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CHAPTER 3

ASSESSING THE HYDROLOGICAL IMPACTS OF CLIMATE CHANGE ON THE AMU DARYA RIVER, AFGHANISTAN

Ashutosh Mohanty, Manoranjan Mishra, Devesh Sharma and Mohammad Waheed Ibrahimzada

ABSTRACT

It is now established by the global scientific community that climate change is a hard reality but the changes are complex in nature and to a great extent uncertain. Global circulation models (GCMs) have made significant contributions to the theoretical understanding of potential climate impacts, but their shortcomings in terms of assessing climate impacts soon became apparent. GCMs demonstrate significant skill at the continental and hemispheric scales and incorporate a large proportion of the complexity of the global system. However, they are inherently unable to represent local subgrid-scale features and dynamics. The first generation approaches of climate change impact and vulnerability assessments are derived from GCMs downscaled to produce scenarios at regional and local scales, but since the downscaled models inherit the...
biases of their parent GCM, they produce a simplified version of local climate. Furthermore, their output is limited to changes in mean temperature, rainfall, and sea level. For this reason, hydrological modeling with GCM output is useful for assessing impacts. The hydrological response due to change in climate variables in the Amu Darya River Basin was investigated using the Soil and Water Assessment Tool (SWAT). The modeling results show that there is an increase in precipitation, maximum and minimum temperature, potential evapotranspiration, surface runoff, percolation, and water yields. The above methodology can be practiced in this region for conducting adaptation and mitigation assessments. This initial assessment will facilitate future simulation modeling applications using SWAT for the Amu Darya River Basin by including variables of local changes (e.g., population growth, deforestation) that directly affect the hydrology of the region.

**Keywords:** Climate change impact; hydrological modeling; SWAT; vulnerability assessment

**INTRODUCTION**

Increasing changes in climatic variables (e.g., precipitation, temperature, snow cover, sea level change) and circulation patterns (atmospheric and oceanic) worldwide over the past four decades have been found to be anthropogenic in nature resulting from increasing emissions of greenhouse gasses from human activity (IPCC, 2007). As a result, the scientific community has put to rest any lingering doubts about the validity of climatic change and significant attention has shifted to regional and local impacts. Of these, changes in hydrological regimes across the globe are of particular concern, having serious implications for both watershed process research and catchment management strategies. Increased evaporation (due to higher temperatures), combined with low rainfall, for instance, has the potential to affect associated runoff. This may cause the disappearance of streams and lakes in highlands – like the Himalayas and Tibetan Plateau – thereby reducing groundwater levels and degrading water quality through the concentration of pollutants. Such a situation is not foreign in developing countries such as Afghanistan where conflict, widespread poverty, and an array of other development challenges intersect with environmental
problems in a volatile mix. Knowledge of change in the hydrological cycle in this arid, high altitude, land-locked country in the Hindu Kush-Himalaya (HKH) region is crucial for the planning of adaptation activities. But, the ability to analyze the impact of climate change on hydrology in Afghanistan and to develop effective mitigation and adaptation strategies is limited due to endemic political instability in the region, weak formal and informal institutions, and lack of long-term time series of observed local climatic variables.

Climate modeling, however, requires plentiful data for making locally relevant projections, simulations, forecasts, and to evaluate uncertainties regarding future changes in climatic conditions. To date, the most credible tools available for simulating the impacts of global climate system change due to increasing greenhouse gases in an unstable country like Afghanistan are Global Circulation Models (GCMs). This method is able to simulate important climate variables at a global scale with good skill. Accordingly, the “first generation” of approaches to assess climate impacts, vulnerability, and adaptation were projections from GCMs downscaled to regional scenarios and local scales. Without appropriate downscaling, these GCMs are of limited value for providing local-scale information on impacts. Yet even downscaled GCMs are merely simplified versions of the climate of the locality, just limited to changes in mean temperature, rainfall, and sea level. Although classic GCMs have made significant contributions to the theoretical understanding of potential climate impacts, their deficiencies soon became apparent.

Beyond the top-down approach of GCMs, the “second generation” of climate impact modeling is a view from the grassroots level. Hydrological modeling is one way to achieve this (see Xu, 1999). But Afghanistan’s current situation of political and social instability juxtaposed with uncertainty of climate change impacts limits the capacity to fully understand the change in the region. Despite these barriers, hydrological models can serve as the first step toward understanding the impacts of climate change at the local scale. In this chapter, the “Soil and Water Assessment Tool” (SWAT) is used to model and analyze the impacts on the hydrological cycle in the Amu Darya River Basin of Afghanistan. SWAT can be used in vulnerable regions for developing adaptation and mitigation strategies. Although limited to land surface change, this kind of initial assessment will facilitate future simulation modeling application by including variables related to local social and environmental changes (e.g., population growth, deforestation) for impact assessments.
CASE STUDY

The impacts of climate change on water resources globally have been recently assessed by the Intergovernmental Panel on Climate Change (IPCC) (i.e., Bates, Kundzewicz, Wu, & Palutikof, 2008; IPCC, 2007). In general, intensification of the global hydrological cycle is expected, affecting both ground and surface water supplies for domestic and industrial uses, irrigation, hydropower generation, navigation, in-stream ecosystems, and water-based recreation. Increases in temperature will result in changes in evapotranspiration, soil moisture, and infiltration. Increased atmospheric CO₂, furthermore, is projected by all GCMs to lead to an increase in global mean precipitation. Changes in rainfall could affect water availability in soils, rivers, and lakes, with implications for domestic and industrial water supplies, hydropower generation, and agricultural productivity. Increased evapotranspiration enhances the water vapor content of the atmosphere and the greenhouse effect, leading to even higher global mean temperature. Land-use change will also play a key role in increased evapotranspiration. In sum, changes in temperature, precipitation and evapotranspiration affecting soil moisture, ground water recharge and runoff could intensify flooding and droughts in various parts of the world (Mirza & Ahmad, 2005). Due to the sensitivity of the hydrological system to warming, global climate change is one of the most pressing environment issues and development concerns of the 21st century (ibid.).

This global-scale assessment of climate change impacts creates the backdrop of the Amu Darya River Basin (Fig. 1), which is the case considered in this study. It only covers 14% of Afghanistan by area, but alone consists of more than half (57%) of the total annual water flow of the country. The Amu Darya is formed by three major source rivers: the Panj River, originating in Afghanistan from two tributaries: the Pamir and Wakhan Rivers; the Murghab River, also originating in Afghanistan and flowing into Lake Sarez in Tajikistan – below which it is called the Bartang River; and the Vakhsh River, originating in Kyrgyzstan (from the Kyzylsu River) as well as Tajikistan (Muksu River branch). On its way to the Aral Depression, only below the confluence of the Panj and Vakhsh rivers, the main stream is called Amu Darya. Below this point, it is joined from the north by the Yaksu and Karnifaghan rivers from Tajikistan, and the Surkhandarya River from Uzbekistan. And from the south, it is joined by the Kokcha and Kunduz rivers from Afghanistan.

The Amu Darya – the classical Oxus River – runs for 2,400 km and receives a large number of tributaries in Central Asia as presented above.
However, it dries up in the Turan Lowlands in Turkmenistan and Uzbekistan. The main reason for this is the excessive use of the water by irrigation for cotton production. Less than 20 years ago, the river ran as far as the Aral Sea. Today’s lack of inflow has been a major factor for the dramatic reduction in the surface area and volume of the Aral Sea, the world’s fourth largest lake as recently as 1960. Huge international efforts are presently being made by the UN, the World Bank and other donors to try to halt or improve the situation of the Aral Sea. Water availability in Amu Darya River Basin for multipurpose uses are mainly functions of valuable precipitation, evaporation, temperature, wind direction, solar radiation, and surface as well as groundwater resources which depend in turn on the amount and mean distribution (in time and space) of water recourses. Therefore, considering variations in precipitation and snow fall are the most significant parameters. Water has a very important role for socioeconomic activities and is essential to maintain agricultural productivity which is the mainstay of the economy of Afghanistan.
The land under cultivation in Afghanistan is limited by rugged and arid terrain. As a result, most agriculture is located on river banks and in flood plain valleys. In the north of Afghanistan rain-fed agriculture predominates, where temperatures are lower during the summer and precipitation is adequate in terms of amount and reliability. In the high mountains, although precipitation is adequate, the potential for cropping is nevertheless limited by the short frost-free season. In most locations of Afghanistan, cropping is impossible without irrigation. Most of the country’s population lives in rural areas, and more than 85% depend on agriculture and animal husbandry.

Three decades of conflict, war, growing poverty, and consecutive years of drought has forced some of the population to move from rural areas to cities. The unstable political and social situation combined with uncertainty due to growing climate variability has reduced the ability of rural populations in Afghanistan to cope with multiple social and environmental stressors. As a result, adaptation strategies are becoming more complex in Afghanistan and the broader HKH region from the individual and community to broader regional and state governance levels. To take water management as an example, managers must always navigate competing interests to reliably provide quality water to farms, businesses, and homes, while managing floods, protecting the environment, and complying with legal and regulatory requirements. Climate change demands this even more so as water availability in the Amu Darya Basin becomes more variable. Impacts are already visible in irrigation due to this. For instance, earlier snow melt leads to enhanced spring floods, but a shortage of water occurs in summer and early autumn, increasing the risk of water shortages particularly in years of drought. This exacerbates the already endemic water scarcity problem in this region (Glantz, 2002, 2005; Masood & Wasiq, 2004).

The Amu Darya River Basin is one of the most productive areas of Afghanistan, thus assessing future hydrological impacts of climate change in the basin is essential for identifying adaptation options. In this chapter, we use GCM projections to run a hydrological model in order to construct a picture of how climate change will impact the Amu Darya River and implicate the stakeholders of this critical resource. Although the above methodology can be widely practiced in this region for developing adaptation plans, there are some limitations: (a) the large uncertainty resulting from the use of GCMs for scenarios of local impacts renders the use of this information problematic, because of the inherent difficulty of linking coarse (GCM) scales and the local scale where impacts occur (downscaled modeling is preferred, but was unavailable for this study due to constraints in time series data related to climate variables, and instability in
the region, additionally leading to use of only one GCM); and (b) the local changes in social and environmental dynamics – in other words the development path taken (e.g., population growth, deforestation) – which affect directly the hydrology of a region, are also highly uncertain. Thus, scenarios of hydrological change for adaptive planning must be interpreted with caution. With this in mind, the next sections present the methods and results of a modeling exercise to assess the hydrological consequences of climate change on the Amu Darya River Basin, the limitations of the exercise, challenges, and recommendations for the way forward.

ANALYSIS OF CLIMATE CHANGE IMPACT ON DIFFERENT HYDROLOGICAL REGIMES: MODELING TECHNIQUES

The need of water in society and nature underscores the necessity to have clear understanding about the impact of global climate change on availability and variability of regional hydrological regimes. The impact of climate change on the hydrological regime of a location can be assessed by projections of climatic variables (precipitation, temperature, and pressure) at a planetary scale, downscaled to local hydrological variables. However, many studies indicate that a scaling dilemma still exists for assessing the impacts of climate change with different hydrological models (e.g., Fowler, Blenkinsop, & Tebaldi, 2007). Despite this problem, linking climatic and hydrologic modeling is increasingly used in vulnerability assessments. And as models develop rapidly, their results are used increasingly in policy circles in order to choose adaptation measures and policies to reduce vulnerability of water users and resources. As mentioned above, the first generation of vulnerability assessments identifies key vulnerabilities based on global-scale information generated by GCMs – an approach with more drawbacks than benefits due to the scaling dilemma. Therefore, this study employs the second generation approach of modeling hydrological change with different GCM scenarios for a ground level impression of impacts and vulnerabilities.

For projections of climate change in the 21st century in the Amu Darya Basin, the A1B and A2 SRES scenarios were selected to simulate water resource changes with the SWAT. The model was calibrated with observed hydro meteorological data for 2004–2008, validated for the period 2001–2010, and projected for 2021–2050.
The following datasets were utilized in addition to the emissions scenarios for the modeling simulation with SWAT:

- Digital elevation model (DEM) from the US Geological Survey’s (USGS) public domain geographic database, HYDRO1K (USGS, 2006), with 1 km² resolution, was used.
- The stream network was clipped from the Asian HYDRO1K dataset which was under six raster and two vector layers:
  - The river basin network was clipped from Afghanistan watershed shapefiles from Afghanistan Information Management Services (AIMS) (AIMS, 2011).
  - Soil characteristics of the study area were extracted from the US Department of Agriculture (USDA), Natural Resources Conservation Service (NRSC), National Cooperative Soil Survey Soil Characterization Database, using HWSD software (Fig. 2) (National Cooperative Soil Survey Soil Characterization Database, 2011)
- Land use/land cover (LULC) map from 1992 was used in SWAT simulation and analysis, sourced from AIMS (Fig. 3) (AIMS, 2011).
- Temperature, precipitation, wind speed, solar radiation, and relative humidity data (daily time scale):

![Soil Type layout of Amu Darya River Basin.](image-url)
Daily, monthly, and annual projected data for selected scenarios (A1B and A2) from the period 2021–2050 were derived from the Canadian Centre for Climate Modelling and Analysis (CCCMA) CGCM3 GCM (CCCMA, 2011).

The DEM of the Amu Darya River Basin in Afghanistan was loaded in the SWAT interface of ArcView GIS software and an automatic delineation process was done. Defining the stream inlet and outlet points was the next step. The number of inlet points determines the number of sub-basins (the next spatial unit used in SWAT below watershed) within the watershed, which is totally dependent on the needs and objectives of the user. Outcome layers and themes added to the project contain the parameters of the watershed’s characterization. After this the details of the elevation of the watershed and the sub-basins are added.

Once the watershed is delineated, hydrologic response units (HRUs) are created, which represent unique combinations of land use and soil within the sub-basin of a particular watershed as shown in Fig. 4. This step allows the user to load land use and soil layers into the current modeling project and determine the land use/soil class combinations and distributions for the delineated watershed and each respective sub-watershed. Watershed land use and soil characterization were performed using two commands in the
“AVSWAT” menu of the “Watershed View”. The themes can be either grid or shape formatted.

The average monthly precipitation (PRECIP), potential evapotranspiration (PET), evapotranspiration (ET), percolation (PERC), surface runoff (SURQ), and water yield (WYLD) as simulated by the SWAT model over the Amu Darya River Basin in Afghanistan for the observed period and future scenarios are represented in Table 1. The data illustrates the following results for selected water balance indicators:

- There is a chance of increase 15 to 30 mm of rainfall of as compared with the 2001–2010 recordings according to the model. This is not a significant increase but may cause some stress in the basin considering other demographic and development changes.
- Temperature of projected future scenarios compared with observed data indicate a change of 1.5°C in minimum and 1.1°C in maximum temperature for the A1B scenario, while a change of 1.6°C in minimum and 1.2°C in maximum temperature for the A2 scenario results (also shown in Fig. 5).
The highest values of PET in both scenarios are reached for the 2021–2050 period as compared with 2001–2010.

Percolation (PERC) increases in rate in the future model scenarios as compared to 2001–2010.

Surface runoff (SURQ): there is a major discrepancy between the observed data and the same period modeled in both scenarios (2001–2010) of about 25 mm. With precipitation virtually the same for both the observed and modeled periods, the difference may be explained by snow and glacier melting. But since there is no glacier or snow component in this SWAT simulation, this highlights another large uncertainty and therefore major drawback. Regardless, the increasing trend in runoff is recorded from the 2001–2010 to 2021–2050 periods for both scenarios, corresponding with the increase in precipitation shown.

Water yield (WYLD): as with surface runoff, the highest value for this component is the observed data, highlighting again a large discrepancy. Otherwise, the trend model is an increase reflecting the parallel rise in precipitation.

Analysis of Tables 1 and 2 indicates that change for both SRES scenarios will occur in all water balance components with respect to the 2001–2010
period, with increases in PRECIP, PET, SURQ, PERC, and WYLD, and a slight decrease in ET.

Table 3 indicates the A1B and A2 ensemble of monthly changes in water balance components in the Amu Darya River Basin with respect to the change from 2001–2010 to 2021–2050. It shows different changes in different components in various months. The largest monthly increase in precipitation is in October (9.7 mm). But March (7.5 mm), January (6.5 mm), and April (6.2 mm) also experience notable increases – critical periods for both winter snow accumulation and spring water flows, which are in turn crucial for agricultural water needs. The maximum negative change occurs in February (−3.3 mm) and May (−1.5 mm) – interestingly also critical winter and spring months hydrologically. PET shows only increases, with maximum values occurring in August, July, and June, respectively, while the minimum increases occur in March and April. Changes in ET show higher variation in all months, with the largest increase in January (2.5 mm), the largest decrease in March (−2.0 mm), and no change in September. PERC changes indicate that except for February (−4.7 mm), the other monthly values increase according to predicted data with the maximum change in January (6.0 mm), however from July to September no change occurs. Monthly SURQ values experience the same pattern of changes as PERC, but the maximum changes are in March and October, corresponding
with the maximum changes in precipitation. Water yield experiences the same pattern of change as PERC and SURQ, though the maximum change value occurs in January and shows no change in the month of September. Fig. 6 illustrates the average monthly change in precipitation and surface runoff from 2001–2010 to 2021–2050 for the ensemble mean of the two SRES scenarios.

As previously mentioned, the results of this type of modeling have limitations, such as uncertainty resulting from the use of a single GCM, only two scenarios, lack of downscaling method, limits to the availability of

<table>
<thead>
<tr>
<th>Time Series</th>
<th>PRECIP</th>
<th>PET</th>
<th>ET</th>
<th>PERC</th>
<th>SURQ</th>
<th>WYLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed (2004–2008)</td>
<td>525.4</td>
<td>1132.0</td>
<td>210.8</td>
<td>67.4</td>
<td>82.1</td>
<td>298.2</td>
</tr>
<tr>
<td>Ensemble mean (2001–2010)–present</td>
<td>525.2</td>
<td>1128.9</td>
<td>272.4</td>
<td>59.4</td>
<td>55.5</td>
<td>243.1</td>
</tr>
<tr>
<td>Ensemble mean (2021–2050)–future</td>
<td>554.2</td>
<td>1173.3</td>
<td>265.7</td>
<td>67.9</td>
<td>64.2</td>
<td>280.1</td>
</tr>
<tr>
<td>Change (ensemble future–ensemble present)</td>
<td>29.1</td>
<td>44.3</td>
<td>−6.8</td>
<td>8.6</td>
<td>8.7</td>
<td>37.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Month</th>
<th>PRECIP</th>
<th>PET</th>
<th>ET</th>
<th>PERC</th>
<th>SURQ</th>
<th>WYLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>6.5</td>
<td>3.1</td>
<td>2.5</td>
<td>6.0</td>
<td>0.7</td>
<td>12.0</td>
</tr>
<tr>
<td>Feb</td>
<td>−3.3</td>
<td>2.1</td>
<td>−0.2</td>
<td>−4.7</td>
<td>−2.7</td>
<td>−3.6</td>
</tr>
<tr>
<td>Mar</td>
<td>7.5</td>
<td>0.8</td>
<td>−2.0</td>
<td>2.5</td>
<td>3.1</td>
<td>6.5</td>
</tr>
<tr>
<td>Apr</td>
<td>6.2</td>
<td>0.4</td>
<td>−2.1</td>
<td>1.6</td>
<td>2.1</td>
<td>5.6</td>
</tr>
<tr>
<td>May</td>
<td>−1.5</td>
<td>2.3</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
<td>2.7</td>
</tr>
<tr>
<td>Jun</td>
<td>−0.2</td>
<td>6.1</td>
<td>−2.7</td>
<td>0.0</td>
<td>0.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Jul</td>
<td>−0.6</td>
<td>7.3</td>
<td>−0.9</td>
<td>0.0</td>
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</tr>
<tr>
<td>Aug</td>
<td>0.1</td>
<td>9.0</td>
<td>−0.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Sep</td>
<td>0.0</td>
<td>6.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Oct</td>
<td>9.7</td>
<td>4.0</td>
<td>−1.4</td>
<td>1.2</td>
<td>2.8</td>
<td>6.7</td>
</tr>
<tr>
<td>Nov</td>
<td>4.3</td>
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<td>−0.7</td>
<td>0.9</td>
<td>2.0</td>
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<tr>
<td>Dec</td>
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<td>0.4</td>
<td>0.3</td>
<td>0.1</td>
<td>1.3</td>
</tr>
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observed data, no consideration of local land-use changes, and no inclusion of the rate and dynamics of glacier and snowmelt change, all of which are important to study the hydrology and water balance of the Amu Darya Basin in Afghanistan. Nonetheless, a preliminary picture of hydrological change is constructed for a glimpse of future water resource vulnerability.

**CRITICAL ANALYSIS AND DISCUSSION**

The assessment of vulnerability of hydrological systems to climate change is not a straightforward exercise because of confusion concerning the conceptualization of vulnerability among different scholarly communities. The IPCC definition of vulnerability has been maintained as a “function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity” (IPCC, 2001, p. 995). The operational definition of vulnerability is imprecise in nature, leading to diverse methodological approaches for assessing it, and often the functional relationship between variables is unexplained. In this case study the process of developing a vulnerability framework includes coordinating disparate techniques: hydrological modeling and climate projection modeling including data for socioeconomic and environmental impact assessment. The realism of the models depends upon access to and availability of reliable data on hydrology, climatic variables, and socioeconomic indicators to develop scenarios that are suitable for a vulnerability and impact
assessment. In an unstable country like Afghanistan it is difficult to get all this information. This limitation combined with the inherent modeling uncertainties limit our understanding of the impacts climate change will have on local systems, raising concerns about the ability to manage water resources by developing simulation models for climatic and hydrological changes at the local scale. These concerns have driven new modeling developments to reduce uncertainty, including how to downscale climate models, to better understand vulnerabilities. Given the instability in Afghanistan, support from international organizations, such as the World Bank and the Food and Agriculture Organization (FAO) should be harnessed for the acquisition of cutting-edge downscaling methods in collaboration with different formal institutions in Afghanistan for the sustainable management of water resources in the Amu Darya and all other basins in the country.

In this context, the present study used the SWAT technique to model the Amu Darya Basin – a large, complex basin with varying soil types and land use and management conditions – to assess the impact of climate change on water resources. The study uses publically available input data to research the long-term impacts of climate variability on hydrology at a sub-basin scale. Simulation of the basin has limited applications, however, due to the complex and varying physiographic conditions and climatic characteristics, which are impossible to represent accurately with limited data availability. This data bottleneck makes mapping the impact of climate change on hydrology and computing vulnerability to extreme events dependent upon projections of climate variables at a coarse, global scale. Due to the Soviet invasion, no hydrological data is available from Afghanistan since 1980 (Upadhyay, 2010). The Taliban, furthermore, destroyed over 100 years of weather data and banned forecasting under their rule (ibid.). Hence the data used in the case study area uses limited observed data (2004–2008). Due to such reasons, studies to understand hydrological vulnerability to climate change in Afghanistan are rare.

In addition to data scarcity, there are significant limitations in applying GCM model projections down to catchment basin scales, as uncertainty becomes a large factor hampering prediction ability. Uncertainty associated with the future socioeconomic attributes in impact assessment studies is also a hindrance (Ghosh & Mishra, 2010). The variable which is most inaccurately generated in the hydrological cycle from GCM to regional scales is precipitation (Ojha, Goyal, & Adeloye, 2010).

Other challenges for assessing the impact of climate change in the Amu Darya Basin include lack of demographic data, inadequate or nonexistence
of water policies, and inefficient management strategies, all in addition to the fact that this type of study is not well developed in this part of the world. The main needs to address these and previously listed challenges and limitations are at the essence capacity building. This should include exchange of experience between highland countries as well as regional and international organizations on climate change modeling methodologies, tools, model projections, downscaling techniques and knowledge gaps. Further development of ways to assess and conceptualize vulnerabilities for better understanding the effects of climate change on sustainable development in Afghanistan and the whole of the HKH region are paramount for adaptive planning at all levels of society in Afghanistan.

CONCLUSIONS

The impact of global climate variability and change on hydrology and water resources needs to be quantified and modeled at river basin scales. The most credible tools of climate projections available are GCMs providing projections at much larger spatial scales. Yet downscaling of GCM projections of climate variability for impact assessment studies – which is very much what is needed on the ground – is hindered by uncertainty factors. The sources of the uncertainties are due to different GCM models (different parameters used for mapping climate systems) as well as uncertainties due to future socioeconomic scenario. The latter has implications on carbon emissions and adapting with upcoming changes, and hence on the climate system, leading to scenario uncertainties. Afghanistan has additional challenges in terms of attempting to use models for effectively mitigating and adapting to climate change. Weak institutions, lack of long-term, time series observations on the hydrologic cycle, and lack of resources to tap into the available data internationally all inhibit attempts at supporting on-the-ground adaptation with climate and hydrological models. Any application of models must factor in these constraints.

The study reported here assessed and identified climate change impacts on sensitive hydrologic parameters by using a SWAT model in the Amu Darya River Basin, one of the most important rivers in Afghanistan. Such assessments are not intended to be accurate predictions or even projections of future climate or hydrological conditions. They provide examples of the direction and relative magnitude of changes in streamflow that could be experienced under a variety of potential future climates. Future projections
of A2 and A1B scenarios of bias-corrected CGCM3 GCM used in SWAT show that there is an increase in the precipitation, and maximum and minimum temperatures. Results show that there is an increase in PET, surface runoff, percolation, and water yield. There is slight decrease in evapotranspiration due to change in high-intensity rainfall. These changes and prior information will be considered in future development in the area.

How useful is such work for local adaptation? That might depend on how severe the study’s limits are, as well as communication of the results to people who need them.

A main limitation of this study is the difficulty in capturing water allocation in the Amu Darya River. That is due to lack of knowledge of local water allocation practices and small-scale patterns, as well as lack of clarity in actors that influence water distribution. The accuracy and quality of this model depend strongly on the quality of the input data and the information available to a water manager. This leads to an interesting feedback loop. Models are not so useful to local actors without locally specific applications. The models cannot be made locally specific without local input. The local actors do not have the small-scale data available. This cycle is difficult to break in a country such as Afghanistan that is starting to rebuild from decades of conflict and neglect while still embroiled in an internal violent conflict.

Nonetheless, should social conditions permit the collection, archiving, and application of reliable and accurate information feeding into the models from the ground up, while contributing from the top-down to local decisions, that will help to support addressing the water management challenges in the Amu Darya Basin. Aspects of such methods, connecting the top-down with the bottom-up, might be transferable elsewhere around the Hindu Kush-Himalayan region. The priority steps are likely to be better management of land use especially with regards to cropping patterns; improved water management, especially regarding conservation of the scarce resources which could become scarcer under climate change; and flood warning systems. Naturally, that will need to involve people in communities more, something which the models applied here do not factor in.

But people often ask for information when changing the way they approach their day-to-day livelihoods. The top-down modeling work presented for the Amu Darya River has the potential for applying directly to local adaptation, as long as some of the limitations are resolved. The modeling work presented here could be further refined by including more accurate and higher resolution data to climate change and hydrological models. Note that the key has been improved accuracy. To a large degree,
the models are precise enough for local adaptation, but not accurate enough. Improving accuracy without changing precision would be a significant step forward for local adaptation.

The work presented here could also be further developed to an integrated, locally relevant model by including information and inputs from water managers, water users, water-related policy makers, and water-related decision makers. That would be everyone from local politicians to dam operators to private engineers building dikes to farmers to villagers collecting their drinking water from a well. Again, a connection between those managing and using the water, and those sitting from afar running the river models, would contribute towards the applicability of climate change and hydrological modeling to local adaptation. That would lead to more sustainable river basin planning and management decisions in Afghanistan, with possible implications for the rest of the HKH region.

To move this forward, specific recommendations are:

1. On the hazard side, a review would be useful of the methodologies and tools available for developing simulation models for climate change parameters and hydrological variables at all scales of the Amu Darya. That needs to take into consideration the knowledge gaps, data gaps, and technology gaps of Afghanistan and the challenges given the security situation there. For example, if top-end PCs are needed to manage data available or to run locally downscaled models, then how useful is it to have those data or models? If the models take several hours to process locally, or if a fast web connection facilities the analysis, how can that be managed in the context of an erratic power supply and unreliable Internet? These questions need to be addressed directly.

2. On the vulnerability side, similar data and analysis limitations exist. There is an absence of comprehensive, locally relevant demographic, sociological, and political data. Similarly, different populations might have different water-related needs and concerns, but that information is unknown. Much more work on the human, social, and community side is needed to match people’s needs with what models can offer.

3. As part of linking 1 and 2, a small-scale assessment of the Amu Darya River through using a local-scale hydrological model driven by local-scale projection of future climate change variables would go a long way toward making models more relevant for local adaptation. That is pushing the limits of what is technically feasible at the moment, but it represents a cutting-edge, exciting research area with a potential to make a difference. Not just in any results, which are unknown, but in supporting
people being more aware of their own environment making their own decisions – even the models, ultimately, are still not accurate enough for local decision-making.

4. All the above need to be managed in the context of Afghanistan’s uncertain future and volatile security situation. Such an approach is almost unprecedented in science and development, but it would assist in learning how to support local adaptation in a protracted conflict zone.

5. The standard development mantra of effective capacity building, capacity development, and capacity maintenance hold true here. The above recommendations need outside support and direction, but cannot be implemented without local control. That requires a long-term commitment from everyone, outsiders and locals, to address capacity gaps and to catalyze efforts to move from information to action — and maintaining that over the long term.

NOTE

1. The A1 scenario is a world where income and way of life converge between regions, characterized by rapid economic growth, a global population that reaches 9 billion in 2050 and then gradually declines, and includes the quick spread of new and efficient technologies. A1B is all of the above, with the added characteristic of having a balanced emphasis on fossil and nonfossil energy sources. The A2 scenario is of a more divided world characterized by independently operating, self-reliant nations, a continuously increasing population, and regionally oriented economic development (IPCC, 2000).

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