Synthesis report on stakeholder and end-user needs

Deliverable 2.1 in project Model-based Global Assessment of Hydrological Pressure (GlobalHydroPressure)

Beldring, Stein; Eisner, Stephanie; Sörensen, Johanna; Olsson, Jonas; Silva, Benedito; Fragoso Jr., Carlos Ruberto; Li, Hong

2020

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Date: 18th May 2020

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1. Introduction

The objective of GlobalHydroPressure is to provide global model-based support for assessing and quantifying the fundamental hydrological pressure in basins worldwide. A consistent and reliable estimation of this pressure is a prerequisite for assessment of vulnerability and resilience to the total, multiple environmental pressure, including both natural and human-driven components. The project will develop existing hydrological models on global and local scales into innovative tools for supporting the decisions of end users. Local case studies span different climatic, areal and topographic characteristics so that hydrological models may be adapted to different characteristics and may then be used to support local vulnerability, resilience and risk assessment in ungauged regions of difficult access, as well as contribute with input to practical tools for adaptation and decision support. The applications covered in the cases include e.g. water resources management, hydropower production, flood risk assessment and agricultural production. An important aspect of GlobalHydroPressure is the multi-scale perspective, as different hydro-meteorological hazards (extreme events) operate on widely different scales in time and space. Examples of extremes include flash floods, with scales down to hours and single km^2, and droughts, with scales up to multi-years and continents.

A key feature of GlobalHydroPressure is the development of hydrological Decision Support Indicators (DSIs), innovative indicators pertinent to the main hydrological pressures tailored for decision support with different time horizons. The DSI concept is an advancement over classical hydroclimatic impact indicators in that it relates the severity and/or likelihood of an event to previous experience of the local population and stakeholders. This is achieved by first defining historical events that serve as a baseline, and subsequently expressing any future events relative to this historic baseline. It is expected that using historical events as a benchmark will greatly improve the stakeholders' and end users' ability to understand the socio-economic implications and to identify the need for action with respect to a predicted future event.

An important aspect of GlobalHydroPressure is the close involvement of stakeholders in all phases of the project, i.e. indicator development, modelling and assessment are driven by stakeholder needs. While stakeholder involvement is implemented locally in the single case study regions, we strive to coordinate these efforts in order to ensure knowledge transfer across the case studies. This report describes the general design of the stakeholder process in the project and presents results on stakeholder and end user needs identified during the 1st year project year. Section 2 will give an overview over the project's six case studies. Section 3 presents the general design of the stakeholder process while results from the stakeholder process, i.e. stakeholder expectations and knowledge needs in the single case studies, are described in section 4. Finally, section 5 summarizes the main outcomes from the stakeholder process in the first project year.

2. Case studies

GlobalHydroPressure strives to develop tools and methods for assessing hydrological pressure worldwide through coordinated case studies in Europe, South America and Asia. These case studies cover a wide range of dimensions with respect to the nature of the hydrological pressures, required decisions by stakeholders, socioeconomic conditions and climates. The spatial extent of the different case studies ranges from a few to several to 10^6 km^2. The temporal horizons for which hydrological pressures will be assessed spans from short-term forecasting (hours to a few days) to long-term climate projections (several decades). Figure 1 visualizes the different case studies with respect to spatial scale, temporal scale and hydrological pressure. Each case study addresses location-specific hydrological risks and adaptation challenges. Nevertheless, three cross-cutting themes can be identified: (i) fluvial flooding and land use change (Brazil, Western Norway), (ii) droughts and agriculture (Sweden, Brazil, China), and (iii) glacier retreat and hydropower production (Norway, China). In the following, the key characteristics of each case study will be briefly described. More detailed information on each case is provided in Appendix A.

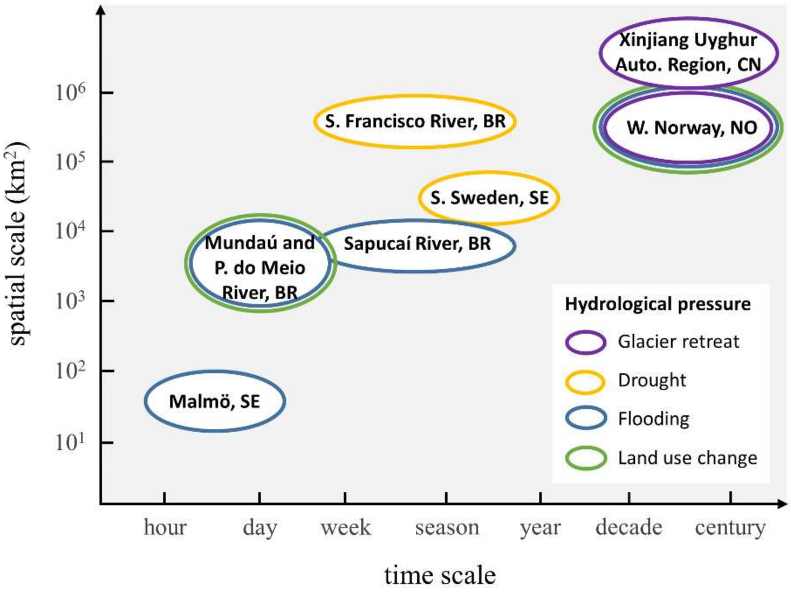


***Figure 1:** Classification of the six case studies with respect to spatial scale, temporal scale and hydrological pressure*

The **Malmö** (SE) case study addresses pluvial flooding events in the city of Malmö caused by heavy rainfall event which appear primarily during the late summer months (July–August). The case study seeks a better understanding of the highly non-linear relationship between extreme rainfall and pluvial flooding as well as a better understanding of climate projections on urban scale.

The **Southern Sweden** case study focusses on drought and water scarcity in the Emån River basin. The region experienced an early summer drought in 2016-2017 leading to scarcity and water use restrictions. Water scarcity is unusual for the region and consequently preparedness was low. Envisaged impacts are to facilitate better decision making related to water scarcity and drought by providing tailored information and tools.

The **Minas Gerais** (BR) case study comprises two river basins, São Francisco and Sapucaí. The São Francisco river basin regularly experiences multi-year drought periods with substantial consequences in several sectors (irrigated agriculture, hydropower production, human well-being) and for socioeconomic development in general. The Sapucaí watershed, in which the city of Itajubá is located, faces recurring flood and drought events. A drought in 2014 and 2015 has caused, in addition to low availability of drinking water, a reduction in volume of the main hydroelectric power plants, causing environmental, social and economic damage. For São Francisco basin the case study aims to evaluate seasonal flow forecasts and short term forecasts will be evaluated for Sapucaí watershed.

The **Alagoas** (BR) case study comprises two medium sized river basins, Mundaú and Paraíba do Meio. Since the mid-1960s, the region has experienced at least eight extreme flash flood events which have led to fatalities and substantial economic losses. The case study strives to develop a short-term flood forecasting with probabilistic flood maps that makes use of existing technologies in the basins (weather radar, automatic gauging stations). This includes hydrological reports with alerts based on water level and a web system for flood prediction.

The **Xinjiang** (CN) case study focusses on the impact of glacier melt for water provision. There are ca. 20000, mostly small glaciers in the region which are an important supplementary water resource to precipitation. Since the 1950s, the glaciers have retreated by 21% to 27% as a consequence of climate change while at the time domestic, industrial and agricultural water demand for has increased. The case study aims to asses the impacts of projected climate change on glacier volume and area, available water resources, runoff seasonality, drought and hydropower potential. Water resources management strategies will be assessed.

Western Norway is characterized by heavy rainfall events which can cause severe fluvial flooding and are projected to become more frequent in a warmer climate. At the same time, severe and prolonged water deficit periods have caused major problems in recent years with substantial impacts on hydropower production. The case study strives to provide improved tools to assess the impacts of climate and land use change on floods and droughts, including implications for hydropower production.

3. Methods of stakeholder involvement

The stakeholder process is mainly facilitated by stakeholder workshops locally organized by the case study leaders. In total, three workshops are planned to take place at the beginning, mid-term, and end of the project, each with a distinct purpose. As outlined in the introduction, one main goal of GlobalHydroPressure is to provide a set of DSIs in each case study, which will be co-developed with the stakeholder group:

- In the first project year, the stakeholder process will identify specific knowledge needs within the stakeholder groups. The results will be the basis for developing a first set of DSIs. In this stage, special attention will be given to similarities between case studies, i.e. common hydrological pressures. Where possible and sensible, case studies should use the same DSI(s).
- In the mid-term workshop, the first set of DSIs and the corresponding modelling results will be presented. The main goal will be to evaluate whether they meet stakeholder needs. Based on the feedback from the stakeholder group, DSIs will be revised and refined.
- The third workshop has the goal to present the final set of DSIs, and generally to disseminate project results and products to the stakeholder and end-user group.

The first series of workshops was carried between August and November 2019. Prior to the workshops, a questionnaire with nine open questions (see info box 1) was jointly developed by all case study leaders with the goal to coordinate the stakeholder process in the different case studies. The questionnaire focusses on identifying the most relevant hydrological pressures in the respective regions from the stakeholders' perspective and identifying critical obstacles for coping with these pressures in terms of missing (or insufficient) knowledge, tools, and institutions. The questionnaire was kept generic in order to fit all case studies; however, the case study leaders could make adjustments and amendments as long as the general structure was preserved. In many case studies, a semi-structured questionnaire was developed from the common template which contained both open-format and closed-format questions. In the case of closed-format questions, it was often chosen to add scales in order to rate likelihood, severity or relevance. The questionnaire structures eventually used in the different case studies are included in Appendix B.

Dedicated stakeholder workshops, as described above, have been carried out in the case studies Minas Gerais, Alagoas, and Western Norway, where representatives from all stakeholder institutions were invited for a joint meeting. The case studies 4.1 (Malmö) and 4.2 (Southern Sweden) build on previous and ongoing research projects with an established stakeholder group and an ongoing stakeholder process. In these two cases, rather than carrying out a separate workshop in 2019, the stakeholder questionnaire was sent to the stakeholder group and completed independently. In case study 4.2, however, user input was collected during a workshop in March 2020. At this stage, a preliminary DSI strategy had been formulated and the questionnaire was designed to get specific feedback on this strategy (see Appendix B), to complement the more general questions in the questionnaire (info box 1).

Lastly, a classical stakeholder process cannot be carried out in the Xinjiang case study. It was originally planned to involve stakeholders from different sectors; however, Xinjiang is a politically sensitive region and we could not find stakeholders willing to commit to the project. Therefore, the case study leader (Dr. Hong Li) will reflect stakeholders' needs based on her knowledge gained from scientific literature, exchange with local researchers, and media such as news and internet.

Info box 1: Set of questions commonly used in the 1st stakeholder workshops

Questions jointly discussed with the stakeholder group

1. What are the most important hydrological pressures, i.e. water-related risks, for economic and social development in your region?

2. Which "exposure units" (economic sectors, infrastructure, ecosystems, places, institutions, population groups) are (most) affected by these pressures?

3. At which time scales do these pressures act (multiday-season-multiannual-decade-century)?

4. At which spatial scales do these pressures act (few km^2 to several tsd. km^2)?

5. What are the most important institutions in your region that make decisions related to the pressures listed above?

6. Please indicate – if available – institutionalised response mechanisms that already exist in your region.

7. Please suggest other response options that would be adequate in your opinion but are not instutionalised yet.

8. With respect to the pressures listed above, which critical information and/or services are currently lacking to support and inform decision- and policymaking?

9. What kind of models/tools are you currently using for decision-making?

Case-study specific questions discussed with the stakeholder group

The stakeholder groups in the single case studies were compiled by the case study leaders and the size of the stakeholder group varies between 3 and more than 20. Across the case studies, the majority of stakeholders comes from the public sector including a broad range of organizations, e.g. regional water management boards, municipalities, county administrations and water utility companies. Detailed information about the single stakeholders in each case study can be found in Appendix C.

4. Results: Stakeholder and end-user needs

Case study 4.1 Malmö City, Sweden

Most important hydrological pressures are:

1. Flood
2. Water scarcity for consumption
3. Landslide
4. Surface water contamination
5. Groundwater contamination
6. Siltation of rivers and reservoirs
7. Water use conflicts
8. Proliferation of diseases
9. Drought

Most important exposure units are population in socially vulnerable situation, government structure (municipal / state), commercial sector, industry, agriculture, transport, power generation, health sector, water supply, aquatic ecosystems.

The time scales at which these pressures act are hours (pluvial flooding), seasons (drought)

The spatial scales at which these pressures act are some streets (pluvial flooding), neighborhoods (pluvial flooding), whole city (pluvial flooding), state (drought)

The most important institutions in the region that make decisions related to the pressures are Civil Defence, City Hall, Water Company, State government, National Agency of Water, Basin Committee

Institutionalized response mechanisms: A water professional has been employed at the city hall to better coordinate the work with pluvial flooding in Malmö. A pluvial flood management plan has been agreed upon.

Other response options that would be adequate but are not institutionalized yet are transition towards more large-scale implementation of blue-green infrastructure. Legal, institutional and economical barriers hinders the implementation currently.

The following critical information and/or services are currently lacking to support and inform decision- and policymaking: To large extent the information needed is available.

The following models are currently used for decision making: Pluvial flood management plan, Design standards for storm water drainage, Flood hazard assessments.

Sources of information: Media, scientific conferences and journals. Formal sources within the municipality and from external organizations.

Case study 4.2 Southern Sweden

Most important hydrological pressures are:

1. Flooding
2. Water supply failure
3. Land slides
4. Surface water pollution
5. Ground water pollution
6. Sedimentation of rivers and reservoirs
7. Conflicting water use
8. Spread of disease
9. Soil water drought
10. Drainage system overload

Most important exposure units are local population, municipalities and government agencies, commercial activity, industry, agriculture, transport, hydropower production, health, drinking water supply, aquatic ecosystems

The time scales at which these pressures act are hours, days, months, seasons, years, decades, centuries

The spatial scales at which these pressures act are local (< 1 km2), small watershed (1-10 km2), large watershed (> 10 km2), county, nation

The most important institutions in the region that make decisions related to the pressures are rescue services, municipalities, water supply agencies, government institutions, national water authorities, water protection board, hydropower sector.

Institutionalized response mechanisms are draining, ground water supply maintenance, water supply reservoirs, limitations on water use and irrigation, reduced pressure in pipes, flood protection areas, dimensioning criteria.

Other response options that would be adequate but are not institutionalized yet are increased reservoir capacity, regional water planning, prioritize water use, designated areas for flooding, delay flow, protect aquatic ecosystem from lack of water.

The following critical information and/or services are currently lacking to support and inform decision- and policymaking: Water supply, water use, water balance, reservoir operation, legal framework,

The following models are currently used for decision making: SMHI data, flood inundation maps, water supply plans, hydrological and hydrogeological models from SMHI and Swedish Geological Survey.

Sources of information: Internet, media, social networks, scientific conferences and journals, cooperation with public authorities, observed data from SMHI.

The workshop in March 2020 focused on three possible “DSI concepts”:

1. Use a historical event as a basis in future forecasts or projections

2. Focus on the time horizon until some critical threshold is crossed
3. Formulate worst-case scenarios

All three concepts were considered interesting and potentially useful for the end-users' purposes. Especially nr. 1 received a positive feedback, which supports that we will focus on this one duing the rest of the project.

Case study 4.3 Minas Gerais, Brazil

Most important hydrological pressures are:

1. River floods
2. Flash floods
3. Urban flooding
4. Catastrophic floods
5. Severe droughts
6. Atypical droughts

Most important exposure units are fishing, water supply, navigation, power generation, transports, agriculture, industry, commerce, public services, population.

The time scales at which these pressures act are monthly, seasonal, yearly

The spatial scales at which these pressures act are local (a few km2) to watershed (several 1000 km2)

The most important institutions in the region that make decisions related to the pressures are Civil Defense / City Hall, Minas Gerais Institute for Water Management, State Secretariat of Environment and Sustainable Development (SEMAD), Fire brigade, Basin Committee, National Center for Monitoring and Alerts for Natural Disasters (CEMADEN), National Water Agency (ANA).

Institutionalized response mechanisms are Construction of flood containment dikes in specific areas, Construction of dams in rural areas to prevent sediment transport, Water conservation projects, Flood alert system, Emergency action plans developed in the municipalities, One-off measures at the local level, such as assistance to populations hit by extreme events, Establishment of municipal environmental monitoring bodies.

Other response options that would be adequate but are not institutionalized yet are Urban planning in all cities, Environmental awareness work (environmental education), Environmental data monitoring network, Recovery of degraded areas, Improvement and expansion of sanitation services, Leadership training in critical region, Disseminate the actions made to civil society, Improve integration between the various bodies interested in the topic, Sustainable practices that are in harmony with the environment (eg agroecology), Update of basin plans.

The following critical information and/or services are currently lacking to support and inform decision- and policymaking: Water quality data, data and images, soil data, hydrological data, flow data, rain forecasts, hydrological forecasts, rain trends, land use and occupation.

Case study 4.4 Alagoas, Brazil

Most important hydrological pressures are drought, floods and water security for the irrigation sector.

Most important exposure units are riverside population, trade market, infrastructure.

The time scales at which these pressures act are seasonal, interannual, decadal.

The spatial scales at which these pressures act are a few km2.

The most important institutions in the region that make decisions related to the pressures are Environmental and Water Resources Government Division, Infrastructure Government Division, Agricultural Government Division, Civil Defense.

Institutionalized response mechanisms are since 2011 the Environmental and Water Resources Government Division has a Hydrological Alert Room which daily monitors the conditions related to the weather and climate during this period of rain in isolated points of the Coast and the Capital Metropolitan Region of the Alagoas State.

Other response options that would be adequate but are not institutionalized yet are short-term flooding forecasting (from hours to days) with probabilistic flood maps; and drought forecasting (from days to months) (e.g. alerts for water uses alerts that can serve as decision-making for mitigation of droughts - contracting well drilling and water trucks);

The following critical information and/or services are currently lacking to support and inform decision- and policymaking web system to flooding prediction; hydrological reports with alerts based on water level for droughts and floods

The following models are currently used for decision making: radar for monitoring precipitation in real time; atmospheric models for precipitation forecasting.

Case study 4.5 Xinjian Uyghur Autonomous Region, China

Most important hydrological pressures are:

1. Less runoff from snow and glacier
2. More frequent extreme rainfall events lead to floods and inundation
3. Limited amount of water available for agriculture and growing demand for water due to shift from cotton to fruit and urban development

Most important exposure units are ecosystems, citizens, agriculture, hydropower.

The time scale is seasonal for agriculture, but also long term for agriculture and hydropower. The time scale for flood and inundation is multi-days.

The pressure for agriculture acts on a large scale, up to several 1000 km^2, but the pressure for flood and inundation acts mainly on a small scale, a few km^2.

The government make decisions and all sectors must follow the guidance from the government.

Case study 4.6 Western Norway

Most important hydrological pressures are:

1. More frequent extreme precipitation events causing flash floods in small catchments, triggering of landslides and urban flooding,
2. Increasing precipitation amounts leading to forest road drainage problems.
3. Changes in precipitation seasonality causing drought stress in vegetation and increasing risk of bark beetle epidemies
4. Changes in precipitation seasonality causing challenges for dimensioning and operation of reservoirs

Most important exposure units are (Re-)insurance sector, Hydropower production, Municipalities, Road authorities, Forest owners and forest industry, Drinking water supply, More responsibilities for public administration.

The time scales at which these pressures act are event time scale: hour to season and the time perspective is the next 50 to 100 years

The spatial scales at which these pressures act are from a few km2 to 100 km2 (flooding and natural hazards) to several 1000 km2 (drought damages and impacts).

The most important institutions in your region that make decisions related to the pressures are Ministry of Agriculture and Food, Norwegian Water Resources and Energy Directorate, Norwegian Directorate for Civil Protection, Ministry for Justice and Public Security, Ministry of Climate and Environment, Norwegian Environment Agency, County Governor.

Institutionalized response mechanisms are Plan and building act, Awareness zones, Water resources act, Several acts for hydropower production, Guidelines published by the respective directorates, Operational forecasting system, Forestry Act.

Other response options that would be adequate but are not institutionalized yet are consulting/advisors for the municipalities, annual harvest plans, duty to notify planned harvest, general strategic planning, action plan to prevent secondary damage from insects, and climate factor 20-40% increase on present-day 200-yr design values.

The following critical information and/or services are currently lacking to support and inform decision- and policymaking: decision support system for multi-reservoir systems (flood), regular communication meetings among hydropower providers, guidelines for clear-cutting, revision of subsidy system for harvest, lack of models that combines the effects of hydrological pressure and forest development/forest vitality at a larger scale (models that could predict what forest structures (age, tree species, managed or unmanaged) that at a landscape scale could be resilient to drought and potential secondary outbreaks of pathogenic insects as a result of climate change).

The following models are currently used for decision making: Event-based rainfall runoff model (PQRUT) and national methods flood frequency analysis, HBV-based system for the hydropower sector, operational flood forecasting and land slide risk systems, risk zone mapping for natural hazards and flooding and no model tools relevant for hydrologic pressure is used for operational planning in forestry.

5. Synthesis and summary

Stakeholder involvement in the different case studies have been defined in a series of workshops during the first project year. Local considerations determine the relevant hydrological pressures, exposure units, time and space scales. The relevant institutions that make decisions regarding the hydrological pressures mostly come from the public sector, however private companies are also involved. This is also reflected in the institutionalized response mechanisms. In order to coordinate stakeholder involvement some common themes are considered in the case studies: (i) fluvial flooding and land use change (Brazil, Western Norway), (ii) droughts and agriculture (Sweden, Brazil, China), and glacier retreat and hydropower production (China, Western Norway). Cross-case knowledge transfer can be performed for these common themes, however given that hydrological pressures in case-studies without overlapping themes are of similar type there is also an option for cross-case comparisons.

A common hydrological pressure in all case studies are floods and droughts, albeit for varying temporal and spatial scales. Extreme precipitation and flood events have an impact on infrastructure, safety and health at scales ranging from local to regional and from hourly to annual. Water scarcity has impacts on ecosystems, water supply, agriculture, forestry and hydropower production, usually at larger temporal and spatial scales. Contamination of surface water and groundwater is another common theme in several case studies. Dimensioning and operation of reservoirs and conflicts over water use are also important exposure units.

The most important institutions that make decisions regarding hydrological pressure are municipal, county and national authorities, insurance companies, hydropower companies, water supply companies, water use boards, agriculture and forest institutions. Both environmental, legal, technical and scientific institutions are represented. Several response options that are not institutionalized are available, including forecasting, strategic planning, models for combined effects, multi-objective decision guidelines for management of resources, water and ecosystems.

Models for forecasting and prediction include various water balance model, event based models and statistical models for extremes (floods and droughts).

The workshop in case study 4.2 held shortly before the finalization of this report supported the possibility to focus on developing Decision Support Indicators that are based on historical extreme events.

APPENDIX A

Case study profiles

1. Case study no.: 4.1
2. Location: Malmö
3. Country: Sweden
4. Domain size: 7 700 hectares
5. Case study area: 4 845 hectares

6. Description of hydrological pressures:
Situated in northern Europe (Fig. 1), Malmö has a temperate climate. Intense rainfall is most common during late summer (Gustafsson et al., 2010), when humid air from the sea reaches the warm land, while stormy weather with extreme waves and water levels is most common during autumn and winter (Hanson and Larson, 2008). The maximum hourly rainfall is 26.1 and 53.4 mm, for 10 and 100 years return period respectively (Hernebring et al., 2015). The mean annual precipitation is 605 mm.

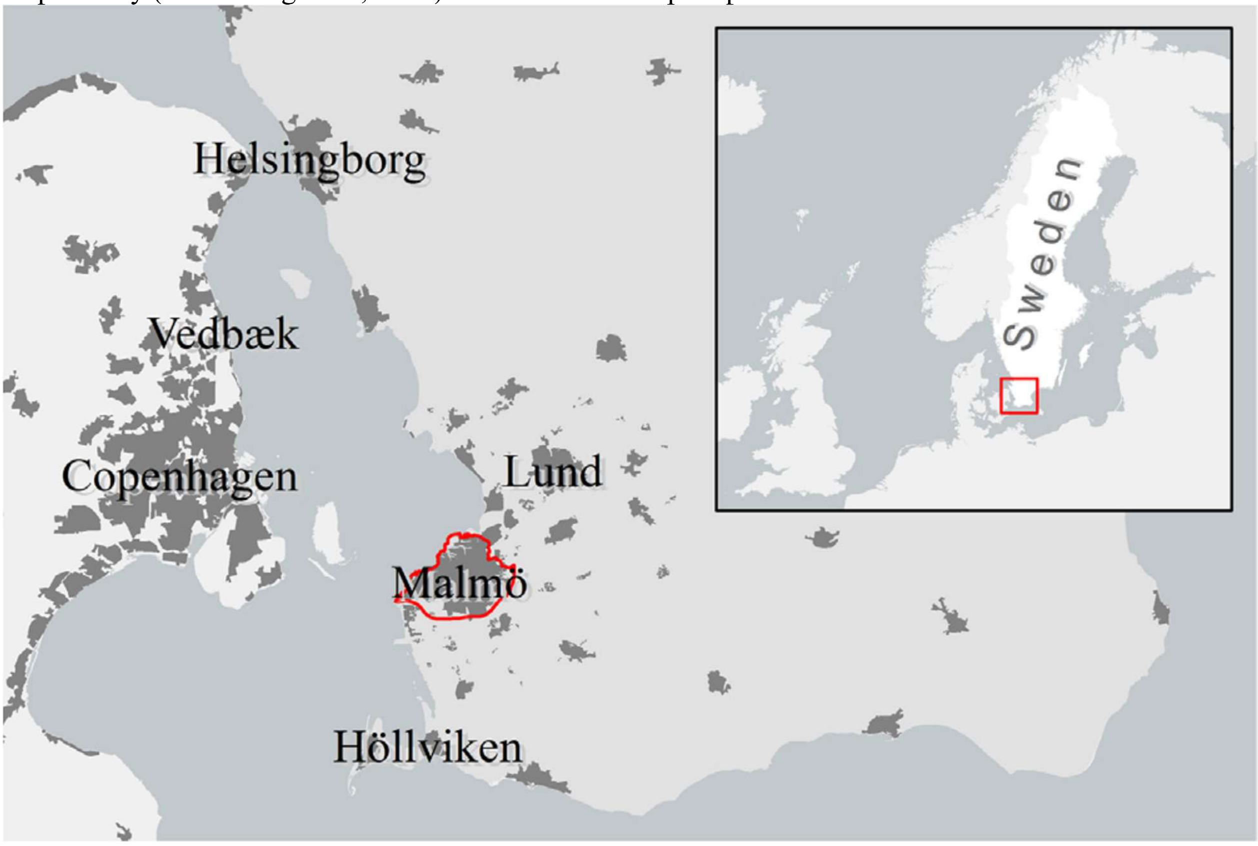


Figure 1. Malmö and the neighbouring cities of Lund, Helsingborg, and Copenhagen (Denmark).
The main cause behind the biggest flood events in Malmö is heavy rainfall. The main flood events appear primarily during the late summer months (July–August). In Malmö, snowmelt is not an important mechanism behind flooding.
Within the inner ring road, where the city is more densely built, 40% of the area has combined system, 7% has semi-separate system and 53% has separate system. Several areas with semi-separate system has been reconstructed to separate system during recent years.

7. Key historical events:
Three recent, severe flood events in Malmö are chosen for detailed analyses: 5 July 2007, 14 August 2010, and 31 August 2014, where the 2014 were much more extreme than the other two (~10 times more flood claims reported). All of these flood events were caused by heavy rainfall. There were also severe flood events on 26 August 1996 and 9 August 1999, but these events were excluded, as little information on these events are available.
During the rainfall event on the 5 July 2007, 89 mm rain fell between midnight and 19.45 in the evening (SMHI, station A) (Fig. 2). The ground was already almost saturated due to recurring rainfall during the weeks before. This led to flooding all around Malmö and 169 flood claims were registered at LF Skåne

and 150 at VA Syd. Flooding was reported to have occurred in locations represented by 245 cells in the 50 50 m grid (from now on notated ‘‘x cells were flooded”). Several areas outside Malmö, like the neighbouring city of Lund (Fig. 1), were also flooded on the 5 July 2007, but the biggest rainfall volume was measured in Malmö.

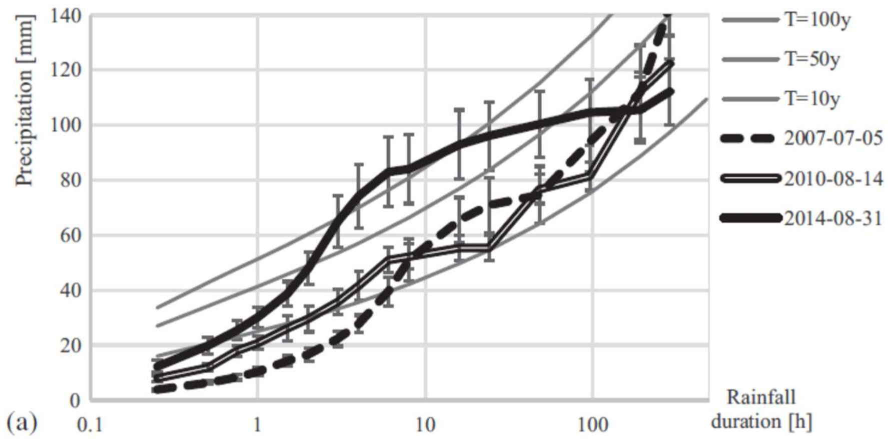


Figure 2. Precipitation volume for different durations during the 2007, 2010 and 2014 events.

On the 14 August 2010, 66 mm rain fell between 06.00 and 19.30 (SMHI, station A), out of which 50 mm fell during the last 3 h (Fig. 2). The number of flood claims sent to LF Skåne was 148 and to VA Syd 210. 270 cells were flooded. The rainfall event also led to severe flooding in northern Copenhagen and 99 mm rainfall was measured in Vedbæk (Fig. 1) (Olesen and Siewertsen, 2010).

The severe flooding on the 31 August 2014 is the biggest flooding event in Malmö so far, with 10 times more flooded cells compared to the 2007 and 2010 events. The flooding affected all parts of the city. A total volume of 101 mm fell between early morning (02.15) and late evening (21.30) (SMHI, station A). During the most intense hours (4.30–7.30), 71 mm fell (Fig. 2). In total, 2649 flood claims were reported to LF Skåne and 2109 to VA Syd, spread over 2388 cells. Many properties within the same cells were flooded. The rainfall was even heavier south of Malmö compared to the city of Malmö. The maximum rainfall was measured in Höllviken (Fig. 1), Vellinge municipality (168 mm in total, 118 mm during 90 min). The rainfall covered a large area including Copenhagen, Denmark. More details on the rainfall is found in a report by DHI (2014a).

During the six most intense hours of the 2014 event, approximately 3.2*10^6 m3 of precipitation fell over Malmö city (Hernebring et al., 2015). The minor, ordinary drainage system could only handle a small part of this (separate system: 0.2*10^6 m3; combined system: 0.25*10^6 m3), while 1.2*10^6 m3 infiltrated during these 6 h and about half of the total volume ran as overland flow to low-lying areas (1.5*10^6 m3). It took approximately four days before all low-lying areas were drained from inundated water (ibid.). The analysis shows that such extreme events cannot be handled only via pipe engineering, but has to be dealt with using appropriate spatial planning and urban design.

8. Identification of stakeholders:

Two stakeholders are central to pluvial flood management in Malmö, VA SYD (public water utility company) and City of Malmö (municipality. Another stakeholder, that are getting more and more important, is the Scanian county board. They have before had a minor role in urban planning, but, as climate politics and disaster risk management is on their table, they are getting more and more involved.

9. Issues to discuss with stakeholders:

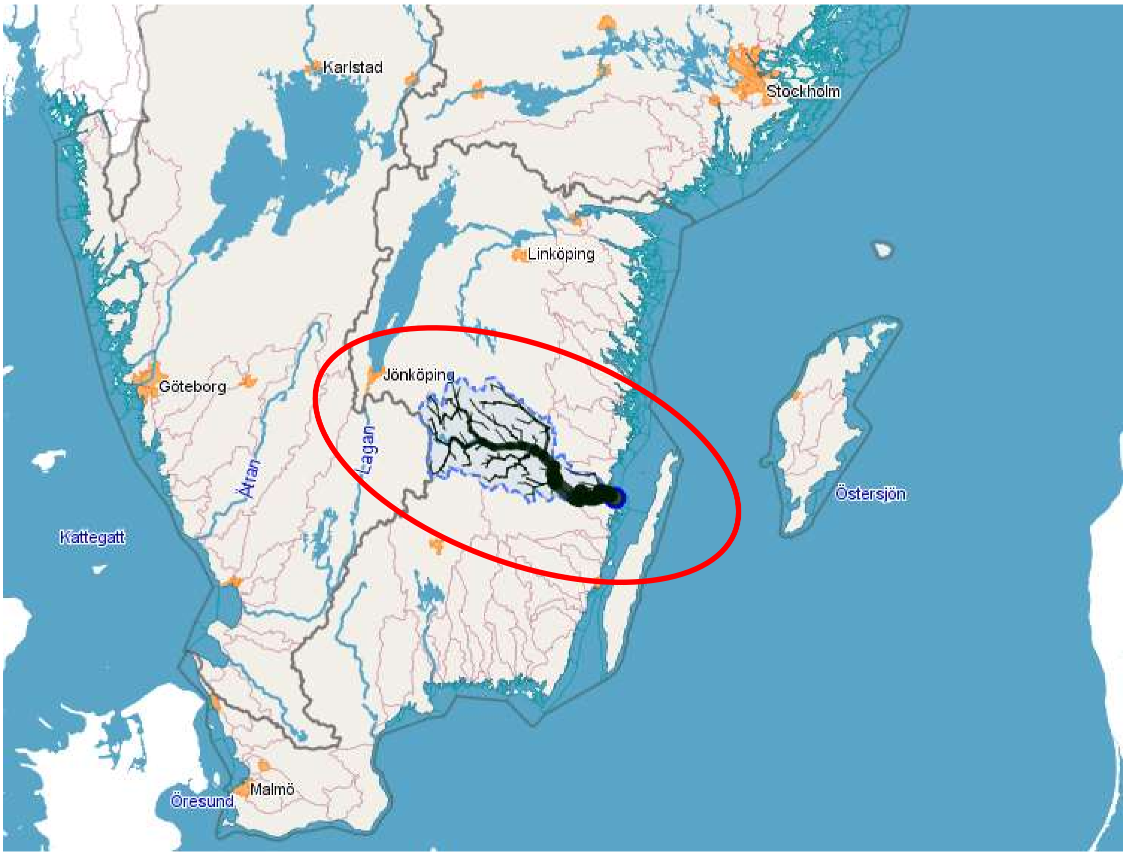
We have done several studies in collaboration with VA SYD, City of Malmö and the Scanian county board. In this project, we will interact with the in order to discuss early results in order to make the results as relevant as possible in their hydrological application.

10. Expected results and impacts:

Better understanding of the relation between extreme rainfall and pluvial flooding – a highly non-linear

relation. Better understanding of climate projections on urban scale.

1. Case study no.: 4.2
2. Location: Emån River
3. Country: Sweden (southern)
4. Domain size: ~30 000 km²
5. Case study area:



6. Description of hydrological pressures:
WP4.2 will focus on drought and water scarcity.

7. Key historical events:
In 2016-2017, southern Sweden experienced a substantial precipitation deficit and in early summer the region faced the worst water scarcity in several decades. Water use was restricted in some 50 municipalities in 12 counties, but eventually a rainy end of the summer improved the situation. Nevertheless, the event became a real eye-opener as water scarcity is unusual in the area and consequently the preparedness was low.

8. Identification of stakeholders:
We have, based on established in-house contacts, identified a gross list of 12 stakeholders for potential inclusion in the project. They mainly represent national and regional authorities and we will try to get also some local/municipal stakeholder involved.
Out of the gross list, the intention is to involve around three for more in-depth discussion and feedback on the developments in the project.

9. Issues to discuss with stakeholders:
The main issues to be discussed are:

- *Formulation of new DSIs.* What information that would help decision-making do they miss today? What is their feedback on the new DSIs and DSI concepts that we come up with?

- *Requirements in terms of scale/resolution and accuracy*. What is the minimum level of detail required for the information to be meaningful? What errors are acceptable (and not)?
-

10. Expected results and impacts:
The ambition of WP4.2 is to propose and evaluate a number of new and "stakeholder-approved" DSIs for water scarcity and drought, that will be implemented (at least pre-operationally) in both national and global model systems. Ultimately the implementation will performed in both "forecast mode" (e.g. coming 6 months) and "climate mode" (e.g. until end of century), although this remains to be decided. The envisaged impacts are better decisions in matters related to water scarcity and drought by the provision of more tailored and "sharper" information than what is available today.

1. Case study no.: 4.3
2. Location: Minas Gerais and other Brazilians Northeast States
3. Country: Brazil
4. Domain size: 639.219 km²
5. Case study area: São Francisco river basin

6. Description of hydrological pressures:
The São Francisco Basin has a large territorial extension, occupying an area covering 6 States and the Federal District. Due to the great variability of physical and climatic characteristics, the basin is divided into four parts, namely: Upper São Francisco, located in the mountainous area where the river rises in the Serra da Canastra; Middle São Francisco, located west of the state of Bahia, this being the largest division; São Francisco Sub-Middle, which lies on the border of the states of Bahia and Pernambuco and extends to the state of Alagoas; Lower São Francisco, located on the border of the states of Alagoas and Sergipe, flowing into the Atlantic Ocean (Fig. 1).

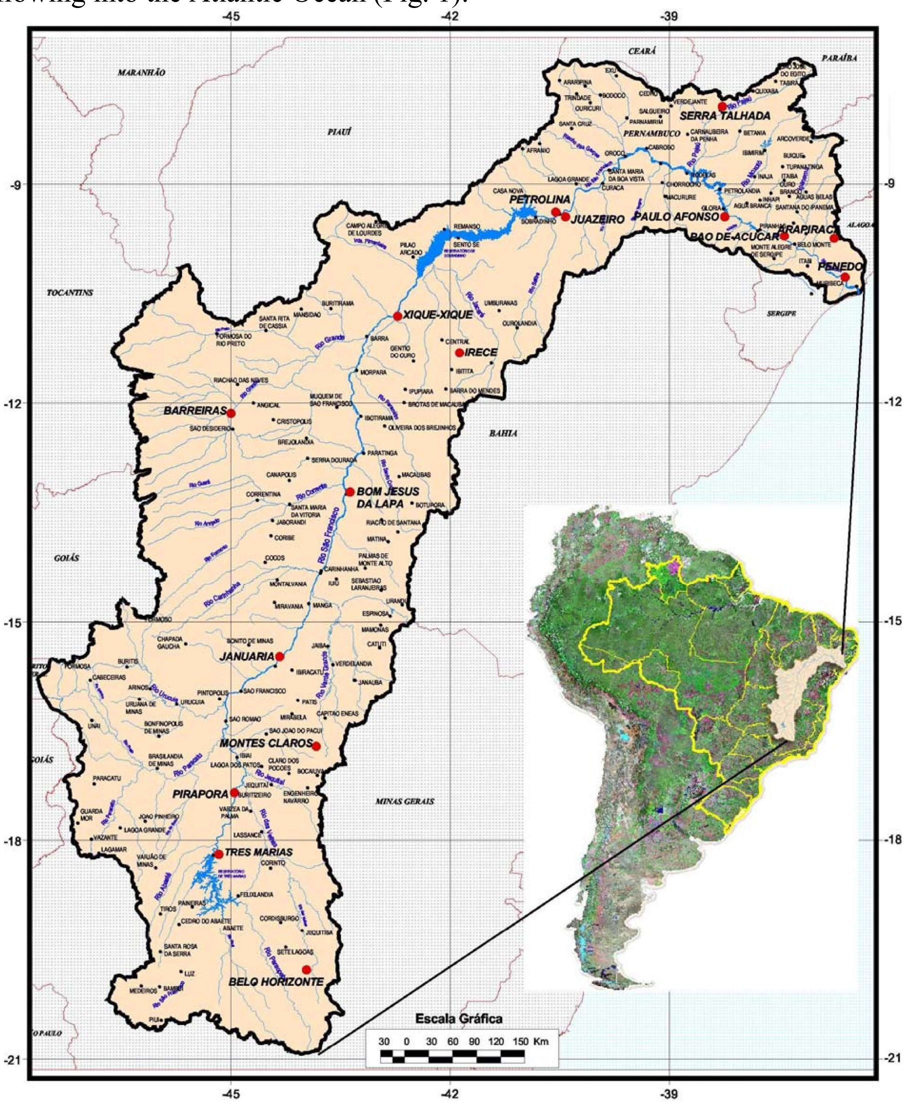


Figure 1: São Francisco river basin (ANA, 2003)

Due to its territorial extension, precipitation in the Basin is influenced by several meteorological systems, namely: South Atlantic Convergence Zone (ZCAS); High Level Cyclonic Vortices (VCAN); Frontal Systems (SF); Intertropical Convergence Zone (ZCIT); and Eastern Disorders (DL).
Its climate is defined by two distinct seasons, one dry and one rainy, with temperatures between 18ºC and 27ºC and little cloudiness. Its climate variability is associated with the transition from a humid and

humid climate present in the Alto São Francisco region to an arid and semi-arid climate in the Sub-Middle São Francisco region. Low cloudiness and high temperature significantly increase potential evapotranspiration, which if not compensated for by rainfall can cause an imbalance in water balance. Moreover, much of the basin is within the region demarcated as a drought polygon, which according to Brazilian law is a region more susceptible to prolonged periods of drought and comprises the north of Minas Gerais and the Northeast region of Brazil.

With regard to the water use of the Basin, an important growing sector is irrigated agriculture, mainly present in the Upper, Middle and Sub-Middle São Francisco. Another important sector is hydroelectric power generation, having several hydroelectric plants along its extension. As many Brazilian states are dependent on the São Francisco Basin for different water uses, knowing their hydrological behavior is extremely important to assist in decision making.

7. Key historical events:

The São Francisco basin have suffered historically from regular droughts, many of which have lasted for 3-4 years. During the 20th century, there were severe droughts in this region: 1903-1904, 1915, 1919, 1931-1932, 1942, 1951-1953, 1958, 1966, 1970, 1976, 1979-1983, 1987, 1990-1993, 1997-1999. And it continues in the 21th century, with drought in the years: 2000-2001, 2007-2008 and 2011-2019, the longest and most intense drought period. These droughts are due to below average rainfall and causes seriously constrained the socio-economic development of the region and the quality of life of the people living in the area.

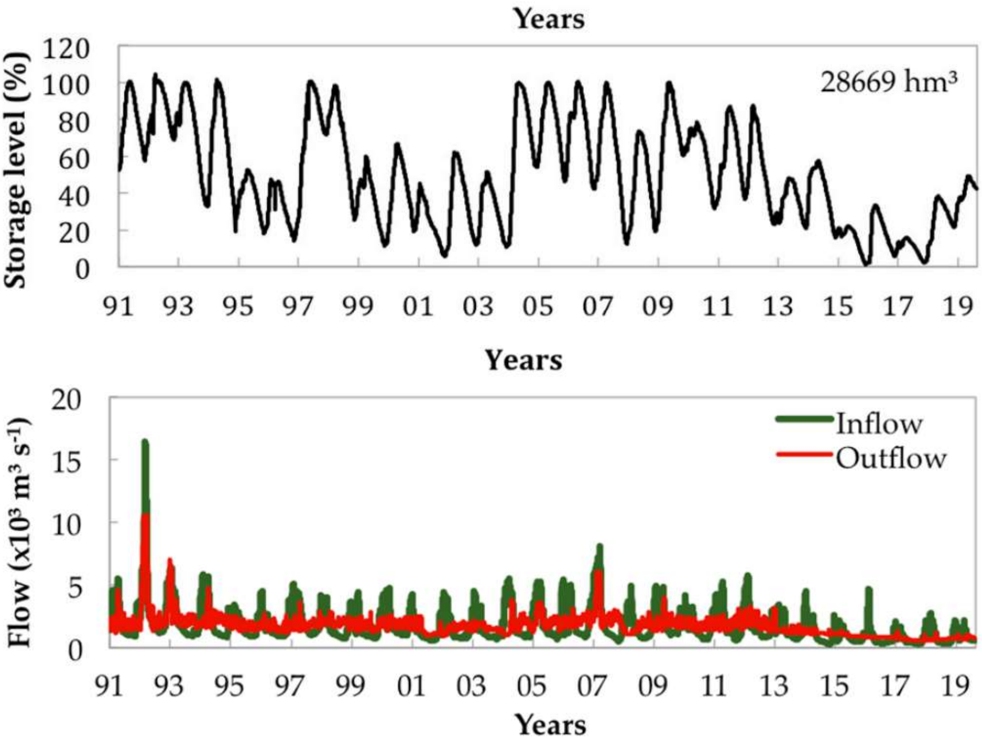


Figure 2: Storage, inflow and outflow in the Sobradinho reservoir (Cunha et al. 2019)

8. Identification of stakeholders:

Hydroelectric companies: CHESF and CEMIG
Water companies: COPASA and municipal water companies
Public and private irrigation perimeters
Industry representatives: FIEMG System, Mining Companies
Public institutions related to water: Minas Gerais Water Management Institute – IGAM, National Water Agency – ANA, National Center for Natural Disaster Monitoring and Alerts – CEMADEN, São Francisco and Parnaíba Valleys Development Company - CODEVASF
Water Committees: São Francisco Basin Committee - CBHSF, local basin committees, Peixe Vivo Agency

For the **GlobalHydroPressure** project, IGAM was included as a stakeholder and CEMADEN is part of the Advisory Board.
9. Issues to discuss with stakeholders: What institutionalized response mechanisms that already exist to prevent hydrological pressures in the basin? How are the decision-making processes related to hydrological processes? What response options that would be adequate and are not institutionalized yet? Which critical information and/or services are currently lacking to support and inform decision- and policymaking? What kind of models/tools are been currently using for decision-making?
10. Expected results and impacts: Better understanding of the causes and consequences of drought occurrences in the whole basin. Evaluation of seasonal forecasting for the basin and the assimilation to produce streamflow forecasts. Better adjust of hydrological models for the whole basin. To generate operational seasonal flow forecasts for the basin.

1. Case study no.: 4.3
2. Location: Minas Gerais State
3. Country: Brazil
4. Domain size: 9,400 km²
5. Case study area: Sapucaí river basin

6. Description of hydrological pressures:
The Sapucaí River Basin is part of the Paraná Basin. It rises from the top of Mantiqueira Mountains at an altitude of 1,650 m and is divided into three parts: Upper Sapucaí, which is located from Campos do Jordão to Wenceslau Braz city; Middle Sapucaí, which extends from the city of Wenceslau Braz to the municipality of Pouso Alegre; and Lower Sapucaí, situated between the city of Pouso Alegre until it flows into the Furnas dam (Fig. 1).
The climate in the basin region has monsoon characteristics, that is, it has a dry and a humid season. In the wet season the main atmospheric systems that are associated with high accumulation of precipitation are the South Atlantic Convergence Zone (ZCAS) and the Frontal Systems (SF).
The persistence of these systems for a long period can cause, in addition to high accumulated rainfall, river floods and landslides.
In recent years, after 2012, low rainfall volumes have led to prolonged drought periods, which have resulted in significant losses to the region's economy. In addition, flash flooding and urban flooding due to very intense and localized rainfall are a major concern for the populations of the cities within the basin in recent years.
The Basin also faces problems with unbridled human occupation due to urbanization and the loss of water quality. To minimize these impacts, environmental services have been implemented to treat domestic and industrial effluents, as well as spring protection programs.

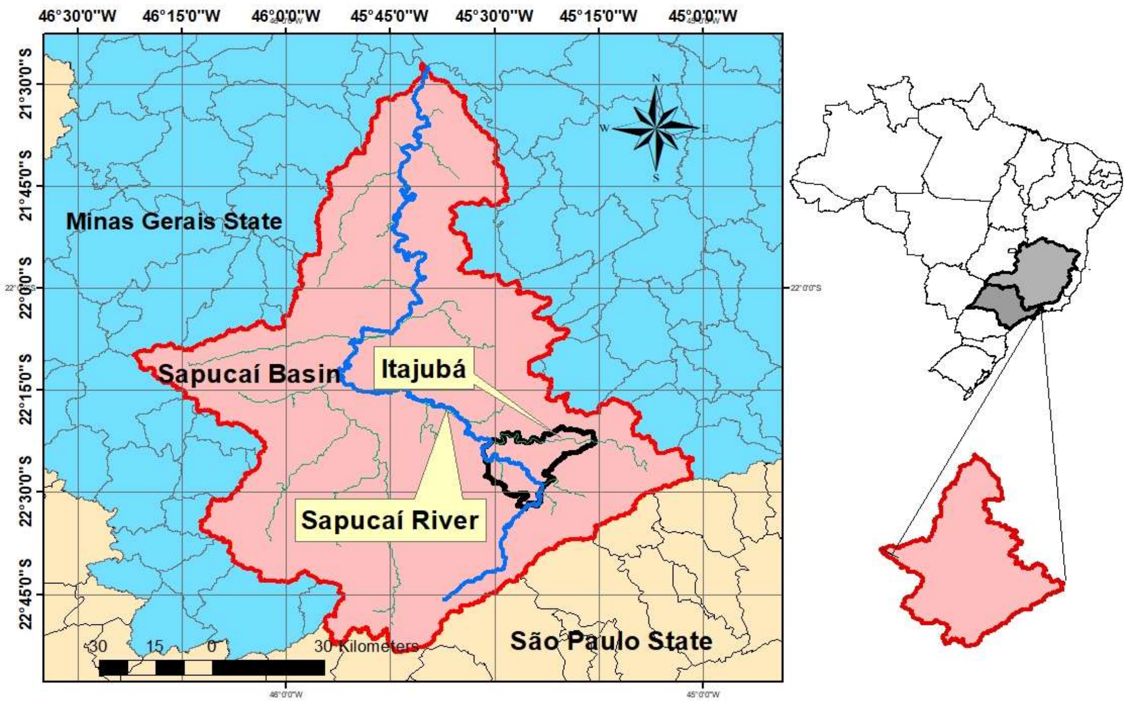
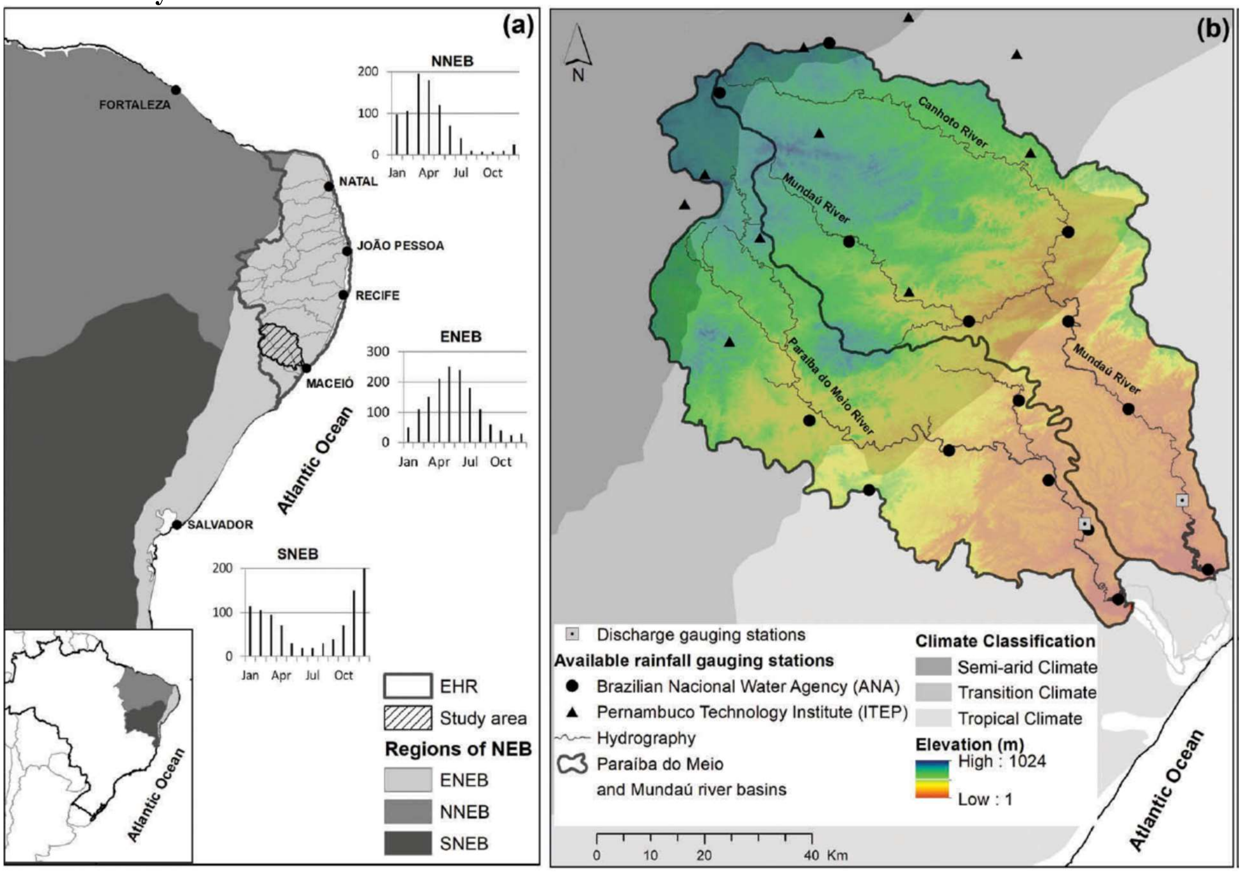


Figure 1: Sapucaí river basin

7. Key historical events:
The Sapucaí Watershed suffers frequent flood problems. The city of Itajubá, which belongs to the Basin, had in its records the first flood occurred in the year 1821. In the city, a total of 10 major floods with levels equal to or greater than 6 m of the water level were registered in relation to the altimetric

elevation of 40 floods of smaller magnitudes, with heights ranging from 4 to 6 m. In addition to the recurring flooding problems, the Basin has suffered from severe drought in recent years, especially in 2014 and 2015. This drought has caused, in addition to low availability of drinking water, a reduction in Furnas hydroelectric level causing environmental damage, social and economic.
8. Identification of stakeholders: Small hydroelectric power plants Water companies: COPASA and municipal water companies Industry Public institutions: Minas Gerais Water Management Institute – IGAM, National Water Agency – ANA, National Center for Natural Disaster Monitoring and Alerts – CEMADEN Sapucaí basin Committee, City Halls For the **GlobalHydroPressure** project, was included as a stakeholder: IGAM, City Halls of Itajubá anda Delfim Moreira and Sapucaí Basin Committee.
9. Issues to discuss with stakeholders: What institutionalized response mechanisms that already exist to prevent hydrological pressures in the basin? How are the decision-making processes related to hydrological processes? What response options that would be adequate and are not institutionalized yet? Which critical information and/or services are currently lacking to support and inform decision- and policymaking? What kind of models/tools are been currently using for decision-making?
10. Expected results and impacts: Better understanding of the causes and consequences of flood drought occurrences in the whole basin. Evaluation of seasonal forecasting for the basin and the assimilation to produce streamflow forecasts. Better adjust of hydrological models for the whole basin. To generate operational flow forecasts for the basin.

1. Case study no.: 4.4
2. Location: Mundaú and Paraíba do Meio River basins, Eastern Northeast Brazil (ENEB)
3. Country: Brazil
4. Domain size: 7283 km^2
5. Case study area:



6. Description of hydrological pressures:

- Historical of flash flood events, at least 8 extreme events from mid-1960's to 2017;

7. Key historical events:

- 1969 – about 1.1 K deaths, 10 K homeless and US$ 30 M in losses;
- 2010 – The largest event registered in terms discharge, i.e. 1250 m^3/s with 27 deaths, 50 K homeless and US$ 500 M in losses.

8. Identification of stakeholders:

- Environmental and Water Resources Government Division
- Civil Defense

9. Issues to discuss with stakeholders:

- Environmental and Water Resources Government Division has a hydrological alert room facility, but only send reports based on observed data (mainly water level from automatic stations).
- They do not have any tool implemented yet to assess or predict floods in Mundaú and Paraíba do Meio river basins, based on the already implemented rain real time monitoring from automatic rain gauges and weather Radar.
- Civil Defense there is no corps of engineering or meteorology. They only use information produced by hydrological alert room, and monitoring occupied risk areas.
- There is not hydrological forecasting system focused on extreme events of floods.

10. Expected results and impacts:

- Short-term flooding forecasting (from hours to days) with probabilistic flood maps, and integration uses of the technologies already implemented in the basins (Weather Radar precipitation estimations, automatic gauge stations);
- Drought forecasting (from days to months) (e.g. alerts for water uses, alerts that can serve as decision-making for mitigation of droughts - contracting well drilling and water trucks);
- Hydrological reports with alerts based on water level for droughts and floods;
- Web system to flooding prediction;
- An agreement can be made in order to formalize the implementation of a decision support system for flooding management

1. Case study no.: 4.5
2. Location: Xinjiang
3. Country: China
4. Domain size: 1.6 million km^2
5. Case study area and catchments for hydrological modelling:
Xiehela and Shaliguilanke catchment

6. Description of hydrological pressures:
The Xinjiang Uyghur Autonomous Region is the largest administrative region in China with geography and climate uniqueness. It is the most remote area from oceans on the earth and water are extremely valuable. The Urumqi River is one of the main rivers in the Xinjiang Uyghur Autonomous Region. The Urumqi River is 214.3 km long and has its sources from the northern slopes of the Tianshan Kalawucheng Mountains, which is the largest mountains in central Asian and crosses four countries. The Urumqi River goes through the city of Urumqi, which is the capital of the Xinjiang Uyghur Autonomous Region and provides water to domestic and industrial needs for more than 2 million people in the city. Additionally, human activities consumer much more water than before after 1950s. More than 50% of river water irrigates farmlands. Effects of human activities has expanded to all the watersheds and all seasons. Water plays a significant role for important sectors, e.g. agriculture, water supply and hydropower production.
There are 20 000 glaciers in the Xinjiang Uyghur Autonomous Region, and they count half glaciers in China. These glaciers are very small and locates sparsely. They are very vulnerable to global warming and they are important supplementary water resources to precipitation.
There is a clear and urgent need to find a balance in water usage between human activities and natural system and to investigate how climate change will affect water availability at different scales.

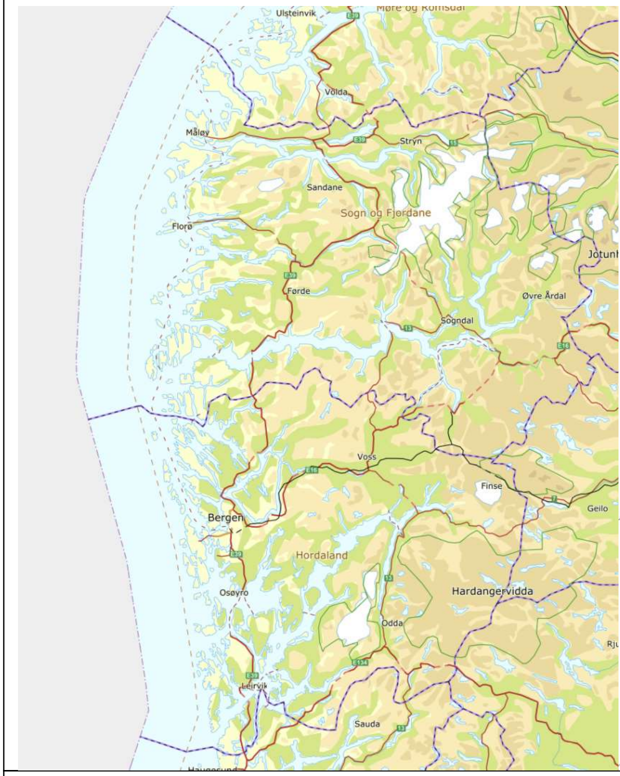
7. Key historical events:
Since 1950s, the glaciers have retreated by from 21% to 27%. The Urumqi Glacier split into two small branches in 1994. After 1950s, runoff in lower reaches decreases, and even disappears in some rivers.

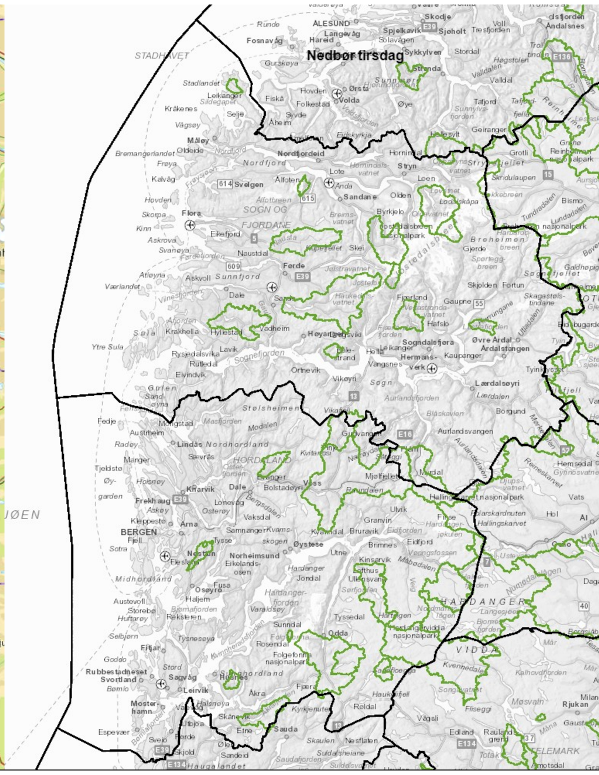
8. Identification of stakeholders:
The stakeholders include local governments, farmers and hydropower companies. The daily life of local people is influenced if the government changes domestic water price or set limitations on water amount that they can use.

9. Issues to discuss with stakeholders:
The issues will focus on climate change and water resources as well as flood and inundation in small scales.

10. Expected results and impacts:
Climate is projected to become warmer and annual temperature is about -1◦C by the end of century (Gao et al. 2017, Science of the Total Environment) and glaciers will shrink dramatically. For example, the Urumqi Glacier No. 1 will lose up to a half (54%) of its 1980 extent in 2050, and up to 80% in 2100. The shrink of glaciers has significant impacts on water resources, human activities and hydropower production. Therefore, we will calculate changes in glacier volume and area, available water resources, changes in runoff seasonality, drought index as well as hydropower potential for the future under different climate scenarios.
Climate change based on WCRP Coordinated Regional Climate Downscaling Experiment will be used as input to hydrological impact models. The HBV model will give hydrological projections, such as glacier melting, runoff, etc. Subsequently, assessment of water resources management strategies for hydropower, irrigation and water supply will be analyzed with the WEAP modelling system using input from the HBV model.

1. Case study no.: 4.6
2. Location: Western Norway
3. Country: Norway
4. Domain size: 34000 km^2
5. Case study area and catchments for hydrological modelling:





6. Description of hydrological pressures:
Western Norway is a region dominated by steep terrain, high amounts of precipitation caused by extratropical cyclones migrating from west to east across the North Atlantic Ocean, a seasonal variation in snow cover and several glacier covered catchments. Many watersheds in this region have been developed for hydropower production, the dominating supply of electrical energy in Norway and a major source of electrical energy in Scandinavia.
This region frequently experiences extreme precipitation events that produce flooding and landslides, causing considerable threats to human health, local communities and infrastructure. Current forest management practice in the region is dominated by clear-cutting and extensive clear-cut areas that increase hydrological risk in two aspects. Firstly, the steep terrain and frequent heavy rainfall events promote the formation of rainfall floods with short concentration times, and higher surface runoff contributions from clear-cut areas are likely to increase peak flood discharges. Secondly, clear-cut areas have a higher erosion potential with deteriorating effects on surface water quality. Given that both risks are tightly related to heavy precipitation events, which are projected to become more frequent in a warmer climate, adaptation strategies need to be developed that minimize hydrological risks from forest management.

7. Key historical events:
Severe and prolonged water deficit periods have caused major problems in Norway in recent years. Low lake and groundwater levels threatened water supply in northern and western Norway in the winter of 2010, and electricity prices rose to unprecedented high levels as a result of the extreme low reservoir storages. Drought situations also occurred in 2018, 2006, 2003, and 1996. At the other end of the hydrologic scale, floods have caused significant challenges to society in form of damages to infrastructure, in particular in the autumn in 2014.

8. Identification of stakeholders:
Four stakeholders from the public and private sectors have been identified, who have confirmed their

support of the project. These stakeholders cover the following sectors:

- Hydropower production
- Natural hazard management
- Private forest owners
- County forest administration

9. Issues to discuss with stakeholders:

A key uncertainty in all hydrological climate change impact assessment is how changes caused by climate will integrate with other changes in a drainage basin. Especially land-use changes can have a huge impact on the hydrological processes, in both urban and rural environments. Here we will explore specifically the impact of forest changes on future hydrology, by coupling local hydrological models to a forest growth model. DSIs related to hydropower operation will be developed, estimated both with WWH and with the local model with and without the forest growth model, and evaluated for different climate projections

10. Expected results and impacts:

Regional simulations with the hydrological model HBV at fine spatial resolution (1 km). The simulations will be driven by historical meteorological data and ensemble national climate projections under two representative concentration pathways to study climate change effects on reservoir inflow and hydropower production. The analysis will focus on events particularly relevant for reservoir operation (size and probability of floods and droughts).

Site-based simulations at fine spatial resolution to study the effect of different harvest and forest management scenarios on runoff and soil moisture status. Drought induced water stress in vegetation will be analyzed for the historic period as well as for the 21st century.

APPENDIX B

Questionnaires for 1st stakeholder workshop

"Stakeholder needs and expectations"

Case study 4.1: Malmö

Case study no. and name:
Time and place of workshop:
Participants (researchers):
Sörensen, Johanna, Lund University

Participants (stakeholders):
–

Questions jointly discussed with the stakeholder group

1. Considering the hydrological pressures listed below, rank them **according to the importance** to the economy and social development of your region, 0 being not important and 5 very important.

Hydrological Pressures	Scale (0 a 5) 0 not important e 5 very					
	0	1	2	3	4	5
Flood					X	
Water scarcity for consumption					X	
Landslide	X					
Surface water contamination				X		
Groundwater contamination			X			
Siltation of rivers and reservoirs	X					
Water use conflicts	X					
Proliferation of diseases				X		
Other: Drought					X	

2. Considering the hydrological pressures listed below, rank them **according to the risk that they will occur** in your region, 0 being no risk and 5 high risk.

Hydrological Pressures	Scale (0 a 5) 0 no risk e 5 high risk					
	0	1	2	3	4	5
Flood					X	
Water scarcity for consumption		X				
Landslide	X					
Surface water contamination			X			
Groundwater contamination			X			
Siltation of rivers and reservoirs	X					
Water use conflicts	X					
Proliferation of diseases		X				
Other: Drought				X		

3. How the sectors / systems of the economy and society will be affected by hydrological pressures, 0 being not affected and 5 greatly affected.

Hydrological Pressures	Scale (0 a 5) 0 not affected e 5 very affected					
	0	1	2	3	4	5
Population in socially vulnerable situation				X		
Government structure (municipal / state)			X			
Commercial sector				X		
Industry			X			
Agriculture					X	
Transport			X			
Power generation	X					
health sector		X				

Water supply		X				
Aquatic Ecosystems			X			
Other:__________________						

4. At what time scale do these pressures act?

( ) minutes
(X) hours – pluvial flooding
( ) days
( ) month
(X) seasonal – drought
( ) anual
( ) decade
( ) century
( ) Other________________

5. At what spatial scale do these pressures act?

(X) Some streets – pluvial flooding
(X) Neighborhoods – pluvial flooding
(X) Whole city – pluvial flooding
(X) State – drought
( ) Country
( ) Other _________________

6. Which major institutions in your region make decisions regarding the pressures listed above (check up to 3 options)?

( ) Civil Defence
(X) City Hall
(X) Water Company
(x) State government
( ) National Agency of Water

( ) Basin Commity

( ) Other ________________

7. Indicate, if available, what actions are being taken in your region to minimize hydrological pressures and their impacts on the economy and social development.

A water professional has been employed at the city hall to better coordinate the work with pluvial flooding in Malmö. A pluvial flood management plan has been agreed upon.

8. Please suggest other response options that would be adequate in your opinion but are not instutionalised yet.

Transition towards more large-scale implementation of blue-green infrastructure. Legal, institutional and economical barriers hinders the implementation currently (see Wihlborg et al. 2019)

9. With respect to the pressures listed above, which critical information and/or services are currently lacking to support and inform decision- and policymaking?

To a great extent, information needed is available

10. What kind of models/tools are you currently using for decision-making?

Pluvial flood management plan

Design standards for storm water drainage

Flood hazard assessments

11. What means of communication do you use to get information about hydrological pressures and / or track them?

( ) Web sites

( ) Newsletter

(X) Newspaper

(   ) Social networks (Facebook, Twitter, ...)

(X) Congresses and events

(   ) Scientific articles and journals

(   ) Popular knowledge

(X) Other: Formal sources within the municipality and from external organisations. From SMHI.

Case study 4.2: Southern Sweden

1. For the hydrological pressures listed below, specify the rank according to the potential impact they would have on the economy and social development of your region or sector, should they occur, where 0 is low impact and 5 is high impact.

Hydrologic pressure	Scale (0 to 5) 0 small impact - 5 large impact					
	0	1	2	3	4	5
Flooding	1		1			2
Drinking water shortage			1		2	1
Landslide		2		1	1	
Surface water pollution		1		1	1	1
Groundwater pollution		1	1		1	1
Sedimentation in watercourses and magasines	1	1	1	1		
Conflicts between different water uses		1		1	1	
Spread of disease				3	1	
Drought						1
Drainage overload						1

2. For the hydrological pressures listed below, indicate the probability of occurrence in your region or sector, where 0 is low probability and 5 is high probability.

Hydrologic pressure	Scale (0 to 5) 0 low probability - 5 high probability					
	0	1	2	3	4	5
Flooding				2		2
Drinking water shortage		1			1	2
Landslide		3		1		
Surface water pollution			1	2	1	
Groundwater pollution		1	2	1		

Sedimentation in watercourses and magasines		3		1		
Conflicts between different water uses			1	1	1	
Spread of disease		1	1	2		
Drought						1
Drainage overload						1

3. To what extent are different sectors or economic and social systems affected by hydrological pressures, where 0 is not affected and 5 is greatly affected.

Hydrologiska påfrestningar	Scale (0 to 5) 0 unaffected – 5 greatly affected					
	0	1	2	3	4	5
Population in socially vulnerable situation		3	1			
Municipality and state				3	1	
Trade		1	3			
Industry		1	1	2		
Agriculture			1		2	1
Transportation		3		1		
Power production		1			2	1
Health		3		1		
Drinking water supply				1	1	2
Aquatic ecosystems				1		3
Annat:___________________						

4. On what time scales do the hydrological pressures act?

( ) Minutes
(1) Hours
(3) Days
(3) Months

(2) Seasons

(1) Years

( ) Decades

( ) Centuries

(x) In all sectors and pressures, all time scales are affected

5. On what spatial scales do the hydrological pressures act?

(3) Locally

(3) Small urban area or catchment

(3) City or large catchment

(2) County

( ) Nation

(1) In all sectors and pressures, all spatial scales are affected

(1) Höglandet - an area that encompasses several municipalities with the same conditions

6. Which major institutions in your region or sector make decisions regarding the hydrologic pressures listed above (fill in up to 3 options)?

(4) Emergency services

(4) Municipality

(3) Water and sanitation companies

(4) Governmental organizations

( ) National water authority

( ) Water conservation society

(1) none

(1) Hydroelectric owners must design dams after hydrological pressures, and the Land and Environmental Court decides on water properties

7. Describe what measures (if any) are being taken in your region or sector to minimize the hydrological pressures and their impact on the economy and social development

- Drainage, maintenance of groundwater drainage systems, irrigation reservoirs, expansion of irrigation capacity, storage of feed
- Different types of restriction of use in low availability of water (drought), eg irrigation prohibition, reduced pressure in pipes, information and appeals. Floods: decision of areas to be flooded and not, measures to increase drainage, lowest buildable level above water surface.

- Expansion of municipal water networks ensures the supply of drinking water and the management of wastewater. Emergency services can assist with temporary water transports in the event of a lack of drinking water and also carry out emergency measures to minimize flood damage. The Swedish Housing Agency can determine rules for construction in areas close to water, and the Swedish Transport Administration designs bridges and road drums to cope with hydrological pressures.

8. Please suggest other measures that you think would be appropriate to take.

- Increased spare water capacity in own facility or through collaboration with neighbors or municipality.
- Regional water planning, increased purification measures on all wastewater, protection zones around lakes and streams and planning / measures for ecosystems
- prioritization of water use;
- allocate areas in landscapes and urban areas to be flooded
- secure water supply through transmission / stable resources, have several options.
- Delay water in the landscape and urban areas
- Flow path mapping
- Spare water capacity and systems (eg water kioskes for the general public)
- Better information on water withdrawal / water use is needed to prioritize which sectors should have priority in a water shortage situation. Some countries (eg the Netherlands) also have a national priority of which water use is most important.
- Sweden also needs regulations that protect aquatic ecosystems from water shortages. There should be rules regarding the impact at low flows, e.g. that no water withdrawals are allowed during a flow below natural MLQ (mean annual minimum discharge). The same rules should also apply when diverting water for hydropower.

9. For the hydrologic pressures listed above, what key information and / or services are currently lacking as a basis for decision-making and guidelines?

- Knowledge of water supply, water balance, water needs and water withdrawals
- Knowledge of how drainage is affected by measures to equalize flows, both during high-flow and low-flow conditions
- Above all, stricter national legislation is needed to implement the above
- Water withdrawals and regulation and their sizes
- Areas and plans for water management
- See answer to question 8. In Sweden, information on water withdrawals / water use, as well as a regulatory framework for mutual prioritization, is needed to ensure community functions during periods of drought.

10. What types of models or tools do you currently use for decision making?

- Especially SMHI's various data bases
- Flood mapping, performed individually by both MSB and consultants
- Water supply plans
- The entire SMHI and SGU model systems and forecasts
- National high-resolution hydrological models in time and space that contain a lot of information about regulations but not water withdrawals.

11. Through which information channels do you obtain information about, or receive continuous updates on, hydrological pressures?

(3) Web pages
(1) Newsletters
(2) Newspapers
(1) Social networks
(2) Conferences and special events
(2) Scientific journals
(1) Public knowledge

(2) Cooperation between authorities

(1) Own observations

Results from a survey made at a workshop on droughts at SMHI on 2020-03-11

Three DSI concepts were presented and discussed: historical event, tme horizon and worst-case scenario.

Historical event

- o principle: forecasts are related to a known historical extreme event
- o o the levels that occurred during the historical event can be used as "critical levels"
- o answers e.g. "are we during the forecast period expected end up in the situation that occurred in 2018?"
- o we hope this helps users to understand and assess effects, based on experience from the historical event

Do you think this approach would add value compared to the information available today? Y: 6; N: 0

Have you already used or come into contact with this approach? Y: 3; N: 2 If yes, in what way?

- At SMHI hydrological forecasting & warning we routinely simulate discharge using the weather during the drought 2018 (but it is not being externally communicated).
- We (county board) often refer to the drought in 2018.
- Well, many actors have the dry summer 2018 in fresh memory, which is good for understanding the scientific information that "non-scientists" needs to make decisions.
- When investigating historical discharge events in Motala River, with knowledge on the impacts on water quality.

How would you define a "historical extreme event"?

- Events with not too long return period. E.g. not only 1000 y but also 100 y or less. If too extreme it may be too easy to ignore in physical planning.
- Must be something that "everyone" can relate to in some way.
- Maybe a link to future climate would be useful. E.g., the drought in 2018 corresponds to a "normal" summer in year 2100.
- For a drinking water producer other variables than discharge may be interesting. Our plants are designed based on certain physical and chemical parameters. So an optimal tool would preferably take also these parameters into account.

Time horizon

- o principle: focus on the time remaining until a critical limit is reached or exceeded
- o this information is normally found in forecasts but rarely communicated explicitly
- o answers e.g. "after how many days will we reach the limit for ecological flow?"
- o we hope this helps users understand the situation from a concrete time perspective which facilitates the planning of efforts

Do you think this approach would add value compared to the information available today? Y: 4; N: 0, maybe: 1

Have you already used or come into contact with this approach? Y: 4; N: 2 If yes, in what way?

- Not in drought situations, but in flood forecasting the “time until warning level” is always an aspect.
- Different time horizons in climate analyses, e.g. until year 2050 or 2100.
- The time it takes for water to flow from the location of a pollution accident to the drinking water source is important information for drinking water producers, in order to decide whether or not to close the water intake.
- News reporting from e.g. South Africa.

How far in advance do you need information to be able to act?

- Far ahead.

Do you have any other comment?

- I would like to know the critical limit for when water in a surface water source needs cooling to become safe for drinking.
- I think it risks leading to too frequent false alarms. If we do not run out of water as “promised” in the forecast people will stop caring.

Scenario (”worst-case”)

- principle: an assessment of the worst that may happen
- in case of water shortage: no rainfall ahead
- answers "what happens if we do not get any rainfall from now on"
- we hope this helps users plan for the worst possible outcome

Do you think this approach would add value compared to the information available today? Y: 5; N: 0, maybe: 1

Have you already used or come into contact with this approach? Y: 4; N: 2 If yes, in what way?

- Not actually experienced or used but know that it exists.
- Through studies in climate strategy. At work we mainly talk about extreme events.
- Strategic water resources planning, long-term water supply considerations, including climate impacts.

Do you have an idea of another relevant "worst-case scenario"?

- When working with worst-case scenarios it is important with information about the probability too. But I think historical extremes are much more interesting because you can relate to them and you know that they actually happened.
- No snow (only rain). Only cloudbursts (no “normal” rain). Or only light rain, no heavy rain, i.e. a lot will evaporate or be absorbed by plants, esp. in summer.
- It would be interesting to include water quality.

Do you have any other comment?

- It may be relevant for long-term planning by drinking water producers.
- Interesting approach for the technical services (water, energy) in my city.
- Our focus is mostly on conceivable measures for different worst-case scenarios.

Case study 4.3: Minas Gerais

Stakeholders Questionnaire: Perception, Needs and Expectations

This questionnaire aims to identify the main hydrological pressures by which users and decision makers are affected, within their areas of expertise. The results will be used to define indicators and computational tools that aim to assist decision making in face of these pressures.

Location:____ date:___________ Time:_________

Identification

Name: ____

Institution / Company: ____

Function / Position: ____

Email: ____

Acting region: ____

OBSERVATION

- **The following questions can be answered individually or can be discussed together with the stakeholder group.**
- **Answer by considering only the region in which you operate (city, group of cities, neighborhoods, state region, river basin, ...)**

1. Rate the hydrological pressures listed below for the dimensions given for your region of operation.

Hydrologic pressure	**It's worrying?** 1 - Nothing 2 - A little 3 - Very	**Occurrence** 0 - Never occurred 1 - Some occurrences 2 - Almost every year 3 - Several times a year	**Affected Areas** 1 - Streets 2 - Neighborhood 3 - City (s) 4 - Watershed	**It is getting worse?** 0 – No 1 – yes
Riverside floods Typical overflow of medium or large rivers and flat areas. Many hours or days to graduate				
Flash flood Typical overflow of small and mountainous rivers. Minutes or a few hours to graduate.				
Urban flooding Drainage system overflow in urban areas (streets and galleries). They form in minutes.				
Catastrophic floods Generated by the disruption of structures such as dikes or dams. They form in minutes..				
Severe droughts They extend for consecutive years.				
Atypical Droughts Longer dry period within the year.				

2. Which of the sectors listed below are significantly affected by hydrological pressures in your region?

Hydrologic pressure	Population	Public services	Trade	Industries	Agricultur e	Transports	Power generation	Navigation	Water supply	Fishing
Riverside floods Typical overflow of medium or large rivers and flat areas. Many hours or days to graduate										
Flash flood Typical overflow of small and mountainous rivers. Minutes or a few hours to graduate.										
Urban flooding Drainage system overflow in urban areas (streets and galleries). They form in minutes.										
Catastrophic floods Generated by the disruption of structures such as dikes or dams. They form in minutes..										
Severe droughts They extend for consecutive years.										
Atypical Droughts Longer dry period within the year.										

3. Which are the most important institutions in your region that make decisions regarding hydrological pressures?

( ) Civil Defense / City Hall ( ) Fire Department ( ) CEMADEN

( ) IGAM ( ) Basin Committee ( )National Water Agency

Outros: ____

4. Indicate, if available, what actions are being taken in your region to minimize hydrological pressures and their impacts on the economy and social development.

____

____

____

____

5. Suggest other options for actions that, in your opinion, would be appropriate, but not yet institutionalized or undertaken, and that could assist in decision making.

____

____

____

6. What data or information do you need for decision-making and currently do not have?

____

____

____

____

7. What media do you use to get information about hydrological pressures and / or to follow them.

( ) Internet news portals
( ) Specialty Bulletins
( ) TV news
( ) Social networks
( ) Congresses and events
( ) Scientific articles and journals
( ) Popular Knowledge
( ) Others______________________

ADDITIONAL COMMENTS

____
____
____
____
____
____
____
____
____

Results and discussions

In order to facilitate the systematization of the data obtained, the results presented below are separated by the questions present in the applied questionnaires (Appendix 1).

- Identification of respondents

Respondents are part of the Sapucaí River Basin Committee (CBH- Sapucaí). According to Article 39 of Law 9,433, the CBHs must be composed of representatives: from the Union; the States and the Federal District whose territories are, even partially, in their respective areas of activity; Municipalities located, in whole or in part, in their area of operation; the users of the waters of its area of operation; civil entities of water resources with proven performance in the basin (BRASIL, 1997).

Thus, the interviewees are part of one of the groups mentioned above, making the results have a tendency to be representative since in this space there is the participation of various representatives of agencies and civil society. The following table presents the information about 27 respondents (Table 1).

Table 1- Identification of respondents

Name	**Institution**
Marielle Andrade	Institute “Fernando Bonilho”
Luís Fernando Borges	Institute State Forest
Michel Pinheiro e Leonardo Rocha	City Hall of Pouso Alegre
Diego Noronha e Taíris Ferreira	City Hall of de Brazópolis
Tales Mota	Minas Gerais State Sanitation Company
Dênio Drummond	Minas Gerais Energy Company
Amanda Lisboa	Foundation “Roge”
Ricardo Corrêa	City Hall of Itajubá
Lara Rezende	City Hall of Itajubá
Carla Figueiredo	Without institution identification
Rogério de Freitas	Foundation “Roge”
Daniele Moreira e Carina Silva	City Hall of Maria da Fé
Leopoldo Ribeiro Junior	Itajubá Research and Education Foundation
José Fernandes	Foundation “Roge”

Francisco Siqueira	Rural Union of Itajubá
Afonso Miranda	Foundation “Roge”
Márcio Magela	Cambui Autonomous Water Service
Paulo Gelhardo	Regional Engineering Council
Antônio Rennó	City Hall of Piranguçu
Renato Oliveira	City Hall of Cambuí
Giovanni Adilson	Secretaria Estadual de Saúde
Juliane Aparecida	City Hall of Delfim Moreira
Laene Montanheiro	Minas Gerais Federation of Industries

- Hydrological Pressures (level of concern, occurrence, affected areas and worsening)

The first question of the questionnaire used a Likert scale (adapted), as this type of methodology addresses ordinal qualitative variables, it has no numerical meaning, being necessary to analyze the “fashion” statistical variable to obtain the results, ie the Analysis is based on the frequency of responses.

Thus, we present in Charts 1 to 6 each of the pressures and the indication of the frequency (f) of the stakeholder responses. It is worth mentioning that one of the questionnaires (#21) was excluded from the tabulation, as it presented two answers to some questions, while leaving the others blank.

In the Chart 1 the results indicate that, for the stakeholders, the riverside floods are of very concern, have some occurrences and the most affected areas are the neighborhoods. The responses are consistent with the large river floods that occur in the Sapucaí River basin. They do not have high frequency but cause great damage when they occur.

Chart 1- Hydrological Pressure (River Floods)

Hydrologic pressure	It's worrying? 1 - Nothing 2 - A little 3 – Very	Occurrence 0 - Never occurred 1 - Some occurrences 2 - Almost every year 3 - Several times a year	Affected Areas 1 - Streets 2 - Neighborhood 3 - City (s) 4 - Watershed
Riverside floods Typical overflow of medium or large rivers and flat areas. Many hours or days to graduate	f = 3 f = 8 **f = 11**	f = 3 **f = 14** f = 4 f = 1	f = 5 **f = 9** f = 2 f = 6

In relation to the flash floods, the results presented in the Chart 2 indicate that this pressure are a little concern for some stakeholders and very worrying for others (close results), have some occurrences and the most affected areas are the neighborhoods. This type of flooding is more frequent than river flooding but causes less damage. For this being less worrying for stakeholders.

Chart 2- Hydrological Pressure (Flash Floods)

Hydrologic pressure	It's worrying? 1 - Nothing 2 - A little 3 - Very	Occurrence 0 - Never occurred 1 - Some occurrences 2 - Almost every year 3 - Several times a year	Affected Areas 1 - Streets 2 - Neighborhood 3 - City (s) 4 - Watershed
Flash flood Typical overflow of small and mountainous rivers. Minutes or a few hours to graduate.	f = 3 **f = 10** f = 9	f = 1 **f =13** f = 6 f = 2	f = 5 **f = 11** f = 4 f = 2

In the Chart 3, the results indicate that the stakeholders are very worrying with urban floods, have some occurrences or almost every year (this answer is justified by the difference between the various regions of the state) and the most affected areas are the neighborhoods. In this case, responses may be affected by recent events in certain cities. This type of event can often cause major damage but is not as remembered as the great floods of rivers.

Chart 3- Hydrological Pressure (Urban Flooding)

Hydrologic pressure	It's worrying? 1 - Nothing 2 - A little 3 - Very	Occurrence 0 - Never occurred 1 - Some occurrences 2 - Almost every year 3 - Several times a year	Affected Areas 1 - Streets 2 - Neighborhood 3 - City (s) 4 - Watershed
Urban flooding Drainage system overflow in	f = 4	f = 3	f = 7

urban areas (streets and galleries). They form in minutes.	f = 8 **f = 10**	**f = 7** **f = 7** f = 5	**f = 9** f = 6 f = 0

In the case of catastrophic floods (Chart 4), the results indicate that, the stakeholders are not worrying. This is explained because for the most of them it never occurred and there are no dams with high risk in the region.

Chart 4- Hydrological Pressure (Catastrophic floods)

Hydrologic pressure	**It's worrying?** 1 - Nothing 2 - A little 3 - Very	**Occurrence** 0 - Never occurred 1 - Some occurrences 2 - Almost every year 3 - Several times a year	**Affected Areas** 1 - Streets 2 - Neighborhood 3 - City (s) 4 - Watershed
Catastrophic floods Generated by the disruption of structures such as dikes or dams. They form in minutes.	**f =11** f =6 f =5	**f =14** f =7 f =1 f =0	**f =10** f =2 f =4 f =6

In the case of severe and atypical droughts (Charts 5 an 6), the stakeholders are of little concern, have some occurrences and areas most affected are watersheds. Even with the severe drought that hit the region in 2014 and 2015, and some atypical droughts in recent years, there is still no major concern about the possibility of new occurrences.

Chart 5- Hydrological Pressure (Severe Droughts)

Hydrologic pressure	**It's worrying?** 1 - Nothing 2 - A little 3 - Very	**Occurrence** 0 - Never occurred 1 - Some occurrences 2 - Almost every year 3 - Several times a year	**Affected Areas** 1 - Streets 2 - Neighborhood 3 - City (s) 4 - Watershed
Severe droughts They extend for consecutive years.	f = 5 **f = 10** f = 7	f = 6 **f = 12** f = 4 f = 0	f = 4 f = 1 f = 2 **f = 15**

In the case of atypical droughts (Chart 6), the results indicate that the stakeholders, atypical droughts are of little concern, have some occurrences and the most affected areas are watersheds.

Chart 6 - Hydrological Pressure (Atypical Droughts)

Hydrologic pressure	**It's worrying?** 1 - Nothing 2 - A little 3 - Very	**Occurrence** 0 - Never occurred 1 - Some occurrences 2 - Almost every year 3 - Several times a year	**Affected Areas** 1 - Streets 2 - Neighborhood 3 - City (s) 4 - Watershed
Atypical Droughts Longer dry period within the year.	f = 3 **f = 11** f = 8	f = 3 **f = 14** f = 5 f = 0	f = 3 f = 1 f = 5 **f = 13**

- Worsening hydrological pressures

Still in the first question of the questionnaire, it was asked if the pressures were getting worse, the available answers were yes or no. For “yes” answers the value “1” was assigned and for the “no” answers the value assigned was “0”. The results obtained can be visualized in the graph (Figure 6) below.

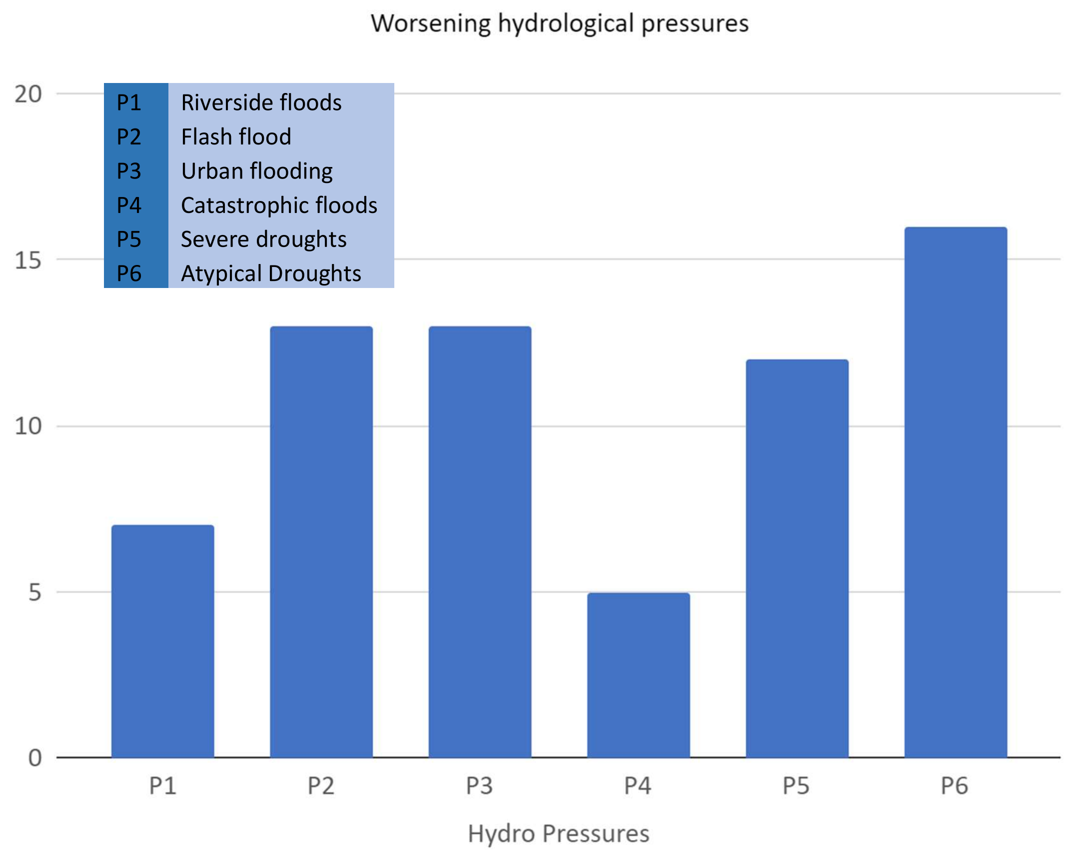


Figure 6- Worsening pressures according to stakeholder perception.

The pressure that suffered the most according to respondents' perception was atypical droughts (p6), followed by rapid floods (p2) and urban flooding (p3).

- Sectors most affected by hydrological pressures in the region

In order to reach the perception of the sectors most affected by hydrological pressures, it was added the occurrence of how many times the sector was listed by the interviewees. That is, each time the sector was marked by one of the stakeholders, the value 1 was added to the spreadsheet, resulting in the following results (Figure 7).

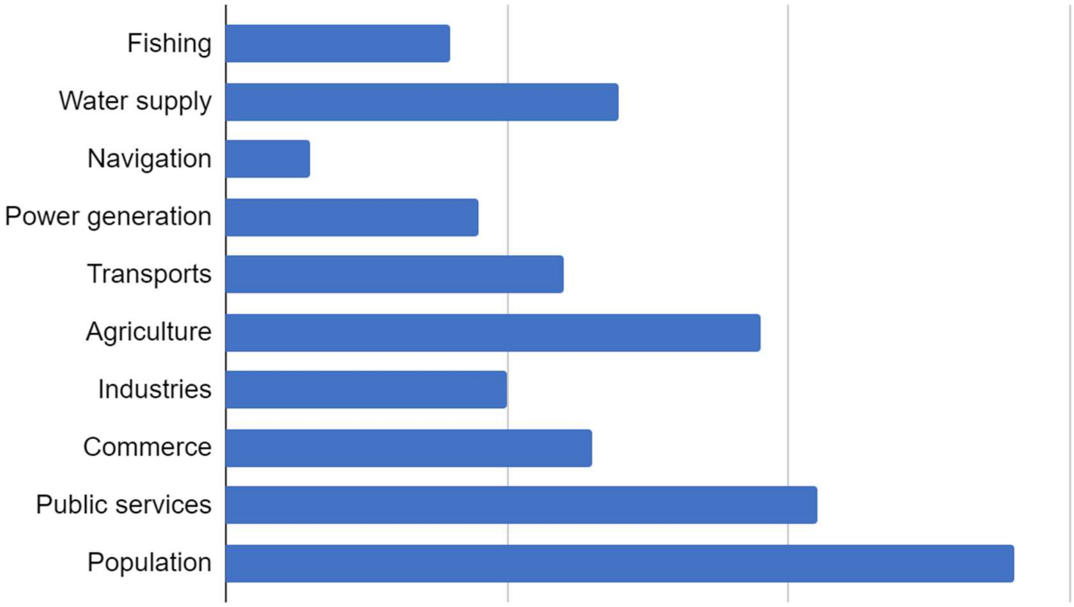


Figure 7- Sectors most affected by hydrological pressures in the region according to stakeholder perception, 2019.

As can be seen, the sectors most affected by hydrological pressures are respectively population, utilities, agriculture, water supply, transport, trade, industry, power generation, fishing and shipping.

These data show that information about hydrological pressures should be provided to the most affected groups, mainly: population, public services and agriculture.

In addition, the results dialogue with the literature on the subject, as is the case of the report presented by Rittl (2012) that pointed out that deaths, homelessness, agricultural losses, shortages, economic impacts and impacts on public health are the most common impacts of climate change.

- Major institutions making decisions related to hydrological pressures

Regarding the most important institutions that make decisions related to hydrological pressures, 6 respondents were provided with the following options:

Civil Defense / City Hall: It is characterized by the set of preventive, relief, assistance and reconstructive actions aimed at preventing or minimizing natural disasters and technological incidents, preserving the population's morale and restoring social normality of municipal cases;

IGAM: Minas Gerais Institute for Water Management, a state agency linked to the State Secretariat of Environment and Sustainable Development (SEMAD), being one of the instruments of decentralized water management in Brazil;

Fire brigade: These are corporations whose main mission is to perform civil defense, fire prevention and firefighting activities, search, rescue and public aid within their respective states;

Basin Committee: collegiate bodies where regional issues related to water management of a given territorial unit (river basin) are discussed;

CEMADEN: National Center for Monitoring and Alerts for Natural Disasters (Cemaden) is a nucleus responsible for the prevention and management of governmental action in the event of natural disasters occurring in Brazilian territory;

National Water Agency (ANA): This is a federal agency, linked to the Ministry of Regional Development, and responsible for implementing the management of Brazilian water resources.

With the options provided, respondents indicated the following institutions as the most important decision makers regarding hydrological pressures (Figure 8).

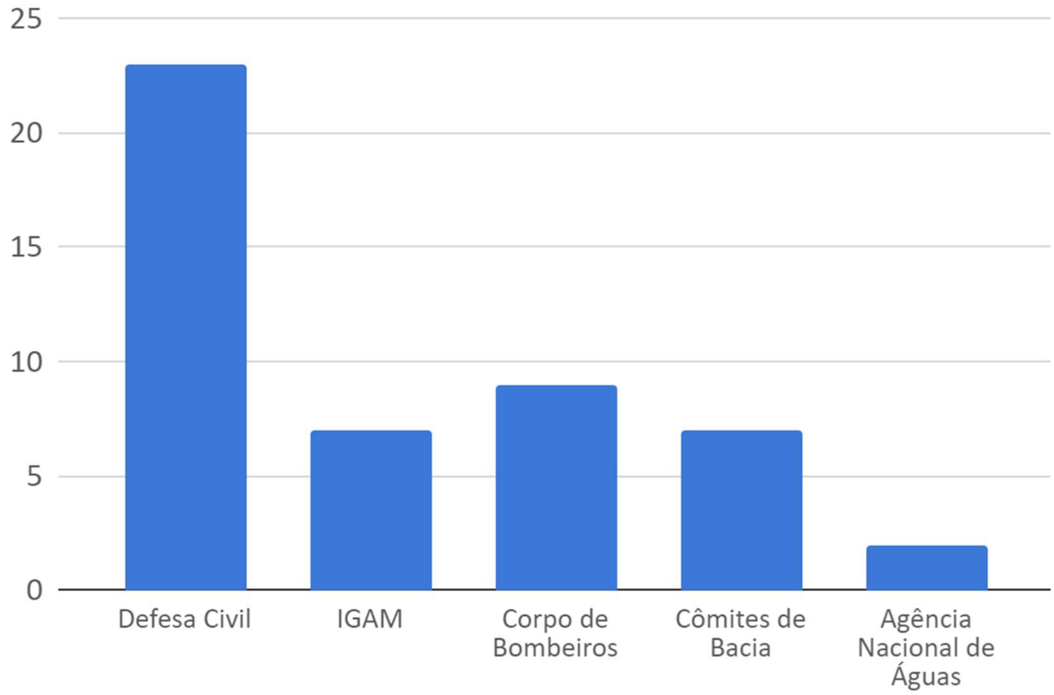


Figure 8- The most important institutions that make decisions related to hydrological pressures according to stakeholder perception, 2019.

It is then noted that the institutions that deserve greater attention in providing information on hydrological pressures in the region are civil defense, IGAM and the Fire Department, respectively.

The results show that all respondents marked civil defense as an important institution in decision making, the answers make sense, since this institution acts at the local level and in fact, is the main tool used by the Government when there is an extreme event. In line with the previous result, the CEMADEM option was not checked by the interviewees once again, which reiterates the knowledge on the subject, since such institution does not act locally when extreme events occur.

- *Actions being taken to minimize hydrological pressures and what actions could be taken*

As a way to facilitate the visualization of the results obtained on the actions that are and could be done to minimize the hydrological pressures, it was decided to present the data in a matrix (Table 2). Answers with the same meaning or information were put together.

Table 2- Actions that are and could be done to minimize hydrological pressures according to stakeholder perception.

Actions being taken	Actions that could be done
Construction of flood containment dikes in specific areas.	Urban planning in all cities.
Construction of dams in rural areas to prevent sediment transport.	Environmental awareness work (environmental education).
Water conservation projects.	Environmental data monitoring network.
Flood alert system.	Recovery of degraded areas.
Emergency action plans developed in the municipalities.	Improvement and expansion of sanitation services.
One-off measures at the local level, such as assistance to populations hit by extreme events.	Leadership training in critical regions.
Establishment of municipal environmental monitoring bodies	Disseminate the actions made to civil society.
	Improve integration between the various bodies interested in the topic.
	Sustainable practices that are in harmony with the environment (eg agroecology).
	Update of basin plans.

Based on the data obtained, it is evident that the project should act mainly in providing information on the subject and in the involvement of civil society, a fact that dialogues directly with the previously proposed objectives.

- Data or information they need for decision-making and currently lack

The question about what data or information stakeholders need for decision-making aimed to identify what their demands are and what information the project should then provide to them.

To facilitate the visualization of the results, we used the so-called "Cloud of Ideas", a methodology that aims to identify which are the most used words in a given speech. We first wrote down all the answers to this question in a Microsoft Word document, then used the "Pro Word Cloud" extension and the results are presented below (Figure 9a and 9b).

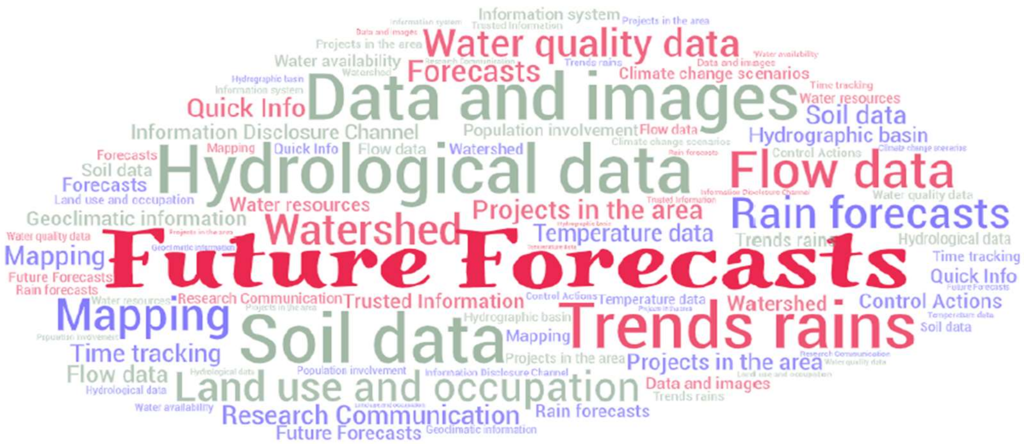


Figure 9- Idea Cloud (English) - data or information that you need for decision-making and currently do not have it.

In the cloud of ideas, the words in evidence were the ones that most appeared in the speeches, in this case, the responses of the stakeholders. Thus, future forecasts and hydrological data are the main demands raised by the interviewees.

- Most commonly used media for information on hydrological pressures

The present question about the media used to obtain information about hydrological pressures aimed to diagnose which strategies the project will use to give the information to the stakeholders. The most commonly used media are listed below in descending order.

1st news portals;

2nd Social Networks;

3rd News on TV;

4th Specialized Bulletins;

5th Congresses and events;

6th Articles and scientific journals;

7th Popular Knowledge.

Case study 4.4: Alagoas

Case study no. and name: Case Study 4.4 – Alagoas-Brazil
Time and place of workshop:
Participants (researchers):
Carlos Ruberto Fragoso Júnior, Carlos Ruberto, Universidade Federal de Alagoas
Wallisson Moreira de Carvalho, Wallisson, Universidade Federal de Alagoas
Denis Duda Costa, Denis, Lund University

Participants (stakeholders):
Hugo Augusto Farias, Hugo, Environmental and Water Resources Government Division
1st Lieutenant José Augusto de Moura Neves, Augusto, Civil Defense

Questions jointly discussed with the stakeholder group

What are the most important hydrological pressures, i.e. water-related risks, for economic and social development in your region?
Drought, floods and water security for the irrigation sector

Which "exposure units" (economic sectors, infrastructure, ecosystems, places, institutions, population groups) are (most) affected by these pressures?
Riverside population, trade market, infrastructure

At which time scales do these pressures act (multiday-season-multiannual-decade-century)?
Seasonal, interannual, decade

At which spatial scales do these pressures act (few km^2 to several tsd. km^2)?
Few km^2

What are the most important institutions in your region that make decisions related to the pressures listed above?
Environmental and Water Resources Government Division, Infrastructure Government Division, Agricultural Government Division, Civil Defense

Please indicate – if available – institutionalized response mechanisms that already exist in your region.
Since 2011 the Environmental and Water Resources Government Division has a Hydrological Alert Room which daily monitors the conditions related to the weather and climate during this period of rain in isolated points of the Coast and the Capital Metropolitan Region of the Alagoas State.

Please suggest other response options that would be adequate in your opinion but are not instutionalised yet.

1. Short-term flooding forecasting (from hours to days) with probabilistic flood maps;
2. Drought forecasting (from days to months) (e.g. alerts for water uses, alerts that can serve

as decision-making for mitigation of droughts - contracting well drilling and water trucks);

With respect to the pressures listed above, which critical information and/or services are currently lacking to support and inform decision- and policymaking?

1. Web system to flooding prediction;
2. Hydrological reports with alerts based on water level for droughts and floods;

What kind of models/tools are you currently using for decision-making?

1. Radar for monitoring precipitation in real time;
2. Atmospheric models for precipitation forecasting.

Case study 4.6: Western Norway

Case study no. and name: Case study 4.6 Western Norway
Time and place of workshop: Nov 1st, 2019, NIBIO offices, Bergen & Nov 13th, 2019, Norwegian Forest Owners' Federation offices, Oslo
Participants (researchers):
Beldring, Stein, NVE
Eisner, Stephanie, NIBIO

Participants (stakeholders):
Glad, Per Alve, Forum for Natural Hazards (Naturfareforum)
Kohlmann, Dirk, County Governor of Western Norway (Fylkesmannen i Vestland)
Villanger, Fredrik, BKK Produksjon AS
Sørlie, Hans Asbjørn, Norwegian Forest Owner Association (Norges Skogeierforbund)

Questions jointly discussed with the stakeholder group

1. What are the most important hydrological pressures, i.e. water-related risks, for economic and social development in your region?

<u>Example hydropower production</u>: Snow and glacier melt and precipitation type influence the seasonal variation of inflow to reservoirs.
<u>Example forestry</u>: More frequent summer droughts lead to water stress and potentially to reduced production and increased mortality.
<u>Example natural hazards:</u> Increased frequency of intense precipitation leads to more frequent flood and landslide events and damage to infrastructure and urban areas.

Hydrological Pressure	**Scale** 0 (not important) to 5 (very important)						
	0	1	2	3	4	5	No answer
More frequent extreme precipitation events							
➢ Flash floods in small catchments					• •	•	
➢ Triggering of landslides			•	•	•		
➢ Urban flooding					• •	•	
Increasing precipitation amounts							
➢ Forest road drainage			•		•		•
Changes in precipitation seasonality, more periods with very much/little precipitation							
➢ Drought stress in vegetation and increasing risk of bark beetle epidemics			• •				•
➢ Challenge for dimensioning and operation of reservoirs			• •			•	

2. Which "exposure units" (economic sectors, infrastructure, ecosystems, places, institutions, population groups) are (most) affected by these pressures?

Exposure unit	Scale 0 (not affected) to 5 (very affected)						
	0	1	2	3	4	5	No answer
(Re-)insurance sector					●	● ●	
Hydropower production				●		●	●
Municipalities					●	● ●	
Road authorities					●	● ●	
Forest owners and forest industry				●		●	●
Drinking water supply				●	●		●
More responsibilities for public administration				●	●	●	

3. At which time scales do these pressures act (multiday-season-multiannual-decade-century)?

Event time scale: hour to season
Time perspective: next 50 to 100 years

4. At which spatial scales do these pressures act (few km^2 to several 1000 km^2)?

Few km^2 to 100 km^2 (flooding and natural hazards) to several 1000 km^2 (drought damages and impacts)

5. What are the most important institutions in your region that make decisions related to the pressures listed above?

Ministry of Agriculture and Food
Norwegian Water Resources and Energy Directorate
The Norwegian Directorate for Civil Protection
Ministry for Justice and Public Security
Ministry of Climate and Environment
Norwegian Environment Agency
The County Governor

6. Please indicate – if available – institutionalised response mechanisms that already exist in your region. *Example: "Climate factor" in the Planning and Building Act.*

Plan and building act
Awareness zones
Water resources act
Several acts for hydropower production (Vannfallrettighetsloven, …)
Guidelines published by the respective directorates
Operational forecasting system
Forestry act

7. Please suggest other response options that would be adequate in your opinion but are not instutionalised yet.

Forest sector:

- Consulting/advisors for the municipalities
- Annual harvest plans
- Duty to notify planned harvest
- General strategic planning
- action plan to prevent secondary damage from insects

«Climate factor»

- 0, 20 or 40% increase on present-day 200-yr design values
- Recommendation, but not mandatory by now

8. With respect to the pressures listed above, which critical information and/or services are currently lacking to support and inform decision- and policymaking?

- Decision support system for multi-reservoir systems (flood)
- Regular communication meetings among hydropower providers
- Guidelines for clear-cutting
- Revision of subsidy system for harvest
- Lack of models that combines the effects of hydrological pressure and forest development/forest vitality at a larger scale (models that could predict what forest structures (age, tree species, managed or unmanaged) that at a landscape scale could be resilient to drought and potential secondary outbreaks of pathogenic insects as a result of climate change)

9. What kind of models/tools are you currently using for decision-making?

- Event-based rainfall runoff model (PQRUT) and national methods flood frequency analysis
- HBV-based system for the hydropower sector
- Operational flood forecasting and land slide risk systems
- Risk zone mapping for natural hazards and flooding
- No model tools relevant for hydrologic pressure is used for operational planning in forestry

Case-study specific questions discussed with the stakeholder group

What can GHP provide/produce (tools, knowledge) in addition to what we already know?

-> Very sector dependent question

APPENDIX C

Stakeholder profiles

Case study 4.1: Malmö

Stakeholder 1 Official name: VA SYD Responsible person: Susanne Steen Kronborg (suggestion) Type of institution (public/private, sector): water utility company (public) At which level does your institution operate? ▪ local ▪ regional □ national □ international □ hydrologic basin □ other What are your institutions main fields of activity and/or business? Public water supply and urban drainage. Public waste management. What are your institution's interests in the GlobalHydroPressure project? More knowledge on design events for pluvial flooding. Climate projections for urban scale.
Stakeholder 2 Official name: Malmö stad (City of Malmö) Responsible person: Pär Svensson (suggestion) Type of institution (public/private, sector): Municipality At which level does your institution operate? ▪ local □ regional □ national □ international □ hydrologic basin □ other What are your institutions main fields of activity and/or business? All municipal tasks, including urban planning. What are your institution's interests in the GlobalHydroPressure project? Follow research on climate change effects and adaptation.

Stakeholder 3

Official name: Länsstyrelsen Skåne (County board for Scania)

Responsible person: Pär Persson (suggestion)

Type of institution (public/private, sector): Government agency in the county of Scania

At which level does your institution operate?

□ local ▪ regional □ national □ international □ hydrologic basin □ other

What are your institutions main fields of activity and/or business?

Coordinate implementation of national laws on regional level in a number of political areas. Among these areas are sustainable societal development, infrastructure and protection against disasters. They should also care about regional interests in relation to the government and parliament.

What are your institution's interests in the GlobalHydroPressure project?

Follow research on climate change effects and adaptation.

Case study 4.2: Southern Sweden

Stakeholder 1

Official name: Länsstyrelsen i Jönköpings Län (County Administrative Board of Jönköping)

Responsible person: Måns Lindell

Type of institution (public/private, sector): County Board

At which level does your institution operate?

□ local x regional □ national □ international □ hydrologic basin □ other

What are your institutions main fields of activity and/or business?

Monitoring and supervision of water-related activities at county level, including water management, drinking water supply and sewerage.

What are your institution's interests in the GlobalHydroPressure project?

Water plays a significant role for important sectors, e.g. forestry, agriculture, water supply, hydropower production, tourism and transport. As climate is changing, various types of hydrological pressures are expected to intensify. One example is water scarcity and drought. Even if the water availability in Sweden is good, in an international perspective, southern Sweden more and more often suffers from water scarcity and in 2017 experienced one of the worst droughts on record. There is a clear need for better decision support material, both on the relatively short term (months or seasons ahead) and on the long term (centuries ahead) for optimum water resources management in a future climate.

Case study 4.3: Minas Gerais

Stakeholder 1

Official name: *Sapucaí River Basin Committee – CBH Sapucaí*

Responsible person: *Aloisio Ferreira Caetano*

Type of institution (public/private, sector): *Public, water resources management*

At which level does your institution operate?

□ local □ regional □ national □ international x hydrologic basin □ other

What are your institutions main fields of activity and/or business?
The River Basin Committees are state bodies, needed to discuss, plan, articulate and propose solutions to the environmental problems of a given geographical unit - in this case, the Sapucaí river basin. It is made up of public authorities, users, and, through Participatory Management, also civil society. Has a decentralized and broad perception on the subject, because the people who make up civil society have local experiences and perceptions of the issues and an internal view of the basin (fragmented), while the members with technical training of the Committee have a more distant external view. of the problems and potentialities of water, have a technical and sometimes more objective formation. Together they bring the commitment to sustainable development of the river basin.

What are your institution's interests in the GlobalHydroPressure project?
Project outcomes may generate tools that will improve water resource management in the watershed, particularly in managing extreme events.

Stakeholder 2

Official name: *Itajubá City Hall*

Responsible person: *Ricardo Augusto Corrêa Ferreira*

Type of institution (public/private, sector): *Public*

At which level does your institution operate?

x local □ regional □ national □ international □ hydrologic basin □ other

What are your institutions main fields of activity and/or business?
Meet the needs of the community through efficient and effective work, using the commitment, education and all available resources to achieve development.
The public administration aims primarily at economic and social development, maintaining the municipality of Itajubá with the best quality of life in southern Minas Gerais.
What are your institution's interests in the GlobalHydroPressure project?
The project will assist Itajubá Civil Defense in mitigating the effects of extreme events in the municipality.

Stakeholder 3 Official name: *Delfim Moreira City Hall* Responsible person: *Juliane Coura* Type of institution (public/private, sector): *Public* At which level does your institution operate? x local □ regional □ national □ international □ hydrologic basin □ other What are your institutions main fields of activity and/or business? *Meet the needs of the community through efficient and effective work, using the commitment, education and all available resources to achieve development.* What are your institution's interests in the GlobalHydroPressure project? *The project will help the city to better plan the city for possible climate changes.*
Stakeholder 4 Official name: *Minas Gerais Water Management Institute -IGAM* Responsible person: *Saulo Freire Crosland Guimarães* Type of institution (public/private, sector): *Public* At which level does your institution operate? □ local □ regional □ national □ international □ hydrologic basin x other (*Minas Gerais State*) What are your institutions main fields of activity and/or business? *The Minas Gerais Water Management Institute has the functions of planning and promoting actions aimed at preserving the quantity and quality of water resources in Minas Gerais. Management is based on the guidelines of the State Water Resources Plan and the Master Water Resources Plans. In addition, Igam is responsible for the methodologies that guide the granting of the right to use water, for monitoring the state's surface and groundwater quality, for research, programs and projects, and for disseminating consistent information on water resources, as well as as well as the consolidation of Watershed Committees - CBHs and Watershed Agencies, with a view to shared and decentralized management, involving all social segments.* What are your institution's interests in the GlobalHydroPressure project? *IGAM expects that the project will generate tools that will assist in decision-making on actions to mitigate extreme events in the state of Minas Gerais.*

Case study 4.4: Alagoas

Stakeholder 1

Official name: Environmental and Water Resources Government Division

Responsible person: Fernando Soares Pereira

Type of institution (public/private, sector): Public

At which level does your institution operate?

□ local x regional □ national □ international □ hydrologic basin □ other

What are your institutions main fields of activity and/or business?

We aim to implement and coordinate the Environmental and Water Resources policies of the State of Alagoas, in addition to directly executing the Water Resources management actions, exercising their supervision, articulating and integrating these policies with the respective regional and national policies.

What are your institution's interests in the GlobalHydroPressure project?

1. Short-term flooding forecasting (from hours to days) with probabilistic flood maps;
2. Drought forecasting (from days to months) (e.g. alerts for water uses, alerts that can serve as decision-making for mitigation of droughts - contracting well drilling and water trucks);
3. An agreement can be made in order to formalize the implementation of a decision support system for flooding management.

Stakeholder 2

Official name: Civil Defense of Alagoas State

Responsible person: Lieutenant Colonel Moisés Pereira de Melo

Type of institution (public/private, sector): public

At which level does your institution operate?

□ local x regional □ national □ international □ hydrologic basin □ other

What are your institutions main fields of activity and/or business?

To manage and prevent disasters and monitoring risks areas, in order to minimize their harmful effects, avoiding at all costs the occurrence of human losses.

What are your institution's interests in the GlobalHydroPressure project?

1. Hydrological reports with alerts based on water level for droughts and floods;

2. Web system to flooding prediction.

Case study 4.6: Western Norway

Stakeholder 1

Official name: Norwegian Forest Owners Association (Norges Skogeierforbund)

Responsible person: Hans Asbjørn Kårstad Sørlie

Type of institution (public/private, sector): Private sector

At which level does your institution operate?

□ local □ regional X national □ international □ hydrologic basin □ other

What are your institutions main fields of activity and/or business?
The Norwegian Forest Owners' Federation works with Forestry Policy, Climate Policy, Ownership Rights and other topics related to Forestry. We represent the forest owners' interests towards the government and other official authorities, politicians and media. We work closely together with other organisations engaged in the same topics, and together with the forest based industry.

What are your institution's interests in the GlobalHydroPressure project?
Forestry activities could influence hydrologic pressure with the temporal removal of tree biomass, which will influence retention and evapotranspiration and thus Hydrologic pressure. Forestry activities will in some areas influence probability and consequence of different types of avalanches. Forest infrastructure with permanent and temporary roads could also influence waterflow, catchment size and turbidity.

Hydrologic pressure could also influence forest productivity, especially in terms of drought events, with reduced production as a result. Forest drought could also lead to reduced defense against pathogenic insect and potentially epidemic outbreaks wit large economic an ecological consequences.

Stakeholder 2

Official name: BKK PRODUKSJON

Responsible person: Fredrik Villanger (project owner BKK P)

Type of institution (public/private, sector): Public owners

At which level does your institution operate?

X local X regional □ national □ international X hydrologic basin □ other

What are your institutions main fields of activity and/or business?
BKK Produksjon (BKK P) is the main hydro power producer in Vestland fylke and a developer of new hydro power projects in the same region. Our main goal is to manage the water resources in the best possible way with respect to:

- optimize the financial results
- reduce socio-economic costs (reduce costs from floods, etc)
- secure supply needs. (Typical save storage for dry periods)

What are your institution’s interests in the GlobalHydroPressure project?
All changes in hydrological pressure will change our decision strategies to obtain our main goal mentioned above. BKK P is interested in changes in near future (and changes seen already today) as well as changes in the long run. BKK P invest in power plants with horizon up to 100 hundred years. Changes in length of dry or wet periods, changes in flash-floods, changes in glaciers run-off, seasonal changes etc. is of the same importance as the changes in the average yearly run-off.

Stakeholder 3

Official name: Naturfareforum

Responsible person: Per Alve Glad

Type of institution (public/private, sector): Public

At which level does your institution operate?

X local **X** regional **X** national □ international **X** hydrologic basin □ other

What are your institutions main fields of activity and/or business?
Naturfareforum is a collaboration between between several Norwegian authorities that to more or less extent have overlapping challenges in connection to natural hazards. The main partners are Norwegian Water Resources & Energy Directorate, Norwegian Road Authorities, Norwegian Railroad Authorities, The Norwegian Meteorological Institute, The Norwegian Directorate for Civil Protection, The Collaboration of Norwegian Municipalities, Norwegian Agricultural Agency, Norwegian Environment Agency. The main task of Naturfareforum is:

- to induce collaboration on all levels to reduce vulnerabilty for unwated natural events (largely due to hydrological extremes)
- to initiate and start up projects that target challenges that are especially overlapping (to avoid duplicate work and conflicting advice)
- to identify areas of short comings or clear points of improvements in connection to societies prevention and handling of natural hazards and advice how to improve

What are your institution’s interests in the GlobalHydroPressure project?
Naturfareforum is mostly concerned with hydrological extremes and any DSIs (Decision Support Indicators) that can be developed within the fields of floods or droughts will be of interest. Within flooding especially Naturfareforum will have a large range interests as we are concerned with everything from floods in large regulated river basins to flash floods in small catchments and urban areas. The effect of climate change on the hydrology in Norway is also very important to the various authorities represented in the Naturfareforum. Effects of land use change on hydrology, example deforestation & urbanization, are also points of interest.

Stakeholder 4

Official name: Fylkesmannen i Vestland

Responsible person: Dirk Kohlmann

Type of institution (public/private, sector):

Public administration

At which level does your institution operate?

□ local X regional □ national □ international □ hydrologic basin □ other

What are your institutions main fields of activity and/or business?
Planning and administrative authority, including county forest planning and designation of protective forests
Consulting function for municipalities

What are your institution's interests in the GlobalHydroPressure project?

- Use project results to Adjust administrative and planning routines
- Thematically incorporate natural hazard protection into general and municipal land use and forest planning
- Proof-of-concept through case studies
- Develop courses for municipalities and land owners