding catchment has been modelled to contextualise the specific hazards of these smaller demo regions within the context of the wider multi-hazardscape. Therefore for the Brague catchment, the surrounding catchments have been taken into account and for the Glinščica catchment, the surrounding Ljubljanica basin forms the spatial extent for the Co$ting Nature analysis. The wider hazardscape for the Lez catchment is not defined yet.

Thames

Hazard potential

The pixel based potential hazard map for the Thames basin (Figure 6) shows relatively higher values towards the south and west of the basin mostly due to steeper upstream slopes and higher precipitation in those areas.

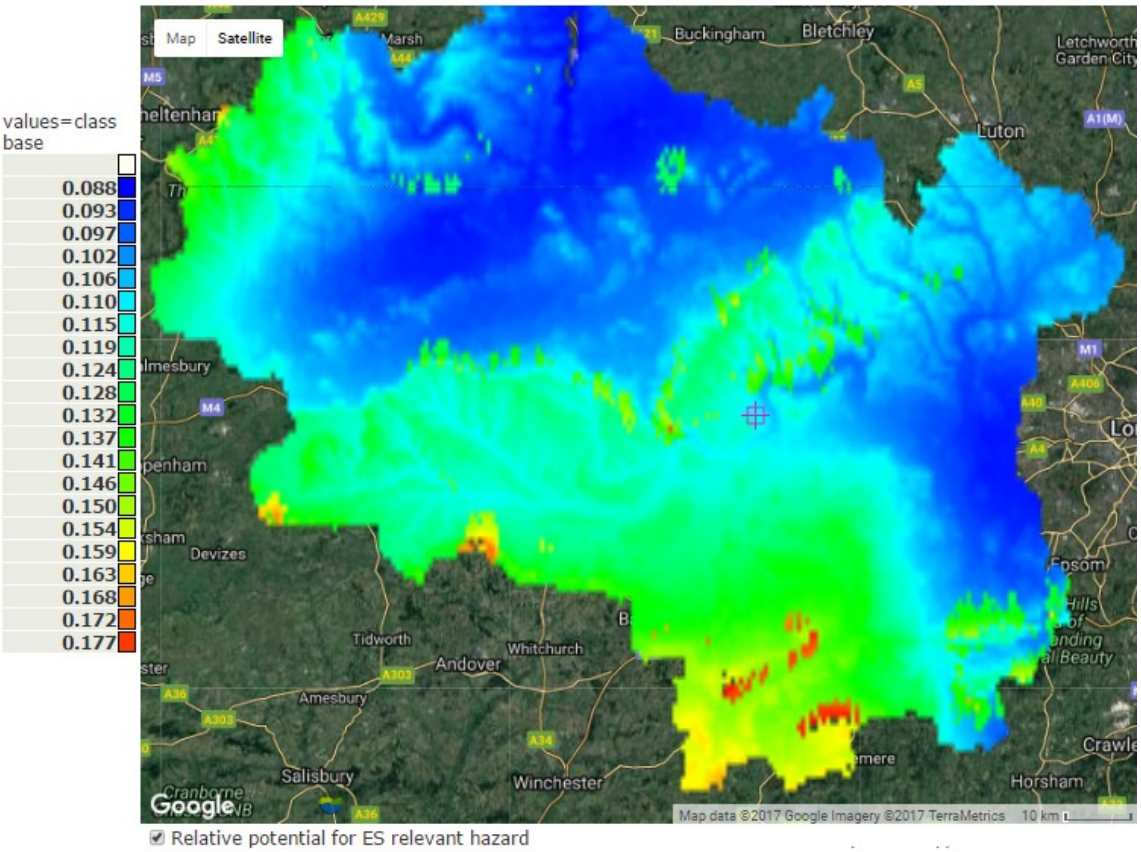

Figure 6. Relative potential for Ecosystem Service potential hazard for the Thames basin by pixel.

Greatest hazard potential

The greatest hazard potential throughout the whole of the Thames basin according to Co$ting Nature comes from fluvial flooding (Figure 7).

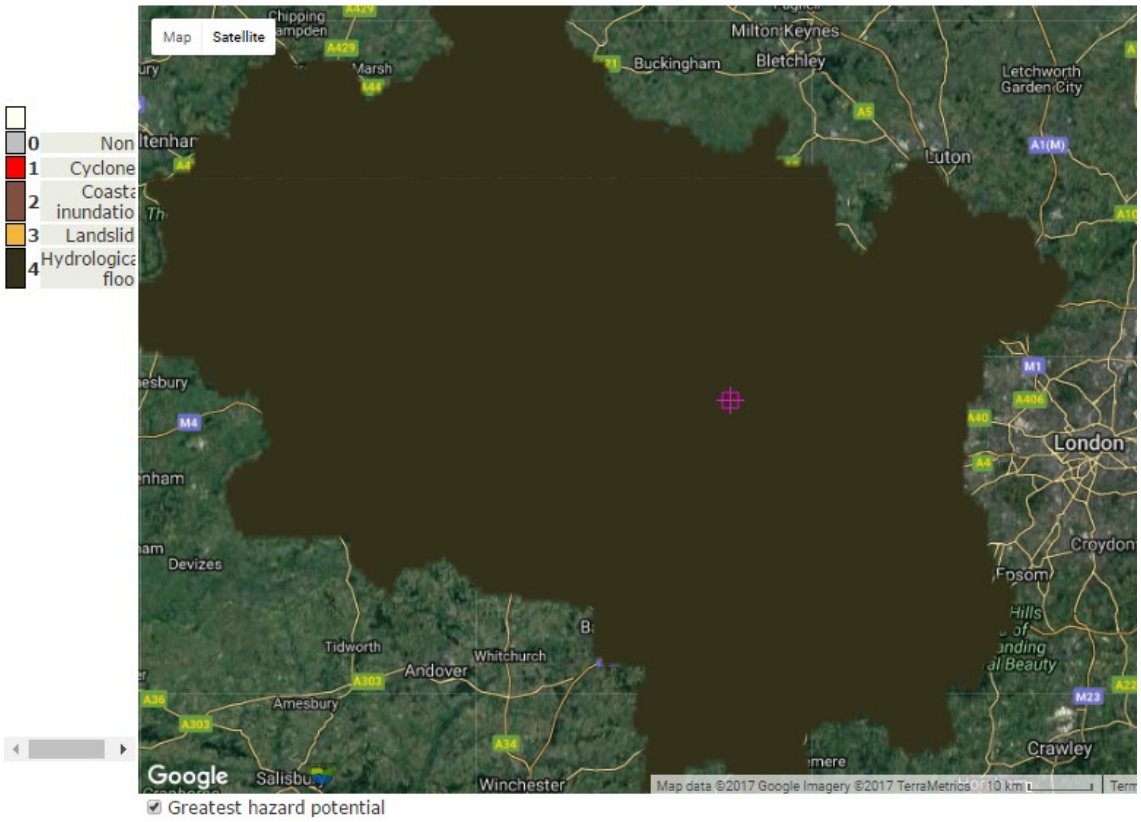

Figure 7. Greatest hazard potential ecosystem service relevant hazard for the Thames basin by pixel.

Brague and surrounding watersheds

Hazard potential

Potential hazard to ecosystem services in the French Mediterranean demo can be found towards the north of the demo area in the Var watershed in the Alps (Figure 8). In general much lower values of potential hazard are located along the coastline.

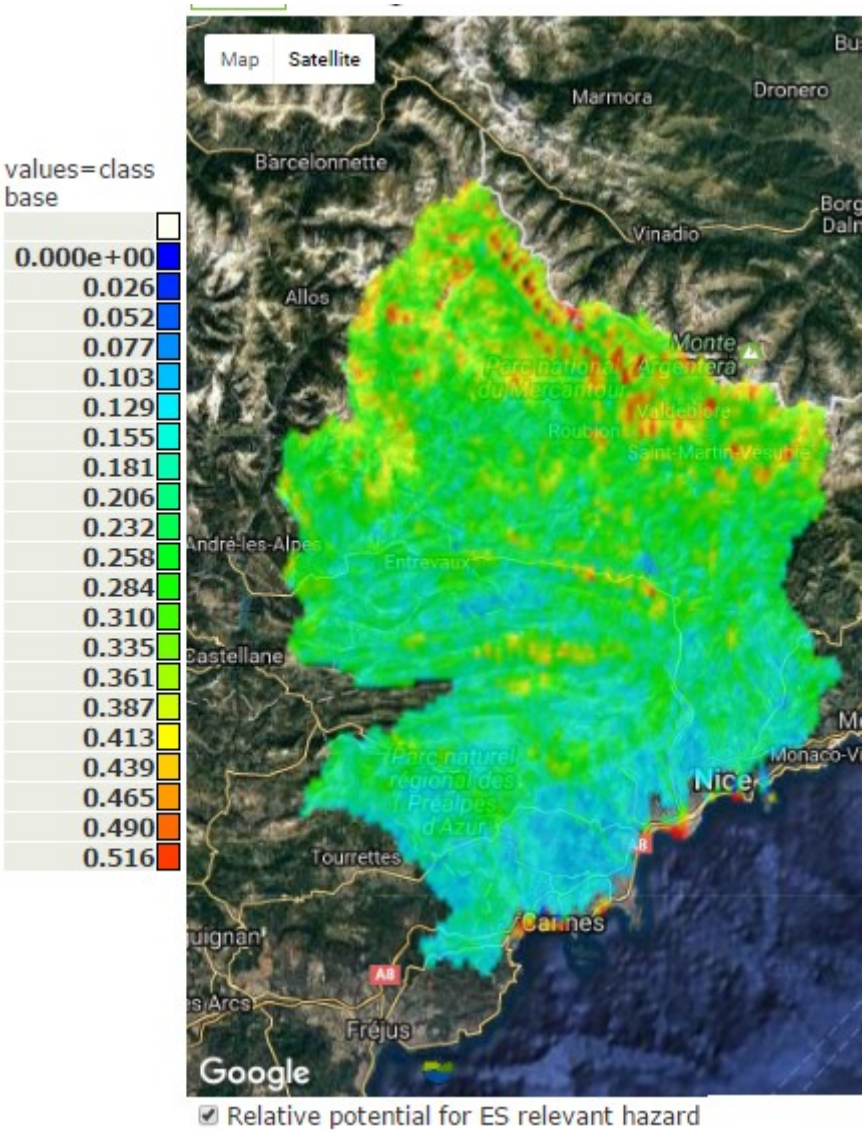

Figure 8. Relative potential for Ecosystem Service potential hazard for Brague and surrounding watersheds by pixel.

Greatest hazard potential

The greatest hazard potential in this demo region comes from floods and landslides for roughly equal areas with landslides more prevalent in areas with steeper slopes (Figure 9).

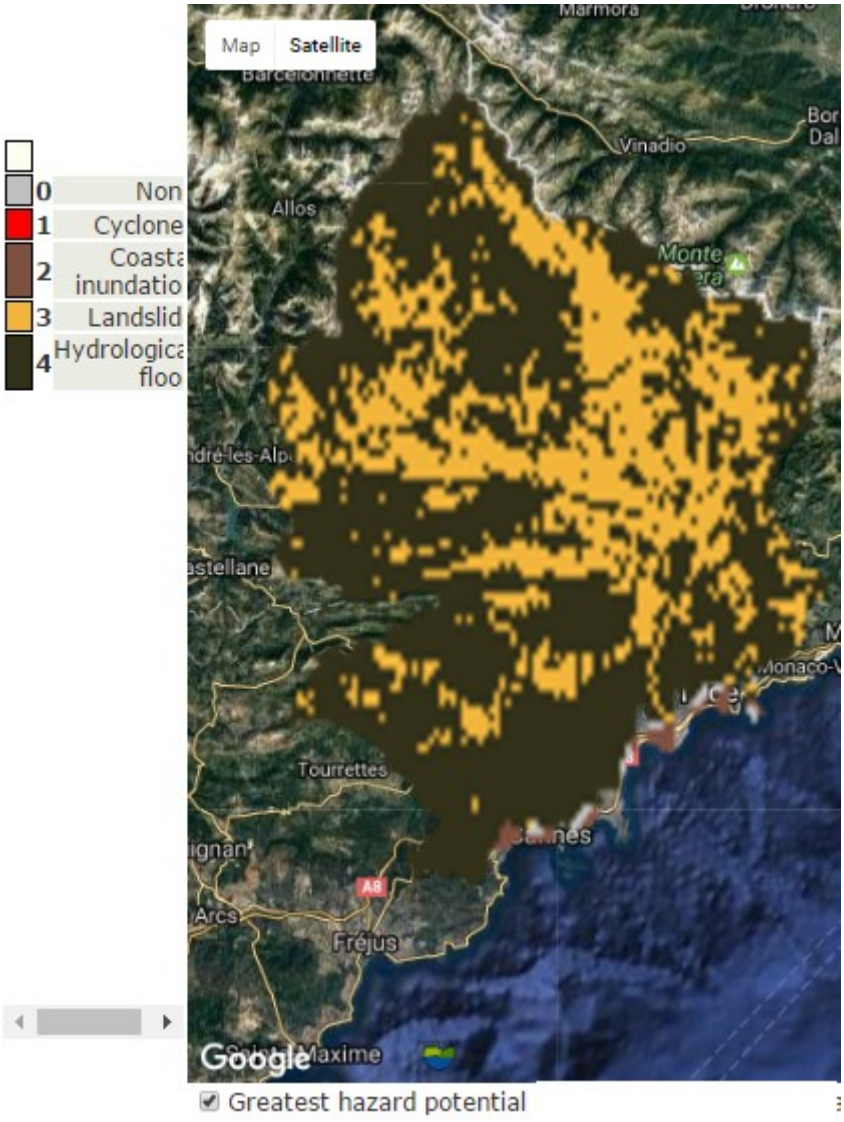

Figure 9. Greatest hazard potential ecosystem service relevant hazard for Brague and surrounding watersheds by pixel.

Lower Danube

Hazard potential

The hazard potential map for the Lower Danube basin shows relatively low values for the low lying parts of the basin but greater hazard potential in the mountains (Figure 10).

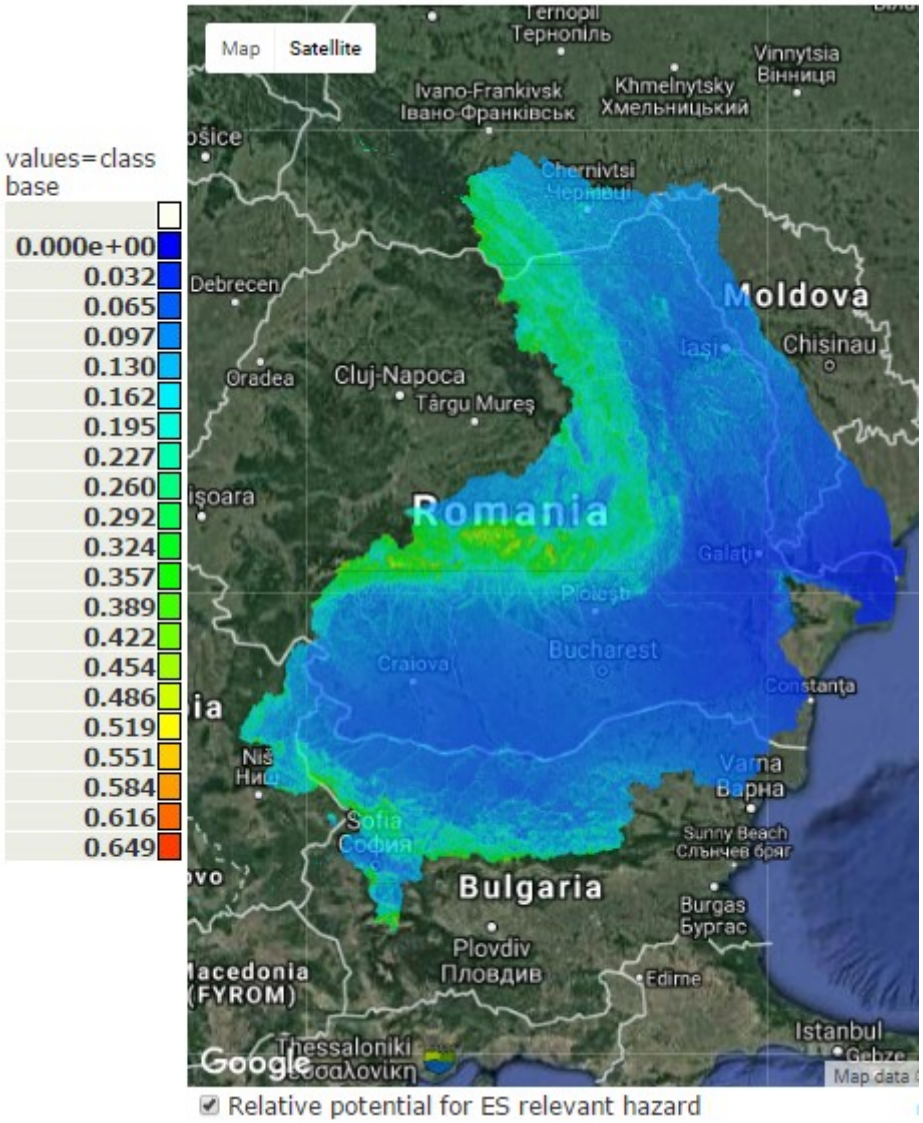

Figure 10. Relative potential for Ecosystem Service potential hazard for the Lower Danube by pixel.

Greatest hazard potential

The greatest potential hazards in the Lower Danube basin are landslides in the mountainous steep terrain and floods in the lower parts of the basin (Figure 11).

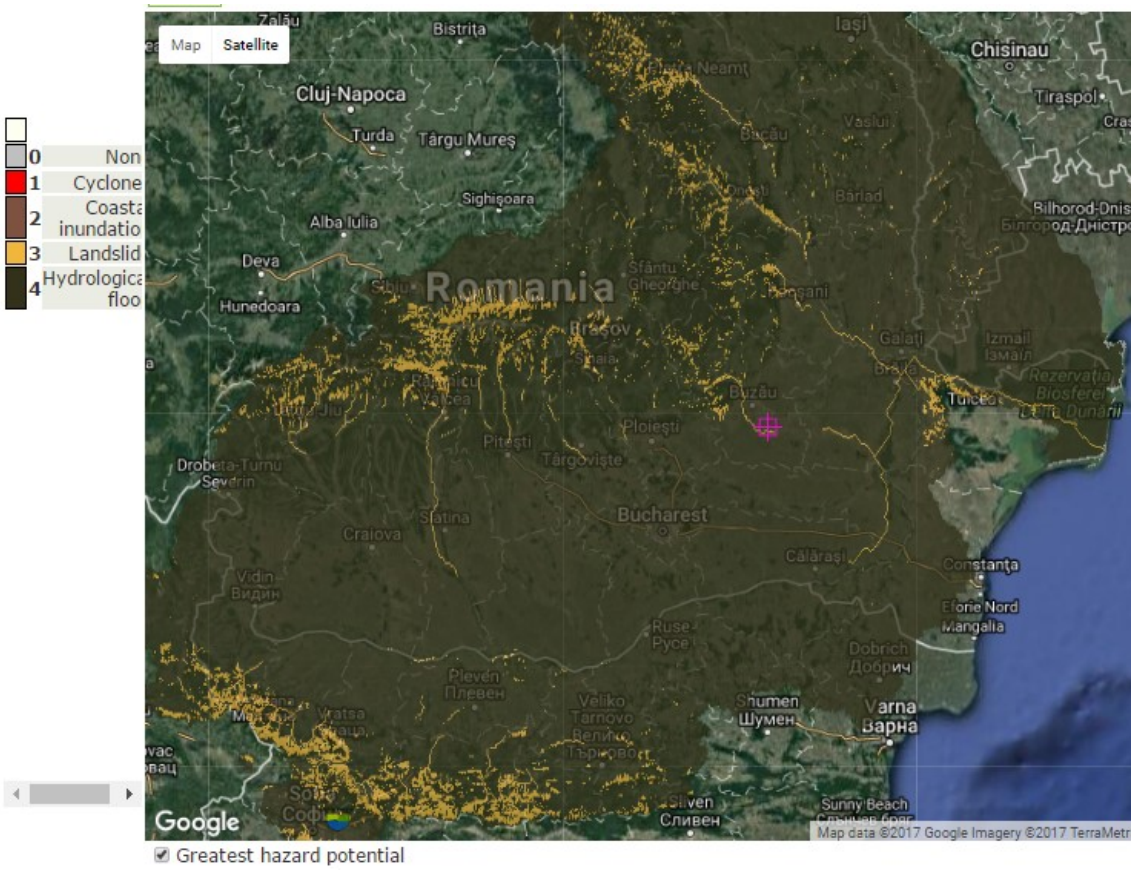

Figure 11. Greatest hazard potential ecosystem service relevant hazard for the Lower Danube by pixel.

Ljubljanica basin - Glinščica catchment

Hazard potential

Potential hazard to ecosystem services in the Ljubljanica basin (the larger basin around the Glinščica catchment demo) is variable with generally higher values found towards the centre and south of the basin (Figure 12).

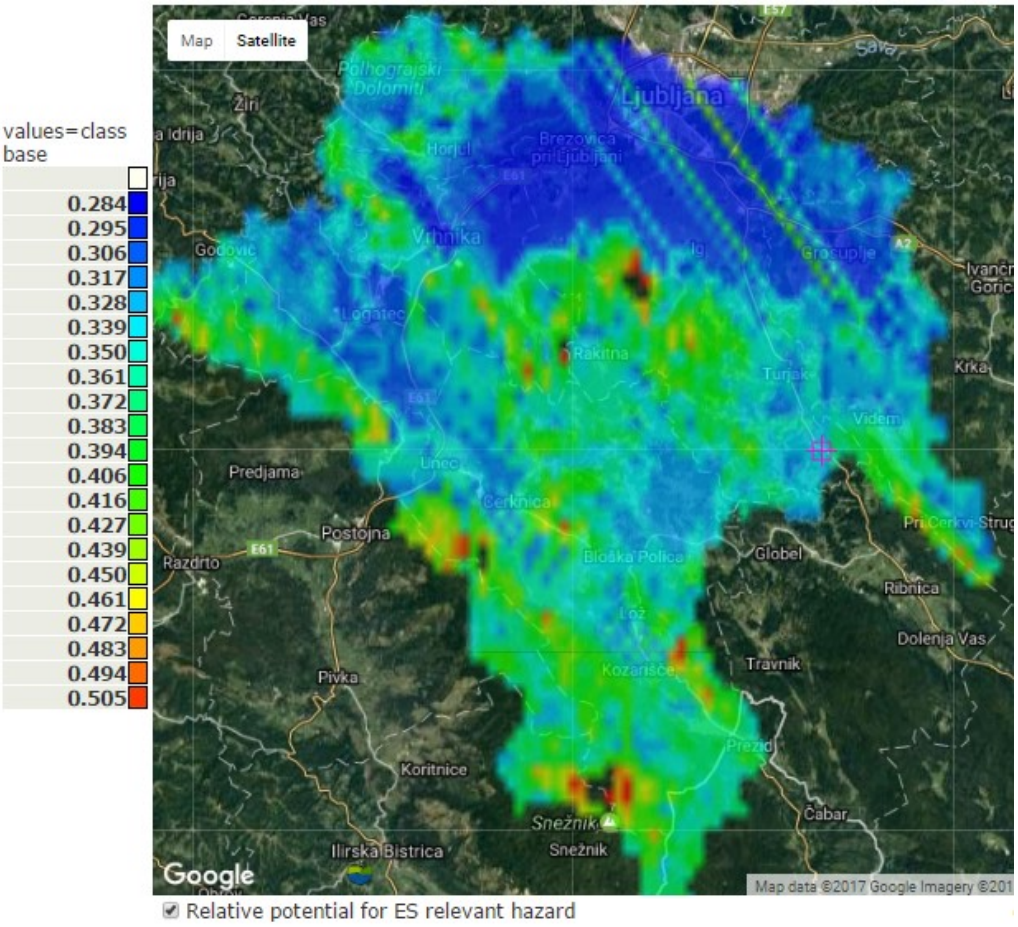

Figure 12. Relative potential for Ecosystem Service potential hazard for the Ljubljanica by pixel.

Greatest hazard potential

The greatest hazard potential in the Ljubljanica basin comes from floods. This is the case for all of the basin (Figure 13).

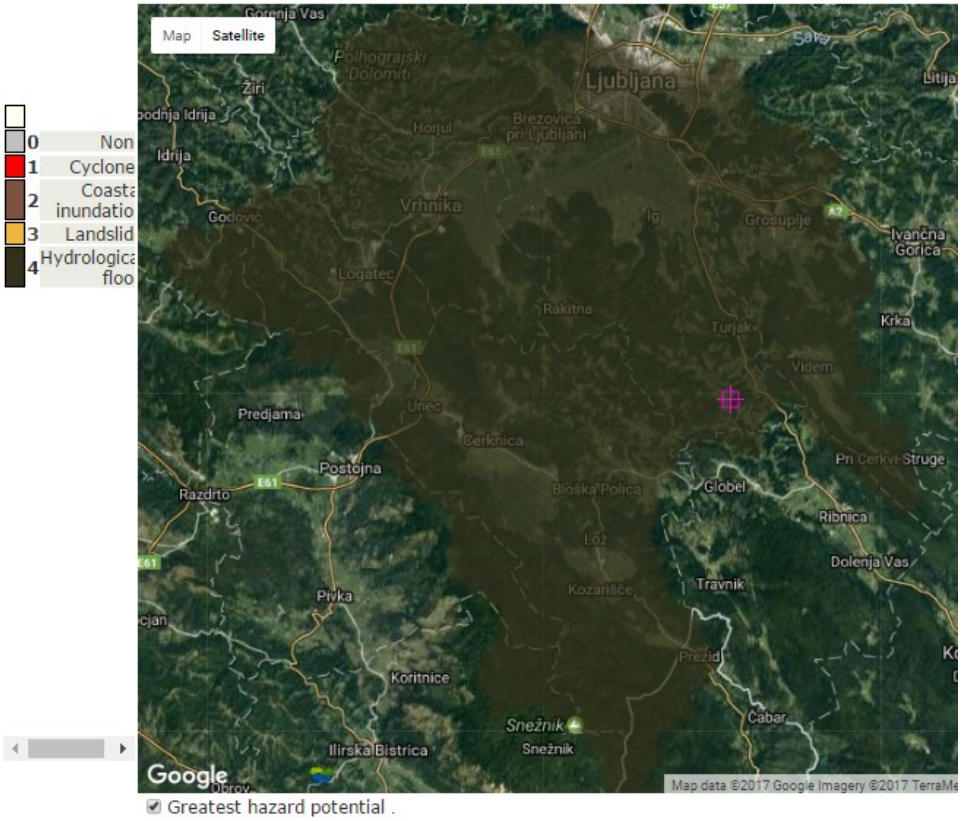

Figure 13. Greatest hazard potential ecosystem service relevant hazard for the Ljubljanica by pixel.

6. Local data for demo basins

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

Thames

There are quite a lot of studies on the key hazard of flooding in the Thames basin with some focusing specifically on the role of groundwater and subsidence. The key studies are listed in table 9.

Table 8. Publications on the Thames basin (KCL), UK.

Key potential hazard	Published studies on hazard	Published studies on hazard change over time
Fluvial Flooding	Marsh, T.J., 2004. The January 2003 flood on the Thames. *Weather*, *59*(3), pp.59-62. 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. Sanders, R. and Tabuchi, S., 2000. Decision support system for flood risk analysis for the river Thames, United Kingdom. *Photogrammetric engineering and remote sensing*, *66*(10), pp.1185-1193. Environment Agency 2013. Flood Event Report Winter 2012/13 West Thames Area. Environment Agency Red Kite House, Howbery Park, Wallingford Oxfordshire, OX10 8BD.	Eum, H.I., Sredojevic, D. and Simonovic, S.P., 2010. Engineering procedure for the climate change flood risk assessment in the Upper Thames River Basin. *Journal of Hydrologic Engineering*, *16*(7), pp.608-612. Piper, G., 2014. Balancing flood risk and development in the flood plain: the Lower Thames Flood Risk Management Strategy. *Ecohydrology & Hydrobiology*, *14*(1), pp.33-38. 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 Climate Model ensemble.*Journal of Hydrology*, *442*, pp.89-104. 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.
Fluvial and Groundwater flooding	Macdonald, D., Hall, R., Carden, D., Dixon, A., Cheetham, M., Cornick, S. and Clegg, M., 2007. Investigating the interdependencies between surface and groundwater in the Oxford area to help predict the timing and location of groundwater flooding and to optimise flood mitigation measures.	
Subsidence and flooding	Royse, K., Horn, D., Eldridge, J. and Barker, K., 2010, May. Flooding and subsidence in the Thames Gateway: impact on insurance loss potential. In *EGU General Assembly Conference Abstracts* (Vol. 12, p. 5286).	

Brague and Lez demo areas

For the French Mediterranean coast there is a wide range of scientific studies on the key hazard of fluvial flooding both on the hazard but also studies looking at the temporal aspect of the hazard (table 10).

Table 9. Publications on the Mediterranean region, near the Brague Basin (Irstea), France.

Key potential hazard	Published studies on hazard	Published studies on hazard change over time
Fluvial Flooding	Andreassian, V. Impact de l'évolution du couvert forestier sur le comportement hydrologique des bassins versants *Université Pierre et Marie Curie Paris V,* **2002** Andréassian, V. Waters and forests: from historical controversy to scientific debate *Journal of Hydrology,* **2004***, 291*, 1 - 27 Cosandey, C.; Andréassian, V.; Martin, C.; Didon-Lescot, J.; Lavabre, J.; Folton, N.; Mathys, N. & Richard, D. The hydrological impact of the mediterranean forest: a review of French research *Journal of Hydrology, Elsevier BV,* **2005***, 301*, 235-249 Lavabre, J.; Torres, D. S. & Cernesson, F. Changes in the hydrological response of a small Mediterranean basin a year after a wildfire *Journal of Hydrology, Elsevier,* **1993***, 142*, 273-299 Shakesby, R. Post-wildfire soil erosion in the Mediterranean: review and future research directions *Earth-Science Reviews, Elsevier,* **2011***, 105*, 71-100 Le Bihan, G. Modèles hydrologiques régionaux pour la prévision distribuée des crues rapides : vers une estimation des impacts et des dommages	Einhorn, B.; Eckert, N.; Chaix, C.; Ravanel, L.; Deline, P.; Gardent, M.; Boudières, V.; Richard, D.; Vengeon, J.-M.; Giraud, G. & Schoeneich, P. Climate change and natural hazards in the Alps *Revue de géographie alpine, OpenEdition,* **2015** Roudier, P.; Andersson, J. C. M.; Donnelly, C.; Feyen, L.; Greuell, W. & Ludwig, F. Projections of future floods and hydrological droughts in Europe under a +2°C global warming *Climatic Change, Springer Nature,* **2015***, 135*, 341-355 Piras, M., Mascaro, G., Deidda, R., & Vivoni, E. R. (2016). Impacts of climate change on precipitation and discharge extremes through the use of statistical downscaling approaches in a Mediterranean basin. *Science of the Total Environment*, *543*, 952-964. Schneider, C., Laizé, C. L. R., Acreman, M. C., & Florke, M. (2013). How will climate change modify river flow regimes in Europe?. *Hydrology and Earth System Sciences*, *17*(1), 325-339.

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Debris flows	Bertrand, M.; Liébault, F. & Piégay, H. Regional Scale Mapping of Debris-Flow Susceptibility in the Southern French Alps *Journal of Alpine Research | Revue de géographie alpine,* **2017**, *104*, 1-14	

Lower Danube

For the Lower Danube demo basin, only a few studies on the hazards of desertification, pollution and fluvial flooding were identified and no studies on changes in these hazards over time could be found (table 11).

Table 10. Publications on the Lower Danube section (GeoEcomar), Romania.

Key potential hazard	Published studies on hazard	Published studies on hazard change over time
Desertification	R.M. Cocheci, Analysis of Restrictive Environments in the South-West Oltenia Development Region, 2016, Urbanism	
Pollution	Fluvius, 2005. Map 5: Danube River Basin District: Significant Point Sources of Pollution, ICPDR, Vienna	

Fluvial Flooding	National Institute of Hydrology and Water Management, Danube water integrated management, 2015 Armas, Iuliana, Radu Ionescu, and Cristina Nenciu Posner. "Flood risk perception along the Lower Danube river, Romania." Natural Hazards 79, no. 3 (2015): 1913-1931. Lower Danube green corridor: floodplain restoration for flood protection (2014), WWF International Danube-Carpathian Programme WWF, Restored floodplain areas would have limited flooding on Lower Danube, 2006 ICPDR, Flood Action Programme, Lower Danube Corridor, 2015	

Glinščica catchment

There are quite a lot of studies on the key hazard of flooding on Slovenian and Glinščica catchment level (Table 12).

Table 11. Publications on the Glinščica catchment.

Key potential hazard	Published studies on hazard	Published studies on hazard change over time
Torrential Flooding	Fazarinc, R., 2010. Zagotavljanje poplavne varnosti jugozahodnega dela Ljublja ne. V: 21. Mišičev vodarski dan 2010. Maribor, Vodnogospodarski biro, Str. 30 -37. URL: ttp://mvd20.com/LETO2010/R5.pdf (Flood protection of SW part of Ljubljana).	A comparison of floods in Ljubljana in the years 1926 and 2010, Martin Legiša, University of Ljubljana, Faculty Of Arts, Department of Geography, 2013
Torrential Flooding	Izdelava kart poplavne nevarnosti za območje DPN za zagotavljanje poplavne varnosti JZ dela Ljubljane , študija, A71-FR/09, 2010, naročnik Ministrstvo za okolje in prostor, Dunajska 48,Ljubljana (Flood hazard maps for the DPN area for flood protection of SW part of Ljubljana).	Komac, B., Natek, K., Zorn, M., 2008. Geografski vidiki poplav v Sloveniji. Ljubljana, Založba ZRC, 180 str. (Geographical aspects of floods in Slovenia).

Torrential Flooding	Ljubljansko barje, hidrologija in analiza poplavnosti, študija, Vodnogospodarski inštitut, 1983; (Ljubljana Marshes, hydrology and permeability analysis).	
Torrential Flooding	Ocena ogroženosti zaradi poplav, Republika Slovenija Ministrstvo za obrambo, Izpostava URSZR Ljubljana, Štab Civilne zaščite za ljubljansko regijo, 2011 (Flood Threat Assessment).	
Torrential Flooding	Načrtovanje celovite ureditve povodja Gradaščice: zagotovitev poplavne varnosti / [besedilo Darko Anzeljc]. - Ljubljana: Ministrstvo za okolje in prostor, Direktorat za okolje, 2007 (Planning comprehensive regulation of Gradaščica watershed: ensuring flood safety).	
Torrential Flooding	Bizjak, A., Repnik Mah, P., 2011. Predlog ukrepov za zmanjšanje poplavne ogroženosti ob malih vodotokih s poudarkom na evidentiranih točkah. V: Natek, K.(ur.). Mali vodni tokovi in njihovo poplavno ogrožanje Ljubljane . Ljubljana, Znanstvena založba Filozofske fakultete, str. 66-76. (Proposed measures to reduce flood risk at small streams, with an emphasis on the recorded points).	
Torrential Flooding	Dobravc, M., 2007. Ocena ogroženosti Mestne občine Ljubljana zaradi poplav. Ljubljana, Mestna občina Ljubljana , 43. Str. (Threat Assessment of the Municipality of Ljubljana due to flooding).	
Torrential Flooding	Hidrološko poročilo o povodnji v dneh od 17. do 21. septembra 2010, 2010, Ljubljana Agencija Republike Slovenije za okolje, 18 str. URL: http://www.arso.gov.si/vode/poro%C4%8Dila%20in%20publikacije/Poplave%2017.%20-%2021.%20september%202010.pdf (Hydrological report on the floods in the period from 17 to 21 September 2010).	
Torrential Flooding	Pregledna ocena ogroženosti mestne občine Ljubljane zaradi naravnih nesreč s poudarkom na potresih in poplavah. Ljub Ljana, Geografski inštitut Antona Melika	

	ZRC SAZU, 69 str. (Transparent assessment of the threat in municipality Ljubljana due to natural disasters, with an emphasis on earthquakes and floods).	
Torrential Flooding	Hidrološko poročilo o poplavah 22. Oktobra 2014. 2014. Ministrstvo za okolje in prostro, Agencija republike Slovenije za okolje, Ljubljana.http://www.arso.gov.si/vode/poro%c4%8dila%20in%20publikacije/PorociloPoplave22okt2014.pdf (Hydrological report on floods on 22 of October 2014)	

7. Conclusions and next steps towards development of Eco: actuary

The results of the Co$ting Nature analysis shows that the greatest hazard potential for most of Europe and for major cities is hydrological flood, followed by landslides. The results show a clear distinction between flood risk dominating in northern Europe and landslide in mountainous southern Europe.

Analysis of available data that can potentially be used to improve datasets in the Co$ting Nature PSS or the Eco: actuary system to be developed resulted in a wide range of spatial datasets available for the Thames and the French Mediterranean demo basins but far less (accessible) data available for the Lower Danube demo basin. This highlights the importance of data availability at the European or Global scale for improvement and use in the Eco:actuary system in order to be able to consistently map hazard potential and risk for all areas.

As a next step the spatial data identified for each demo basin area will be reviewed for its usefulness and applicability within the Eco:actuary system. In addition, further global datasets on some of the other key hazards identified will be scoped as well as more updated global datasets that can be used to calculate hazard mitigation provided by nature.

8. References

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