RESEARCH PROGRAM ON Water, Land and Ecosystems
CGIAR
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Estimating water use by crops and other vegetation in the Volta basin using WaterWorld

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Scope and objective:

This guide focuses on how to run a baseline analysis using the WaterWorld hydrological model (Mulligan, 2013) with a particular focus on how to use the results to estimate the water use by crops and other vegetation in the Volta basin.

WaterWorld is a testbed for the development and implementation of land and water related policies for sites and regions globally, enabling their intended and unintended consequences to be tested *in silico* before they are tested *in vivo*. WaterWorld can also be used to understand the hydrological and water resources baseline and water risk factors associated with specific activities under current conditions and under scenarios for land use, land management and climate change. It incorporates detailed spatial datasets at 1-square km and 1 hectare resolution for the entire world, spatial models for biophysical and socio-economic processes along with scenarios for climate, land use and economic change. A series of interventions (policy options) are available which can be implemented and their consequences traced through the socio-economic and biophysical systems. The model integrates with a range of geobrowsers for immersive visualisation of outcomes.

Input data for application of this model anywhere globally (from remote sensing and other global sources) is included in the system. However, users can also use this model with their own datasets. Application with the provided datasets takes only half an hour and requires no GIS capacity. Bringing in your own datasets will take much longer depending on the availability, level of processing, format and consistency of those datasets and also requires GIS capacity.

Typical applications of the model include, water resources assessment, water security analysis and hydrological ecosystem services accounting. Also climate impacts analysis and land and water management.

Audience: Conservation and development NGOs, GO and NGO Policy analysts, agriculture and industry (e.g. extractives), education and academic research.

Description and application

To access the tool, go to http://www.policysupport.org/waterworld and click on the relevant link to create a free account which can be used with the scientist user level interface. This guide uses the megauser level interface as some of the features described are not available for the scientist version. Access to this user level can be granted on a case basis. These new features will make their way into the scientist version of time. For more information please contact Mark Mulligan at King's College London (mark.mulligan@kcl.ac.uk)

After logging in, there are four easy steps to run the model for a baseline simulation. All these steps are also documented in training video's. At each step you can find the link for the relevant video.

Running a baseline analysis in WaterWorld

Step 1: Define study area
Video: here

The model can be run at 1-km and 1-ha resolutions with a tiled extent of 1-degree (~100 km) or 10-degrees (~1000 km). The 1-ha resolution can only be run within the 1-degree tiles. The 1-km resolution can be run within tiles of 10 degrees or at country or large river basin level. To select your study area, you can either move the map until your area is within the highlighted tile (blue for 1-km, 10 degrees and pink for 1-ha, 1 degree) or select a country or basin from the dropdown list (Figure 1, A). Once you have selected your area, you need to give it a name (Figure 1, B) and click on Step 1: Define area.

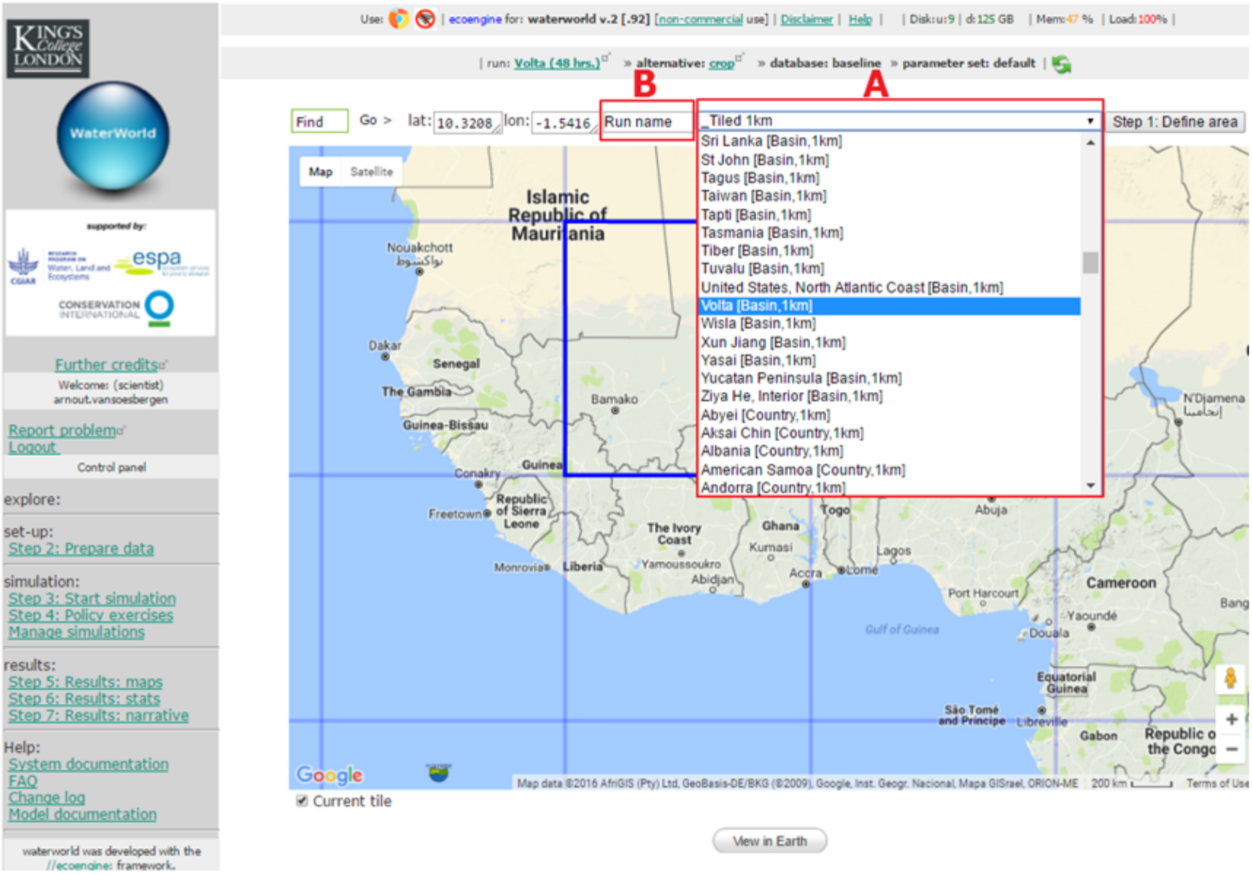

Figure 1: Define area for running the model

Step 2: Prepare data
Video:here

Step 2 is about preparing the data. WaterWorld comes with all necessary data included to run the model. For each model run however, data will have to be prepared and copied to your personal workspace (linked to your account). To set up data for a model run, click on Step 2: Prepare data (Figure 2, A). This will then open up a window where you can view the list of data (list baseline workspace data) or Copy data to your workspace (Figure 2, B) which is required to run the model. When clicking on this, the system will take a few minutes to gather and copy the necessary data to your workspace on the servers. When the data is ready you can view the workspace data by clicking on the +/- next to show workspace data (Figure 2, C).

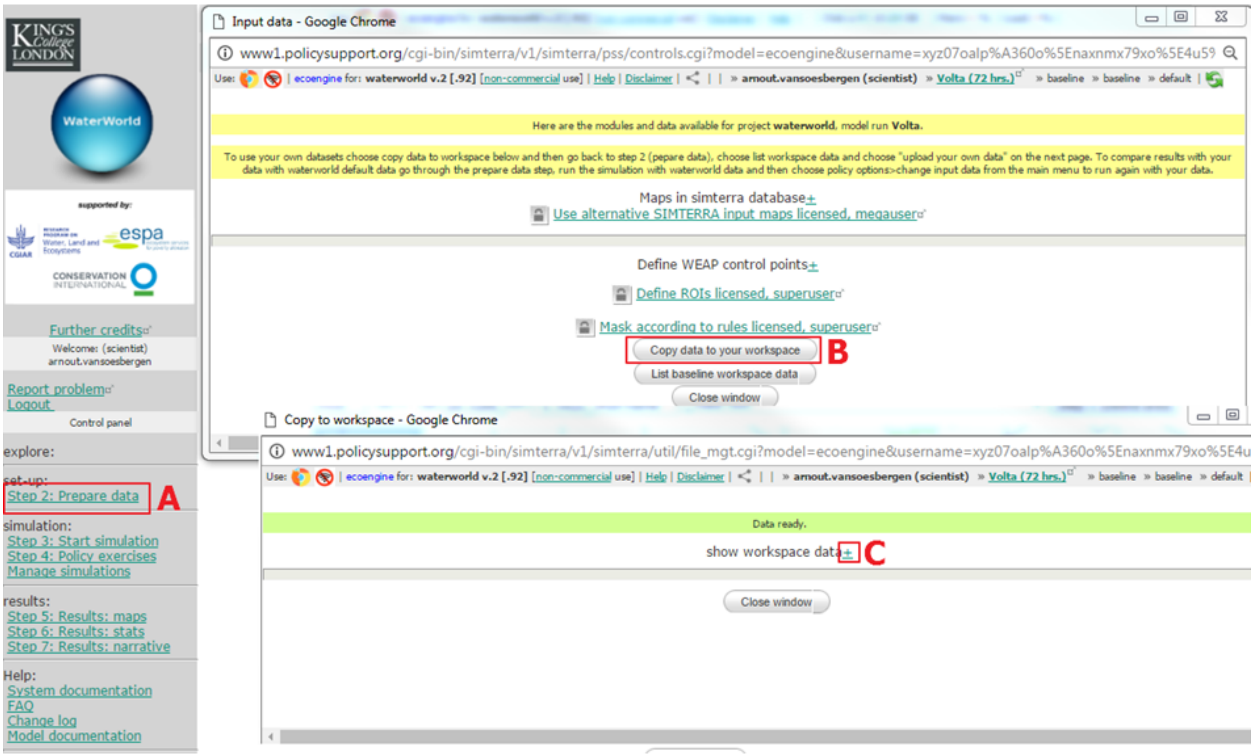

Figure 2: Step 2: prepare data

Visualising data

Opening up the list of workspace data (Figure 2, C) will show the list of all datasets necessary to run the model. Around 140 spatial datasets are required for a run. Maps that have a license to redistribute can be downloaded in a variety of GIS formats (Figure 3, A), or can be viewed (Figure 3, B), depending on the license.

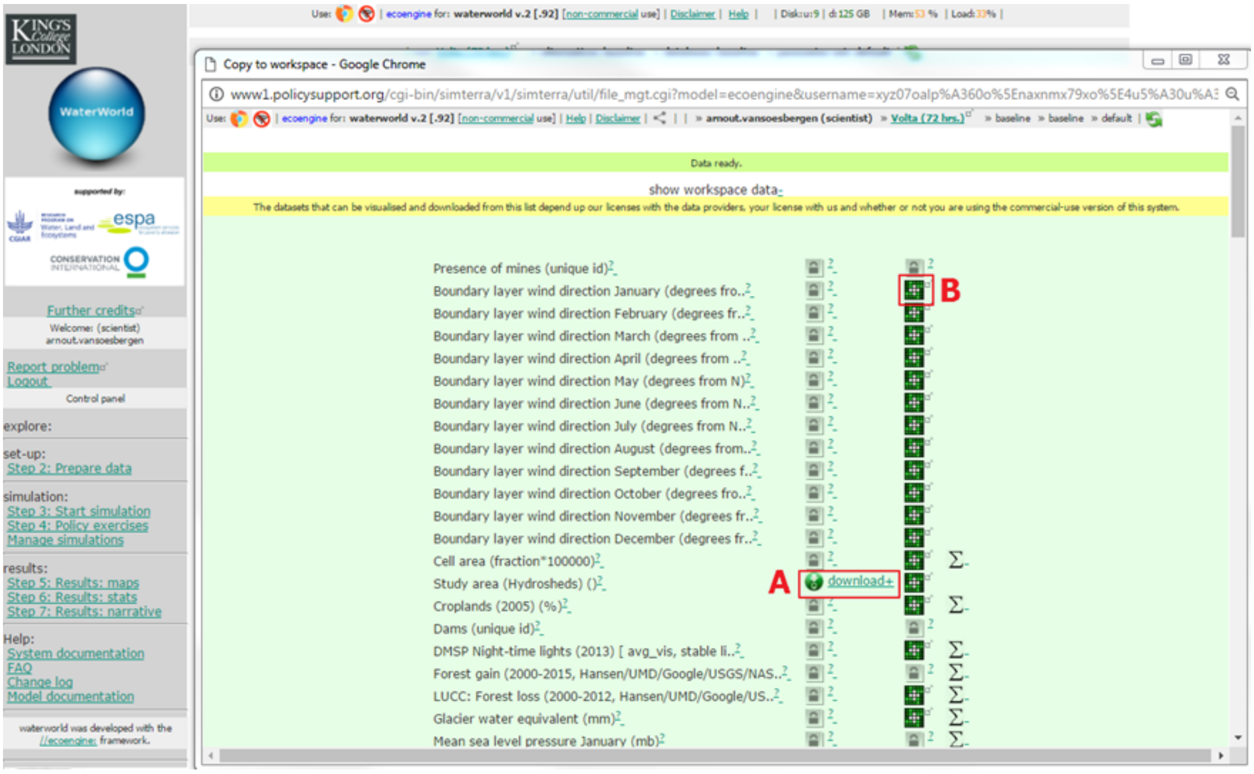

Figure 3: Download or visualise maps in workspace

Clicking on the green view map icon (Figure 3, B) will open up a map viewer window with a number of options similar to those in a GIS. Any map (input or output) can be overlaid on Google Earth or Google maps. Some of the options are shown in Figure 4, showing a pixel based map of tree cover (A), and overlaid on Google Maps (B) for which you can query individual pixel values by moving the map until the crosshair overlays your pixel of interest and clicking on Query. Maps can also be aggregated over other maps by selecting a map from the View by dropdown above the main map, e.g. select protected areas (C) to view the mean tree cover percentage in protected areas (D)

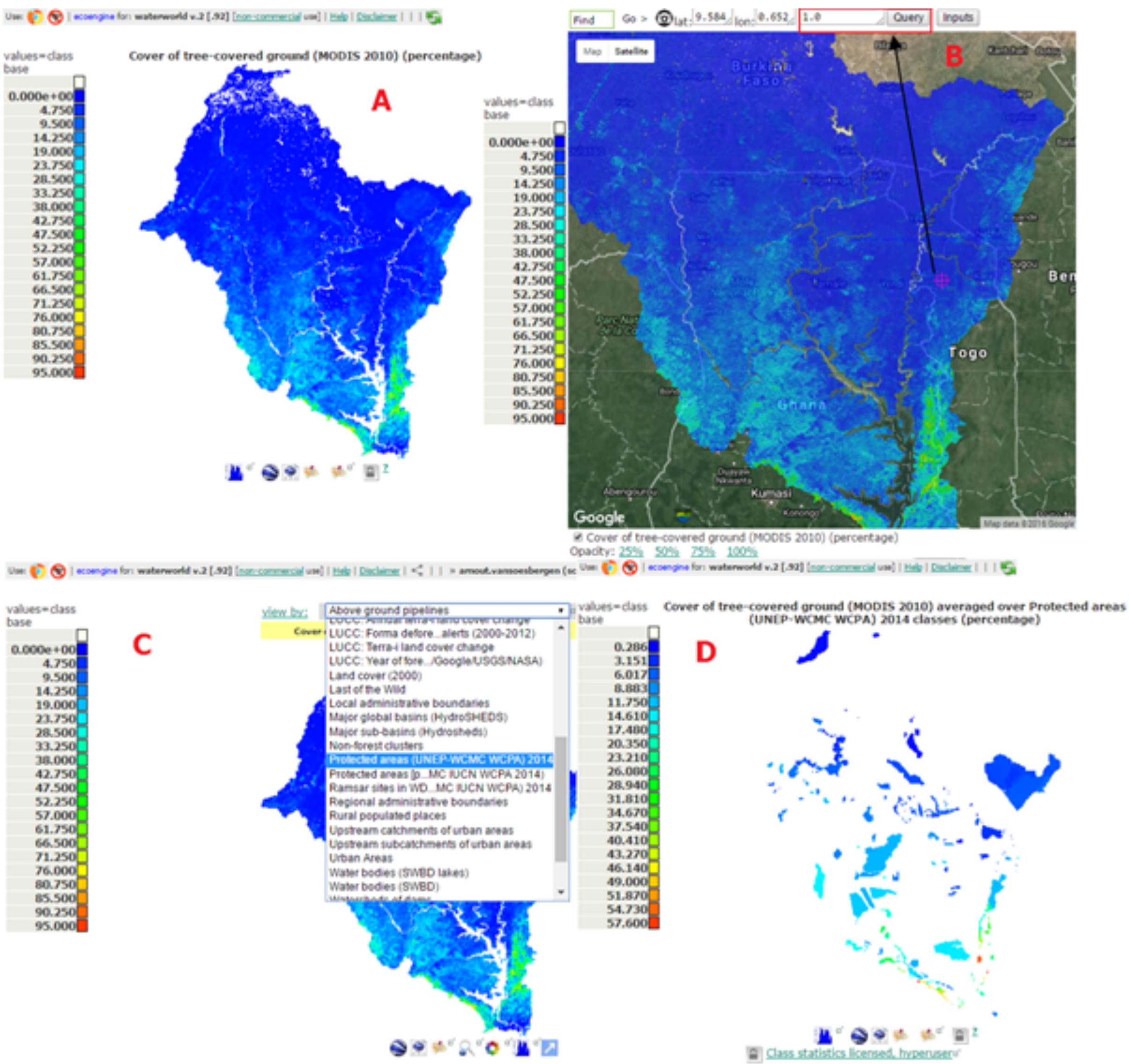

Figure 4: visualising input and output maps

Step 3: Start simulation
Video: here

Once all data has been copied over to your workspace, you can start the simulation by clicking on Step 3: start simulation in the left hand control panel on the main page (Figure 4). This will then open a simulation window where you can choose whether you want to write monthly maps or not. Clicking on Write maps will create monthly output maps. The default is not to write monthly maps as these are not always necessary and take up a lot of space on the servers however to calculate a

seasonality map it is necessary to run monthly maps. After you have selected to write monthly maps, click on Start to set the simulation running. A simulation will take around 10 minutes to run a sophisticated hydrological baseline. If the area has never been run before by anyone else, this can take 24 hours (because of preprocessing) but once started, window or computer can be switched off. The run will complete without user interaction.
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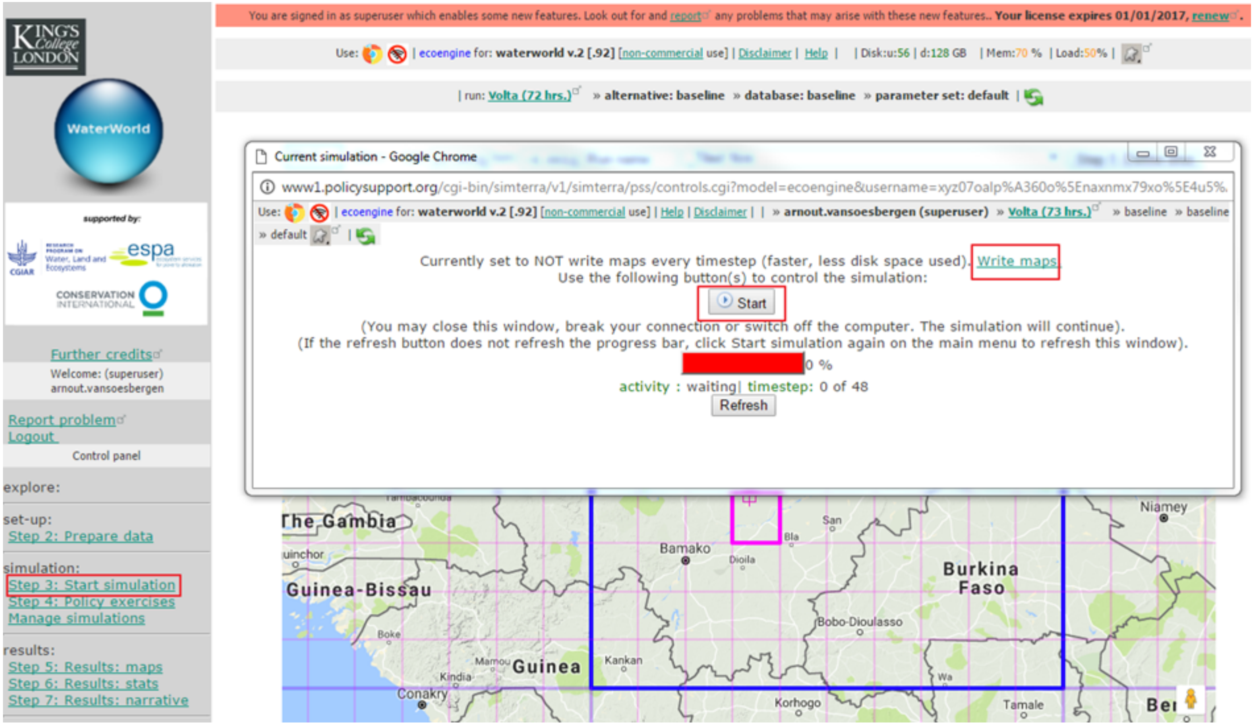

Figure 5: Step 3: start simulation

Step 5: Results maps
Video: here

Once the simulation has finished you can look at the results by clicking on Step 5: results maps in the left control panel on the main page. Step 4 is skipped as that step is for scenario simulations which can only be run after a baseline run has been done. Map outputs from all runs (baseline and scenario) are always in step 5. This will open up a new window showing all the map results as shown in Figure 5. You can view and interrogate the output maps by clicking on the green view map icon (A) which gives you all the options to view and analyse the maps as discussed in the previous section.

Figure 6: Step 5: results: maps

Estimating water use by crops and other vegetation in the Volta basin

Once a baseline has been run in WaterWorld, water use statistics of crops and other vegetation can be calculated. To do this, select the option of Analyses, metrics and reporting (Figure 7) in the Step 5: results maps window.

The output datasets that appear on this list depend upon your licensed user level and whether or not you are using the commercial-use version of this system.

Analyses, metrics and reporting
Costs mapping+
Benefits mapping+
Water quality mapping+
Key output maps-

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 (m^3/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)	

Figure 7: Analyses, metrics and reporting in results maps window

This will then open up another window where expanding the options next to Hydrology (Figure 8, A) provides a number of hydrological analysis functions. Clicking on the calculate next to crop water use will then calculate the actual evapotranspiration of all major crop types as well as pasture and natural vegetation.

Topographic metrics: New +
Natural infrastructure: New +
Terrain and streams: New +
Hydrology: New - A

Variable	Explanation	Calculate
Crop water use [modelling]	Actual evapotranspiration of major crop types, pasture and natural vegetation (green water)	Calculate B
RS based Human footprint on water quality	Calculates the human footprint on water quality using RS based water balance data.	Calculate
World Bank WAVES Water accounting	Calculates water WAVES stock and flow accounts nationally.	Calculate
RS based natural capital footprint on water quality	Calculates the natural capital footprint on water quality using RS based water balance data.	Calculate

Cloudforests: New +

Figure 8: Calculate crop and other vegetation water use in WaterWorld

The resulting window shows monthly (if monthly output maps run) and annual maps (e.g. Figure 9 A) for each major crop type as well as croplands, pastures, natural vegetation and total actual evapotranspiration. Statistics of water use in mm for each of these vegetation types can be shown by clicking on the expand next to show stats (B).

Figure 9: WaterWorld crop and vegetation water use

Documentation and further reading:

Model and data documentation for version 1 can be found here and system (interface and functionality) documentation is here. A presentation on the science behind the PSS can be found here (English) and here (Spanish) [opens in Google docs viewer]. Download: (EN, ES). A powerpoint demo of the system functionality is here (English) and here (Spanish) [opens in Google docs viewer]. Download: (EN, ES)

References:

Model description:

Mulligan, M., & Burke, S. M. (2005). FIESTA: Fog interception for the enhancement of streamflow in tropical areas, Appendix 4a to Final Technical Report of DFID-FRP Project no. R7991.

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.

Example applications:

Mulligan, M., Rubiano, J., Hyman, G., White, D., Garcia, J., Saravia, M., ... & Leonardo Saenz-Cruz, L. (2010). The Andes basins: biophysical and developmental diversity in a climate of change. *Water International*, *35*(5), 472-492.

Bruijnzeel, L. A., Mulligan, M., & Scatena, F. N. (2011). Hydrometeorology of tropical montane cloud forests: emerging patterns. *Hydrological Processes*, *25*(3), 465-498.

van Soesbergen, A. J. J., & Mulligan, M. (2014). Modelling multiple threats to water security in the Peruvian Amazon using the WaterWorld policy support system. *Earth System Dynamics*, *5*(1), 55.

Synthesize measured and modelled water data to determine on-field water consumption by crops, and water consumption for vegetation producing other ecosystem services
This has been analysed using WaterWorld at the Volta scale and is available here Volta Crop water use (columns B:Oo)

Evaluate non-crop demands on water in the basin
This has been analysed using WaterWorld at the Volta scale and is available here Volta Crop water use (column P)

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