Workshop on changes in water resources and adaptation options in the Indian-Himalayan basins

Workshop Report

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Executive summary

This report summarized the first workshop within the WaterRain-Him project on changes in water resources and adaptation options in the Indian-Himalayan basins, The workshop took place on November 16th and 17th, 2015 at the National Institute of Hydrology, Roorkee, Uttarakhand, including participants from international, national, regional and local actors from different sectors directly or indirectly affected by changing patterns of the Ganga basin hydrology due to climate change, as well as scientists from India, Sweden and the U.K.

The two-day workshop was entitled “Changes in Water Resources and Adaptation options in the Indian Himalayan basins” with special emphasis to the upper Ganges region and gave various stakeholders in the upper Ganga River basin the opportunity to: 1) gain a better understanding of the impacts of a changing climate on hydrology in the region, 2) provide input and feedback to modellers to ensure that hydrological modelling results are useful for local decision makers and communities, and 3) discuss in direct exchange with researchers potential measures for sustainable water resources management in light of already existing management plans (e.g. Uttarakhand State Action Plan on Climate Change (SAPCC) and the Uttarakhand Disaster Management plans).

The workshop participants identified a number of key areas for researchers to improve results and ensure more policy and locally relevant project outcomes. For example, to ensure the confidence in the model for the policy makers and the planners, link research with planning of water resources and make results accessible to policy makers. A continuous dialogue between modeller and stakeholder should be mandatory to ensure understanding of results and implementation of mitigation measures.

The stakeholders also identified a number of important adaptation options for tackling climate change in the Uttarakhand region; early warning systems, bridging gaps between science, policy and stakeholders, planning for disasters and extreme events and provide necessary infrastructure and resources to identify and tackle impact.

The development of adaptation strategies and their implementation will be further discussed in the second workshop within the WaterRain-Him project.

1. Introduction

The Indian Himalayan-fed basins pose extraordinary scientific challenges with respect to understanding, quantifying and predicting availability of water resources. Changes in the climate are already present, at the same time as the region is experiencing land use changes and water exploitation at an unprecedented scale. To improve the understanding of the basins and the potential impacts due to environmental and societal change, the “WaterRain-Him: Changes in Water Resources and Adaptation options in the Indian-Himalayan basins” project, funded by the Swedish Research Council, is currently conducting large scale hydrological modelling for present climate and future scenarios in the region. The modelling exercise is partly informed by the needs of stakeholders representing various water end-users in the region, as identified in direct communication between modellers and these stakeholders (e.g. in the workshop this report is summarizing).

The WaterRain-Him project aims to assess the impact of climate change, land use and population dynamics on water fluxes in the Indian-Himalayan basins. Based on modelling exercises and in-depth end-user dialogs, robust and holistic adaptation strategies are being developed to drive planning for efficient water resource management for food security and poverty alleviation. The main motivation of the project is the understanding and reduction of environmental impacts on these water resources at the local and regional scale. Impacts are amplified where various changes are taking place at the same time, e.g. population increase, climate and land use change, and are most visible and detrimental for the hydropower and agriculture sectors. Throughout the project, a continuous dialogue will be held between stakeholders and modellers, to ensure a joint learning process, that information and results generated by the modelling team is relevant to stakeholders and identification of stakeholder relevant adaptation and mitigation options.

The project runs over 3 years until December 2017 and engages four project partners: Swedish Meteorological and Hydrological Institute (SMHI), Stockholm Environment Institute (SEI), National Institute of Hydrology (NIH) and India Institute of Technology (IIT Delhi). WaterRain-Him ultimately aims to contribute to the development of national and state action plans on water resource management under changing environmental conditions in the India-Himalayan basin. The WaterRain-Him project is organized according to the flow chart in Figure 1.

In order to achieve the linkage between the hydrological modellers and stakeholders focusing on the various aspects of water resource management in the Ganga river basin – i.e. to bridge science and policy -, two international workshops will be held during the lifespan of the project. The first workshop took place on November 16th and 17th, 2015 at the National Institute of Hydrology, Roorkee, Uttarakhand. 19 participants and seven organizers attended the event, including international, national, regional and local actors from different sectors directly or indirectly affected by changing patterns of the Ganga basin hydrology due to climate change, as well as scientists from India, Sweden and the U.K.

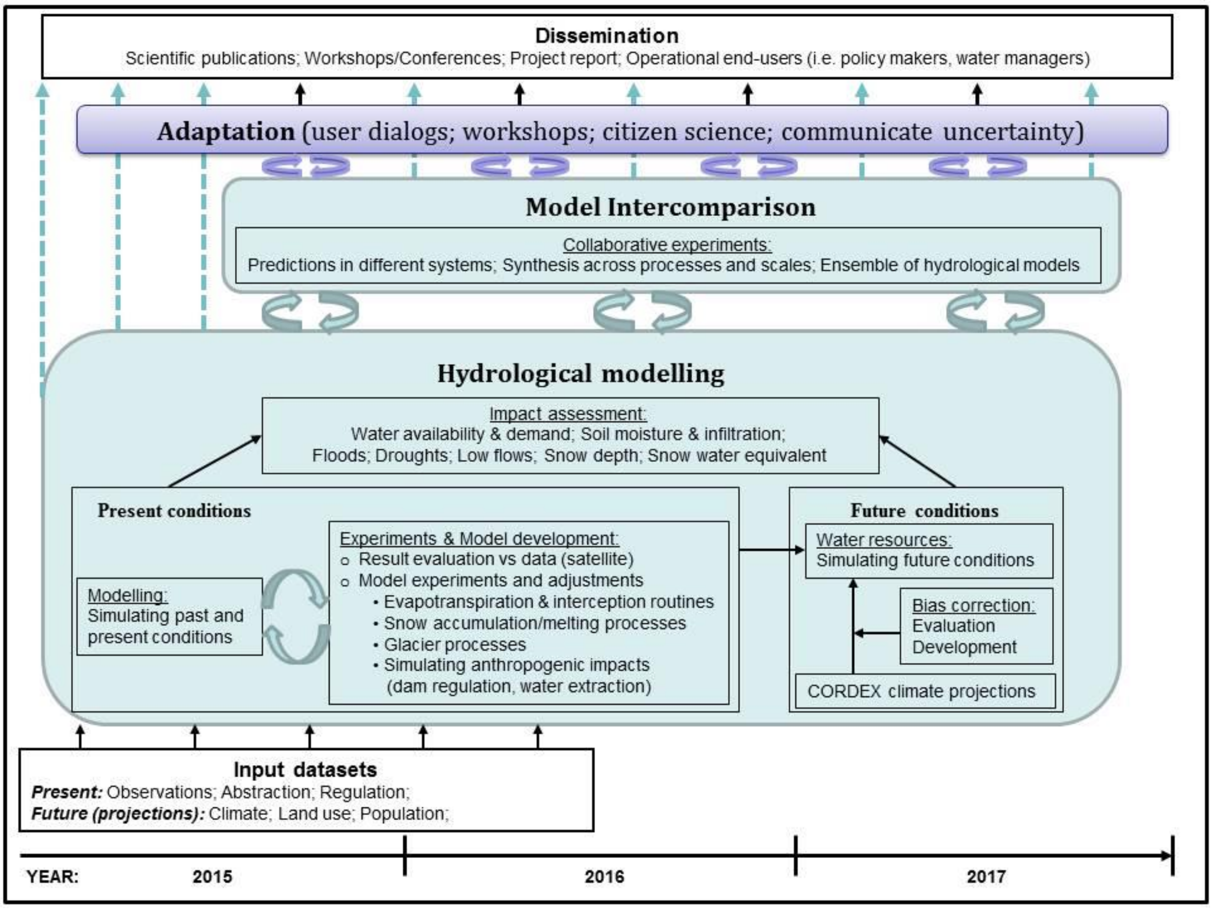

Figure 1: Methodology framework for the WaterRain-Him project.

The two-day workshop, which was organized in a number of plenary sessions and break-out group discussions, was entitled "Changes in Water Resources and Adaptation options in the Indian Himalayan basins" with special emphasis to the upper Ganges region and gave various stakeholders in the upper Ganga River basin the opportunity to: 1) gain a better understanding of the impacts of a changing climate on hydrology in the region, 2) provide input and feedback to modellers to ensure that hydrological modelling results are useful for local decision makers and communities, and 3) discuss in direct exchange with researchers potential measures for sustainable water resources management in light of already existing management plans (e.g. Uttarakhand State Action Plan on Climate Change (SAPCC) and the Uttarakhand Disaster Management plans).

In this report, we summarise the findings and point towards methods for water management adaptation to a changing climate as informed by the outcome of the workshop discussions.

2. Stakeholder identification

The present workshop was the first out of two workshops proposed within the WaterRain-Him project. The second workshop is scheduled for 2017 and will include the entire Indian Himalayan region, focusing more on adaptation options and include stakeholders from all over the country. This initial workshop focused primarily on the upper Ganges region with local stakeholders and was selected to be held in Roorkee, Uttarakhand. The Upper Ganges region was selected for various reasons. First, it contains the head waters of the Ganges River and has a huge hydropower potential for the country. Being a perennial river, Ganges is very important for water supply for various purposes in the flood plain region, mainly irrigation as it forms the major livelihood of the people in this region. Therefore, it was prudent to consider the upper Ganges as based on the criteria of being directly affected by changes in water flows in the Ganga region as a consequence of climate change.

Stakeholders were identified to represent multiple key actor groups in the region with regard to water resources and climate change; e.g. irrigation practices, the forestry sector, hill roads infrastructure officers and disaster management, environment and livelihood agencies. We identified a number of government agencies, local municipalities and development institutes and private actors in the region to identify suitable stakeholder representatives and strived to achieve a balance between the key actor groups Stakeholders were grouped into categories of academia, research and development institutes, local and regional government, the public sector and representatives from non-governmental organizations (NGOs). We aimed to have an even distribution of participants between all groups; however, we had a small over-representation of the government sector and NGOs were under-represented. For a full list of workshop participants see in Appendix 2.

3. Outcomes from numerical experiments

The workshop plenary sessions were mainly focussing on presenting results of numerical hydrological modelling experiments related to the WaterRain-Him project and are summarized in the following chapter. The presented findings are the result of a number of projects related to the WaterRain-Him; the CORDEX project, the HighNoon project and numerous projects of the National Institute of Hydrology.

3.1. Changes in long-term fluxes

Results on long-term changes for different time periods on hydro-climatic fluxes, floods and droughts have been produced for the reference period 1976-2005 and the transient/future period 2006-2099 have been produced within the CORDEX-South Asia initiative (Giorgi et al., 2009), applied in several basins. The CORDEX results presented at the workshop show how much precipitation patterns will change for three different future time periods (early-, mid-, and end-century). For the upper Ganga basin, consistent (based on different emission scenarios; RCPs) increases in precipitation can be identified by the end of the century (see Figure 2). The change in specific runoff shows a relatively large variation depending on the emission scenario: for example, a decrease under RCP2.6 can be seen, while the runoff increases for the other scenarios. Changes in snow patterns indicate that increasing temperature will decrease snow depths. Moreover, with high flows there comes an increased risk of flooding in the region in the future.

The CORDEX project generates a number of key conclusions about climate change impacts in the Uttarakhand region where most workshop participants are active. For example, that the distribution of change varies in space, depending on the climate change scenarios and time horizon. Another key finding is that the precipitation in the Uttarakhand region will change between 5-20 percent and evapotranspiration changes will be within the same range and runoff patterns indicate high spatial variability, up to 40-50 percent increase over scenarios during the mid-century and towards the end of the century. Moreover, snow depth reduction was detected to be up to 40 % and high flows change by around 40 % under the extreme scenarios. Drought projections predict a higher frequency of moderate and severe wet and dry years as well as changes in return periods are expected, but there is no clear pattern. Finally, trends in high flow show a significant increase towards the end of the century for extreme scenarios and there will be less “normal years” in the future.

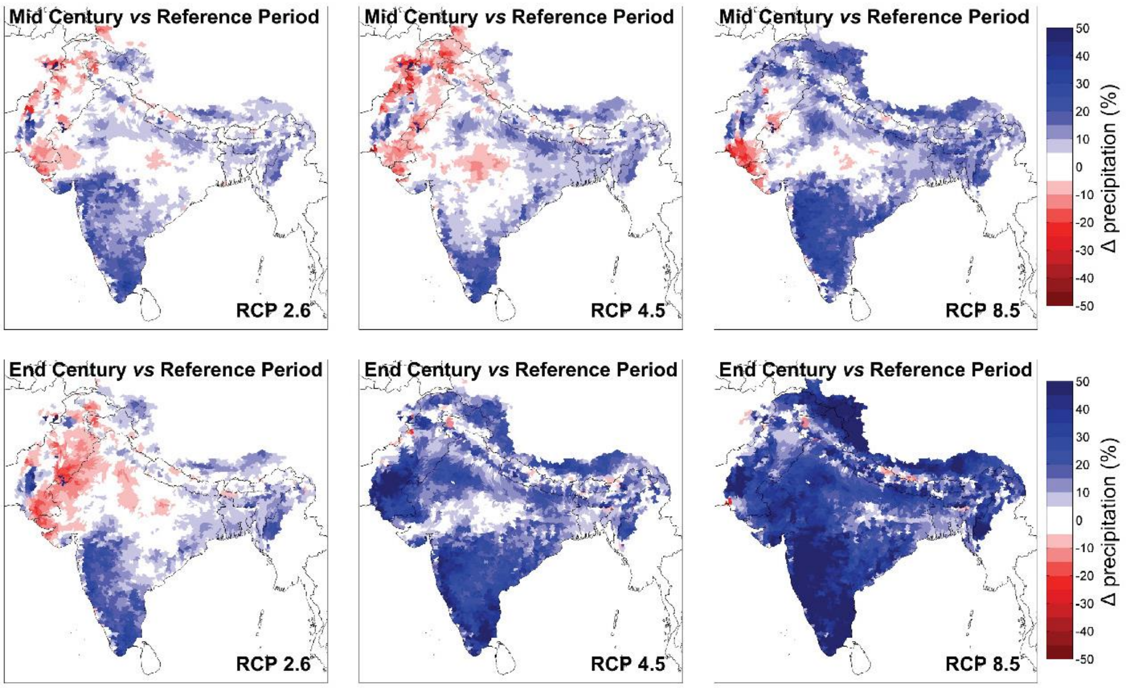

Figure 2: Relative change in precipitation for each climate projection (different RCP scenarios; columns 1-3) and period (top and bottom row for mid- and end-century respectively) (Pechlivanidis et al., 2016).

With common objectives to WaterRain-Him, the HighNoon project aimed, among others, to predict the implications of changing the mid-term and end-century climate scenario projections. The HighNoon project is a European Union project using the physically based SWAT hydrological model to predict climate change impact in the Ganga basin (Eddy et al., 2011; Siderius et al., 2013).. Results clearly indicate that runoff in the Ganga basin will increase in the future, and especially towards the end of the century. Moreover, precipitation will increase but water stress is still expected to increase as a result of a precipitation pattern with more extreme rainfall events rather than an evenly distributed rainfall throughout the year. Finally, some reduction in the water stress level is expected by the end of the century.

3.2. Change in hydro-climatic extremes

Climatic extremes were analysed and presented based on the Standardized Precipitation Index (SPI). Because SPI is normalised, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI. Analysis of meteorological extremes using the SPI showed that the frequency of occurrence of severe and extreme years (both wet and dry) will increase in the future (Figure 3a-c).

Hydrological extremes were next analysed based on discharge return periods. Analysis of flood return periods also showed that the magnitude of flow will increase in the future; e.g. a 10 year event in the present climate will be equal to a 7 year event in the future climate (Figure 3d).

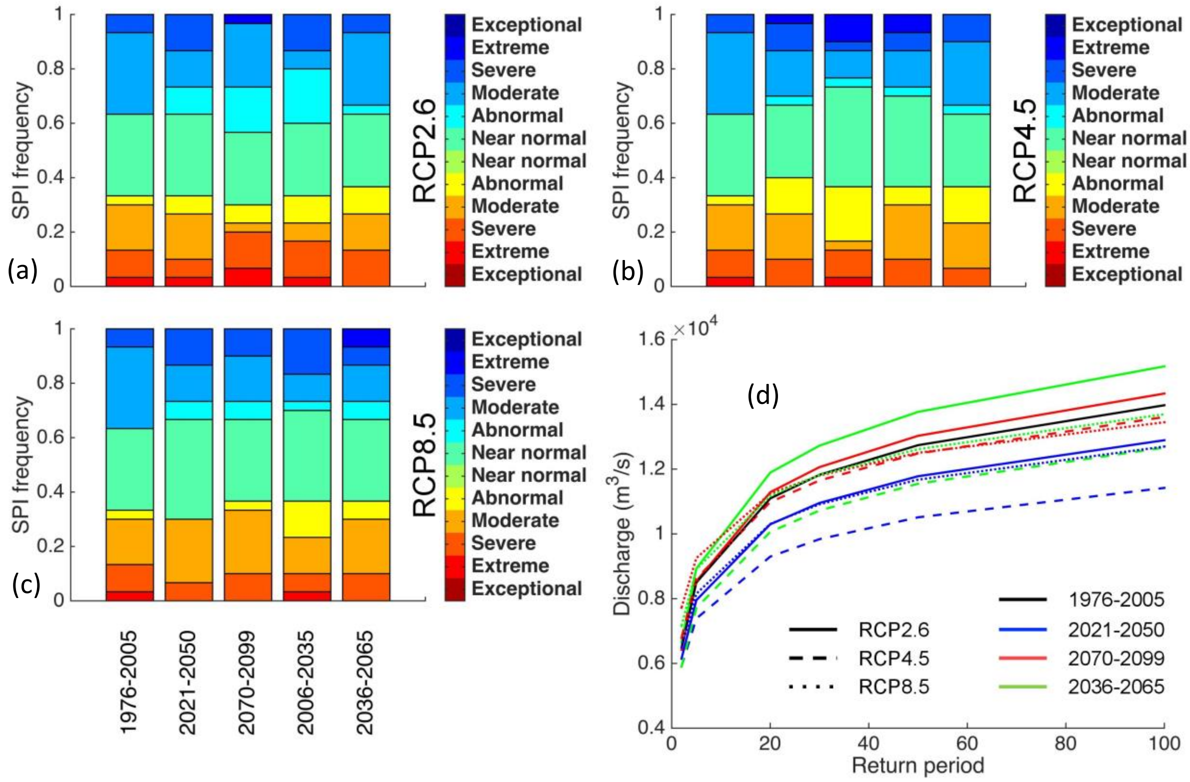

Figure 3: Hydrological drought analysis based on the Standardised Precipitation Index (SPI) for: (a) RCP2.6, (b) RCP4.5, and (c) RCP8.5. (d) Discharge return periods for different time horizons and RCP scenarios.

3.3. Changes in the Himalayan region

Based on previous research from the National Institute of Hydrology (NIH) on the three trans-boundary Himalayan river systems of India presented at the workshop, glacier- and snow-melting contribute largely to the river flows in the Himalayan region. Thus, it is necessary to estimate the snowmelt contribution of the three Himalayan river systems, i.e., Indus, Ganges and Brahmaputra. Moreover, the rate, volume and timing of snow melt are likely to change due to climate change, therefore, impact of climate change on the snowmelt runoff and total streamflow of the large Himalayan rivers require further research. Some studies related to snowmelt runoff modelling and impact of climate change in various sub-basins of the three river systems have been carried out by NIH in the past (Singh & Jain, 2003; Jain et al, 2011; Sarkar, 2015; Soni et al, 2015). However, the studies are limited to hypothetical scenarios of climate change. There is a large knowledge gap around the effects of glacier and snow melt in the region calling for increased attention, resources and measures to predict and prevent negative impacts on river flows.

3.4. Future directions

Integrated water resource development and management frameworks are required in order to deal with the expected climate change induced impacts in the region. Further, increased sharing of knowledge and information is essential for the sustainable use of water resources and selection of suitable adaptation options to climate change impacts. However it is problematic to set a baseline for the Ganga river basin, and issues of how the baseline is set must be considered for future modelling studies in the region.

Among various objectives, the WaterRain-Him project contributes to research-driven policy development related to water resource management in the Ganga region, the following steps have been identified to narrow the gap between science and policy making in the region:

- Frameworks for water management and planning at local level should be continuously updated and information should be accessible to stakeholders, end-users and policy and decision makers.
- Provision of a reliable baseline to investigate the present stress conditions for groundwater resources
- Translate how all stakeholders are currently using water resources, as well as their expected needs.

Finally, the question is whether or not it is possible to identify and decide on sustainable policies for water resource management in the region, satisfying all stakeholders and user needs. The discussion with the stakeholders during the workshop also pointed towards the lack of available scientific solutions, e.g. adaptation and mitigation options, to tackle climate change and its impact on water resource use, specifically developed and implemented in the Ganga River and in the Himalayan-fed basins. This is likely due to the rivers' trans-boundary nature, inaccessible terrain (highly steep), and publically unavailable network of gauging stations/sites.

4. Description of the interactive group discussions

4.1. Objectives and implementation

In addition to the plenary sessions of the workshop, which mainly addressed the outcome of the hydrological modelling exercises (see Chapter 3), various break-out group discussions were set up to stimulate and encourage discussion amongst stakeholders and between stakeholders and hydrological modellers. These discussions were aimed at giving stakeholders the possibility to provide direct feedback to the attendant scientists on modelling results and spark an exchange of ideas for desirable future developments of the model campaigns to make them more useful for the key stakeholders in the target region. In addition, the exchange of views on presented project results between stakeholders was encouraged.

Each of the two breakout sessions had three breakout groups that were chaired by scientists from SEI and SMHI as well as note-takers from NIH. Each group consisted of 8-9 participants, with an even distribution from the different stakeholder groups, i.e. academia, R&D institutes, local and regional government, the public sector and NGOs. The results of both breakout sessions were reported back to the plenary afterwards.

4.2. Outcomes

As a result of the break-out group discussions, a number of **outstanding data needs** were identified, e.g. that modelling results should provide spatial distribution of water to be most useful to stakeholders and policy and decision makers.

Stakeholders also **identified key concerns** in respect to water resource management, i.e. **water harvesting, water conservation, recycle and reuse, cleanliness of water bodies, availability of** (reallocation of) **water** (storages, e.g. snow and ice) under changing scenarios (land use and/or climate) and **efficient and effective water distribution systems**.

The most prominent request from stakeholders was that the **modelling results should be adapted to a more stakeholder relevant spatial scale**, and that results are validated at the same scale. This would enforce the trustworthiness of the results, as aspect that is of great importance to stakeholders. Workshop participants agreed that modelling results can play an imperative role in sustainable water resource management and planning for future climate change impacts in the region. Exchange of knowledge and dissemination of modelling results according to the water end users' needs and participatory modelling will also play an important role in order to achieve sustainable water resource use in the long term.

To prioritize needs and feedback, the stakeholders were asked to create a "wish-list" to identify their most important needs as addressed by the question "What is the most important thing to get out of the modelling in the project?"

Below is a shortlist of the points that were raised most frequently within the group:

- Ensure the confidence in the model for the policy makers and the planners.
- The model should also be able to show the impact of adaptation measures.
- Model validation is important to ensure stakeholder confidence in modelled results
- Link research with planning of water resources, which would be helpful for policymakers
- The model should not be restricted only to hydrological modelling but connect to atmospheric models, land-surface models and biophysical models and treat all modelled results as a single entry to achieve holistic results
- The model should be site specific and assess resource availability.
- The model should consider actual snow melt, surface and groundwater, recharge of groundwater and springs and other activities
- The model should be applicable and area specific.
- The model should be accessible to policy makers and the uncertainty should be acceptable to them to ensure confidence
- The process should be participatory. Continuous dialogue between modeller and stakeholder should be mandatory to ensure understanding of results and implementation of mitigation measures

The stakeholders also identified requirements for cross-sector adaptation strategies that should tackle the impact of environmental change on water resources in the upper Ganges region. The summary of the discussions in the break out groups are presented in Table 1. The participants were asked to rank the adaptation strategies according to their importance.

Table 1: Identified adaptation strategies ranked as "very important" or "important".

<table>
<tr><th></th><th colspan="2">Adaptation strategies</th></tr>
<tr><th></th><th>Very important</th><th>Important</th></tr>
<tr><td>Awareness raising</td><td>• Knowledge exchange
• Bridging gaps between science, policy and stakeholders
• Early warning systems
• Livelihood development programs (awareness generation programming)</td><td>• Participatory studies for preparation and awareness raising
• Learning from traditional water use management
• Creation of model villages focusing on; water conservation, water harvesting and best practices</td></tr>
</table>

Adaptation to changing weather patterns	• Maintaining ecosystems • Planning for disasters and extreme events	• Shifting to crops that can be cultivated in hilly regions • Stop pine nurseries that contribute to changing climate/weather and hydrological flows • Change of sowing time • Tackling increased population of animals (e.g. wild boars) that destroy fields and forests (as an effect of climate change) • Soil conservation • Tackle increased pest attacks as a result of changing climate, by e.g. using more pest resistant crop cultivars • Increase government aid for afforestation, cash crops, solar power etc. • Multiple cropping • Retain/ be less dependent on natural resources
Adaptation to floods and droughts	• Build structures for flood prevention and adaption • Develop and improve early-warning systems • Water storage capacity • Infrastructure development • Alternative crops/drought resistant crops	• Identify hotspots for extreme events • Increase slope stability • Strengthen and encourage water conservation • Develop disposal policies • EIA for interlinking basins • Network of measurement/monitoring stations • Alternative energy sources (e.g. solar/nuclear power)
Improving institutional capacity	• Improved monitoring through increased/improved instrumentation • Provide hydrological modelling outputs to policy makers and planners (and decision makers in general), including confidence measures • Check all current policies that already – often indirectly – link to climate change and its effects on water resources (e.g. state and national action plans • Coordination of all	• Provide solutions to people • Develop a centralized database over water resources and their status • Development and further implementation of water allocation policies/legislation • Provide and promote renewable energy

	implementation agencies • Resettlement policy	solutions • Disaster mitigation management committee (DMMC) • National disaster management force (NDMF)
Development and management of water resources	• Water harvesting	• Site suitability studies to inform building of new structures • Study historical hydro-meteorological data • Precision farming • Sedimentation studies • Water quality studies • Disposal policy • Polices for stopping deforestation and promoting afforestation

Stakeholders also identified focus areas for adaptation strategies, e.g. by improving institutional capacity, including integrated planning for extreme events at national and local level; provision of adequate financial support; building a comprehensive, robust and accessible database of the land use, demography and infrastructure along with current information on climate, weather, water resource structures etc. for accurate planning; establish a National Network of all knowledge- based institutions; provide insurance for reducing vulnerability to climate change by transferring or sharing risk; develop policy structures and implement them.

There was agreement that adaptation strategies should focus on knowledge exchange and increasing awareness among stakeholders, policy and decision makers as well as modellers. Capacity building is imperative and strategies should encourage community adaptation in water, flood and drought management. Prioritizing development and sustainable management of water resources, to enhance water storage capacity and increase water productivity, will be vital in order to tackle the expected climate change induced hydrological impacts in the upper Ganga basin.

5. Conclusions

The workshop on changes in water resources and adaptation options in the Indian-Himalayan basins was held at the National Institute of Hydrology in Roorkee and included a number of key stakeholders within the Uttarakhand region. The participants were discussing climate change and adaptation in the Himalaya basin and represented a number of important sectors in the region that will be greatly effect by, or deal with, impacts of climate change.

The atmosphere during the workshop was open and constructive and the participants were invited to provide feedback to project researchers to increase science-policy interaction and better communicate research results that is directly related to a variety of stakeholders. The modellers presented recent key findings about expected future climate-change induced impact in the Uttarakhand region, such as changes in snowmelt, increased run-off and precipitation, however also increased dry-spells and less “normal years” regarding rainfall and climatic conditions.

The workshop participants identified a number of key areas for researchers to improve results and ensure more policy and locally relevant project outcomes. For example, that one key feature is to ensure the confidence in the model for the policy makers and the planners. Moreover, to link research with planning of water resources and make results accessible to policy makers. A continuous dialogue between modeller and stakeholder should be mandatory to ensure understanding of results and implementation of mitigation measures.

The stakeholders also identified a number of important adaptation options for tackling climate change in the Uttarakhand region; early warning systems, bridging gaps between science, policy and stakeholders, planning for disasters and extreme events and provide necessary infrastructure and resources to identify and tackle impact.

The development of adaptation strategies and their implementation will be further discussed in the second workshop within the WaterRain-Him project.

Acknowledgements

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Appendix 1: Article

Need for climate change adaptation in the Indian-Himalayan region to secure water supplies

The capacity of the water storages will be affected due to climate change, impacting the hydrologic regime in low land areas. The Indian-Himalayan areas need to adapt to climate change securing sustainable development and combatting poverty.

The Himalayas have more snow and ice than anywhere else outside the poles, which makes this region with all its associated large river systems especially vulnerable to climate change and related impacts. Beside impacts on drinking water supplies and hydro-energy, those on agriculture are of major concern, given that the economy largely depends on agricultural production.

Researchers from SMHI, together with researchers from the National Institute of Hydrology (NIH), India, the Stockholm Environmental Institute (SEI), Sweden, and the Indian Institute of Technology (IIT Delhi), India, investigated the possible climate change impacts on local water availability with the aim to further link these findings to policies for promoting sustainable management of water resources.

Workshop for knowledge sharing

A two-day workshop in Roorkee, India, allowed project partners to disseminate knowledge to stakeholders and the scientific community, with a particular focus on the upper Ganges region. The workshop aimed to develop a solid foundation for locally important water management and adaptation options as well as formulation of integrated river basin development plans, to tackle future climatic conditions. Such information is useful in deciding water allocation and use, highlight areas of particular concern and prevent potential user conflicts in planning for sustainable and efficient water resources management for agriculture, industry, food security and poverty alleviation.

Photo 1: Workshop participants at the National Institute of Hydrology, India, in November 2015.

Changes in precipitation and hydro-climatic extremes

The presented results showed that, by the end of the century, Indian-Himalayas could be experiencing up to 40% changes in precipitation, evapotranspiration and runoff, while reductions are expected for snow depths. Hydro-climatic extremes will also be affected with increasing frequency of severe dry and wet years and also flood occurrences.

“The change is of roughly the same magnitude as in previous calculations for the region, highlighting the consistency in the expected changes in the hydrological regimes, and hence improving our confidence of taking important adaptation measures” says Ilias Pechlivanidis, a researcher in hydrology at SMHI and leader of the WaterRain-Him project.

New detailed hydrological projections

The WaterRain-Him project is one of the first of its kind in which researchers will assess the combined impacts from environmental change (climate, land use and population) on water resources and propose suitable adaptation measures. The project will make use of the new detailed regional climate simulations from the CORDEX-SA initiative over the Himalayas. The results will be compared with those of earlier studies of the region performed by other research groups and the WaterRain-Him project partners.

Patrick Büker, a researcher at SEI, remarked: “The project focuses on three large river systems, Indus, Ganges and Brahmaputra, using various environmental change projections and hydrological models. This means that we can incorporate a large range of hypotheses for future scenarios in the hydrological projections and identify the suitable adaptation measures considering the projected uncertainty.”

The key to environmental change adaptation

In a next step, SMHI's research staff are continuing their work together with Swedish and Indian researchers targeting climate adaptation linked with changed water balance and hydro-climatic extremes.

"Adaptation to a changed environment requires cross-sector cooperation at all levels of society. The local influence of actors involved in planning and decision-making is of course necessary, as well as considering regional and national demands for the consideration of climate variability," says Ylva Ran, Researcher at SEI.

Photo 2: The workshop organizing committee; from the left: Patrick Büker (SEI, York), Ilias Pechlivanidis (SMHI, Sweden), Ylva Ran (SEI, Sweden), Archana Sarkar (NIH, India), and A.K. Gosain (IIT Delhi, India).

Research method

Climate projections from the CORDEX South-Asia and other initiatives have been used to improve confidence in regional trends of hydro-climatic key variables and increase robustness in hydrological long term predictions. These projections were bias-corrected to be directly useful for assessing impacts at the regional and/or local scale and finally introduced into various hydrological models from SMHI, NIH and IIT Delhi to assess the impact of climate change on water resources in the Ganges basin.

Link to the news article at SMHI web portal:

http://www.smhi.se/en/research/research-news/need-for-climate-change-adaptation-in-the-indian-himalayan-region-to-secure-water-supplies-1.96786