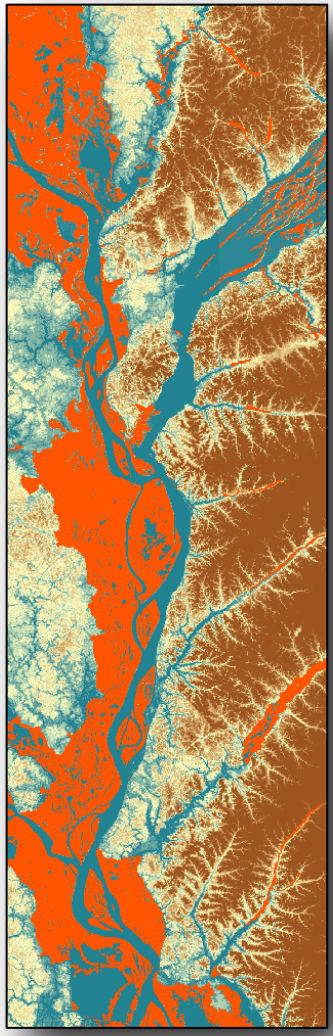
Groundwater Assessment Platform

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

eawag aquatic research

Swiss Federal Institute of Aquatic Science and Technology

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

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

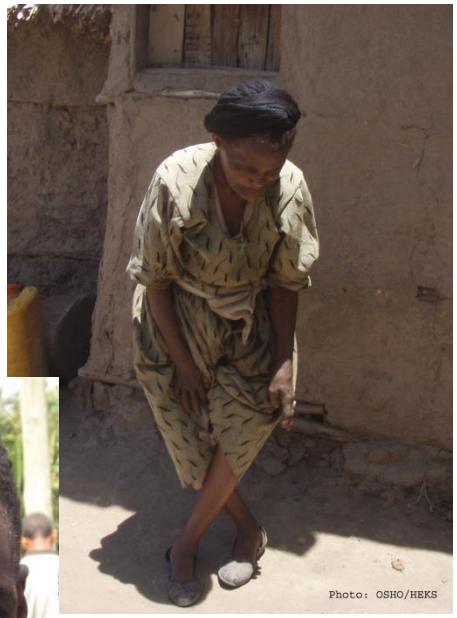
Geogenic (natural) groundwater contamination

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 μg/L

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



Global arsenic map, 2008 (Ravenscroft et al., 2008)

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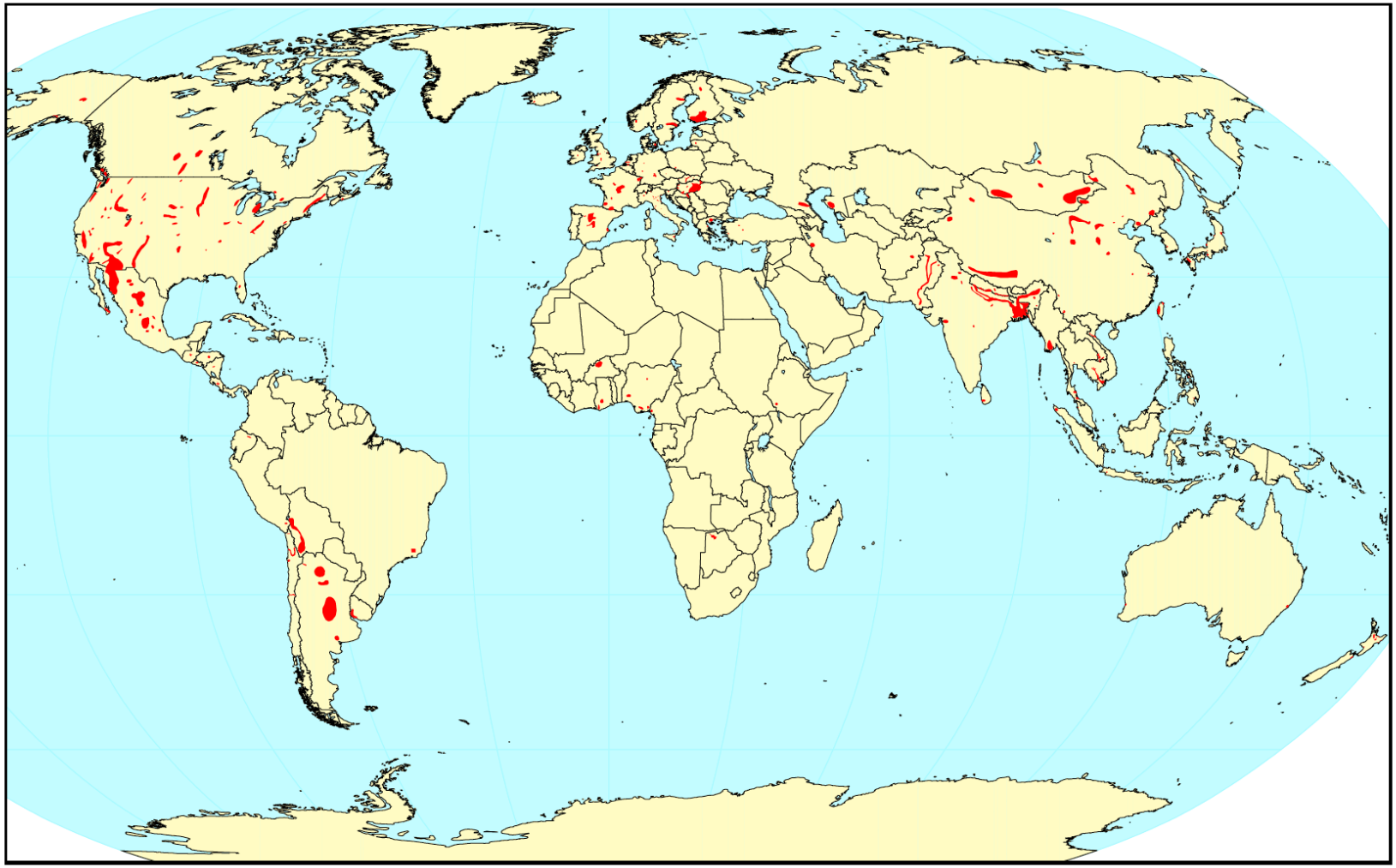
Various regions discovered in recent years

But large areas are still uncharted



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

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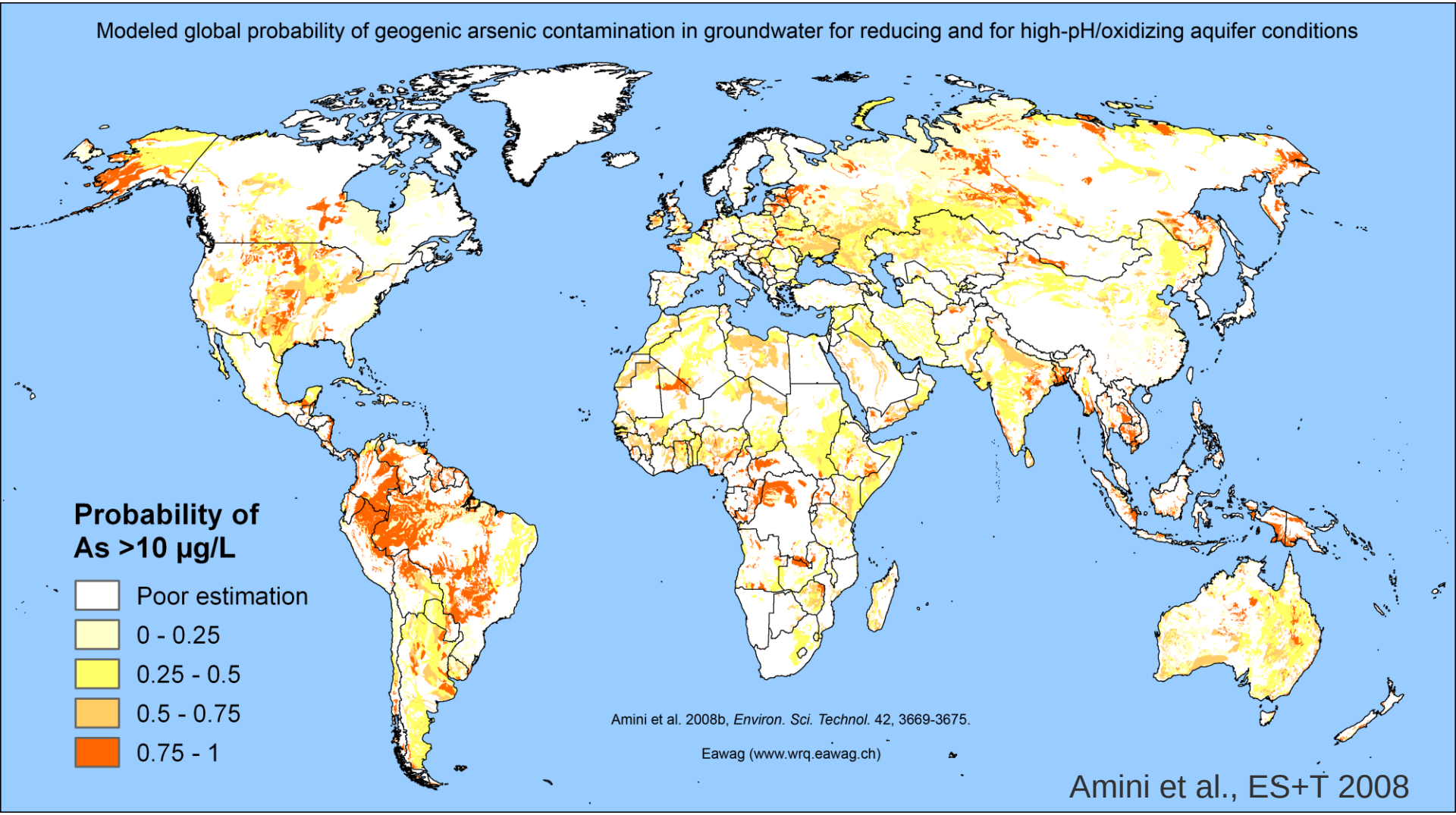
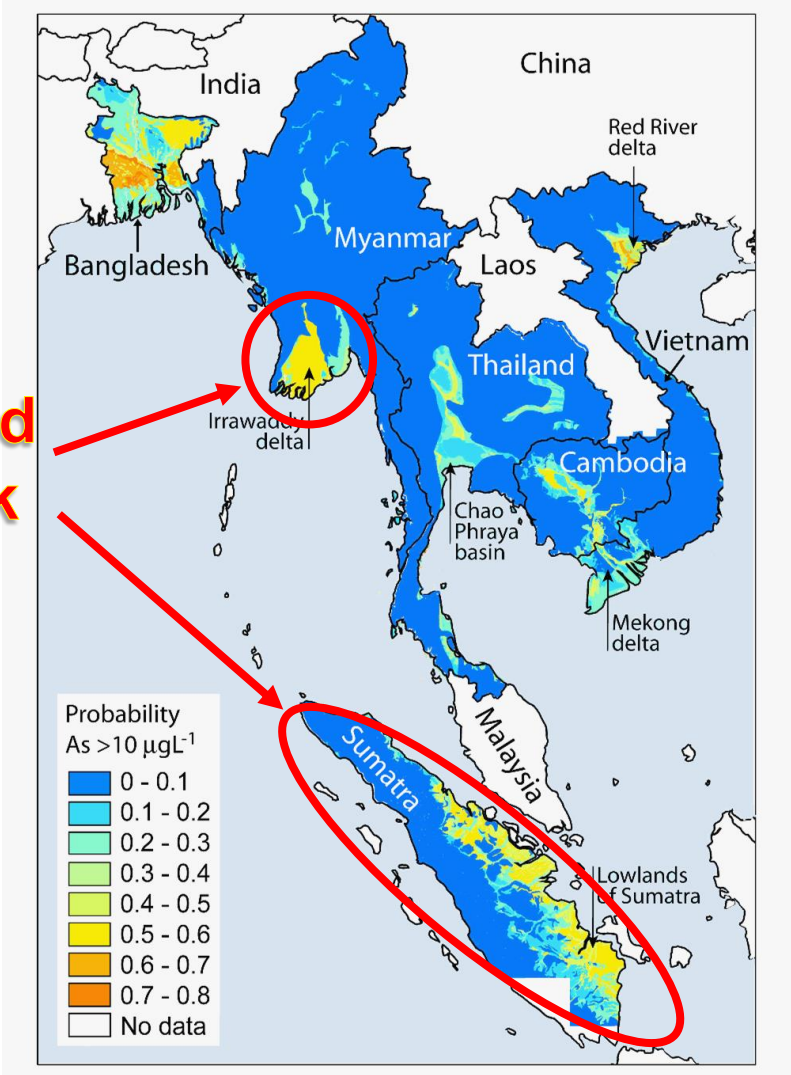


Detailed model, Southeast Asia



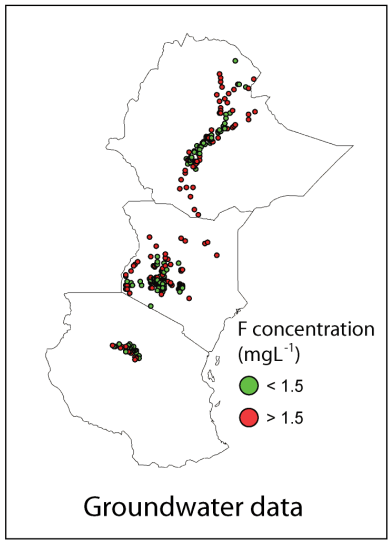
predicted high-risk regions

Winkel et al.,
Nature Geoscience, **2008**

Concept of geostatistical prediction modeling

Groundwater Assessment Platform

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

Logistic regression

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:

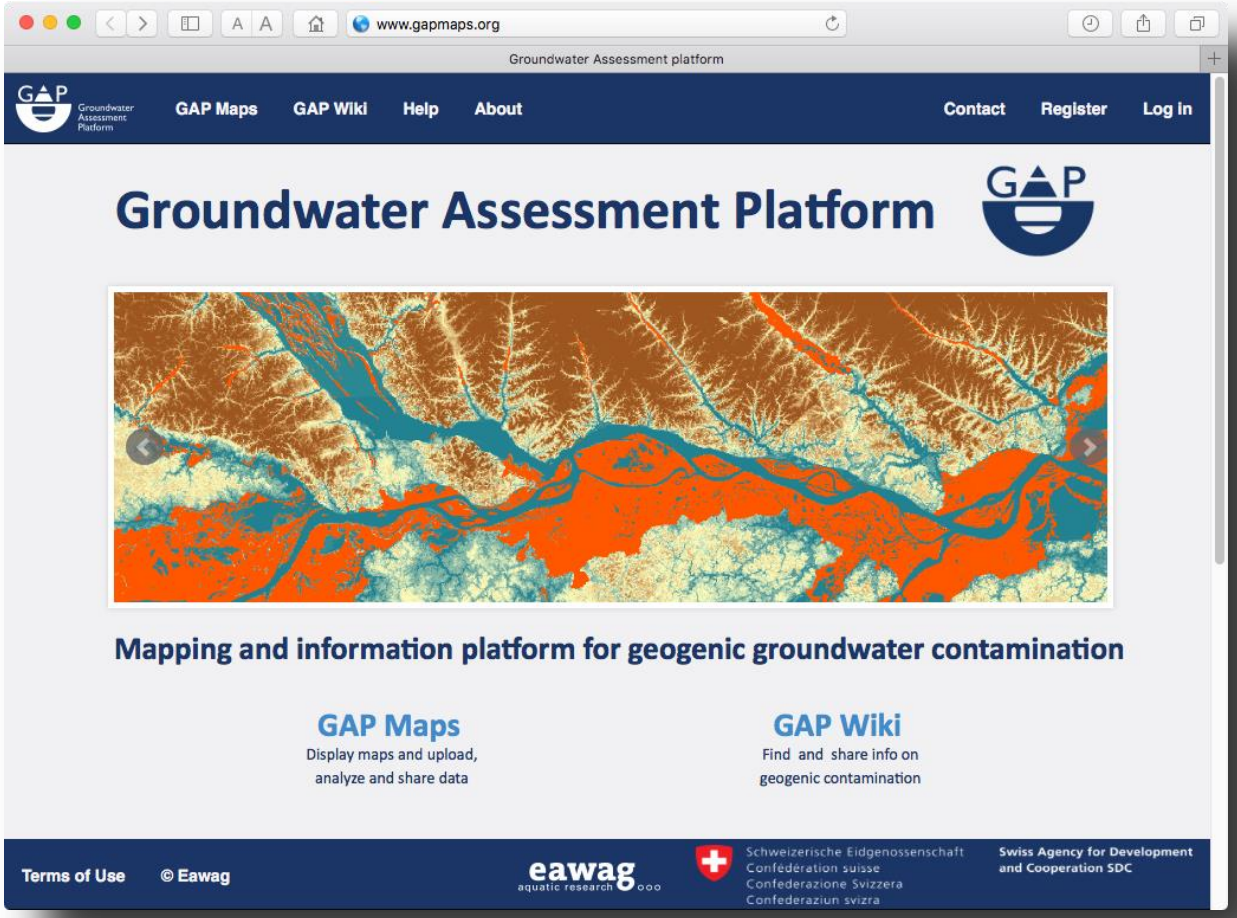
$$P(x) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x)}}$$

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

Groundwater Assessment Platform

www.gapmaps.org

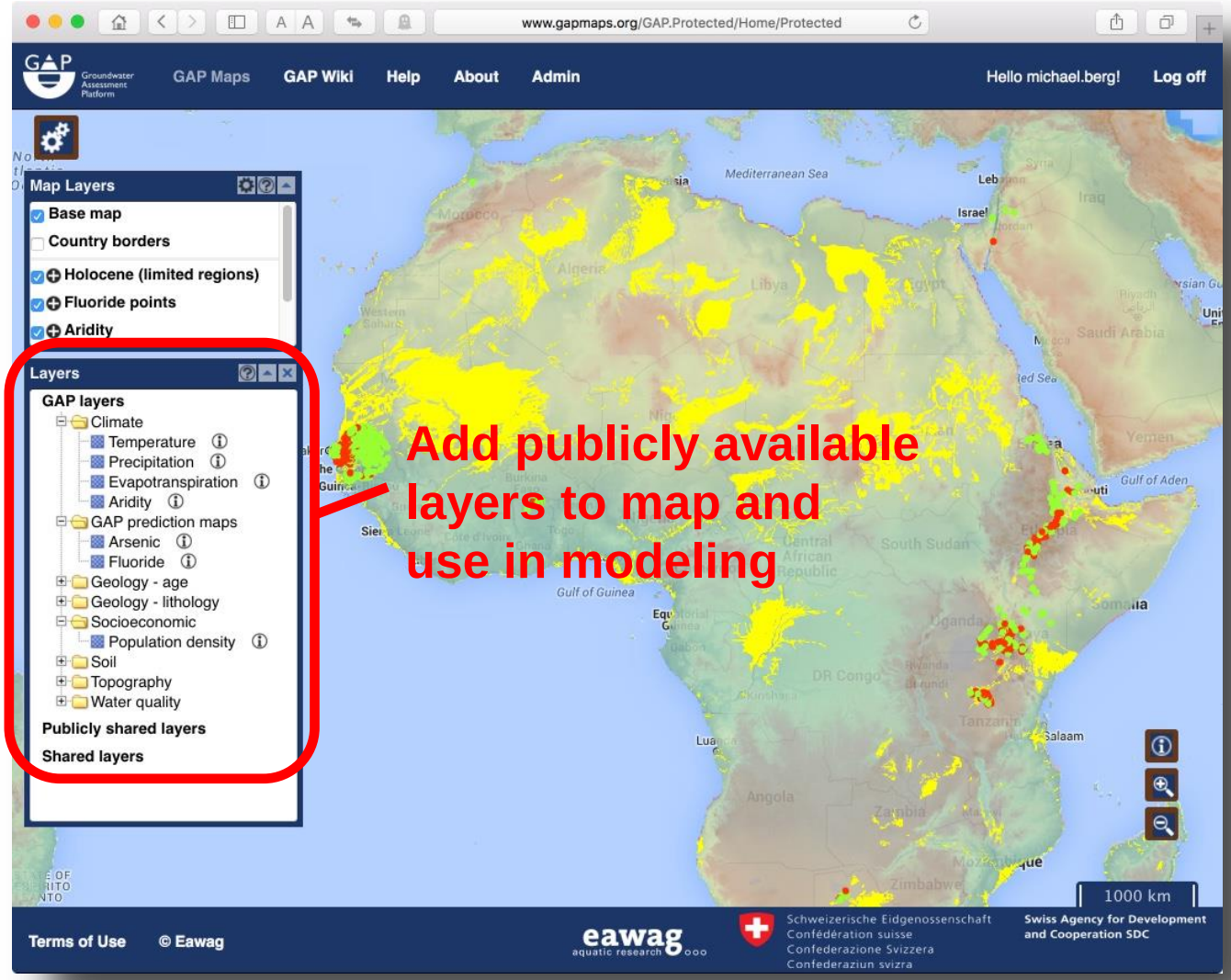
Free, interactive online GIS platform for **mapping**, **statistical modeling** and **dissemination** of information on geogenic groundwater contamination



- Mapping
- Modeling
- Sharing
- Wiki

Visualize, analyze, share data and knowledge

Groundwater Assessment Platform



PUBLIC

- View existing models and data

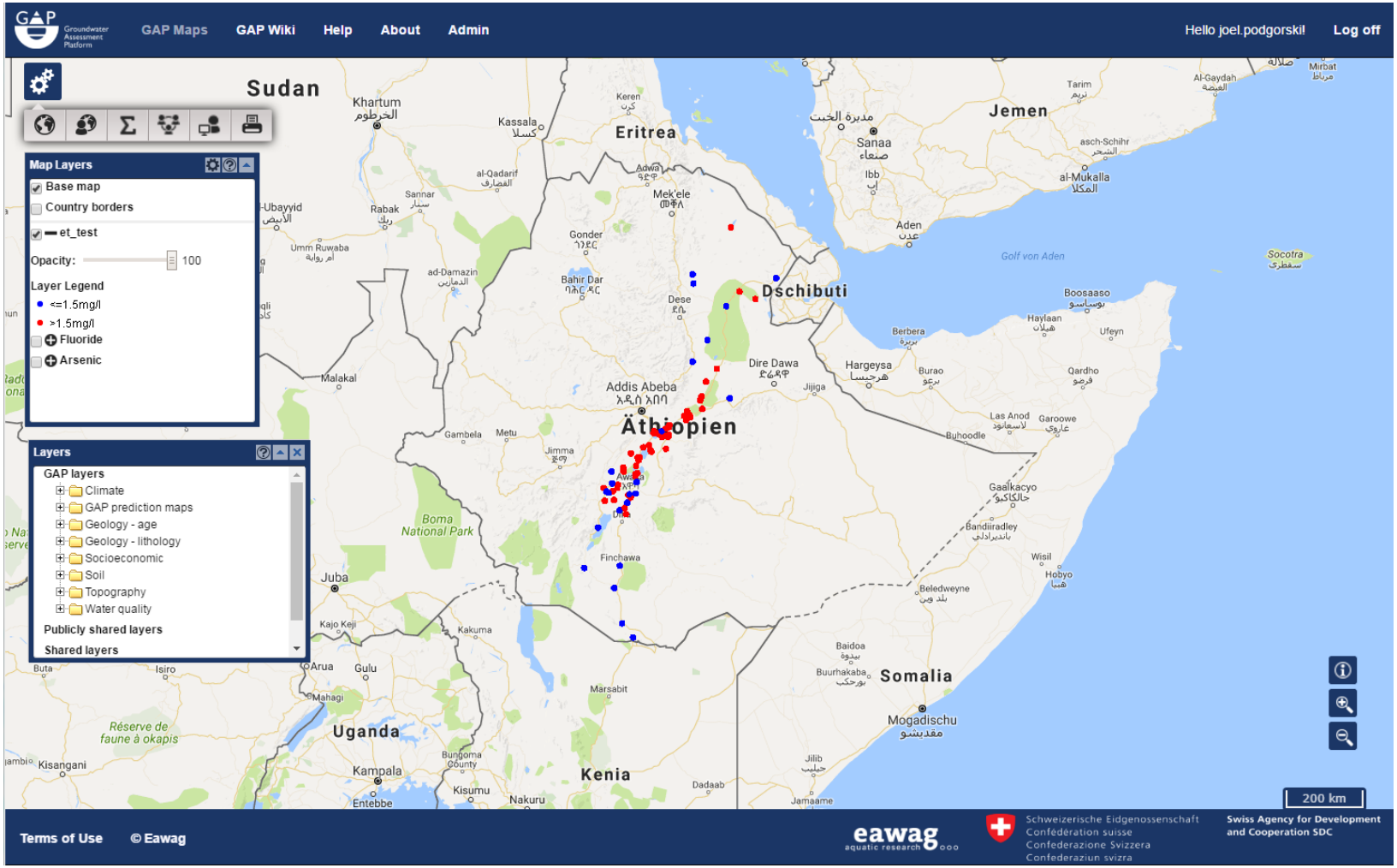
PRIVATE (login)

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

COMMUNITY

- Share data and models with user-created communities

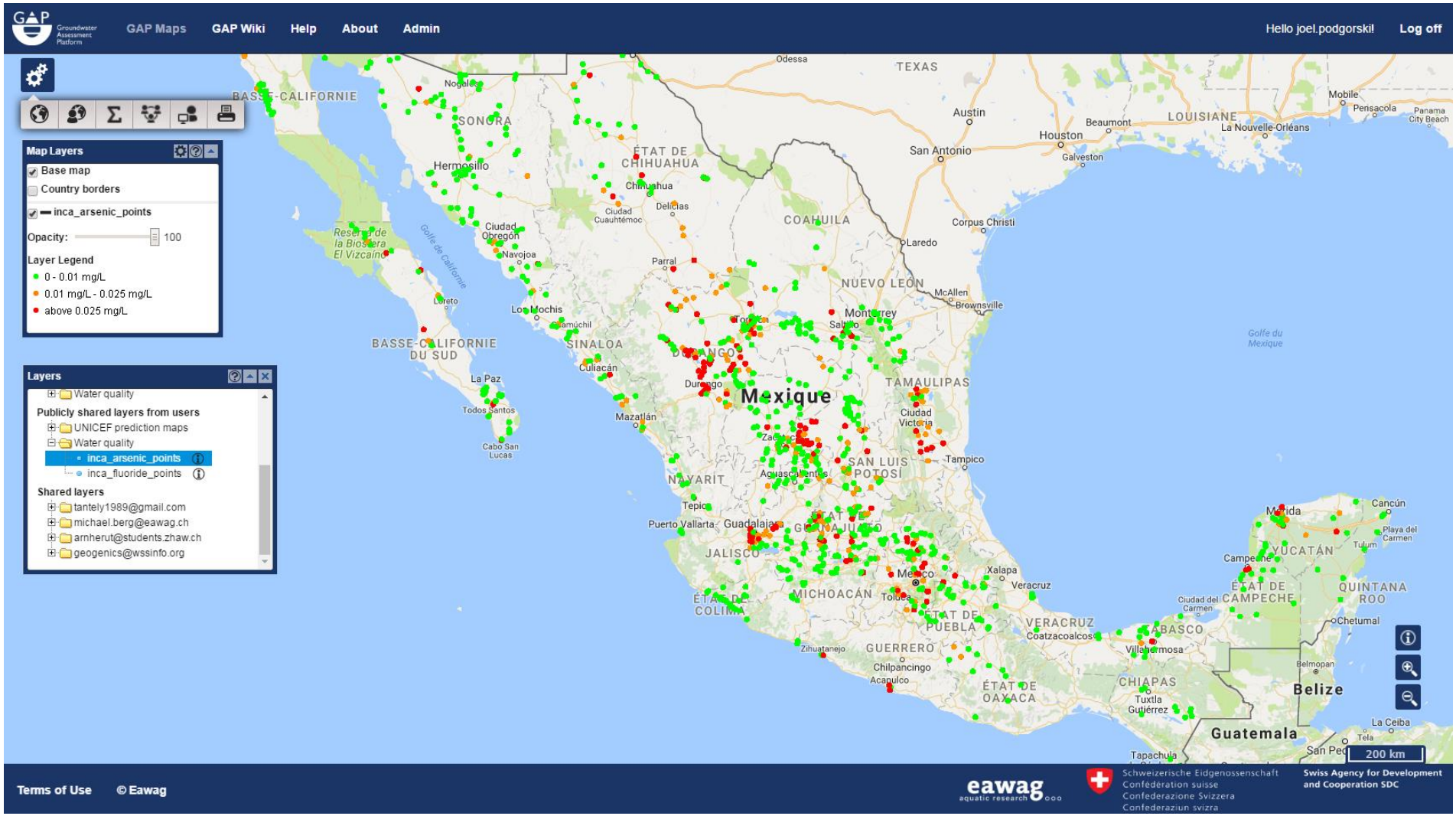
Modify point symbology



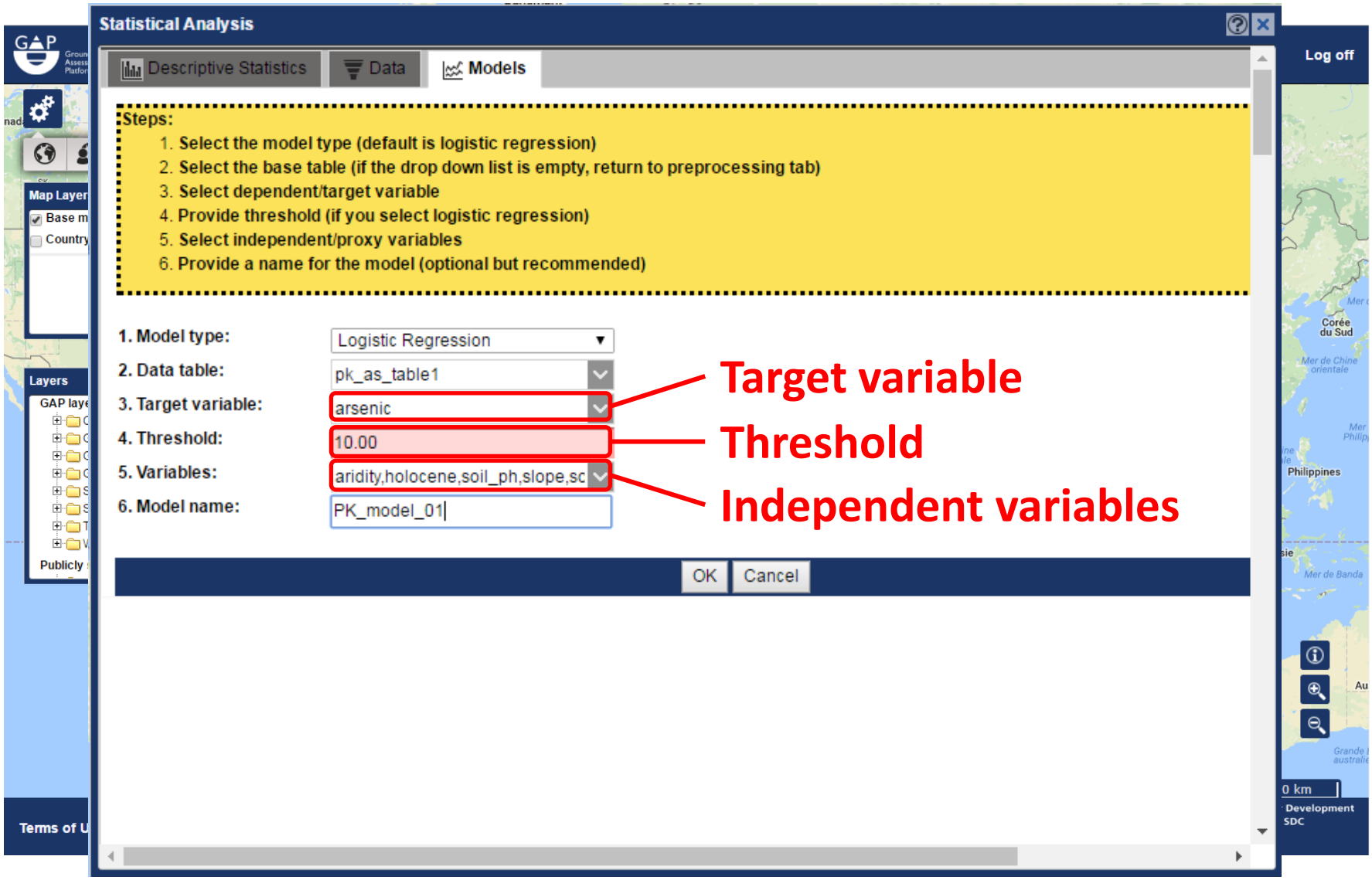
- **Change shape and color of points**
- **Add filters to control what to display**

Share data publicly

Example: arsenic concentrations from Mexico



Statistical modeling



Model output in GAP

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Coefficients of independent variables

Statistical Analysis

Descriptive Statistics | Data | Models

Return

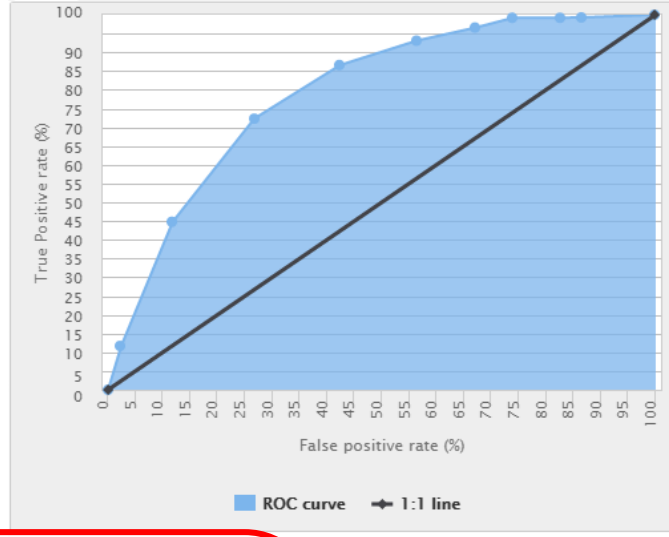
Model coefficients

	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_	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

ROC curve

Model Chart

AUC

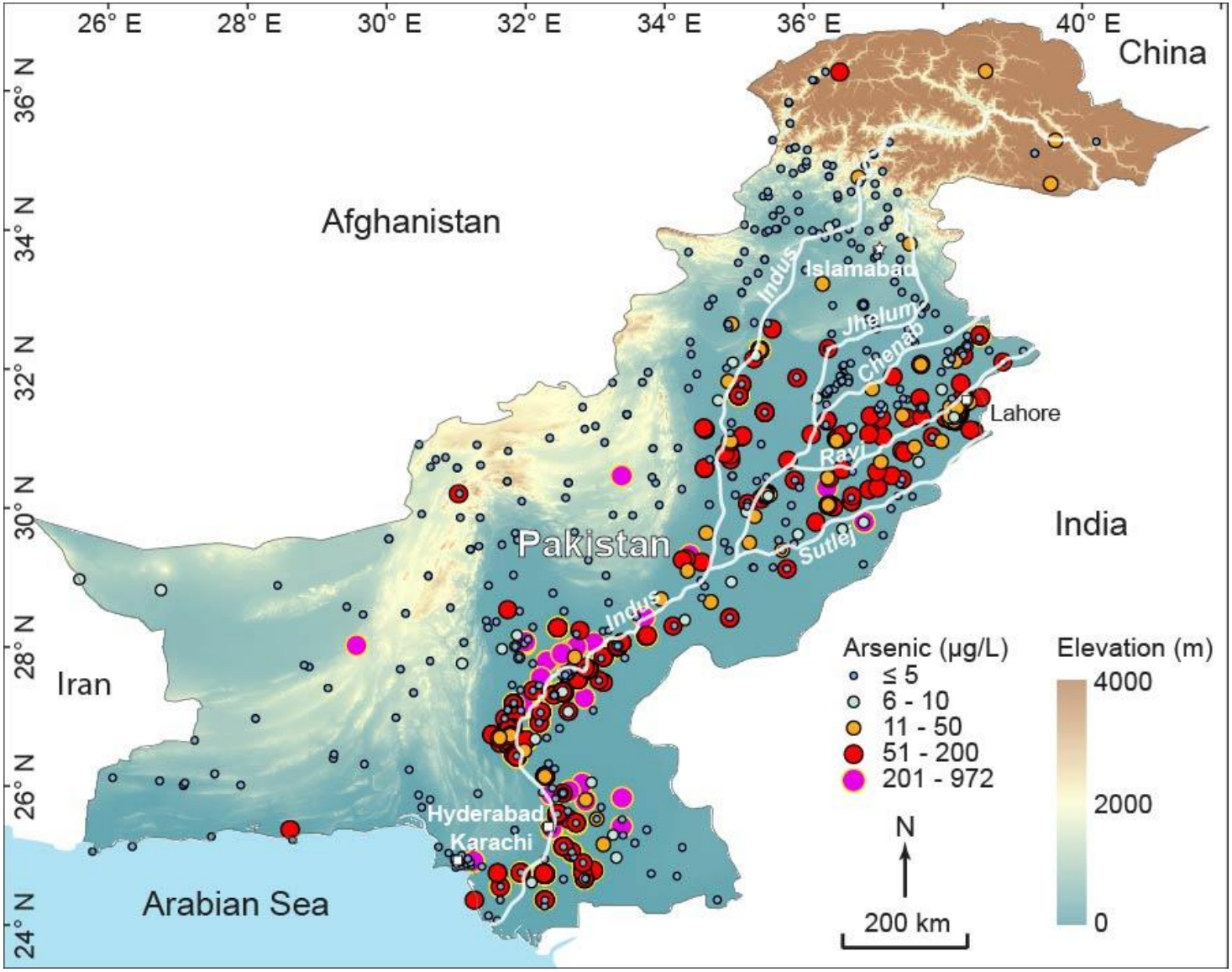


Model classification

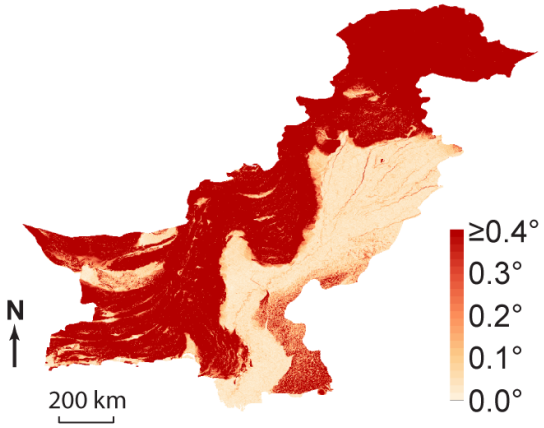
	Id	Cutoff	Measured high	Measured low	Predicted high	Predicted low	False pos. rate	False neg. rate	Sensitivity	Specificity	Accuracy	Efficiency
1	113	0	835	415	835	0	1	0	1	0	0.668	0.5
2	113	0.1	835	415	829	56	0.865	0.007	0.993	0.135	0.708	0.564
3	113	0.2	835	415	828	72	0.827	0.008	0.992	0.173	0.72	0.583
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

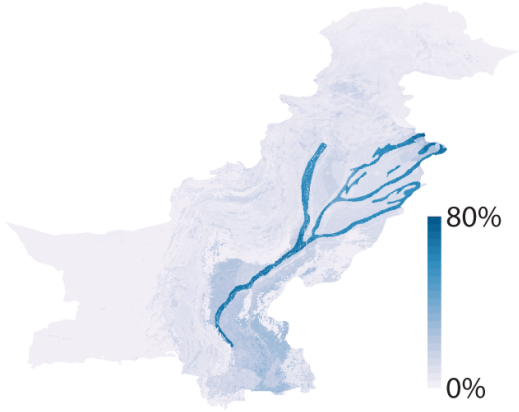
Pakistan arsenic study



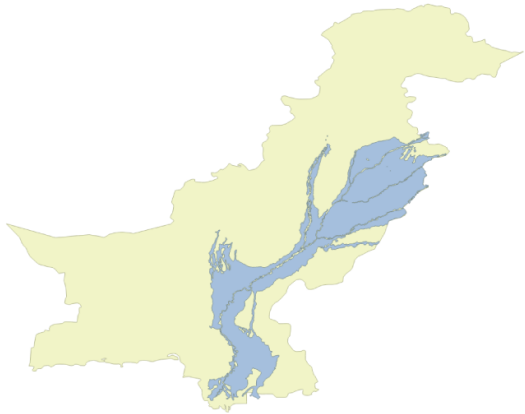
Predictor variables



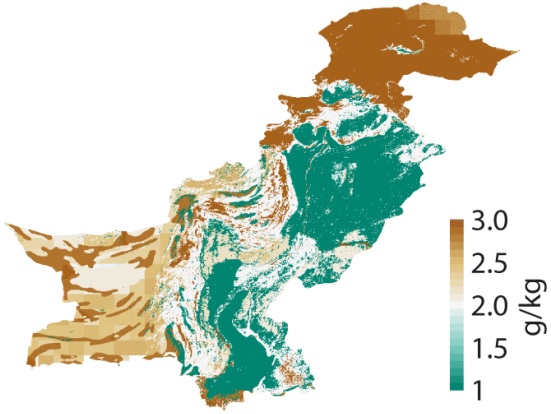
slope



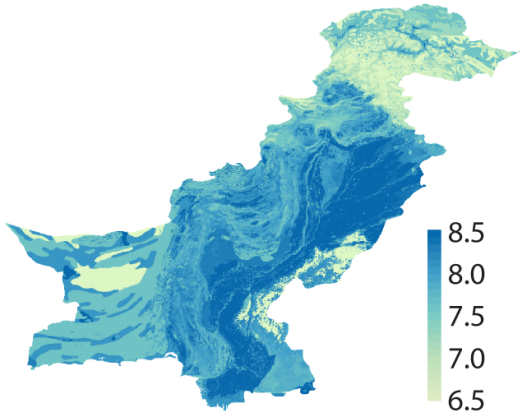
fluvisols



Holocene fluvial sediments



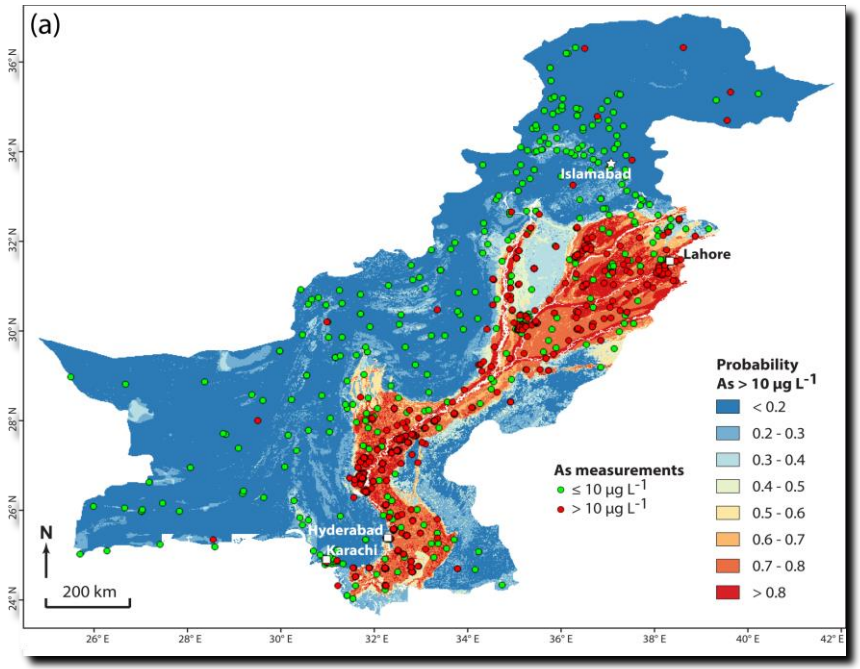
soil organic carbon



soil pH

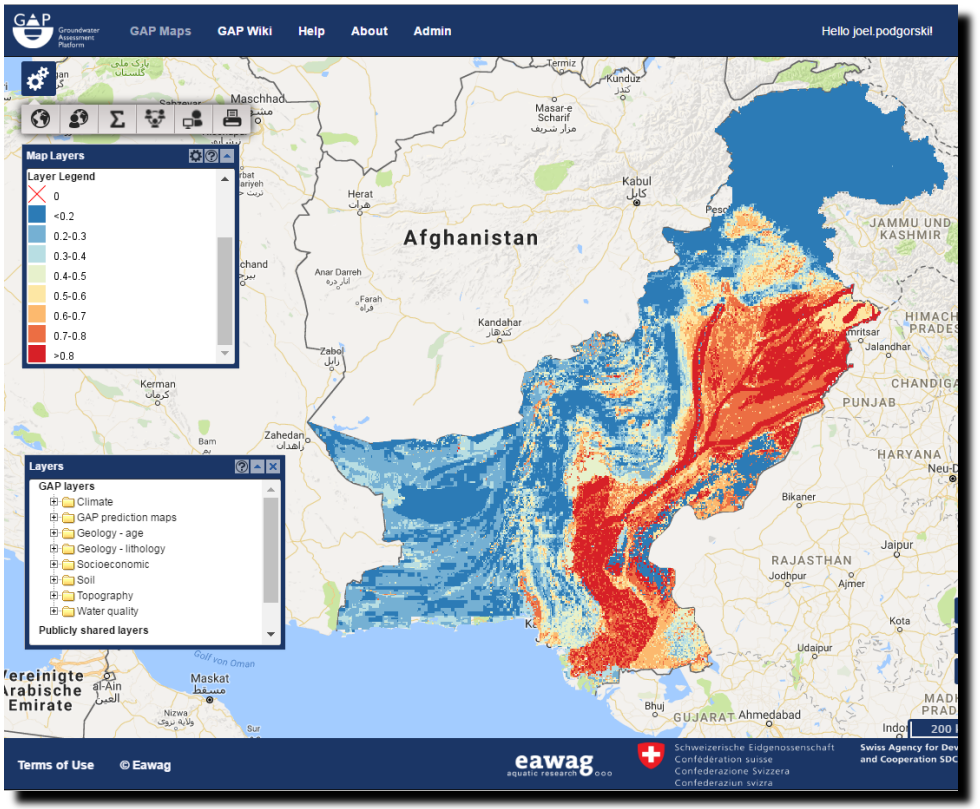
Modeling comparison: manual coding vs. GAP

Arsenic prediction map for Pakistan created offline with the R language



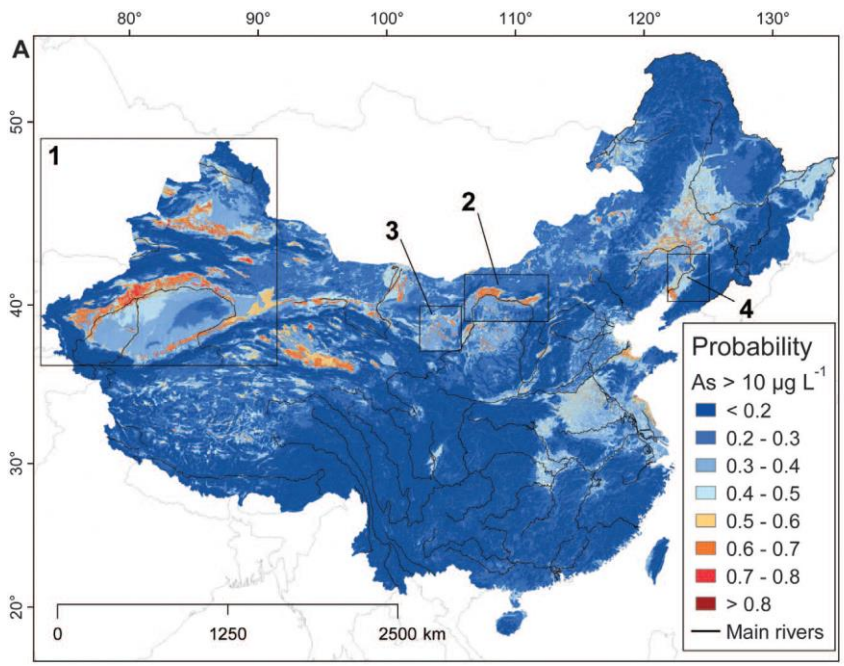
Podgorski et al., 2017, in review

Arsenic prediction map for Pakistan created on GAP



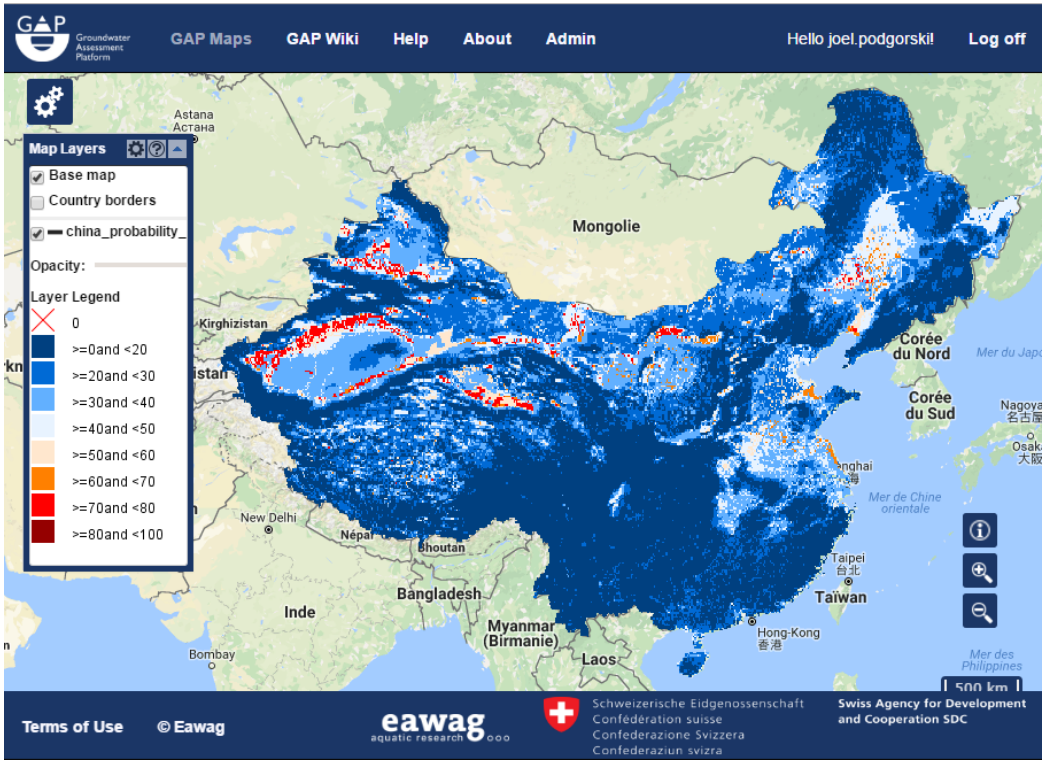
Modeling comparison: China

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

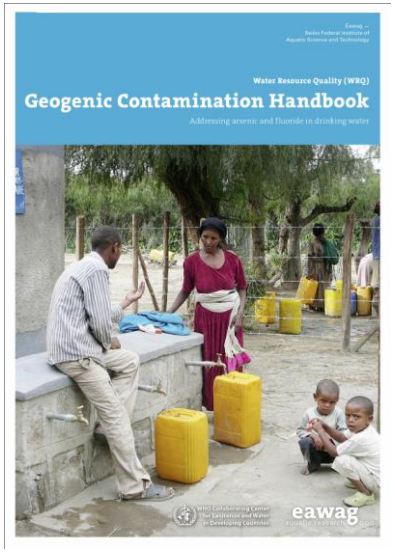
- Water treatment, covered in the Geogenic Contamination Handbook (at www.gapmaps.org)
- Identify contaminated regions through prediction modeling

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

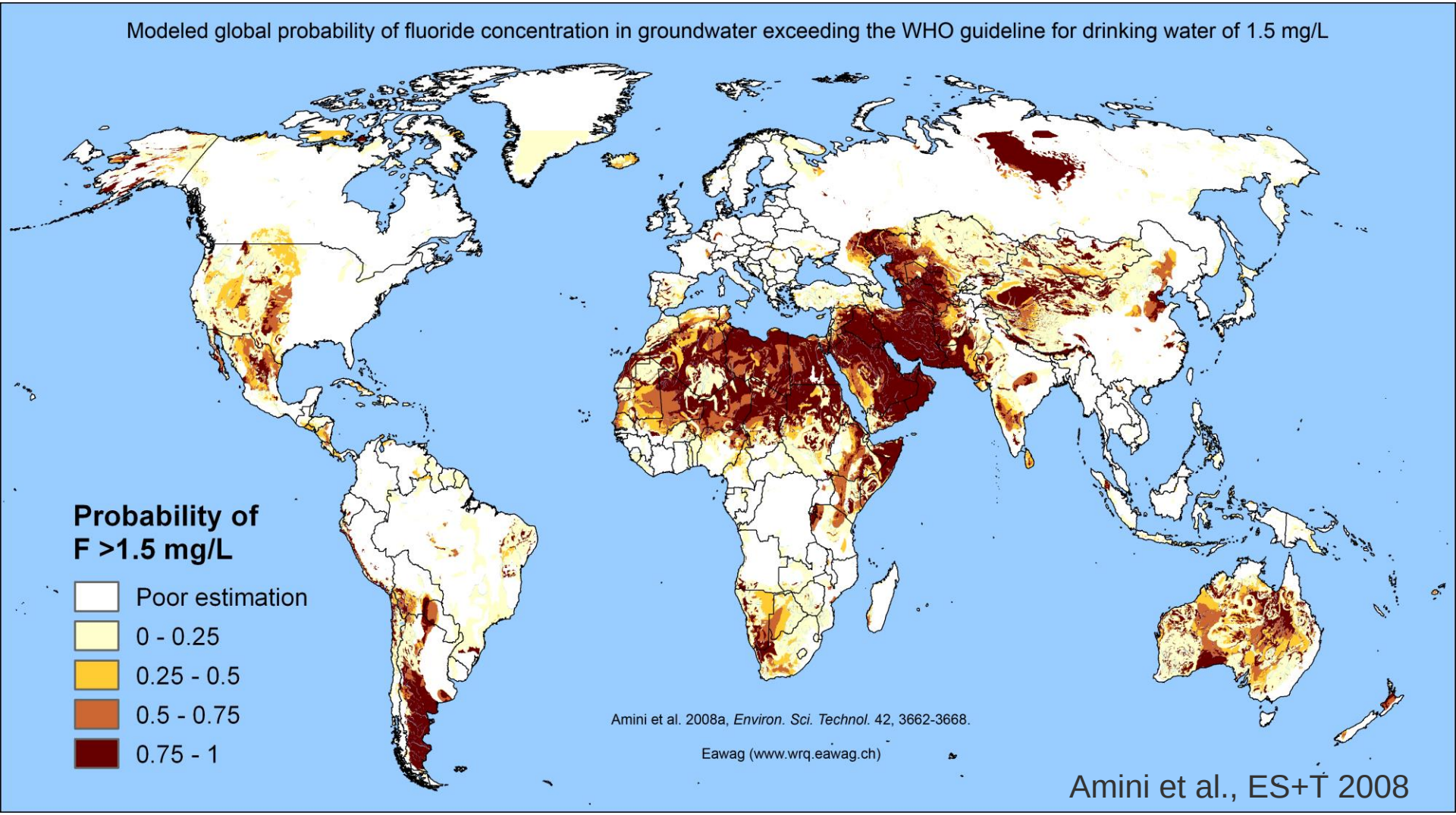
Background to GAP

- 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



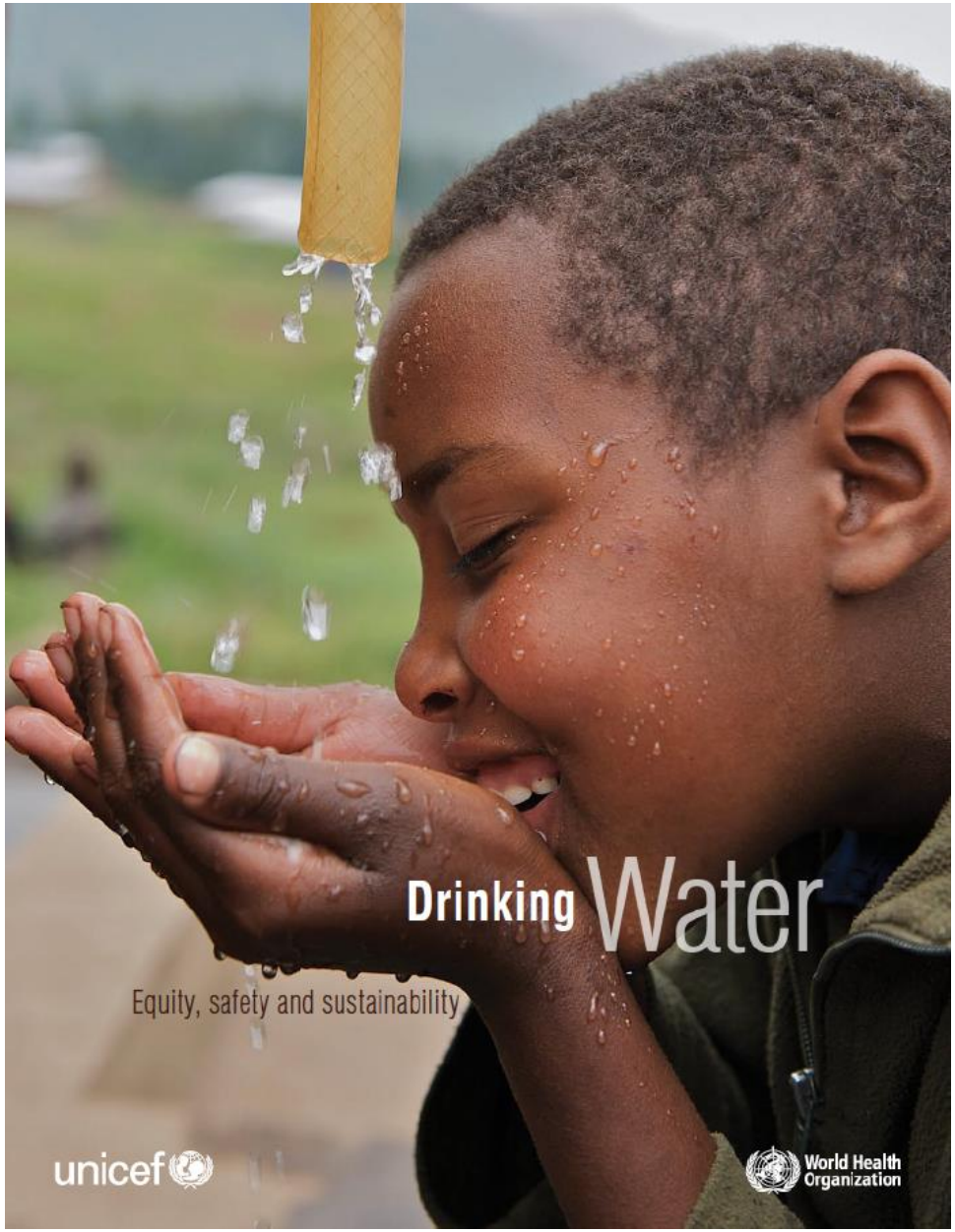
1st-generation global risk map for **F** >1.5 mg/L

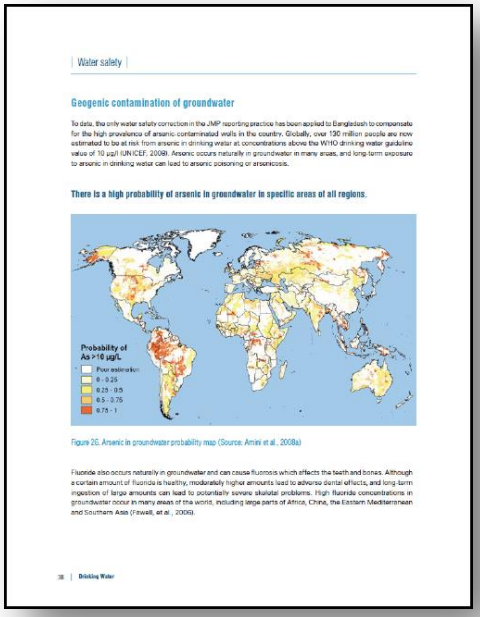
Groundwater Assessment Platform



WHO-Unicef synthesis on drinking water, 2011

Groundwater Assessment Platform





Water safety

Geogenic contamination of groundwater

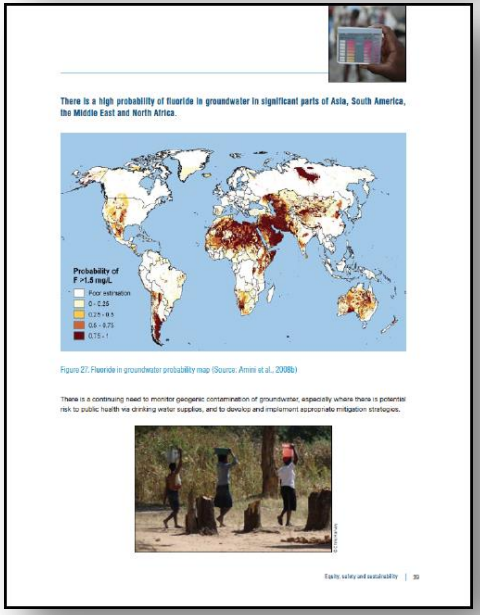
To date, the only water safety correction in the JMP reporting practice has been applied to Bangladesh to compensate for the high prevalence of arsenic contaminated wells in the country. Globally, over 130 million people are now estimated to be at risk from arsenic in drinking water at concentrations above the WHO drinking water guideline value of 10 µg/l (UNICEF, 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: Amini et al., 2008a)

Fluoride also occurs naturally in groundwater and can cause fluorosis which effects 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 (Fewtrell, et al., 2006).

38 | 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: Amini et al., 2008b)

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

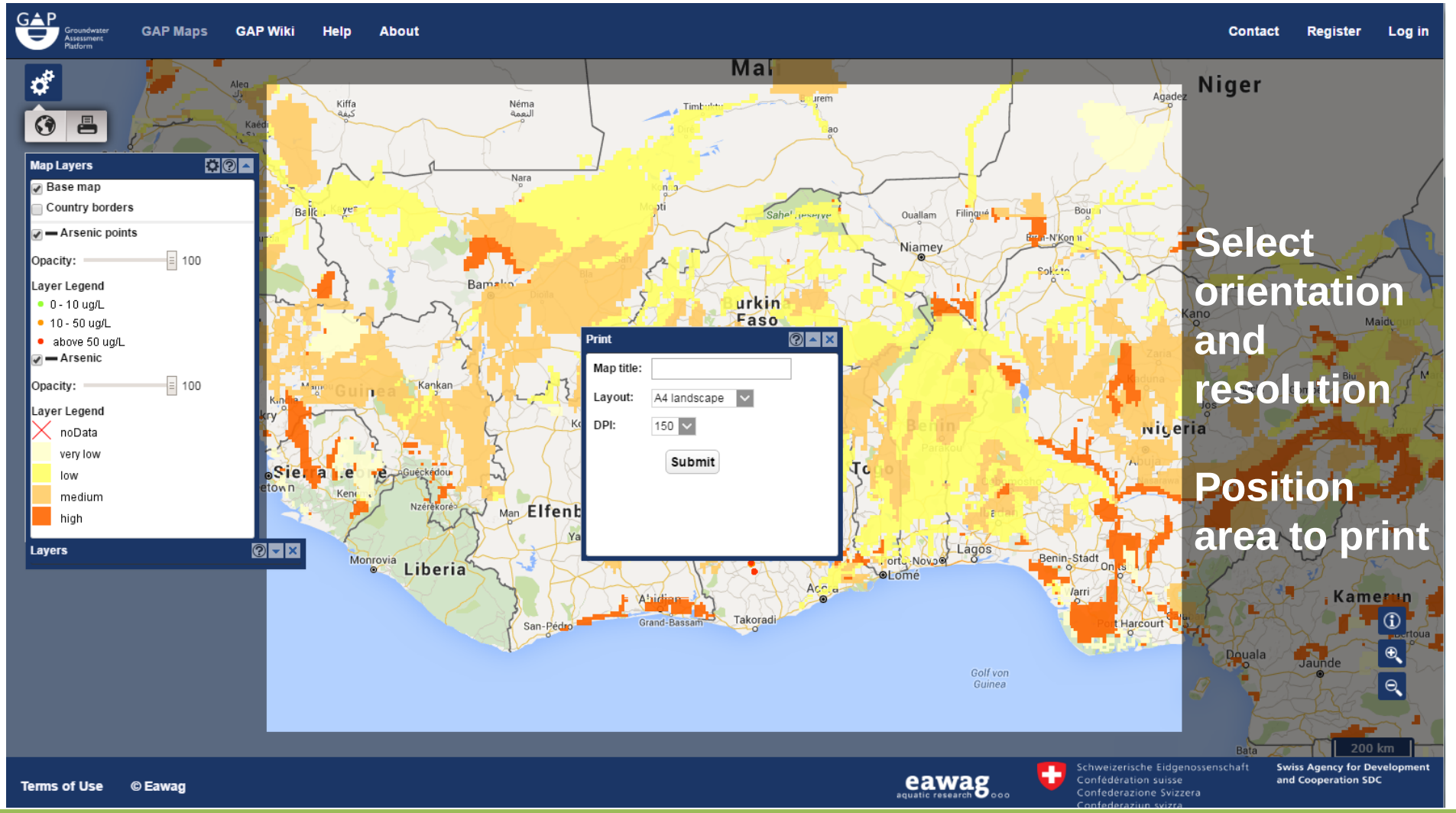
Equity, safety and sustainability | 39

GAP risk maps featured in chapter on water safety

eawag aquatic research

Print PDF of area of interest

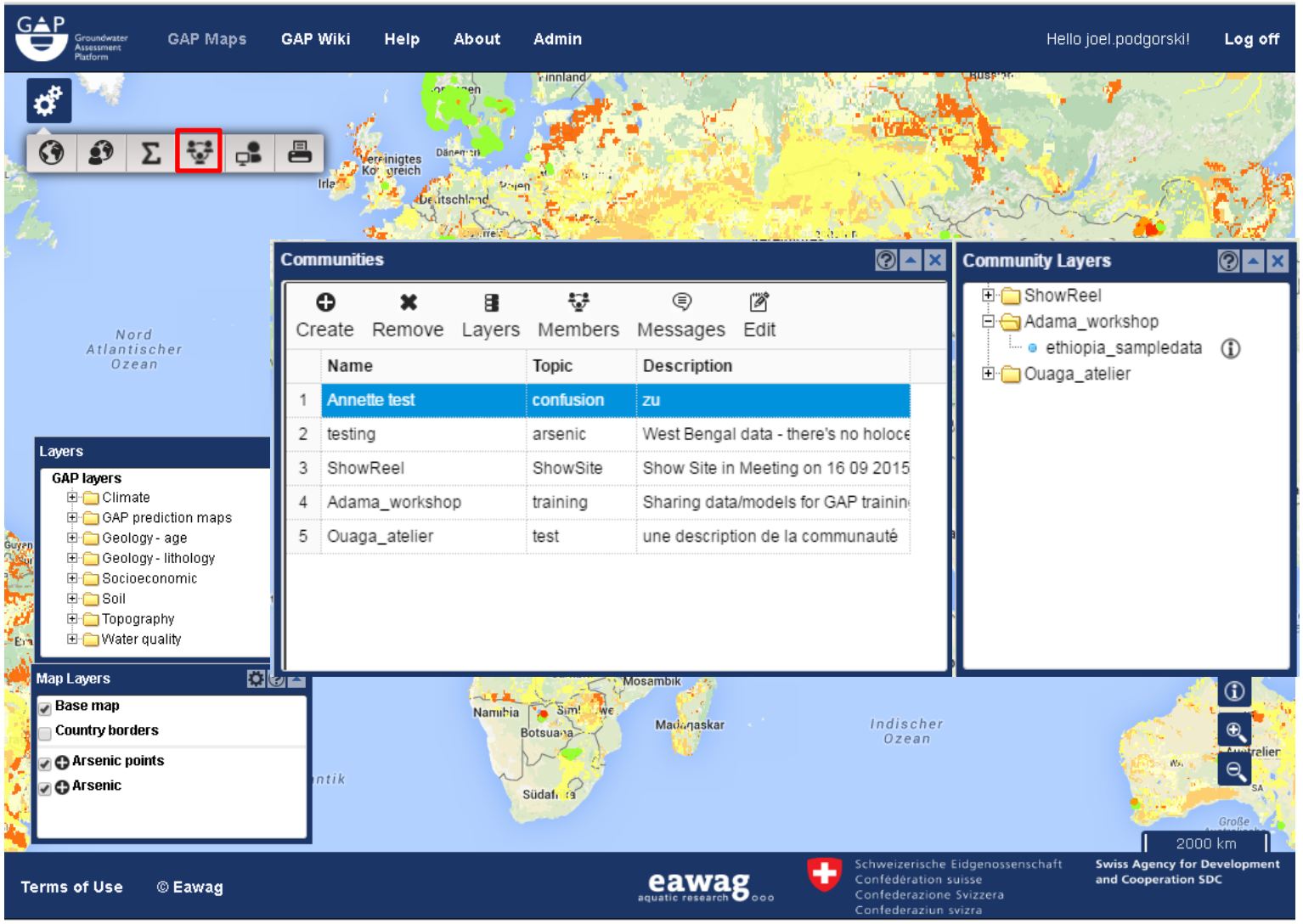
Groundwater Assessment Platform



→ Can also export GIS layer of own data/models

Communities

Share data and models with a select group of users



Help

page | discussion | view source | history

GAP Help

The Groundwater Assessment Platform (GAP; 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**
enic contamination.

navigation
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- GAP Help
- GAP Feedbacks

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Search
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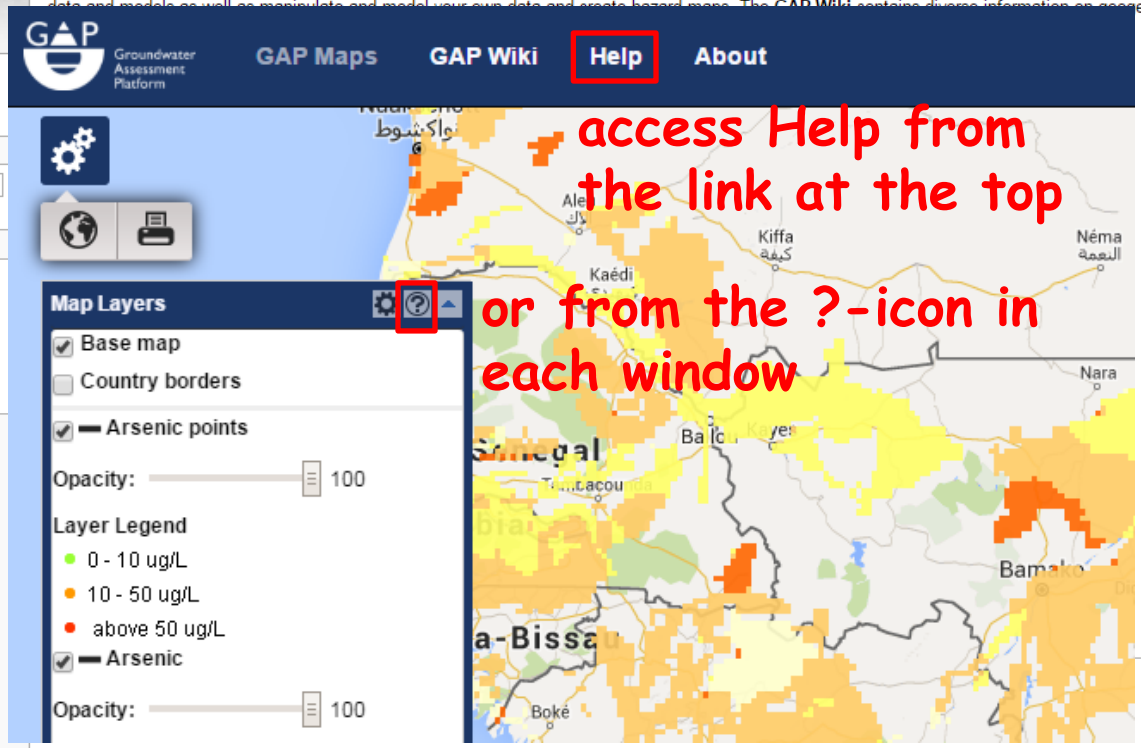
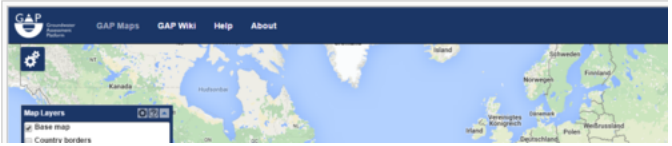
tools
- What links here
- Related changes
- Special pages
- Printable version
- Permanent link
- Page information



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 Ma



Additional functionality when logged in

GAP Wiki – help to expand the compendium

Groundwater Assessment Platform

www.gapmaps.org/GAP_Wiki

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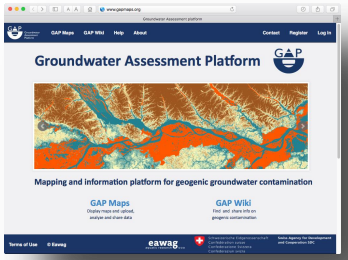
Here you can find information about geogenic contamination and contribute your own articles. We invite all users to use GAP Wiki as a platform to exchange information about geogenic contamination. Adding and editing articles is quick and easy to learn. Please visit the page Creating and editing GAP Wiki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

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

- **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)



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Features the **Geogenic Contamination Handbook**

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