“NAture Insurance value: Assessment and Demonstration”

NAIAD

SC5-09-2016 Operationalising insurance value of ecosystems
Grant Agreement nº 730497

Deliverable 2.4

Guidelines and pilot version of the eco:actuary policy support system

Due date of deliverable: 31/05/2017
Actual date of submission: 29/05/2017
Date of revised deliverable submission: 24/09/2018

Start date of project: 01-12-2016
Duration: 36 months
Name of partner responsible for deliverable: CHD
Authors: Mulligan M., Burke S., van Soesbergen A., Douglas C.

Dissemination Level		
PU	Public	**X**
CO	Confidential, only for members of the consortium (including the Commission Services)	

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730497.

The opinions expressed in this document reflect only the author’s view and in no way reflect the European Commission’s opinions. The European Commission is not responsible for any use that may be made of the information it contains.

EDITION INFORMATION

Table 1: Versions

VERSION	EDITION DATE	MODIFICATION	WRITTEN BY	CONTROLLED BY
1	19-4-18	FIRST EDITION FOR THE BRAGUE CATCHMENT	MARK MULLIGAN (KCL)	
2	27-4- 18	FINAL DRAFT	A VAN SOESBERGEN (KCL)	
3	28-4-18	FINAL VERSION FOR REVIEW	A VAN SOESBERGEN	MARK MULLIGAN (KCL)
4	28-5-18	INTERNAL REVIEWER 1		PETER VSN DER KEUR (GEUS)
4	28-5-18	INTERNAL REVIEWER 2		MORTEN EJSING (CPH)
5	29-5-18	FINAL VERSION	A VAN SOESBERGEN	MARK MULLIGAN
FINAL	29-11-17	CO REVISION-SUBMISSION		ELENA LOPEZ GUNN
REVISION	06-09-18	EC REVISION		EC-PO
REVISION	21-09-18	AUTHOR REVISION	MARK MULLIGAN	COORDINATORS
REVISION	25-09-18	CO REVISION-SUBMISSION	LAURA VAY (PM)	COORDINATORS

INDEX

1. Introduction 5
Aim of deliverable 5
Review of key existing catastrophe models 5
Gaps in existing actuarial decision support around NBS 11
Key insurance relevant mitigation by NBS 11
Key insurance relevant adaptation mechanisms and representation in catastrophe models 13
Defining an Eco:Actuary 13
What the Eco:Actuary provides 14
Audience and potential use cases 15
Uses and potential mis-uses 16
Pilot version of the EcoActuary: methods 16
Pilot version of the EcoActuary: guidelines 17
Creating an account 17
Define Area 18
Prepare Data 19
Edit catastrophe model parameters 20
Hazard ensemble 20
Asset inventory 21
Damage functions 21
Mitigation infrastructure 23
Run simulation 23
Results maps 23
2. Conclusions 25
3. References 26

EXECUTIVE SUMMARY

This document provide a review of existing catastrophe models and their relevance to green infrastructure, sets up the rationale for developing an Eco:Actuary and describes the basic premise and operation of the pilot version of the tool. The pilot version of Eco:Actuary at www.policysupport.org/ecoactuary provides the opportunity to highlight the potential uses and value of the tool. It is now possible for project partners and insurance stakeholders to begin trialling the tool, thereby enabling further co-development. Through further use the system will be further developed and refined for final delivery in month 34.

1. Introduction

Aim of deliverable

In this deliverable, NAIAD describes the pilot version of the Eco:Actuary catastrophe model. This document provide a review of existing catastrophe models and their relevance to green infrastructure, sets up the rationale for developing an Eco:Actuary and describes the basic premise and operation of the pilot version of the tool. Over the coming months this version will be presented to, and further co-developed with, one to one and through a series of trainings. Through further use the system will be further developed and refined for final delivery in month 34. Eco:Actuary is focused on a global user body and applications around the world, including throughout European and for European insurers with insured assets outside of Europe. This deliverable is not final documentation for the Eco:Actuary, since the pilot version is in co-development, it provides a summary of the evolving tool and some initial documentation that will allow project members and partners to begin exploring the tool.

REVIEW OF KEY EXISTING CATASTROPHE MODELS

Catastrophe models (often referred to as 'cat models') calculate the likelihood and severity of potential future catastrophes in order to adequately prepare for their financial impact. Cat models are used by insurers, reinsurers, governments, capital markets and other financial entities to assess and quantify natural catastrophe risk. They are used for: underwriting (the assessment of risk, exposure, the amount of insurance offered, the premium and whether or not to offer an insurance policy); risk selection (where underwriters screen out high risks and pass them onto the public part of the private-public partnership, with significant consequences for the taxpayer); calculating the total financial reserves needed to meet future claims in the event of catastrophe; and the development of mitigation strategies to avoid unnecessary losses.

Catastrophe modelling emerged in the late 1980s to early 1990s as a consequence to technological improvements in mapping risk and measuring hazard, and in response to a series of devastating natural disasters (Grossi & TeHennepe 2008, Maynard et al 2014). Cat models use observed data on past hazards and associated loss to approximate the risk associated with future catastrophes in regards to their magnitude and frequency, and can include explicit modelling of particular phenomena such as windstorm clustering and storm surges. Financial characteristics are then used to calculate the probability and size of potential loss.

Cat models are typically composed of four modules: exposure, hazard, vulnerability and financial (LMA 2013). An initial set of theoretical events (i.e. varying from 10,000 - 800,000 events) are created which ideally represent the range in intensity of the hazard in question. The exposure module includes information about the asset such as its location, physical characteristics and any insurance policy terms. The hazard module assesses risk associated with the event under consideration. The vulnerability module uses both the output of the hazard module and characteristics of the asset to create vulnerability curves and a damage ratio (anticipated loss to replacement value) reported. The financial module uses the damage ratio to create an event loss table which provides modelled losses associated with each specific theoretical catastrophic event. This information is used to calculate the exceedance probability (EP) which is either presented as an EP curve or as a return period statistic. The EP curve displays the probability that a financial loss will exceed a certain amount in a year, with losses running along the x-axis (independent) and exceedance probability along the y-axis (dependent). The return period describes the number of years that may pass between events which exceed a given loss. For example, a 0.4% probability of exceeding a given loss in a year corresponds to a probability of one loss every 250 years (i.e. a 250 year return loss period). The area under the EP curve is referred to as the Annual Average Loss (AAL) and it represents the average loss of all modelled events weighted by their probability of annual occurrence. As this metric is standardised it is good for comparing risks that have been quantified in different ways.

There are two main cat models AIR and RMS. Other smaller models include EQECAT/CoreLogic, JBA and AON. These are all proprietary models, so detailed information about the models are difficult to obtain (Table 1-6). A notable exception to this situation is HAZUS which is a freely available cat model developed by the American Government; however, no input data is provided for regions outside of the U.S.A (Table 6; FEMA 2018). The various cat models produce different results due to differences in their input data, assumptions and model construction (LMA 2017).

Unfortunately it is not possible to conduct an academic comparison of cat models: due to their strict licensing conditions the models are not available for experimentation. Furthermore, even if such experiments could be conducted, commercial confidentiality issues prevent the details of proprietary catastrophe model structures from being described in public domain documents. Sampson et al (2014) suggest such experimentation is urgently required, and found that sensitivity to input rainfall was greater than the uncertainty in the hazards and vulnerability; and so uncertainty in cat models may be greater than commonly believed. Cat models already have several acknowledged sources of uncertainty. For example, uncertainty exists in the data, assumptions and calculations of each module and because the output of each module is used in each successive module, the financial metric produced in the final module carries a lot of uncertainty (LMA 2013). Similarly, any events falling near the tails of the EP curve are associated with a high degree of uncertainty and must be treated with caution (LMA 2017). Additionally,

since cat models have been used for less than 40 years [the first three successful commercial providers of cat models were AIR (1987), RMS (1988) and EQECAT (1994)], cat models rely on a relatively short-term historical loss dataset which is insufficiently long to adequately represent the pattern of particularly severe events.

The models continue to develop: RMS released a high resolution cat model for European inland flooding which covers over 8000 catchments across 15 countries, and uses high resolution flood maps - a 5m horizontal grid for all of Europe, except for in the UK where a 2m resolution exists (RMS, 2018). Within the cat modelling industry there is also a movement towards transparency and greater collaboration between organisations through the Oasis Loss Modelling Framework, a non-for-profit organisation owned by members of the insurance and re-insurance industry (Arthur 2017). Oasis LMF is part of a newly funded (2017-2020) EU H2020 project, Oasis Innovation Hub for Catastrophe and Climate Extremes Risk. Oasis LMF is an open source platform enabling catastrophe models to be developed, deployed and executed in a transparent and standardised manner. This allows the results of different models to be directly compared. Approximately 80 models from 15 different providers are currently being adapted to run on the platform. The natural catastrophe risk modelled varies by company and country/region. Another component to this initiative is a repository of existing risk data, maps, tools and services has been compiled (Oasis Hub). Oasis LMF is a valuable progression in the evolution of cat modelling, with its focus on transparency, validation and accessibility. However as many, if not all, of the catastrophe models available in the platform require a fee, financial barriers still exist for some potential users and there is a need for a no-fee catastrophe model. . The tables below provide details of the major catastrophe models by organisation. Examples relevant to flood modelling are prioritised.

Table 1. Summary of Catastrophe Model AIR.

Environmental Hazards Modelled	Hurricane, Tornado, Earthquake, Winter storm
Coverage	Global; specific countries for each hazard
Data Inputs	Property values, construction types, and occupancy classes
Availability/Cost	Fee
Treatment of Hazard Mitigation (ecosystem services)	No

Treatment of Adaptation	Allows for the removal/addition of flood protection measures
Validation	During model development and final model results compared against historical data. Also uses peer-review and expert opinion.

Table 2. Summary of Catastrophe Model RMS.

Environmental Hazards Modelled	Flood (fluvial, pluvial, snowmelt, groundwater), Earthquake, Hurricane, Severe Storm
Coverage	Global; specific countries for each hazard
Data Inputs	Topography, land use, flood defences, risk vulnerability, simulated precipitation
Availability/Cost	Fee
Treatment of Hazard Mitigation (ecosystem services)	No
Treatment of Adaptation	Allows inclusion of temporary and permanent mitigation measures i.e. flood defenses
Validation	No details provided

Table 3. Summary of Catastrophe Model Core Logic (previously EQECAT).

Environmental Hazards Modelled	Flood (fluvial, pluvial), Earthquake, Hurricane, Tornado, Winter Storm, Wildfire
Coverage	Global; specific countries for each hazard
Data Inputs	Riverine flood contains precipitation, precipitation to discharge, discharge to water height, water height to flood defences, defence failure to flood propagation modules. Built environment module to represent likely structure type and elevation of buildings. Hazard analysis resolution at 50m x 50m hazard cells*

Availability/Cost	Fee
Treatment of Hazard Mitigation (ecosystem services)	No
Treatment of Adaptation	No?
Validation	Precipitation data against historical meteorological/hydrological data and flood maps. Built environment against visual inspection for sample postcodes and census data. Vulnerability functions against studies and claims. Loss results against insurance company portfolio losses*

*EuroFlood Risk Model

Table 4. Summary of Catastrophe Model AON

Environmental Hazards Modelled	Hurricane, Earthquake, Flood (pluvial, fluvial), Tsunami, Severe Weather, Wildfire
Coverage	Global; specific countries for each hazard
Data Inputs	Site, Building, Property, Insurance Coverage Terms, Construction, Occupancy, Location (address, postcode, soil). Environmental: Storm Prediction Centre (SPC) - NOAA; national datasets
Availability/Cost	Fee
Treatment of Hazard Mitigation (ecosystem services)	No
Treatment of Adaptation	Flood model allows removal/addition of levee systems
Validation	No details provided

Table 5. Summary of Catastrophe Model JBA

Environmental Hazards Modelled	Flood (pluvial, fluvial, sea surge)

Coverage	Flood (pluvial, fluvial, sea surge)
Data Inputs	5m resolution mapping for UK, model factors in flood duration; water salinity.
Availability/Cost	Fee
Treatment of Hazard Mitigation (ecosystem services)	No
Treatment of Adaptation	No?
Validation	No details provided

Table 6. Summary of Catastrophe Model HAZUS.

Environmental Hazards Modelled	Earthquake, Flood (river, coastal), Tsunami, Hurricane
Coverage	USA only; platform can be used elsewhere but no datasets provided
Data Inputs	National datasets for USA only (user can replace with more accurate local datasets if available). Own data required for Tsunami module.
Availability/Cost	Free, but requires ArcView license and Spatial Analyst Extension for flood module. Model linked to specific version(s) of ArcGIS
Treatment of Hazard Mitigation (ecosystem services)	No
Treatment of Adaptation	Flood model allows users to look at impact of mitigation measures i.e. flow regulation devices, elevating structures or acquiring properties in floodplains
Validation	The flood model was externally validated

Gaps in existing actuarial decision support around NBS

Climate change. It is reported that Cat Models generally not use climate models as their principal method of pricing storm risk (Dizard 2017). Climate change trends may be *implicitly* built into catastrophe models, using available historical data and multiple event scenarios; however climate change trends are not always *explicitly* incorporated into the modelling output (Maynard et al 2014). This is because the extreme weather events associated with climate change have very large uncertainties and are therefore too difficult to incorporate into a pricing models, which demand more certainty in frequency and magnitude and location of events.

Insurance policies are usually renewable on an annual basis, so prices reflect the probability of events in the annual timescale. However catastrophic events have return periods of much longer time periods, but insurers and their clients may be unwilling to cover these events due to their impact on premiums. Premiums need to generate enough capital reserves to pay out over these catastrophic events, however uncertain they may be. More information is needed on the risk of neglecting to include the very big but low frequency catastrophic event.

Nature Based Solutions. As outlined in the following section, these are often small scale and their effectiveness is difficult to assess, which means that risk policy decision makers find it difficult to justify the use of NBS to reduce insurance risk. NBS are not well represented in cat models.

Geographical coverage. The availability of very high-resolution flood risk models used by insurers are restricted to selected countries and global regions. This leaves capability gaps, so simpler models or modelling techniques need to be deployed to account for insured flood risk exposures in those areas. The high precision terrain and flow data needed for cat models is often available for limited areas only. Cat models may not cover the upstream areas in such detail, which is where NBS are often located.

Key insurance relevant mitigation by NBS

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

Mitigation offers the best solution to the increasing hazard risks on insurers and the insured. One of the barriers in making mitigation schemes successful is the often substantial up-front investment needed to accrue benefits over a number of years through reduced losses. Models such as Eco:Actuary are needed to aid decision-makers in the public and private sector assess the relative benefits of different risk mitigation measures, including Nature Based Solutions (NBS).

NBS for *flooding* involves increasing the floodwater storage capacity upstream of urban areas. Floodplain storage capacity is calculated using the elevation model. Water body and wetland storage capacity calculates the excess storage available for floodwaters. Canopy storage capacity takes into account the interception by tree covered areas, and soil storage capacity takes the land use and management into account. Increasing any of these storage capacity will impact the flood hydrograph by slowing down floodwaters, increasing out of bank storage and affecting the relative timing for peak flows to arrive at flow confluences, thus changing flooding risk in the main river and downstream.

Flooding risk can also be mitigated by enhanced infiltration, where more rainfall is stored in the soil, so that water flow across the land to a stream is significantly slowed. The infiltration capacity of a landscape to store water is a function of its underlying geology and topography, land use (in particular the urban/rural balance) and land management such as tillage regimes in agriculture. In urban areas SUDS (sustainable urban drainage schemes) seek to promote open areas of infiltration capacity in swales, permeable pavements and green roofs.

Small scale *drought* storage schemes in semi-arid areas such as in the Mediterranean environments have been established for thousands of years to allow populations to survive droughts. These are often very effective and therefore would have significance for drought insurance. For example, simple systems could use naturally occurring rock outcrops to divert rainwater to a central collection area. A concrete wall is built to direct the water that trickles down the rock surface into a sand and gravel filter into underground cisterns. Urban rainwater harvesting techniques such as rain barrels and cisterns can be used for non-potable uses such as toilet flushing. However in more recent times population pressures have meant that a larger scale solution to drought storage is needed, and solutions include artificial recharge. This is where an aquifer is used as additional storage to provide extra water for populations during droughts. However these systems require a significant investment in infrastructure of pumps, pipelines, recharge wells and reservoirs. They also require the aquifer recharge area to remain undeveloped so that the underground water is not polluted by people living above it, so it is attractive to smaller rural towns only. Drought mitigation NBS include those based on enhanced infiltration, such as rain gardens and permeable pavements to help replenish local groundwater reserves. While some of the water will lost though evapotranspiration (a dis-service), some will be stored, although a significant amount of well-designed enhanced infiltration schemes will be needed for the increased storage to be relevant in terms of drought insurance.

Key insurance relevant adaptation mechanisms and representation in catastrophe models

Catastrophe models are stochastic models where the physical processes in the landscape are not explicitly modelled. Many thousands of years of synthetic data are compiled for each flood peril, which generates thousands of discrete events, thereby providing model stability and allowing for very extreme events to occur. These “black box” models mean it is difficult to understand the impact of changes in exposure such as adaptation for example raised infrastructure against floods, water demand management and water use efficiency for droughts. A more transparent, flexible catastrophe modelling approach is needed so that insurers and their clients can gain more control over how they evaluate risk.

DEFINING AN ECO:ACTUARY

Eco:Actuary is a web based policy support system for understanding (insurance) risk and mitigation by nature based solutions. An actuary determines probability (and financial consequences) of risks and works with accountants and underwriters to set insurance rates (premiums). In recent decades actuaries have also worked with catastrophe models. Catastrophe modelling (or cat modelling) is the process of using computer models to estimate losses that may be sustained due to a catastrophic event such as a flood or drought. Catastrophe models may also calculate the role of adaptation in minimising risks but do not generally calculate the role of mitigation by green infrastructure in their assessments. The Eco:Actuary is a spatially detailed catastrophe model designed to determine mitigation of risk by specific configurations of green infrastructure (GI) and by asset adaptation. It is intended to help understand the asset value protected by GI, alongside other co-benefits of GI (i.e. other ecosystem services).

The Eco:Actuary is designed to help advise risk reduction and resilience to avoid losses. Like most catastrophe models the Eco:Actuary is focused on financial impact, not loss of life and must include probability and severity of loss mitigated (the annualised average loss - AAL). It must work with imperfect information and at a catchment scale. It must connect and add value to other CAT models (by being freely available, opening up an API, and using open formats). It must work fast and be focused on the short term (most insurance transactions are annual). Uncertainty is important so the Eco:Actuary must communicate outcomes relative to uncertainty and make non modelled perils, limitations and multi-hazard interactions transparent. As well as calculating a baseline asset value at risk, the Eco:Actuary needs to allow climate, land use, socio-economic development scenarios in order to better understand changing risk and the role of green and grey infrastructure investments. The intended audience includes insurers, large business, governmental and non-governmental investors, and

development and conservation organisations. To comply with ASOP No. 38, any user of the EcoActuary must understand their reliance upon it, understanding of it, and ensure appropriate, validated, use.

The Eco:Actuary must provide additionality upon the existing suite of CAT models. This is achieved through its free and open format (in contrast to many cat models), its use of global datasets for spatially detailed internationally consistent predictions and its focus on adaptation and mitigation by green infrastructure. It a changing insurance market focused on Green Bonds and other financial instruments for reducing risk through mitigation and adaptation (in addition to the usual insurance based risk reduction), it is more and more important to know how different strategies for economic and environmental investment and development may affect risk profiles. At the very least Eco:Actuary provides those using existing cat models to run a comparator for their case studies using global data and thereby understand better the uncertainties involved.

The Eco:Actuary will be a coupled software/hardware model that couples web-based spatial software decision support with some of the Internet of Things (IoT) instruments developed by the FreeStation project that will both collect and receive data from the Eco:Actuary platform to support continuous model calibration through measurement of climate, soil moisture (drought) and flow (flood) data. This will also support the now casting functionality proposed in which the system will combine spatial data with near real time inputs to understand near-term risk and response.

WHAT THE ECO:ACTUARY PROVIDES

The EcoActuary will calculate multi-hazard risk and risk mitigation by nature-based solutions and through asset adaptation including the co-benefits of risk mitigating natural capital. It provides:

- A detailed phenomenological and process model, coupling elements of WaterWorld and Co$tingNature PSS and new functions
- A valuation interface for connection to others' valuation data
- A spatial model capable of application at scales from local to global (1ha, 1km or 10km spatial resolution)
- All required data supplied globally, from Earth Observation and OpenStreetMap
- Fast results (full analysis in 20-60 minutes)
- A simple to use interface (web-based, firefox or chrome, no GIS reqd)
- Uncertainty and validation tools
- Sophisticated land use and management scenarios
- Interventions for DRR through mitigation and adaptation
- Results downloadable in GIS formats

- Training materials

The Eco:Actuary helps map the following for data poor areas globally:

- Ecosystem-service-relevant multi-hazard potential (starting with flood and drought)
- Relative, economic and insurance exposure to these potential hazards
- Potential damage and disruption losses including:
  - Replacement value (pilot version), productivity disruption value (final version)
  - Utilities disruption value, Travel time disruption value (final version)
  - Supply chain disruption value(final version)
- Potential and realised hazard mitigation services provided by existing and planned natural capital and their relative and economic value
- Relative and economic value of co-benefits of natural capital
- Economic values and trade-offs mapped in EcoActuary with coefficients required of user

It can help answer questions like: What is the financial exposure to risk at the catchment to national scale?
How is this exposure affected by new built-infrastructure? How is this exposure mitigated by (existing or planned) green-grey mitigation strategies and what are their co-benefits/co-disbenefits? How can asset adaptation reduce damage and increase resilience?

AUDIENCE AND POTENTIAL USE CASES

The audience and potential use cases for Eco:Actuary include the following:

- **CAT modellers.** It is always better to use more than one model (AIRS, RMS, EQECAT, HAZUS)
- **Organisations with assets.** For scenario modelling of likely insured and uninsured losses for suites of assets to help define best portfolio of retained and transferred risk (risk finance optimisation).
- **Developers, planners, governments and other investors (eg World Bank).** To help identify risks that existing and proposed developments are exposed to in the short and long term. Helps understand impacts of new green infrastructure on risk patterns locally and downstream.
- **Environment and Conservation NGOs.** To enable evaluation of different green infrastructure investments for EbA (Ecosystem based adaptation to climate change) and risk management co-benefits of biodiversity conservation or ecosystem services investments.

- **Insurers and risk assessors, catastrophe modellers**. For open, rapid, free additional risk assessment tool, especially for data poor areas. Impacts of climate and land use, infrastructure and asset growth, value growth. To help with new insurance industry focus on incentivising risk mitigation measures.
- **Re-insurers, capital markets (green, CAT bonds), rating agencies, regulators**. To enable assessment of global risk portfolios using consistent methods and data. Helps identify concentration of risk and options for risk mitigation, diversification.
- **Emergency services, disaster planning authorities, DRR.** For hazard awareness, risk assessment for effective regional scale emergency planning investment
- **Academics and students.** To help in education around risk, exposure, insurance and impacts of climate change and climate change adaptation.

USES AND POTENTIAL MIS-USES

EcoActuary is for regional to national level scenario modelling of potential economic losses for hazard events of different frequency, distribution and type. It is also for understanding role of green infrastructure and asset adaptation in changing risk and magnitude of loss locally and downstream (and co-benefits) and analysis of possible impacts of scenarios for climate and land use, on downstream (insured) assets (of changing value, growth). It enables understanding of uncertainty and of what is not yet possible to model well. It is free and open so facilitates comparison and inter-operability with other models (through an academia-industry collaboration). It also enables analysis of global risk portfolios with consistent data and methods and provides multi-hazard analysis, on a process modelling basis at high spatial detail. In this way it can also facilitate hazard and exposure visualisation and education. EcoActuary is not for detailed pixel or building level modelling of the inundation extent or depth from a specific rainfall event in a specific location or detailed flood risk or multi-hazard mapping for planning regulation of specific developments and associated defenses. Neither is it suitable for engineering and hydraulic analysis for adaptation decision-making. Eco:Actuary, as any model, is only as good as the quality of the input data. As Eco:Actuary relies on the resolution of its input earth observation data, the model cannot accurately model the effect of very small-scale NBS interventions or street level flood risk.

PILOT VERSION OF THE ECOACTUARY: METHODS

This document does not provide detail on methods since it reports on a pilot version still in development. The overall methodology is described here. Eco:Actuary uses probabilistic catastrophe risk modelling. We first calculate the *potential* risk of *hazard*, then the spatial distribution of asset value. We then bring together information on the realised risk of hazard, vulnerability and insurance conditions to create an assessment of potential financial losses in a given year. This is done first for a baseline simulation under current asset distribution, climate,

land use conditions and then again as a scenario for climate or land use change or an investment intervention in mitigation by green, grey infrastructure or adaptation of the assets.

Potential risk of hazard. The flood model only is described in the pilot version. Eco:Actuary currently uses a rainfall intensity frequency distribution (adaptable by the user where historical observations are available) coupled with global rainfall maps to simulate 12000 events sampled from the distribution which indicate where, how frequently and with what intensity and volume rainfall falls.

[R]ealised risk of hazard. The flood storage metrics of WaterWorld (see D2.1-D2.3) are used to calculate retention and thus runoff after green mitigation infrastructure is accounted for.

Asset [Va]lue distribution. In the pilot version, OpenStreetMap data (OSM) is used alongside valuation data by asset class and asset types to map asset value spatially. The pilot version covers only replacement values [USD].

[Vu]lnerability. Vulnerability is considered to be damage at given intensity of event and is parameterised for each asset type, hazard type and hazard intensity in a method similar to the mean damage ratio (MDR). MDR for flooding is parameterised as the fraction of full replacement value at given ratio of simulated flow to long term average max. monthly flow. It depends on exposure type (residential, commercial, industrial) which determine the height of buildings and the asset value at different heights from the ground (and thus susceptible or otherwise to inundation). MDR also depends on insurance coverage: eg building, +contents, +business interruption, though this is not currently considered.

[In]surance conditions include the fraction of value that is liable *i.e.* the share of loss between policyholder (*i.e.* the excess), insurer, reinsurer and any payout limit. These are not yet coded in the pilot.

Financial Loss is thus a function of ([R],[Va],[Vu],[In]) and can be expressed in terms of annual (loss) exceedance probability for example.

PILOT VERSION OF THE ECOACTUARY: GUIDELINES

This is a quick start overview of the Eco:actuary process - a more detailed user guide will be accessible from the Eco:actuary website.

Creating an account

Open the Eco:Actuary website (www.policysupport.org/ecoactuary) in Firefox or Chrome browser (system may not work well with Microsoft browsers). If you have not already done so, set up a free user account, by first clicking on **create account** on the left hand menu (Figure 1). When you receive your confirmation email you can then login. System and model documentation that is still being developed can be accessed under **help** on the left hand menu.

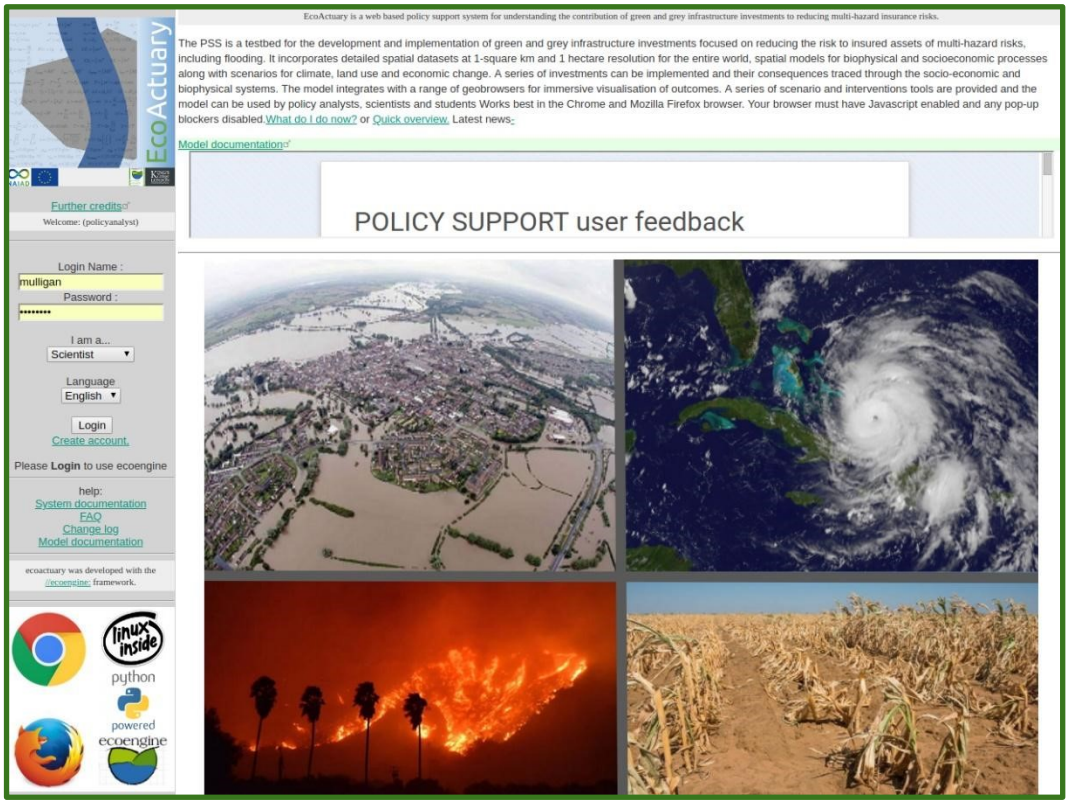


Figure 1. Welcome page of eco:actuary where users create an account and login.

Define Area

Move the Google map until the crosshair in the centre of the map is above your area of interest, or type a place name or coordinates (latitude, longitude) in the green 'Find' box and press GO. The defined area for simulation will be the "tile" (square) area containing this point. The size of the tile can either be a ten degrees (low resolution) or one degree tile (high resolution), according to the resolution selected. If a country or global basin is preferable to the tile, then choose from the list of countries and basins available in the drop down box. Figure 2 shows the area selected as 'UK of Great Britain and Northern Ireland [Country, 1km] which means this area will be run for the entire country at the 1km spatial resolution.

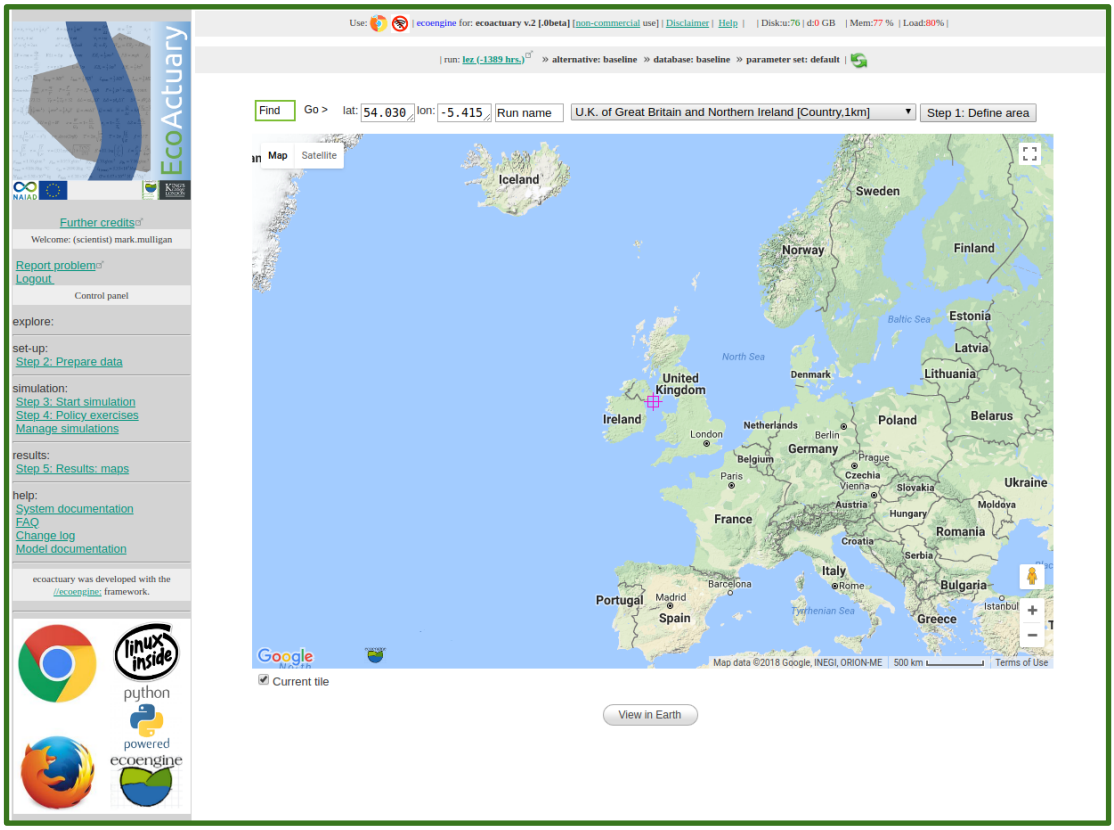


Figure 2. Defining the area of the run as 'UK of Great Britain and Northern Ireland at 1km resolution.

Prepare Data

This step is where the system accesses all data about your site stored on our global databases. If any have not been selected by a previous user you will need to build (extract and format) them so click '*Build missing maps*' if this button appears on this page. When they are built, you will be asked to click '*prepare data*' again to list them. Once all input datasets are ready, or if the 'Build' stage was not necessary, click "**Copy data to your workspace**" at the bottom of the page. This will copy all the data to your workspace on the ecoengine servers, (not to your local computer). After this you can view the data maps using the "*geobrowse*" button as shown in Figure 3. If the data is licenced for re-distribution then the "*download*" link will be active.

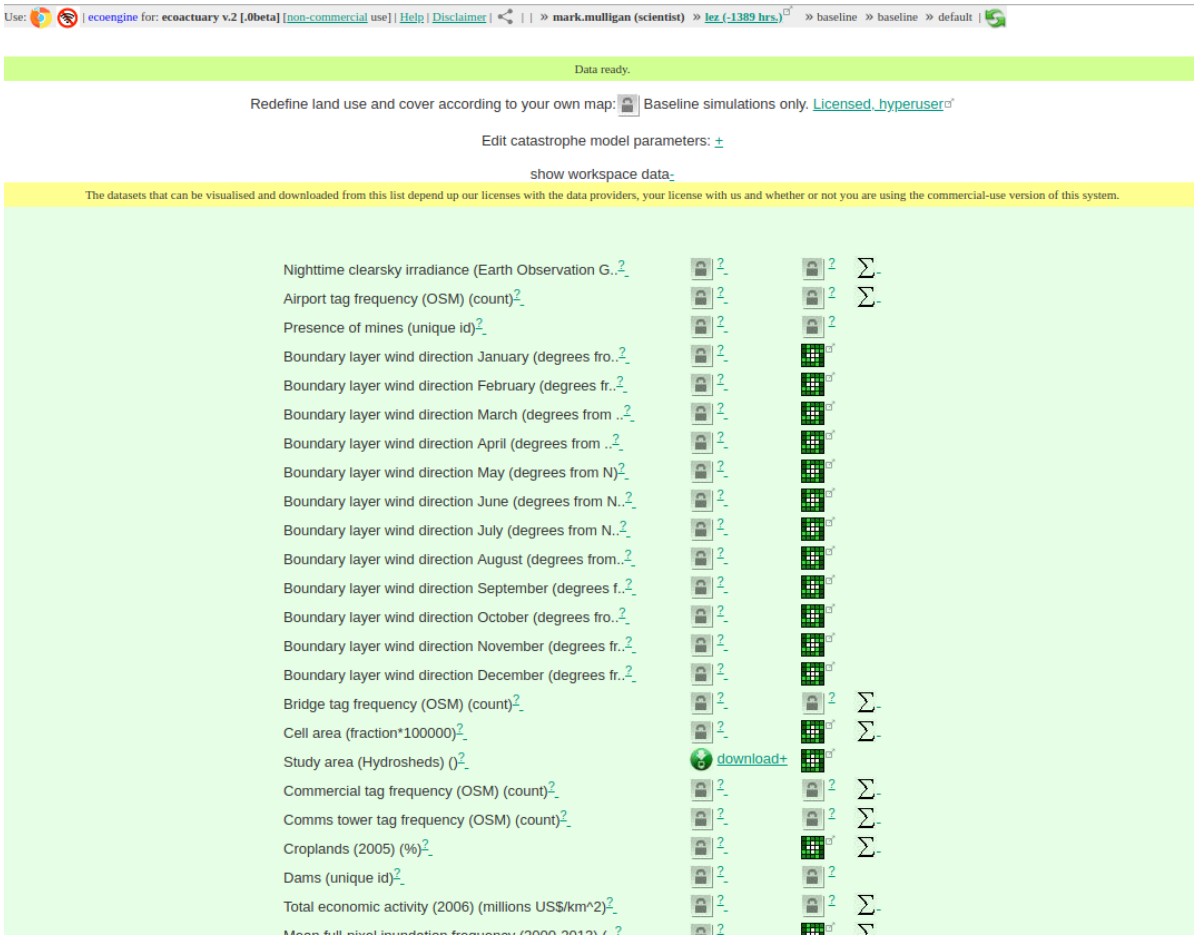


Figure 3. The data from the Simterra servers can be viewed and downloaded according the licensing agreement.

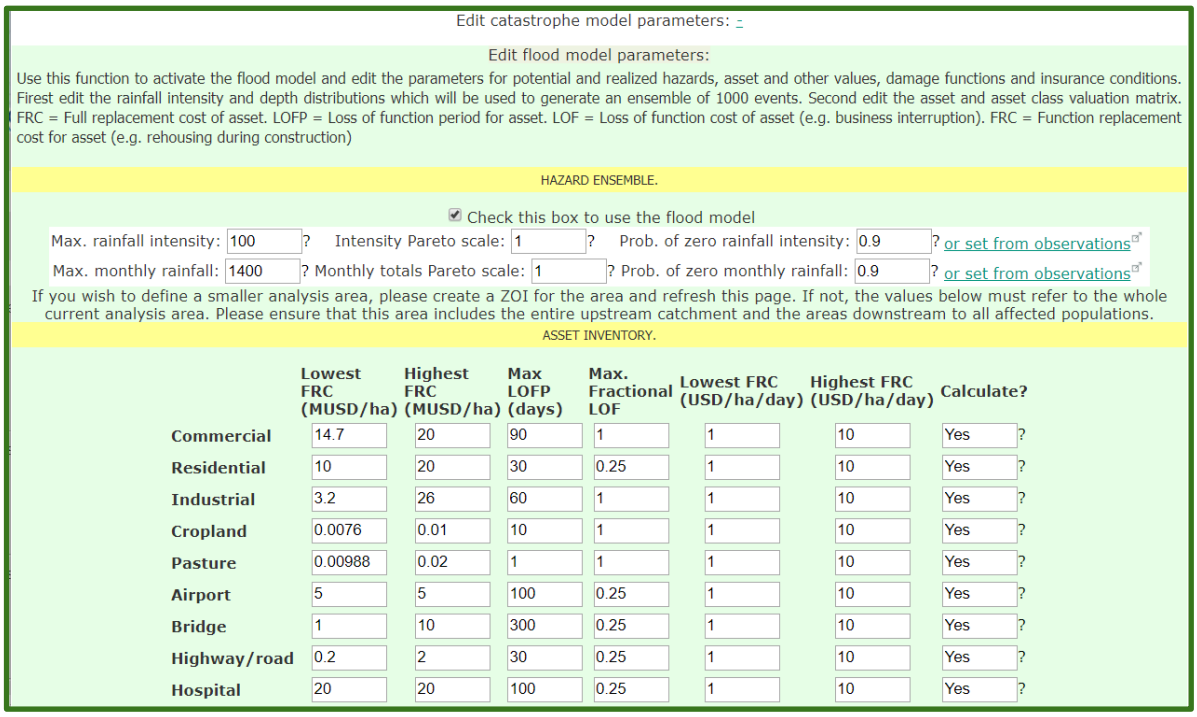
Edit catastrophe model parameters

Hazard ensemble

The hazard ensemble provides the frequency distribution of rainfall event intensity and size from which the 12000 samples are chosen and run. They can be set from a couple of parameters (with default supplied, see figure 4) and will eventually also be set from input long term, high frequency rainfall observations. There is also the potential here to connect to connect FreeStation rainfall gauges. The hazard ensemble differs between hazard types. Only flooding is currently implemented.

Asset inventory

The asset inventory lists asset classes and asset types and allows the user to specify full replacement costs (FRC), loss of function (LOF) costs and periods and function replacement costs (FOC) as well as an indication of whether the specific asset class should be included in the calculation or not (Figure 4). The asset inventory is the same for all hazard types.


Edit catastrophe model parameters: -

Edit flood model parameters:

Use this function to activate the flood model and edit the parameters for potential and realized hazards, asset and other values, damage functions and insurance conditions. Firest edit the rainfall intensity and depth distributions which will be used to generate an ensemble of 1000 events. Second edit the asset and asset class valuation matrix. FRC = Full replacement cost of asset. LOFP = Loss of function period for asset. LOF = Loss of function cost of asset (e.g. business interruption). FRC = Function replacement cost for asset (e.g. rehousing during construction)

HAZARD ENSEMBLE.

Check this box to use the flood model

Max. rainfall intensity: 100 ? Intensity Pareto scale: 1 ? Prob. of zero rainfall intensity: 0.9 ? or set from observations

Max. monthly rainfall: 1400 ? Monthly totals Pareto scale: 1 ? Prob. of zero monthly rainfall: 0.9 ? or set from observations

If you wish to define a smaller analysis area, please create a ZOI for the area and refresh this page. If not, the values below must refer to the whole current analysis area. Please ensure that this area includes the entire upstream catchment and the areas downstream to all affected populations.

ASSET INVENTORY.

	Lowest FRC (MUSD/ha)	Highest FRC (MUSD/ha)	Max LOFP (days)	Max. Fractional LOF	Lowest FRC (USD/ha/day)	Highest FRC (USD/ha/day)	Calculate?
Commercial	14.7	20	90	1	1	10	Yes ?
Residential	10	20	30	0.25	1	10	Yes ?
Industrial	3.2	26	60	1	1	10	Yes ?
Cropland	0.0076	0.01	10	1	1	10	Yes ?
Pasture	0.00988	0.02	1	1	1	10	Yes ?
Airport	5	5	100	0.25	1	10	Yes ?
Bridge	1	10	300	0.25	1	10	Yes ?
Highway/road	0.2	2	30	0.25	1	10	Yes ?
Hospital	20	20	100	0.25	1	10	Yes ?

Figure 4. Interface for editing catastrophe model parameters and asset inventory in EcoActuary.

Damage functions

The damage functions differ for each hazard type. Only flooding is currently implemented. For flooding we specify the damage function for each asset class and asset type at different depths of inundation as shown with dummy data in Figure 5. These data will be set to representative values from standard sources such as the MCM, Smith et al. (1994), Pistrika et al. (2014), Scawthorn et al. (2006), but users will be able to edit the damage functions per asset and asset class for their own data.

DAMAGE FUNCTIONS.

	<0.5m FRC (fraction)	0.5-2m FRC (fraction)	2m+ FRC (fraction)	<0.5m LOFP (fraction)	0.5-2m LOFP (fraction)	2m+ LOFP (fraction)
Commercial	0.1	0.5	0.75	0.1	0.5	0.75 ?
Residential	0.1	0.5	0.75	0.1	0.5	0.75 ?
Industrial	0.1	0.5	0.75	0.1	0.5	0.75 ?
Cropland	0.1	0.5	0.75	0.1	0.5	0.75 ?
Pasture	0.1	0.5	0.75	0.1	0.5	0.75 ?
Airport	0.1	0.5	0.75	0.1	0.5	0.75 ?
Bridge	0.1	0.5	0.75	0.1	0.5	0.75 ?
Highway/road	0.1	0.5	0.75	0.1	0.5	0.75 ?
Hospital	0.1	0.5	0.75	0.1	0.5	0.75 ?
Hydropower plant	0.1	0.5	0.75	0.1	0.5	0.75 ?
Pipeline	0.1	0.5	0.75	0.1	0.5	0.75 ?
Power utility	0.1	0.5	0.75	0.1	0.5	0.75 ?
Railway	0.1	0.5	0.75	0.1	0.5	0.75 ?
Retail	0.1	0.5	0.75	0.1	0.5	0.75 ?
School	0.1	0.5	0.75	0.1	0.5	0.75 ?
Telecoms	0.1	0.5	0.75	0.1	0.5	0.75 ?
University	0.1	0.5	0.75	0.1	0.5	0.75 ?
Waste water plant	0.1	0.5	0.75	0.1	0.5	0.75 ?
Water treatment plant	0.1	0.5	0.75	0.1	0.5	0.75 ?

MITIGATION INFRASTRUCTURE.

Figure 5. Interface for editing asset inventory parameters in Eco:Actuary.

Mitigation infrastructure

The mitigation infrastructure component (Figure 6) allows the user to identify the green infrastructure mitigation in place that contributed to flood storage and infiltration related mitigation. The details of the floodplain, water body etc. can be entered here by changing the default values.

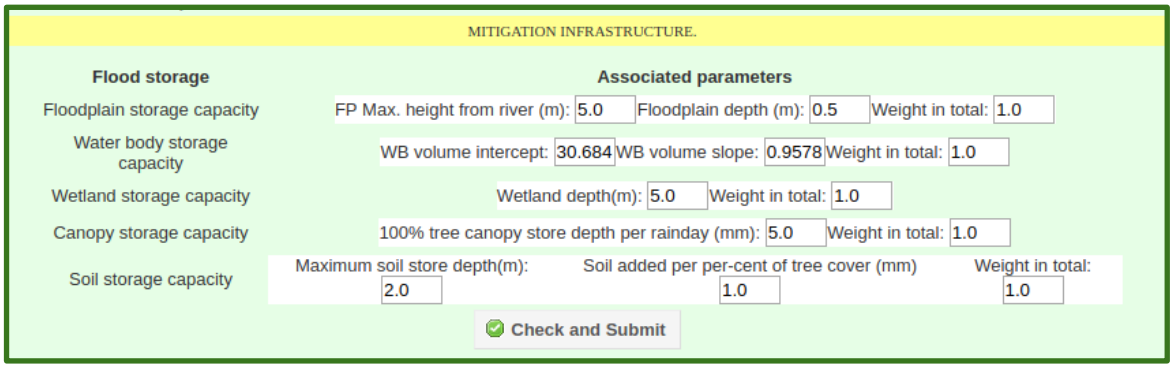


Figure 6. Interface for editing natural mitigation infrastructure parameters in Eco:Actuary.

Run simulation

The next step is to Click “start simulation” in the left hand navigation bar in the welcome page for Eco:Actuary. The screen shown in figure 7 appears; click **Start** and the programme is now running remotely on the ecoengine servers.

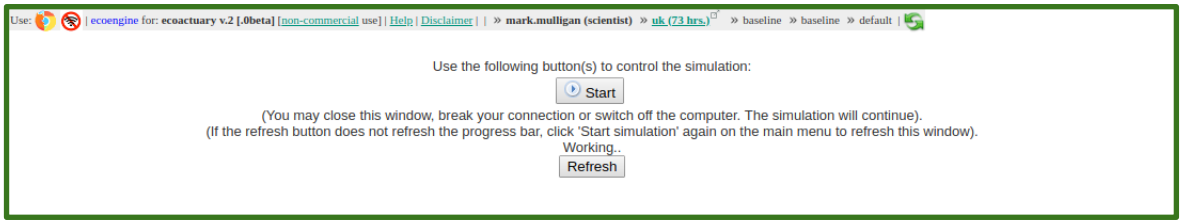


Figure 7. Running the eco:actuary simulation.

Results maps

To see the results return to the home page and click *Step 5 - Results maps*. A large number of GIS functions and calculations are available for processing and displaying the results, for example visualisation in Google maps; or the results can be downloaded for use in a GIS software on your local computer. Figure 8 shows results displayed in the Google maps viewer for number of asset types (left) and asset of greatest value (right).

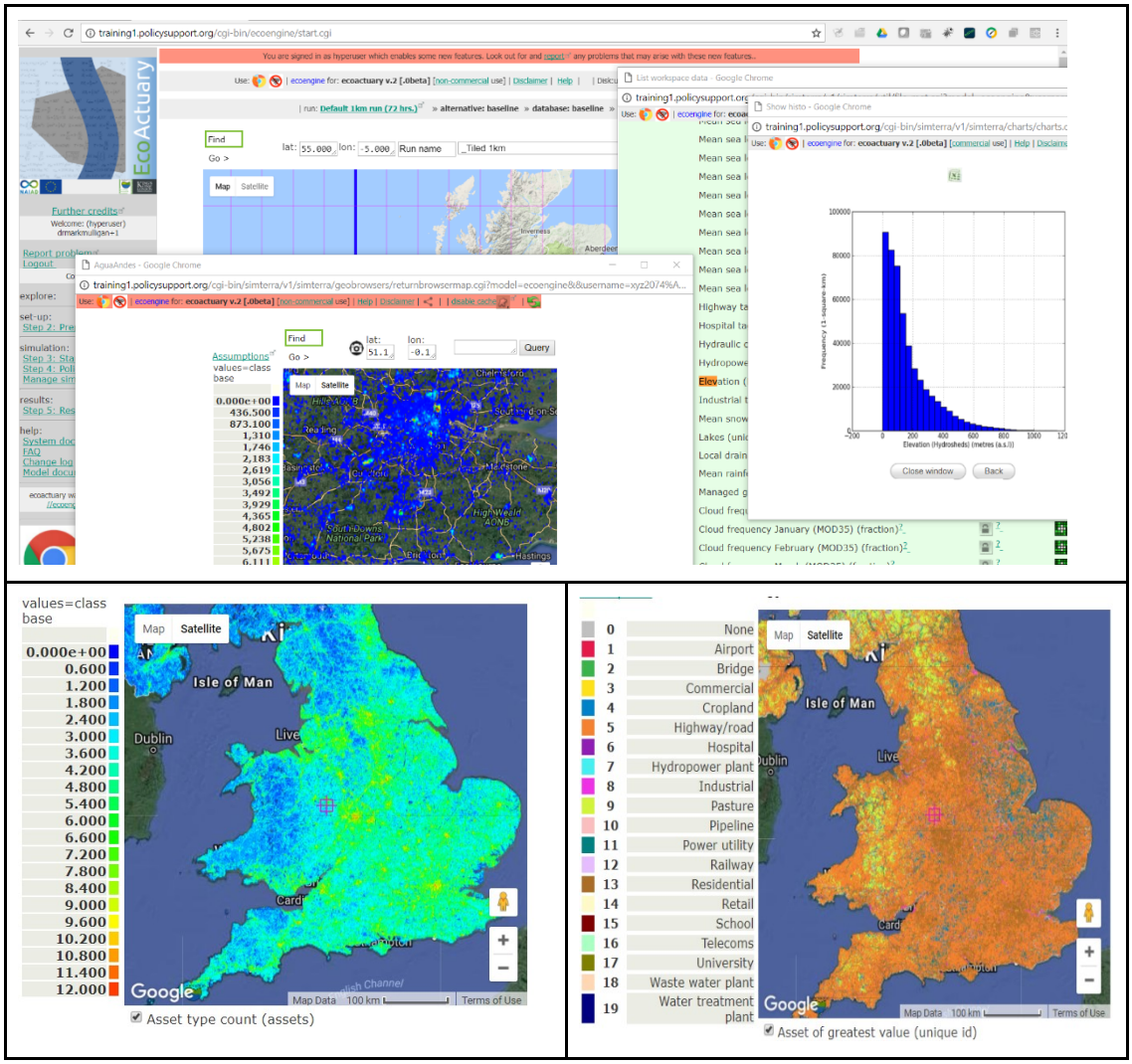


Figure 8. Some results examples: Asset number (left) and asset of greatest value (right).

2. Conclusions

The pilot version of Eco:Actuary at www.policysupport.org/ecoactuary provides the opportunity to highlight the potential uses and value of the tool. It is now possible for project partners and insurance stakeholders to begin trialling the tool, thereby enabling further co-development. The next steps include the following:

(a) continued engagement and training of project partners for application of WaterWorld, Co$tingNature and Eco:Actuary in the demo regions (Arnout van Soesbergen, Sophia Burke)
(b) Continued engagement and training of insurance industry and and conservation stakeholders based in London and the UK to facilitate co-development of Eco:Actuary, alongside application of WaterWorld and Co$tingNature, its integration with industry workflows and initiatives and feedback (Caitlin Douglas and Sophia Burke)
(c) Continued development of EcoActuary algorithms and spatial datasets for flood and drought (Mark Mulligan and Arnout van Soesbergen)
(d) Continued development of FreeStation integration with EcoActuary and development of a monitoring network at selected demo sites (Mark Mulligan, Arnout van Soesbergen, Sophia Burke)

3. References

Arthur 2017. Catastrophe Modelling - Model Vendors vs Open Source Models. News & Articles. Arthur Website. Last Updated: 16 October 2017. Accessed 26/04/2018 Available: http://arthur.co.uk/catastrophe-modelling-model-vendors-vs-open-source-models/

FEMA 2018. Hazus. Federal Emergency Management Agency Website, U.S. Department of Homeland Security Website. Last Updated: 04/24/2018. Accessed: 26/04/2018 Available: https://www.fema.gov/hazus

Grossi, P and TeHennepe C. 2008. Catastrophe modelling fundamentals. Pgs 7 - 9 in The Review Worldwide Reinsurance: A Guide to Catastrophe Modelling. Informa UK Ltd. 24 pages

LMA (Lloyds Market Association) 2013. Catastrophe Modelling Guidance for Non-Catastrophe Modellers. June 2013. 14 pages

LMA (Lloyds Market Association) 2017. Understanding Uncertainty in Catastrophe Modelling for Non-Catastrophe Modellers. January 2017. 12 pages

Maynard, T., Beecroft, N., Gonzalez, S., and Restell, L. 2014. Catastrophe Modelling and Climate Change.Lloyds. 41 pages

Pistrika, A., Tsakiris, G. and Nalbantis, I., 2014. Flood depth-damage functions for built environment. Environmental Processes, 1(4), pp.553-572.

RMS 2018. RMS Europe Inland Flood HD Models Datasheet. RMS website. Date Accessed: 18 April 2018 Available: http://forms2.rms.com/rs/729-DJX-565/images/rms-european-inland-flood-datasheet.pdf

Sampson, C. C., Fewtrell, T. J., O'Loughlin, F., Pappenberger, F., Bates, P. B., Freer, J. E., and Cloke, H. L. 2014. The impact of uncertain precipitation data on insurance loss estimates using a flood catastrophe model, Hydrol. Earth Syst. Sci., 18, 2305-2324, https://doi.org/10.5194/hess-18-2305-2014

Scawthorn, C., Flores, P., Blais, N., Seligson, H., Tate, E., Chang, S., Mifflin, E., Thomas, W., Murphy, J., Jones, C. and Lawrence, M., 2006. HAZUS-MH flood loss estimation methodology. II. Damage and loss assessment. Natural Hazards Review, 7(2), pp.72-81.

Smith, D.I., 1994. Flood damage estimation- A review of urban stage-damage curves and loss functions. Water S. A., 20(3), pp.231-238