



Groundwater  
Assessment  
Platform

[gapmaps.org](http://gapmaps.org)

## GIS-BASED GROUNDWATER QUALITY ASSESSMENT AND PREDICTION WITH THE GROUNDWATER ASSESSMENT PLATFORM (GAP)

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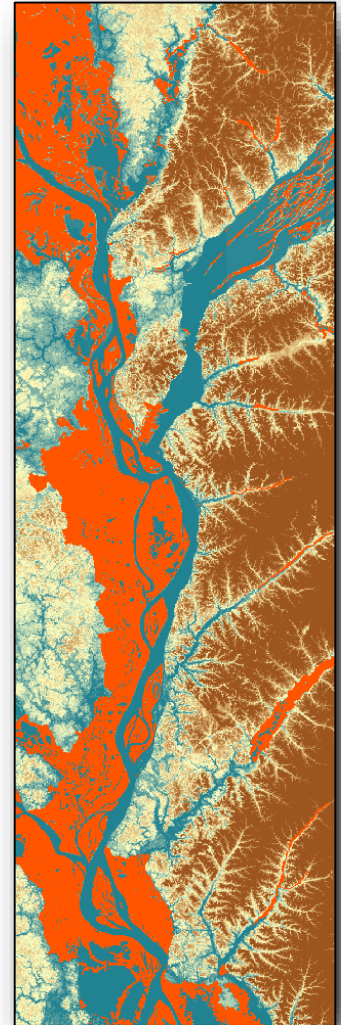
**eawag**  
aquatic research ooo

Swiss Federal Institute of  
Aquatic Science and Technology



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

Swiss Agency for Development  
and Cooperation SDC



# Geogenic (natural) groundwater contamination



Groundwater  
Assessment  
Platform

- Geogenic contamination is widespread, affecting up to 10% of wells worldwide
- Over 300 million people globally are exposed to high levels of arsenic (As) and fluoride (F)
- Little is being done to combat the situation in low-income countries



**Arsenic (~140 million)**  
causes skin lesions,  
pulmonary disorders,  
internal cancers  
WHO: 10  $\mu\text{g/L}$



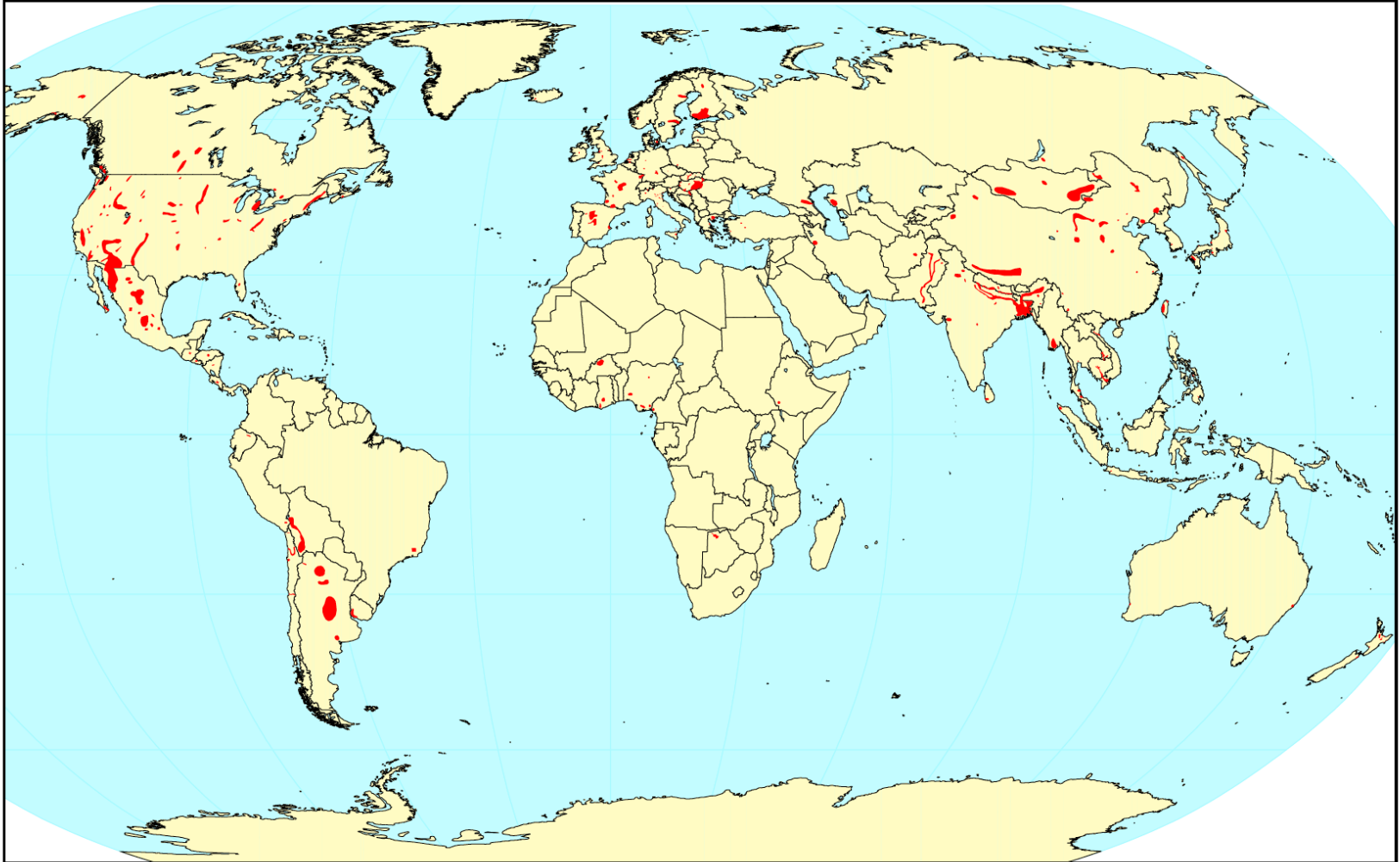
**Fluoride (~200 million)**  
causes dental mottling  
& decay and crippling  
skeletal deformation  
WHO: 1.5 mg/L



Photo: OSHO/HEKS

Various regions discovered in recent years

**But large areas are still uncharted**

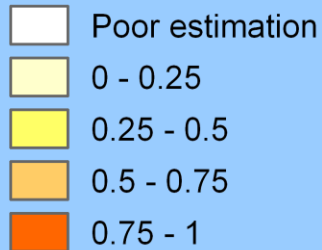




# Global risk map for As >10 µg/L

Modeled global probability of geogenic arsenic contamination in groundwater for reducing and for high-pH/oxidizing aquifer conditions

## Probability of As >10 µg/L

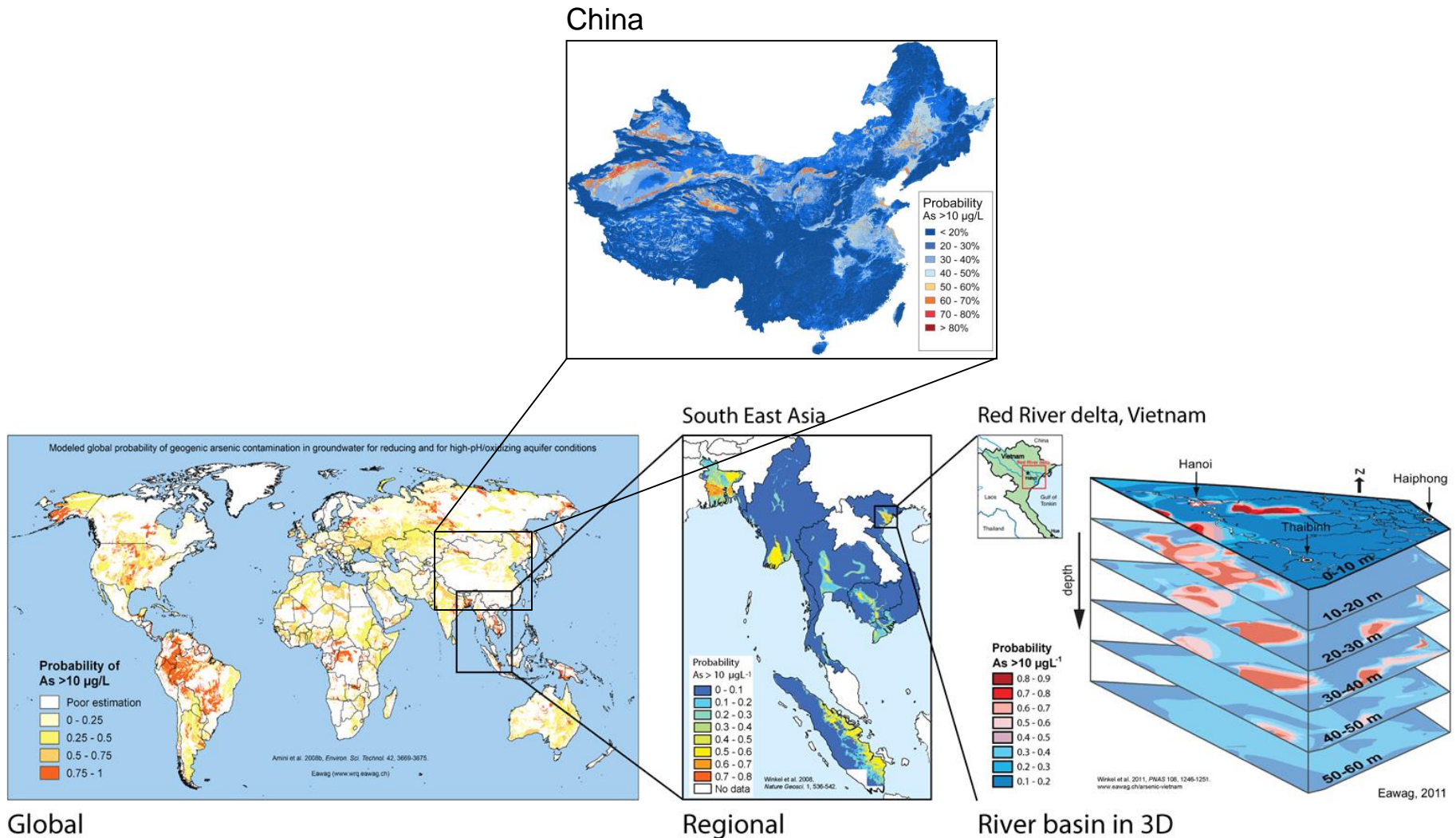


Amini et al. 2008b, *Environ. Sci. Technol.* 42, 3669-3675.

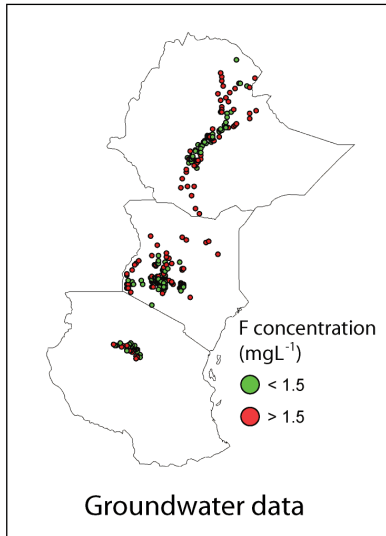
Eawag ([www.wrq.eawag.ch](http://www.wrq.eawag.ch))

Amini et al., ES+T 2008

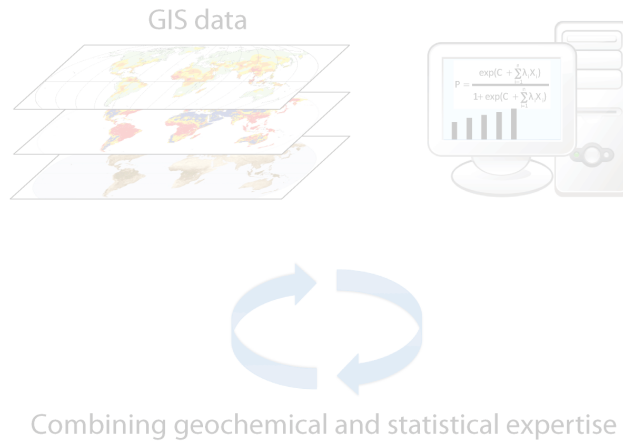
## Arsenic probability modeling at different scales:



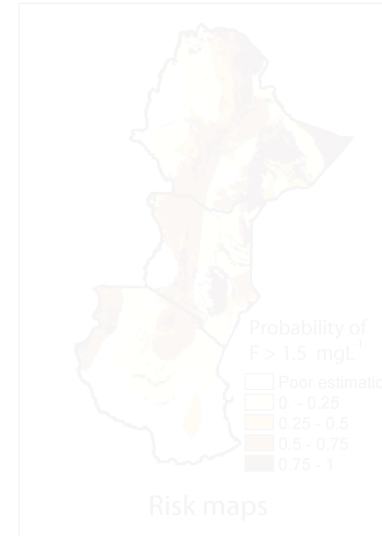
## Concentration data



## Geo-statistical modeling



## Identifying risk areas



## Mitigation



### Relevant geospatial data

- Increasingly available in digital GIS format
- Often free of charge
- Resolution and coverage increasing

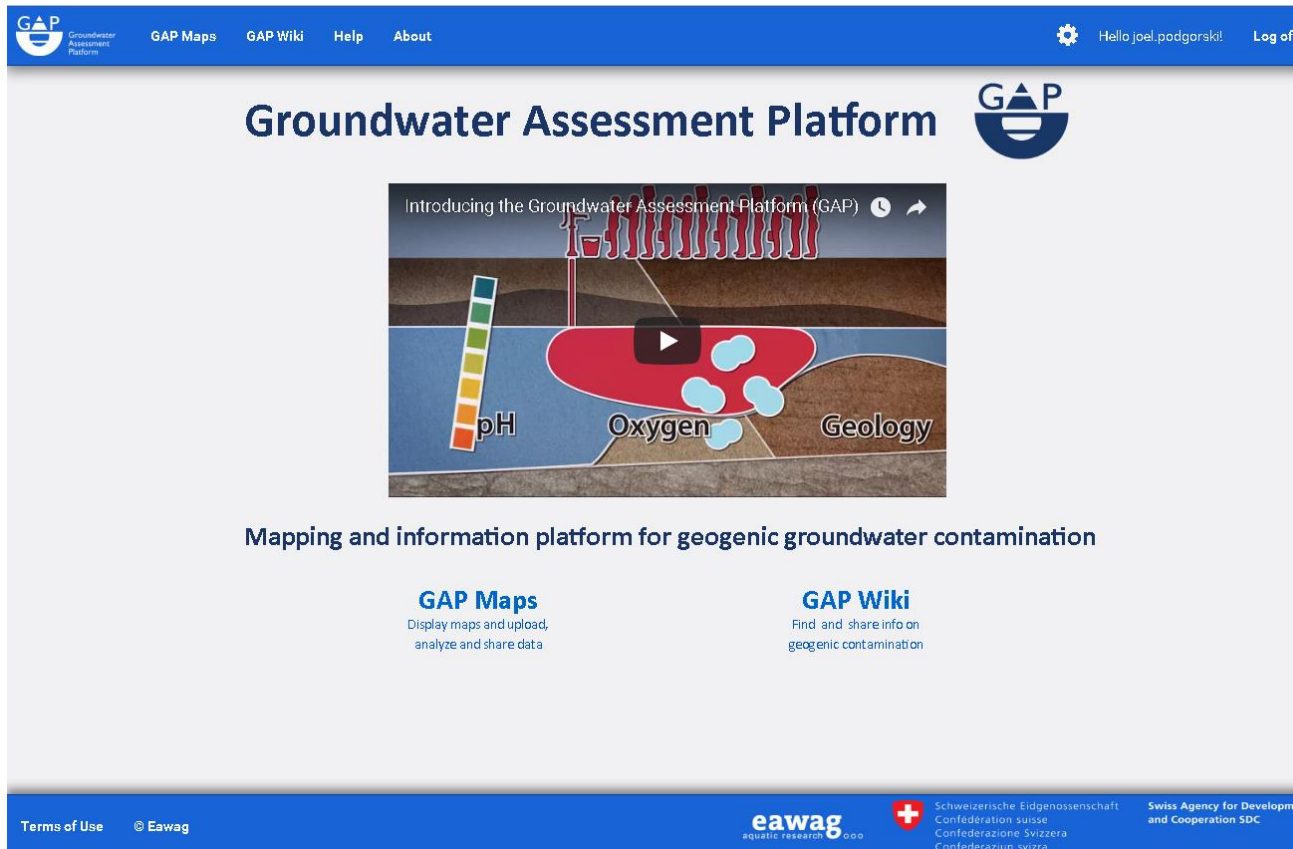
Gives the probability of a binary (0 or 1) target variable being "positive" (i.e. true or 1) for a linear combination of predictor variables:

$$P(x) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x)}}$$

where  $P$  is probability,  $\beta$  is a regression coefficient,  $x$  is an independent variable.

## [www.gapmaps.org](http://www.gapmaps.org)

Free, interactive online GIS platform for **mapping**, **statistical modeling** and **dissemination** of information on geogenic groundwater contamination



The screenshot shows the GAP website interface. At the top is a blue navigation bar with the GAP logo, links for 'GAP Maps', 'GAP Wiki', 'Help', and 'About', a user greeting 'Hello joel.podgorski!', and a 'Log off' button. The main content area features the title 'Groundwater Assessment Platform' and a large video player titled 'Introducing the Groundwater Assessment Platform (GAP)'. The video thumbnail depicts a cross-section of the ground with a red plume of contamination, a pH scale, and labels for 'Oxygen' and 'Geology'. Below the video, the text 'Mapping and information platform for geogenic groundwater contamination' is displayed. Two buttons are present: 'GAP Maps' with the description 'Display maps and upload, analyze and share data', and 'GAP Wiki' with the description 'Find and share info on geogenic contamination'. The footer contains links for 'Terms of Use' and '© Eawag', along with logos for 'eawag aquatic research', the Swiss Confederation in multiple languages, and the 'Swiss Agency for Development and Cooperation SDC'.

- Mapping
- Modeling
- Sharing
- Wiki



www.gapmaps.org/GAP\_Wiki

Create account Log in

Page **Discussion** Read View source View history Search


**GAP Wiki**

Here you can find information about geogenic contamination and contribute your own articles. We invite all users to use GAP Wiki as a platform to exchange information about geogenic contamination. Adding and editing articles is quick and easy to learn. Please visit the page [Creating and editing GAP Wiki articles](#) for more information.

**Table of contents**

The GAP Team has started the GAP Wiki with chapters from the Geogenic Contamination Handbook. The table of contents is periodically updated with new articles. You can download the complete "Geogenic Contamination Handbook" [here](#).

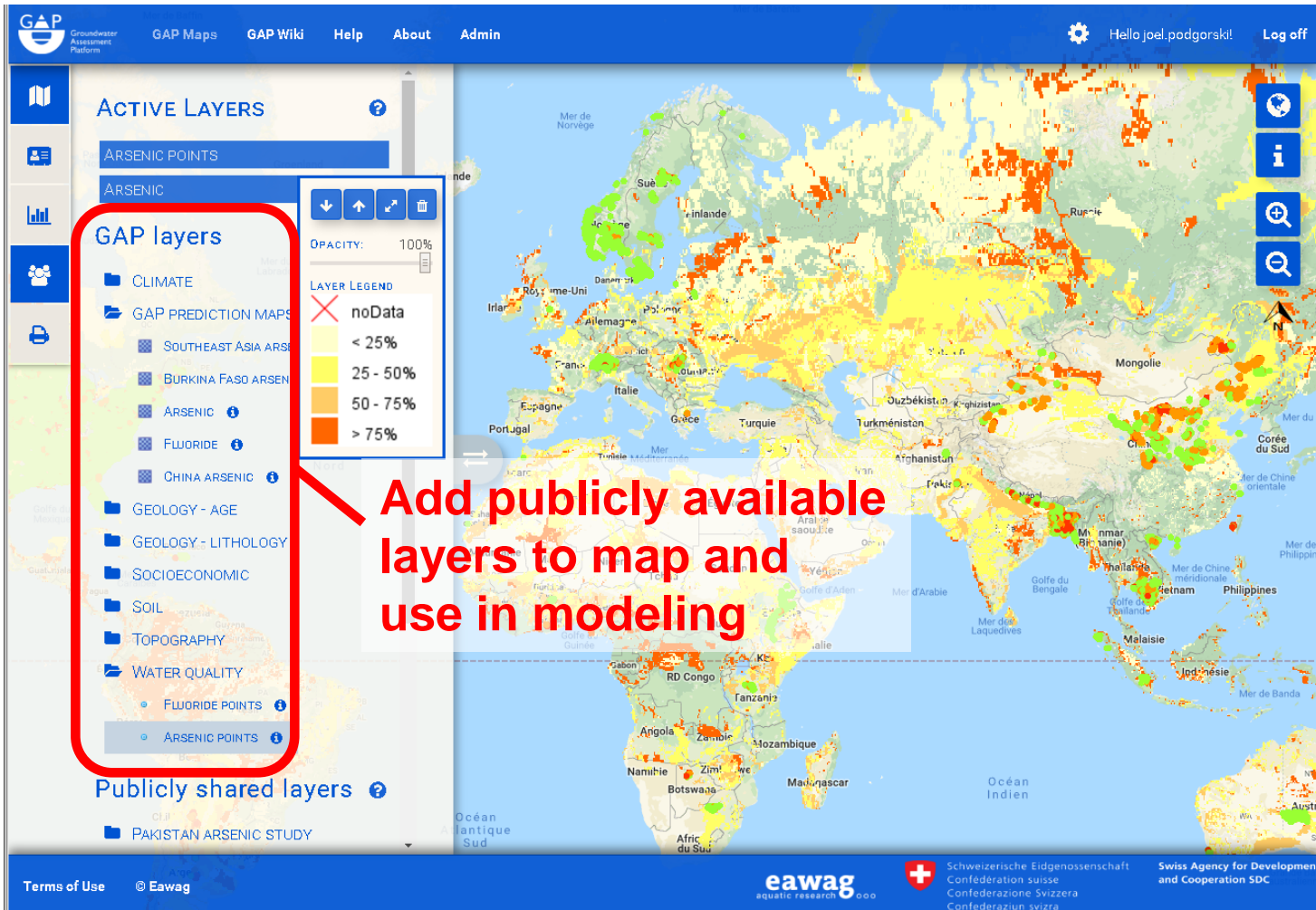
- **Geogenic contamination**
  - Geogenic contamination - Arsenic (*Handbook chapter*)
  - Geogenic contamination - Fluoride (*Handbook chapter*)
  - The development of probability maps
- **Nutritional intake and health risks**
  - Nutritional intake and health risks - Arsenic (*Handbook chapter*)
  - Nutritional intake and health risks - Fluoride (*Handbook chapter*)
  - Quantitative health risk analysis (*Handbook chapter*)
- **Water sampling and analysis**
  - Water sampling and analysis - Arsenic (*Handbook chapter*)



Woman collecting fluoride-treated water at the community filter in Wayo Gabriel, Ethiopia (*Terms of use: Cite original source from Handbook*)

Features the  
**Geogenic  
Contamination  
Handbook**

Read/add/edit  
pages on the  
subject of  
geogenic  
contamination



## PUBLIC

- View existing models and data

## PRIVATE (login)

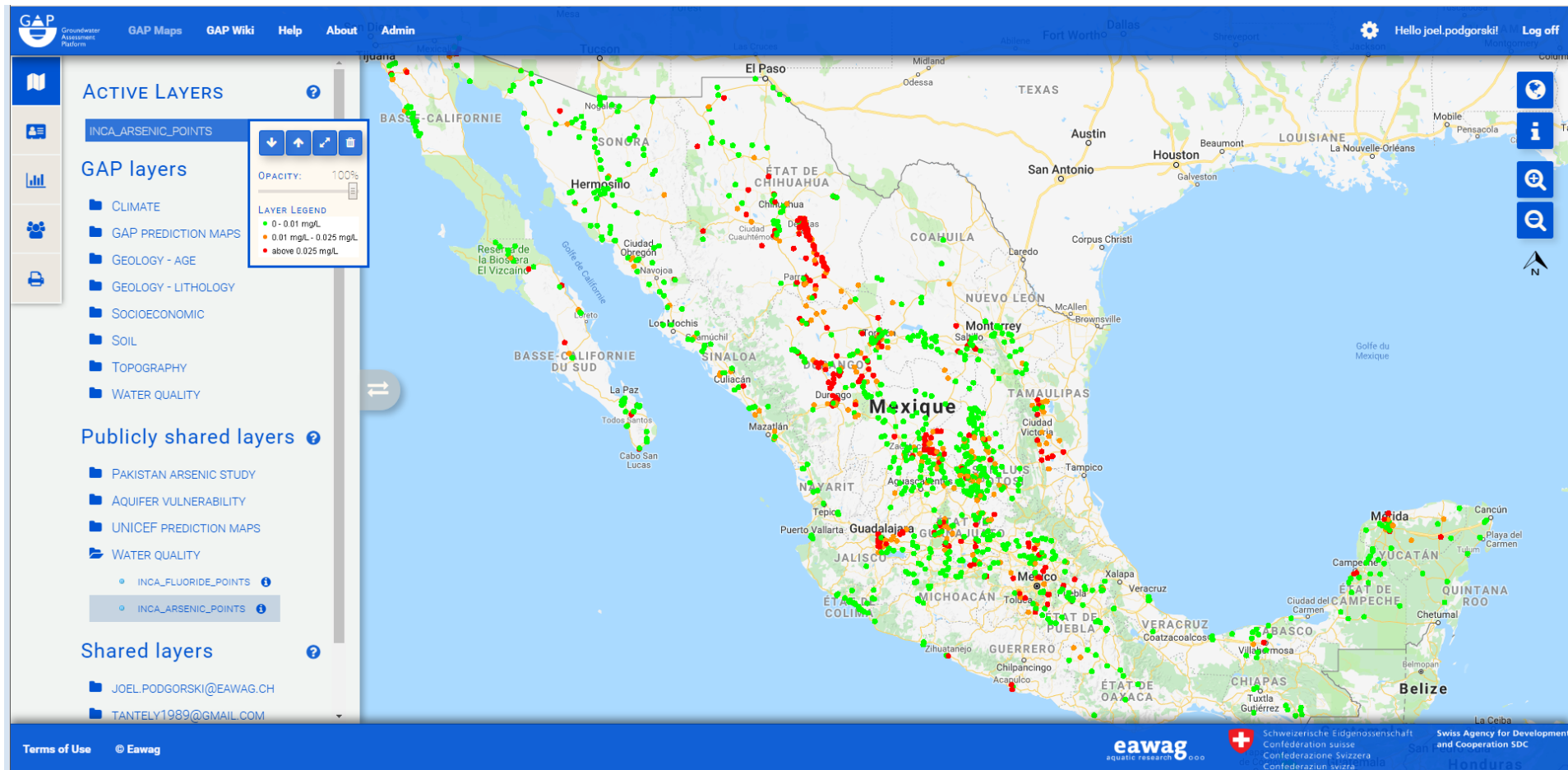
- Upload, display & share own data
- Create own predictive model

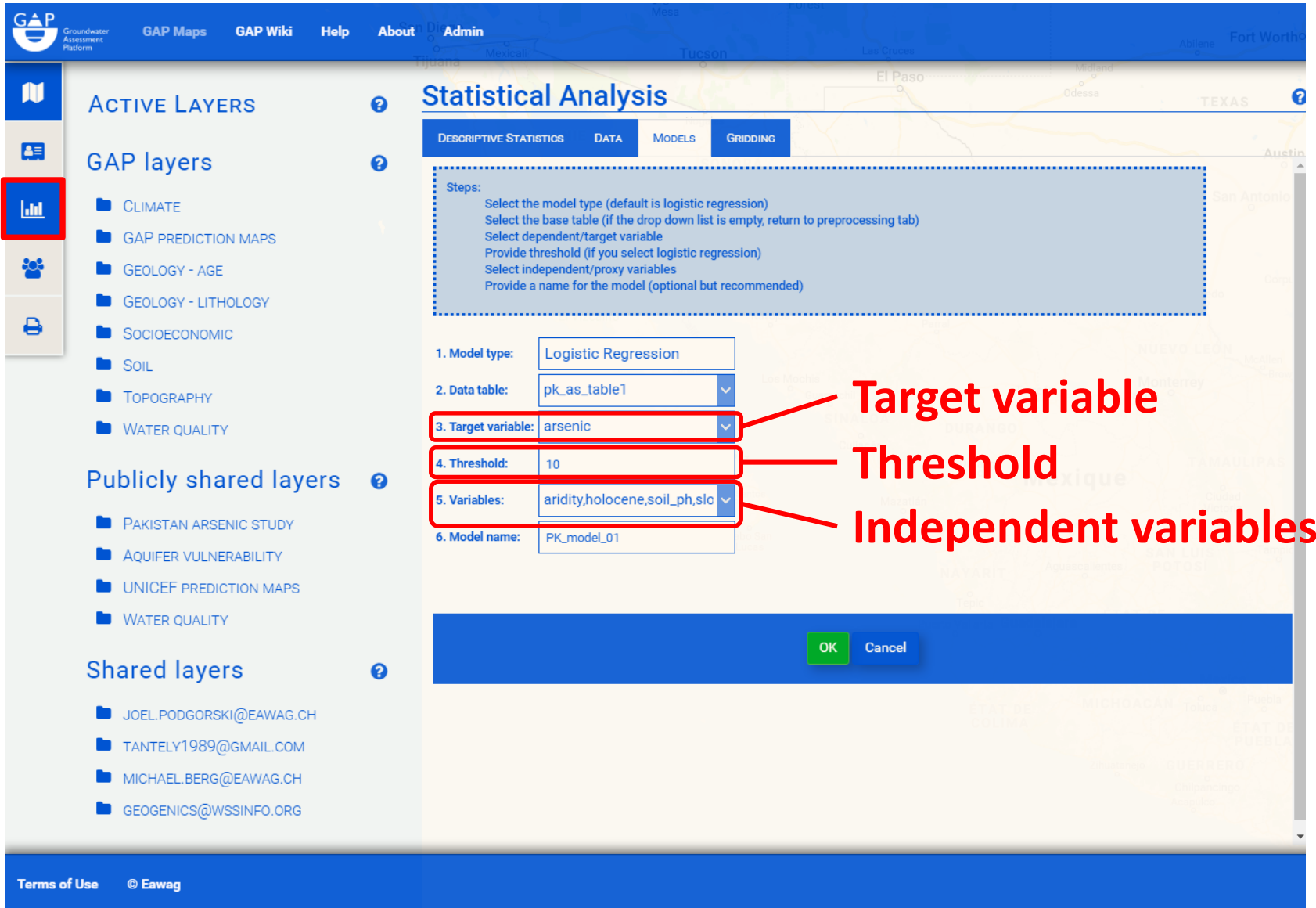
## COMMUNITY

- Share data and models with user-created communities

# Modify symbology and share data publicly

## Example: arsenic concentrations from Mexico





The screenshot shows the 'Statistical Analysis' interface of the Groundwater Assessment Platform (GAP). The interface is divided into a left sidebar and a main content area. The sidebar contains 'ACTIVE LAYERS' (GAP layers and Publicly shared layers) and 'Shared layers'. The main content area has tabs for 'DESCRIPTIVE STATISTICS', 'DATA', 'MODELS', and 'GRIDDING'. The 'MODELS' tab is selected, showing a 'Steps' section with instructions and a form for model configuration. The form includes fields for 'Model type', 'Data table', 'Target variable', 'Threshold', 'Variables', and 'Model name'. Red boxes and arrows highlight the 'Target variable', 'Threshold', and 'Variables' fields, with labels 'Target variable', 'Threshold', and 'Independent variables' respectively.

**Statistical Analysis**

DESCRIPTIVE STATISTICS DATA MODELS GRIDDING

**Steps:**

- Select the model type (default is logistic regression)
- Select the base table (if the drop down list is empty, return to preprocessing tab)
- Select dependent/target variable
- Provide threshold (if you select logistic regression)
- Select independent/proxy variables
- Provide a name for the model (optional but recommended)

1. Model type: Logistic Regression

2. Data table: pk\_as\_table1

3. Target variable: arsenic

4. Threshold: 10

5. Variables: aridity,holocene,soil\_ph,slo

6. Model name: PK\_model\_01

OK Cancel

**Target variable**

**Threshold**

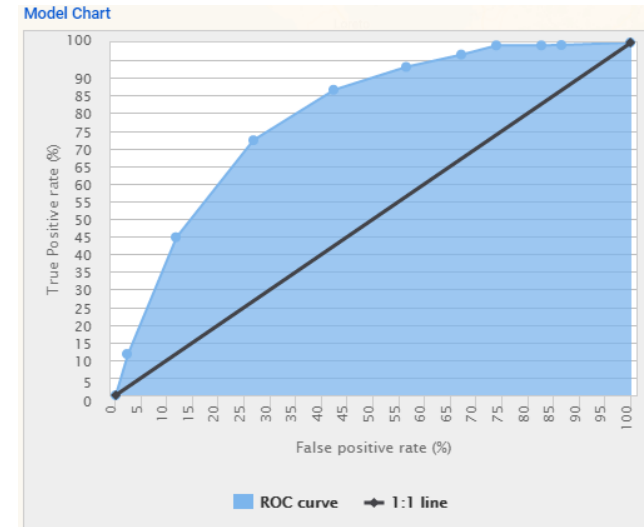
**Independent variables**



## Coefficients of independent variables

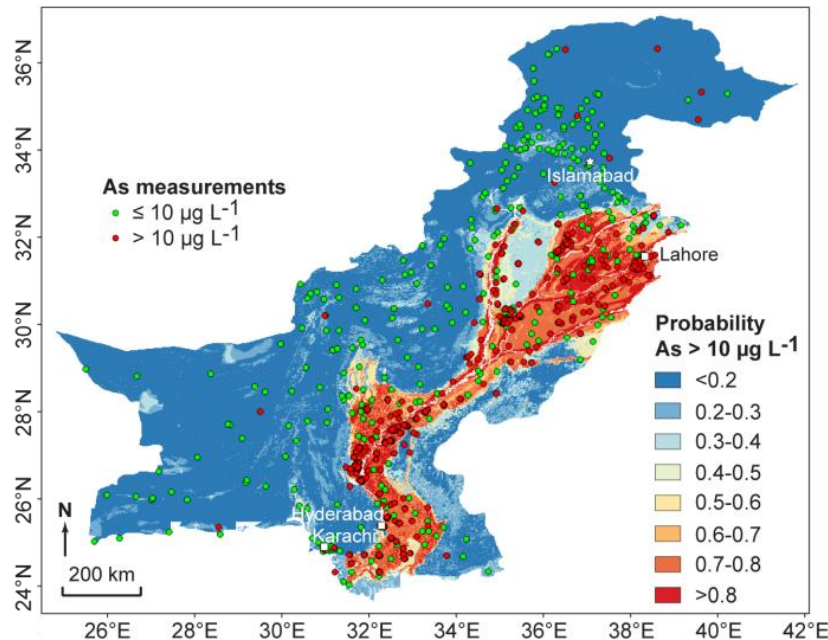
Statistical Analysis										
DESCRIPTIVE STATISTICS DATA MODELS GRIDDING										
Return										
Model coefficients										
	Id	Step	Parameter	Coefficient	Std	Wald	Odds	Lower	Upper	P-value
1	113	0	Intercept	-7.38	1.49	-4.94	0.00	0.00	0.01	0.000
2	113	0	holocene	-0.30	0.15	-1.95	0.74	0.55	1.00	0.051
3	113	0	slope	-0.29	0.08	-3.57	0.75	0.64	0.88	0.000
4	113	0	soil_fluvisols_pk_v2	0.03	0.01	6.33	1.03	1.02	1.05	0.000
5	113	0	soil_ph_mosaic_soilgrids_t	1.06	0.17	6.16	2.88	2.06	4.03	0.000
6	113	0	soil_oc_soilgrids6m_hwsd	-0.58	0.16	-3.62	0.56	0.41	0.77	0.000
Model classification										
	Id	Cutoff	Measured hig	Measured low	Predicted hig	Predicted low	False pos. rat	False neg. rat	Sensitivity	Spec. f
1	113	0	835	415	835	0	1	0	1	0
2	113	0.1	835	415	829	56	0.865	0.007	0.993	0.135
3	113	0.2	835	415	828	72	0.827	0.008	0.992	0.173
4	113	0.3	835	415	828	108	0.74	0.008	0.992	0.26
5	113	0.4	835	415	807	136	0.672	0.034	0.966	0.328
6	113	0.5	835	415	777	181	0.564	0.069	0.931	0.436
7	113	0.6	835	415	723	239	0.424	0.134	0.866	0.576
8	113	0.7	835	415	604	304	0.267	0.277	0.723	0.733
9	113	0.8	835	415	374	366	0.118	0.552	0.448	0.882
10	113	0.9	835	415	98	405	0.024	0.883	0.117	0.976

## ROC curve



## Statistics with different cutoff values

## Arsenic prediction map for Pakistan created offline with the R language

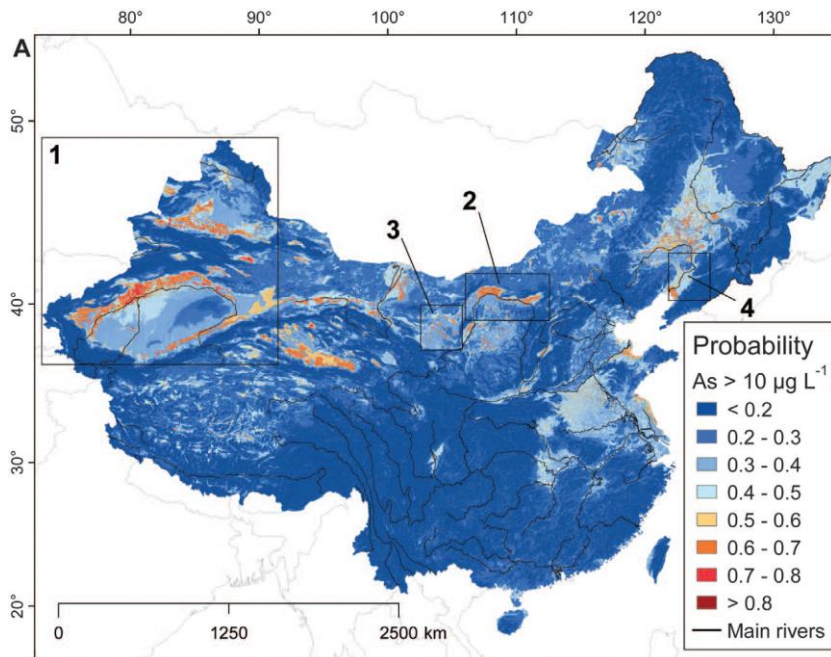


Podgorski et al., 2017

## Predictor variables:

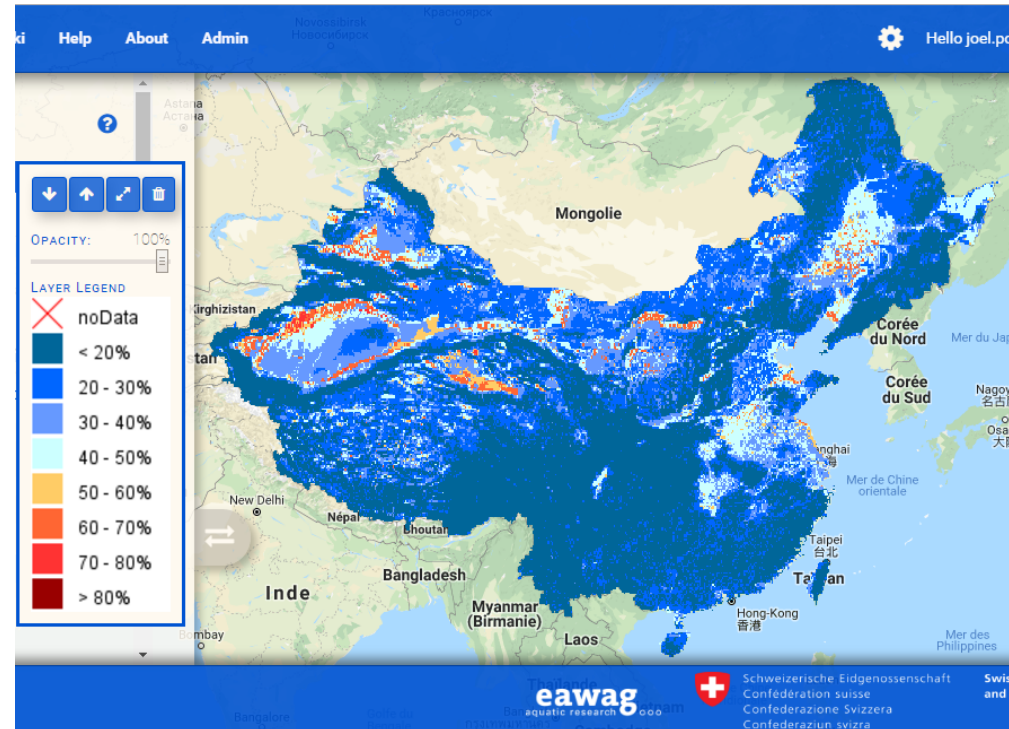
slope, fluvisols, Holocene fluvial sediments, soil organic carbon, soil pH

Arsenic prediction map for China  
created offline



Rodríguez-Lado et al., 2013

Arsenic prediction map for China  
created in GAP



→ Very similar results between modeling via manual coding and modeling with GAP





# Thank you



**[www.gapmaps.org](http://www.gapmaps.org)**

The screenshot displays the GAP Maps web application. The top navigation bar includes links for 'GAP Maps', 'GAP Wiki', 'Help', 'About', 'Contact', 'Register', and 'Log in'. The left sidebar contains a 'Map Layers' panel with checkboxes for 'Base map', 'Country borders', and 'Arsenic points', along with opacity sliders. Below this is a 'Layer Legend' for arsenic concentration, showing categories: '0 - 10 ug/L' (green), '10 - 50 ug/L' (yellow), and 'above 50 ug/L' (orange/red). A 'Print' dialog box is open in the center, showing options for 'Map title', 'Layout' (A4 landscape), and 'DPI' (150), with a 'Submit' button. The main map area shows a map of West Africa with arsenic concentration layers overlaid. The bottom footer includes the 'eawag' logo, the text 'aquatic research', and logos for the 'Schweizerische Eidgenossenschaft', 'Confédération suisse', 'Confederazione Svizzera', 'Confederaziun svizra', and the 'Swiss Agency for Development and Cooperation SDC'.

**Select orientation and resolution**

**Position area to print**

→ Can also export GIS layer of own data/models

## Share data and models with a select group of users

The screenshot shows the GAP Maps interface. The top navigation bar includes links for GAP Maps, GAP Wiki, Help, About, and Admin. The user is logged in as 'Hello joel.podgorski!' with a 'Log off' button. The main map area displays a map of Europe with various data layers. A toolbar on the left includes icons for settings, map, layers, and communities. The 'Communities' panel is open, showing a table of communities. The 'Annette test' community is highlighted. The 'Community Layers' panel on the right shows a list of layers including 'ShowReel', 'Adama\_workshop', 'ethiopia\_sampledata', and 'Ouaga\_atelier'. The bottom of the interface includes a footer with 'Terms of Use', '© Eawag', and logos for 'eawag aquatic research', 'Schweizerische Eidgenossenschaft', 'Confédération suisse', 'Confederazione Svizzera', 'Confederaziun svizra', and 'Swiss Agency for Development and Cooperation SDC'.

	Name	Topic	Description
1	Annette test	confusion	zu
2	testing	arsenic	West Bengal data - there's no holoc...
3	ShowReel	ShowSite	Show Site in Meeting on 16 09 2015
4	Adama_workshop	training	Sharing data/models for GAP training
5	Ouaga_atelier	test	une description de la communauté

The screenshot displays the GAP website interface. At the top, there are tabs for 'page', 'discussion', 'view source', and 'history'. The main header includes the GAP logo and navigation links: 'GAP Maps', 'GAP Wiki', 'Help' (highlighted with a red box), and 'About'. Below the header, a map of West Africa is shown with various locations labeled. A 'Map Layers' panel is open on the left, showing options for 'Base map', 'Country borders', and 'Arsenic points'. The 'Arsenic points' layer is checked, and its opacity is set to 100. A legend for the 'Arsenic' layer is also visible, with color-coded ranges: 0 - 10 ug/L (green), 10 - 50 ug/L (yellow), and above 50 ug/L (orange). Red text annotations are overlaid on the map: 'access Help from the link at the top' points to the 'Help' link in the top bar, and 'or from the ?-icon in each window' points to a question mark icon in the 'Map Layers' panel.

**GAP Help**

The Groundwater Assessment Platform (GAP; [www.gapmaps.org](http://www.gapmaps.org)) hosts information on geogenic contamination of groundwater by arsenic and fluoride. It provides tl and field experiences as well as to interact with other users and create probabilistic maps for any area on the globe. The site has *two main sections* (Figure 1). In **GAP M** data and models as well as user data and model outputs, data and maps based maps. The **GAP Wiki** contains diverse information on geogenic contamination.

**access Help from the link at the top**

**or from the ?-icon in each window**

In case you have questions or require help while using the site, you can click on **Help** in the top bar to open the help page, which explains all of the features of GAP Map



# Additional functionality when logged in

**GAP** Groundwater Assessment Platform

GAP Maps GAP Wiki Help About Admin

Hello joel.podgorski! Log off

**My Layers**  
**Statistical Analysis**  
**Communities**  
**Manage Account**

**Layers**

- GAP layers
  - Climate
  - GAP prediction maps
  - Geology - age
  - Geology - lithology
  - Socioeconomic
  - Soil
  - Topography
  - Water quality

**Map Layers**

- ☒ Base map
- ☐ Country borders
- ☒ Arsenic points
- ☒ Arsenic

2000 km

**eawag**  
aquatic research

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC