

**USING SPATIAL INFORMATION TO SUPPORT DECISIONS ON
SAFEGUARDS AND MULTIPLE BENEFITS FOR REDD+**



STEP-BY-STEP TUTORIAL: VERSION 1.0
EVALUATING THE IMPORTANCE OF FORESTS FOR
WATER PROVISION AND LIMITING SOIL EROSION,
A MODELLING APPROACH USING WATERWORLD



The UN-REDD Programme is the United Nations Collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries. The Programme was launched in September 2008 to assist developing countries prepare and implement national REDD+ strategies, and builds on the convening power and expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and UN Environment.

The UN Environment World Conservation Monitoring Centre (UNEP-WCMC) is the specialist biodiversity assessment centre of UN Environment, the world's foremost intergovernmental environmental organisation. The Centre has been in operation for over 35 years, combining scientific research with practical policy advice.

Prepared by Arnout van Soesbergen and Xavier de Lamo

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Contents

1. Introduction.....	1
2. Running a baseline simulation	3
2.1. Getting started.....	3
2.2. Set up, run and view baseline results	4
2.2.1. Step 1: Define run	4
2.2.2. Step 2: Prepare data	5
2.2.3. Step 3: start simulation.....	8
2.2.4. Step 5: results: maps.....	9
2.2.4.1. Pixel-based water balance results	10
2.2.4.2. Aggregated water balance results	12
2.2.5. Other outputs	12
3. Running a scenario simulation	14
3.1. Set up, run and view scenario results	14
3.1.1. Step 4: policy exercises -setting up a scenario.....	14
3.1.2. Step 4: policy exercises: running the scenario	17
3.1.3. Step 4: policy exercises: examining results.....	18
3.1.3.1. Change in water balance	19
3.1.3.2. Change in runoff	21
3.1.3.3. Change in soil erosion.....	22
4. Additional results and managing simulations	23
4.1. Additional results	24
4.1.1. Step 6: Results: stats	24
4.1.2. Step 7: Results: narrative	24
4.2. Manage simulations.....	25
4.3. System and model documentation.....	26
Annex I: Using WaterWorld with your own land-cover data.....	25
Annex II: Scenario: Reforesting non-forested areas.....	33

1. Introduction

REDD+ is a voluntary climate change mitigation approach that has been developed by Parties to the UNFCCC. It aims to incentivize developing countries to reduce emissions from deforestation and forest degradation, conserve forest carbon stocks, sustainably manage forests and enhance forest carbon stocks. This will involve changing the ways in which forests are used and managed, and may require many different actions, such as protecting forests from fire or illegal logging, or rehabilitating degraded forest areas.

REDD+ has the potential to deliver multiple benefits beyond carbon. For example, it can promote biodiversity conservation and secure ecosystem services from forests such as water regulation, erosion control and non-timber forest products. Some of the potential benefits from REDD+, such as biodiversity conservation, can be enhanced through targeting areas where actions can have the greatest impact. Spatial analysis can be used to help identify such areas.

The purpose of this tutorial series is to help participants in technical working sessions, who are already skilled in GIS, to undertake analyses that are relevant to REDD+. The tutorials have been used to build capacity in a number of countries to produce datasets and maps relevant to their spatial planning for REDD+, and to develop such map products. Maps developed using these approaches appear in a number of publications whose aim is to support planning of strategy options that enhance biodiversity and ecosystem services as well as delivering climate change mitigation (see <http://bit.ly/mbs-redd> for country materials). There is of course no requirement for countries to use the approaches described in these tutorials.

Where countries have identified biodiversity conservation as a goal for REDD+, and to be consistent with the Cancun safeguards for REDD+ on protecting biodiversity, it is useful to identify areas where specific REDD+ actions are feasible and can protect threatened species. It may also be useful to identify areas outside forest where threatened species may be vulnerable to the displacement of land-use change pressures or to afforestation.

Many countries have identified that it is a priority for their REDD+ actions to maintain or enhance freshwater provisioning and/or soil erosion control. Maps that quantify these services in the presence or absence of forest can assist in REDD+ planning.

This tutorial demonstrates a modelling methodology using the freely available¹ web-based WaterWorld model and policy support system (www.policysupport.org/waterworld) to evaluate the importance of forests for water provisioning and limiting water-driven soil erosion. For example, forests may stabilize soils on steep slopes in areas of high rainfall, benefiting downstream water uses such as human consumption, hydroelectric power generation and river navigation. The modelling and analysis presented in this tutorial can be used to help answer questions such as:

- Where is forest loss likely to result in increased erosion and consequent sedimentation?
- Where might retaining or restoring forests play an important role in retaining soil/reducing sedimentation?

¹ For non-commercial use only.

- What is the role of forests in the local water balance and where is forest loss likely to have a large effect on it?

WaterWorld (Mulligan, 2013²) is a fully distributed, globally applicable process-based spatial hydrological model that can be used to understand baseline hydrology and water resources as well as the potential impacts of land use, land management and climate change. It incorporates detailed remotely sensed and globally available spatial datasets allowing for the model to be run anywhere in the world at 1-ha (1-degree tiles) and 1-km (country, basin, 10 degree tiles) spatial resolutions without the need for users to supply data. However, you can also apply the model with your own datasets if you have purchased an advanced user license (see Annex 1). The system also includes spatial models for biophysical and socio-economic processes as well as scenarios for climate, land use and economic change. All outputs can be visualized and analysed in the web-based interface or downloaded in a variety of GIS formats.

There are a number of limitations to be aware of when using this software:

- It provides estimates of hydrology per pixel, for erosion especially, local sub-level characteristics have a large impact.
- It uses global data and assumptions which are not calibrated locally
- If your catchment crosses two tiles you have to run both separately and stitch the result together using GIS software
- The processing runs on WaterWorld's servers so only a limited number of simulations can be stored. (Results can be downloaded and runs deleted so you can run a new simulation)

In the context of REDD+, WaterWorld analysis was used in 2016 in a valuation report for Ethiopia, where it was used to look at forest soil erosion control on cropland in order to estimate their economic value of soil erosion control. It has also been used in working sessions to develop in-country capacity to use spatial decision-support tools (DST) to inform REDD+ planning. In Mongolia, this was done at provincial scale, where the importance of forests for water provisioning and limiting water-driven soil erosion was identified in consultation workshops as amongst the most valued services provided by forests.

- UNEP (2016) The contribution of forests to national income in Ethiopia and linkages with REDD+. United Nations Environment Programme: Nairobi.
- Narangerel, Z., Nandin-Erdene, G., de Lambo, X., Simonson, W., Guth, M. and Hicks, C. (2016) Using spatial analysis to explore potential for multiple benefits from REDD+ in Mongolia. Joint report of the Information and Research Institute of Meteorology, Hydrology and Environment (IRIMHE), UNEP World Conservation Monitoring Centre and Mongolia National UN-REDD Programme, Ulaanbaatar.

² Mulligan, M. (2013) WaterWorld: a self-parameterising, physically-based model for application in data-poor but problem-rich environments globally Hydrology Research 44 (5) 748–769. Doi:10.2166/nh.2012.217

3. Running a baseline simulation

3.1. Getting started

This tutorial will use the free non-commercial version of the WaterWorld model. This gives access to the basic system, accessing the full sophisticated model and modules but with limited storage of simulations and limited map analysis functionality and scenarios/policy options. For each step in this tutorial, there are also online narrated instruction videos available that can be used alongside it or as a recap on how to use the model. These videos are available here: <http://www.policysupport.org/self-paced-training/function-by-function-english> (English), <http://www.policysupport.org/self-paced-training/waterworld-spanish> (Spanish).

To access the WaterWorld model, go to www.policysupport.org/waterworld. Click on Access PSS here (scientist user level) if you already have an account for policysupport.org. If you don't have an account, click on Create an account. The PSS is designed to work with the **Google Chrome** or **Firefox** internet browsers. Using the system with Internet Explorer may result in odd behavior and is not recommended.

- Once you have set up an account and clicked on the correct link for scientist user level, you will see the below log in screen. Fill in your details (**login name and password**), leave the “I am a...” dropdown to the default **Scientist** and click **Login**.

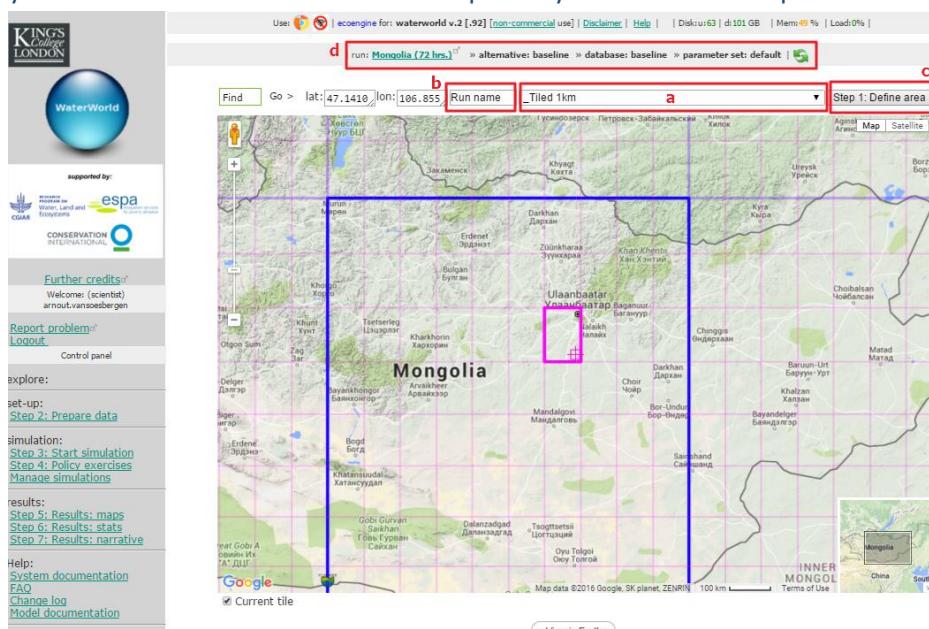
If you are in a training session, your trainer may have access to training servers and a user account for the duration of the training. In that case, access the model through the following web-link: <http://www.policysupport.org/waterworld/training> and follow the instructions from your trainer.

3.2. Set up, run and view baseline results

3.2.1. Step 1: Define run

- Once logged in, you will see the below screen with a map in the centre of the page. To set up a run for your area of interest you can:
 - Use the dropdown list (**a**) to select a basin or country,
OR
 - Type the name of a **place of interest** in the **Find box** and click go.
OR
 - If your country or basin is not available, you can **move the map** with your mouse and **select an area** indicated by the blue 10-degree (~1000 x 1000 km) tile or the purple 1-degree (~100 x 100 km) tile. The highlighted tile will be the area selected for the run. The model resolution for countries, basins and the blue 10 degree tiles is by default ~ 1 square kilometre. The model resolution of the purple 1-degree tiles is ~1 square hectare. Simulation time is the same for both scales, unless the tile has not been run before, in which case it can take up to 24 hours or more. It is also possible to run a simulation for a whole basin or country, which will usually take longer.

To select either the blue or purple tile (and thus resolution) for your area, **select Tiled 1km or Tiled 1ha from the dropdown list (a)**. If your area of interest falls between different tiles, you will need to run the simulations separately and stitch the maps later in a GIS software.



- When you have selected your tile, basin or country of interest and selected the model resolution (tiles only), you need to **give your run a name (b)**.
- When you are happy with the selection and have given the run a name, **click on Step 1: define area (c)**. This will set your simulation area.

- d. Information on your current run will always be displayed at the top above the map (**d**). Click the **refresh button** to make sure this is updated.

You can also access more information about your run by clicking on the hyper linked run name.

3.2.2. Step 2: Prepare data

The next step is to prepare all the necessary data for a simulation. The model includes all necessary data to do a run, but data needs to be copied over from the data server to your personal workspace associated with your user account.

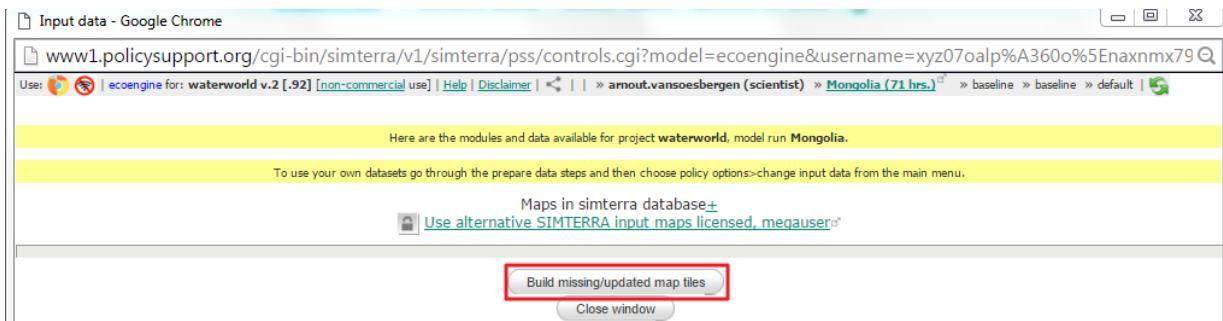
- To do this, click on **Step 2: Prepare data** on the control panel on the left (**a**). This will open up a new browser window where you can view the list of input data.
- Click on the **±** next to **Maps in SIMTERRA database** (**b**) to expand the list of input data.
- Click on the link **Copy data to your workspace** (**c**) to tell the system to copy over all the data to your workspace.

The screenshot shows the WaterWorld interface. On the left, there's a sidebar with logos for King's College London, CCAFS, and Conservation International, and links for 'Further credits', 'Report problem', and 'Logout'. The main area has a map of Mongolia with labels like 'Хөвсгөл нүүр бал', 'Усийнбозьрк', 'Петрэвэл-Заванхалайский', 'Логик', and 'Хилок'. Below the map, there's a search bar with 'lat: 47.1410 lon: 106.855 Run name: Tiled 1km'. At the bottom of the main area, there's a sub-menu titled 'Input data - Google Chrome' with several options. One option, 'Copy data to your workspace', is highlighted with a red box. Other options include 'Define WEAP control points', 'Define ROIs licensed, superuser', 'Mask according to rules licensed, superuser', and 'List baseline workspace data'.

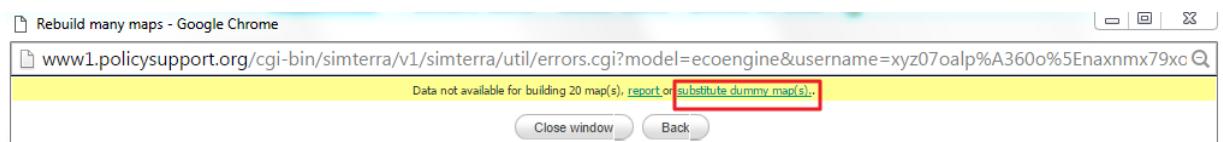
Box 1: Troubleshoot data issues

In some cases (i.e. if the model has not been run before for your selected region or data has been updated), you will need to build or update missing data. In that case, the below window will open and you can simply click on **Build missing/updated map tiles**

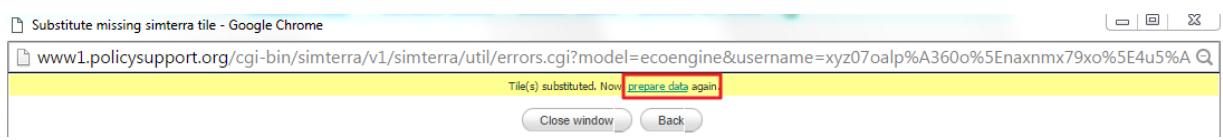
******IMPORTANT Note: This can take 72 hours, so if running in a training environment make sure that the tiles are built prior to the training******



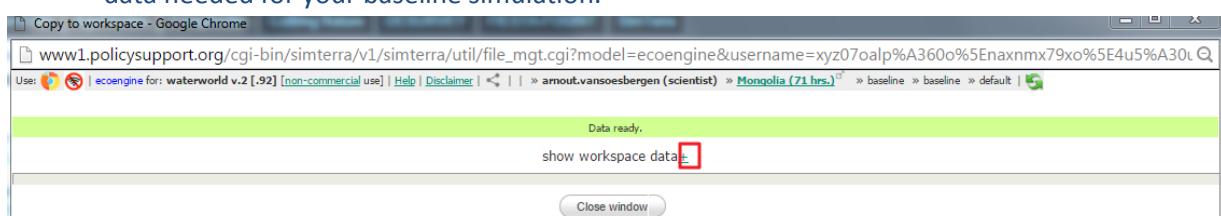
Data may not be available, in which case the system allows for the use of dummy maps (note: this is only the case for non-critical maps and it is unlikely that it will have a large effect on model results). If this is the case, the below screen will show and you can click **substitute dummy maps**. There is also the option to report missing maps.



The next window will inform you that the tiles have been substituted and you can click on the **prepare data** link to resume preparing data. This will bring you back to the main 'prepare data' page where you can click on **Copy data to your workspace**



- Once your data has been copied over to your workspace, the below screen will appear. Again, click on the ± next to **show workspace data** to expand the list of data. This will show all the data needed for your baseline simulation.



- Some datasets are available to download (indicated by: [download+](#)), while others are only available to view () and some datasets cannot be viewed or downloaded ().

This depends on the license associated with each dataset. However, all data can be used for the model run.

There are also sum icons on this page (Σ), click on these and then hover your mouse over result to show statistics for that dataset.

The screenshot shows a list of datasets available for download. The datasets listed are:

- Presence of mines (unique id)?
- Boundary layer wind direction January (degrees fro.)?
- Boundary layer wind direction February (degrees fr.)?
- Boundary layer wind direction March (degrees from ..)?
- Boundary layer wind direction April (degrees from ..)?
- Boundary layer wind direction May (degrees from N)?
- Boundary layer wind direction June (degrees from N..)?
- Boundary layer wind direction July (degrees from N..)?
- Boundary layer wind direction August (degrees from ..)?
- Boundary layer wind direction September (degrees f..)?
- Boundary layer wind direction October (degrees fro..)?
- Boundary layer wind direction November (degrees fr..)?
- Boundary layer wind direction December (degrees fr..)?
- Cell area (fraction*100000)?
- Study area (Hydrosheds) ()?
- Croplands (2005) (%)?

For each dataset, there are three icons: a download icon, a sum icon (Σ), and a detailed view icon. The download and sum icons are located in the top right corner of the list area.

Take a moment to review the default datasets for your study area. Consider whether the data fits with local knowledge and other data that is being used within related analyses. When using WaterWorld to assess the impact of forest cover and deforestation, reviewing the tree cover map is especially important. WaterWorld default tree cover map is MODIS-based, please consider whether this map is consistent with any available national forest maps. The map could also be reviewed by visually comparing it with recent satellite imagery in Google Maps using the functionalities available in WaterWorld. If the difference between the tree cover data and the satellite imagery or national forest maps are large, consider using a more accurate land-cover dataset. For instructions on how to upload and use your own land-cover map, see Annex I.

3.2.3. Step 3: start simulation

Once your data has been prepared, you can start a (baseline) simulation.

- Click on **Step 3: start simulation** on the control panel on the left (a). This will open up a new window where you can start the simulation.
- Click **Start** (b) in the new window to run the simulation. The progress bar will update you on what activity and how much time is left for the simulation. This should take no more than 20 minutes to run. If you close this window, the simulation will continue.

The screenshot shows the WaterWorld simulation progress window. The window title is "Current simulation - Google Chrome". The URL is "www1.policysupport.org/cgi-bin/simterra/v1/simterra/ps/controls.cgi?model=ecoengine&username=xyz07oalp%A360o%5Enaxnmx%79xo%5E4u5%A30u%A3l4&lang=en". The window displays the following information:

- Find: Go > lat:47.1410 lon:106.855 Run name: Tiled 1km Step 1: Define area
- Writing maps every timestep is licensed!
- Use the following button(s) to control the simulation:
 - Start** (b)
 - (You may close this window, break your connection or switch off the computer. The simulation will continue).
 - (If the refresh button does not refresh the progress bar, click Start simulation again on the main menu to refresh this window).
- Progress bar: 0 %
- activity : waiting| timestep: 0 of 48 Refresh

3.2.4. Step 5: results: maps

Note: in order to produce simulations of the hydrology, the model makes several simplifications and assumptions. In reality, in any area there will be some greater complexity and these assumptions may not be completely correct. This creates some uncertainty in the accuracy of the model simulations, for example the model assumes that all woody vegetation affects the hydrology in the same way, whereas specific tree species can affect the hydrology in different ways. Please take a look at the documentation to assess whether the main model assumptions match your knowledge of your study area.

(We have not missed a step - Step 4 is covered below, in section 4)

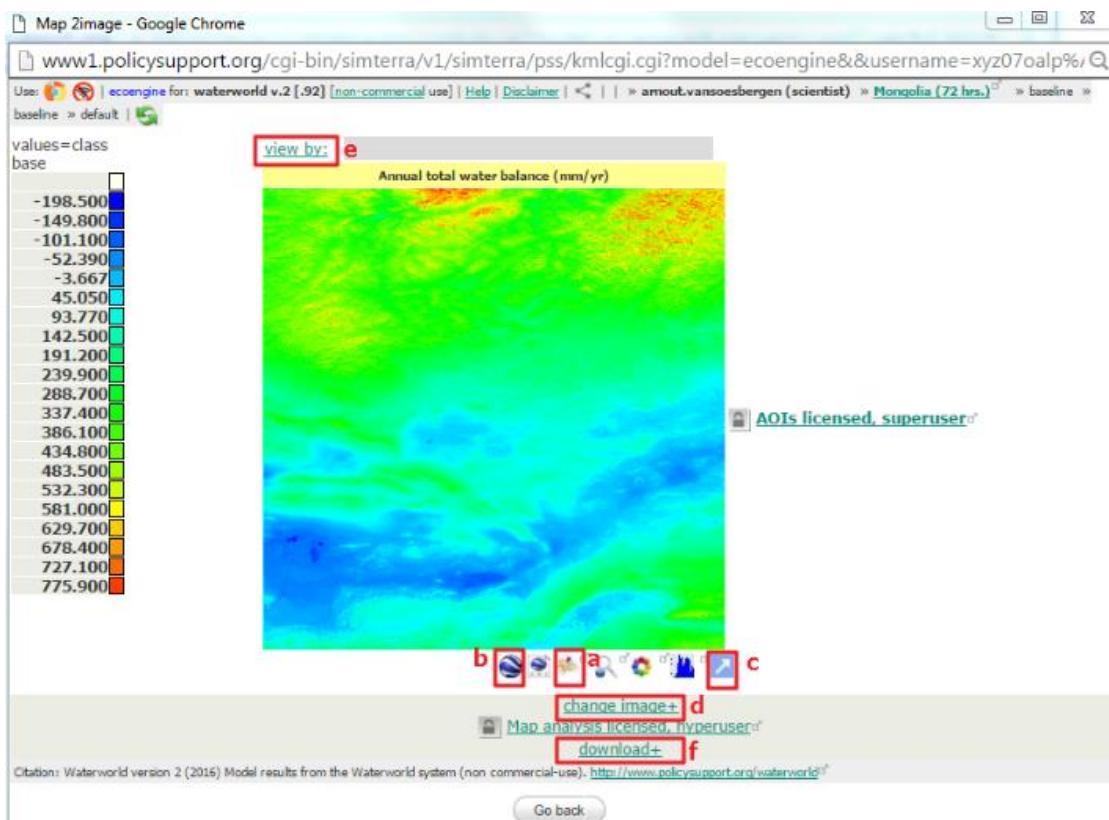
- When the simulation is finished you can view the spatial results of your simulation. Click on **Step 5: results: maps** on the control panel on the left (**a**). This will open a new window with a list of outputs.

Some of the other options available on this page (with ±) are only available to licensed user levels.

Name	Explanation	Show
Rainfall	Total annual (wind-driven) rainfall (mm/yr)	
Water balance	Local water balance (mm/yr) (rainfall+fog+snowmelt minus actual evapotranspiration (AET)). Where water balance is negative local AET is supported by upstream sources of water and/or groundwater	
Runoff	Total annual runoff (m³/yr). Calculated as water balance cumulated downstream. Negative water balance (AET>precipitation) in a cell consumes runoff from upstream.	
Hillslope net erosion	Hillslope net erosion (mm/yr). Net erosion (erosion minus deposition) on hillslopes	
Total net erosion	Total net erosion (mm/yr). Net erosion (erosion minus deposition) from hillslopes and channels (streams/rivers)	
Mean annual human footprint on water quality (pollution)	Mean percentage of water that may be polluted (human footprint index)	

You can browse the various result maps by clicking on the view icon next to the map descriptions.

- Click on the Water balance icon (**b**) in the **Show** column. This opens up the map of simulated annual total water balance in mm/year. This is based on long term mean incoming rainfall + simulated fog + simulated snowmelt minus the actual (simulated) evapotranspiration for each pixel.

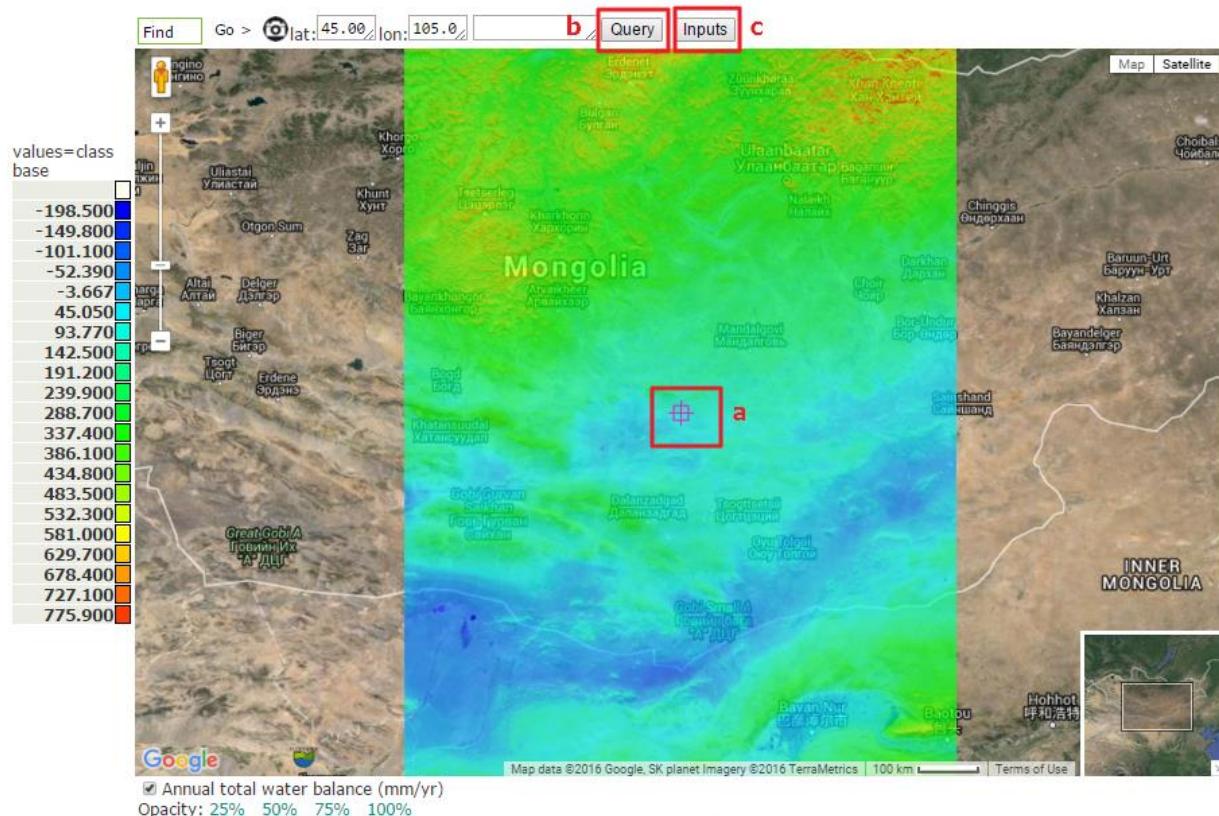


The browse map window provides a number of features that allow you to:

- View the map in context using Google maps (**a**) or overlaid on Google Earth (**b**) (requires Google Earth to be installed (free from https://www.google.com/intl/en_uk/earth/explore/products/desktop.html)).
- Pop out the map (**c**) which will open the map in a new window. This is useful if you want to compare maps as each time you click on the show map icon, it will refresh the main view window with the new map.
- Change the image (**d**) in terms of setting the minimum and maximum value to rescale the map (e.g. for only showing positive or negative numbers) and changing the colour scale options.
- The view by function (**e**) allows you to aggregate the map (average pixel-based values) by a range of other maps such as administrative boundaries, sub catchments, protected areas, important conservation areas and others.
- Finally, you can download the map as ascii, geotiff and other GIS formats. Click on the ± next to download (**f**), and select your preferred option. This will generate a download link for a zip file with the map.

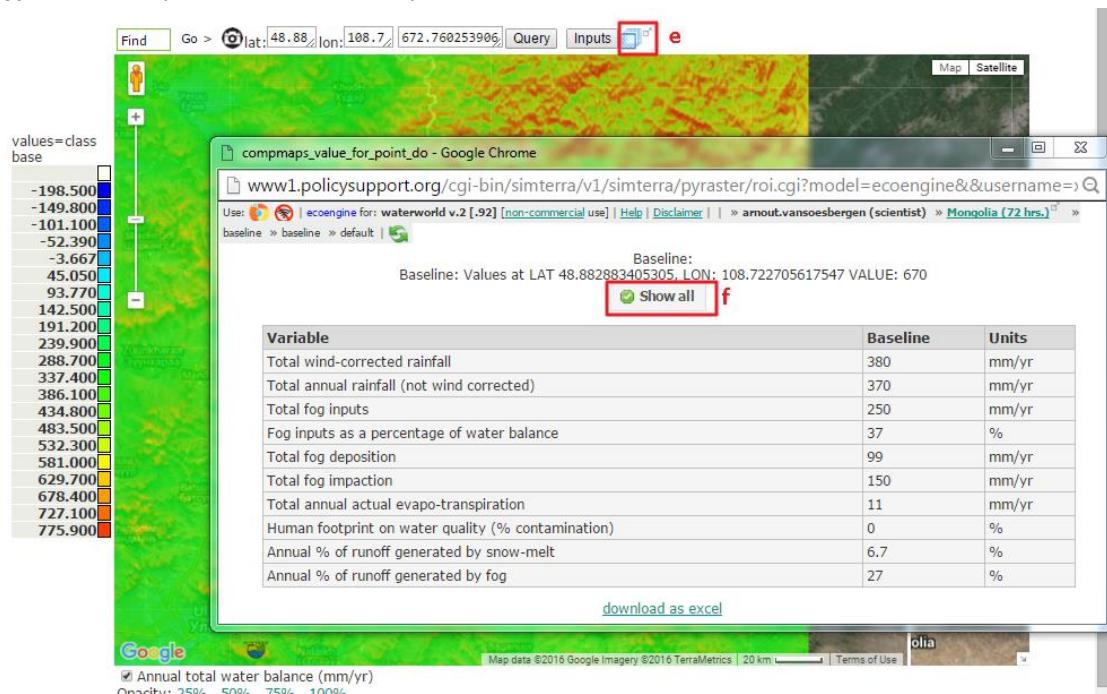
3.2.4.1. Pixel-based water balance results

- a. To add spatial context to the water balance map, click on (**a**) - view using Google maps. This will request the system to overlay the Water balance pixel-based map for the study region tile (here in Mongolia) over the satellite imagery available in Google Maps.

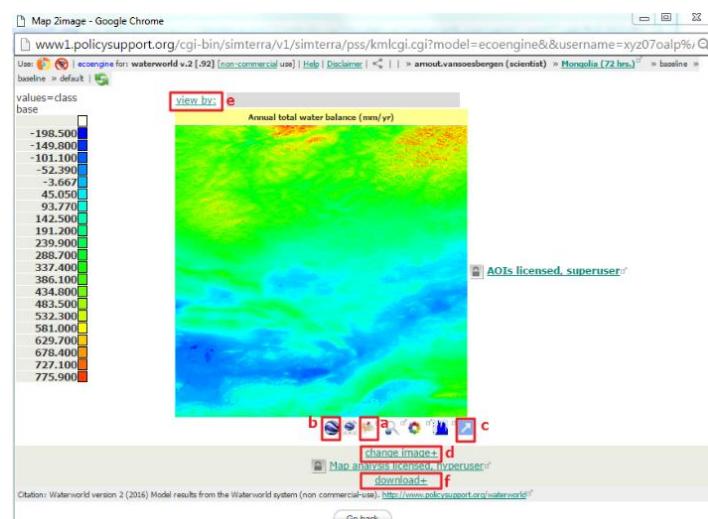


- To obtain individual pixel values, Move and Zoom the map with your mouse until the crosshair (a) overlays the pixel of interest Click on **Query** (b) to show the value of that pixel in the box next to the Query button.
- To view the values of the other components that make up the water balance click on **Inputs** (c). This will show a new icon (e).

Since the water balance is made up of wind corrected rainfall + fog + snowmelt – evapotranspiration, it may be useful to look at these values and see its relevant contribution for a particular pixel to identify which components are more important.



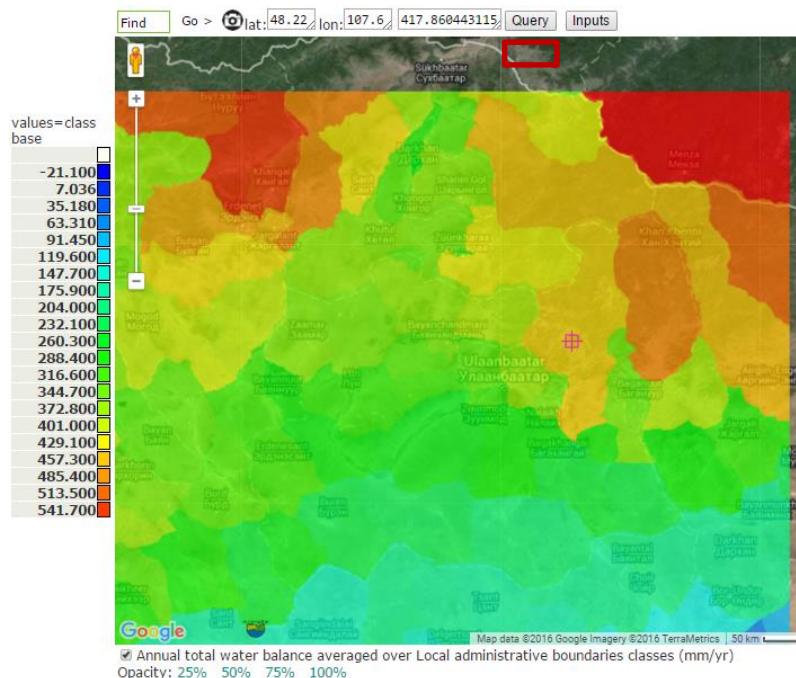
- d. Click on the icon (e) to open up a new page showing all variables involved in the calculation of the water balance.
- e. Click **Show all** (f) to display the values for the selected pixel (coordinates are displayed above the Show all button).
- f. Close all the pop-up windows so that you are back to the main browse map window.



3.2.4.2. Aggregated water balance results

It is possible to aggregate individual pixel values into broader regions to obtain average values for administrative regions or watersheds, this is useful when analysis is being carried out for a certain region of interest and to reduce the uncertainty of individual pixel values.

- a. Click on the **view by** function (e) to look at the mean annual water balance (mm/year) averaged over local administrative regions.
- b. Click on the view on Google map (a) to view the map
- c. On resulting map you can query the values for each administrative region with the Query button.



3.2.5. Other outputs

Using the map view options you can view and analyse other model outputs in a similar fashion. The rainfall map shows the annual wind-driven rainfall (mm/year). This is based on long term mean rainfall data combined with wind speed and topographic data to create more realistic rainfall spatial estimates. Calculating wind driven rainfall is particularly important in mountainous areas.

The runoff map (m^3/yr) shows the annual runoff from rivers and streams calculated as pixel-based water balance values accumulated downstream, where negative water balance (i.e. actual evapotranspiration > precipitation) consumes runoff from upstream.

The hillslope net erosion and net erosion maps show net soil erosion (erosion minus deposition) on hillslopes and from streams and rivers respectively. These values are calculated using WaterWorld's soil erosion module (based on Thornes 1990) with values provided in mm per square metre per year. These can be converted to other units such as tonnes per hectare by dividing the value in mm by 1000 to obtain the volume in cubic metres, and multiplying by the number of cubic metres in a hectare ($10,000 \text{ m}^2$). Then to obtain soil weight, identify a reasonable local value for the bulk density of soil, which ranges roughly between 1.2 and 1.7 metric tonnes per cubic metre of soil.

The mean annual human footprint on water quality is an index of potential pollution of water. This is calculated by taking into account all upstream potential polluting sources (point and diffuse, e.g. mines and agricultural areas). High values mean a high likelihood of pollution while low values indicate relatively clean water. Potential pollution is based on available data on potential polluting sources (e.g. extractives) from global datasets, which may or may not be accurate for your study region.

Please note that the resulting values are average values per pixel. For erosion in particular there is likely to be intra-pixel variability which can affect the impact of deforestation, for example the location of deforestation in respect to local variations in slope and streams.

4. Running a scenario simulation

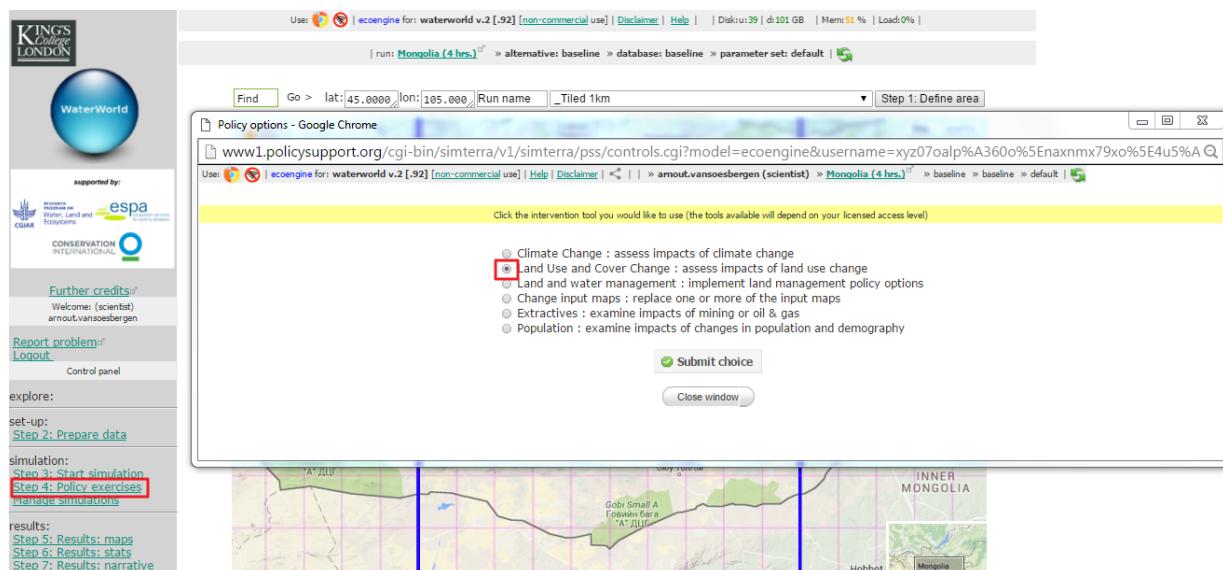
4.1. Set up, run and view scenario results

This section explains how to run and interpret a scenario simulation. WaterWorld has many built-in options for alternatives, i.e. by changing certain climate and/or land use input parameters you can assess the difference this makes to output parameters. Since this is done by calculating a change from the baseline, you can only set up and run a scenario analysis once you have finalised a baseline simulation. Typically that baseline might be the present-day forest cover.

The example used in this tutorial is how to run a land-use change scenario to assess the role forests play in water provision and soil erosion regulation. To do that, all existing forest (tree cover) will be removed in the scenario and the resulting changes in water provision and soil erosion analysed.

4.1.1. Step 4: policy exercises -setting up a scenario

- To start a scenario simulation, click on **Step 4: Policy exercises** on the left control panel. This will open a new window where you see all the categories of built-in scenario options. The availability of scenario options depends on your user level. At scientist user level, only climate change and land-use and -cover change scenarios are available.
- To run a **land-use and -cover change scenario**, select this option using the radio button and click **Submit choice**



This will open a new window as below. There are two main choices in this window. The first option is conversion of forest to herbaceous and vice-versa (**a**). This essentially replaces forest cover with pasture or cropland (herb cover) or a reforestation of agricultural land. The other main choice is to create your own land-cover type (**b**). The WaterWorld model uses three vegetation functional types as land-cover information. These are tree, herb and bare soil functional types and are fractional, i.e. for each pixel there is a percentage value of tree cover, herb cover and bare soil cover adding up to 100% in total. The “**create your own land-cover type**” option allows you to set the percentage of each of these functional land-cover types.

For both options (forest conversion and create land-cover type) you can choose to **use a pre-defined rule** or **define your own rule**. The pre-defined rule is an easier option that allows you to target your land-use change within certain boundaries such as outside and within protected areas and at defined ranges of elevation. The “**define your own rule**” option allows you to target your changes based on any of the built-in maps and for any given value within those maps. You can also combine or exclude areas from different maps.

- c. Click on the ± next to define your own rule for the create land-cover type option (c).

Chosen policyoption - Google Chrome
www1.policysupport.org/cgi-bin/simterra/v1/simterra/pss/policy.cgi
User: | ecoengine for: waterworld v.2 [.92] [non-commercial use] | Help | Disclaimer | » armout.vandoesbergen (scientist) » Mongolia (3 hrs.) » baseline » baseline » default | Working...
LAND USE AND COVER CHANGE: choose the scenario that you wish to apply.
View recent land use and cover change
FOREST TO HERBACEOUS and HERBACEOUS TO FOREST: Changing forest cover replaces forest (tree cover) with pasture or cropland (herb cover).Changes of between -99% and 99% represent selective deforestation and afforestation respectively. Deforest a given percentage per pixel of trees with e.g.-15 or reforest by a given percentage per pixel of trees e.g. 15.Specify where and by what percentage (per pixel) deforestation or reforestation should occur:
a Use a pre-defined rule: ±
...or define your own rule: ±
CREATE LAND COVER TYPE: For each row that you want to apply, set the corresponding percentage of tree, herb and bare soil functional types (FTs) per pixel to achieve the land cover that you wish, for example pasture might be 10% tree FT, 85% herb FT and 5% bare FT, a crop might be 10% tree FT 50% herb FT and 40% bare FT
b Use a pre-defined rule: ±
...or define your own rule: ±
...or copy your own tree, herb and bare maps: | Licensed, superuser |
...or upload your own tree, herb and bare maps: | Licensed, superuser |
...or run land use change model: | Licensed, hyperuser |
...or define from a land use or cover classification: | Licensed, superuser |
[List baseline workspace data](#)

This will expand the menu as below where you can define your scenario.

Chosen policyoption - Google Chrome
www1.policysupport.org/cgi-bin/simterra/v1/simterra/pss/policy.cgi
User: | ecoengine for: waterworld v.2 [.92] [non-commercial use] | Help | Disclaimer | » armout.vandoesbergen (scientist) » Mongolia (3 hrs.) » baseline » baseline » default | Working...
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a Use a pre-defined rule: ±
...or define your own rule: ±
CREATE LAND COVER TYPE: For each row that you want to apply, set the corresponding percentage of tree, herb and bare soil functional types (FTs) per pixel to achieve the land cover that you wish, for example pasture might be 10% tree FT, 85% herb FT and 5% bare FT
b Name for my scenario: Deforest
Set/change tree, herb, bare covers: 0 %85 %15 % for approx: 100 per-cent of land,cluster, pixels:
where: Cover of tree-covered ground (MODIS 2010)
c > d this value: 0
e other rules: ±
Define converted areas as: Unchanged Fraction of water exposed to contamination: 1, or: scale the default for land use.
Mean conversion cost (USD per ha.): 100
 Check and Submit

- d. The first thing to do is to provide a name for your scenario (a). This can be any name you wish but runs are identified by their name therefore sometimes it may be useful to provide some information on the scenario in the run (e.g. Deforest or Climate Change).
- e. The next thing to do is to set or change the fractional values for your tree, herb and bare functional land-cover types. In this example, the tree cover is set to 0 to remove all trees and leave the land cover to a pasture type with 85% herbaceous cover and 15% bare soil (b).

- f. The next thing to do is to target where this change should happen. This scenario is aimed at the removal of forest (tree cover) and therefore, the map of **Cover of tree-covered ground**, based on MODIS data, is selected from the where dropdown list (**c**).

Note, that there are many other maps to choose from in this dropdown, for example interventions can also be targeted at certain elevations, administrative boundaries or protected areas.

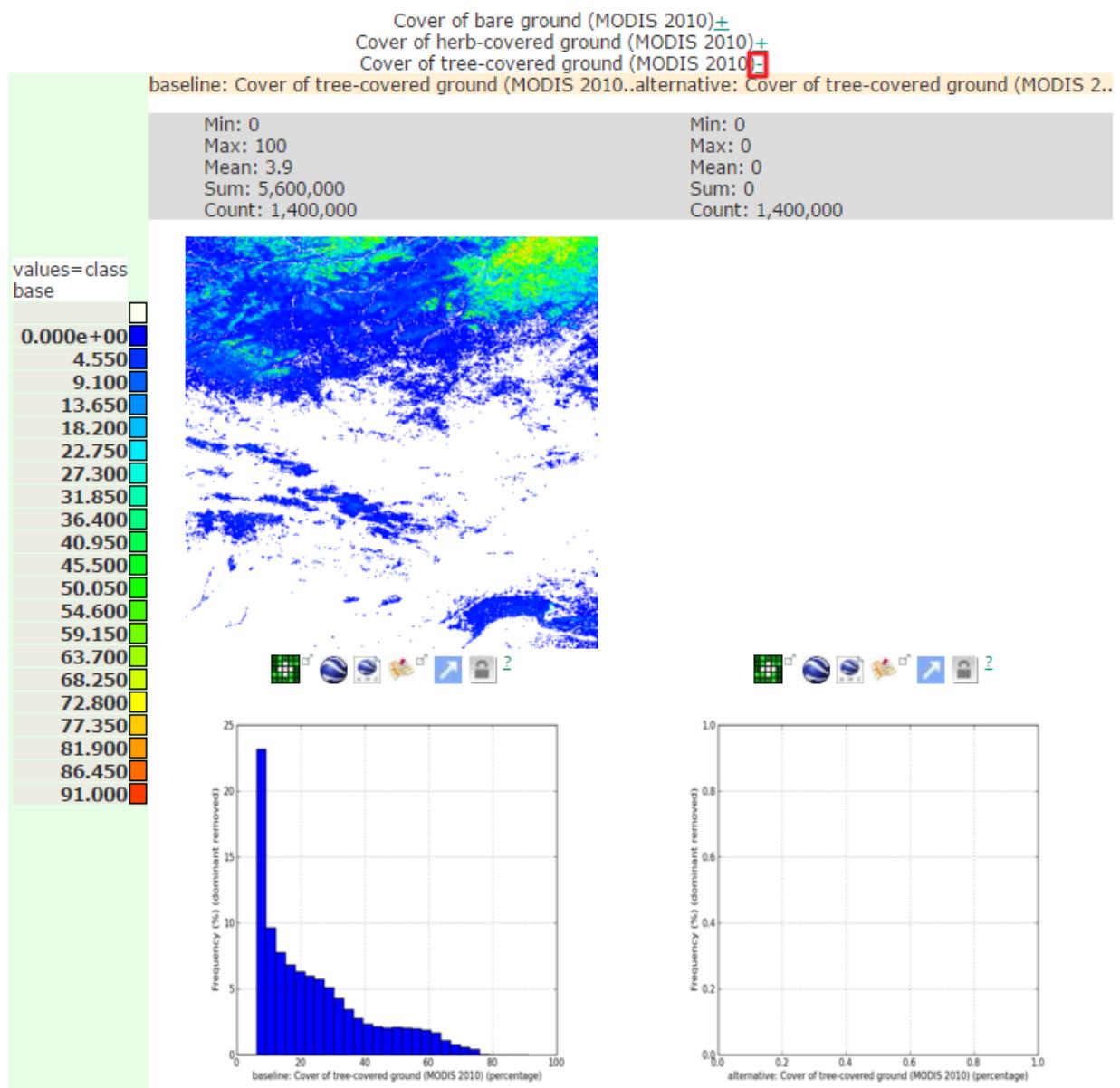
- g. Within each of those maps you can also set the value above, below or equal the intervention should be targeted. In this scenario all tree cover should be removed therefore the value is set to greater than (>) 0 (**d**).
- h. Finally, there are some options to define the land use of the converted areas (e.g. agriculture, natural, protected, etc.). This will mainly impact the water quality index and is set to **Unchanged** for this scenario (**e**). Once all options are set, click on **Check and Submit** and the system will start to build the scenario.

Setting up the scenario takes a few minutes and the system will show the progress. Once this is finalised you see the below screen. From here you can view the scenario and compare with the baseline, directly start to run the scenario or look at the alternative data in your workspace.

- i. Whenever you set up a scenario it is good practice to review it, and how it compares with your baseline, before running it to understand the changes to your data. To do this click on the **Show baseline and scenario**. This will show a list of all maps that have changed.



- j. Click on the ± next to the name of the variable to open up the baseline and scenario map for that variable as well as some statistics and a histogram of the data. The below figure shows the change for the tree-cover map and since the scenario aimed to remove all tree cover, there is no tree cover in the scenario map (right). Also examine the other two maps that have changed, bare and herb-covered ground to see the changes for these maps.



4.1.2. Step 4: policy exercises: running the scenario

Now that the scenario has been prepared and examined, you can start the scenario run. You can do this by going back to the window that opened after scenario building and click on **Run scenario (a)** or choose **Step 3: Start simulation** from the control panel on the left (**b**).

*****IMPORTANT:** if you do want to run it from the control panel make sure you refresh the page so that the system will run your scenario and not your baseline again. All control panel actions will always work on the run highlighted at the top of the main page (**c**). Make sure to refresh the page so you are sure to work on the correct run (in this case you can see the scenario run (alternative: deforest) is the selected run. You can refresh the page by clicking the **refresh** button (**d**) or press **F5** on your keyboard.

Clicking **Run scenario (a)** will start the scenario run but you may not see the progress window. If this happens you can click on **Start simulation (b)** and the run progress window should open. The run should take the same length of time as the baseline run.

The screenshot shows the WaterWorld software interface. On the left is a control panel with various links and buttons. In the center is a map of Mongolia with specific regions labeled. At the top, there is a header bar with user information and system status. A red box highlights the 'Run scenario' button in the control panel, which corresponds to step (a). Another red box highlights the 'Step 3: Start simulation' link in the control panel, which corresponds to step (b).

4.1.3. Step 4: policy exercises: examining results

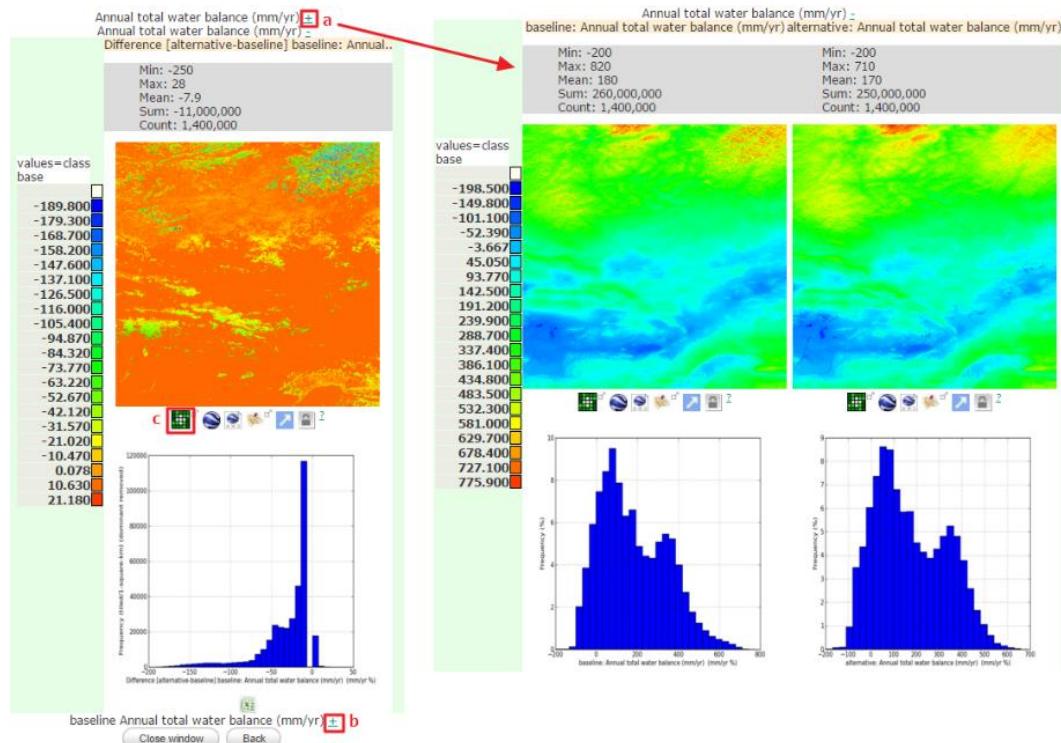
Once your scenario run is finished you can start examining the results. Click on **Step 5: results maps** in the left hand control panel (a).

The screenshot shows the WaterWorld software interface. On the left is a control panel with various links and buttons. In the center is a table of results maps. A red dashed arrow points from the 'Step 5: Results: maps' link in the control panel (a) to the 'Results maps' table in the center. Another red box highlights the 'Step 5: Results: maps' link in the control panel, which corresponds to step (a). A third red box highlights the 'Change' icon next to the first row in the results table, which corresponds to step (b).

Name	Explanation	Change from baseline
Change in rainfall	Change in total annual (wind-driven) rainfall (mm/yr)	
Change in local water balance	Change in local water balance (mm/yr). Calculated as net evapotranspiration minus precipitation. If water balance is negative, real AET is less than precipitation. If positive, sources of water and/or groundwater	
Change in runoff	Change in total annual runoff (mm/yr). Calculated as water balance (AET - precipitation) in a cell consumed runoff from upstream.	
Change in hillslope net erosion	Change in hillslope net erosion (mm/yr). Net erosion (erosion minus deposition) on hillslopes and channels (streams/rivers)	
Change in total net erosion	Change in total net erosion (mm/yr). Net erosion (erosion minus deposition) from hillslopes and channels (streams/rivers)	
Change in human footprint on water quality (pollution)	Change in mean percentage of water that may be polluted (human footprint index, %)	

4.1.3.1. Change in water balance

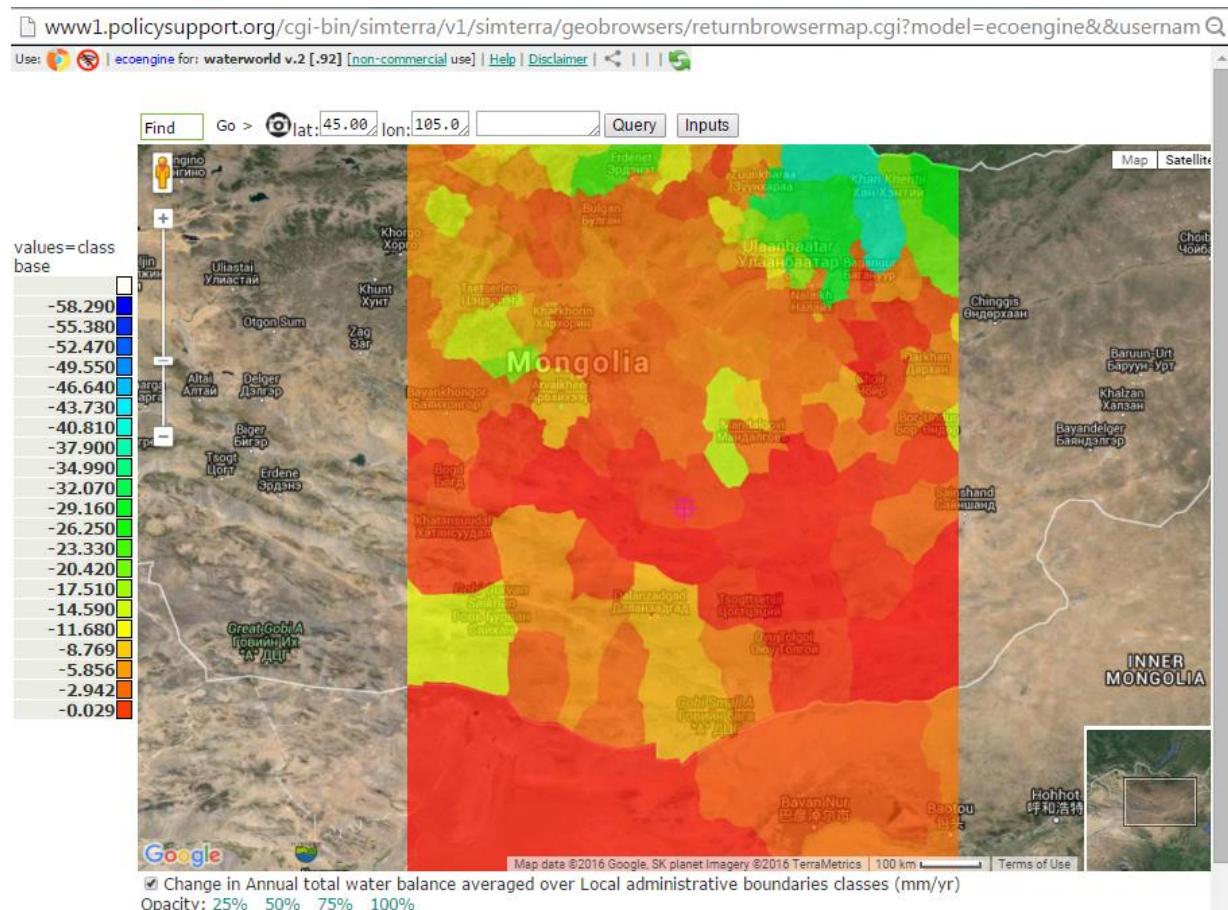
- a. Click on the change icon (**b**) to produce a change map (i.e. change from baseline) as below (left) for the change in water balance. By default the map window will show the change for this output variable.
- b. Click on the \pm next to the top **Annual total water balance (mm/yr)** (**a**) to open up the baseline and scenario map next to each other with map statistics. This allows for easy comparison (right).



- c. Click on the \pm at the bottom of the change window page (**b**) to see the percentage change from the baseline for this output variable.
- d. The green icons under each map (**c**) allow you to interrogate the output by aggregating over other maps, changing colour ramps and overlaying on Google maps and Google Earth.

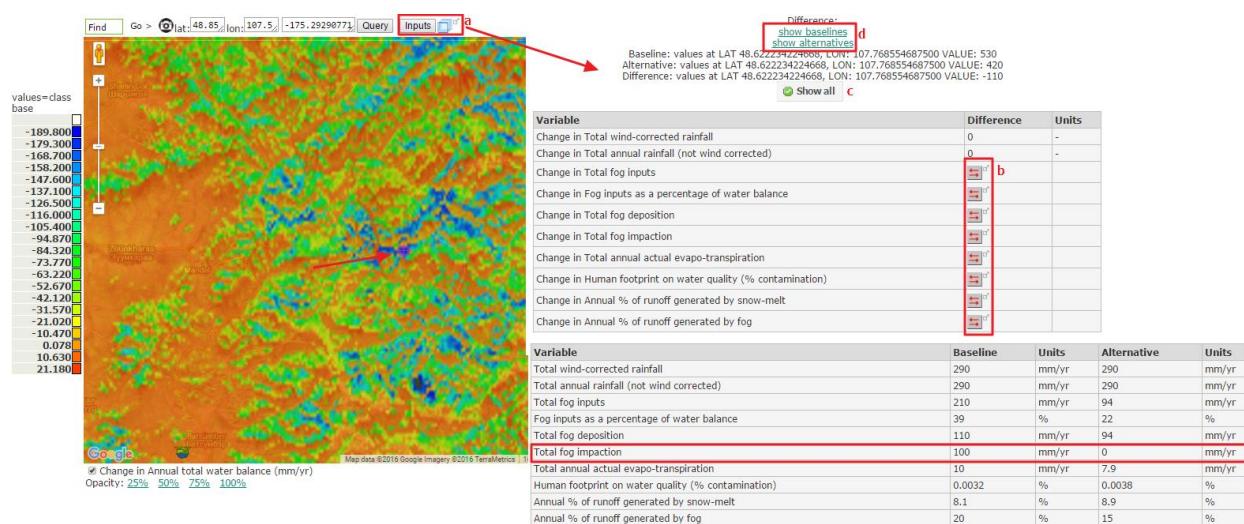
The map of change in water balance highlights those areas where a removal of forest leads to an increase or decrease in water balance. Areas where there was no or low tree cover in the baseline will therefore show limited or no change in this map.

- e. When aggregating the results by local administrative boundaries (click the green icon (**c**) and select **Local administrative boundaries** on the **View by** dropdown list above the map in the new window). In our Mongolia example, it is clear that no administrative region sees an increase in water balance overall and that those areas located north of Ulaanbaatar are impacted most (see map below) with mean negative changes of around 40 mm/yr. These regions also had the highest water balance for the baseline situation (see section 3.2.4.1) and were high in tree cover.



- f. To further understand the changes in water balance you can look at all the Inputs for individual pixels. This is best done for the pixel-based map. To do so, **view the pixel-based water balance change map and show in Google map mode** (see below left map).
- g. Move the crosshair to an area of great change (blue areas in map) and click on **Inputs** and the **query inputs** icon that then becomes active (**a**). You can obtain the baseline and scenario values for that pixel to understand what drives the change.
- h. In this new window you can click the change icons (**b**) for individual parameters or the **Show all** button (**c**). Alternatively you can view the values for the baseline and alternatives by clicking on the respective links at the top of the window (**d**).

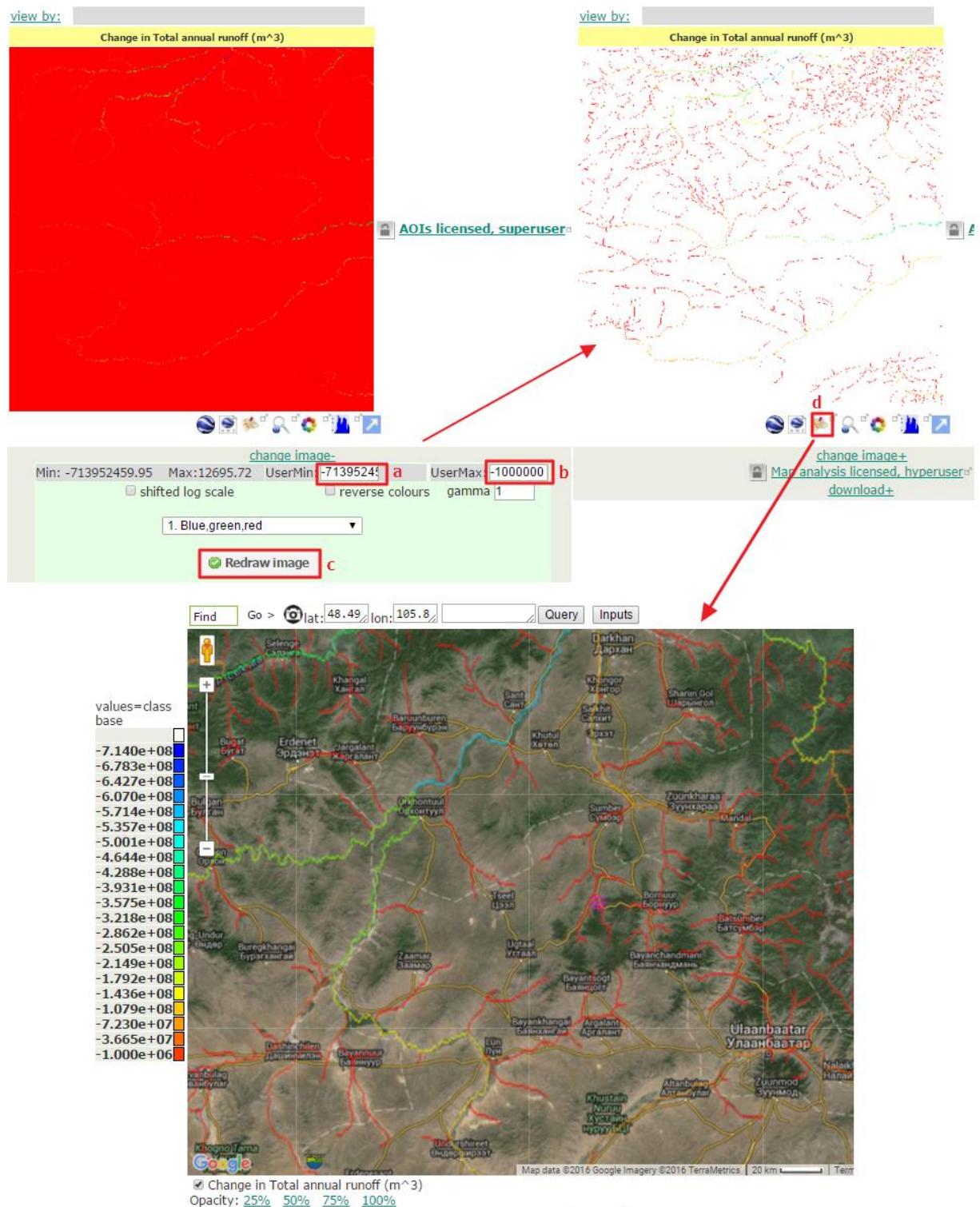
Comparing the values for the baseline and scenario alternative (see screenshot below) reveals that the key difference in this region is the total fog impaction, i.e. the amount of fog captured by the trees is reduced to zero. With amount of rainfall not changing, and only a marginal decrease in water loss through actual evapotranspiration, the changes in fog capture explain the reduction in overall water balance and thus water availability.



4.1.3.2. Change in runoff

The changes in water balance lead to changes in runoff and thus the delivery of water. Since the water balance decreases in most areas, the changes in runoff are negative as well.

- To examine the changes in runoff, click on the **change** icon next to change in runoff in the **Results maps** window.
- Click on the \pm next to change image under the map in the resulting window to change the range of values to be shown in the map. This is useful as runoff is calculated for every pixel but the changes in rivers and streams are of most interest.
- Since most changes are negative you can set the map to only show the largest negative changes by copying and pasting the min value into the Usermin box (**a**) and setting a value for Usermax (**b**). In this example a Usermax of -100,000 gives good results. Click **Redraw image** (**c**) to implement the changes. Setting these values results in the runoff map shown on the right in the figure below.
- Click the **overlay on Google maps** icon (**d**) on the resulting map, a clear picture of changes in runoff along the stream flow network is shown.
- Move the map to overlay the crosshair on your point of interest and clicking the **Query** button to look at individual values at points.



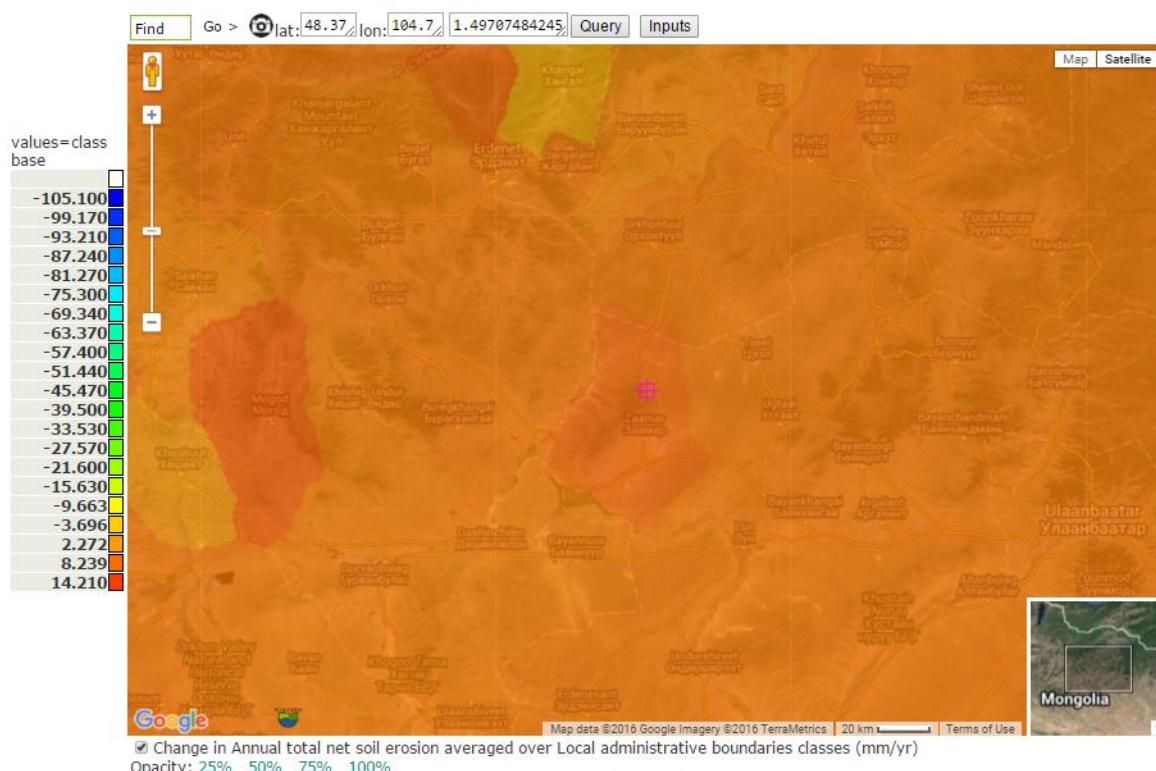
4.1.3.3. Change in soil erosion

- a. To examine the changes in soil erosion under this scenario, click on the **change** icon next to change in **total net erosion** in the **Results maps** window.

This is the change in total net erosion in mm/yr. Net erosion is the gross soil erosion (i.e. the eroded soil) minus the deposition (the amount of material that gets deposited within a pixel).

Net erosion is the volume of soil that ends up in streams and rivers as sedimentation. Change in net soil erosion typically shows positive as well as negative values and changes tend to be small for most pixels. Given that soil erosion is partly dependent on local-scale factors not considered in this analysis due to model resolution, it is recommended to aggregate results over large areas for a better, more confident interpretation of model results.

- b.** Click on the **View by** dropdown above the change map and select the **Local administrative boundaries** map. You can then view the map in Google map overlay to query the mean changes by administrative region as well as looking at the inputs for individual pixels through the **Inputs** button.



The results highlight those areas where the total removal of forest is projected to increase soil erosion (orange/red). In this example, this is the case for most of the study region although in some areas a mean decrease in soil erosion can be observed. This increase in soil erosion is likely to result in an increase of sedimentation of the eroded soil material downstream, with possible negative consequences on water quality, hydropower generation and other activities. The combination of this map with the location of important downstream infrastructures can help identifying where erosion may have a large impact.

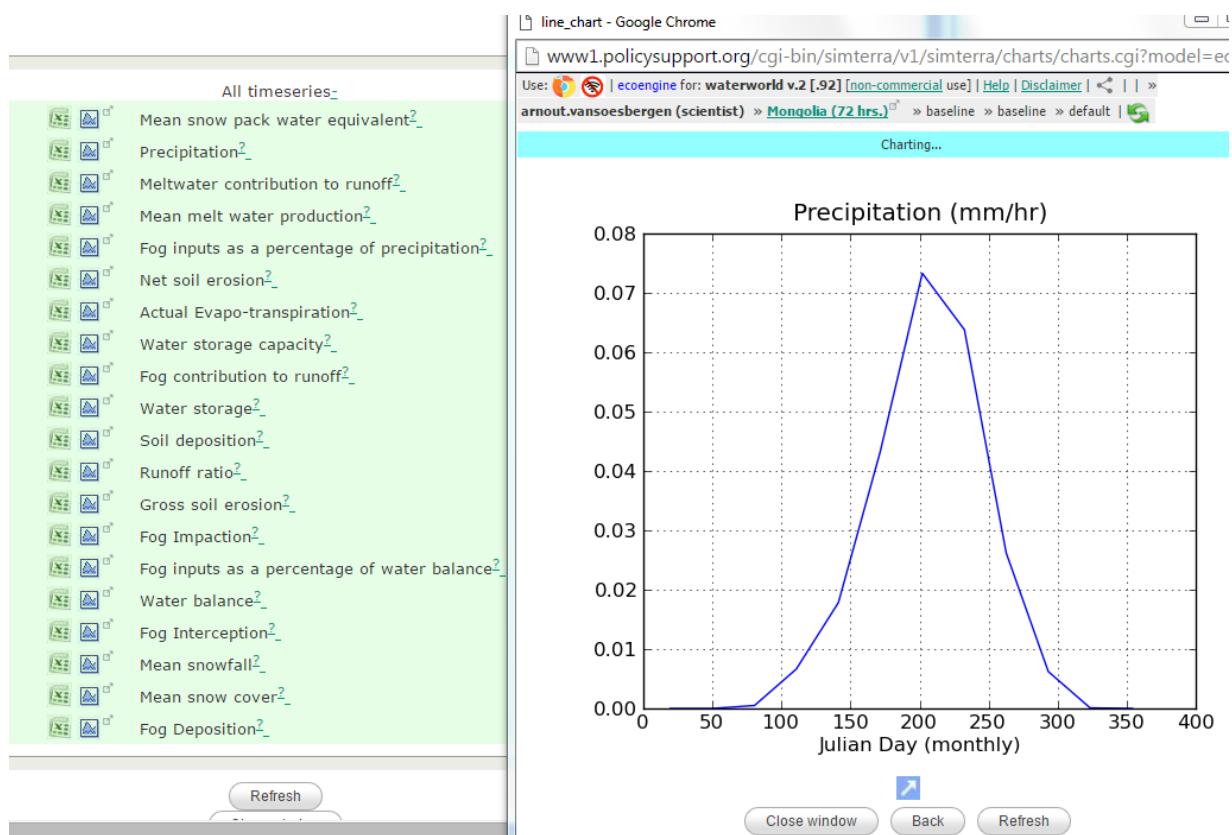
5. Additional results and managing simulations

The most important outputs of the WaterWorld model are the spatial results, i.e. the maps reviewed in section 3.2.4. However, the model also provides statistics and narrative results, which are reviewed in this section, in 5.1.1 and 5.1.2 respectively. Another important feature of the model covered here is the management of simulations, i.e. how to view existing simulations and delete old runs. Finally, this section describes some of the documentation and help functions available in WaterWorld.

5.1. Additional results

5.1.1. Step 6: Results: stats

Similar to **Step 5**, this step is available after running a baseline or scenario simulation. It allows you to view time series across a year for a number of key variables (e.g. precipitation), and download the data as Excel files. Time series are always based on mean values for the entire model region (i.e. tiles, countries or basins).



These time series could help to understand how forest loss may impact on erosion and water flow through the year, possibly identifying critical time periods.

5.1.2. Step 7: Results: narrative

In addition to the map and graph results, the model provides a narrative result under **Step 7**. This useful feature provides key information about the run and results. To build and see the narrative values, you need to click **Show all** in the narrative window. This feature provides overview results for your extent of analysis, i.e. mean values for the tile as well as pixel-based minimum and maximum values. These

statistics quickly provide a user with the range of results and the contribution of different components of the water balance for instance.

For this baseline run-

Water balance (mm/yr) for the area was on average 180 with a 25th percentile of 51 and a 75th percentile of 310 ,an absolute minimum of -200 and maximum of 820 . This reflects an area average precipitation (mm/yr) of 170 with an absolute minimum of 29 and maximum of 510 . Actual evapo-transpiration (mm/yr) ranges from Working.. to show with a mean of show.Fog inputs are show in relation to precipitation at show % on average, amounting to show mm/yr on average but ranging from show to show mm/yr.

Show all

5.2. Manage simulations

The manage simulations functionality (under **Simulation** in the control panel) enables you to get information about runs and selecting and delete runs. When clicked, you need to choose the type of simulation (resolution 1-km² or 1 hectare) and click on **Submit** choice. This will open a window where you can see information about your runs. At the top you will see the number of runs you have stored and how many you can store (**a**). Each time you define a run this will add a run to the list (even if you don't run that simulation) so it is good practice to only keep those runs that you want to keep. **Also, runs will be deleted automatically after 72 hours if disk space is required.** Key information about your baseline runs, such as coordinates, are displayed next to the map with a run-status (**b**). Underneath this are options to choose the baseline (if you are switching between runs) or delete the baseline and scenarios (**c**). At the bottom are displayed all scenarios you have set up for this run. Clicking on the run details will provide information on the settings used in the scenario. You can also choose and delete the scenario here and set it running if you haven't run it yet (**d**).

You are storing a total of **3** runs (baselines and alternatives) at different spatial resolutions across all PSS from a maximum of **10** **a**
 If you are experiencing problems with the system then delete all old runs using the next link as some may no longer be compatible with the system
[Delete runs older than 1 day old from all PSS](#)
[Delete runs older than 1 week old from all PSS](#)
[Delete all but current baseline and associated alternatives](#)

Here is a list of previous **baseline** runs of type **1** and origin : **b** Click the relevant links to view or choose a run

Baseline run: Mongolia

username :	Mongolia
runname :	Mongolia
model_version :	2.[.92]
runtype :	tiled/1-square-km
bbox_north :	50.0
bbox_south :	40.0
bbox_west :	100.0
bbox_east :	110.0
date_created :	(2016, 2, 1)
run_period_begin :	
run_period_end :	
b run_status :	completed
alternative :	baseline
database :	baseline
paramset :	default
data :	prepared
archive_status :	
write_timestep_maps :	0
current_moi :	
current_aols :	
current_zol :	
customisations :	False

Centre coordinates: 45.0,105.0
[Choose this baseline](#) **c** [Delete this baseline \(and associated alternatives\)](#)

This simulation is subject to deletion in: 72 hrs. Simulations past their consume by date are deleted automatically as disk space is required.

Alternatives for Mongolia:

View run details reforest	Choose run Choose this run	Run status started	Delete run Delete this run
------------------------------	-----------------------------------------------	-----------------------	-----------------------------------------------

d

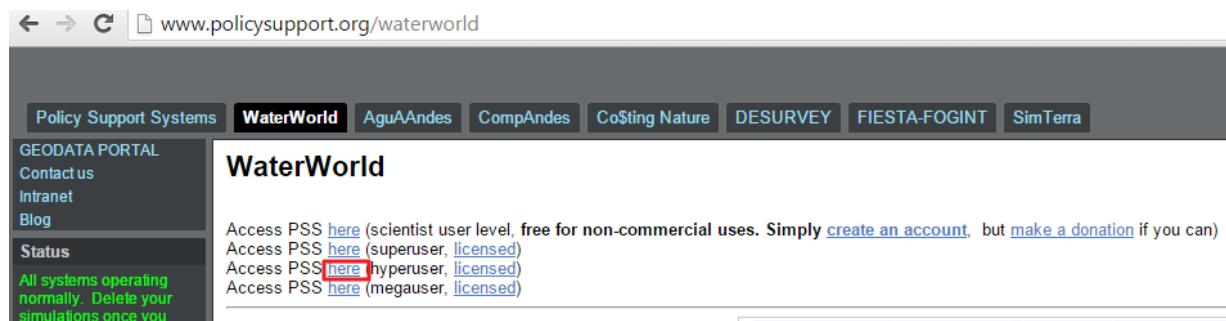
5.3. System and model documentation

The WaterWorld model is well documented with system and model documentation available from the control panel under **Help**. The System documentation provides you with an online user guide as well as more information on citation and use policies. There are also links to online videos demonstrating the various steps on the use of the model. The model documentation provides more detail on the various model components and the science, equations and assumptions behind all modules and submodules. Finally, there is a Frequently Asked Questions (FAQ) link, under Help, which is worth consulting first whenever you have a question or generate errors when using the model.

Annex I: Using WaterWorld with your own land-cover data

This annex demonstrates how to use the advanced features of WaterWorld to provide the model with your own land-cover data and run a simulation. This feature requires a higher (licensed) user level, so is not available on the freely accessible system. More info on additional functionality and license costs can be found here: <http://www.policysupport.org/access-costs>

- a. The additional functionality is available from **hyperuser** level and above so in order to use this feature, log in as a **hyperuser** by clicking on the **hyperuser** link on the main log in page.



Once logged in you will see the same WaterWorld interface with the map in the centre, as shown in the tutorial for Science user level access. When moving between user levels, it is in most cases necessary to **re-define and re-run** simulations, as different outputs are available to different user levels.

Therefore, you will need to re-define your baseline simulation for your area of interest if you haven't defined this as hyperuser:

- b. To do this, first set up and define your run again (see section **2.2.1** in the main tutorial) and prepare your data as described in section **2.2.2**.
- c. After copying over the workspace data, click on the ± symbol next to **show workspace data (a)** and download a map of the **Study area (b)** as ascii file. You can use this map later as a template

to prepare your own data for upload to the system. Once downloaded you can close the workspace data page.

The screenshot shows a list of datasets available for download. The datasets include various boundary layer wind direction measurements from January to December, cell area fractions, and study areas. A red box labeled 'a' highlights the star-shaped icon at the top right of the page. Another red box labeled 'b' highlights the 'download+' button at the bottom right.

- d. The next step is to set up the model with your own land-cover data. The first thing to do is to upload your own dataset to the system so it can be used in setting up a simulation. To do this, click on the little star shaped icon at the top of the page (a)

The screenshot shows a map of Mongolia with a grid overlay. Various locations are labeled in both English and Mongolian script. A red box labeled 'a' highlights the star-shaped icon in the top right corner of the interface. The map also includes a legend and several buttons for search and navigation.

This will open up a page (**Define roi_form**) where you can define points of interest (**POIs**), zones of interest and areas of interest. Points of interest can be used to read values from input and output maps. Zones of interest (**ZOIs**) can be used to identify areas to apply scenarios and interventions, to mask these areas or to aggregate results by and calculate metrics for these areas. **ZOIs** can be set by uploading a map, by applying rules, specifying a bounding box or by defining watersheds upstream from selected points.

Areas of interest (**AOIs**) are categorical maps that define a series of classes, for example land-use maps. Therefore this is the option to choose to upload your land-cover map to the system.

- e. In the Define ROI page click on the ± symbol next to **new AOIs by uploading map (a)**. This will expand the upload AOI function. To upload your map you will have to make sure it is a raster

based map (a zipped ARASCII file). The exact characteristics required can found by clicking on the ± next to characteristics (b) and the name to use by clicking on the ± next to Name of AOI (c)

Define roi form - Google Chrome

www1.policysupport.org/cgi-bin/simterra/v1/simterra/html/html.cgi?model=ecoengine&&username=xyz070alp%A360o%5Enaxnmx79xo%5E4u5%A30u%A:

130.171 User: ecoengine for: waterworld v.2 [92] [non-commercial use] | Help | Disclaimer | > arnout.vansoesbergen (hyperuser) » Mongolia (70 hrs.) » baseline » baseline » default | ↻

areas, or to calculate metrics based on these areas.:

Current _ZOI map: zoi_.remove.

from existing ZOIs: ±

new ZOI by applying rules: ±

new ZOI by uploading map: ±

new ZOI by specifying a bounding box: ±

Define areas of interest. These are categorical maps that define a series of classes represented by different integer numbers. They can be used to view input or output map metrics by area, mask maps or upload maps to represent categorical classes such as land use.:

Current _AOIs map: aoiszip_.remove.

choose existing AOIs: ±

new AOIs by uploading map: a

Upload your AOIs map. You must provide a zipped ARASCII file:

maps must have these characteristics b
maps must have these names c

Name of AOIs file e.g. aois.zip

Check and Submit

Define watersheds of points. These functions calculate the catchments of points based on their topographic upstream areas.:

First, define points on map, New

...or choose from existing POIs: ±

Opening up these two windows shows the required characteristics for your uploaded map:

Upload your AOIs map. You must provide a zipped ARASCII file:

maps must have these characteristics_

ARCASCII format zipped individually (one ASCII per zip) using winzip (.zip) or gzip (.gz). File should use period (.) NOT comma (,) as decimal separator for numbers. Zip file name should be same as basename for variable e.g wcpref.zip for file containing wcpref1.asc to wcpref12.asc or country.zip for file containing country.asc

Your AOIs map can have any integer values but -9999 or 1e31 is expected for missing values

ncols	1200
nrows	1200
xllcorner	100.0000000000000000
yllcorner	40.0000000000000000
cellsize	0.0083333333333333
NODATA_value	-9999

maps must have these names_

aois.asc

Name of AOIs file e.g. aois.zip

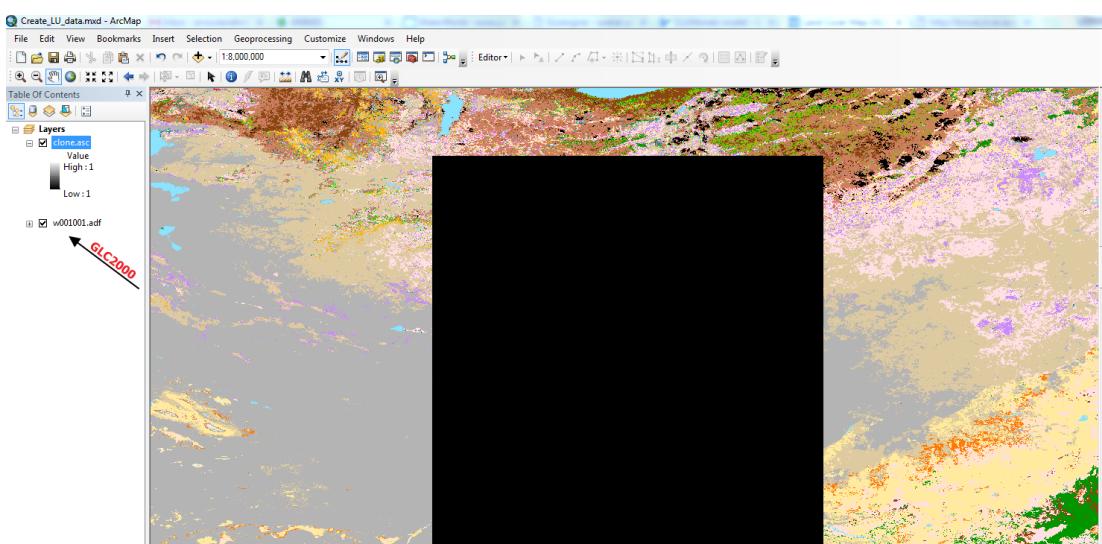
- f. Preparing a map to upload will need to be done in GIS software such as ArcMap or the freely available QGIS or SAGA GIS. A reference to how to do this using SAGA GIS can be found in the online documentation of the system: <https://goo.gl/pDmkqg>
- g. **Box A1** describes how to prepare your own data using ArcMap, using the GLC2000 land-cover dataset (Belwood, 2005) as an example.

Box A1: Preparing GLC2000 data for use in WaterWorld using ArcMap v10.3

This example describes how to prepare GLC2000 categorical land-use data for use in WaterWorld using ArcMap v10.3. GLC2000 is a freely available global land-cover dataset at 1-km resolution developed by the Joint Research Centre. The data can be downloaded here: <http://www.un-spider.org/links-and-resources/data-sources/land-cover-map-glc2000-irc>

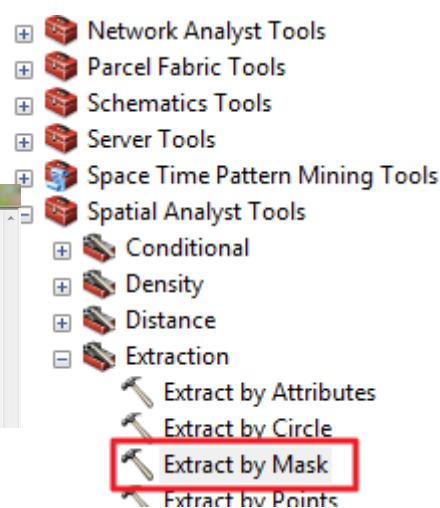
- Unzip the previously downloaded Study area map from WaterWorld (clone.zip) on your computer and load the unzipped arcascii file (clone.asc) into ArcMap.
- Also load the GLC2000 global dataset to your ArcMap view.

Note: the clone.asc raster from WaterWorld is in geographic projection (lat/lon) with WGS84 datum. In this case, the GLC2000 is in the same projection. If you are using different data make sure to convert it to lat/lon WGS84 before continuing.



- The first thing to do is to extract the same region from GLC2000 as our mask data. For this you can use the **extract by Mask** tool in the **Spatial Analyst Toolbox**:

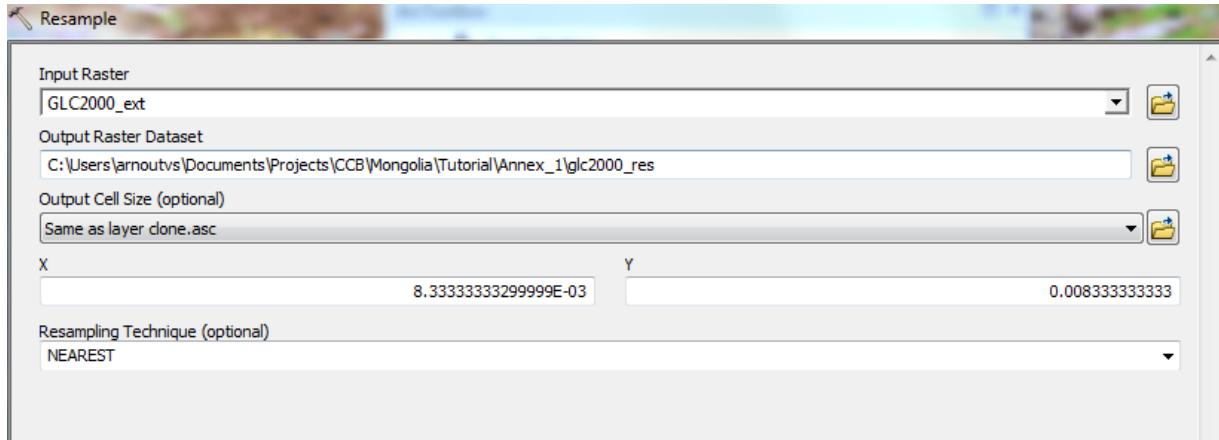
- In the toolbox window, define the GLC2000 raster as **input raster** and your clone as a **mask**:



The resulting map is an extract of the GLC2000 dataset with the same extent as our clone map. However, the resolution of GLC2000 is slightly different than the clone map.

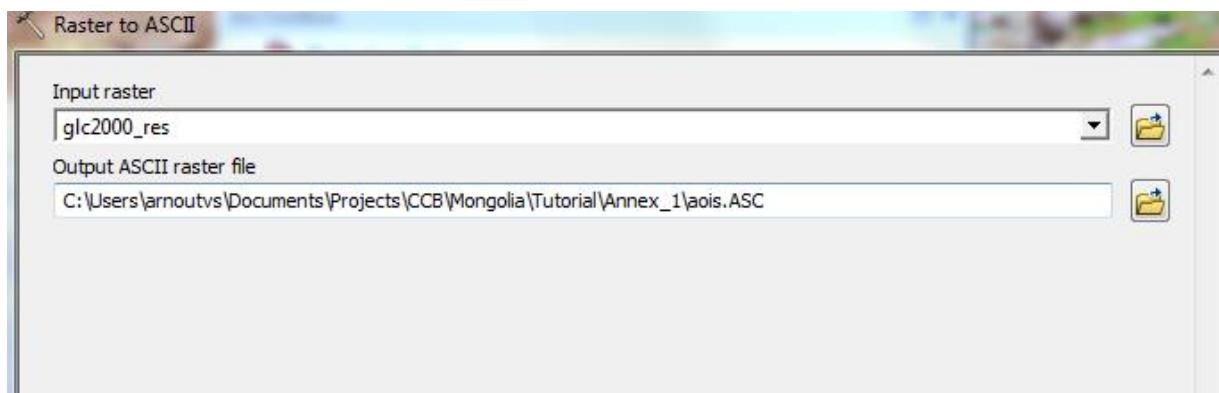
- Right-click on each of the layers and click **properties>>source** to look at the raster information for both datasets. The GLC2000 dataset has a different number of rows and columns (1120x1120) and cell size (0.008928) than the clone map (1200 x 1200) cell size 0.0083333.

- f. To correct for this you need to resample the extracted map. Run the **Resample tool** (found in the **Data Management>>Raster>>Raster Processing toolbox**)
- g. Use the **extracted dataset from the previous step as your input raster**, define an output raster and select the **clone.asc** layer as the output **cell size**. Use the default **NEAREST** as the **resampling technique**.

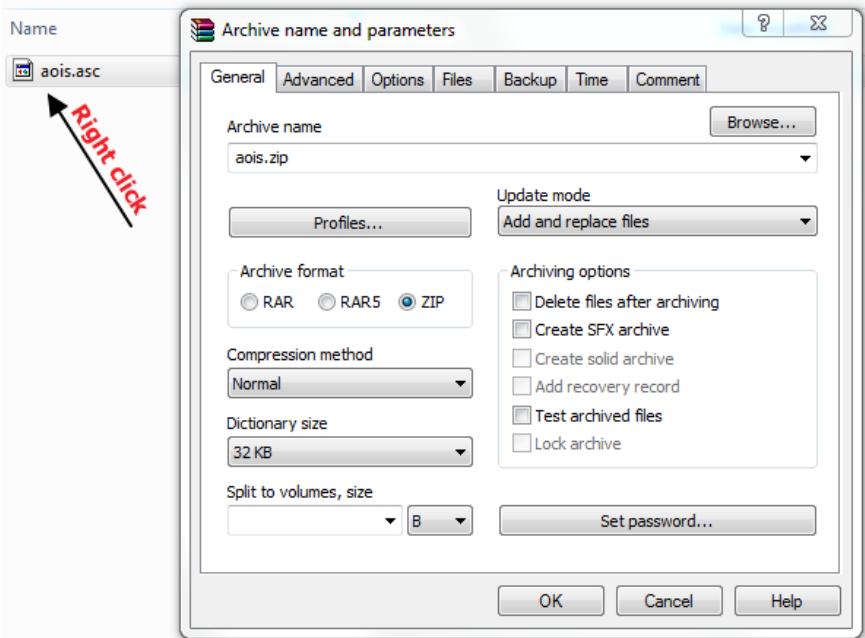


The resulting map should have the same numbers and rows and columns as the clone map (1200 x 1200) and a cell size of 0.003333 (check by selecting the source tab on the layer properties).

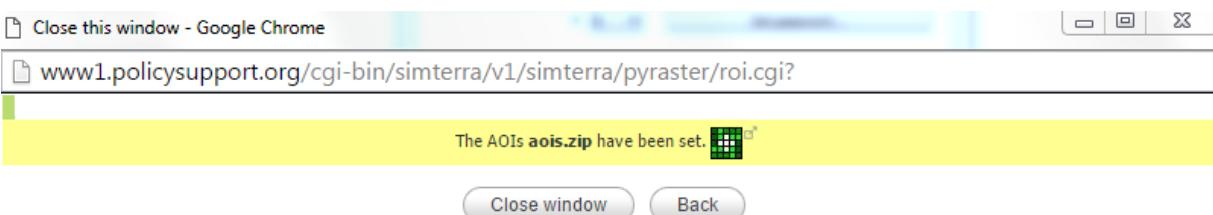
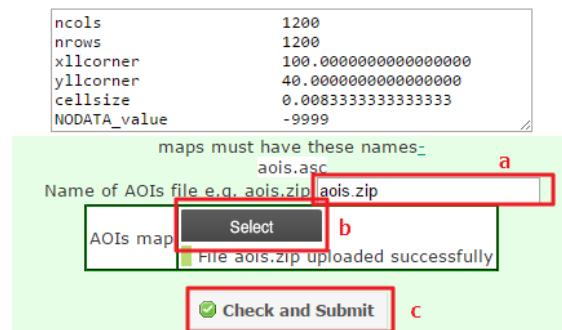
- h. The next step is to export this map as an ascii file. To do this select **Conversion tools>>From Raster>>Raster to ASCII** from the toolbox. Use the **resampled raster** as input and name your output raster **aois.asc**



- i. The final step in preparing your data for WaterWorld is to browse to the folder where you saved your ascii file and zip the file so you have a file with extension .zip. Name the file **aois.zip**. If you don't have zip software you can use the freely available winrar (<http://www.rarlab.com/download.htm>).
- j. If you have winrar (or other software) to zip, right-click on the ascii file in your folder and select the Archive format as **ZIP** (see winrar example below).



- k. Once you have prepared your data in the correct format and with the correct names, you can upload it to the system. Make sure to provide the name of the zip file (aois.zip) in the name box (a) and then click on **Select** (b). This will allow you to browse to the folder where you saved the zipped data file. You will receive an error message with uploading if the data is not in the right format or does not have the correct name. Once you have provided a name and selected the data you can click on **Check and Submit** (c)
- l. If all went well you will see the following screen and you can look at your uploaded map by clicking on the green view map icon



- m. The next step is to replace the existing land-use data in the system with your uploaded map. To do this, click on **Step 2: Prepare data** again and click on **List Workspace data** in the page that

opens. You will now see an option to **Redefine land use and cover according to your own map**. Clicking on the ± icon next to this (a) will open up the settings window.



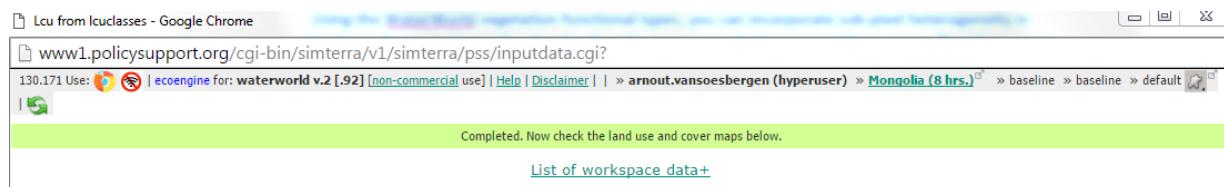
- n. In the redefine map window, choose the land classification you want to use from the dropdown (a). If you uploaded your AOI correctly, you should see the **aoiszip** map in the dropdown. Select this and it will open up your map in a separate window.
- o. You can now tell the system which values of your land-cover/use map (codes) correspond with the land use/cover classes in WaterWorld. Using the WaterWorld vegetation functional types, you can incorporate sub-pixel heterogeneity in land use classes as it uses fractional values for tree cover, herb cover and bare cover. Therefore, even though at 1-km pixel resolution, you can specify a pixel to be 80% tree cover, 15% shrub cover and another 5% bare cover rather than classifying the whole pixel as forest. Therefore you can incorporate actual tree cover fractions for different forest types more accurately which is important for modelling water and soil erosion processes. If you do specify that one code (land-cover class from the inputted land-cover map) does correspond to more than one land cover (for example both pasture and cropland, or Forests (tree cover), Grassland (herb cover) and Bare soil or rock (bare cover)), you need to make sure that the total for that code adds up to 100%. . Additionally, if the input land-cover/land-use map includes many classes (codes) it is likely that several may correspond to the same class within WaterWorld. Where this is the case, make sure that the order of the codes is the same as the order values (see example below).

	Codes used..	Values to ..
Pasture	18	80 percentage.
Cropland	16, 17, 18	100, 100, 20 percentage.
Natural/Recovering	-	1 not used.
Protected	-	1 boolean.
Mining	-	1 boolean.
Oil & Gas	-	1 boolean.
Urban	22	1 boolean.
Roads	-	1 boolean.
Forests (tree cover)	2, 4, 5, 6, 9	90, 90, 50, 50, 50 percentage.
Grassland (herb cover)	2, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15	10, 10, 40, 40, 40, 100, 100, 100 percentage.
Bare soil or rock (bare cover)	5, 6, 9, 19	10, 10, 10, 100 percentage.

Using the GLC2000 classification in the example above, class 18 in the GLC2000 classification is a mixed land use class corresponding to 80% pasture and 20% cropland while classes 16 and 17 are purely cropland classes. Therefore class 18 is set to 80% for pasture and 20% cropland, while classes 16 and 17 are set to 100% cropland (b). Classes 2 and 4 are forest (tree cover) classes in the GLC2000 classification with around 90% tree cover and 10% herbaceous (shrubs/grassland/other small herbaceous cover) while classes 5,6 and 9 only have 50% tree cover, 40% herbaceous and another 10% bare cover. Classes 10-15 are purely grassland classes and are thus set to 100% grassland (c). Any values

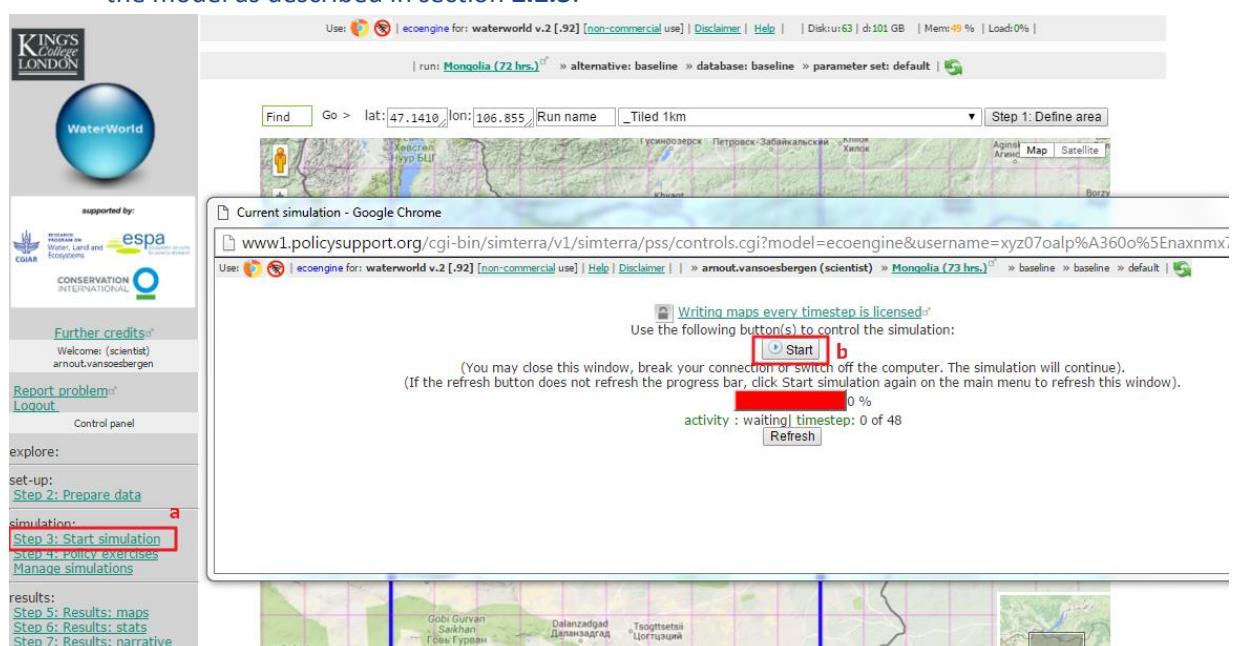
you want to leave to default (i.e. built-in WaterWorld data) leave the “-“. Values for mining, oil & gas, urban, roads and protected areas are Boolean, i.e. present or not present. Therefore the value is set to 1 for those classes.

- p. Once you are happy with the classification click **Check and Submit** and WaterWorld will replace the relevant land use and cover maps according to these settings. When finished, click on the ± icon next to the **List of workspace data** to see the following page where you can check the land use and cover maps that have changed.



In this example, the maps for pasture, croplands, urban, cover of bare ground, cover of herb-covered ground and cover of tree-covered ground will be different to the built-in data for WaterWorld. Always make sure to check if the maps show what you expect based on your own land-cover/use data before running the model.

- q. An alternative way of using this feature is to let WaterWorld decide on the values to use for the different classes. This can be done for all land-cover types where the value is displayed as (-). When you provide a code of your own land-use map in the code field and leave the value as (-), WaterWorld will calculate the value based on statistics within all areas covered by that code for the built-in data. For instance, if you have a map representing forest areas, you can provide that code and WaterWorld will calculate what values to use for tree cover, herb cover and bare cover based on statistics from the built-in data.
- r. Once you are satisfied with the data, click on **Step 3: start simulation** in the control panel on the left (**a**). In the new window that opens click **Start** (**b**) to start the simulation. This will run the model as described in section 2.2.3.



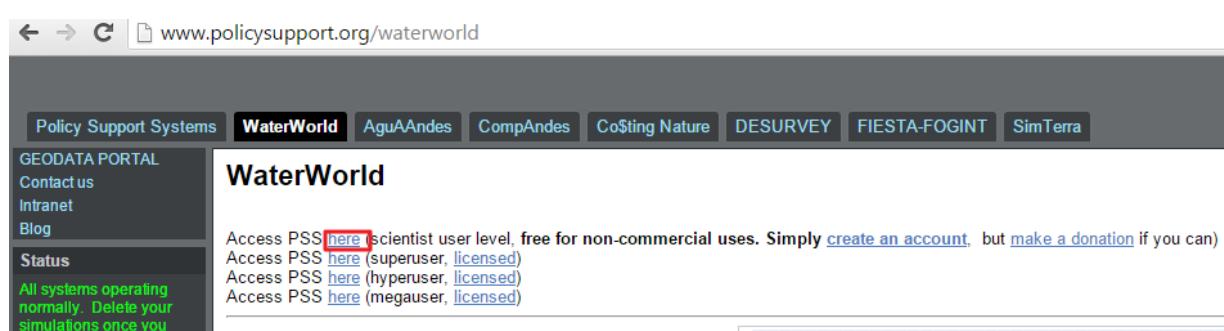
- s. When you have finished running the baseline scenario, you can then continue with a scenario simulation as described in section 3.

Annex II: Scenario: reforesting non-forest areas

This annex demonstrates how to run a scenario whereby all non-forest areas are reforested. This analysis could be used for helping to prioritize forest restoration options, by identifying areas in the landscape where reforestation would have the largest positive impact on soil erosion reduction and water provision.

This analysis can be carried out using the free Scientist user interface to the system and is very similar to the deforestation analysis demonstrated in Chapter 3.

- a. To get started, log in as a Scientist on the main log in page.



- b. Once logged in, you can either access any simulations carried out previously for this user level or set-up and run a new baseline (see sections 2.2.1 to 2.2.3 in the main tutorial on how to do that). By default the system will show you the last run selected. To select another run or to revert back to a baseline run for a particular area use the **Manage Simulations** function (see section 4.2).

Setting up the scenario

- c. Once you have finished or selected a baseline run, click on **Step 4: Policy Exercises** on the left hand control panel to set up the scenario simulation.

- d. To do a reforestation scenario, select the **Land Use and Cover Change: assess impacts of land-use change** option from the window that opens

- e. Next, click on the ± icon next to **define your own rule** (similar to section 3.1.1).

Instead of deforesting you will now aim to increase the tree cover in areas that have no tree cover or are not forested. There are a number of ways to target the increased tree cover. You can increase tree cover everywhere, where the current tree cover is equal to 0, effectively reforesting every pixel without any tree cover. Another option is to target non-forest clusters. Forest clusters are areas where tree cover is greater than 50% therefore using this map, areas with low to medium tree cover will also be targeted rather than only pixels with no tree cover.

- f. In this example, set the value for tree cover to **100%** and herb and bare to **0%**, selecting a value of **0** on the Forest clusters map as target area and **Define converted areas as Unchanged**.

LAND USE AND COVER CHANGE: choose the scenario that you wish to apply.

[View recent land use and cover change](#)

FOREST TO HERBACEOUS and HERBACEOUS TO FOREST: Changing forest cover replaces forest (tree cover) with pasture or cropland (herb cover). Changes of between -99% and 99% represent selective deforestation and afforestation respectively. Deforest a given percentage per pixel of trees with e.g. 15 or reforest by a given percentage per pixel of trees e.g. 15. Specify where and by what percentage (per pixel) deforestation or reforestation should occur:

Use a pre-defined rule: [±](#)
...or define your own rule: [±](#)

CREATE LAND COVER TYPE: For each row that you want to apply, set the corresponding percentage of tree, herb and bare soil functional types (FTs) per pixel to achieve the land cover that you wish, for example pasture might be 10% tree FT, 85% herb FT and 5% bare FT; a crop might be 10% tree FT 50% herb FT and 40% bare FT

Set/change tree, herb, bare covers:	100	%0	%0	% for approx:	100	per-cent	of land,cluster, <input checked="" type="checkbox"/> pixels:
where	Forest clusters						

other rules: [±](#)

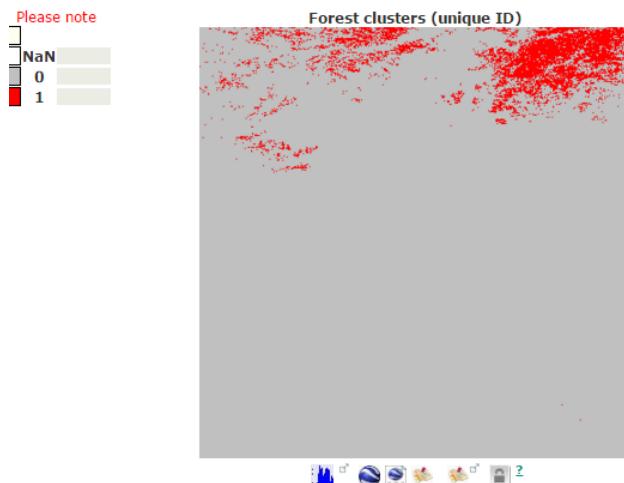
Define converted areas as: **Unchanged** ▾ Fraction of water exposed to contamination: **1** ▾, or: scale the default for land use.
Mean conversion cost (USD per ha.): **100**

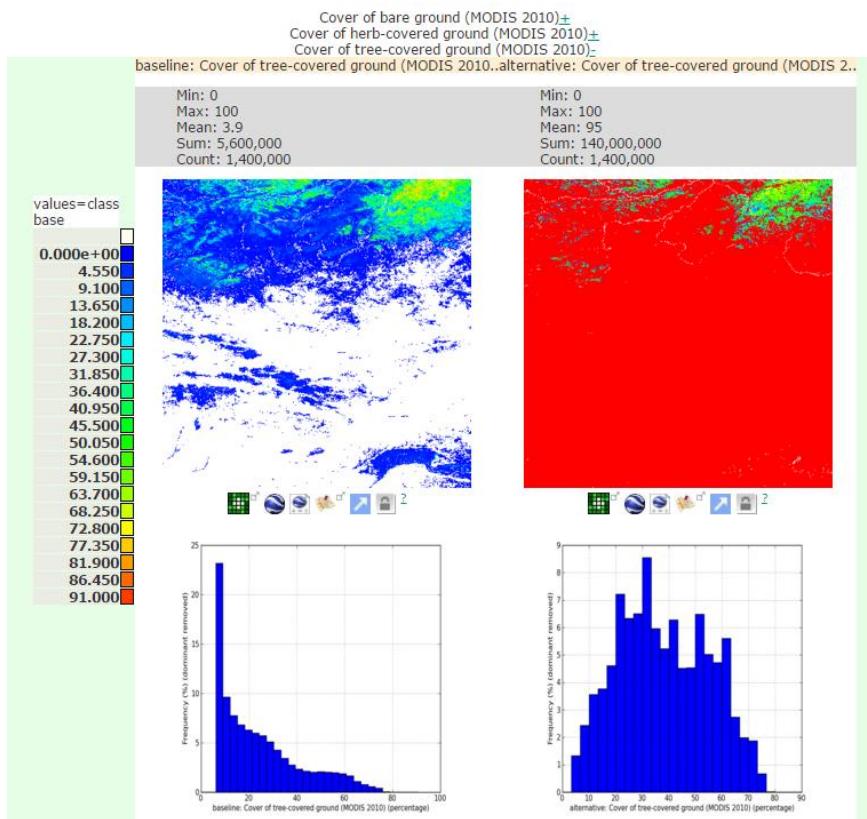
Check and Submit

- g. Click **Check and Submit**. Once the scenario is built, you can examine the changes in the vegetation functional-type maps (as described in section 3.1.1 in the main tutorial). Tree cover has now been set to 100% outside the forest clusters.

- h. Now to run the scenario click on the **Run scenario** icon in the window that opened after building the scenario

Or click on **Step 3: start simulation** on the control panel in the main window. (Make sure to refresh the page so you are certain you are running your reforestation scenario.)



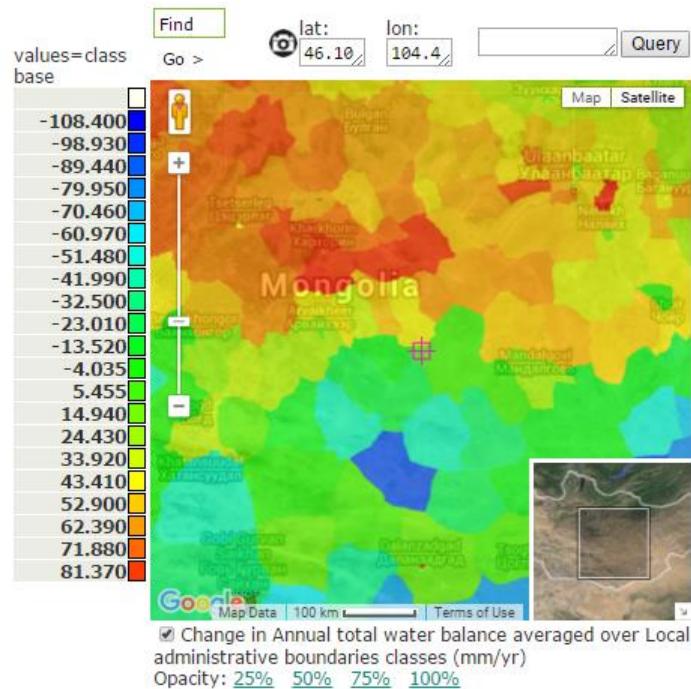


Results

- When the scenario simulation is finished you can examine the results by following the steps outlined in section **3.1.3** in the main tutorial.

The main variables of interest in a reforestation scenario are the projected impacts on the water balance and net soil erosion. These can be examined at pixel basis or aggregated by region. Follow the steps in section **3.1.3** to view the change in water balance map by local administrative region. This will give you a map as below. In our example, reforesting leads to variable changes in the water balance where some areas see an increase in water yield and others show a decrease. Of course the pixel-based output map will show you more detail, but aggregating by region may make it easier to visualize particular areas where the effects of reforestation would be greatest.

The desired change in water balance depends on the objective of the study. In some areas, a reduction in water is beneficial to reduce water management problems whereas in others increases in water balance are desirable. Also, the change in water balance and erosion will also depend on how restoration is carried out locally (e.g. which slopes in the 1 km² area are restored) and other factors not considered in this analysis, such as tree species used (e.g. different tree species can have very different impact on water balance).



Changes in net soil erosion are also variable, although most areas see a reduction in net soil erosion as a result of increased tree cover. Again, this can be visualized at pixel level but similar to the water balance, it is often useful to aggregate this by broader regions to see where reforesting will provide the greatest impact.

