



Groundwater
Assessment
Platform

gapmaps.org

Water quality prediction mapping with the Groundwater Assessment Platform (GAP)

Joel Podgorski, Jay Matta, Ruth Arnheiter, Michael Berg

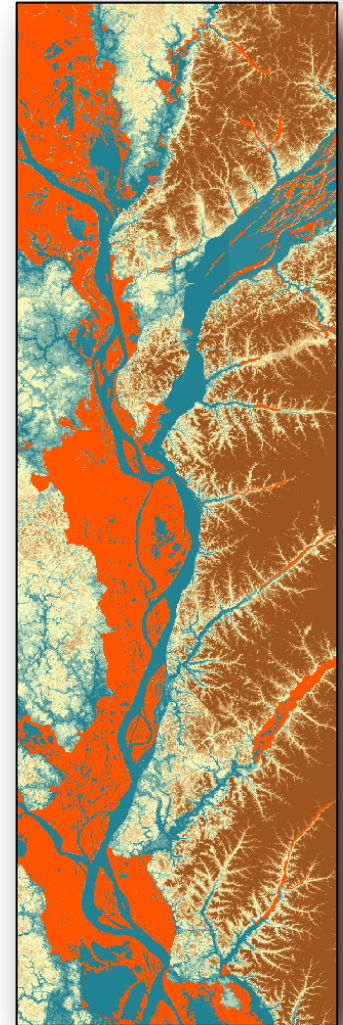
Contact: joel.podgorski@eawag.ch

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aquatic research o o o
Swiss Federal Institute of
Aquatic Science and Technology



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Swiss Agency for Development
and Cooperation SDC



International Conference on Geology, Mining, Mineral and Groundwater Resources of the Sub-Saharan Africa
Livingstone, Zambia, 12 July 2017

- 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 $\mu\text{g/L}$

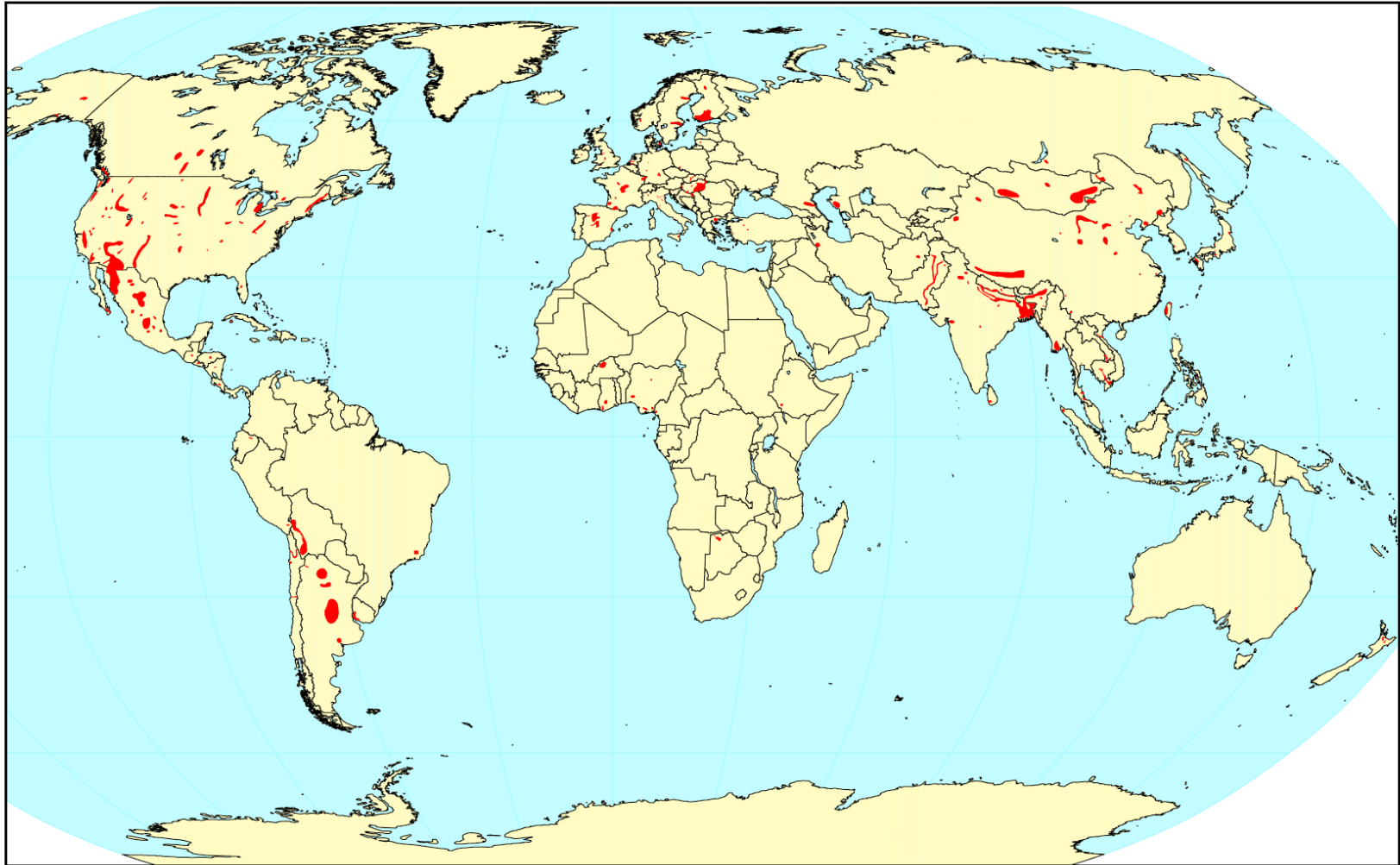


Fluoride (~200 million)
causes dental mottling
& decay and crippling
skeletal deformation
WHO: 1.5 mg/L



Various regions discovered in recent years

But large areas are still uncharted

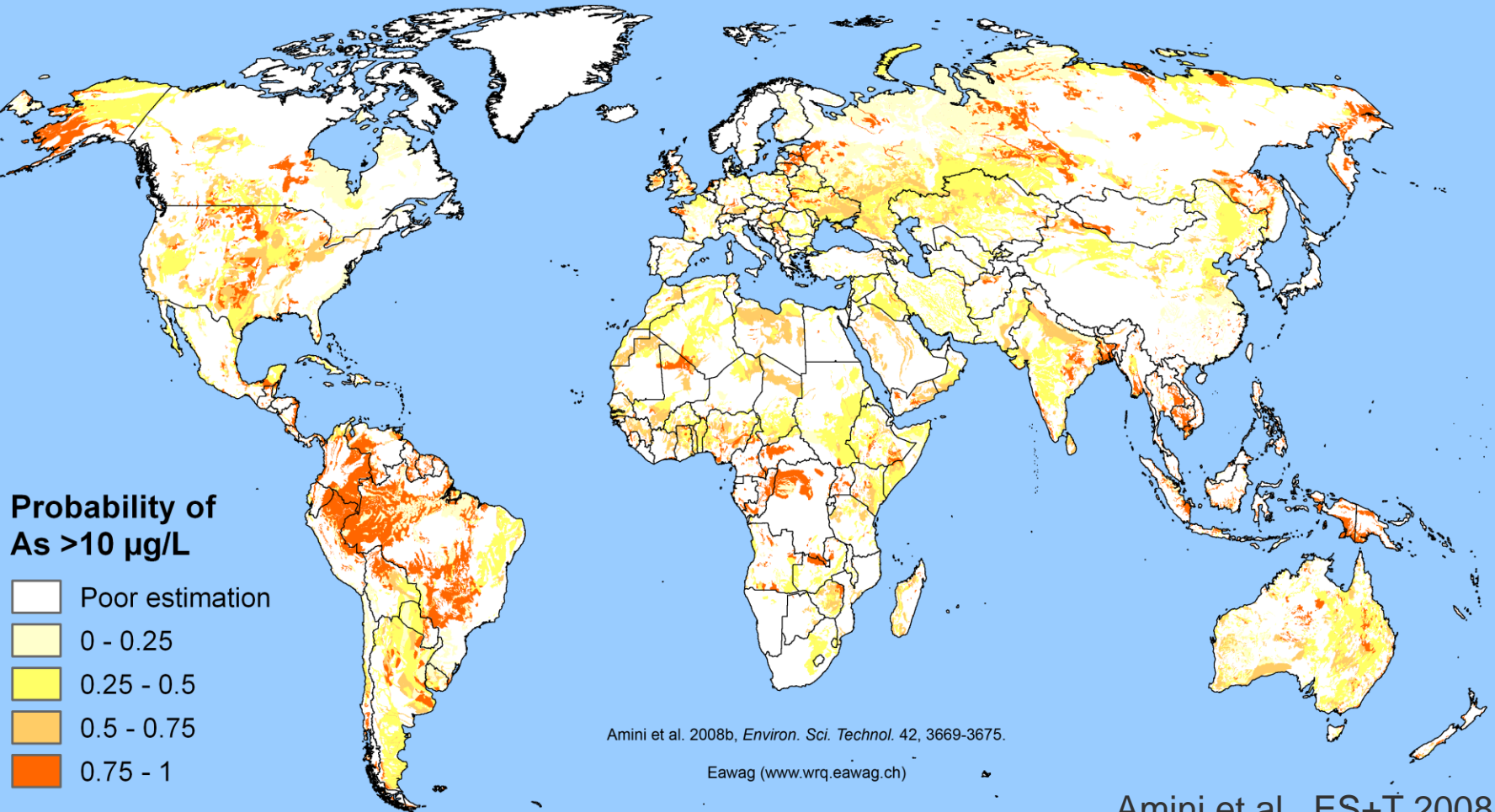


1st-generation global risk map for As >10 µg/L



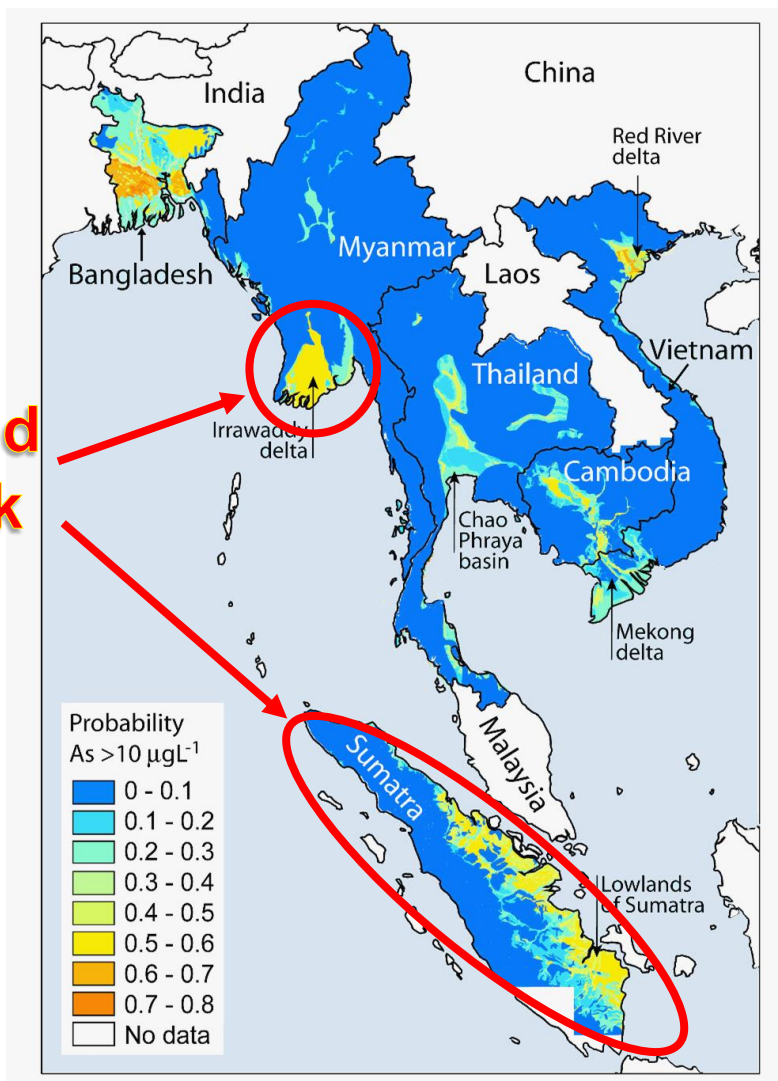
Groundwater
Assessment
Platform

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



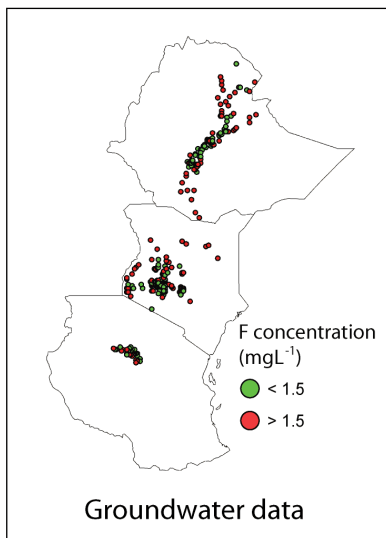
Amini et al., ES+T 2008

**predicted
high-risk
regions**

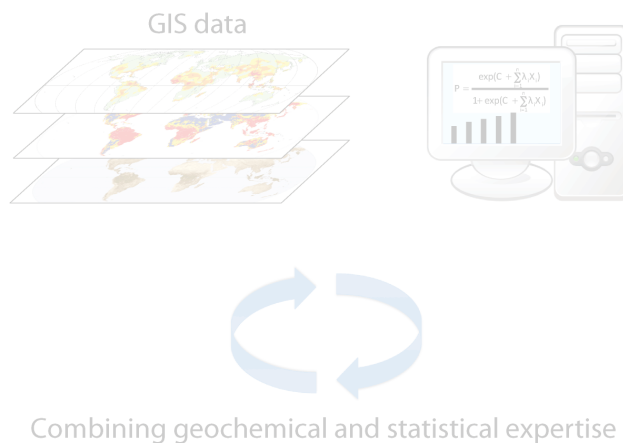


Winkel et al.,
Nature Geoscience, 2008

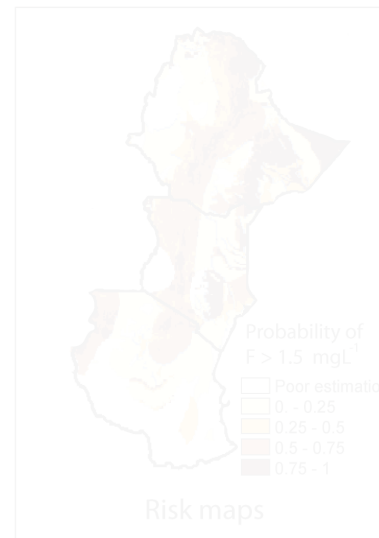
Concentration data



Geo-statistical modeling



Identifying risk areas



Mitigation



Relevant geospatial data

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

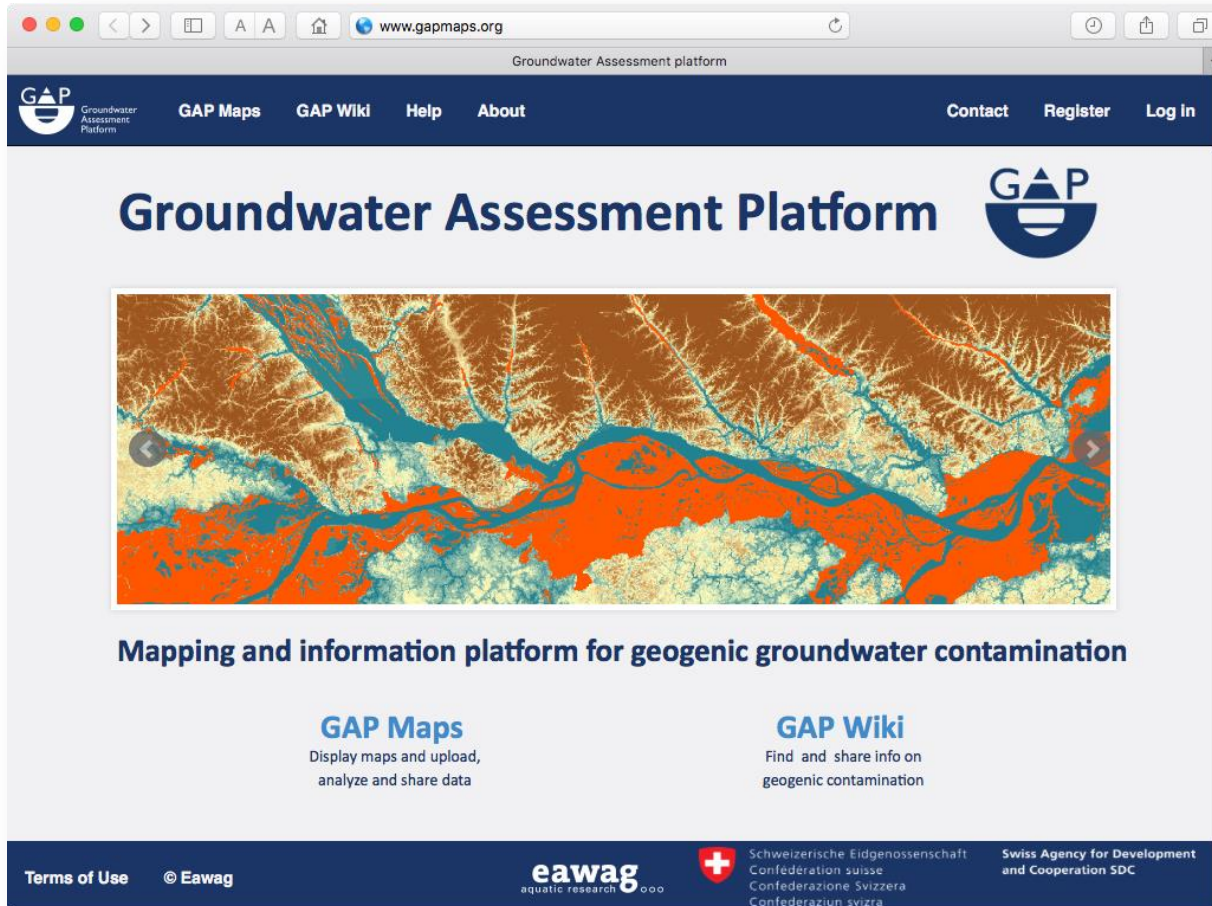
Gives the probability of a binary (0 or 1) target variable being "positive" (i.e. true or 1) for a linear combination of predictor variables:

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

where P is probability, β is a regression coefficient, x is an independent variable.

www.gapmaps.org

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



The screenshot shows a web browser window with the URL www.gapmaps.org. The page features a dark blue navigation bar with the GAP logo and links for 'GAP Maps', 'GAP Wiki', 'Help', 'About', 'Contact', 'Register', and 'Log In'. Below the navigation bar, the main heading 'Groundwater Assessment Platform' is displayed next to the GAP logo. A large map of a river basin is shown, with the river and its tributaries highlighted in blue and orange. Below the map, the text 'Mapping and information platform for geogenic groundwater contamination' is visible. Two main sections are highlighted: '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 the 'Terms of Use' link, the Eawag logo, and the logos for the Swiss Agency for Development and Cooperation SDC in German, French, Italian, and English.

- Mapping
- Modeling
- Sharing
- Wiki



www.gapmaps.org/GAP.Protected/Home/Protected

GAP Groundwater Assessment Platform

GAP Maps GAP Wiki Help About Admin

Hello michael.berg! Log off

Map Layers

- Base map
- Country borders
- Holocene (limited regions)
- Fluoride points
- Aridity

Layers

GAP layers

- Climate
 - Temperature
 - Precipitation
 - Evapotranspiration
 - Aridity
- GAP prediction maps
 - Arsenic
 - Fluoride
- Geology - age
- Geology - lithology
- Socioeconomic
 - Population density
- Soil
- Topography
- Water quality

Publicly shared layers

Shared layers

Add publicly available layers to map and use in modeling

1000 km

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eawag aquatic research

Schweizerische Eidgenossenschaft
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Swiss Agency for Development and Cooperation SDC

PUBLIC

- View existing models and data

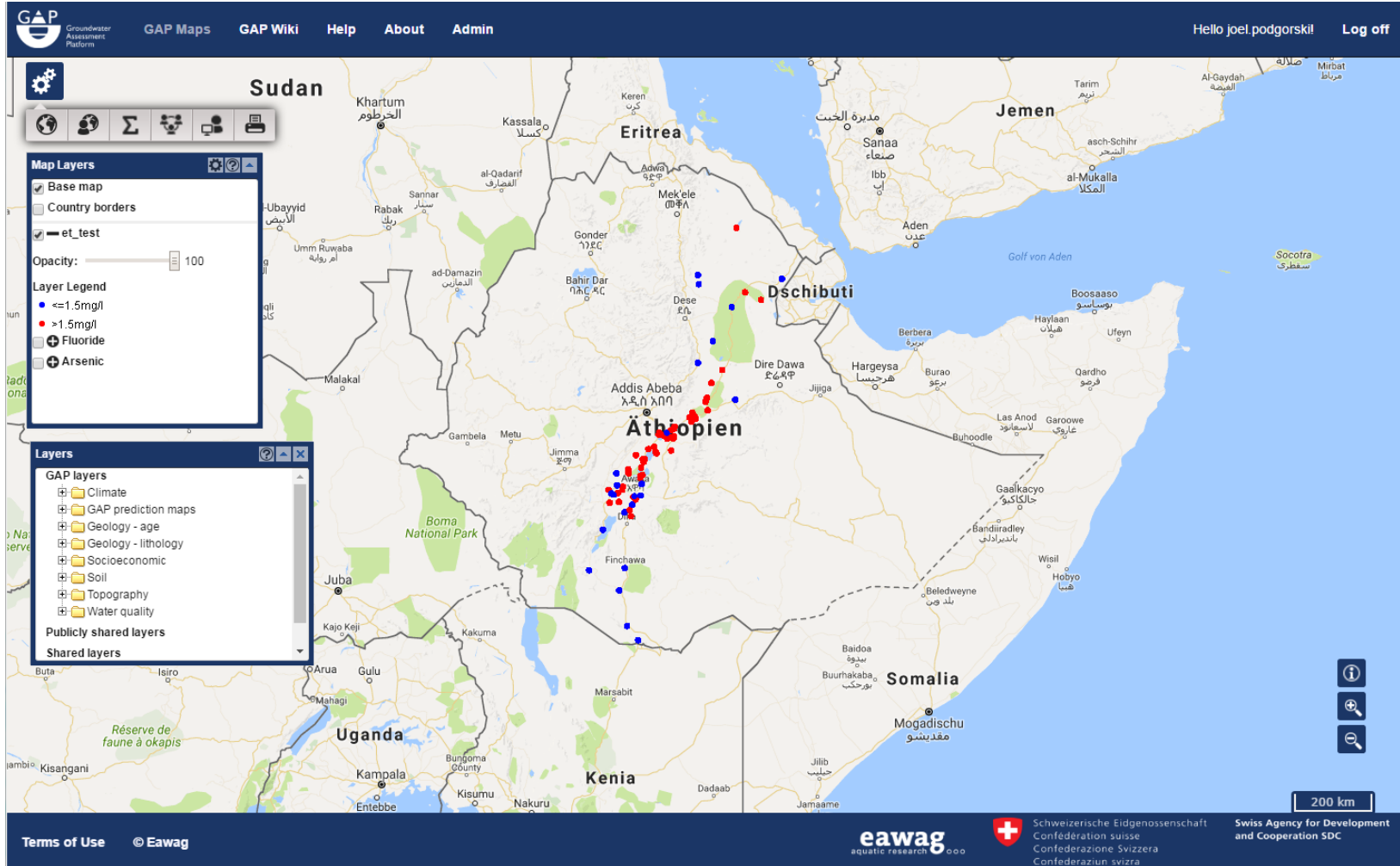
PRIVATE (login)

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

COMMUNITY

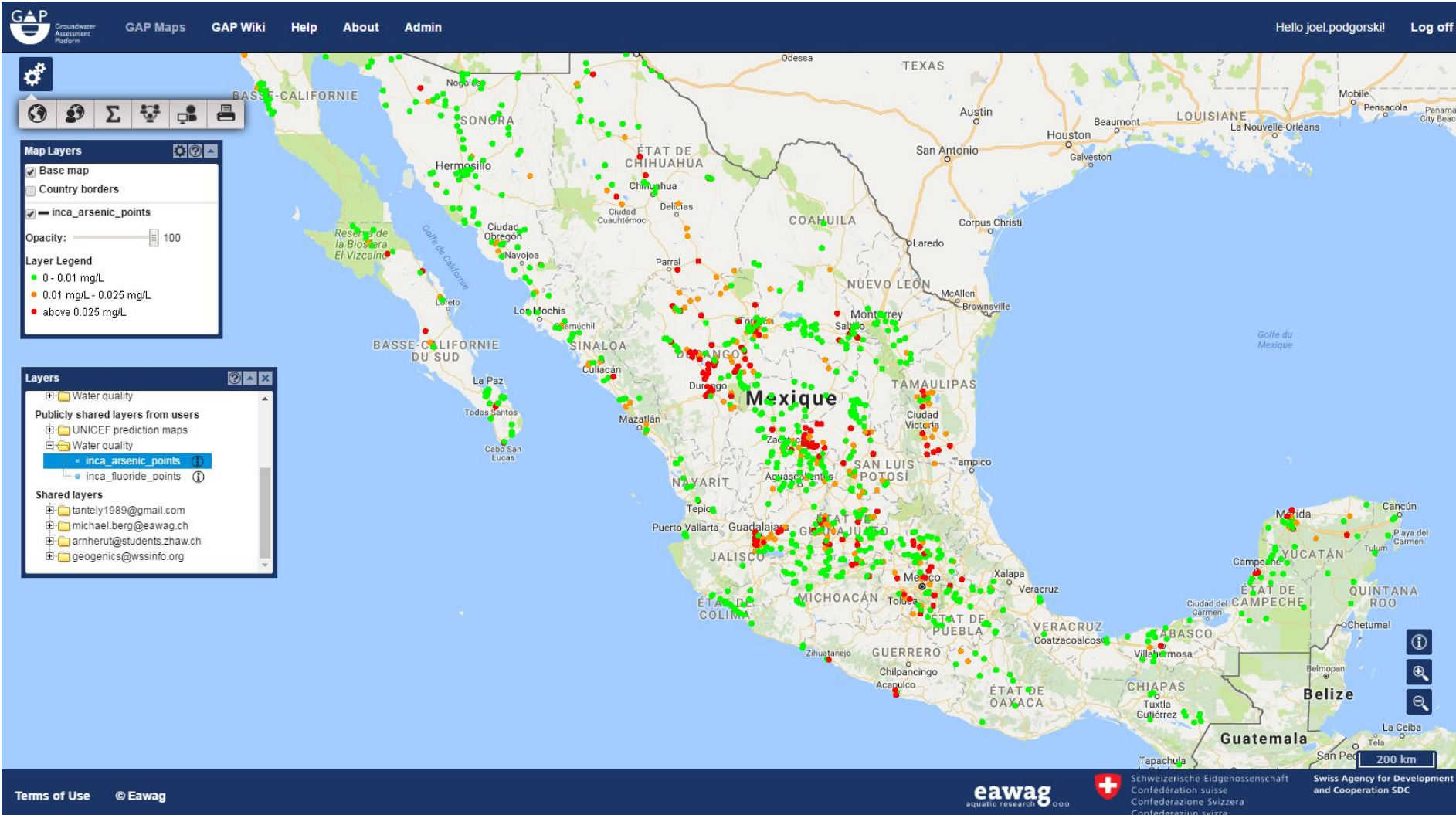
- Share data and models with user-created communities

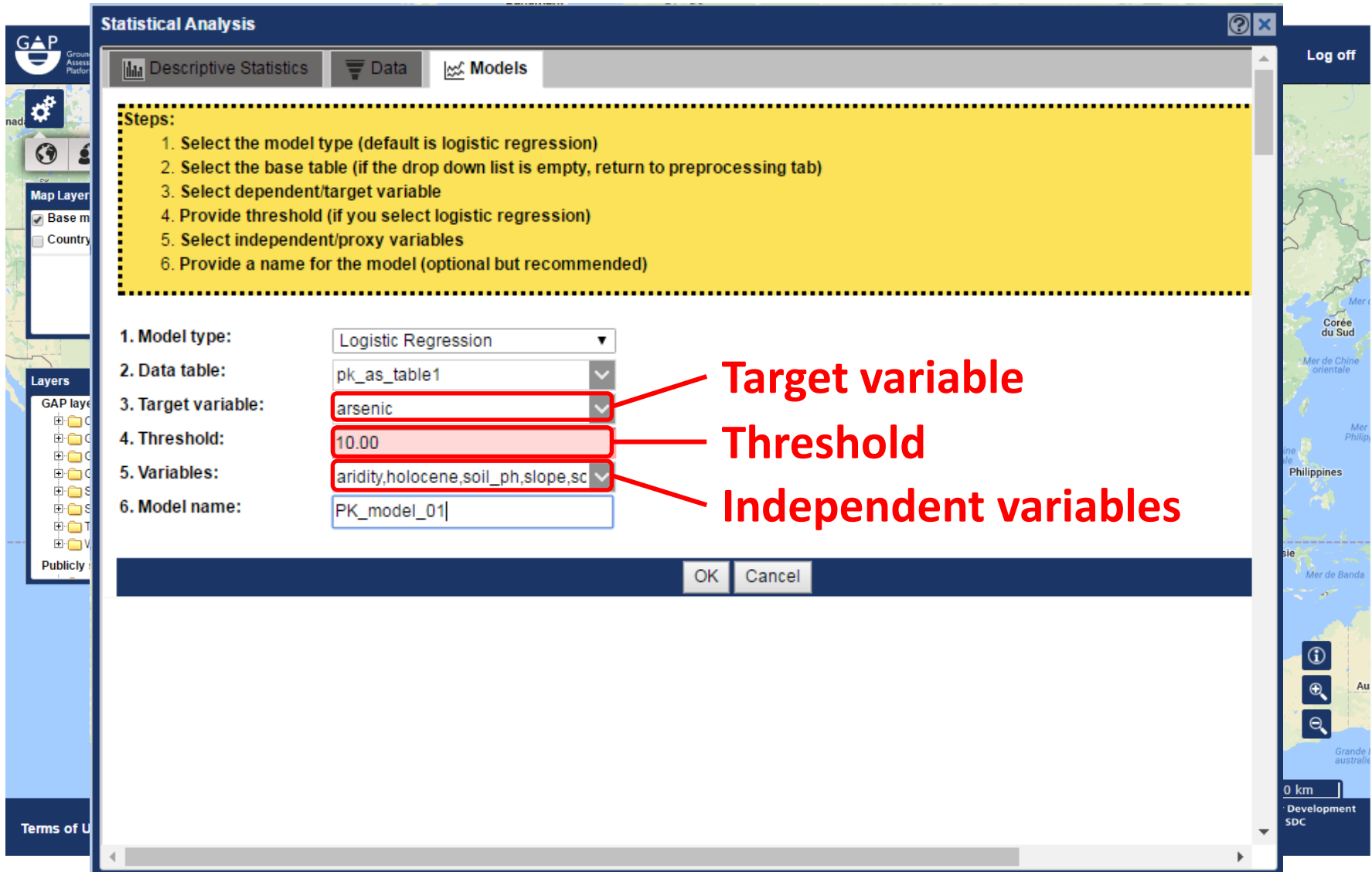
Modify point symbology



- Change shape and color of points
- Add filters to control what to display

Example: arsenic concentrations from Mexico





Statistical Analysis

Descriptive Statistics | Data | Models

Steps:

1. Select the model type (default is logistic regression)
2. Select the base table (if the drop down list is empty, return to preprocessing tab)
3. Select dependent/target variable
4. Provide threshold (if you select logistic regression)
5. Select independent/proxy variables
6. 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: 10.00

5. Variables: aridity,holocene,soil_ph,slope,sc

6. Model name: PK_model_01

OK Cancel

Target variable

Threshold

Independent variables

Coefficients of independent variables

ROC curve

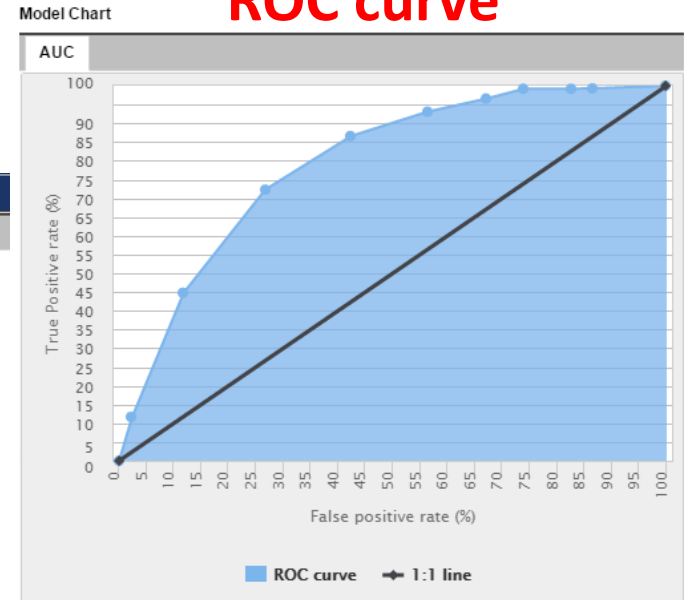
Statistical Analysis

Descriptive Statistics | Data | Models

Return

Model coefficients

Id	Step	Parameter	Coefficient	Std	Wald	Odds	Lower	Upper	P-value
1	113	Intercept	-7.38	1.49	-4.94	0.00	0.00	0.01	0.000
2	113	holocene	-0.30	0.15	-1.95	0.74	0.55	1.00	0.051
3	113	slope	-0.29	0.08	-3.57	0.75	0.64	0.88	0.000
4	113	soil_fluvisols_pk_v2	0.03	0.01	6.33	1.03	1.02	1.05	0.000
5	113	soil_ph_mosaic_soilgrids_	1.06	0.17	6.16	2.88	2.06	4.03	0.000
6	113	soil_oc_soilgrids6m_hwsd	-0.58	0.16	-3.62	0.56	0.41	0.77	0.000

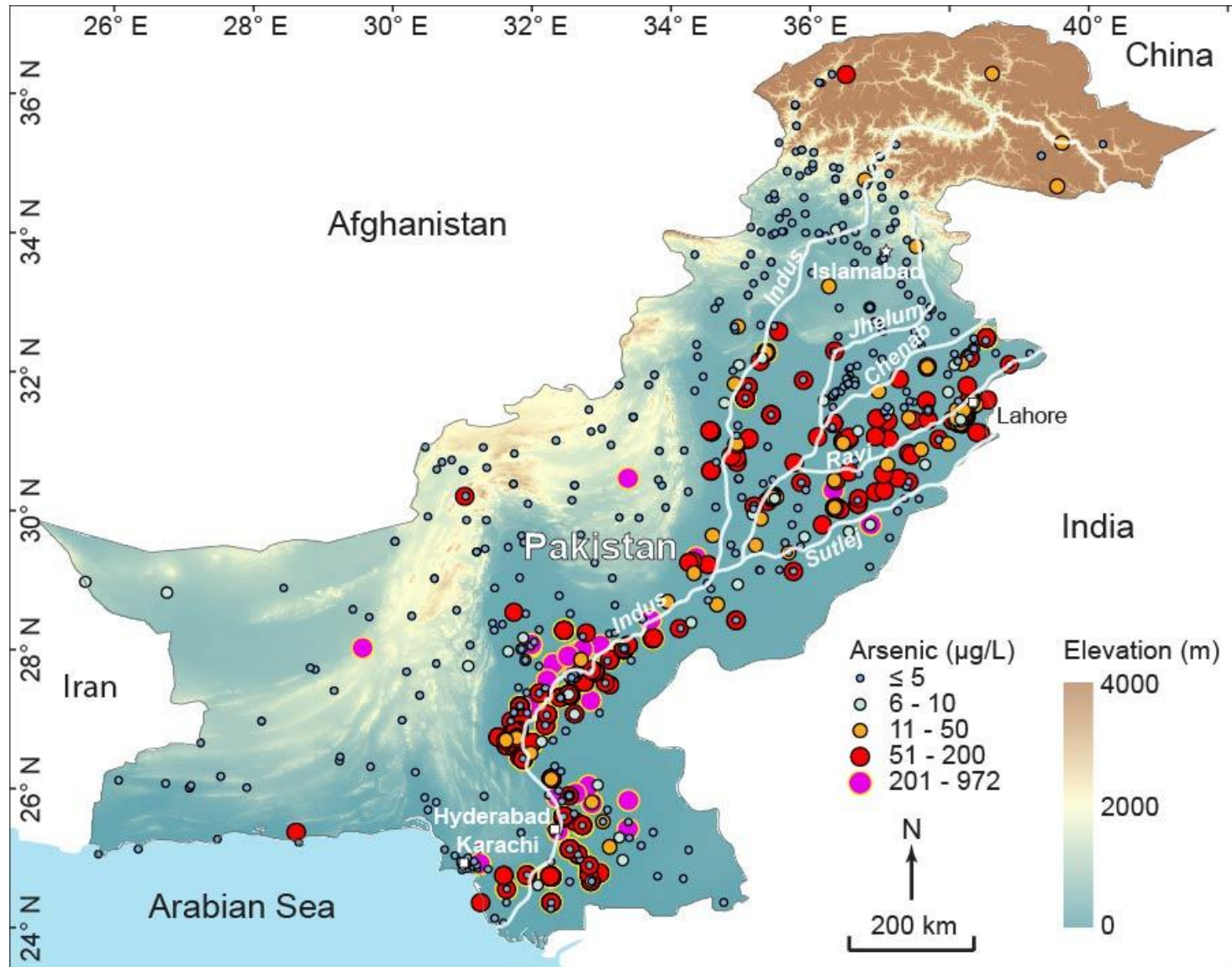


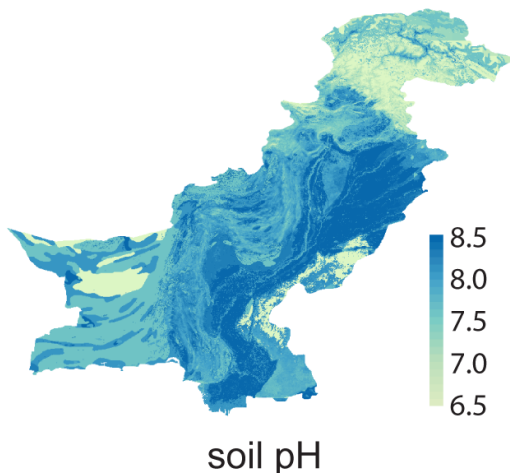
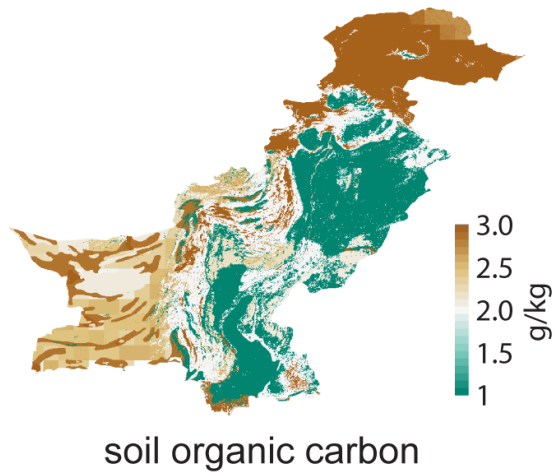
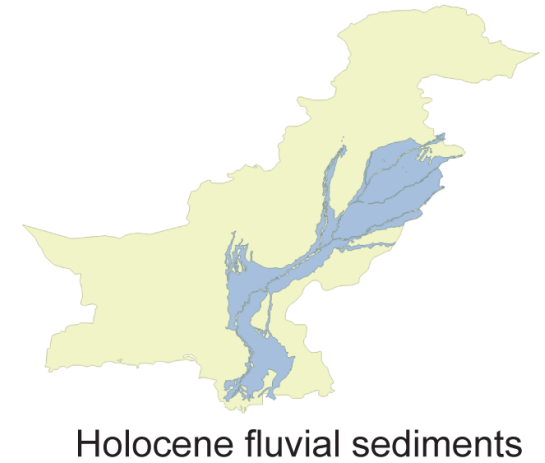
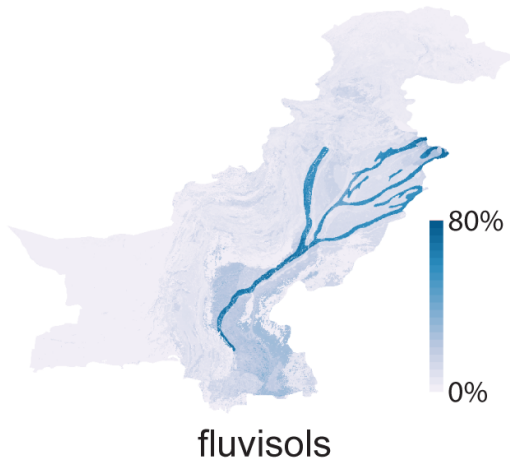
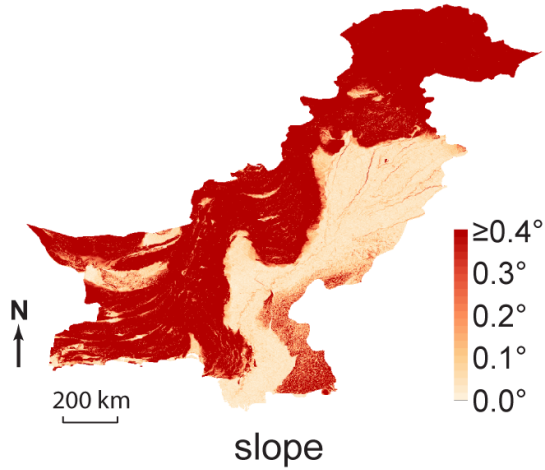
Model classification

Id	Cutoff	Measured high	Measured low	Predicted high	Predicted low	False pos. rate	False neg. rate	Sensitivity	Specificity	Accuracy	Efficiency	
1	113	0	835	415	835	0	1	0	1	0	0.668	0.5
2	113	0.1	835	415	829	56	0.865	0.007	0.993	0.135	0.708	0.564
3	113	0.2	835	415	828	72	0.827	0.008	0.992	0.173	0.72	0.583
4	113	0.3	835	415	828	108	0.74	0.008	0.992	0.26	0.749	0.626
5	113	0.4	835	415	807	136	0.672	0.034	0.966	0.328	0.754	0.647
6	113	0.5	835	415	777	181	0.564	0.069	0.931	0.436	0.766	0.683
7	113	0.6	835	415	723	239	0.424	0.134	0.866	0.576	0.77	0.721
8	113	0.7	835	415	604	304	0.267	0.277	0.723	0.733	0.726	0.728
9	113	0.8	835	415	374	366	0.118	0.552	0.448	0.882	0.592	0.665
10	113	0.9	835	415	98	405	0.024	0.883	0.117	0.976	0.402	0.547
11	113	1	835	415	0	415	0	1	0	1	0.332	0.5

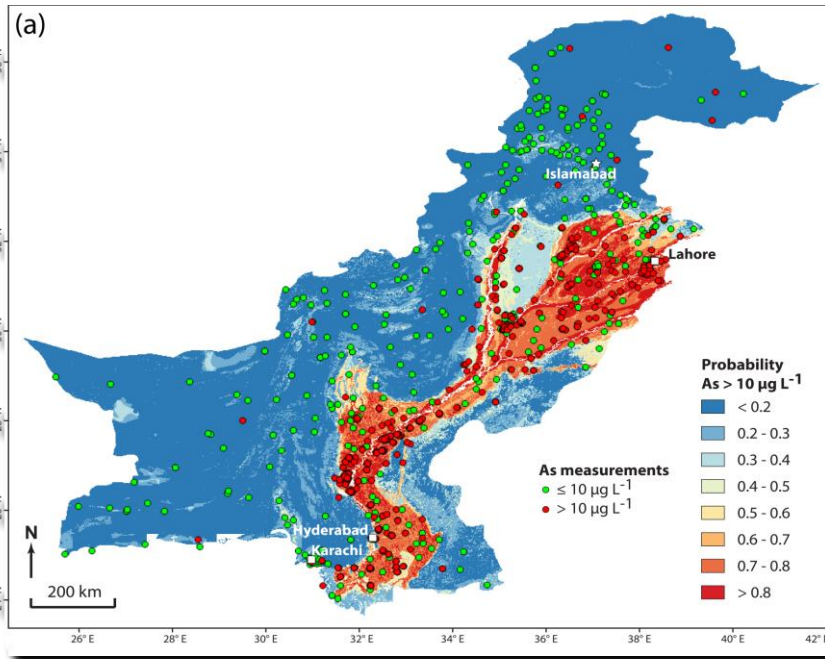
Statistics with different cutoff values

Pakistan arsenic study



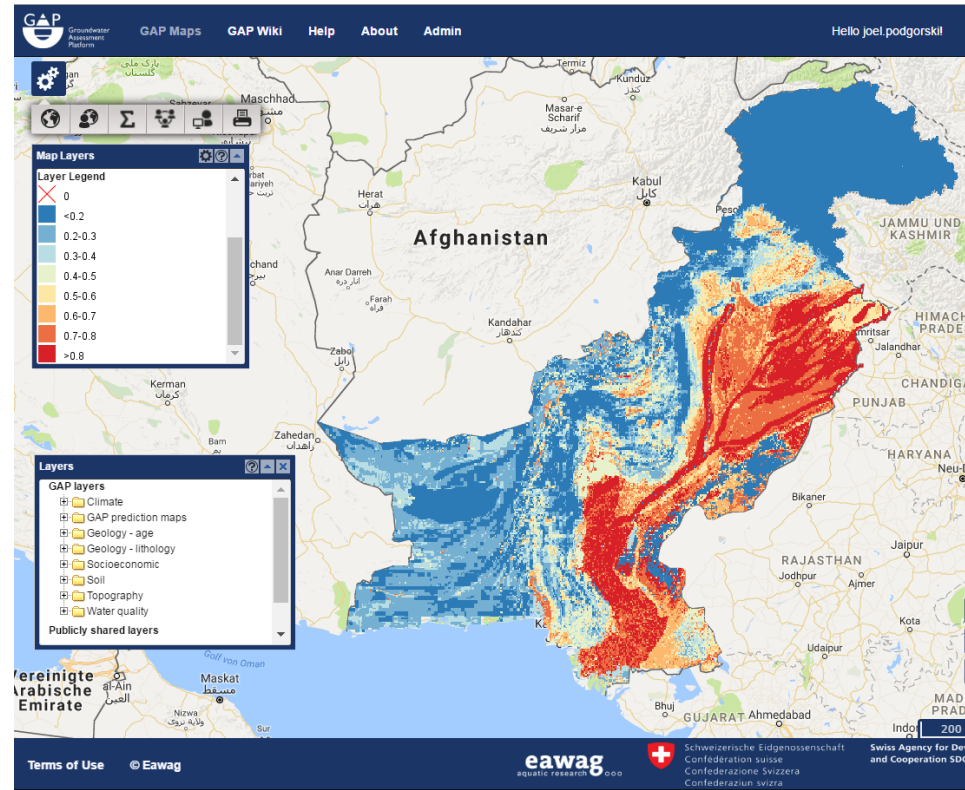


Arsenic prediction map for Pakistan created offline with the R language

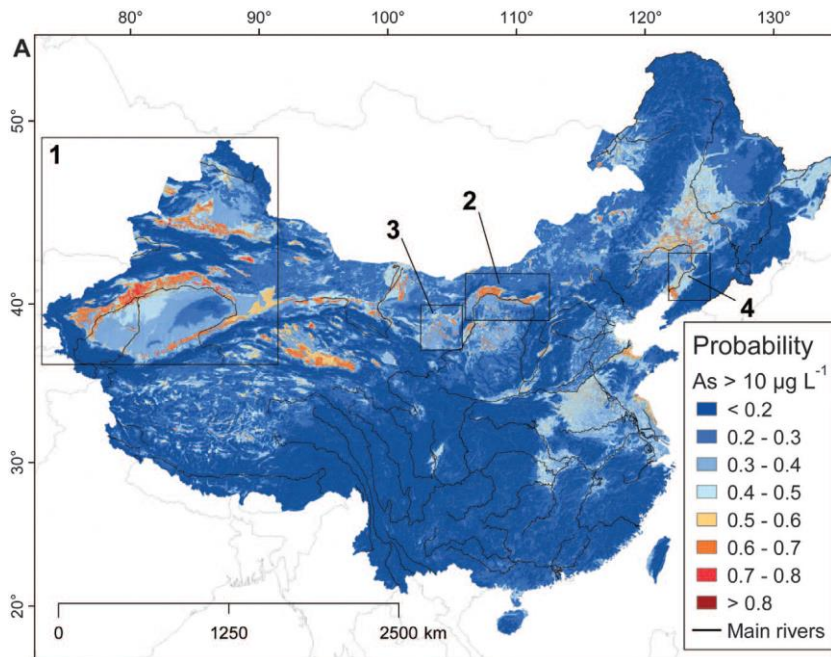


Podgorski et al., 2017, in review

Arsenic prediction map for Pakistan created on GAP

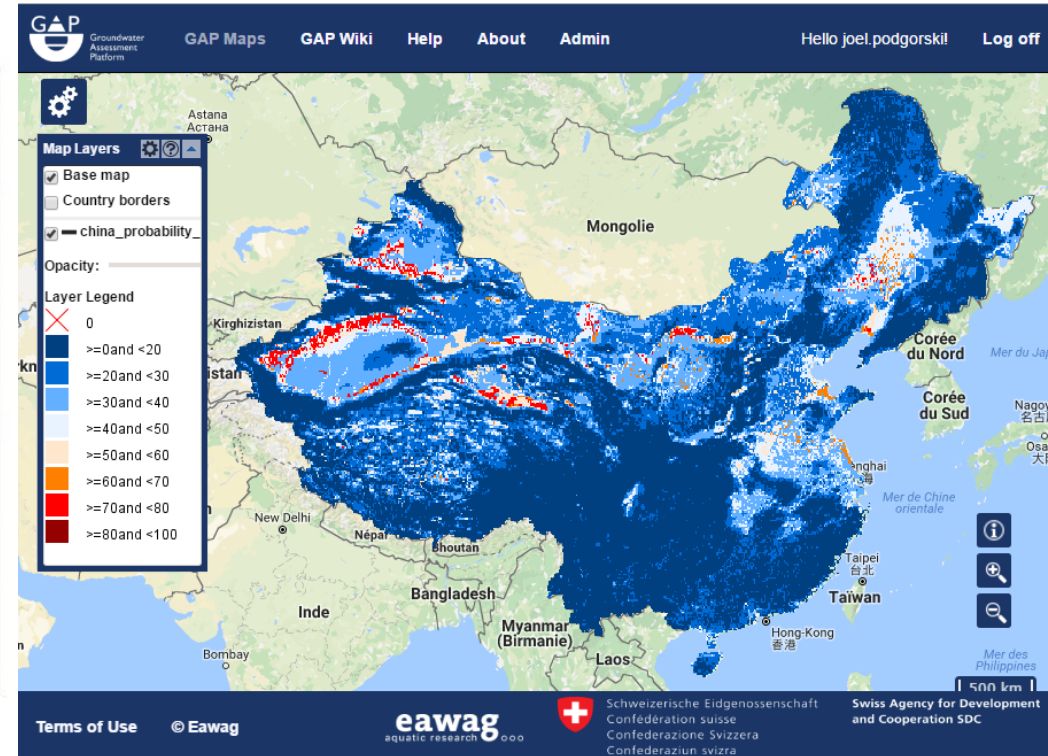


Arsenic prediction map for China created offline



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



Groundwater
Assessment
Platform

www.gapmaps.org

Goal to reduce number of people affected

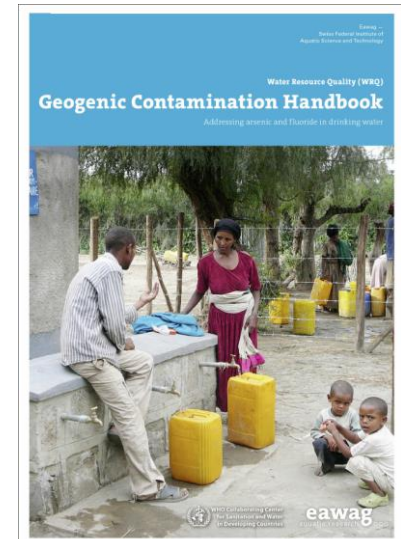
- Water treatment, covered in the Geogenic Contamination Handbook (at www.gapmaps.org)
- Identify contaminated regions through prediction modeling



The following gaps have been identified:

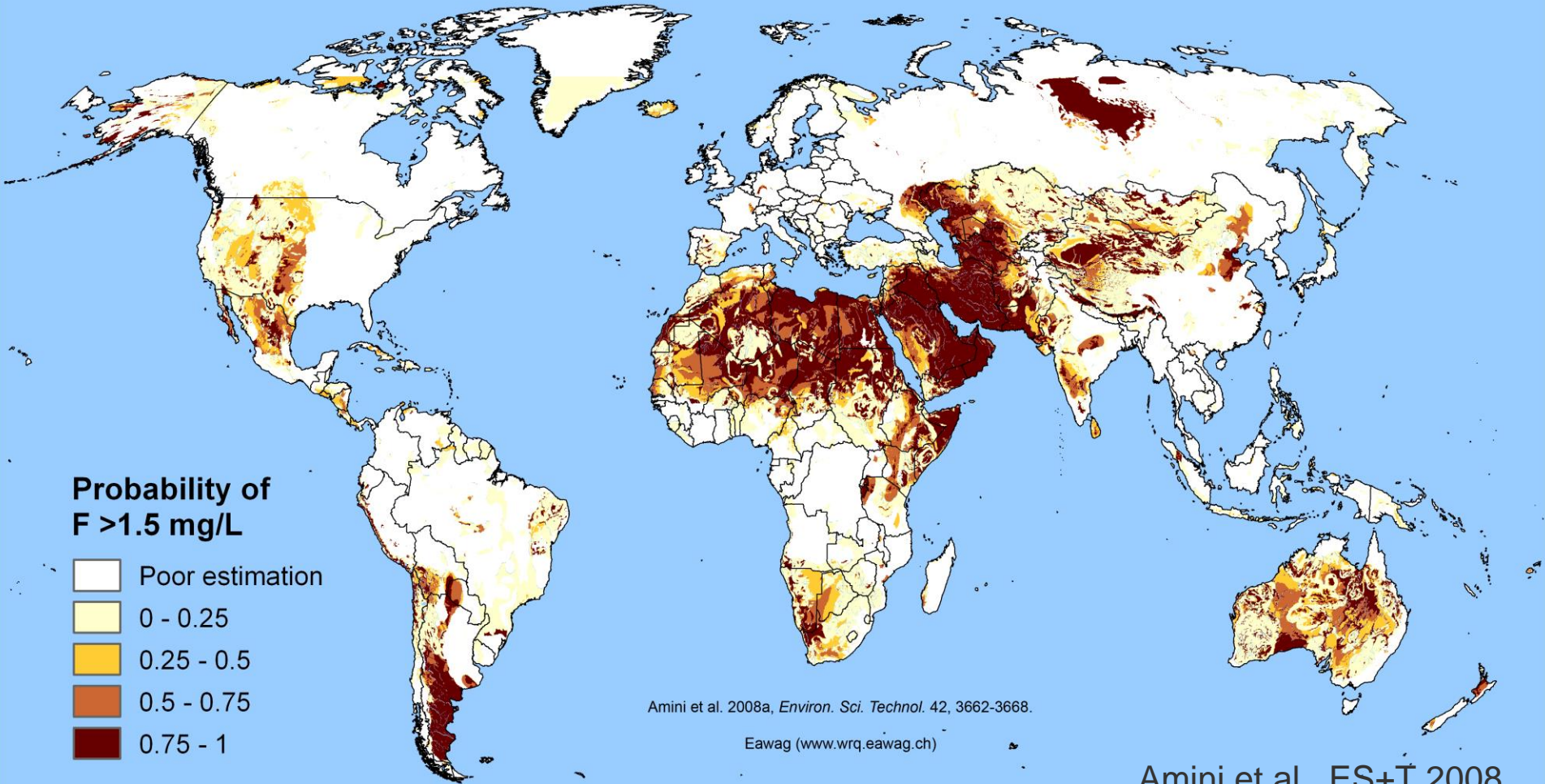
- Gaps in knowledge of potential arsenic and fluoride contamination
- Gaps in expertise to create and manage data
- Gaps in opportunity to share and exchange information

- GAP was launched in mid-2014 and is funded by Swiss Agency for Development and Cooperation (SDC) until end of 2017
- GAP is a follow-up to the Water Resource Quality (WRQ) project (2006-2012), which:
 - focused on detection & mitigation of geogenic contaminants (As, F) in groundwater;
 - culminated in the publication (2015) of the Geogenic Contamination Handbook
- Both projects initiated/led by the late Annette Johnson

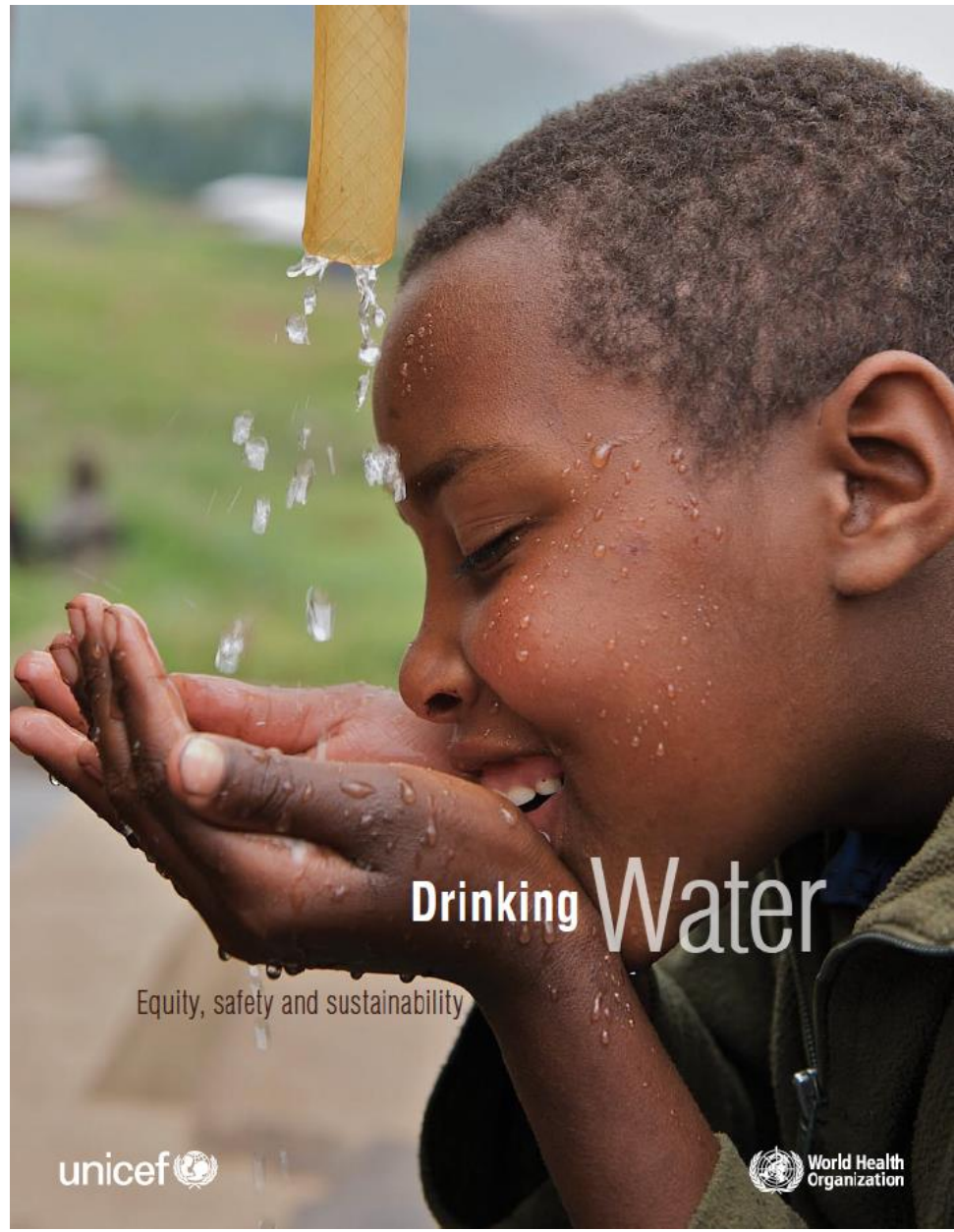


1st-generation global risk map for F >1.5 mg/L

Modeled global probability of fluoride concentration in groundwater exceeding the WHO guideline for drinking water of 1.5 mg/L



Amini et al., ES+T 2008



Water safety

Geogenic contamination of groundwater

To date, the only water safety correction in the JMP reporting practice has been applied to Bangladesh to compensate for the high prevalence of arsenic contamination in the country. Globally, over 100 million people are now estimated to be at risk from arsenic in drinking water at concentrations above the WHO drinking water guideline value of 10 µg/l (JMP/CIET, 2008). Arsenic occurs naturally in groundwater in many areas, and long-term exposure to arsenic in drinking water can lead to arsenic poisoning or arsenicosis.

There is a high probability of arsenic in groundwater in specific areas of all regions.

Figure 26: Arsenic in groundwater probability map (Source: Arini et al., 2008)

Fluoride also occurs naturally in groundwater and can cause fluorosis which affects the teeth and bones. Although a certain amount of fluoride is healthy, moderately higher amounts lead to adverse dental effects, and long-term ingestion of large amounts can lead to potentially severe skeletal problems. High fluoride concentrations in groundwater occur in many areas of the world, including large parts of Africa, China, the Eastern Mediterranean and Southern Asia (Fawell, et al., 2009).

Drinking Water

There is a high probability of fluoride in groundwater in significant parts of Asia, South America, the Middle East and North Africa.

Figure 27: Fluoride in groundwater probability map (Source: Arini et al., 2008)

There is a continuing need to monitor geogenic contamination of groundwater, especially where there is a potential risk to public health via drinking water supplies, and to develop and implement appropriate mitigation strategies.

Safety, safety and sustainability | 30

GAP risk maps featured in chapter on water safety

Print PDF of area of interest

Map Layers

- Base map
- Country borders
- Arsenic points

Opacity: 100

Layer Legend

- 0 - 10 ug/L
- 10 - 50 ug/L
- above 50 ug/L

Arsenic

Opacity: 100

Layer Legend

- noData
- very low
- low
- medium
- high

Print

Map title:

Layout: A4 landscape

DPI: 150

Submit

Select orientation and resolution

Position area to print

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eawag aquatic research

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→ Can also export GIS layer of own data/models

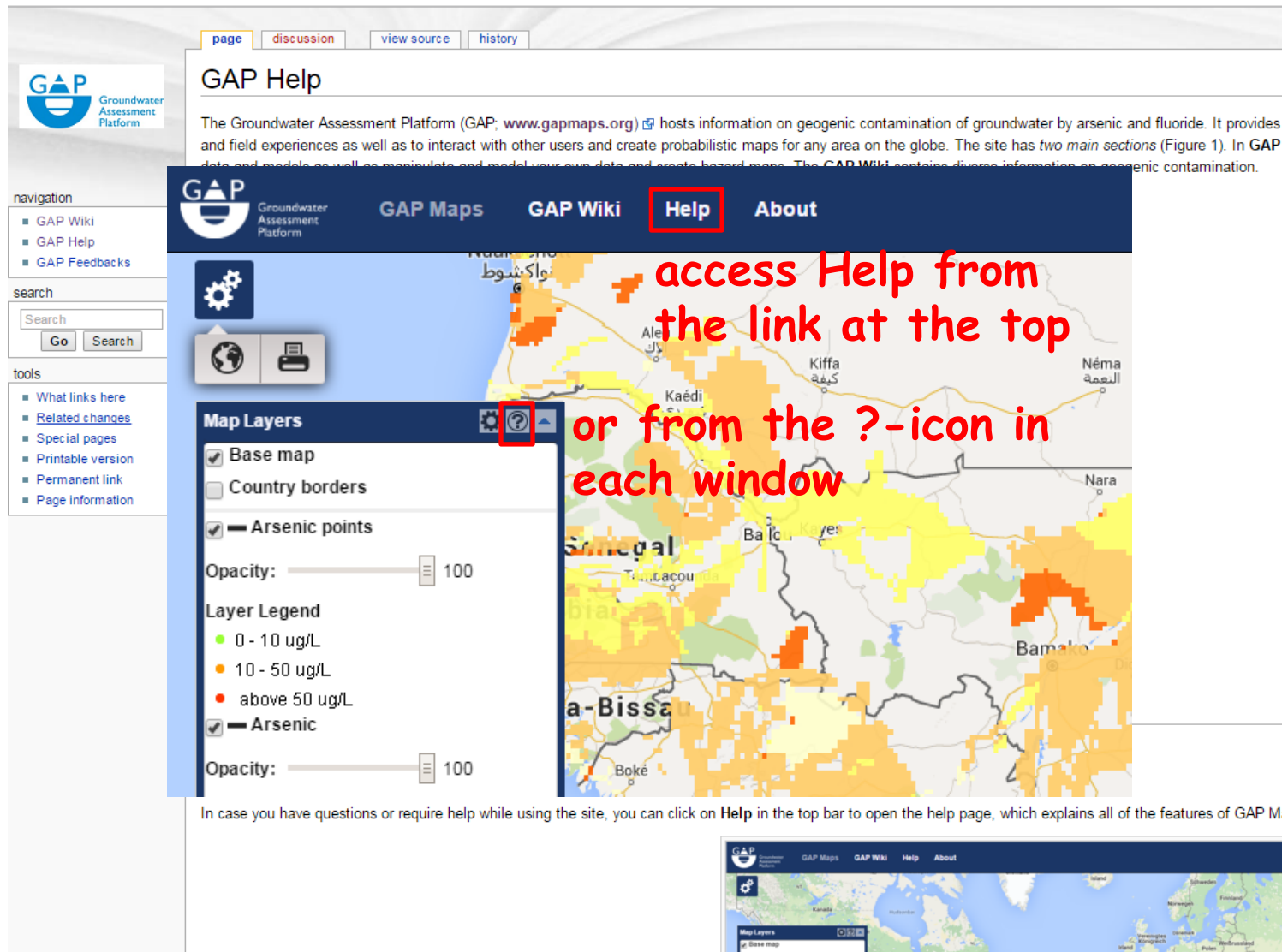
Share data and models with a select group of users

The screenshot shows the GAP web interface with the 'Communities' panel open. The panel contains a table of community entries and a 'Community Layers' sidebar.

	Name	Topic	Description
1	Annette test	confusion	zu
2	testing	arsenic	West Bengal data - there's no holocce
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 'Community Layers' sidebar shows a tree structure:

- ShowReel
 - Adama_workshop
 - ethiopia_sampledata
 - Ouaga_atelier



GAP Help


The Groundwater Assessment Platform (GAP; www.gapmaps.org) hosts information on geogenic contamination of groundwater by arsenic and fluoride. It provides tools 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 Maps**, users can view, download, and share data and models as well as manipulate and model your own data and create hazard 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 Maps.

Additional functionality when logged in



The screenshot displays the GAP Maps web application interface. At the top, there is a navigation bar with the GAP logo, 'Groundwater Assessment Platform', and menu items: 'GAP Maps', 'GAP Wiki', 'Help', 'About', and 'Admin'. On the right side of the navigation bar, it says 'Hello joel.podgorski!' and a 'Log off' button.

Below the navigation bar is a toolbar with several icons. Four of these icons are highlighted with red boxes and have red vertical labels pointing to them: 'My Layers' (person icon), 'Statistical Analysis' (sum icon), 'Communities' (group of people icon), and 'Manage Account' (user profile icon). A gear icon for settings is also present.

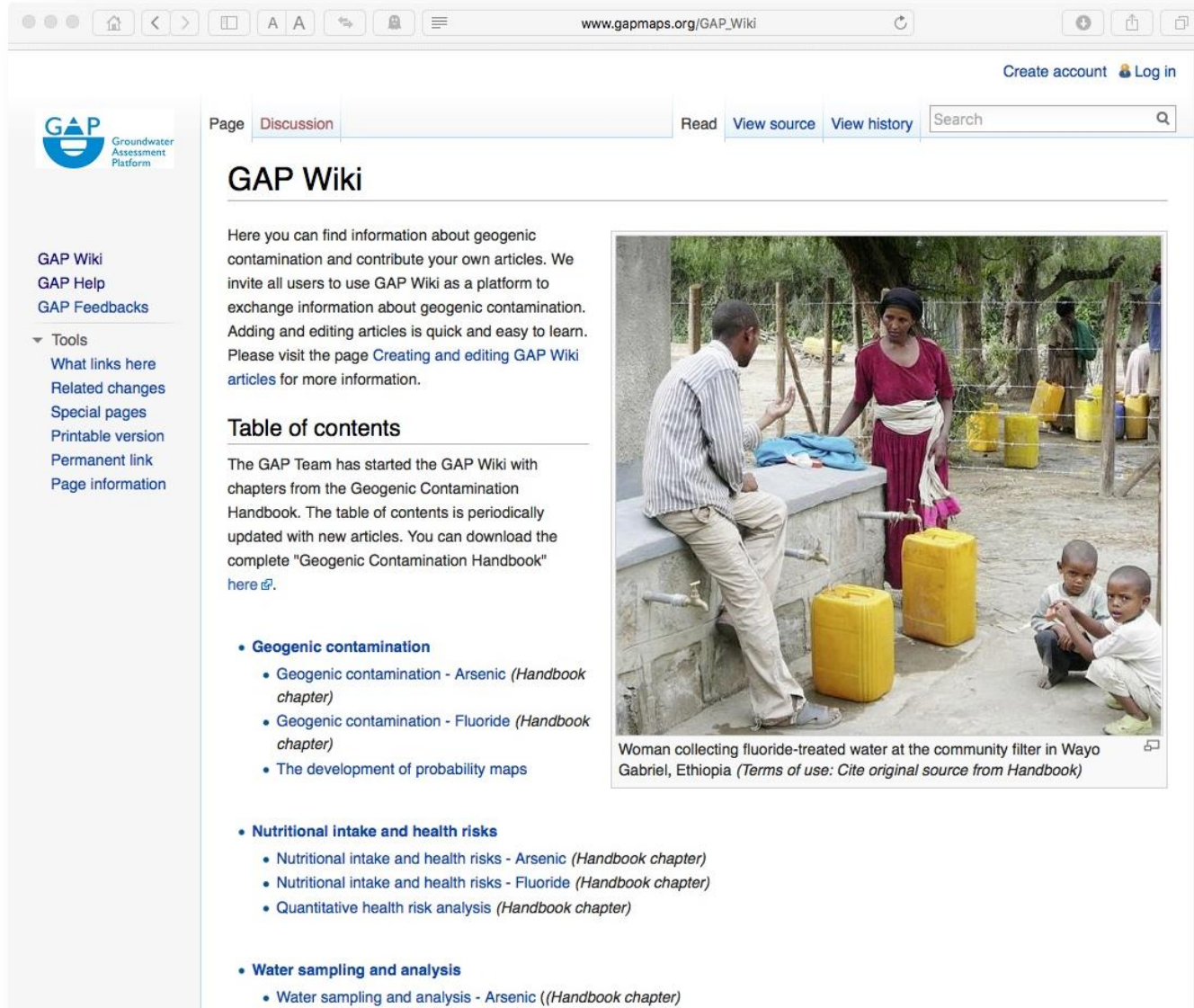
The main area of the interface is a world map showing groundwater assessment data. The map is color-coded, with green and yellow indicating lower risk and orange and red indicating higher risk. Various countries and regions are labeled, including Germany, France, Italy, Greece, Turkey, Iran, Afghanistan, Pakistan, India, China, and many others.

On the left side of the map, there are two panels:

- Layers:** A list of data layers with expand/collapse icons. The layers include: Climate, GAP prediction maps, Geology - age, Geology - lithology, Socioeconomic, Soil, Topography, and Water quality.
- Map Layers:** A list of map display options with checkboxes. The options are: Base map (checked), Country borders (unchecked), Arsenic points (checked), and Arsenic (checked).

At the bottom of the map, there is a scale bar for 2000 km and a legend icon. The footer of the interface contains the following information:

- Terms of Use and © Eawag
- eawag aquatic research logo
- Schweizerische Eidgenossenschaft Confederation suisse Confederazione Svizzera Confederaziun svizra
- Swiss Agency for Development and Cooperation SDC

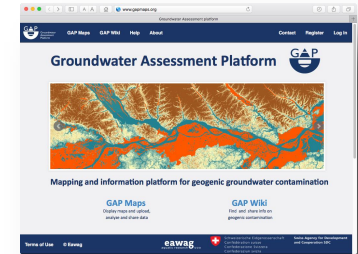


The screenshot shows the GAP Wiki website interface. At the top, there is a navigation bar with 'Page', 'Discussion', 'Read', 'View source', and 'View history' tabs. A search bar is located on the right. The main content area features the title 'GAP Wiki' and a paragraph explaining the platform's purpose: '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.'

Below the text is a 'Table of contents' section with the following items:

- 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*)

A photograph shows a woman in a red dress collecting water from a community filter in Wayo Gabriel, Ethiopia. Two children are sitting on the ground nearby. The caption reads: 'Woman collecting fluoride-treated water at the community filter in Wayo Gabriel, Ethiopia (*Terms of use: Cite original source from Handbook*)'.



gapmaps.org

Features the **Geogenic Contamination Handbook**

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