

## Module 6: The Water – Energy – Food Nexus

### Introduction

In Module 4 and 5 we looked at possible adaptation and mitigation options in the sector of agriculture including livestock and forestry. Module 6 provides an overview of the water-energy-food nexus and the impact of climate change on it. Particular focus is given to the water and energy dimensions.

### Water – Energy – Food Nexus

Many countries face a challenge in meeting the growing demands for food, water and energy, which is further compounded by climate change. For example adaptation measures such as intensified irrigation or water desalination are often energy intensive. Similarly, mitigation measures can add pressure on water, land and biodiversity resources. Effective adaptation and mitigation measures require a sustainable use of resources, coordinated efforts to minimize trade-offs and to maximize synergies<sup>1</sup>. However, measures are often formulated with a sectoral focus and can lead to an increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future (maladaptation)<sup>2</sup>.

#### Box 1: Definition water-energy-food nexus

The nexus approach is a **holistic vision of sustainability that tries to balance different development goals by managing trade-offs and exploring opportunities for synergies** in light of growing demand for resources and other key drivers. In practical terms, it presents a conceptual approach to better understand the **interactions between the natural environment and human activities** and to work towards a more coherent approach to natural resources management vis-à-vis our social, economic and environmental goals.

Source: [Hamdy A. et al., 2014: The Water-energy-food security nexus in the Mediterranean: challenges and opportunities.](#)

The **Water-Energy-Food Nexus** approach contributes to cross-sectoral interactions by integrating management and governance across sectors and scales. It highlights the interdependence of water, energy and food security and the natural resources that underpin them.

The nexus affects the extent to which water, energy and food security objectives can be simultaneously achieved. The agri-food supply chain, for example, accounts for 30% of the world's energy consumption and 70% of the world's freshwater use. At the same time, water is critical for health and livelihoods. As conflicts for limited water resources grow, the risks of re-allocation of water for other applications, particularly energy generation, also increase. There is growing evidence of governments having to make the choice between water, energy and food security given the limited resources available. These choices are expected to become more difficult as the need for meeting rising energy demands, particularly in developing countries, becomes more pressing. Therefore, it is necessary to explore integrated solutions to ease the pressures and formulate development pathways based on sustainable and efficient use of limited resources.

### The interlinkages between the nexus elements

The nexus elements, water, energy and food (food/feed/fibre), have many linkages that are affected by climate change (Figure 1). The current and future strength of those linkages varies among countries, depends on production systems, demands and management options (e.g. electricity demand, new technologies and water management), and is affected by climate change (e.g. reduced water availability due to climate change).

<sup>1</sup> [Rasul G. & Sharma B., 2015: The nexus approach to water–energy–food security: an option for adaptation to climate change, Climate Policy](#)

<sup>2</sup> [IPCC, 2011: Special Report on Renewable Energy Sources and Climate Change Mitigation](#)

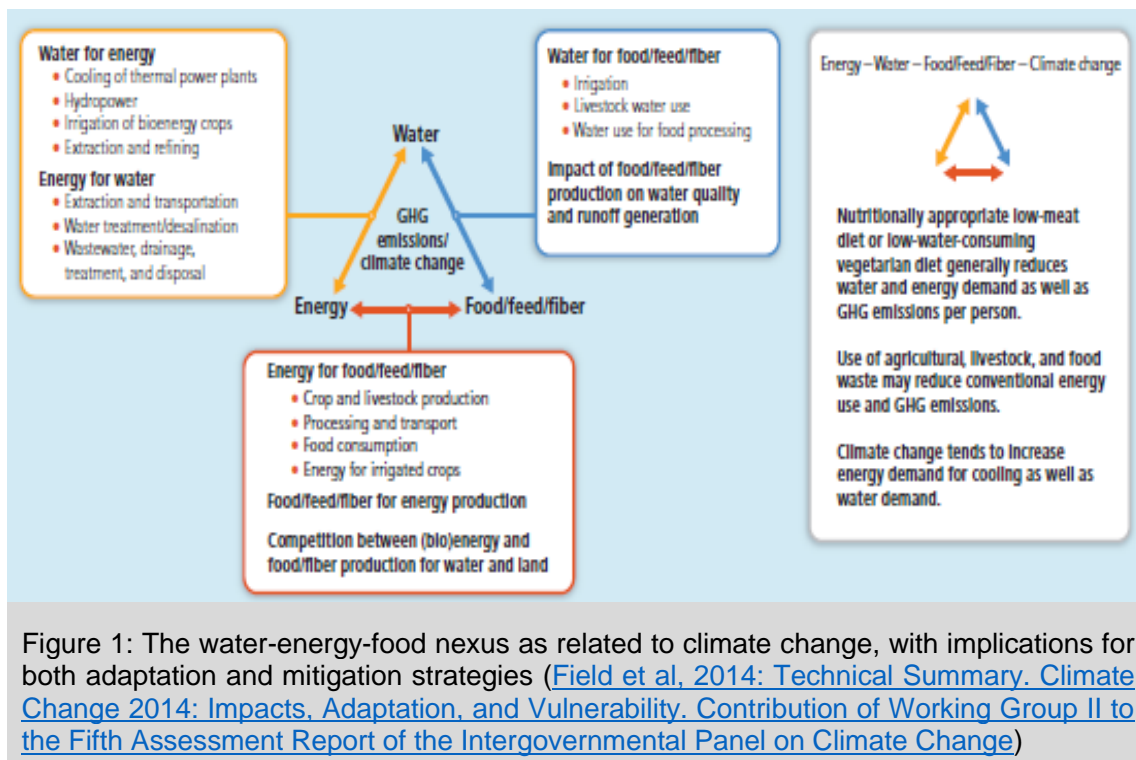


Figure 1: The water-energy-food nexus as related to climate change, with implications for both adaptation and mitigation strategies (Field et al, 2014: Technical Summary. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change)

Energy production often requires large amounts of water (**water for energy**), either directly (e.g. for hydropower or irrigation of crop-based energy sources) or indirectly (e.g. for cooling of thermal plants, for extraction and refining fossil fuels). Depending on the country, water for energy ranges from a few percent in most developing countries to more than 50% of freshwater withdrawals in some developed countries. At the same time, energy is required to extract (e.g. lifting water from aquifers), transport, treat, supply and dispose water (**energy for water**). Energy requirements will depend on the type of water source for e.g. groundwater is generally more energy intensive than water surface.

The production of food/feed/fibre requires water for irrigation, livestock feeding and food processing (**water for food**) as well as energy for irrigation systems, livestock production and transportation (**energy for food/feed/fibre**).

The linkages among water, energy, food/feed/fibre and climate are also linked to land use and management. For example, afforestation increases carbon sequestration and reduces soil erosion, but it can reduce water availability and affect the climate. Land degradation often results in higher fertilizer demand and surface runoff, which leads to a reduction in water and energy use efficiency that can compromise food security.

The **interlinkages** between energy, food/feed/fibre, water, land use, and climate change has implications for security of supplies of energy, food and water; adaptation and mitigation pathways; air pollution reduction; and health and economic impacts. This nexus is increasingly recognized as critical to effective decision-making regarding **climate-resilience**, although tools to support local and regional-scale decision support remain limited.

## The nexus for South Asia

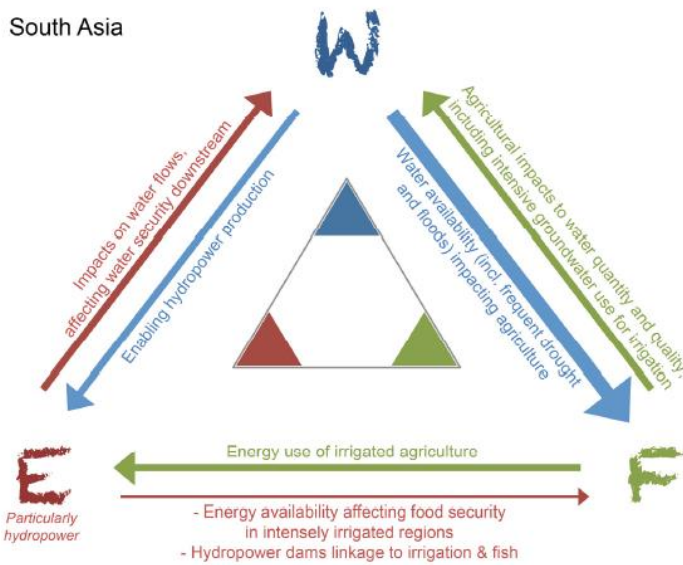


Figure 2: The nexus for South Asia. Arrow thickness refers to the significance of the connection/impact in the region. The “status triangle” in the middle indicates the current levels of water security (blue), energy security (red) and food security (green) ([Keskinen M et al., 2016: The Water-Energy-Food Nexus and the Transboundary Context: Insights from Large Asian Rivers. Water 8: 193](#))

In South Asia, including Afghanistan, water plays a key role in food security. In most regions agriculture requires intensive irrigation. Energy use to pump groundwater has increased rapidly (up to 6 times between 1980 and 2000) in the last decades, while groundwater tables have lowered impacting water availability. The region is characterized by its water scarcity for several months in a year making a large part of the region energy and water deficient. Food production using water and energy intensive irrigation has a significant impact on overall water and energy security. To ensure water, energy and food security there are now plans to tap the abundant hydropower potential of the rivers. The constructions of dams will have both local and transboundary environmental and social impacts, which will create pressures on the other nexus sectors<sup>3</sup>.

## Towards a green economy?



A nexus approach can support the transition to a **green economy** which aims at resource use efficiency and greater policy coherence. To succeed a green economy must go beyond sectoral solutions and actively **address water, energy and food security at the same time**. Based on better understanding of the inter-dependence of water, energy and climate policy, this approach is likely to become important for achieving the Sustainable Development Goals<sup>4</sup>.

### Box 2 : Definition of green economy

Economy that results in **improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities**. In its simplest expression, a green economy can be thought of as one which is **low carbon, resource efficient and socially inclusive**.

Source : [Green Economy Initiative, UNEP](#)

<sup>3</sup> [Keskinen M et al., 2016: The Water-Energy-Food Nexus and the Transboundary Context: Insights from Large Asian Rivers. Water 8: 193](#)

<sup>4</sup> [United Nations, 2015: Transforming our World: The 2030 Agenda for Sustainable Development](#)

## The water dimension

Freshwater-related risks of climate change increase significantly with increasing GHG concentrations. Climate change over the 21st century is projected to **reduce renewable surface water and groundwater resources significantly** in most dry subtropical regions, intensifying competition for water among sectors<sup>5</sup>.

Water is the driving element in the nexus. Water acts, on the one hand, as an enabler for food production and energy and on the other hand as an inhibitor for food and energy production in areas of water scarcity. The water sector is also most vulnerable to climate change (Figure 2). It faces many stresses due to demographic shifts, urbanisation, changing patterns and levels of consumptions and mismanagement of water resources. Climate change acts as a stress multiplier.

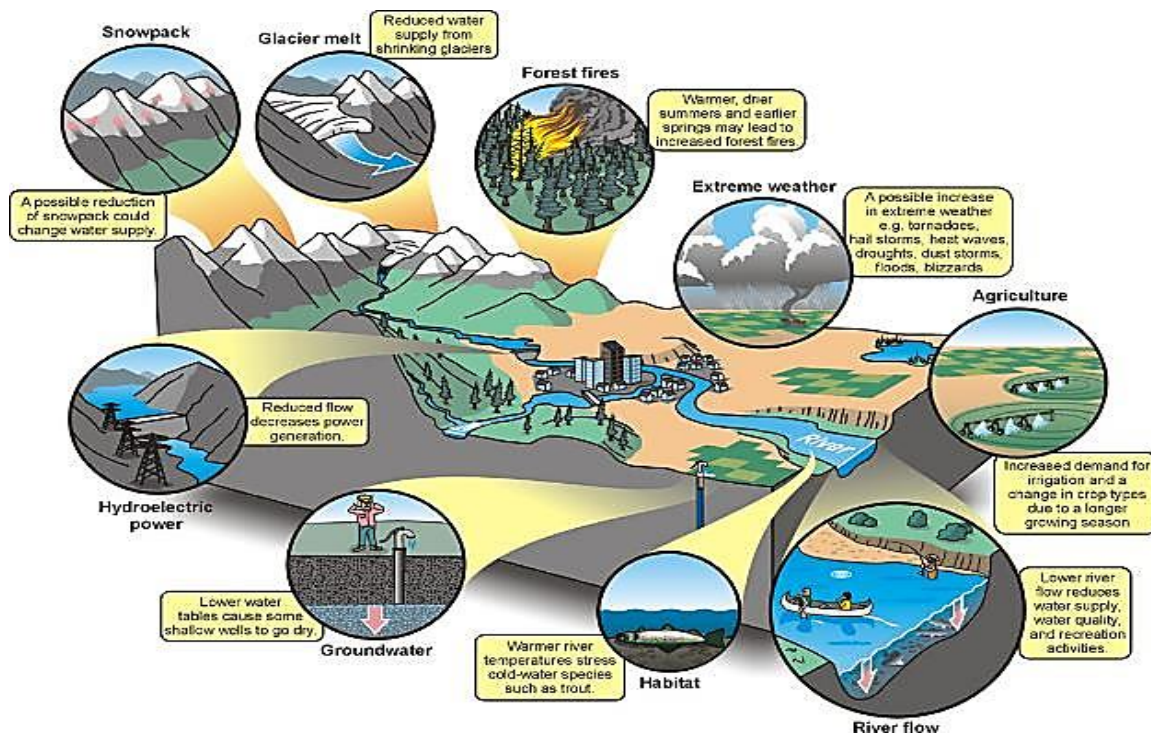


Figure 2: An illustration of possible impacts of climate change on water resources ([Natural Resources Canada](#))

In Afghanistan the mean rainfall has decreased slightly since 1960 at an average rate of 0.5 mm per month (or 2% per decade). The decreases arise largely due to reductions in rainfall between March and May, the wettest season. But this is offset by small increases between June to August and September to November<sup>6</sup>. Most of the precipitation falls in the months of November to April. The deserts receive less than 100 mm of rain a year, whereas the mountains receive more than 1000 mm of precipitation, mostly as snow<sup>7</sup>.

The water sector faces stress at different levels: water for production (irrigation), human consumption (drinking and sanitation) and ecosystems (watershed management). The lack of water availability will increase pressure on Afghanistan and surrounding states to claim the greatest possible share of regional water sources. Water disputes have plagued the central Asian region for years and will continue as climate change increases water scarcity in the region. Efforts by Afghanistan to increase its share of water use in the region may have regional

<sup>5</sup> IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*

<sup>6</sup> McSweeney, C., New, M. & Lizcano, G. 2010. *UNDP Climate Change Country Profiles: Afghanistan*

<sup>7</sup> <http://www.afghanistans.com/Information/Climate.htm>



implications<sup>8</sup>. Droughts and floods, the most economically and socially destructive disasters in Afghanistan, will impact water supply, demand and its quality and quantity.

Various sources, including the Special Report on Climate Change and Water by the IPCC<sup>9</sup>, state that current water management practices may not be robust enough to cope with the impacts of climate change.

There are different approaches for better management of water resources. **Integrated Water Resource Management (IWRM)** focuses on water allocation among different users and uses (water for people, water for food, water for nature, and water for industry; Figure 3) and hence can contribute to conflict resolution in the context of increased competition for scarce water (see [Concept Note on Integrated Watershed Management](#)). While



Figure 3: IWRM at a glance ([Global Water Partnership](#))

runoff and recharge due to climate change are expected to occur at a slower pace than changes caused by human demands for water, at least in the short term. (cf. [FAO, 2013: Climate-smart Agriculture Sourcebook](#)).

Risk and vulnerability assessment provide indication about water availability at the local level (cf. [Module 7](#)). A practical guidance through key questions in Annex 2 can guide the assessment of water availability.

## WASH in the context of climate change

Climate change has a major impact on the water cycle and hence affects people's access to **safe water, sanitation and hygiene (WASH)**, especially through extreme events such as floods and droughts. When planning WASH infrastructure, it is important to consider climate projections. As floods become more frequent and intense, an increased proportion of available surface water will be lost in peak discharges, reducing the quantity of accessible water for WASH. Surface water sources and unimproved wells with limited storage are likely to be most vulnerable to extended dry periods and an increased intensity of rainfall events. As more water is 'lost' as runoff during floods, and dry periods are likely to increase, there will be a greater need to store water. However, rainwater harvesting schemes may become less effective due to changes in the distribution of rainfall patterns and as warmer water temperatures could lead to greater transmission of diseases<sup>10</sup>.

The following adaptation options in WASH have been proposed:

- Adopting the **"waterflex" concept**, in which supply systems rely on a variety of different water sources rather than a single one.
- Increasing **storage capacity**, including subsoil (percolation tanks as opposed to surface storage structures).
- Increasing **water use efficiency** and rapid reduction of water losses at all levels.
- Implementing **water safety plans** to protect water from source to tap.

<sup>8</sup> [Savage M. et al., 2009: Socio-Economic Impacts of Climate Change in Afghanistan. A Report to the Department for International Development.](#)

<sup>9</sup> [Bates, B.C. et al., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat.](#)

<sup>10</sup> [Calow R. et al., 2011: Climate change, water resources and WASH: a scoping study. Overseas Development Institute, London](#)

- Augmenting the supply of water through **reuse and recycling** and taking advantage of unconventional water sources for supply (rain water) in regions where precipitation is scarce.
- Revisiting **water and wastewater treatment** approaches given higher silt loads and bacterial loads, also in ground water (due to higher temperatures and reduced dilution).
- Using **green urban infrastructure** to better manage runoff (green roofs)
- **Reintegration of water into the environment** for re-use rather than waste water treatment

## The energy dimension

Afghanistan has huge potential for renewable energy, which can help reduce GHG emissions as the country moves towards greater energy use. Renewable energy sources include hydro, solar, wind, geothermal, biomass and wood. Estimates indicate that in Afghanistan solar radiation averages about 6.5 kWh per square meter per day and the skies are sunny about 300 days per year. Consequently, the potential for solar energy development is high, not only for solar water heaters for homes, hospitals and other buildings, but also for generating electricity. Besides these, biomass/biogas and geothermal can provide significant renewable energy for rural communities (cf. [Alternative energy](#)). Availability of renewable resources and their current use status is presented in Table 1.

Bioenergy (cf. [Alternative energy](#)) can play a critical role in mitigation, but there are issues to consider, such as the sustainability of practices and the efficiency of bioenergy systems. Evidence suggests that bioenergy options with low lifecycle emissions, some already available can reduce GHG emissions; outcomes are site-specific and rely on sustainable land use management and governance. Barriers to large-scale deployment of bioenergy include concerns about GHG emissions from land, food security, water resources, biodiversity conservation and livelihoods.

The agricultural food production undergoes a certain degree of transformation or processing. During this stage, energy is required to preserve food, reduce post-harvest losses and extend the availability of food over a longer period of time (cf. [Module 3](#)). The lack of access to reliable and affordable energy is a key challenge for the food processing industry, as it affects its competitiveness<sup>11</sup>. This highlights the need for the food processing sector to reduce energy consumption, increase energy efficiency and integrate renewable energy to enhance sustainability and economic competitiveness. Renewable energy resources can meet energy demand for primary food production both directly and indirectly. Where adequate renewable energy resources exist, they can be used as a substitute for fossil fuels to generate traction, heat or electricity for use on farms<sup>12</sup>. Decentralised renewable energy solutions could not only supply energy for subsistence and small-scale farming, but also provide attractive energy supply solutions for large-scale farming, small and medium-sized enterprises and industry-sized agro-processors. Therefore, they have the potential to support rural economic development, bringing co-benefits to farmers, landowners, businesses and rural communities.

The complex interplay of food, energy, and water demand and supply requires a **holistic approach and institutional mechanisms** to coordinate the actions and strengthen complementarities and synergies among the three sectors of water, energy, and food and other policies such as climate and biodiversity. It is important to understand the interdependence of subsystems within a system across space and time and focus on system efficiency rather than the productivity of individual sectors to provide integrated solutions that contribute to **water, energy, and food policy** objectives. Ensuring policy coherence and coordination across sectors and stakeholders would help to build synergies and generate co-benefits to produce more with less and contribute to long-term sustainability with limited environmental impact.

<sup>11</sup> [FAO, 2011: Energy-Smart Food for People and Climate](#)

<sup>12</sup> [http://www.irena.org/documentdownloads/publications/irena\\_water\\_energy\\_food\\_nexus\\_2015.pdf](http://www.irena.org/documentdownloads/publications/irena_water_energy_food_nexus_2015.pdf)

**Table 1: Potential and Status of Renewable Energy in Afghanistan (Adapted from NEPA, 2013: Afghanistan initial national communication to the United Nations Framework Convention on Climate Change**

Resource	Potential	Status
<b>Hydro</b>	For the next 5 to 10 years, potential is estimated at about 800 MW, which consists of all sizes of hydropower plants, including storage based and run-of-the-river plant.	The Ministry of Rural Rehabilitation and Development (MRRD) has completed pre-feasibility studies of micro hydropower (MHP) plants in nine provinces. MRRD has installed over 840 (MHP) plants with a capacity of 14 MW.
<b>Wind</b>	Commercially exploitable wind resources exist in many parts of the country. 31,600 km <sup>2</sup> of the country can support large scale wind power plants. Major wind resource areas: Northwestern Nimroz, Western Farah, Western Herat, Eastern Balkh, Northern Takhar; wind corridor areas: Near Jabalsaraj, Sarobi, and Targari in eastern Afghanistan.	Only a few micro wind turbines have been installed in different parts of the country.
<b>Solar</b>	The country has excellent solar energy resources throughout its regions (on average, over 5.5 kWh/m <sup>2</sup> /day annual global horizontal insolation and at least 300 days for most of the country, with the south having the highest insolation). There exists a significant potential for solar heating (water and space) and standalone solar PV application for household lighting. Surveys indicate that kerosene is the most common fuel for lighting in non-electrified communities.	Over 100,000 solar home systems (SHSs) have been installed in various parts of the country by MRRD. However, MRRD discontinued the program due to quality related issues. Other donors and international NGOs are also involved in promotion of SH.
<b>Bio-mass/Bio-gas</b>	<p>Significant amounts of biomass are produced in the form of crop residues and animal waste, much of which is collected and used outside the commercial economy as unprocessed fuel for household heating and cooking. Municipal solid waste produced by urban population is dumped. Waste could be disposed in proper landfills to produce methane gas as fuel.</p> <p>Establishment of provincial network of rural biogas service centers will provide the infrastructure necessary to support dissemination, financing and maintenance. Also, training at community level of technical and managerial skills for construction of biogas plants has to be developed.</p> <p>Strategic efforts may include investing in design research to make biogas suitable for different climatic conditions and developing models that take into account local problems like low temperature, and different fuel inputs for biogas systems.</p>	Dried animal dung and crop residue are the two dominant sources of thermal fuel at the household level. These are followed by bushes and firewood, both of which are generally collected. An estimated 200 small biogas digesters have been installed in Kandahar. About 100 plants were installed in Jalalabad area by an Afghan NGO. Recently, MRRD initiated biogas promotion in Nangarhar Province.
<b>Geothermal</b>	<p>Active geothermal systems are located in the main axis areas of the Hindu Kush, which runs along the Herat fault system, up to the Wakhan corridor in the Afghan Pamir. Geothermal systems of Afghanistan are mainly associated with the fault and fracture networks, seismic activity encountered at this boundary and its associated branching fault systems.</p> <p>There is potential for direct-use applications of these resources, such as in the food processing,</p>	Prospects of low to medium temperature geothermal resources are widespread all over Afghanistan

fruit drying, refrigeration, fish hatchery and farming, carpet and wool processing, recreation and tourism and other small-scale industries. Development of potential geothermal prospects for commercial use, reconnaissance surveys are required to identify resources.

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## Further reading

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## Annex

**Annex 1:** Impacts from development activities and climate change on the different elements of the water cycle (FAO, 2013: [Climate-smart Agriculture Sourcebook, FAO](#))

Elements of the water cycle	Impact from	
	Development activities	Climate change
Annual precipitation	No or minor impact	Expected to increase globally during the 21st Century, with potentially great spatial variations
Interannual variations in precipitations	No impact	Expected to increase everywhere
Seasonal variability of rainfall	No impact	Expected to increase everywhere
Soil moisture stress (droughts)	Limited impact: some agricultural practices can deplete soil moisture faster than natural vegetation	Moisture stress to generally increase as a result of increasing variability of rainfall distribution (longer periods without rain) and increasing temperatures
Floods	Moderate impact: flood intensity and impact can be exacerbated by changes in land use and unplanned development in alluvial plains	Increased as a result of increasing frequency and intensity of extreme rainfall events
Snow and glacier melt	Limited impact through deposit of pollutants and change in the reflecting power of the surface (albedo)	Rising temperatures lead to accelerated snow and glacier melt with initial increases in river flow followed by decreases
River discharge	High impact in water scarce areas, where reservoir construction and water diversion for agriculture and other uses are modifying runoff regimes and reducing annual flow. Large-scale water conservation measures also have an impact on river discharge	Increased variability as a result of changes in rainfall patterns. Changes in snow and glacier melt induce changes in seasonal patterns of runoff. Changes in annual runoff expected to vary from region to region (see Figure 3.2)
Groundwater	High impact: large-scale development of groundwater resources in many regions are already threatening the sustainability of aquifers in many dry areas	Varies as a function of changes in rainfall volumes and distribution. Impact is complex, with floods contributing to increasing recharge, and droughts leading to increased pumping
Evapotranspiration	Limited impact in agriculture: some crops have higher evapotranspiration rates than natural systems, other less	Increases as a function of temperature increases
Water quality (in rivers, lakes and aquifers)	High impact from pollution in highly developed areas	Moderate impact through temperature increases
Salinity in rivers and aquifers	High impact from water withdrawal in highly developed areas (mostly in arid regions)	Potentially high impact where sea water level rise combines with reduced runoff and increased withdrawal

Box: Some practical guidance when assessing water availability

**Two main questions to be asked:**

**1. How has water availability changed over the years and what is the situation today?**

Access to local level weather data and climate projections has improved significantly in recent years. Some important links are listed here. If necessary, further information can be found on secondary national climate data.

- A map of all weather stations and long term data from them is available here: <https://www.wea-dapt.org/placemarks/maps>
- Climate projections can be found here: [http://cip.csag.uct.ac.za/webclient2/datasets/africa-merged/#nodes/seasonality-cmip3?folder\\_id=24&extent=46640](http://cip.csag.uct.ac.za/webclient2/datasets/africa-merged/#nodes/seasonality-cmip3?folder_id=24&extent=46640).
- A step wise guide on how to use this information in project design is available here: <https://www.wea-dapt.org/knowledge-base/using-climate-information>

The use of **proxies** is important. Information about the introduction of new crops needing less water or drought-resistant varieties, the length of the rainy season resp. dry season (comparison of the amount of days in the past versus today), changes in the amount of rainfall, runoff and flooding; occurrence of extreme events (drought, floods) give important information how the situation regarding temperature and rainfall has been changing.

**2. How will water availability change over the time?**

In projects where climate change impacts can have a direct effect on the project outcomes, it is crucial to bring in the **time dimension** and assess the climate change impacts accordingly:

- **Assess the climate change impacts (short to long-term)**
  - on project outcomes in the project timeframe (short-term 1-5 years).
  - on medium term-sustainability of project impacts (6-15 years).
- **Will climate change play a role in it?**

Consider the climate change projections and trends; certain tendencies can be observed that have an influence on the water availability (e.g. rise in temperature and/or precipitation etc.). What role will climate change play? Or are there more crucial factors (e.g. demographic growth, environmental changes) to be considered?

Where data on water resources availability are lacking, a water level monitoring system can represent an alternative (temporary) option. Climate trends well complement the water-level monitoring system as basis for decision-making regarding the regulation of water uses.

Source: HELVETAS Swiss Intercooperation, 2016