



**Co\$ting nature : Application of WDPA datasets to
managing ecosystem services**

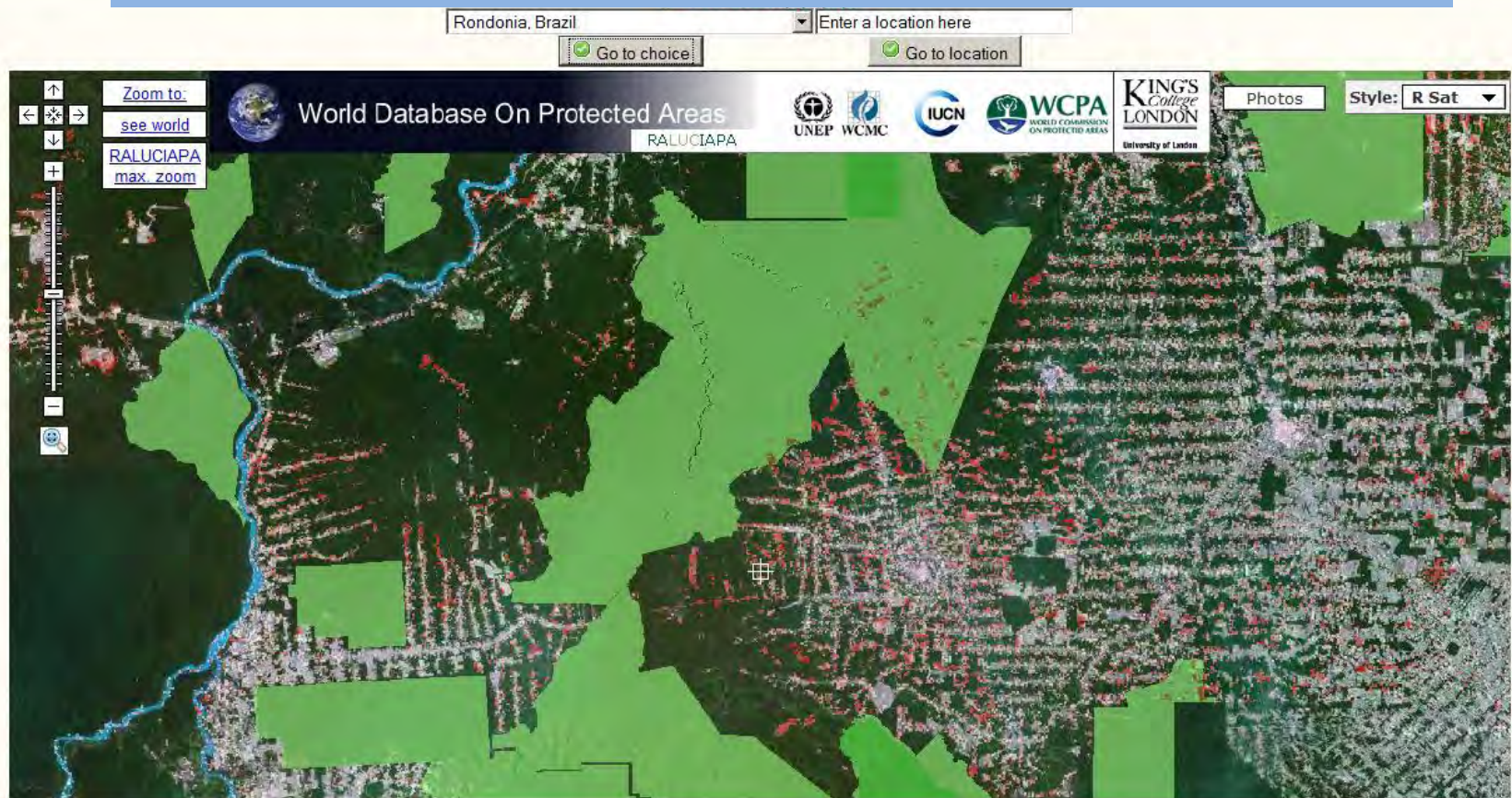
Mark Mulligan,
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Reader, King's College London
mark.mulligan@kcl.ac.uk

Changes in the terrestrial environment affect the services that those environments provide to humanity

Better management of change requires:

- Monitoring of changes
- Assess the impact on environmental service provision
- Test the outcome of hard (eng.) or soft (policy) interventions

RALUCIAPA : static tree cover difference 2000-2005, with WDPA





PARASID – dynamic, near real-time 16 day monitoring of land cover change based on neural network analysis of MODIS data. Land use change Rondonia 2004-present (more yellow=more recent)



Co\$ting Nature

Aim:

To step back from the complexities and detail of ongoing site specific studies on ecosystem services and provide a global assessment of the geographical variation in ecosystem service provision and its economic value:

- to **hotspot** areas of high dependence on particular ecosystems
- to identify areas where **protection could secure better services**
- as a means of informing the development of payment for environmental services (**PES**) schemes
- starting with **water** and **carbon** services from **protected areas**

Collaborative: KCL-UNEP-WCMC



Water quantity services

- Protected ecosystems do not necessarily generate more rainfall than agricultural land uses.
- Protected ecosystems may have higher evapotranspiration and thus lower water yields

Thus quantity benefits difficult to prove

Water regulation services

- Protected ecosystems do not protect against the most destructive floods
- For 'normal' events they do encourage more subsurface flow and thus more seasonally regular flow regimes

Likely benefits especially in highly seasonal environments



Water quality services (quantity for a purpose)

- Protected ecosystems encourage infiltration leading to lower soil erosion and sedimentation
- Unprotected land will tend to have higher inputs of pesticides, herbicides, fertilisers ...

Clear benefits of PA's: generation of higher quality water than non-protected areas

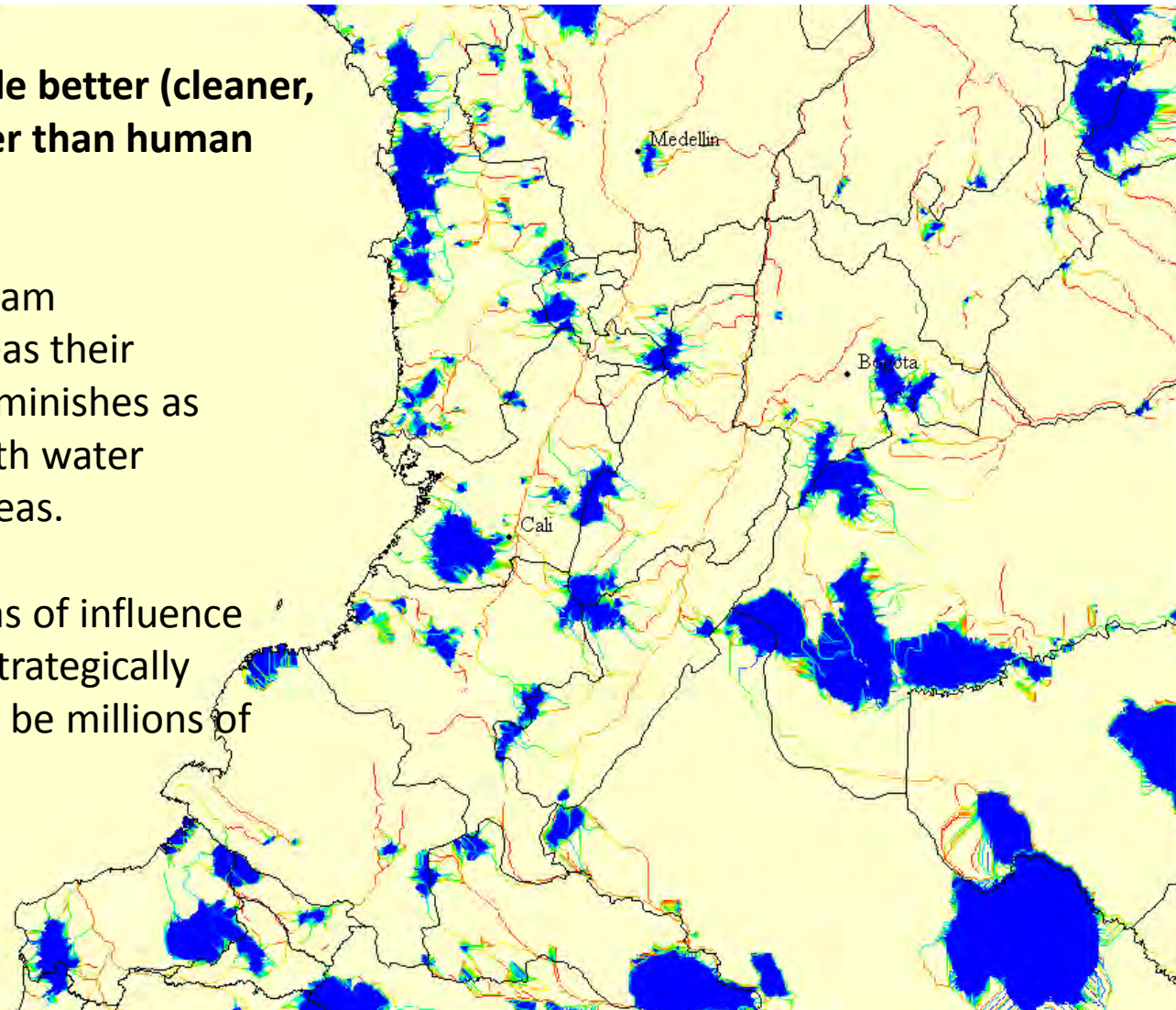
Tracing the impact of protected areas on water

Assumption:

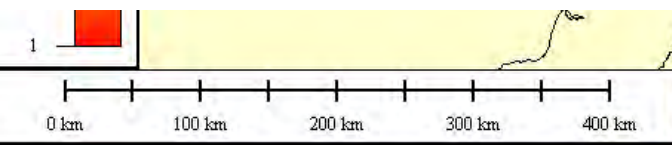
Protected areas provide better (cleaner, better-regulated) water than human dominated areas.

As you travel downstream from the protected areas their contribution to flow diminishes as rivers are swamped with water from non-protected areas.

Populations in the areas of influence benefit greatly. With strategically positioned Pas this can be millions of people

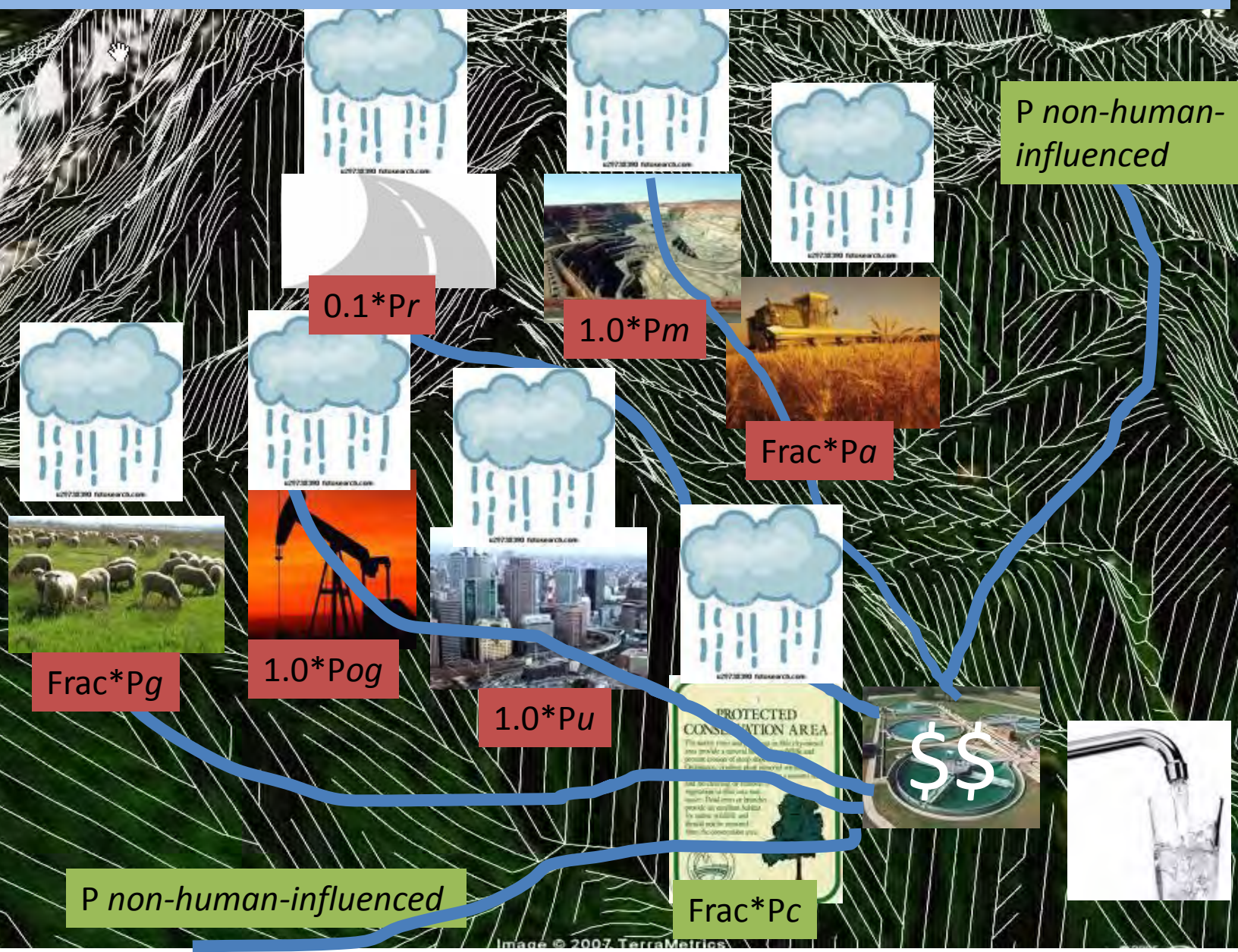


% of water originating in a protected area – WDPA 2009 (Colombia) [gl_pc_wc_fin]

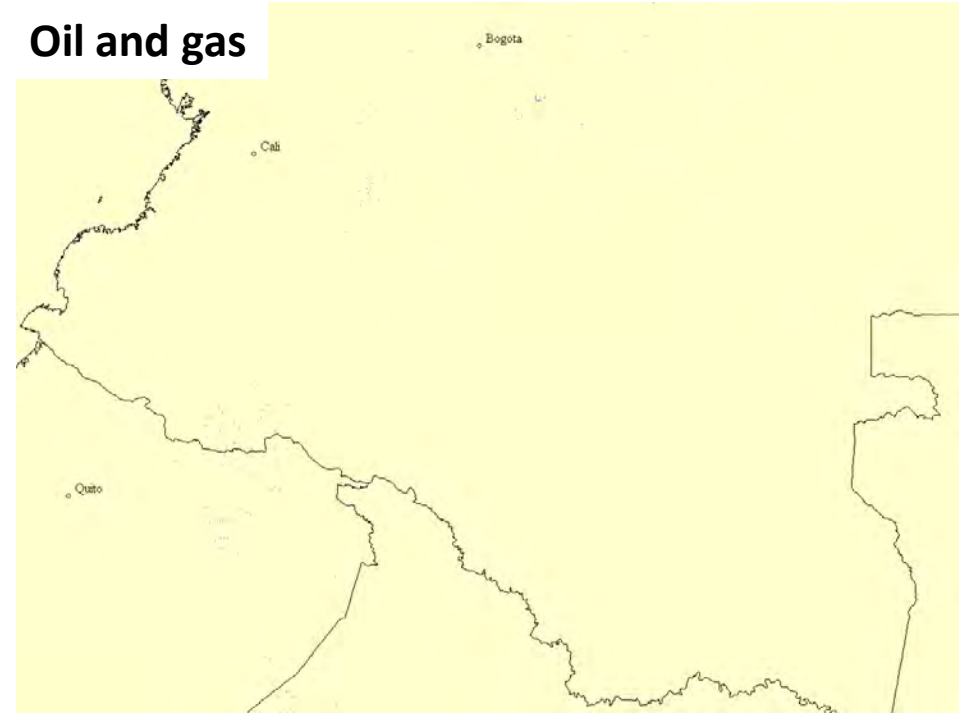
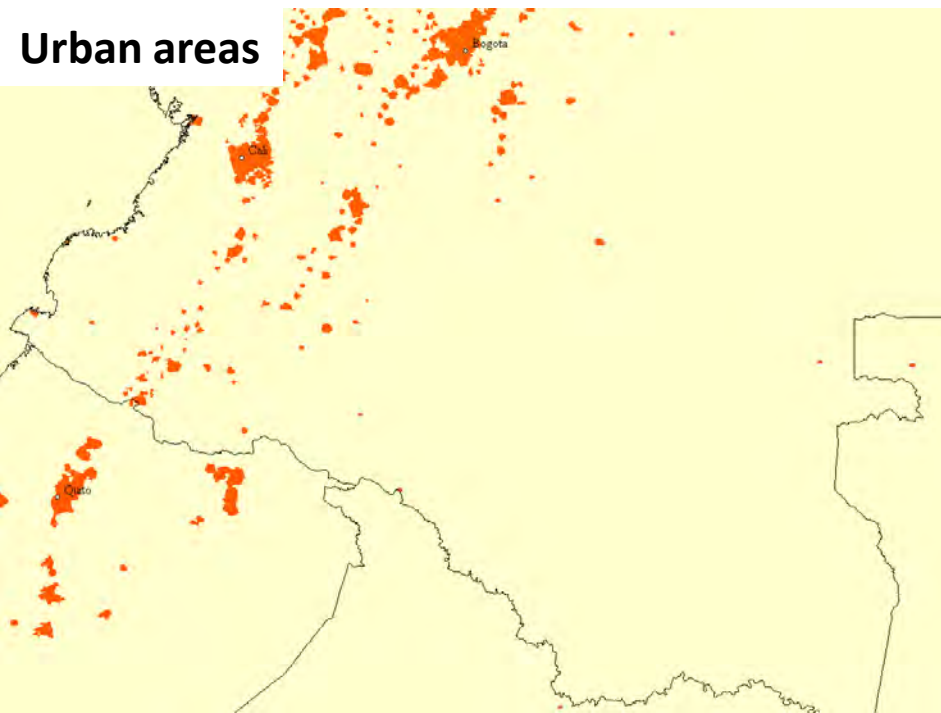
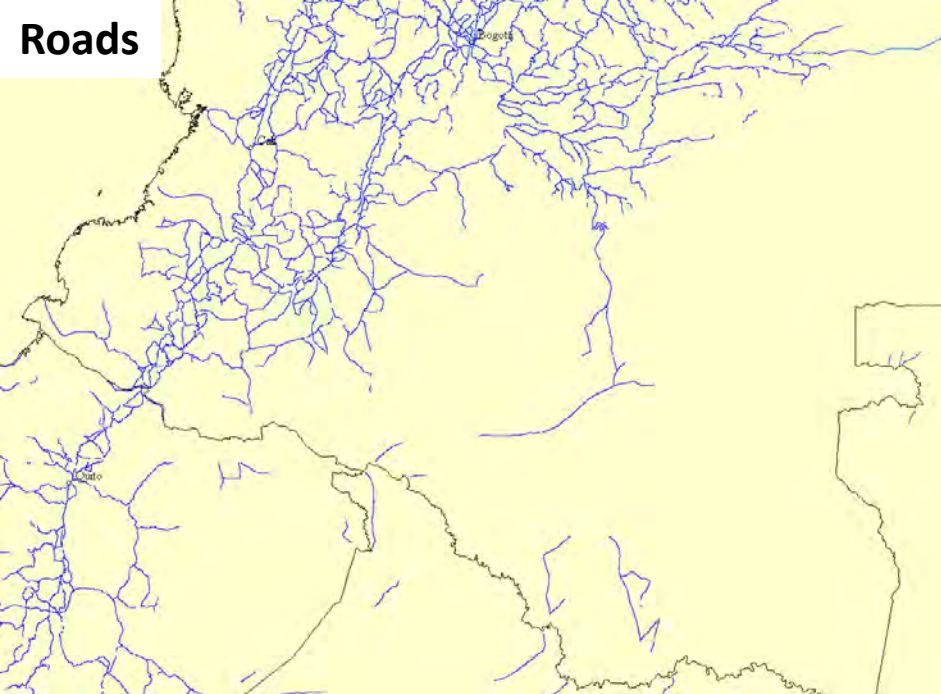


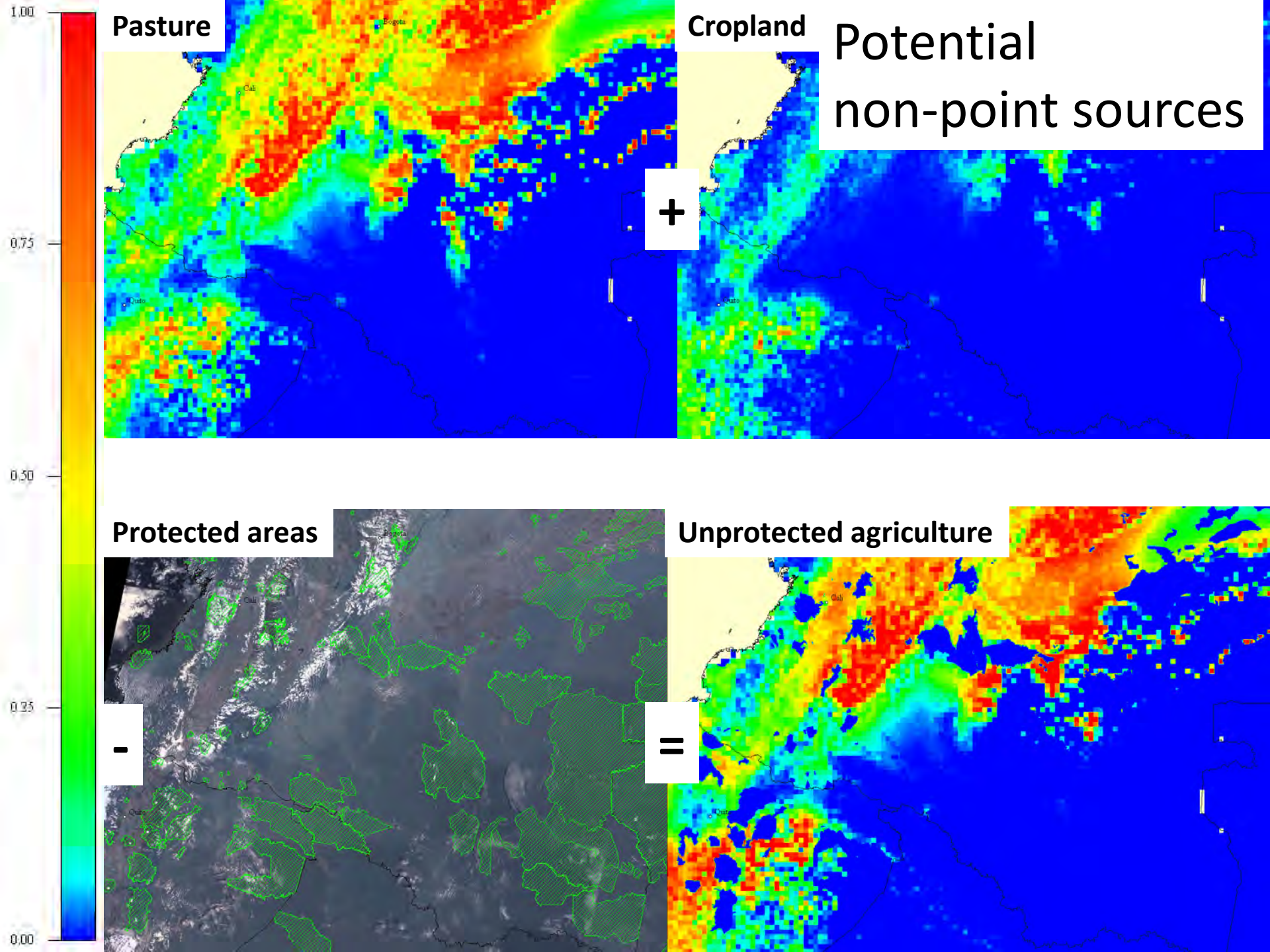
see www.kcl.ac.uk/geodata

Water quality : protected areas and the human footprint on water

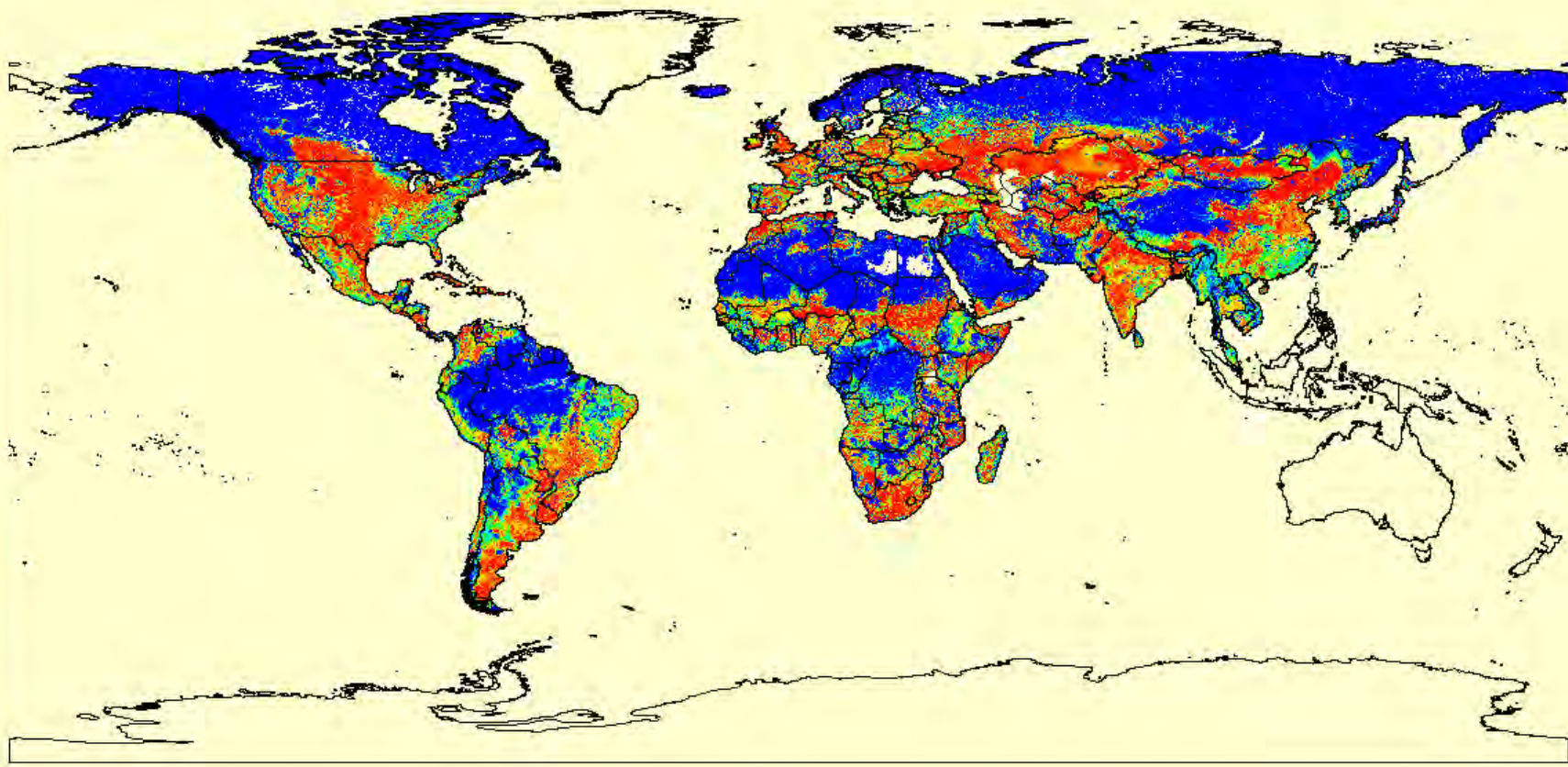


Human Footprint on Water at a point=upstream($\sum P_{polluting} / \sum P_{total}$)

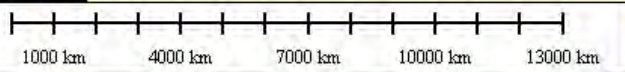




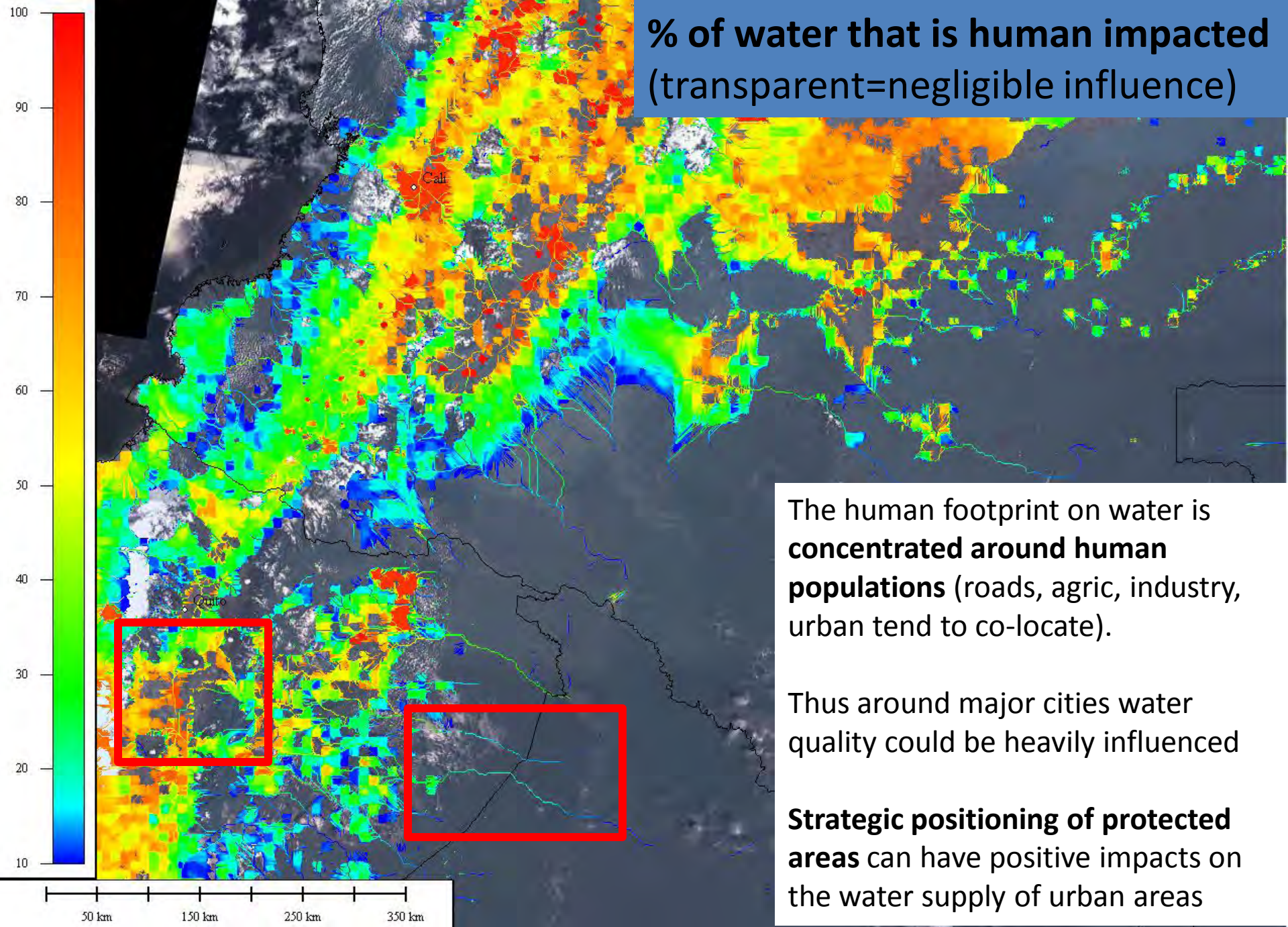
% of water supply that is human impacted



At the global scale dominated by the human agricultural footprint



% of water that is human impacted
(transparent=negligible influence)



The human footprint on water is **concentrated around human populations** (roads, agric, industry, urban tend to co-locate).

Thus around major cities water quality could be heavily influenced

Strategic positioning of protected areas can have positive impacts on the water supply of urban areas

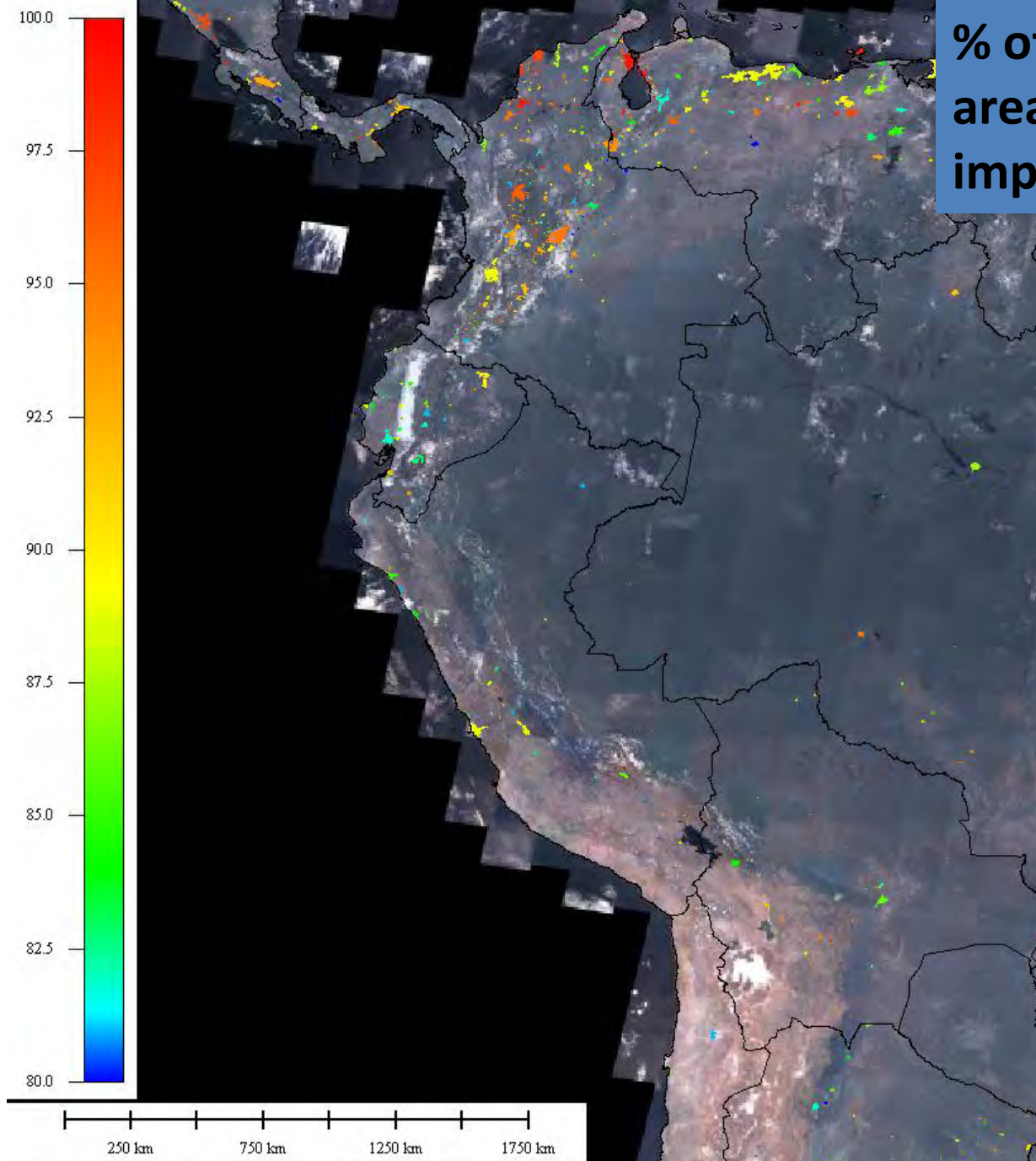
% of water supply to urban areas that is human impacted

Colombia has a lot of water but also high population, extensive urbanisation and agriculture in the Andes.

Colombia's urban water supplies are thus **heavily influenced** by upstream human activity

This necessitates costly diversion schemes or water treatment.

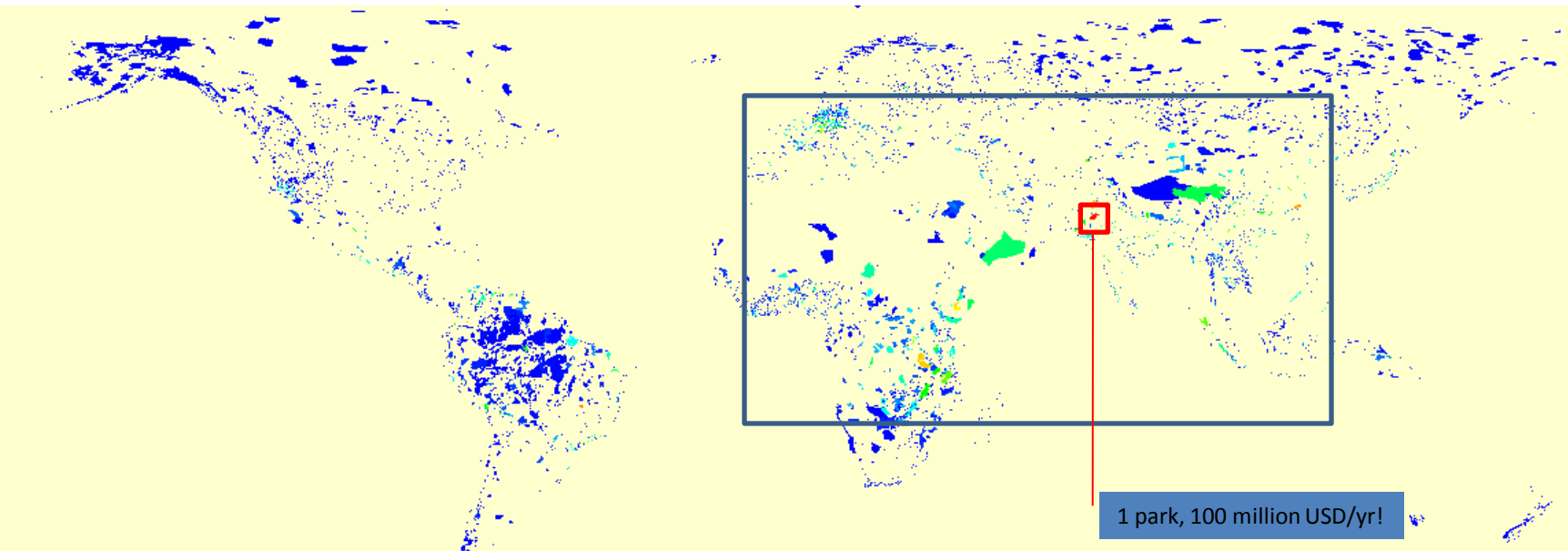
Putting a natural PA buffer between populations and the mess they create can deliver clear water quality benefits at low cost.



The economic value of water falling as rain on protected areas

Mean cost of drinking water to the user for 83 countries is 0.76 USD/m³ (up to 2.61 USD/m³ in some developed countries). A number of studies indicate **willingness to pay double current water costs** for improved water quality from PWS (Manez Costa and Zeller, 2005, Ortega-Pacheco et al. 2009).

Method: We calculate actual human **water use by summing the population downstream** of each park, assuming each person consumes the average water use globally (50m³/person/yr), **calculating how much of this water is derived from the PA**, multiplying by the global average price (0.76 \$/m³) and assigning to the upstream park.

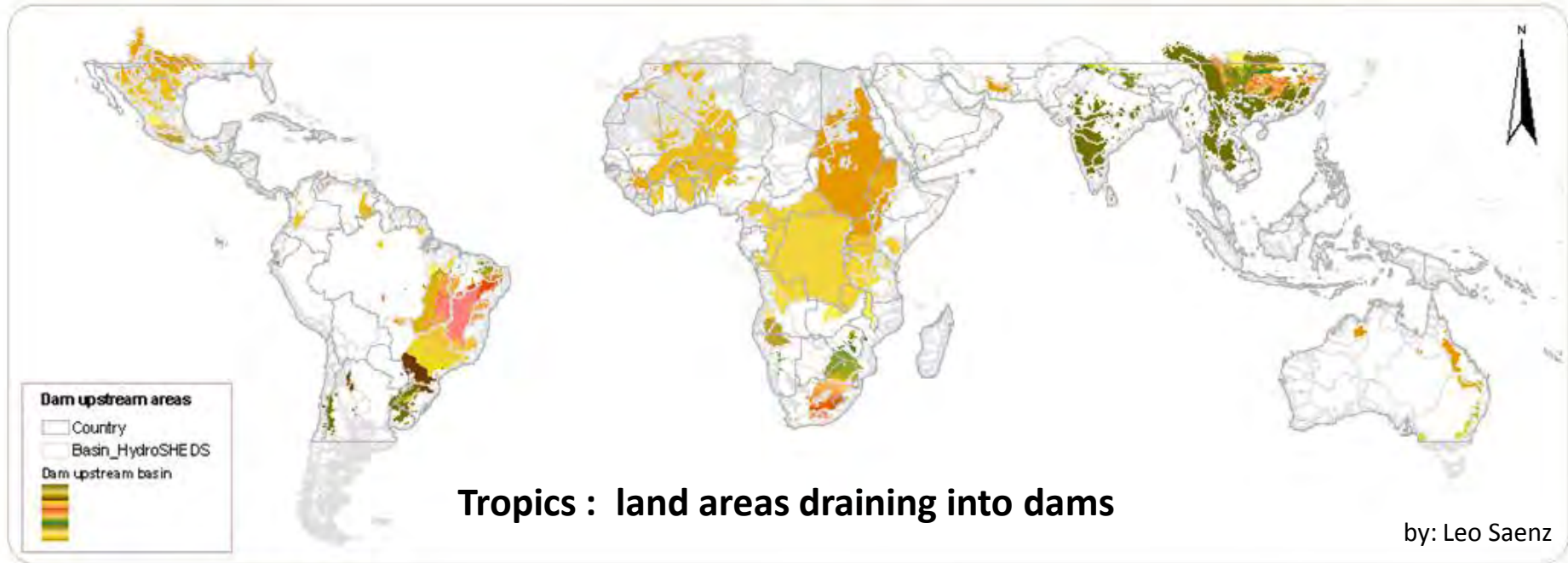


Result: Parks which produce a lot of water and are also upstream of dense populations provide a lot of economic value. The most valuable park for water is Cholistan (PK) – a large park upstream of Karachi (pop. 18 million) in a low rainfall region.

Realisable water value of protected areas (millions of US\$/park/yr).

Australia excluded.

Dams : points in the landscape at which water=money



The first georeferenced global database of dams www.kcl.ac.uk/geodata

There are at least 29,000 large dams between 40N and 40S

57% in Asia, 23% in South America. 80% are in China, India, Brazil, South Africa, Zimbabwe, Mexico

33% of land area between 40S and 40N drains into a dam and this surface provides important **environmental** and **ecosystem** services to specific companies, **who might pay for those services to ensure they are sustained**, passing the cost on to you and me.

Carbon services

Total CO₂ uptake of ecosystem (carbon service) = carbon stock (carbon already sequestered and stored) + **carbon sequestration** (additional net carbon uptake per year)

Mature forests = high stock, low sequestration (good not to cut and burn because this will add carbon to the atmosphere but they are not taking up much carbon annually)

Younger forests = lower carbon stock but greater long term sequestration than many land uses so less of a carbon injection if cut and burned. But, if cut and replaced by a less productive cover results in loss of carbon uptake, accumulating year on year.

Sequestration can be calculated from:

Net primary production NPP = uptake of carbon by photosynthesis minus the autotrophic respiration losses by vegetation

$$= S * c * fAPAR(NDVI) * e * p(T) * CO_2 \text{ fert} * (1-r)$$

S: global solar radiation [MJ/m²/d]

c: climatic efficiency, Mc Cree K.J. (1972) [dimensionless]

fAPAR: Fraction of absorbed PAR (photosynthetic active radiation); fAPAR is estimated from the remotely sensed NDVI (Normalised Difference Vegetation Index) by means of a linear equation, suggested by Myneni (1992) [dimensionless]

e: Photosynthetic efficiency, Wofsy et al. (1993) [gC/MJ(APAR)]

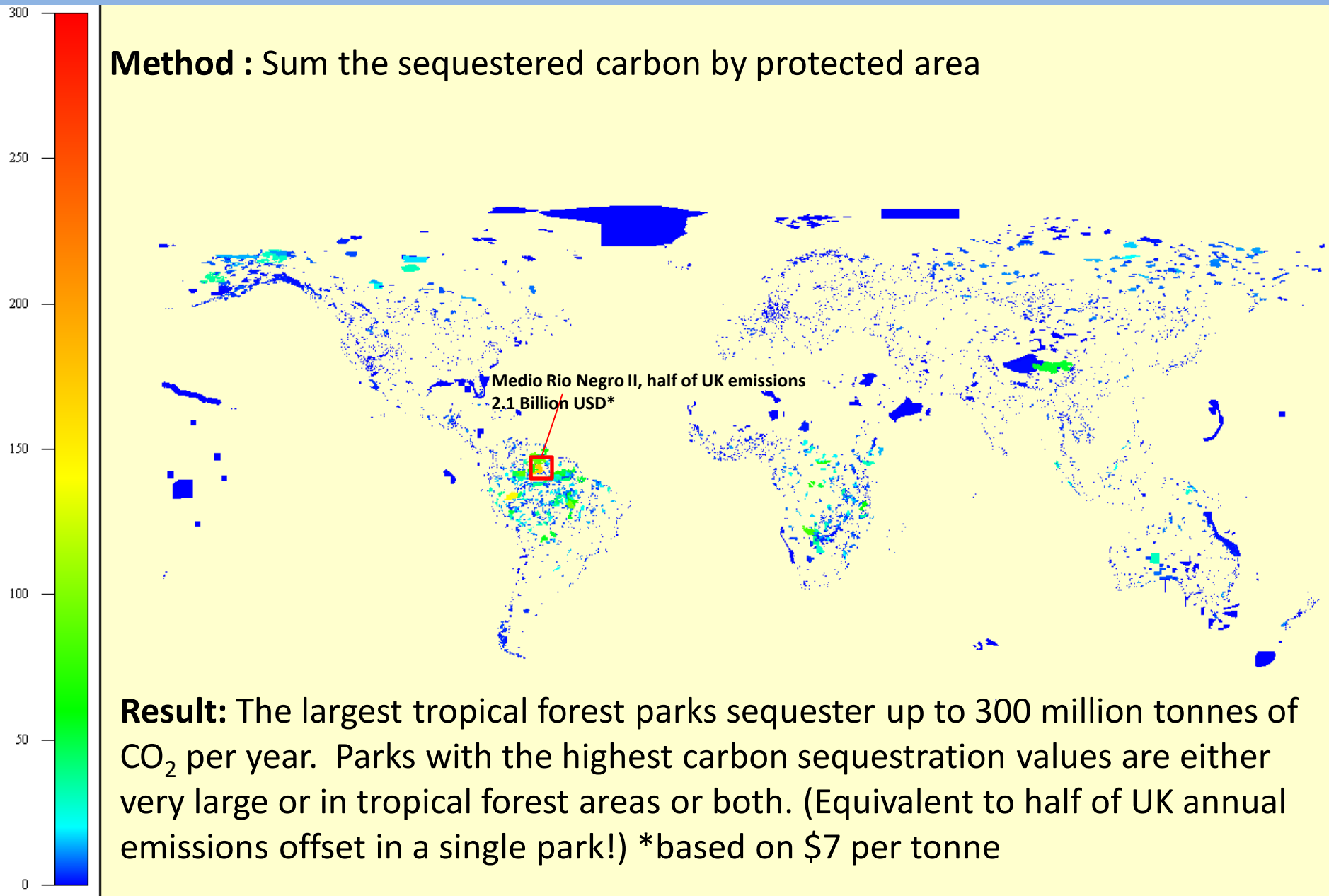
p(T): Normalised temperature dependency factor, Johnson et al. (1954), and parameterised according to data of Lommen et al. (1971) [dimensionless]

CO₂ fert: Normalised CO₂ fertilisation factor, Veroustraete (1994) [dimensionless]

r: fraction of assimilated photosynthates consumed by autotroph respiration; is modelled as a simple linear function of daily mean air temperature, Goward & Due (1987)

What is the carbon sequestration of the parks?

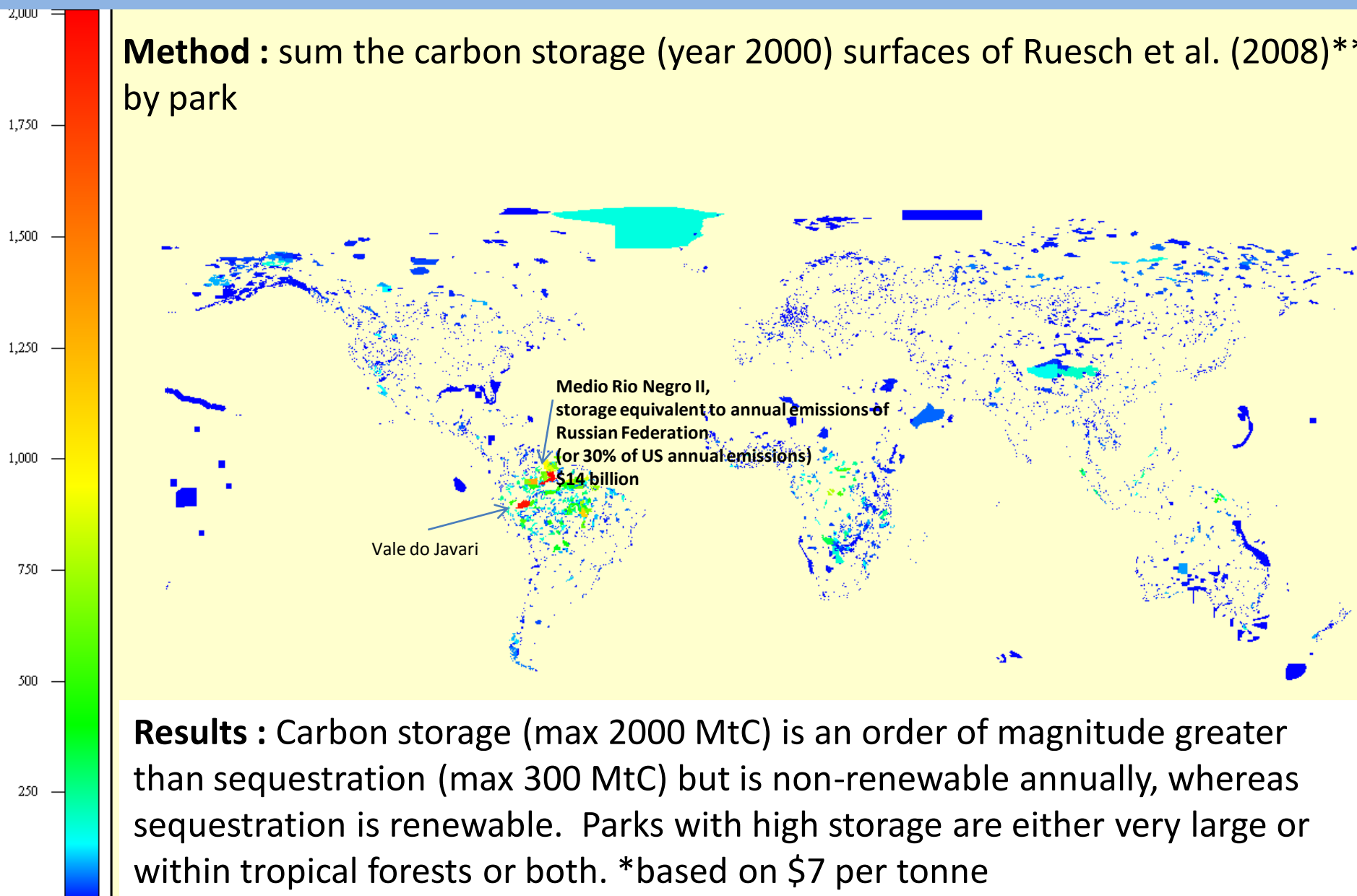
Method : Sum the sequestered carbon by protected area



Total carbon sequestration by PA (millions of tonnes C/yr)

What is the carbon storage of the parks?

Method : sum the carbon storage (year 2000) surfaces of Ruesch et al. (2008)** by park



Results : Carbon storage (max 2000 MtC) is an order of magnitude greater than sequestration (max 300 MtC) but is non-renewable annually, whereas sequestration is renewable. Parks with high storage are either very large or within tropical forests or both. *based on \$7 per tonne

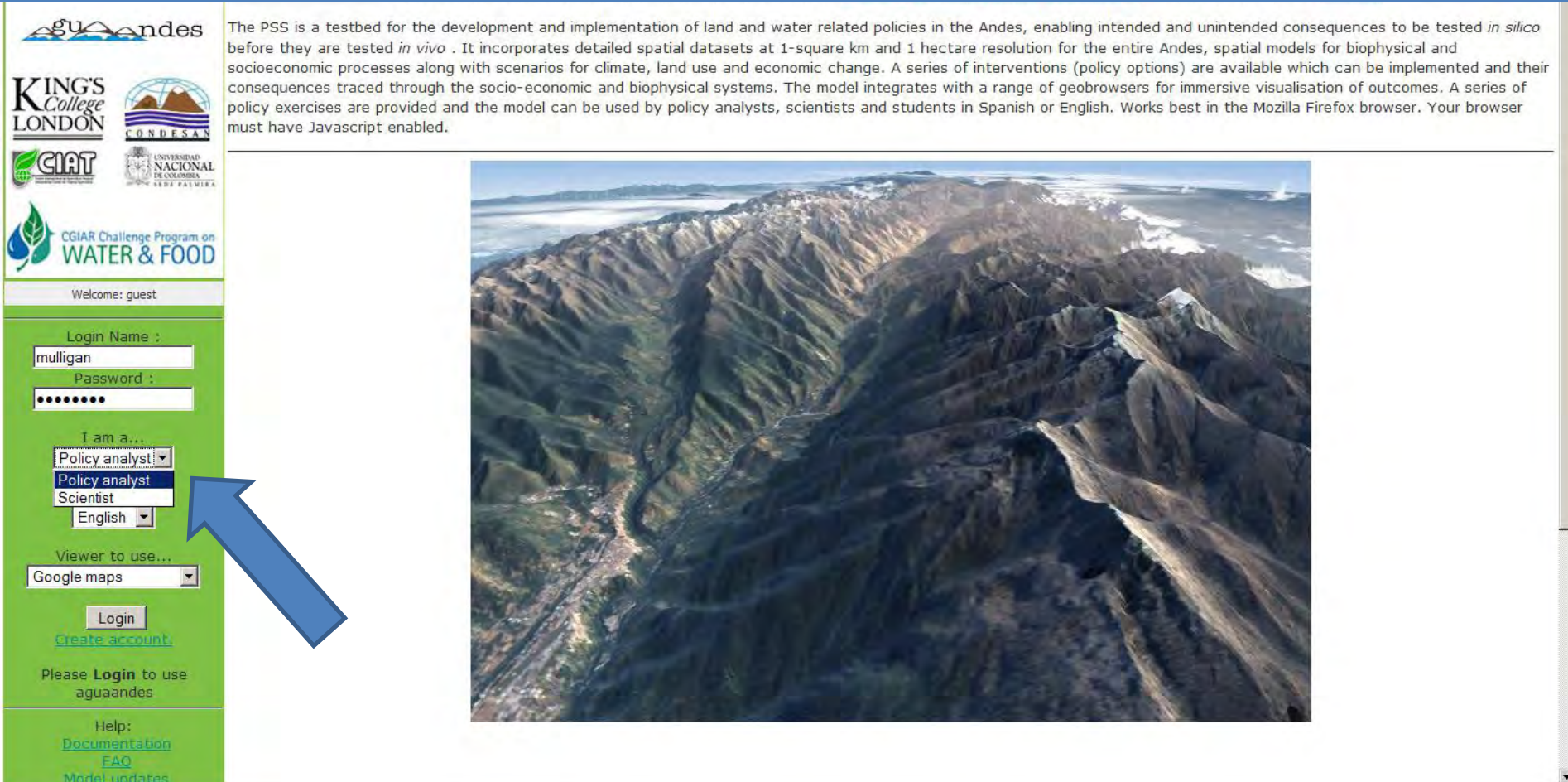
Carbon storage (M tonnes C)

**Ruesch, Aaron, and Holly K. Gibbs. 2008. New IPCC Tier1 Global Biomass Carbon Map For the Year 2000.

But what to do about it? :

Policy and negotiation support systems e.g. AguaAndes (www.policysupport.org/links/aguaandes)

The PSS is a testbed for the development and implementation of land and water related policies in the Andes, enabling intended and unintended consequences to be tested *in silico* before they are tested *in vivo* . It incorporates detailed spatial datasets at 1-square km and 1 hectare resolution for the entire Andes, spatial models for biophysical and socioeconomic 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. A series of policy exercises are provided and the model can be used by policy analysts, scientists and students in Spanish or English. Works best in the Mozilla Firefox browser. Your browser must have Javascript enabled.



Welcome: guest

Login Name :
mulligan

Password :
••••••

I am a...
Policy analyst
Scientist
English

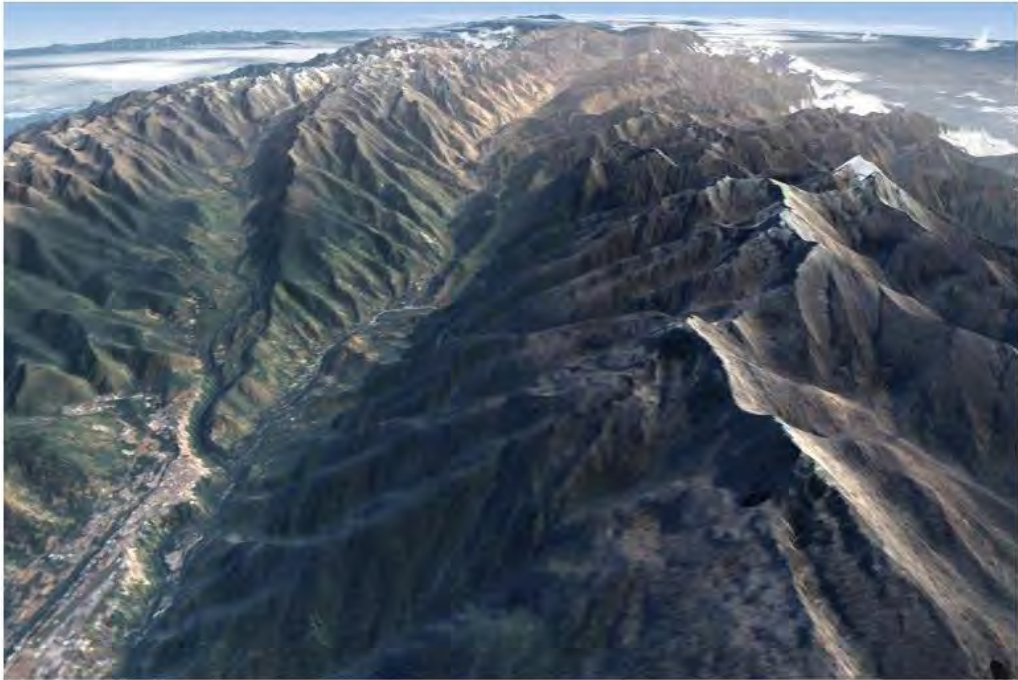
Viewer to use...
Google maps

Login

[Create account](#)

Please **Login** to use aguaandes

Help:
[Documentation](#)
[FAQ](#)
[Model updates](#)



It is different things to different people. The interface changes for scientists (detailed), policy analysts (less detailed)

The Agua-Andes PSS for the CPWF Challenge Program on Water and Food - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.policysupport.org/cgi-bin/aguaandes/start.cgi?

Google Search

AguaAndes is a web based policy support system designed and implemented for the [CGIAR Challenge Programme on Water and Food \(CPWF\)](#) basin focal project for the Andes [BFP-ANDES](#).

The PSS is a testbed for the development and implementation of land and water related policies in the Andes, enabling intended and unintended consequences to be tested *in silico* before they are tested *in vivo*. It incorporates detailed spatial datasets at 1-square km and 1 hectare resolution for the entire Andes, spatial models for biophysical and socioeconomic 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. A series of policy exercises are provided and the model can be used by policy analysts, scientists and students in Spanish or English. Works best in the Mozilla Firefox browser. Your browser must have Javascript enabled.

Welcome: guest

Login Name :
mulligan

Password :
●●●●●●

I am a...
Policy analyst

Language
English

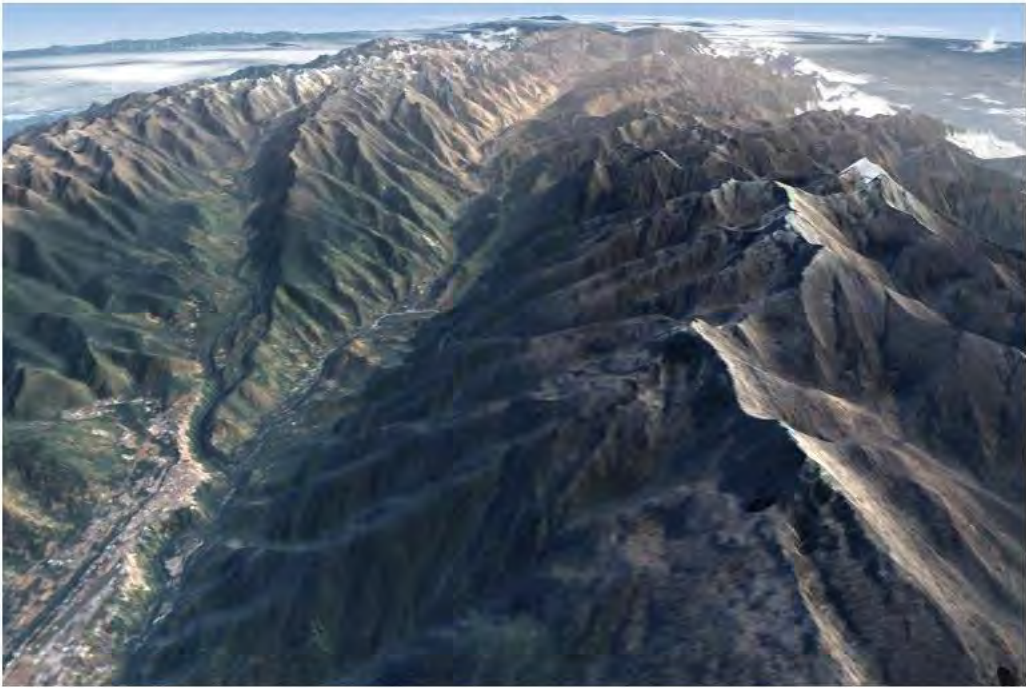
English
Spanish

Login

[Create account](#)

Please **Login** to use aguaandes

Help:
[Documentation](#)
[FAQ](#)
[Model updates](#)



Multilingual.

The Agua-Andes PSS for

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andes

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CIAT

UNIVERSIDAD NACIONAL DE COLIMBA

CIAT Challenge Program on WATER & FOOD

Welcome: drmarkmulligan_gmail.com

Control panel

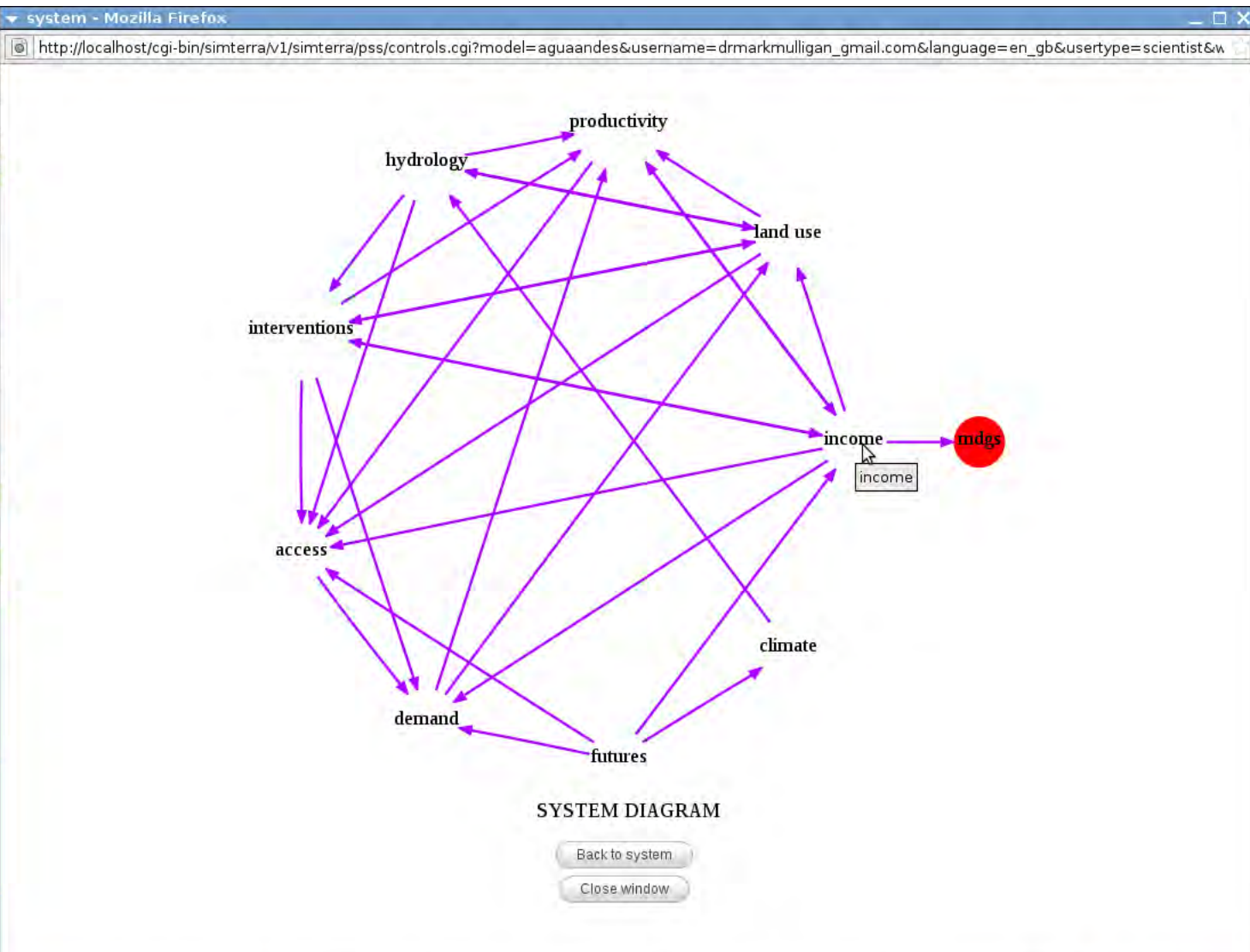
explore: [Community](#), [Team](#), [Wall](#), [Blog](#), [View desktop system](#)

set-up: [Define area](#), [Prepare data](#), [Set parameters](#), [Set futures](#), [Set interventions](#)

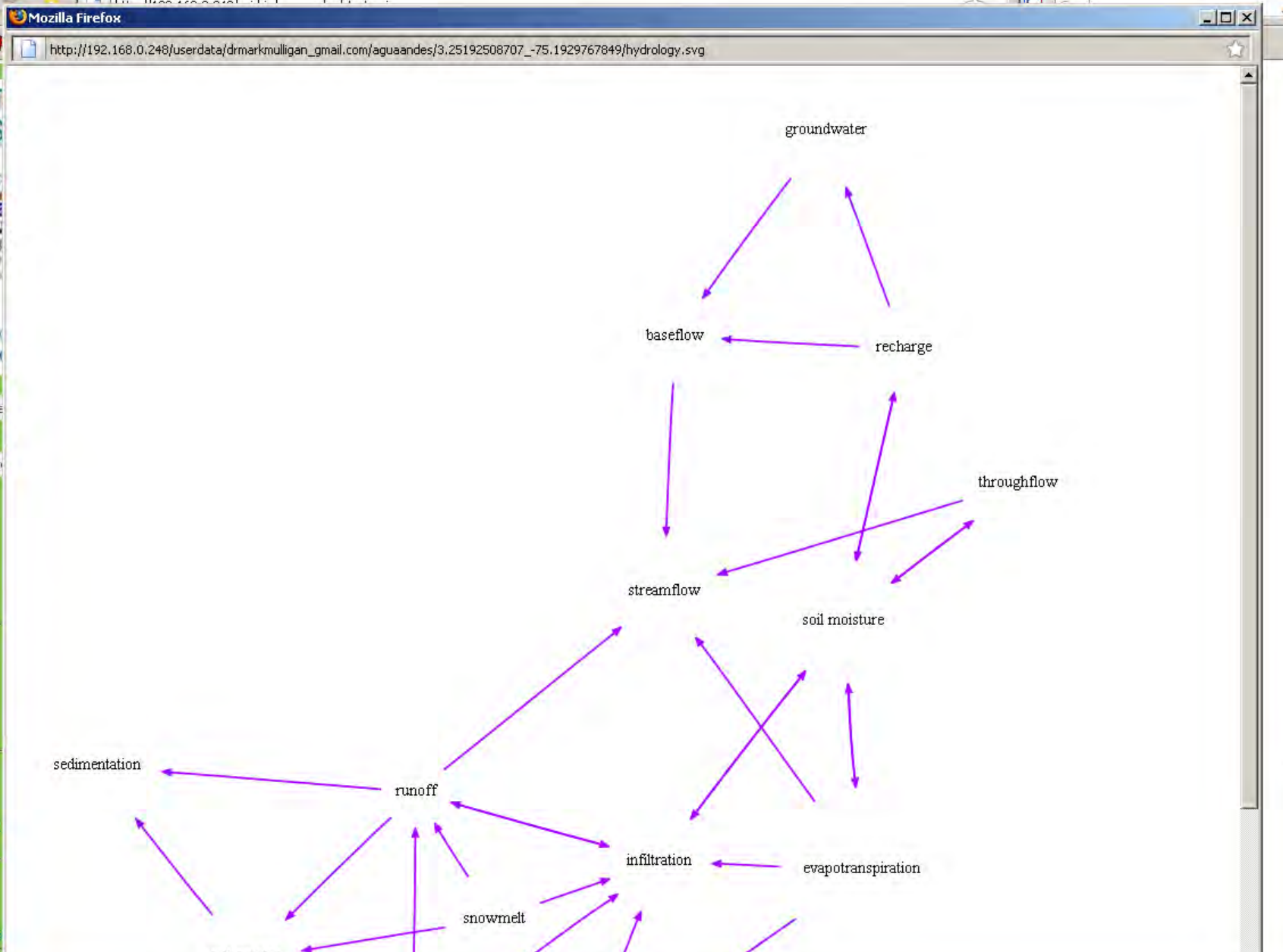
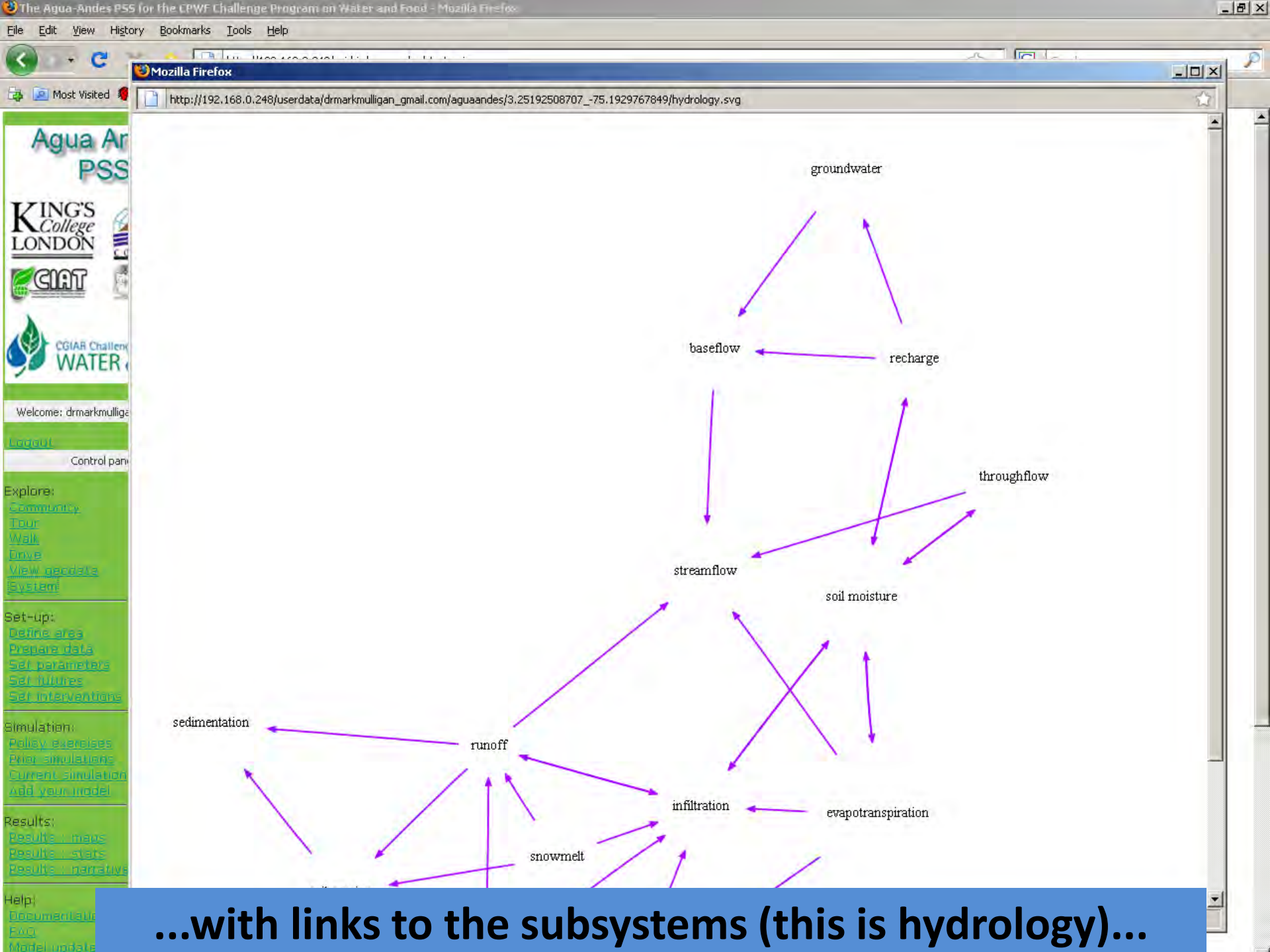
simulation: [Policy exercise](#), [Prior simulations](#), [Current simu](#)

Done

Applicatio



Shows the system being modelled...
Includes water based environmental services sources and sinks



...with links to the subsystems (this is hydrology)...

The Agua Andes PSS for the CPWF Challenge Program on Water and Food - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://192.168.0.249/cgi-bin/aguaandes/start.cgi

Most Visited Customize Links Free Hotmail iGoogle RT Radio Times - The Ulti... Snapfish Yahoo! Mail (nofearso... CANALPLAN AC - Can...

Agua Andes PSS

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Control panel

Explore:
[tourer](#)
[explorer_walk](#)
[explorer_drive](#)
[view_geodata](#)

Set-up:
[define_area](#)
[input parameters](#)
[set scenarios](#)
[policy options](#)

Simulation:
[policy exercises](#)
[prior simulations](#)
[current simulation](#)
[developer](#)

Results:
[results maps](#)

Explore Set-up Simulation Results

[tourer](#) [explorer_walk](#) [explorer_drive](#) [view_geodata](#)

Google Earth

File Edit View Tools Add Help

Search

Fly To Find Businesses Directions

Fly to e.g., 37 25' 19.1"N, 122 05' 06"W

Places

My Places

- dams_dev.kmz
- Temporary Places
- drmarkmulligan_gmail.com
 - choose_location
 - choose location
 - view_geodata
 - tools

Layers

- Primary Database
- Geographic Web
- Roads
- 3D Buildings
- Street View
- Borders and Labels

click for this tile

You start by defining the area you want support for. The underlying SimTerra database has 1 degree raster tiles (@100m resolution, shown) and 10 degree tiles (at 1km resolution), globally for hundreds of variables

The Agua-Andes PSS for the CP

input_data - Mozilla Firefox

http://www.policysupport.org/cgi-bin/simterra/v1/simterra/pss/controls.cgi?model=aguaandes&username=xyzk720742f55z90o%5E920z5%A3ua2&language=xyzxo%5E9m&usertype=xyznuzoxpzn&whichform=xyzzocp%5Ek0p0&viewer =

Layer : hydrology, 2b31mean7 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM precipitation (mm/month) July
Layer : hydrology, 2b31mean8 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM precipitation (mm/month) August
Layer : hydrology, 2b31mean9 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM precipitation (mm/month) September
Layer : hydrology, 2b31summy (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Annual total TRMM precipitation (mm/year)
Layer : hydrology, 2b31sumwndpre (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Annual total TRMM wind-driven precipitation (mm/year)
Layer : hydrology, 2b31wndpre1 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) January
Layer : hydrology, 2b31wndpre10 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) October
Layer : hydrology, 2b31wndpre11 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) November
Layer : hydrology, 2b31wndpre12 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) December
Layer : hydrology, 2b31wndpre2 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) February
Layer : hydrology, 2b31wndpre3 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) March
Layer : hydrology, 2b31wndpre4 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) April
Layer : hydrology, 2b31wndpre5 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) May
Layer : hydrology, 2b31wndpre6 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) June
Layer : hydrology, 2b31wndpre7 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) July
Layer : hydrology, 2b31wndpre8 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) August
Layer : hydrology, 2b31wndpre9 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Mean monthly TRMM wind-driven precipitation (mm/month) September
Layer : hydrology, clone (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Study area
Layer : hydrology, lddhydro1k (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	Local drainage direction
Layer : hydrology, vcfbare2000 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	MODIS VCF 2000 % bare
Layer : hydrology, vcfherb2000 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	MODIS VCF 2000 % herb
Layer : hydrology, vcfree2000 (map)	<input checked="" type="checkbox"/>	,overwrite?	<input checked="" type="checkbox"/>	doc	<input checked="" type="checkbox"/>	geobrowse	MODIS VCF 2000 % tree

All 180 maps found.

Time-series data.

Look-up tables.

Copy data to your workspace

List workspace data

The data are downloaded to your workspace on our servers (since AguaAndes runs on our servers not your local computer). Links are provided so that you can download any data which are not copyrighted or you can view the data *in situ*.

The Agua-Andes PSS for workspace_list - Mozilla Firefox

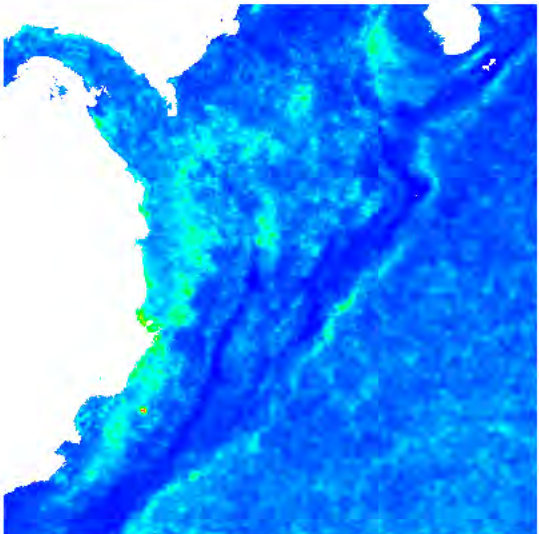
http://localhost/cgi-bin/simterra/v1/simterra/pss/kmlcgi.cgi?model=aguaandes&username=drmarkmulligan_gmail.com&language=en_gb&tab=input_data&currer

> drmarkmulligan_gmail.com > aguaandes > input_data > workspace_list > map_2image

values=class
base

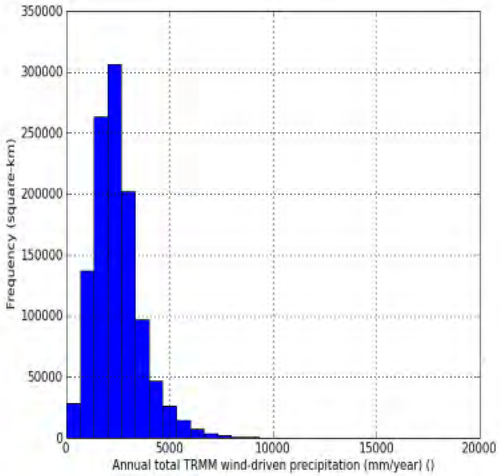
mv
48.63
1043.61
2038.59
3033.56
4028.54
5023.52
6018.50
7013.47

Annual total TRMM wind-driven precipitation (mm/year) 0



change_images - Mozilla Firefox

http://localhost/cgi-bin/simterra/v1/simterra/charts/charts.cgi?model=aguaandes&us



Max:19948.18 UserMin: UserMax:

shifted log scale
 reverse colours

(valid: 0.1 to 10) 1

1. Blue,green,red

Redraw image

Go back

Done Open Notebook

This is 1km rainfall for your tile from the SimTerra database. System allows some in-situ interpretation, changing of colour scales etc and visualisation in GE and GM as well as download as zipped ARCASCII

The Agua-Andes PSS for the CPU

http://www.policysupport.org/cgi-bin/simterra/v1/simterra/geobrowsers/returnbrowsermap.cgi?model=aguaandes&&viewer=xyz92&LEGENDIMAGE=xyz%2A2xkz0%2AInx7k0p0%2Ak720742l55z90o%5E92oz5%A

Basins: La Gallega Go > Enter a location here Go > lat: lon:

Style: Satellite

values=class
base
mv

32.01
993.73
1964.54
2930.35
3896.17
4861.98
5827.79
6793.61
7759.42
8725.24
9691.05
10656.86
11622.68
12588.49
13554.30

Andes basins
 Annual total TRMM precipitation (mm/year)

Refresh
Go back

Find: annual tot Next Previous Highlight all Match case

Done

Open Notebook

e.g. ...rainfall geobrowsed in Google Maps

aguanDES
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CONDESAN
CIAT
UNIVERSIDAD NACIONAL DE COLOMBIA
CGIAR Challenge Program on WATER & FOOD


current run: temp | refresh_page | notebook | scientist | gm | disk: 176 GB

change_run - Mozilla Firefox

http://www.policysupport.org/cgi-bin/simterra/v1/simterra/simulation/simulation.cgi?model=aguaandes&

Simulation period is from 1 to 48. Use the following button(s) to control the simulation:

(If you close this window or break your connection with the internet the simulation will stop)

 10 %

activity : hydrology : reading data... | timestep : 5 of 48

Transferring data from www.policysupport.org...

Open Notebook

Welcome: drmarkmulligan_gmail.com

Logout

Control panel

explore:
[Community](#)
[Tour](#)
[Walk](#)
[Drive](#)
[View geodata](#)
[System](#)

set-up:
[Define area](#)
[Prepare data](#)
[Set parameters](#)
[Set futures](#)
[Set interventions](#)

simulation:
[Policy exercises](#)
[Prior simulations](#)
[Current simulation](#)
[Add your model](#)

results:



You can then run the simulation, looking at impacts of e.g. land use change, climate change, dam building, designation or LUCC in PAs

The Agua-Andes PSS for the CPWF Challenge Program on Water and Food - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://localhost/cgi-bin/aguaandes/start.cgi

Google Search AutoLink AutoFill Send to Settings

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current run: temp | refresh_page | notebook | scientist | gm | disk: 28 GB

Basins: La Gallega Go > Enter a location here Go > lat: hydrology/timestep/Precmmh - Mozilla Firefox

http://localhost/cgi-bin/simterra/v1/simterra/charts/charts.cgi?model=aguaar

hydrology/timestep/Budget - Mozilla Firefox

http://localhost/cgi-bin/simterra/v1/simterra/charts/charts.cgi?model=aguaar

(Water balance (mm/hr))

auto-refresh: [stop] [start]

hydrology/timestep/SoilErosion - Mozilla Firefox

http://localhost/cgi-bin/simterra/v1/simterra/charts/charts.cgi?model=aguaar

(Soil erosion (mm/hr))

auto-refresh: [stop] [start]

hydrology/timestep/Precmmh - Mozilla Firefox

http://localhost/cgi-bin/simterra/v1/simterra/charts/charts.cgi?model=aguaar

(Precipitation (mm/hr))

auto-refresh: [stop] [start]

Done Open Notebook

Done Open Notebook

Done Open Notebook

Time series of simulation outputs can be viewed during or after a simulation

The Agua-Andes PSS for the CPWF Challenge Program on Water

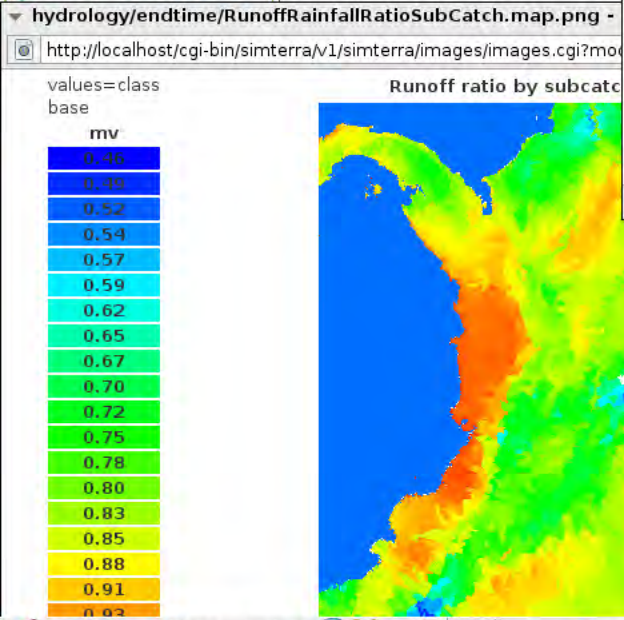
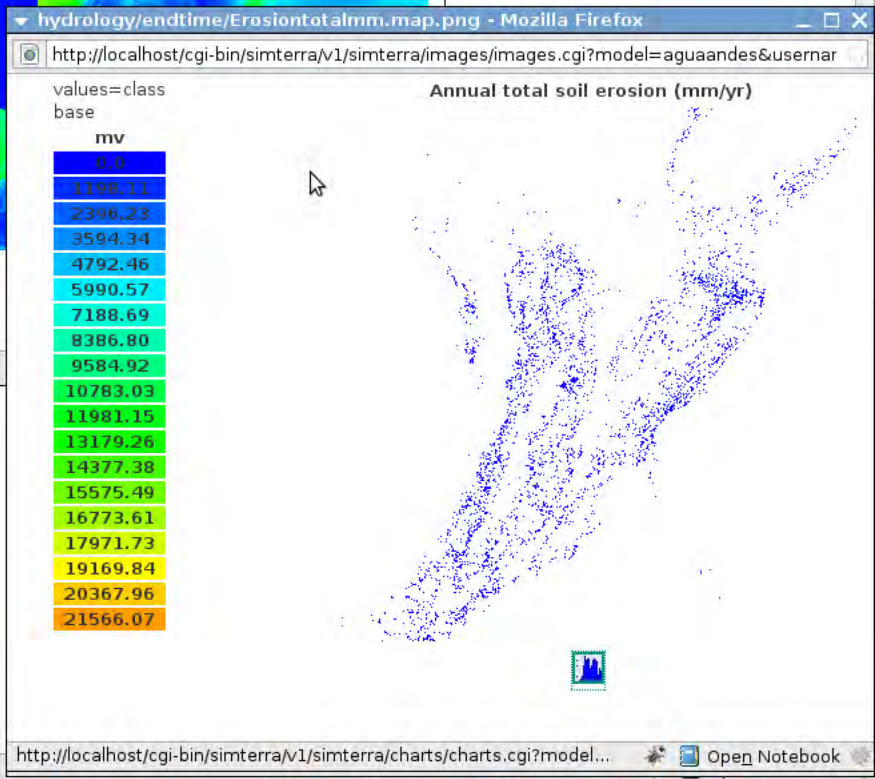
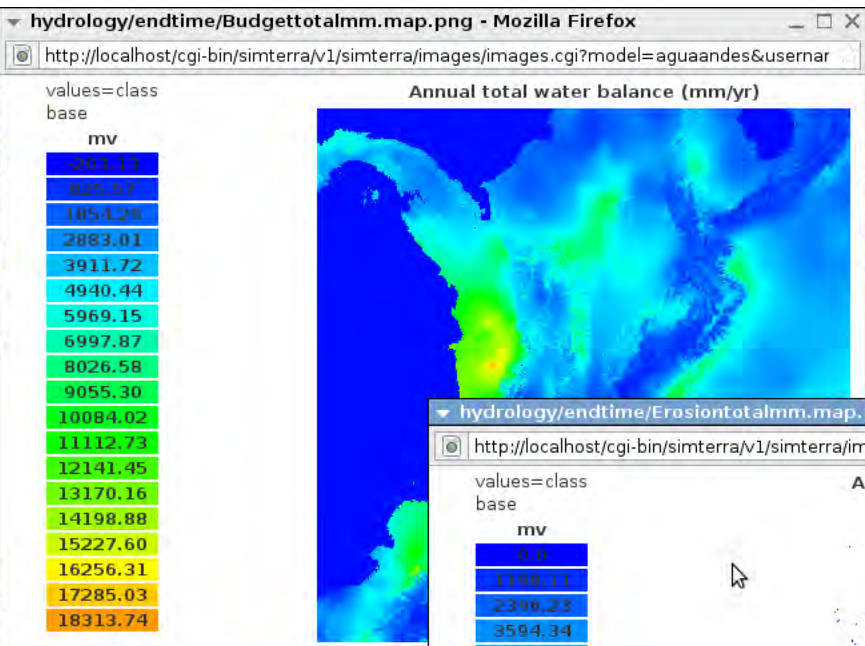
File Edit View History Bookmarks Tools Help

http://localhost/cgi-bin/aguaandes

Google Search

Basins: La Galle

CGIAR Challenge Program on WATER & FOOD



Spatial simulation outputs can be viewed during or after a simulation, all on the web

...and can be visualised in a geobrowser



KING'S College LONDON



CIAT



CGIAR Challenge Program on WATER & FOOD

Welcome: drmarkmulligan_gmail.com

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[Define area](#)
[Prepare data](#)
[Set parameters](#)
[Set futures](#)
[Set interventions](#)

simulation:
[Policy exercises](#)
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[Add your model](#)

results:
[Results - maps](#)

Done

AguaAndes - Mozilla Firefox

http://www.policysupport.org/cgi-bin/simterra/v1/simterra/geobrowsers/returnbrowsermap.cgi?model=aguaandes&&viewer=xyz92&LEGENDIMAGE=xyz%2A2xkz0%2AInx7k0p0%2Ak72074255z90o%5E920z5%A

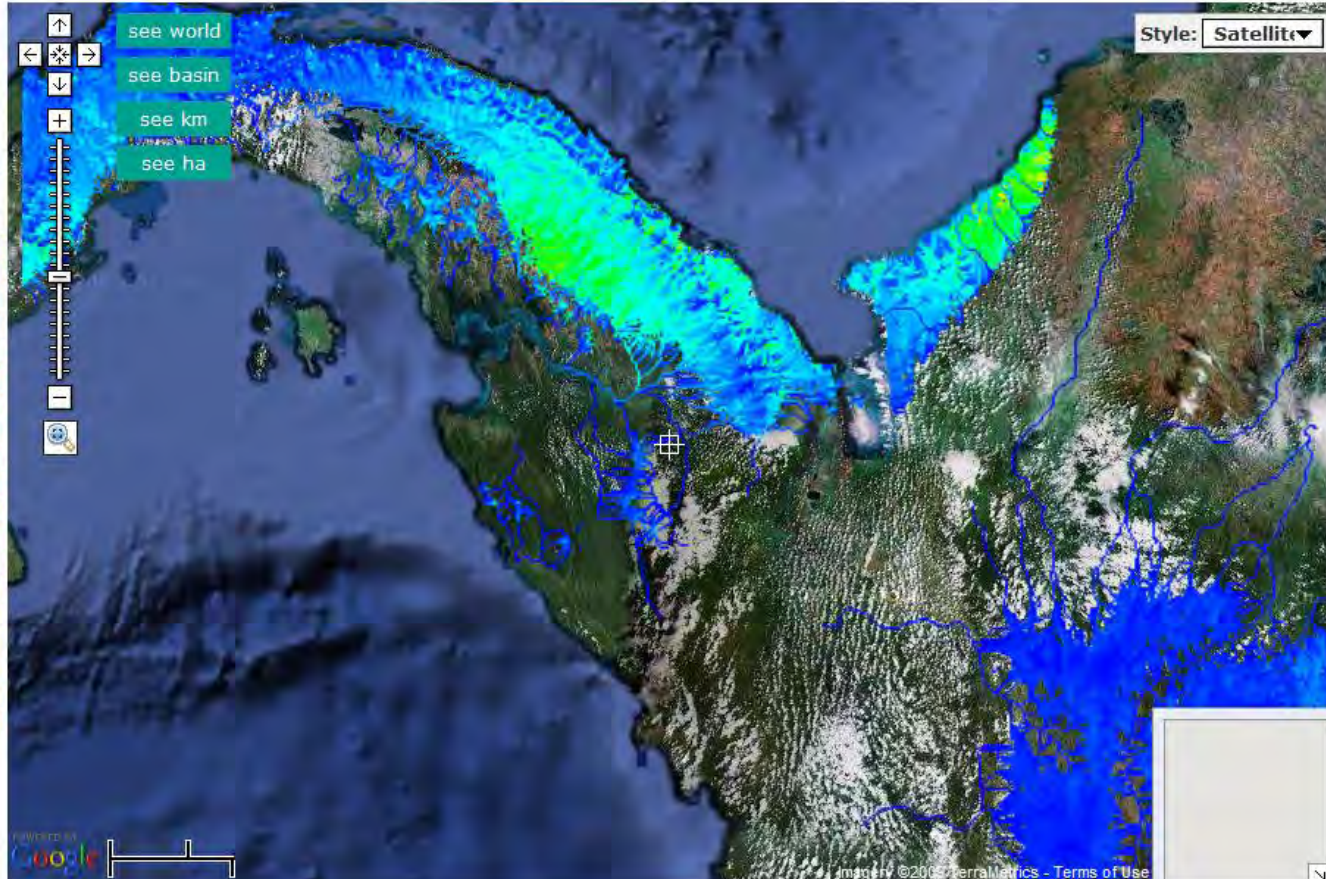
Basins: La Gallega Go > Enter a location here Go > lat: 7.961317 lon: -77.585449

Style: Satellite

values=class base

mv
0.0
0.04
0.09
0.14
0.18
0.23
0.28
0.33
0.37
0.42
0.47
0.52
0.56
0.61
0.66
0.71
0.75
0.80
0.85

see world
see basin
see km
see ha



Andes basins
 Percentage of runoff derived from fog (%)

Refresh

System is in *beta*, looking for one or two further applications/users to test the system

Thank you



Questions?