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Water Security in a New World

Zafar Adeel
Benno Böer *Editors*

The Water, Energy, and Food Security Nexus in Asia and the Pacific

Central and South Asia

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Water Security in a New World

There is a greatly heightened sense of awareness amongst politicians, policymakers, researchers and the general public that water security is a new and emerging threat. Just in the past few years, a number of high-level meetings involving the world's leaders and thinkers have focused on water security. With water security now commanding global attention, specific questions are posed on the likelihood of armed conflict and war over shared water resources, on the continuing availability of water resources to produce sufficient food for 9 or 10 billion people, on the probability of providing safe drinking water to every man, woman and child, and on the impact of climate change to create extreme water events – such as typhoons, floods and droughts – for which we are not prepared. By bringing together inputs from the world's leading thinkers, experts, practitioners and researchers, the Water Security in a New World series aims to provide evidence-based and policy-relevant responses to these and many other questions related to water security. The volumes in this series will provide in-depth analysis of the various dimensions of water security and are meant to be used by researchers, policymakers and practitioners alike.

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SHORT SUMMARY

Securing the "Nexus" of water, energy, and food resources serves as a starting point for utilizing emerging region-wide opportunities

Since the independence of the Central Asian states in the 1990s, following the demise of the Soviet Union, and the emergence of the regional trade and political ties, the evolution of the region has also been subject to common drivers – external and internal – offering new opportunities. The long-term social and economic success of the region depends on how water, energy and food security are achieved on a regional scale that combines Central Asia and South Asia, which are generally treated separately in policy and scholarly work. This book considers how securing the "Nexus" of water, energy, and food resources serves as a starting point for utilizing emerging region-wide opportunities.

The book offers an in-depth rationale explaining why dealing with this region globally makes sense by:

- Establishing the basic facts around the state of water, energy and food resources;
- Looking into regional issues and unpacking the Nexus into water-energy and water-food relationships;
- Undertaking an analysis of the cross-cutting themes for Nexus security;
- Building upon the discussions to formulate an integrated narrative around the Nexus;
- Exploring how the new global development framework, in the form of the Sustainable Development Goals, might offer a new perspective for achieving the Nexus security in the region.

Contributions from **18 international authors** covering **15 countries** across the Central and South Asia region

The book will be a great source of information for research communities, practitioners, and policymakers dealing with any aspect of water, energy, or food security in Central and South Asia.

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"Since wars begin in the minds of men and women it is in the minds of men and women that the defences of peace must be constructed"

Foreword

The main driver of planetary-scale change is the population-driven growth in demand for resources. Pioneer ecologist Heinrich Walter in his 1980 'Confessions of an Ecologist' correctly concluded that the anthropogenic change, in particular population dynamics, coupled with the 'blind belief in technology' are the two most important challenges for ecosystem functioning and human life.

Central and South Asia, in the context of this book, includes Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka in the south, and Afghanistan, Iran, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan in the central part of Asia. The combined human population of these countries has grown from about 980 million in 1980 to over 2 billion in 2020. The population of these countries is predicted to continuously grow and to reach a peak between 2055 and 2100, with the exception of Sri Lanka, which has almost reached its peak today.

The long-term social and economic success of the region depends on how water, energy, and food security are achieved at a regional scale. This book provides an overview of the current regional status of water, energy, and food security in Central and South Asia. It describes how achieving the Sustainable Development Goals depends on effectively managing and planning for the water-energy-food nexus throughout the region.

In this volume 'The Water-, Energy-, and Food-Security Nexus in Central and South Asia,' an overview of the sub-region is presented, and the nexus-concept is introduced. The volume is a part of a three-volume series to examine in an integrated manner the water-energy-food nexus in the Asia and Pacific Region. It explores the socioeconomic implications of the nexus approach with a focus on cross-cutting issues, such as climate change, gender, urbanization, impacts on environment and economy, and transboundary issues. It provides new insights into nexus solutions for the region.

It is time to re-adjust global, regional, national, provincial, and local priorities with a clear view towards those parameters that are of the greatest importance for human survivability.

I thank the Simon Fraser University for the partnership, jointly producing this volume with UNESCO, and I congratulate the editors and authors of the volume for the production of this well-structured scholarly work, under the able leadership of Dr. Zafar Adeel and Dr. Benno Boer.

Shahbaz Khan
Director, UNESCO Office in Beijing,
and former Director, Regional Science
Bureau in Jakarta

Preface

The combined region of Central and South Asia presents some unusual challenges and interesting opportunities. Some major regional-scale challenges include food insecurity, land degradation, energy insecurity, scarcity of water resources, and gender inequities; these challenges are further exacerbated by global drivers such as climate change, urbanization, population growth, and more recently, the COVID-19 pandemic. However, there are also some unique opportunities in the region to overcome these challenges and excel at human wellbeing, economic progress, and sustainable ecosystems. The main focus of this book is on securing water, energy, and food resources as a fundamental starting point for utilizing these region-wide opportunities.

The genesis of this book can be traced back to a similar volume developed a few years ago, titled "The Water, Energy, and Food Security Nexus in the Arab Region." The continued demand for that book from various governmental agencies and research and professional organizations provided the impetus for undertaking a similar analysis for the Asia-Pacific region. To accommodate the wide diversity of social, economic, and environmental conditions in this vast region, it was split into three volumes. This volume benefits from following a similar thematic approach adopted in its sister publications on the Pacific and the East and Southeast Asian regions.

The contributing authors in this volume represent a very wide diversity of disciplinary backgrounds—from social scientists to economists to political scientists to environmental researchers to engineers. This diversity provides a richness of perspectives to review the situation in the Central and South Asian region. Interestingly, this diversity yields some common thought streams that can yield benefits for the region as a whole. Some interesting ideas have been explored by the authors—including development of new regional trade corridors, approaches for sharing of many transboundary water resources, initiatives to reduce poverty and enhance inclusive economic growth, and creation of early-warning systems that benefit from shared capacities.

Various chapters of the book also explore the institutional frameworks that can be gainfully employed in the Central and South Asian region to fully avail the opportunities available today and those emerging in the near future. The 2030 Agenda for Sustainable Development and the accompanying Sustainable Development Goals (SDGs) play a central role in any discussion about development frameworks in this region. Several chapters also explore a wide range of multi-stakeholder institutions and regional cooperation mechanisms available in the region. The notion of overcoming geopolitical rivalries and moving towards common good of the population configures quite centrally in this discussion.

Overall, the book strikes an optimistic tone despite the numerous, chronic challenges encountered in the region. The optimism is driven by the overwhelming economic and political benefits of mutual cooperation and the capacity of the regional political leadership to take bold steps to overcome common problems.

As the editors of the volume, we believe that this intellectual exercise fills an important niche in the knowledge domain and offers some practical solutions that can be adopted by a range of stakeholders, most notably national governments. The book also identifies areas and themes that can benefit from a much deeper analysis and development of region-specific solutions. Finally, we hope that this volume will trigger a number of research investigations that consider the nexus of water, energy, and food security in the Central and South Asia as an integrated and inter-twined domain.

Surrey, Canada — Zafar Adeel
New Delhi, India — Benno Böer
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Part I
A Region-Wide Overview

Chapter 1
An Integrated Overview of the Water, Energy, Food Nexus in Central and South Asia

Zafar Adeel and Benno Böer

Abstract This chapter provides a description of the nexus between water, energy, and food security in the Central and South Asian region, including a description of the commonalities and differences. This description serves as the rationale for the regional footprint used in this book and the interactions between the countries including in the region. It provides an overview of the geopolitical considerations that make the region strategically important to the world. The following dynamic drivers of large-scale and strategic changes in the region are briefly discussed: geopolitical forces and events, trends related to urbanization, impacts of the global climate change, and emerging factors such as the COVID-19 global pandemic. A brief summary of the regional challenges and opportunities is provided, which serves as an introduction to the four sections of this book and various chapters: developmental and economic challenges; threats to water, energy, and food security; and political volatility. Finally, this chapter provides a section-by-section overview of the book as a whole.

Keywords Water, energy, and food in Central and South Asia · Geopolitical regional challenges · Urbanization and population dynamics · COVID-19 · Climate change

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1.1 Introduction

1.1.1 Defining the Central and South Asian Region

In typical organizational and geographical distribution, Central Asia and South Asia are organized distinctly and the geographical footprint varies depending on the context. In the United Nations system, this region falls under the geographical coverage of the United Nations Economic Commission for Asia and the Pacific (UNESCAP). In the context of this book, this region is described as including the following countries in the Central Asian subregion: Iran, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan; and the following countries in the South Asian subregion: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. The corresponding maps are shown as Figs. 1.1 and 1.2, respectively.

Given the proximity of China to this region and its economic and geopolitical influence on the countries in this region, the discussion in this book duly considers the corresponding issues pertinent to the water-energy-food nexus. For example, China is situated upstream on a number of transboundary river systems in the region. Further, its Belt and Road Initiative[1]) has an impact on the economic development across the countries in this region, and beyond.

Climatologically, the Central and South Asian region covers a whole range of the main climate zone spectrum, including tropical, sub-tropical and temperate zones, and within this realm a set of climate types occurs, such as the humid and sub-humid tropical climates in Bangladesh, south India, and Sri Lanka, semi-arid Steppe climates of Central Asia, alpine climates in northern Pakistan, northern India, Nepal, and Bhutan, as well as hyper-arid dry desert climates in the south of Iran and Pakistan. Moreover, it includes the maritime high-humidity climate of the Maldives, with its constant sea breezes and constantly high temperatures above 25 °C, and high annual rainfall averages between 2500 and 3800 mm. According to the climate classification of Siegmund and Frankenberg (2013) the two factors temperature and water balance are the most important climate-ecologically relevant indicators of an area, and this, in turn, is a major factor for freshwater availability and food-production.

1.1.2 Unique Features of This Region

The Central and South Asian region sits at the middle of geographical, geopolitical, economic, and historical cross-roads. Since the independence of the Central Asian states in the 1990's, following the demise of the Soviet Union, and emergence of regional trade and political ties means that the region's evolution has also been subject to common drivers—external and internal. In South Asia alone, home to about 1.8 billion people, growing concerns for securing water, energy, and food

[1] https://en.wikipedia.org/wiki/Belt_and_Road_Initiative.

Fig. 1.1 Overview of the geographical area covered in this volume (*Source* United Nations, 2023). *Disclaimer* The boundaries and names shown, and the designations used on this map do not imply official endorsement and acceptance by the United Nations. The dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

require innovative thinking and out-of-the box responses. The long-term social and economic success of the region depends on how water, energy, and food security is achieved at a regional scale—combining Central Asia and South Asia, which are typically treated separately in policy and scholarly work. This book undertakes a region-wide analysis of the "Nexus" between water, energy, and food security. It does so by identifying the present state of play, deeply analyzing cross-cutting drivers (e.g., climate change, economic shocks, health scares, widespread poverty, environmental crises, and rapid urbanization), and offering insights into possible solutions.

Fig. 1.2 Geographical representation of the South Asia region, as used in this book (*Source* United Nations, 2023)
Disclaimer: The boundaries and names shown, and the designations used on this map do not imply official endorsement and acceptance by the United Nations. The dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

1.1.3 The Concept of a Nexus Between Water, Energy, and Food Security

The concept of strategic, policy, and pragmatic nexus between managing water, energy, and food domains has emerged in the twenty-first century, leading to a consolidated description that emerged from a major international conference in Bonn during November 2011 (Hoff 2011). This concept is built on the argument that water, energy,

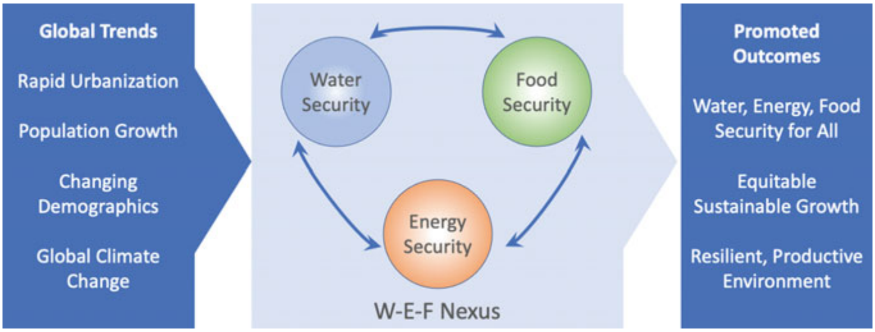

Fig. 1.3 A schematic description of the water, energy, food nexus, including a listing of global trends that drive the nexus, and a listing of promoted outcomes. Adapted from Hoff (2011)

and food represent three cross-linked services that are essential to economic, social, and environmental development of any country or region. It is critical to understand that these three services and the accompanying sectors are intertwined and cross-linked to constitute a triangular relationship. The triangularity of this relationship posits that if one of the apexes of the triangle is influenced or disturbed, the other two must also change in response; schematically, this arrangement is shown in Fig. 1.3.

It is important to note that a number of externalities influence the nexus between water, energy, and security, also summarized in Fig. 1.3: urbanization patterns, population growth, changes to population demographics, environmental and economic impacts of global climate change, and other political and economic drivers. Most recently, the COVID-19 global pandemic has also influenced this nexus in multiple ways, demonstrating how an externality can perturb the three interlinked domains. The integrated and mutually cohesive strategic planning of the three resource domains is meant to achieve a number of desirable and promoted outcomes, including the following shown in Fig. 1.3. First, securing safe and sufficient water for every individual and their livelihoods, providing sustainable, reliable, and modern forms of energy to everyone, and ensuring sufficient and nutritious food for everyone. Second, ensuring sustainable economic growth which assures equitable distribution of benefits to all. Third, protecting and conserving the environmental resources in a manner to achieve resiliency against adverse impacts and sustained productive utilization for generations to come.

The international dialogue on the water, energy, food nexus has identified a number of action areas that can facilitate the achievement of the promoted outcomes shown in Fig. 1.3. First, governments must incorporate a greater level of policy coherence between the water, energy, and food sectors, while integrating such policy formulation with national and regional development pathways. Second, there should be a worldwide focus on accelerating the provisioning of these three resources to the most disadvantaged populations, which is often referred to as the "bottom billion." Third, the approaches along the nexus must incorporate technological and management innovations that can lead to increased productivity and reduction of losses.

Fourth, it is essential to mobilize consumers to understand the impact of their choices on the security of water, energy, and food; achieving such mobilization must be based on increased access to knowledge and awareness that allows consumers to make informed choices. Achieving success along these four action areas requires generation of targeted knowledge, provisioning of incentives to individuals and organizations, and development of institutional frameworks that reward favorable transitions.

In a broad sense, a number of roadblocks remain in Central and South Asia in achieving water, energy, and food security. The various contributors to this volume have explored these challenges and, in many cases, identified solutions or pathways that can help achieve the promoted outcomes.

1.1.4 Objectives of This Book

This book, including the individual chapters authored by world-class experts, aims to achieve the following broad objectives:

- provide an overview of the current regional status of water, energy, and food security in Central and South Asia, relying on the state-of-the-science research and information sources on this topic;
- identify common themes and threads that interlink water, energy, and food, and illustrate how these common threads (e.g., hydropower generation, food production) create impacts on the entire nexus;
- describe how achievement of Sustainable Development Goals (SDGs) is integrally linked to securing the water-energy-food nexus throughout the region;
  - highlight how populations dynamics, combined with bio-geographical and anthropo-ecological factors are major drivers of water-, food-, and energy security, and its nexus, and,
- identify knowledge and policy gaps, particularly focusing on what is known, what is working in which countries, and what lessons can be extracted with regional implications.

1.2 Dynamic Drivers of Change in Central and South Asia

It has been argued that we live in the Anthropocene Epoch (Crutzen and Stoermer 2000) because the drivers of change over geological timeframes—such as solar variation, volcanic eruptions, plate tectonics, proliferation and abatement of life, impacts from meteorites, and changes to Earth's orbit and spin—are being overtaken by the anthropogenic impacts on a planetary scale. These impacts, coupled with resource depletion, are the hallmarks of the Anthropocene Epoch. World-renowned ecologist

Heinrich Walter (1989) in his '*Confessions of an Ecologist*' already concluded in his memoirs that the combination of anthropogenic change, in particular population growth, coupled with the 'blind belief in technology', are the two most important challenges for ecosystem functioning and keeping the human life support system intact.

In the context of the Central and South Asian region, it is important to understand the dynamic drivers of change and use that knowledge to develop evidence-based and scientifically supported responses. Such understanding must be driven by inclusive and comprehensive dialogue that engages a broad range of stakeholders that encompass the scientific community, policy makers, private sector representatives, and the general public. The following description is intended to highlight and summarize some of the most significant drivers of change, including geopolitics, urbanization, climate change, as well as the worldwide COVID-19 pandemic.

1.2.1 Geopolitical Forces and Events

1.2.1.1 Long-Term Conflict in Afghanistan

The long-term conflict in Afghanistan has been going on since the mid-1970s, and it has been prescribed and analyzed by many authors, some of which have described the conflict as unsolvable, due to the ethno-geographical and ethno-historical dimensions of Afghanistan and some of the bordering areas (Goepner 2018). The conflict has resulted in millions of Afghans seeking asylum in Pakistan, Iran, and elsewhere. In addition, a number of volunteers traveled from different parts of the world to join the struggle, which was already involving numerous major outside forces, causing long-term political instability. Further instability was caused by drug-production and trade: by 2000 Afghanistan accounted for an estimated 75% of the world's opium supply, which by 2005, increased to 90%, most of which was processed into heroin and sold in Europe and Russia. Specific estimates have been provided by UNODC (2021). Needless to say, that the long-term conflict has a major adverse impact on food, energy, and water security of Afghanistan, and it also influences other countries in the neighbourhood as well as further away. For example, almost 90,000 ha of land that could be used for the production of food-crops, have been diverted for opium production. In addition, any long-term conflict inevitably distracts the focus and reduces the capacity of directly involved communities from securing food, water, and energy production, supply, and trade.

The most recent development in this long-term conflict was the Taliban takeover on 30 August 2021, when the last American military plane departed Afghanistan, ending almost 20 years of western military presence in the country. How exactly these developments will influence the short, medium, and long-term water, energy, and food security in Afghanistan and the region, remains to be seen. However, there is no doubt, that the anticipated near future changes will significantly impact human lives.

1.2.1.2 Global Sanctions on Iran

Over the years, beginning in 1979, sanctions on arms, banking, energy, shipping, trade, and other sectors have taken a serious toll on Iran's economy and people. Numerous publications describe the situation or aspects of it (Fathollah-Nejad 2014; Butler 2019; Sahraian et al. 2021). The energy sector has been hit especially hard due to Iran's oil-dominated economy. The average Iranian citizen suffers from inflation, which has been estimated at 25% annually, leading to a drastic increase of food-costs, such as for bread and chicken. The economic sanctions are having an impact on the purchasing power of ordinary Iranians, whether as a result of inflation, scarcity, or through the removal of government subsidies.

1.2.1.3 Terrorism

Terrorism has impacted the Central and South Asian region over the past four decades in various forms and intensity (Rosand et al. 2009; Akhmat et al. 2013). Those impacts permeate the water-energy-food nexus also. Damaging water supply, quality, and infrastructure by terrorist attacks could adversely impact public health, possibly causing loss of life. Terror activities range from vandalizing infrastructure, including large infrastructure, such as dams and water-reservoirs, and intentionally or inadvertently polluting water-sources with toxic or pathogenic substances. A brief history of terrorism has been published by UNODC (2018).

Despite the lack of large-scale attacks against agriculture, it remains vulnerable due to the economic and social significance of an agro-terrorist attack. The production and distribution of the food supply is a complex system, involving over ten waypoints between the farm and the consumer. Many of these waypoints, such as farms, feedlots, import/export, markets, mills, packaging operations, processing plants, ranches, restaurants, shipping, shops, slaughterhouses, storage sites, stores, and wholesalers, are vulnerable to sabotage (Craft 2017). The World Health Organization warned that '*the malicious contamination of food for terrorist purposes is a real and current threat, and deliberate contamination of food at one location could have global public health implications. Chemical, biological or radionuclear agents might be used deliberately to harm civilian populations and food might be a vehicle for disseminating such agents*' (WHO 2002). This WHO document provides advice on strengthening of national systems to respond to food terrorism.

The impact of terrorism on energy supply and infrastructure is very real. '*Terrorist organizations have always been interested in targeting oil and gas facilities. Striking pipelines, tankers, refineries and oil fields accomplishes two desired goals: undermining the internal stability of the regimes they are fighting, and economically weakening foreign powers with vested interests in their region*' (Luft and Korin 2003). In the past decade alone, there have been scores of attacks against oil targets. The 1991 Gulf War Oil Spill, the biggest oil spill known to humanity, caused the intentional release of an estimated 1.29 million tons of oil into the Gulf, significantly impacting the energy system by wasting large amounts of oil as well as the destruction of oil infrastructure, adversely impacting the marine ecosystem, and threatening the functioning of vital seawater desalinization plants (Krupp et al. 1996). Another example of energy terrorism was the drone-attack of the Saudi-Aramco oil facilities in September 2019, and as recent as 7 March 2021. Toft et al. (2010) analyzed the number of terror attacks that occurred between 1997 and 2008. In their paper, for the Central and South Asian region, the most vulnerable countries that have witnessed most energy-terrorism attacks on their territory included in order of number of attacks: Pakistan, India, Sri Lanka, Iran, Nepal, and Bhutan.

1.2.1.4 China's Belt and Road Initiative

In 2013, China launched the "Belt and Road Initiative"[2] (BRI) as a platform for inducing innovative thinking on its development investments facing the outside world (Liu and Dunford 2016). The BRI comprises international cooperation with its partner countries in five general policy domains: (1) coordinating development policies; (2) forging infrastructure and facilities networks; (3) strengthening investment and trade relations; (4) enhancing financial cooperation; and (5) deepening social and cultural exchanges (Liu and Dunford 2016; Johnston 2019). The BRI utilizes Chinese foreign aid, humanitarian assistance, and financial investments and loans to achieve its objectives in all five of the listed domains (Johnston 2019).

The geographical footprint of BRI is quite extensive and covers at least three continents, while proclaiming to be open to all nations (Johnston 2019). Because of China's immediate proximity to the Central and South Asian region, the BRI has interlinkages to essentially all the countries in that region. A great deal of the infrastructure-related investment under the BRI, loan-funded in most of the cases (Pairault 2018), can significantly impact the water, energy, and food security—both directly by providing corridors for trading of these resources and indirectly by incentivizing economic activities that may have impacts on the nexus. Implementation of this strategic initiative is still in early stages and forecasting its long-term impacts would be speculative. One should note that China is a major trading partner for the countries in this region; for example, China had a total trade with Central Asian countries as follows: USD22.5 billion with Kazakhstan, USD1.5 billion with Kyrgyzstan, USD2.1 billion with Tajikistan, USD9.3 billion with Turkmenistan, and USD4.5 billion with Uzbekistan (Contessi 2016). Given the scale of China's economic investments, the potential impacts on the developing and intermediate economies in the Central and South Asian region can be very significant. An ongoing analysis of the BRI's influence on the nexus is therefore critical.

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[2] The BRI started as a combination of "Silk Road Economic Belt" in Kazakhstan in September 2013, followed by the "Maritime Silk Road" in Indonesia in October the same year. In December 2013, the Chinese Communist Party combined these initiatives into a single one, which was initially termed as the "One Belt One Road" initiative (a direct translation of the Chinese language name "yidaiyilu"). This terminology is now re-phrased officially as the Belt and Road Initiative (BRI).

1.2.1.5 The Ukraine-Russia Conflict

The Ukraine-Russia armed conflict, that intensified into a war in February 2022, has already dramatically impacted global energy distribution and costs, and hugely impacted global food-security, especially based on the availability of wheat (World Food Programme 2022, UN Global Crisis Response Group on Food, Energy and Finance 2022). The scale and scope of the impact is not yet fully predictable, particularly because a pathway to peace does not appear to be feasible in the short term. The war has already caused highly adverse impacts on global food and energy security, and in some places, it has reached crisis-levels. Billions of people are facing extreme cost of living increases based on high food and energy expenditures, due to escalating global energy, fertilizer, and food price shocks (Benton et al. 2022; United Nations 2022). Further, secondary adverse impacts can be expected by industrial nations turning to previously phased out "dirty" energy sources, particularly locally sourced coal and gas extraction through hydraulic fracturing, which will inevitably contribute to the exacerbation of global climate change that will further impact food, water, and energy security.

1.2.2 Population Growth and Urbanization Trends

Most of the countries have steep population growth rates (Table 1.1) multiplying their total populations between 1980 and 2040 by a factor of 2 or even 3, with the exception of Sri Lanka (data source: UN DESA 2022). For most countries the growth trend will remain for the next 35–80 years, respectively, before an equilibrium will be reached. However accurate these data between 1980 and 2020 are, and however accurate the population growth forecasts are, it is clear that the overall trend already has an enormous impact on water, energy, and food security, due to natural limitations on the supply of clean water, food, and energy, and this challenge will remain for decades to come. Population dynamics, together with climate change and natural and man-made disasters are probably the three most decisive factors for sustainable human living in the Central and South Asian region in terms of water-, energy-, and food-security.

The availability of clean freshwater is a human right. In some locations, freshwater is already scarce, especially in dry-desert areas. Poor water quality and inadequate sanitation are threats to water security and have adverse impacts on food security, health, educational opportunities, and the environment. Currently there are already more than 4.7 billion people globally suffering a lack of access to clean freshwater for at least one month per year (UNESCO 2019). The population growth as documented and predicted in Table 1.1 will inevitably have an adverse impact on access to clean water, unless knowledge and skills of the general public are being augmented and adaptation measures applied, keeping socio-ecological factors and carrying capacities in mind. Equally, the impact of population dynamics on energy supply gives reason for concern: 1.2 billion people globally have little or no access

Table 1.1 Population distribution in the Central and South Asian region

Country	Population 1980	Population 2000	Population 2020	Prospects 2040	Expected population peak
Afghanistan	13,356,000	20,780,000	38,928,000	56,912,000	77,016,000 (ca. 2085)
Bangladesh	79,639,000	127,658,000	164,689,000	188,417,000	192,649,000 (ca. 2055)
Bhutan	407,000	591,000	772,000	885,000	906,000 (ca. 2055)
India	698,953,000	1,056,576,000	1,380,004,000	1,592,692,000	1,651,019,000 (ca. 2060)
Iran	38,650,000	65,623,000	83,993,000	98,594,000	105,213,000 (ca. 2060)
Kazakhstan	14,796,000	14,923,000	18,777,000	22,370,000	27,918,000 (ca. 2100)
Kyrgyz Republic	3,611,000	4,921,000	6,524,000	8,307,000	10,985,000 (ca. 2100)
Maldives	ca. 169,000	279,000	541,000	ca. 560,000	586,000 (ca. 2060)
Nepal	15,016,000	23,941,000	29,137,000	34,889,000	35,324,000 (ca. 2050)
Pakistan	78,054,000	142,344,000	220,892,000	302,129,000	404,495,000 (ca. 2095)
Sri Lanka	15,036,000	18,778,000	21,413,000	22,186,000	22,186,000 (ca. 2040)
Tajikistan	3,905,000	6,216,000	9,538,000	13,846,000	25,328,000 (ca. 2100)
Turkmenistan	2,877,000	4,516,000	6,031,000	7,409,000	8,560,000 (ca. 2085)
Uzbekistan	15,899,000	24,770,000	33,469,000	40,608,000	44,403,000 (ca. 2070)
Total	**980,199,000**	**1,511,637,000**	**2,014,167,000**	**2,389,244,000**	
China	1,000,089,000	1,290,551,000	1,429,324,000	1,449,031,000	1,464,340,000 (ca. 2030)

Source UN DESA (2022)

to electricity (Routley 2019). A number of these people, therefore, rely on firewood collection or illegal logging, which at least partially contributes to deforestation (Rhodes et al. 2006). With increasing demand and limited arable land available, it is essential to transition towards responsible production and consumption of biomass. Moreover, according to the World Food Programme's Hunger Map 2019 (World Food Programme 2019), *there are 821 million people—more than 1 in 9 of the world* *population—who do not get enough to eat*. How will population increase by hundreds of millions of people in the next decades impact on food security?

1.2.2.1 Major Mega-Cities in the Region

We often refer to a mega-city as a city with more than 10 million inhabitants, although some other definitions are also considered in the published literature; additionally, city-limits are not always clearly defined, leading to differing estimates of a city's population. Table 1.2 shows the mega-cities and largest cities in the Central and South Asian countries. Three countries are clearly in the lead in terms of total numbers of mega-cities, including India, Pakistan, and Bangladesh.

Table 1.2 Mega-cities in the Central and South Asian region

Country	Mega-Cities (UN DESA) and *largest city* (Wikipedia)	Population 2018
Afghanistan	*Kabul*	4,220,000
Bangladesh	Dhaka	19,578,000
Bhutan	*Thimphu*	115,000
India	Bangalore Chennai Delhi Kolkata Mumbai	11,440,000 10,456,000 28,514,000 14,681,000 19,980,000
Iran	*Tehran*	8,896,000
Kazakhstan	*Almaty*	2,000,000
Kyrgyz Republic	*Bishkek*	1,053,000
Nepal	*Kathmandu*	1,442,000
Pakistan	Karachi Lahore	15,400,000 11,738,000
Sri Lanka	*Colombo*	5,600,000
Tajikistan	*Dushanbe*	863,400
Turkmenistan	*Ashgabat*	1,031,000
Uzbekistan	*Tashkent*	2,486,000
China	Beijing Chongqing Guangzhou Shanghai Shenzhen Tianjin	19,618,000 14,838,000 12,638,000 25,582,000 11,908,000 13,215,000

Source UN DESA (2022)—https://www.un.org/en/desa/products/un-desa-databases and Wikipedia (2021)—https://en.wikipedia.org/wiki/List_of_countries_and_dependencies_by_population

1.2.2.2 Footprint of Urban Growth

‘*Food waste is a massive global problem that has negative humanitarian, environmental and financial implications. Roughly one-third of the food produced in the world for human consumption every year - approximately 1.3 billion tonnes - gets lost or wasted*’. The ‘*per capita waste by consumers is between 95–115 kg a year in Europe and North America, while consumers in sub-Saharan Africa, South and Southeastern Asia, each throw away only 6-11 kg a year*’ (UNEP no date). Needless to say, that food-, energy-, and water-supply in most urban centers, especially large and mega-cities depend on rural areas and trade. This, in turn, means, that the larger the urban settlement, the larger its environmental footprint on the surrounding area, causing an increase of natural habitat loss via encroachment of agricultural ecosystems into natural places. The burning of agricultural by-products not only contributes to the significant release of greenhouse gases, but it also contributes to vehicular emissions and dust, to the massive urban air-pollution in cities. For example, New Delhi counts as one of the most air-polluted cities in the world. The water-demand of urban places is frequently supplied by water resources further away from the cities, such as dams, rivers, and aquifers, causing significant and ecologically noticeable pressure on the water-source. Consequently, it is highly important to put in place measures that aim to increase the efficiency of urbanization and land use, including via good infrastructure planning that supports efficient use of energy, water, and food, considering waste reduction, forest conservation, and restoration, as well as science-based ecosystem management. UNESCO, UN Habitat and SEAMEO (2021) developed a simple and affordable model, called UNESCO Green Academies, to retrofit existing schools and universities into places that develop the knowledge and skills of the students and the general public for better urban environmental management. If we consider three million schools globally, the application of this concept could create a substantial increase in environmental awareness and skills, contributing to the trend towards significantly lower urban footprints. Only one UNESCO Green Academy exists for the time being (in Ethiopia); however, Central and South Asian countries and cities have a huge potential to benefit from converting as many schools as possible according to this concept.

1.2.3 Climate Change Impacts

Climate change, broadly interpreted, is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. Climate change is caused by natural factors, as well as by human-specific impacts. For decades, there has been an increasing concern regarding anthropogenic contributions to climate change. The accelerated warming of the earth’s atmosphere is significantly influenced by the massive release of greenhouse gases and reduced carbon-sequestration, due to deforestation and the loss of blue-carbon ecosystems (WWF 2018; European Commission no date). The reason for concern is obvious:

changes in climate conditions can bring flooding, droughts, and changes in temperature, which in turn will cause significant changes in natural, urban, and agro-ecosystems. Agriculture, forestry, human health, and other parameters depend on climate conditions.

Ecosystem services, water security, food security, and the energy security for human wellbeing are all inextricably linked to climate conditions. Sustainable Development Goal 13 addressing Climate Action explicitly states in Target 13.1. to strengthen the resilience and adaptive capacity regarding climate-related hazards and natural disasters in all countries. Moreover, Target 13.3. demands improvements to education, awareness raising, and building human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning systems. This clearly demonstrates how highly important it is to develop science-based knowledge, skills and preparedness for climate events and climate adaptation, including shock events on a global scale.

The United Nations recognizes that climate change is a threat to global peace and security. Extreme weather events cause adverse impacts on the water, energy, and food nexus, with the potential to trigger social discontent and unrest. In recent years, we have observed massive wildfires, unusual droughts, extreme hurricanes, and immense floods. These weather-related phenomena are linked to the increase of greenhouse gases in the Earth's atmosphere (WWF 2018). To enable competency-based discussions, it is important to speak with the same vocabulary and science-based knowledge when addressing climate issues. This is, unfortunately, frequently not the case. Climate literacy needs a science-based foundation. UNESCO, ILO, IOM, UNDP, UNDRR, UN ESCAP, UNICEF, and UNDRR have completed the production of climate-science-literacy materials (UNESCO 2022). The materials are available in English and Spanish for free download.[3]

The changing weather patterns in Central and South Asia have a profound effect on the region's national economies. The agricultural sector is a key pillar of national economy in many of these countries, and the sector is increasingly vulnerable to the unpredictability and extreme variations in weather conditions caused by climate change (FAO 2015). However, climate change as an impact factor cannot be viewed on its own because there are clearly at least three major additional factors adversely affecting food-security, such as rapid population growth, land-use methods not supported by scientific evidence, and the wastage of water-resources and food-waste.

Table 1.3 shows a few items of major socio-ecological and socio-economic relevance related to the water, energy, and food security nexus. According to the United Nations' Committee on World Food Security, food security is defined as the means that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life (FAO 2006). The FAO defines it as "*The concept of food self-sufficiency is generally taken to mean the extent to which a country can satisfy its food needs from its own domestic production.*" This means a 100% food self-sufficiency where food production is equal to food consumption. Some countries are more than

[3] https://bangkok.unesco.org/content/climate-science-literacy-asia-pacific.

self-sufficient, whereas other countries have a food deficit, as shown in Table 1.3, for cereals and starchy roots, with an output of greater than 140% for Kazakhstan at one end of the spectrum, compared with less than 60% in the case of Bhutan.

Total renewable water resources include the long-term average water availability in km^3 combining precipitation, groundwater, and surface water inflows from surrounding countries. Table 1.3. shows data obtained from Wikipedia (2020), with data from 2011, calculated as per capita. There are huge differences when comparing the countries in the region, with huge per capita resources availability in Bhutan, whereas Pakistan's, India's, and Iran's renewable water per capita being highly limited.

Challenges of undernourishment are less pronounced in Kazakhstan (less than 2.5% of the population), as well as Iran, Turkmenistan, and Uzbekistan (all rated at less than 5% of the population), when compared against Afghanistan, which has comparatively very high rates of undernourishment (25–35% of the population), possibly related to the long-term conflict in Afghanistan, described in Sect. 2.1.1 (FAO et al. 2020).

The same enormous difference can be observed by simply comparing geographical country size, the smallest being Bhutan (38,394 km^2) and Sri Lanka (65,610 km^2), in comparison to geographical giants, such as, India (3,287,000 km^2), Kazakhstan (2,725,000 km^2), and Iran (1,648,000 km^2).

The climatic conditions are also highly diverse, as can be observed, for example by comparing the average annual temperatures, which are as low as 1.6 and 2.0 °C for the Kyrgyz Republic and Tajikistan, respectively, in contrast to Sir Lanka (27 °C) and Bangladesh (25 °C). In addition, especially for the large countries, there are diverse climatological situations within the countries, especially the main parameters of temperature, precipitation, and evapotranspiration, causing substantially different conditions for agriculture, pastoralism, forestry, and water availability.[4] At the time of writing this manuscript (September 2022), the temperature difference ranged from −8 °C in north-eastern Pakistan to 44 °C in South-Eastern Iran (day time temperatures 14:00), and snow cover could be observed in high-altitude parts of Afghanistan, Bhutan, northern India, Iran, Kazakhstan, Kyrgyz Republic, Nepal, Pakistan, Tajikistan, and Uzbekistan; whereas, Bangladesh, Sri Lanka, most of India, and large areas of most of the countries appeared free of snow.

1.2.3.1 Glacier Retreat

Central Asia's glaciers are losing vast amounts of ice every year. The 2014 Dushanbe Seminar Report (Diebold 2014) concluded that '*Global warming and climate change will have effects on the high mountains of Central Asia. Most likely glaciers will be melting more rapidly. This will have consequences not only for the water balance*

[4] Live data on weather can be obtained on https://www.ventusky.com/?p=16.9;98.3;4&l=temperature-2m.

Table 1.3 Unique geographical socio-ecological and socio-economic characteristics include the following items

Country	Country Size km^2 (google)	Total renewable water resources km^3 (Wikipedia 2020[a])	Renewable water m^3 per capita (UNSD 2011)[b]	Average annual temperature (°C) (Wikipedia 2020[c])	Prevalence of undernourishment in the total population in 2017–19 (WFP 2020) percentage	Food self-sufficiency for cereals and starchy roots in percent Clapp (2017)	GDP ($)
Afghanistan	647,230	25	2389	12.60	25–34,9	85–99	1970
Bangladesh	148,460	1227	7567	25.00	5–14,9	85–99	4570
Bhutan	38,394	35	106,292	7.40	data not available	<60	9700
India	3,287,000	1911	1582	23.65	5–14,9	100–114	7680
Iran	1,648,000	137	1876		<5	60–84	21,050
Kazakhstan	2,725,000	66	7062	6.40	<2,5	>140	24,450
Kyrgyz Republic	199,900	24	6142	1.55	5–14,9	60–84	3780
Maldives	300	0.03	98	27.65	5–14.9	60–84	11,801
Nepal	147,516	211	7296	8.10	5–14,9	85–99	3110
Pakistan	796,095	247	1321	21.00	5–14,9	60–84	5860
Sri Lanka	65,610	53	2492	26.95	5–14,9	85–99	13,110
Tajikistan	143,100	22	14,589	2.00	data not available	85–99	4050
Turkmenistan	491,210	106	12,067	15.10	<5	85–99	18,490
Uzbekistan	448,978	49	2656	12.05	<5	60–84	8810
China	9,597,000	2840	2140	6.95	<2,5	85–99	18,170

[a]https://en.wikipedia.org/wiki/List_of_countries_by_total_renewable_water_resources
[b]https://unstats.un.org/UNSDWebsite/
[c]https://en.wikipedia.org/wiki/List_of_countries_by_average_yearly_temperature
Source Wikipedia (January 2021), World Food Programme (2020) and Clapp (2017)

in the Aral Sea basin. It will lead among others to natural disasters like landslides, glacial lake outburst and it will affect the socio-economic development of the region'.

1.2.3.2 Sea-Level Rise

Coastal areas are immensely exposed to sea-level rise (McGranahan et al. 2006; Vivekananda and Bhatiya 2016) including coastal mega-cities, in the geographical context of this book, Dhaka, Karachi, and Kolkota, as well as numerous other large settlements in costal South Asia.

Especially the Maldives, consisting of 1,190 islands and no ground surface higher than three meters above sea-level, and most of its land below one meter above sea-level, is one of the most vulnerable countries to sea-level rise and coastal flooding.

1.2.3.3 Changes to the Hydrological Cycle

Changes in the hydrological cycle include changes in evaporation, evapotranspiration, cloud-formation, high-altitude winds, precipitation, surface water bodies and run-off, soil infiltration and aquifer recharge, shallow and deep ground-water resources, as well as coastal and marine seawater dynamics, including sea-level changes. These changes are being caused by climate-fluctuations, both, natural and anthropogenic, the functioning of the biosphere, in particular by inter-tidal mangrove stands and terrestrial forests, as well as by river straightening, dams, deforestation, surface-sealing, massive freshwater extraction, and other factors.

The most alarming scenarios are of course prolonged droughts, adversely impacting water-, food, and energy-supply, massive floods, causing the decline or loss of crop-harvests, and infrastructural damage to water-reservoirs, as well as the slow increase in seawater-levels. This is of increasing concern for highly productive delta agro-systems, such as, the Bengal Delta (formed by the confluence of the rivers Ganges, the Brahmaputra, and Meghna), as well as the Indus Delta, and deltas of many more rivers, where seawater intrusion and salinization of agricultural land can be anticipated (Eslami et al. 2012; Rahman et al. 2019; Bricheno et al. 2021). In Pakistan, the University of Karachi's *Dr. Mohamed Ajmal Khan Institute for Sustainable Halophyte Utilization* (ISHU), as well as in the United Arab Emirates, the International Centre for Biosaline Agriculture (ICBA), as well as the Chinese Academy of Sciences, and more recently the Tunisian *Science Institute of Blue Carbon Ecosystem Research and Development for Climate Change Adaptation and Mitigation* (in planning), as well as other halophyte and salinity research groups in many are of the world are studying how biosaline agriculture can work under increased soil-water conditions exposed to high salinity levels. It is believed this will become even more important when the effects of seawater intrusion into delta systems force farmers to turn from freshwater systems to agriculture under high-salinity conditions.

1.2.3.4 Impacts on Food Production

Climate change has a substantial impact on food production, since every plant species (Böer and Sargeant 1998) and food crop that is under cultivation or collected from nature, has a bio-geographical range that it cannot exceed. Every plant, including every food plant, fodder plant, and all other plants have certain thresholds for the average annual temperatures, maximum and minimum temperatures, as well as soil and water conditions under which they can germinate, grow, produce flowers and seeds, and undergo the entire reproductive cycle. Should the temperature and water-supply regimes change noticeably, that would cause the crops-species to grow outside the ecological optimum, which in turn causes changes, possibly reductions in crop harvests. Should the regime tilt beyond the ecological tolerance, that would mean that the crop-species cannot be produced and grow anymore, and it would have to be replaced (if possible), with an alternative food-crop that is more tolerant to the new climatic situation when compared to the crop that was previously produced. This would also require the whole food-production and consumption network to adapt to new soil melioration, fertilization, possibly irrigation and drainage methods, different harvest-systems, times, machinery, storage, transport, trade, and it would still need to be in line with the supply and demand, as well as cultural acceptability.

1.2.3.5 Increase in Energy Demand

Climate change can trigger an increase for energy demand, either for heating or for cooling of human accommodation, including in large and mega-cities, but also, via forced changes in agricultural systems triggering an increase in energy demand, for example, by introducing more energy-demanding crop-production, harvest, storage, transport, trading, and consumption systems.

A rise in temperature could lead to more cooling requirements in summer and in warm areas, whereas increased winter cold temperatures, significantly reduce cooling requirements in winter.

According to van Ruijven et al. (2019) '*the future energy demand is likely to increase due to climate change, but the magnitude depends on many interacting sources of uncertainty.*' The authors believe that warming increases global climate-exposed energy demand around 2050 by more than 25% in the tropics.

1.2.4 COVID-19 Pandemic

The global COVID-19 pandemic that started in China in November 2019, and that caused step-by-step the partial or complete lock-down of countries, has had a substantial impact on the health and economic situation in the region, long-term consequences for economic development, as well as potential impact for the water-energy-food nexus, yet to be assessed in detail. Table 1.4 shows the number of people that had been infected with COVID-19, number of deaths, as well as the number of people that have recovered.

The COVID-19 pandemic has put a significant strain on public health systems in the Central and South Asian region. Governments, UN agencies, and other partners are assessing the socio-economic impacts still unfolding. The whole socio-economic loss, including the loss of jobs and income, income-based migration, as well as the effect on the water, energy, and food security can only be comprehensively assessed once the situation has globally improved. Measures to contain the spread and health impact of the disease have already led to a breakdown in supply chains

Table 1.4 COVID-19 statistics in the Central and South Asian region

Country	Worldometer 5 September 2022 Total cases (confirmed)	Worldometer 5 September 2022 **Total deaths** Total recovered	Worldometer 5 September 2022 Deaths/1 million
Afghanistan	194,355	**7783** 172,407	191
Bangladesh	2,012,761	**29,328** 1,957,271	174
Bhutan	61,076	**21** 60,961	27
India	44,462,445	**528,007** 43,880,464	375
Iran	7,533,087	**143,995** 7,307,292	1668
Kazakhstan	1,390,109	**13,684** 1,359,538	710
Kyrgyz Republic	205,716	**2991** 196,406	443
Maldives	184,856	**308** 163,687	549
Nepal	997,868	**12,007** 983,333	397
Pakistan	1,570,206	**30,593** 1,530,962	133
Sri Lanka	670,176	**16,711** 652,967	773
Tajikistan	17,786	**125**	12
Turkmenistan	*No data*	*No data*	*No data*
Uzbekistan	243,830	**1637** 241,486	47
World	610,457,828	**6,504,142** 587,358,890	834.4

Source Worldometer (September 2022)

and interruptions of production units, as well as demand shocks caused by declines in consumption, investment, and exports.

It is remarkable, for the time being, that with the exception of Iran, all countries under consideration on this volume have lower COVID-19 death/per million population rates, when compared with the world average (Table 1.4). Naturally, the figures can be more or less accurate, and certainly influenced by a variety of factors, including the number and accuracy of tests, climate conditions, natural resilience, as well as average age of the population (and the corresponding immune-system strengths), which would influence the number of asymptomatic cases, which would remain undetected. Another remaining question, globally valid, of course is: did the person die with COVID-19 infection, or because of the COVID-19 infection?

In any case, the total number of confirmed infected persons is more than 610 million (Worldometer September 2022), with the total number of deaths exceeding 250,000 people. Not only is this very tragic, sad, and often highly traumatizing for the relatives, who, in addition to their emotional loss often suffer the loss of an income provider, it is most certainly also having a significant direct and indirect impact on the local food-, water-, and energy-security situations, due to the inability of hospitalized persons of being productive during treatment, quarantine, and recuperation.

1.3 Key Challenges and Opportunities in Central and South Asia

1.3.1 Economic Growth and Developmental Challenges

All the countries in the Central and South Asian region have undergone significant structural changes in the past two decades, in conjunction with economic growth (Osmani 2018); these changes are reflected in the growth rates of the economy of this period, as shown in Table 1.5. In general, South Asian economies have not kept pace with other East and Southeast Asian economies, while there has been considerable population growth (Osmani 2018). Overall, the Central Asian economies have performed better in comparison to South Asia, with higher annual average growth rates in the Gross Domestic Product (GDP). Multiple factors impact the economic performance of national economies, including but not limited to: population growth rates, strength of democratic institutions, history of colonialism and its pervading impacts on national institutions, geographical advantages and disadvantages (e.g., being landlocked), access to water resources and related agricultural productivity, and political stability and trajectory of democratic institutions (Osmani 2018).

Some countries in the region have shown remarkable deceleration in their economies over the past decade (2010–2020), as shown in Table 1.5—notably including Afghanistan, Bhutan, Iran, and Kazakhstan. Other countries have either maintained the economic growth rate or demonstrated a minor drop; including India, Kyrgyz Republic, Maldives, Pakistan, Sri Lanka, Tajikistan, and Uzbekistan; we

Table 1.5 Economic growth rate in Central and South Asia, described in terms of growth of Gross Domestic Product (GDP)

	GDP Growth Rate %[a]	
	2000–2010	2010–2020
Afghanistan	9.5	3.2
Bangladesh	5.7	6.6
Bhutan	8.7	4.6
India	6.9	6.1
Iran	4.8	1.3
Kazakhstan	8.3	3.4
Kyrgyz Republic	4.5	4.0
Maldives	5.6	4.0
Nepal	3.9	4.7
Pakistan	4.7	4.3
Sri Lanka	5.6	4.2
Tajikistan	8.1	6.9
Turkmenistan	8.3	8.3
Uzbekistan	7.1	6.1

[a]Based on annual average growth rate
Source World Bank (2018) and World Development Indicators database http://wdi.worldbank.org/table/4.1

should note here that the GDP growth rate of these countries is still reasonable, except for Maldives and Pakistan which hover around 4% annual growth in GDP. Bangladesh has shown remarkable growth in its economy; this acceleration is accompanied by a significant decline in the population growth rate, resulting in a sharp rise in GDP per capita values (Osmani 2018). Strength of economy and its growth rate is a major determinant in the national capacity to respond to water, energy, and food security challenges, and the resilience against external shocks such as climate-related disasters and the global COVID-19 pandemic.

1.3.2 Sustainable Development Goals and Their Implementation

The Sustainable Development Goals (SDGs) adapted by the United Nations General Assembly in 2015 present the global roadmap for addressing economic, social, and environmental challenges facing the world. The various SDG targets and indicators have a bearing on the water, energy, food nexus; it can be argued that the most direct correlation with the water, energy, food nexus is for the following goals:

- SDG 2 that aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture.

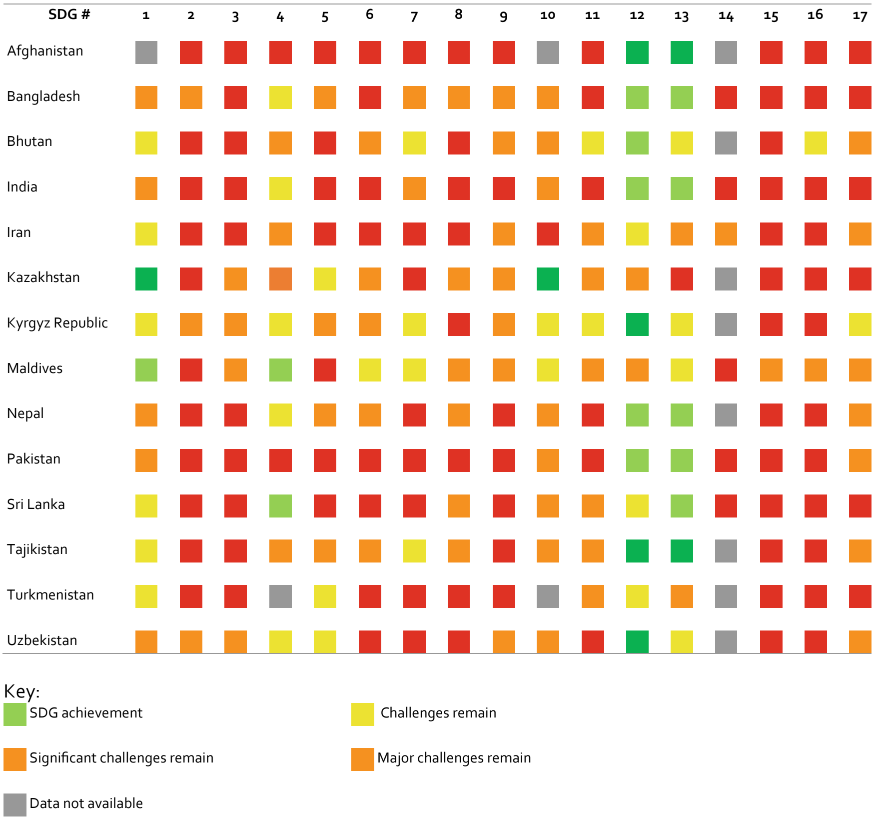
- SDG 6 that aims to ensure availability and sustainable management of water and sanitation for all.
- SDG 7 that aims to ensure access to affordable, reliable, sustainable, and modern energy for all.
- SDG 8 that promotes sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
- SDG 12 that ensures sustainable consumption and production patterns.
- SDG 13 that aims to take urgent action to combat climate change and its impacts.
- SDG 17 that aims to strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

One may argue that it would be important to review the progress of the countries in Central and South Asian region against the targets set within the SDG framework. The most detailed and up to date analysis is provided in the Sustainable Development Report 2022 (Sachs et al. 2022); such a SDG-by-SDG comparison for the region is summarized in Table 1.6. It is important to point out that the SDG "dashboard" represents a composite of data and analyses produced by a number of international organizations, civil society organizations, and research centers (Sachs et al. 2022). We must also recognize that this summary of progress towards SDG targets is influenced by a number of factors discussed earlier in this chapter including the Ukraine war, the COVID-19 pandemic, the political turmoil in Afghanistan, and prolonged economic sanctions against Iran.

A review of Table 1.6 demonstrates that of the seven SDGs identified above, most countries in the region appear to be struggling and doing poorly to achieve the underlying targets. For SDG 2 and SDG 6, all countries appear to have major or significant challenges in achieving food and water security for all, respectively. The situation appears to be more encouraging for achieving the energy-related targets for SDG 7 in the region. Another positive aspect is around SDG 12 and SDG 13, for which most countries in the region seem to be on target or close to achieving the targets. One may argue that SDG 17 represents that capacity of the countries to enhance responses in achieving SDG targets, and the situation does not look particularly hopeful for any of the countries in the region.

The Sustainable Development Report 2022 (Sachs et al. 2022) also provides a composite SDG Index for each country, on a scale of 0–100. The SDG Index scores for all countries are used to rank them in accordance with the relative effectiveness of their SDG implementation strategies. Such scores and ranking are presented in Table 1.7. Of the 163 countries ranked according to their SDG Index, none of the Central and South Asian countries except the Kyrgyz Republic rank in the top 50. Afghanistan, India, and Pakistan rank the lowest and considerably behind the rest of the countries in the region. Such performance in implementing the 2030 Agenda for Sustainable Development translates into relatively limited capacity to meet the SDG targets pertaining to water, energy, and food nexus; we can also directly observe this outcome in Table 1.6.

Table 1.6 2022 SDG dashboard for Central and South Asia



Data source: Sachs et al. (2022)

1.3.3 New Energy Corridors in Central and South Asia

In terms of fossil fuel-based energy resources, the Central Asian states (i.e., the former Soviet Republics) possess significant reserves that far exceed their domestic consumptive needs (Pradhan 2022). These fossil fuel reserves have been historically underdeveloped. Overall, this situation considerably increases the geopolitical significance of these countries as the net energy exporters in the region. By the same token, development of energy corridors to export these resources to various international markets and their geographic location also gain strategic importance. The Kyrgyz Republic and Tajikistan are the two most energy scarce countries in terms of fossil fuel reserves, but their potential for hydropower generation enables them to also be considered net energy exporters.

A number of energy corridors have been discussed, primarily meant to export oil and natural gas from Kazakhstan and Turkmenistan to the rest of the of the world. A

Table 1.7 Ranking of Central and South Asian countries in accordance with their respective SDG Index score and ranking

	Rank	Score
Kyrgyz Republic	48	73.7
Kazakhstan	65	71.1
Maldives	67	71.0
Bhutan	70	70.5
Sri Lanka	76	70.0
Uzbekistan	77	69.9
Tajikistan	78	69.7
Iran	88	68.6
Nepal	98	66.2
Turkmenistan	99	66.1
Bangladesh	104	64.2
India	121	60.3
Pakistan	125	59.3
Afghanistan	147	52.5

Source Sachs et al. (2022)

typical example of such a corridor is the gas pipeline project called the Turkmenistan-Afghanistan-Pakistan-India (TAPI) gas pipeline (Sachdeva 2010). This project has been marred, however, because of the uncertainties surrounding natural gas supply in Turkmenistan, the worsening security situation in Afghanistan as discussed earlier, and the escalating political tensions between India and Pakistan (Pradhan 2022). To meet its increasing energy demands, India has also signed exploration agreements with its counterparts in Kazakhstan, focused on natural gas reserves in the northwestern Caspian Sea (Sajjanhar 2016). The Central Asia South Asia Regional Energy Markets (CASAREM) is a regional electricity network that connects the Kyrgyz Republic and Tajikistan (being net exporters) to Afghanistan (the energy importer).

1.4 Organization of This Book

1.4.1 Section I—A Region-Wide Overview

A regional overview establishes the basic facts around the state of water, energy, and food resources; this section is meant as the foundation upon which further exploration and analysis is built. Lal provides an overview of the state of food security in the region, with a particular focus on the role of soil condition in ensuring agricultural productivity. Qadir provides a detailed analysis of the regional interface between water and food security, thus offering key insights into one-third of the nexus. Rahimzoda similarly analyzes the water-energy interface, particularly focusing on the role of Tajikistan in this region (as also discussed in Sect. 3.3).

1.4.2 Section II—Regional Issues

This section turns its attention to regional issues and unpacks the nexus into key strategic action areas. Zia discusses the role of early warning systems (EWS) in achieving water-, energy-, and food-security at a regional scale. Rochholz and her colleagues take an in-depth look at the impact of climate change on the nexus. Pandey and Midha discuss how gender perspectives can be incorporated in the nexus dialogue and related policy solutions.

1.4.3 Section III—Cross-Cutting Themes for Nexus Security

In this section, a number of cross-cutting themes are explored with an eye towards the major drivers of policy and development strategies in the region. Mawani focuses on the South Asian experience of how gender interplays with food and water insecurity, particularly the overlay of other cultural barriers to women's engagement in decision-making processes. Tiwari undertakes an in-depth analysis of the economic policies enacted to reduce poverty in the Central and South Asian region. Akram and his colleagues analyze how the implementation of the SDGs fits into the larger picture of water, energy, and security for the region.

1.4.4 Section IV—An Integrated Narrative

The two chapters in this concluding section undertake the development of an integrated narrative based on the discussions throughout the book. This section explores how the new global development framework in the form of SDGs might offer a new perspective for achieving the nexus security in the region. Lone makes an argument that the security of water, energy and food resources is closely tied to with achievement of long-term peace and security. A final wrap-up chapter by Adeel gazes into the crystal ball to play out some future scenarios based on the evidence presented in the book.

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Chapter 2
Managing Soils for Food Security in Central and South Asia

Rattan Lal

Abstract Food insecurity in densely populated South Asia remains a major issue despite the success of the Green Revolution, and the problem also exists even in the sparsely populated Central Asia. Growing population, changing climate, degrading soils, increasingly vulnerable ecoregions, and worsening political stability are among numerous contributors to food insecurity in Central and South Asia. There exists a strong "soil degradation – global warming – food insecurity nexus" which must be addressed through translation of proven agronomic and pedologic science into action by prudent governance and political will power. Prominent processes of soil degradation include decline of soil structure along with crusting and compaction, accelerated erosion by water and wind, excessive withdrawal of water, along with eutrophication and contamination, depletion of soil organic matter content, pollution of air, mining of plant nutrients by extractive practices, rapid salinization and acidification of soil, and growing risks of waterlogging because of flood irrigation, etc. Global warming is adversely affecting the agronomic yield and taking a collective action at a regional level through cooperation among all countries, is critical to addressing the serious issue of food and nutritional insecurity that cuts across political, ethnic, and national boundaries. Risks of stagnating and declining agronomic productivity, along with aggravating soil degradation because of changing climate and inappropriate soil/crop/water management, is an especially urgent issue in densely populated South Asia that cannot be ignored. Food wastes, 30 to 40% of grains and even more for fruits and vegetables, are crime against nature and humanity and must be urgently addressed. It would be prudent and nature-friendly to adopt policies which discourage the in-field burning of crop residues, scalping of topsoil for brick making, using flood-based irrigation, puddling of soil followed by inundation of rice paddies in arid and semi-arid regions and broadcasting of fertilizers. Subsidies, such as those for irrigation and nitrogen fertilizers, must be changed into payments for ecosystem services provisioned through adoption of recommended management practices. Thus, stronger investment in agriculture and transformational changes in

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policies are needed to achieve Sustainable Development Goal 2 (Zero Hunger) of the 2030 Agenda for Sustainable Development of the United Nations.

Keywords Soil degradation · Soil health · Food security · Malnutrition · South Asia · Central Asia · Sustainable agriculture · Carbon sequestration · Global warming · Aral Sea · Irrigation · Salinization · Adaptation · Mitigation · Water management · Green Revolution

2.1 Introduction

Food security indicators include availability, affordability or access, stability, nutritional quality, safety, utilization, and retention of nutrient-rich food (Fig. 2.1). A critical and objective review of these indicators highlight the urgency of addressing the severe prevalence of food insecurity not only in South Asia (SA) but also in Central Asia (CA). Thus, the Sustainable Development Goal (SDG) 2 of the United Nations is not on track. Over two-thirds of the world's poorest and most food-insecure people live in developing countries (Gautam and Andersen 2017), and SA is a region prone to poverty and food insecurity. SA has population of ~2 billion (B) people, and it is home to 22% of the world population and 40% of the world's poor (Aggarwal and Sivakumar 2011). The ever-increasing population has stressed the finite soil and water resources (Nawaz et al. 2021), and aggravated food insecurity. The latter has persisted in SA despite the success of the Green Revolution which tripled cereal production during the second half of the twentieth century (Mughal and Fontan Sers 2020). The data in Table 2.1 indicate that the prevalence of food insecurity in SA during 2019 was 257.3 million (M) people or 13.4% of the total population. In comparison with 2005, the absolute number of food-insecure people in SA decreased from 328 M to 257.6 M in 2019, and it is projected to decrease further to 203.6 M by 2030. Similarly, the percentage (%) of food-insecure population in SA decreased from 20.6 in 2005 to 13.4 in 2019 and is projected to decrease to 9.5% by 2030 (Table 2.1). In comparison, food security in CA is relatively better than that in SA. The number of under-nourished people was 6.5 M in 2005, 2.0 M in 2019 and is projected to decrease by 2030. Similarly, the percentage of food-insecure population in CA in 2005 was 11.0 and declined to 2.7 to 2019 and will be less than 2.5 in 2030 (Table 2.1). Both regions, SA and CA, are far away from fulfilling their commitment to achieving the SDG 2 of the United Nations.

During the 25 years since 1995, significant progress has been made in reducing food insecurity in SA, including in India, Nepal, and Sri Lanka because of rapid economic growth. The Green Revolution of the 1960s and 1970s transformed cereal production (especially of wheat) (Shiferaw et al. 2013) and of rice in SA. However, the serious problem of food insecurity persists in SA because of (a) degradation of natural resources including soil, water, vegetation, biodiversity, and air; (b) land misuse and soil mismanagement; and (c) inappropriate and outdated policies. Therefore, the objectives of this chapter are to discuss the following: (1) the state of soil and per

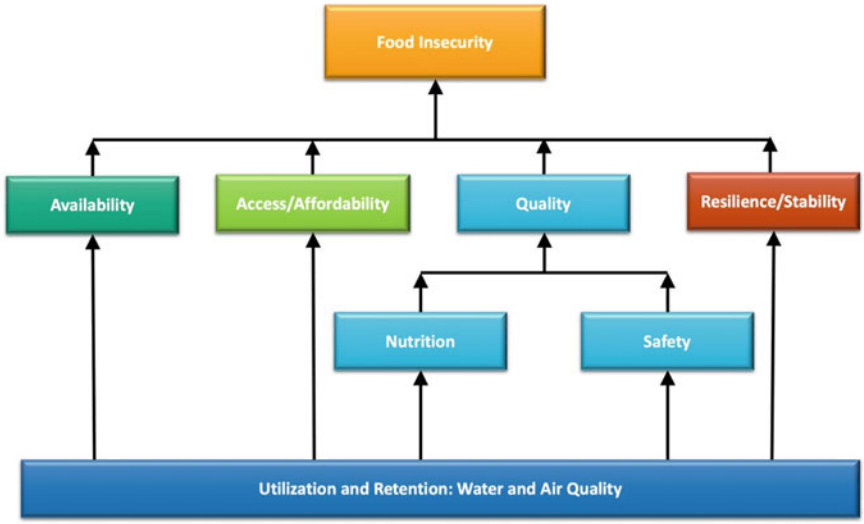

Fig. 2.1 Indicators of the prevalence of food insecurity

capita availability of key natural resources in the context of growing population; (2) basic principles and technological options for protection, sustainable management, and restoration of soil and other natural resources; and (3) some policy interventions needed to address undernutrition and malnutrition in Central and South Asia.

2.2 The State of Soil Resources of Central and South Asia

Agricultural land misuse and soil mismanagement are among the widespread causes of food insecurity, and their effects on soil degradation are being exacerbated by extreme events related to global warming. Soil degradation caused by land misuse and soil mismanagement, is a major challenge in both Central and South Asia contributing to widespread problems of food and nutritional insecurity in both regions. The state of the soil of these regions is reflected in the poverty and low wellbeing of the people, especially of those in SA. Similar to the SDG 2, the regions' commitment to take an effective climate action (SDG 13) and achieve the land degradation neutrality (SDG 15) are also not on track of to be accomplished by 2030.

2.2.1 South Asia

SA region includes Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka. The SA region, often used synonymously with "Indian subcontinent," is the

Table 2.1 Prevalence of under-nutrition in Central and South Asia

Country	% Undernourished			Country	# Undernourished (M)		
	Year				Year		
	2000–2002	2004–2006	2017–2019		2000–2002	2004–2006	2017–2019
South Asia	18.5	20	13.4	**South Asia**	274.2	318	254.7
Afghanistan	47.8	36.2	29.9	Afghanistan	10.4	9.3	11.1
Bangladesh	16	14.3	13	Bangladesh	20.8	19.9	20.9
India	18.6	21.7	14	India	199.6	249.4	189.2
Nepal	23.6	16.9	6.1	Nepal	5.7	4.3	1.7
Pakistan	21.2	17.7	12.3	Pakistan	31	28.4	26.1
Sri Lanka	17	14.8	7.6	Sri Lanka	3.2	2.9	1.6
Central Asia	13.3	11.1	2.9	**Central Asia**	7.4	6.5	2.1
Azerbaijan	17.1	4.8	<2.5	Azerbaijan	1.4	0.4	n/a
Kazakhstan	6.6	7.4	<2.5	Kazakhstan	1	1.1	n/r
Kyrgyzstan	15.3	9.1	6.4	Kyrgyzstan	0.8	0.5	0.4
Tajikistan	n/a	n/a	n/a	Tajikistan	n/a	n/a	n/a
Turkmenistan	6.9	4.3	4	Turkmenistan	0.3	0.2	0.2
Uzbekistan	18	14.9	2.6	Uzbekistan	4.5	3.9	0.8

Adapted from FAO (2020)

most densely populated region of the world with the total population of ~2 B (United Nations 2019). The geographical area of SA is 5.1 M km^2. It has a wide range of complex biomes south of the Himalayan Mountains. There are strong climatic gradients as characterized by regions receiving both the highest and the lowest amount of rainfall in the world. The region also has diverse soils and physiographic characteristics which create numerous opportunities and some serious challenges for transforming the food systems.

In SA, where more than 94% of the area suitable for agriculture is already being cultivated, heavy monsoonal rains on steep lands cause severe water erosion (Wijesinghe and Park 2017). Desertification of arid regions, ~100 ha/yr, is adversely affecting cropland in Pakistan and India (Hasnat et al. 2018). Extreme climatic events are aggravating soil degradation in SA (Farooq et al. 2019) which is caused by water and wind erosion, salinization, depletion of soil organic matter (SOM) content, decline of soil fertility and elemental imbalance, lowering of the water table, and loss of topsoil to brick making. However, data on the reliable estimates of the extent and severity of degradation, and its impact on agronomic productivity, are not available. The ISRIC and UNEP (1991) reports are 30 years old and need to be updated using standard methodology (Table 2.2). In this regard, some progress has been made at the country level (e.g., India, Pakistan, Bangladesh). For example, Bhattacharyya et al. (2015) reported that soil degradation in India affects 147 M ha of land, including 94 M ha from water erosion, 9 M ha from wind erosion, 16 M ha from acidification, 14 M ha from flooding, 6 M ha from salinity, and 7 M ha from a combination of factors (Table 2.3). In comparison, ICAR and NAAS (2010) reported that 104 M ha of land are prone to different soil processes (Table 2.3). The wide variation in these estimates highlights the need for improvement and standardization of methodology and application at a regional scale for all countries within SA which cover a wide range of climates, soil types, and ecoregions. Furthermore, such a severe problem has a major impact on the economy and human wellbeing. For example, India supports 18% of the global human population (Table 2.21 in Appendix) with 15% of the world's livestock population on merely 2% of the global land area. Degradation of the finite soil resources has severe adverse impacts on the nation's economy and wellbeing of its people, who are mirror image of the land, and the vice versa.

Hasnat et al. (2018) undertook a regional study on the environmental issues and problems of SA. They observed that most vulnerable ecoregions are grasslands and mountain forest ecosystems of the Himalayas and the Sundarbans delta of Ganges and Brahmaputra. Forests of SA are threatened by deforestation and urbanization. The Thar desert is expanding at the rate of 100 ha/yr. and this may adversely affect 13,000 ha of cropland in India and Pakistan. Water supplies are threatened by coastal flooding, changes in river flow, and high temperatures due to global warming. The severity and extent of soil degradation in SA are among major causes of food and nutritional insecurity.

Table 2.2 Extent and severity of soil degradation by different processes in South Asia

Process	Land area affected (M ha)	
	FAO, UNDP, UNEP (1994)	FAO-RAPA (1992)/FAO (1991)
Water erosion	81.7	111.0
Wind erosion	59.0	38.7
Soil fertility decline	42.4	–
Waterlogging	5.7	8.5
Salinization	28.5	17.7
Lowering the water table	19.8	–

Adapted from FAO, UNDP, and UNEP (1994), FAO (1991), and FAO and RAPA (1992)

Table 2.3 Comparative estimates of soil degradation by different processes in India

Process	Land area affected (M ha)	
	ICAR and NAAS (2010)	Bhattacharyya et al. (2015)
Water erosion	73.3	94
Wind erosion	12.4	9
Acidification	5.7	16
Flooding	1.1	14
Salinity	5.4	6
Others	–	7
Total	104.2	147

Adapted from Bhattacharyya et al. (2015) and ICAR and NAAS (2010)

2.2.2 Central Asia

The region is comprised of six countries that obtained independence from the former Soviet Union in 1991 (Azerbaijan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) with a total land area of ~400 M ha (Lal 2007). Grazing land is the predominant land use. Soil degradation affects one-third of the terrestrial area in CA (Mirzabaev et al. 2015) and is adversely affecting economic growth, human wellbeing, social equity, and ecosystem services (Hamidov et al. 2016). About two thirds of the total land are drylands and prone to desertification. Consequently, a large proportion of the land in these countries is degraded (Lipton 2019), and estimates of soil conservation vary with changes in the projected climate (Table 2.4). The data on the extent of soil degradation in CA shown in Table 2.5 indicates the complexity of the diverse processes involved. Not only are the processes of degradation diverse, but there may also be interaction between land use and the degradation process. Development of the irrigation scheme had adverse and irreversible impacts

Table 2.4 Estimated soil conservation in Central Asia under the current temperature and precipitation (1996–2012) and with 1.5 °C and 2.0 °C global warming

Global warming	Temperature (°C)	Precipitation (mm/y)	Soil conservation (Mg/ha)
Unreadable (1996–2015)	8.1	189	8.2
1.5 °C	8.8	193	8.1
2.0 °C	9.3	204	8.0

Adapted from Ma et al. (2020)

Table 2.5 Extent of soil degradation in Central Asia

Country	Total land area (M ha)	Land area affected (M ha)					
		Salinity	Sodicity	Shallowness	Erosion	Total	% of total land area
Kazakhstan	270.0	21.5	107.1	38.6	7.8	175.0	94.6
Kyrgyzstan	19.2	0.1	–	10.7	5.6	16.4	85.5
Tajikistan	14.0	0.7	–	6.8	3.7	11.2	80.0
Turkmenistan	47.0	7.3	1.7	3.5	0.7	13.2	28.1
Uzbekistan	42.5	6.3	4.6	3.9	1.3	16.1	37.8
Total	392.7					231.9	59.1

Adapted and recalculated from Bot et al. (2000) and Gupta et al. (2009)

on the Aral Sea (Table 2.6). Irrigation of 2 M ha of cropland in the Fergana Valley made the desert land bloom, but this devastated the fourth largest lake of the world even over the short period of five decades. It was a water management disaster (Micklin 1988). Excessive water withdrawal for irrigation has dried out the Aral Sea, desertified it into a sea-bed of salt-enriched dust blown into the surrounding land while adversely affecting the environment and wellbeing of the people of the region (Wæhler and Dietrichs 2017). While cotton production expanded, grazing lands were prone to desertification and irrigated lands to secondary salinization. While similar to SA, reliable estimates of the extent and severity of degradation by different processes are not available. Yet the problem of soil degradation is being aggravated by the current and projected climate change. Since the year 2000, the average temperature of the region has increased by +0.5 °C to +1.6 °C and major land uses (e.g., cropland, pastureland, and forest land) are prone to desertification. Land area affected by degradation of pastures is estimated at 20% in Kyrgyzstan, 89% of summer pastures and 97% of winter pastures in Tajikistan, and 70% of all pastures in Turkmenistan (Lipton 2019).

Soils are prone to desertification and erosion, salinization, and forest degradation, which are causing severe economic losses (Lipton 2019). Grazing and pasture lands are adversely affected (Reddy 2016), and the problem is aggravated by arid and semi-arid climates which are sensitive to anthropogenic perturbations (Zhang et al.

Table 2.6 Shrinkage of the area of the Aral Sea (10^3 Km^2) over 50 years by water mismanagement for irrigation

Year	Area (10^3 Km^2)
1960	68.0
1987	40.8
1997	6.8
2014	0

Water diverted from Syr Darya for irrigation of 2M ha of cotton on the Fergana Valley

Data collated from Micklin (1988) and Wæhler and Dietrichs (2017)

2017). Mirzabaev et al. (2015) estimated that because of the land use and cover change between 2001 and 2009, the annual cost of land degradation in CA was about US$6B. Of this $4.6B was caused by degradation of rangeland, $0.8B by desertification $0.3B by deforestation and $0.1B by abandonment of cropland. The costs of action against land degradation are found to be five times lower than the cost of inaction in CA over a 30-year horizon. The cost of action was estimated to be $53B over 30 years, compared to the cost of no action at $288B over that same time period. Robinson (2016) also reported that degradation from vegetation grazing affected 79% of pasture area. In addition to wind erosion and drought, secondary salinization is a major process of soil degradation, with adverse effect on soil quality in CA.

Global warming may further aggravate soil degradation by erosion and other processes. Soil conservation, the prevention of soil loss from erosion, and limiting the related decline in soil fertility by overuse, may also become major challenges by the present and projected global warming. Ma et al. (2020) estimated that future soil conservation may decrease with climate change by 4.7% with 1.5 °C global warming and by 7.9% with 2 °C warming (Table 2.4).

2.3 Yield Trends

Increased yields of cereals in SA during the second half of the twentieth century has caused the decline in prevalence of undernutrition in SA over time (Table 2.1). Therefore, additional increase in productivity of cereals is critical to eliminating food insecurity in SA. Mughal and Sers (2020) reported that each 1% increase in cereal production and yield would lead to 0.84% decrease in prevalence of undernourishment. The impact is significant over a period of 3 years and this positive impact is specifically significant with regards to the yield of rice and maize. Yields of cereals and pulses in SA from 1961 to 2019 show an increasing trend and are specifically high in Bangladesh and Sri Lanka (Table 2.7), with cereal yields greater than 4.7 Mg/ha. For example, the average yield of cereals in SA increased from 1 Mg/ha in 1961 to 3.4 Mg/ha in 2019. Yet, the mean yield of cereals in SA is lower than that of the

Table 2.7 Temporal trends in crop yields in South Asia

Country	Cereals (Mg/ha)					Pulses (kg/ha)				
	1961	1980	2000	2010	2019	1961	1980	2000	2010	2019
Afghanistan	1.12	1.35	0.81	2.01	2.11	878	988	1020	1071	683
Bangladesh	1.68	2.01	3.38	4.29	4.81	695	630	773	1013	1110
India	0.95	1.35	2.29	2.68	3.40	540	400	704	650	698
Nepal	1.85	1.69	2.14	2.29	3.09	494	534	772	815	1120
Pakistan	0.86	1.61	2.40	2.61	3.12	490	374	598	549	574
Sri Lanka	1.77	2.50	3.34	3.97	4.74	457	872	919	1102	1144
South Asia	1.01	1.42	2.35	2.76	3.38	540	414	693	650	700
China	1.21	2.95	4.76	5.53	6.28	876	1243	1398	1408	1790
USA	2.52	3.77	5.85	6.98	8.03	1405	1620	1823	1905	2004
World	1.35	2.16	3.06	3.55	4.11	637	666	843	903	992

Adapted from FAOSTAT (2021)

world average (4.1 Mg/ha); the average yield in China is 6.2 Mg/ha and that of the US is 8.0 Mg/ha. Thus, there is room for vast improvement in productivity of cereals in SA.

Similar to the trends of cereal yield, those of pulses are also improving, except those in Afghanistan, likely because of political instability. In Bangladesh, Nepal, and Sri Lanka, the average yields of pulses were more than 1.1 Mg/ha in 2019 (Table 2.7). Mean yield of pulses in SA of 700 kg/ha in 2019 is lower than that of the average yield for the world (~1 Mg/ha), China (1.8 Mg/ha) and the US (2.0 Mg/ha). Thus, the yield of pulses in SA can be improved, especially with effective conservation of soil water in the root zone and with integrated soil fertility management (ISFM). Drought stress is a major cause of low yield of pulses grown under rainfed conditions in India and Pakistan. In general, the mean yield of cereals and pulses can be increased by 25 and 50%, respectively, in SA by adoption of better agronomic management (i.e., soil, water, crop, pests) and improved varieties. It is also argued that food insecurity in SA Is aggravated by political problems. Thus, in addition to producing adequate amount of food, it is also critical to solve social and political issues (Zakaria and Junyang 2014). Conflicts must be resolved politically, ethnic violence mitigated amicably, international arm trades reduced judiciously, military expenditures minimized prudently, and civil and political rights protected socially. In the meantime, it is important to reduce food losses and wastes both morally and ethically to achieve food security in SA. Kummu et al. (2012) estimated that as much as a quarter of the food supply (614 kcal/cap/yr) is lost within the global food supply chain. The production of these wasted food accounts for 24% of the total freshwater resources used in food crop production (27m^3/cap/yr), 23% of the total global cropland area, (31 × 10^{-3} ha/cap/yr), and 23% of the global fertilizer use (4.3 kg/cap/yr). Relative to the total food production, small resource losses in food waste occur in SA, but are substantial enough in the context of almost 2 B people who live in the

Table 2.8 Temporal trends in crop yield in Central Asia

Country	Cereals (Mg/ha)						Pulses (kg/ha)					
	1992	1995	2000	2005	2010	2019	1992	1995	2000	2005	2010	2019
Azerbaijan	1.34	0.58	0.94	1.00	0.80	1.14	724	586	1126	1112	771	928
Kazakhstan	2.78	1.63	2.67	2.68	2.61	3.23	813	800	1869	1263	3230	2388
Tajikistan	0.99	0.92	1.31	2.16	3.12	3.64	742	515	483	1481	3113	3295
Turkmenistan	2.21	1.79	2.12	2.93	1.70	1.51	2941	869	1690	1800	1785	1806
Uzbekistan	2.00	2.05	2.69	4.04	4.46	4.61	491	851	1260	1690	1586	3916
Central Asia	1.41	0.78	1.25	1.48	1.29	1.55	732	617	1180	1414	1490	1417
China	4.37	4.66	4.76	5.23	5.53	6.28	1234	1439	1398	1533	1407	1789
USA	5.38	4.65	5.85	6.45	6.98	8.03	1680	1910	1823	1864	1905	2004
World	2.78	2.77	3.06	3.27	3.55	4.11	768	799	843	861	904	992

Adapted from FAOSTAT (2021)

region (Table 2.21 in Appendix). If the lowest food losses can be achieved globally, there would be enough food for 1 B extra people (Kummu et al. 2012). Above all, sustainable management of soil and agriculture must always be given a high national priority.

The population of CA is much less compared with that of SA, but it is also increasing rapidly and is projected to increase from 72 M in 2018 (Table 2.22 in Appendix) to 90 M by the end of the Century (Jalilov et al. 2016). Food demand in developing countries is growing 1% annually, which is equivalent to 170 kg per capita in CA (Shiferaw et al. 2013). Yield of cereals in CA is lesser than that of SA and has stagnated since 1992 (Table 2.8). The average cereal yield of 1.6 Mg/ha in 2019 is about one-third that of the world average, one-quarter that of China and one-fifth that of the US. Thus, the average cereal yield has even a greater potential of improvement in CA than that of SA. Cereal yields are relatively higher in Uzbekistan compared with those in most countries of SA. In contrast to cereals, the average yield of pulses in CA at 1.4 Mg/ha is almost double that in SA. The average yield of pulses in CA are more than that of the world average (1.4 vs 1.0 Mg/ha) but lower than that of China (1.8 Mg/ha) and that of the US (2.0 Mg/ha). Thus, yield of pulses in CA can be improved in Azerbaijan and Turkmenistan through improved agronomic management and by growing improved varieties (Table 2.8).

2.4 Natural Resources Available for Food Production

Densely populated countries of SA have limited cropland area, with no scope for horizontal expansion. Total cropland area of SA decreased from 277 M ha in 1961 to 238 M ha between 2010 and 2018. Of this, 70% of the total cropland area in SA is that in India (~169 M ha), followed by Pakistan (~31 M ha), Bangladesh/Afghanistan, (~8 M ha each) and Nepal/Sri Lanka (~12.3 M ha each) (Table 2.9).

Table 2.9 Temporal trends in cropland area (M ha) in South Asia

Year	South Asia	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1961	277.1	7.70	8.88	160.99	1.83	30.73	1.54
1970	231.8	8.00	9.08	164.48	1.85	30.70	1.89
1980	237.5	8.05	9.38	168.44	2.28	31.34	1.92
1990	239.8	8.04	9.84	169.98	2.35	30.88	1.90
2000	239.2	7.75	8.80	170.13	2.46	31.70	1.91
2010	237.7	7.91	8.64	169.23	2.33	30.24	2.18
2015	238.3	7.91	8.56	169.42	2.33	31.79	2.30
2018	238.3	7.91	8.56	169.42	2.33	31.30	2.37

Adapted from FAOSTAT (2021)

Total cropland area of six countries in CA decreased from 44 M ha in 1992 to ~39 M ha in 2018 (Table 2.10). Of this, the largest land area (~30 M ha or >75%) is that of Kazakhstan, followed by 4.5 M ha in Uzbekistan, 2.4 M ha in Azerbaijan, 2 M ha in Turkmenistan, 1.4 M ha in Kyrgyzstan, and 0.9 M ha in Tajikistan (Table 2.12).

The data in Table 2.11 show the temporal trends in land area under pasture in countries of SA that decreased from ~96 M ha in 1961 to 78 M ha between 2010 and 2018. Of this, the largest land area under pasture (grazing/rangeland) of 30 M ha (~40%) is in Afghanistan, followed by 10.3 M ha (~13%) in India, 5 M ha (6%) in Pakistan, ~ 2 M ha (~3%) in Nepal, 0.6 M ha in Bangladesh, and 0.4 M ha in Sri Lanka (Table 2.11). The land area under pastures in CA is constant at about 255 M ha (Table 2.12), of which 186 M ha is in Kazakhstan, 32 M ha in Turkmenistan and 21 M ha in Uzbekistan. Most pastureland in CA are degraded and prone to desertification. Dust storms are severe in now dried out Aral Sea Basin (see the above section) and affect the surrounding land area and its people.

Table 2.10 Temporal trends in cropland area (M ha) in Central Asia

Year	Central Asia	Azerbaijan	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
1992	44.0	2.01	35.20	1.39	0.99	1.55	4.85
1995	43.8	2.04	34.86	1.33	0.96	1.80	4.84
2000	39.4	2.06	32.30	1.42	0.89	2.00	4.83
2005	37.7	2.06	28.69	1.36	0.87	2.10	4.72
2010	37.6	2.12	28.80	1.335	0.88	2.00	4.53
2015	38.4	2.17	29.73	1.36	0.86	2.00	4.48
2018	38.6	2.35	29.88	1.37	0.85	2.00	4.46

Adapted from FAOSTAT (2021)

Table 2.11 Temporal trends in land area under pasture (M ha) in South Asia

Year	South Asia	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1961	95.7	30.0	0.60	13.97	1.72	5.0	0.19
1970	95.0	30.0	0.60	13.00	1.72	5.0	0.44
1980	94.2	30.0	0.60	12.11	1.79	5.0	0.44
1990	94.4	30.0	0.60	11.30	1.80	5.0	0.44
2000	95.7	30.0	0.60	10.85	1.79	5.0	0.44
2010	78.1	30.0	0.60	10.34	1.79	5.0	0.44
2015	78.0	30.0	0.60	10.26	1.80	5.0	0.44
2018	78.0	30.0	0.60	10.26	1.80	5.0	0.44

Adapted from FAOSTAT (2021)

Table 2.12 Temporal changes in land area under pastures in Central Asia between 1992 and 2018

Year	Central Asia	Azerbaijan	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
1992	255.1	2.4	186.3	8.7	3.5	33.8	22.9
1995	254.6	2.5	182.3	9.1	3.6	33.7	22.8
2000	254.1	2.7	185.1	9.3	3.7	33.5	22.5
2005	251.4	2.7	183.6	9.4	3.8	32.8	21.8
2010	254.6	2.7	188.4	9.3	3.9	32.0	21.1
2015	252.6	2.6	186.5	9.2	3.9	31.8	21.1
2018	252.4	2.4	186.4	9.2	3.9	31.8	21.1

Adapted from FAOSTAT (2021)

Land area equipped for irrigation in SA is large and canal irrigation in northwestern India and the Punjab province started since the 1930s (Table 2.13). Irrigated land area is especially large in the Indo-Gangetic Plains where both surface water (river water from the Himalayas) and ground water are being used. Total area equipped for irrigation in SA increased from 45 M ha in 1961 to 111 M ha in 2018. Of this, 70 M ha of irrigated land is in India and 20 M ha in Pakistan (Table 2.13). The irrigated land area in CA expanded during the Soviet era. The land area equipped for irrigation in CA was about 10 M ha in 1992 and has remained constant over the past three decades. Of the total irrigated area, 40% is in Uzbekistan and is mostly used for cotton production (Table 2.14).

Rather than the total cropland and the pastureland allocated for food production, it is the per capita availability of land which is an appropriate determinant of food and nutritional security. The per capita crop land area in some countries of SA is already less than 0.1 ha in Bangladesh (0.053 ha) and Nepal (0.083 ha) (Table 2.15). The per capita cropland area in SA decreased from 0.374 ha in 1961 to 0.126 ha in 2018, primarily because of the rapid increase in population. The irrigated cropland area is an important factor affecting food and nutritional security. The per capita irrigated

Table 2.13 Irrigated land area (M ha) in South Asia from 1961 to 2018

Year	South Asia	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1961	44.6	2.38	0.43	25.95	0.07	10.75	0.34
1970	52.7	2.39	1.46	30.49	0.12	12.78	0.40
1980	65.5	2.51	1.52	40.84	0.52	14.68	0.46
1990	79.3	2.90	2.79	49.50	0.84	15.73	0.52
2000	95.5	3.20	4.19	60.43	1.14	18.09	0.57
2005	102.1	3.21	4.88	64.65	1.19	18.98	0.57
2010	107.4	3.21	5.18	67.70	1.25	20.20	0.57
2015	110.9	3.21	5.50	70.40	1.37	20.20	0.63
2018	111.0	3.21	5.55	70.40	1.37	20.20	0.64

Adapted from FAOSTAT (2021)

Table 2.14 Irrigated land area (M ha) in Central Asia from 1992 to 2018

Year	Central Asia	Azerbaijan	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
1992	11.1	1.41	3.56	1.01	0.72	1.50	4.28
1995	10.8	1.45	3.05	1.08	0.72	1.75	4.25
2000	9.9	1.43	2.10	1.05	0.72	1.85	4.20
2005	9.9	1.43	1.97	1.02	0.73	1.99	4.20
2010	10.1	1.43	2.07	1.02	0.76	2.00	4.26
2015	10.2	1.43	2.07	1.02	0.82	2.00	4.31
2018	10.2	1.45	2.07	1.02	0.82	2.00	4.31

Adapted from FAOSTAT (2021)

land area in SA decreased from 0.073 ha in 1961 to 0.059 ha in 2018. The maximum per capita irrigated land area in SA in 2018 is 0.095 in Pakistan, followed by that of 0.086 ha in Afghanistan, ~0.052 ha for each in India and Nepal, and 0.03 ha each in Bangladesh and Sri Lanka (Table 2.16). In comparison to SA, per capita cropland area in CA decreased from 0.853 ha in 1992 to 0.535 ha in 2018 (Table 2.17). The highest per capita cropland area is 1.631 ha in Kazakhstan and the lowest of 0.094 in Tajikistan (Table 2.17).

Per capita irrigated land in CA, because of the low population, is relatively more in CA (Table 2.18) than that in SA (Table 2.16). Comparatively, the per capita irrigated land area in CA of 0.215 ha in 1992 decreased to 0.142 ha in 2018. The maximum per capita irrigated land area in 2018 was 0.341 ha in Turkmenistan and the minimum of 0.09 ha in Tajikistan (Table 2.18). The per capita irrigated land area in 2018 was 0.162 ha Kyrgyzstan, 0.146 in Azerbaijan, 0.133 ha in Uzbekistan (Table 2.18). The per capita land area in semi-arid/arid countries is also prone to soil degradation by secondary salinization, which is a serious practice in CA countries. However, the

Table 2.15 Per capita cropland (ha/per capita) in South Asia

Year	South Asia	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1961	0.374	0.840	0.180	0.350	0.178	0.667	0.152
1970	0.314	0.717	0.142	0.297	0.164	0.531	0.152
1980	0.251	0.602	0.118	0.2401	0.153	0.415	0.127
1990	0.201	0.648	0.095	0.195	0.124	0.281	0.110
2000	0.164	0.373	0.069	0.161	0.103	0.223	0.102
2005	0.151	0.308	0.063	0.148	0.094	0.193	0.106
2010	0.139	0.271	0.059	0.137	0.086	0.169	0.108
2015	0.130	0.230	0.055	0.129	0.086	0.156	0.110
2018	0.126	0.213	0.053	0.125	0.083	0.147	0.112

Recalculated from FAOSTAT (2021) and United Nations (2019)

Table 2.16 Per capita irrigated land (ha/per capita) for South Asia

Year	South Asia	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1961	0.073	0.260	0.009	0.056	0.007	0.233	0.033
1970	0.072	0.214	0.016	0.057	0.010	0.223	0.037
1980	0.070	0.188	0.019	0.058	0.036	0.188	0.030
1990	0.067	0.234	0.027	0.057	0.044	0.146	0.030
2000	0.066	0.154	0.032	0.057	0.047	0.127	0.030
2005	0.064	0.125	0.035	0.056	0.046	0.118	0.029
2010	0.063	0.110	0.035	0.055	0.046	0.113	0.028
2015	0.061	0.093	0.035	0.053	0.051	0.101	0.030
2018	0.059	0.086	0.034	0.052	0.049	0.095	0.030

Recalculated from FAOSTAT (2021) and United Nations (2019)

Table 2.17 Per capita cropland (ha/per capita) in Central Asia

Year	Central Asia	Azerbaijan	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
1992	0.853	0.270	2.159	0.312	0.179	0.397	0.227
1995	0.824	0.262	2.201	0.290	0.166	0.428	0.212
2000	0.712	0.254	2.030	0.289	0.143	0.443	0.195
2005	0.645	0.242	1.862	0.267	0.129	0.442	0.178
2010	0.598	0.234	1.772	0.249	0.117	0.393	0.159
2015	0.561	0.226	1.692	0.227	0.102	0.359	0.145
2018	0.535	0.236	1.631	0.217	0.094	0.342	0.137

Recalculated from FAOSTAT (2021) and United Nations (2019)

Table 2.18 Per capita irrigated land (ha/per capita) for Central Asia

Year	Central Asia	Azerbaijan	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
1992	0.215	0.189	0.218	0.226	0.130	0.385	0.200
1995	0.204	0.187	0.193	0.236	0.125	0.416	0.189
2000	0.179	0.176	0.141	0.213	0.116	0.410	0.170
2005	0.170	0.168	0.128	0.201	0.107	0.419	0.159
2010	0.160	0.158	0.127	0.188	0.101	0.392	0.149
2015	0.149	0.149	0.118	0.172	0.097	0.358	0.139
2018	0.142	0.146	0.113	0.162	0.090	0.341	0.133

Recalculated from FAOSTAT (2021) and United Nations (2019)

risks of secondary salinization are even greater in CA and drying out of the Aral Sea has jeopardized future expansion of the irrigated land area.

Per capita pastureland area in SA decreased from 0.158 ha in 1961 to 0.041 ha in 2018. The highest per capita pastureland area in SA is that in Afghanistan at 0.807 ha and the least at 0.004 ha in Bangladesh (Table 2.19). Comparatively, the per capita pastureland in CA decreased from 4.951 ha in 1992 to 3.503 ha in 2018 (Table 2.20). The highest per capita pastureland area of 10.176 ha in 2018 is in Kazakhstan and the lowest of 0.245 ha in Azerbaijan. The per capita pastureland area in 2018 is 5.442 ha in Turkmenistan, 1.456 ha in Kyrgyzstan, 0.650 ha in Uzbekistan, and 0.426 ha in Tajikistan (Table 2.20).

Table 2.19 Temporal changes in per capita (ha/capita) pastureland in South

Year	South Asia	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1961	0.158	3.272	0.012	0.030	0.168	0.109	0.018
1970	0.128	2.685	0.009	0.023	0.143	0.086	0.035
1980	0.100	2.246	0.008	0.017	0.119	0.064	0.029
1990	0.080	2.417	0.006	0.013	0.095	0.046	0.025
2000	0.067	1.444	0.005	0.010	0.075	0.035	0.023
2005	0.049	1.169	0.004	0.009	0.069	0.031	0.023
2010	0.046	1.028	0.004	0.008	0.066	0.028	0.022
2015	0.043	0.872	0.004	0.008	0.066	0.025	0.021
2018	0.041	0.807	0.004	0.008	0.064	0.024	0.021

Recalculated from FAOSTAT (2021) and United Nations (2019)

Table 2.20 Temporal changes in per capita (ha/capita) pastureland in Central Asia

Year	Central Asia	Azerbaijan	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
1992	4.951	0.325	11.425	1.953	0.637	8.667	1.070
1995	4.732	0.316	11.511	1.996	0.628	8.009	1.000
2000	4.591	0.330	12.404	1.888	0.593	7.418	0.908
2005	4.300	0.317	11.920	1.850	0.559	6.894	0.824
2010	4.053	0.294	11.590	1.708	0.515	6.290	0.739
2015	3.688	0.270	10.615	1.544	0.458	5.721	0.683
2018	3.503	0.245	10.176	1.456	0.426	5.442	0.650

Recalculated from FAOSTAT (2021) and United Nations (2019)

2.5 Recommended Management Practices to Improve Soil Quality and Advance Food Security

Strategies to achieve food and nutritional security in SA and CA outlined in Fig. 2.2 include the following: (a) improving agricultural productivity, (b) increasing food distribution, (c) enhancing access to food, and (d) strengthening public/private sector partnership. Agriculture in SA and CA is challenged by resource-fatigue and declining crop productivity which are widening the yield gap because of soil and environmental degradation. The yield gap ranges from 14–47% for wheat, 18–70% for rice, and 36–77% for maize (Kumar et al. 2019). Sustainable soil management and soil restoration are critical to increasing and sustaining agronomic productivity. The need for a widespread adoption of recommended management practices (RMPs) is not only just for advancing food and nutritional security, but also critical for transformation to climate-resilient and negative emission farming techniques (Lal 2021) and reversing the widespread problem of soil degradation in SA (Lal 2010). The strategy is to create a positive soil/terrestrial carbon budget so that soil organic carbon (SOC) contents and stocks can be restored in the root zone (0–30 cm layer) and soil quality enhanced. Low agronomic yield, especially those of cereals, is because of suboptimal SOC content, often as low as 0.5% in the rootzone. In addition to improving crop yields, re-carbonization of soil (and the terrestrial biosphere) would also enhance the nutritional quality of the food, especially the density of micronutrients (Fe, Zn, Cu, I, Mo, etc.), vitamins, and protein content (Lal 2009). For restoring SOC content and improving soil quality, it is the right time to stop in-field (Shyamsundar et al. 2019) burning of crop residues. Viable alternatives must be identified and implemented to effectively address the serious and wide spread environmental problem of “fields-on-fire” (Shyamsundar et al. 2019) through discussions, education, technologies, incentives, policies and determining alternative uses of crop residues and implementing them in partnership with the private sector. Burning of the precious resource, degrading soil health, polluting the environment, and jeopardizing human health must stop.

Fig. 2.2 Strategies to achieve food and nutritional security

2.5.1 Sustainable Management of Soil

Sustainable management of the finite and fragile soil resource is essential (Fig. 2.2). Some examples of sustainable soil management discussed here apply both to SA and CA. Protecting and restoring the quality of degraded soils is the critical determinant of improving food security in SA (Purakayastha et al. 2016). Thus, there is a need for identification and use of appropriate soil quality indices for the site-specific conditions for all crops, but specifically for the rice-based system in SA (Basak et al. 2016). Important among sustainable soil management issues are the following: declining and low SOM content, degrading soil structure and accelerating soil erosion, increasing drought stress and declining groundwater level, depleting soil fertility and increasing micronutrient deficiencies, accelerating heat wave and increasing risks of salinization, ad-hoc urbanization and growing trends in the removal of fertile topsoil for brick making (Nawaz et al. 2021). Important RMPs for SA (and CA) include restoration of SOM content, rainwater harvesting, efficient use of water and integrated soil fertility management. Site-specific factors must be considered in adaptation and fine-tuning of RMPs. Sustainable intensification (SI) involves strategies which enhance crop yield but reduce its negative environmental impacts (Jain et al. 2020). The concept of eco-intensification (EI) is also promoted and is focused on enhancing the use of efficiency of inputs and "producing more from less" (Lal 2018). EI is specifically suited for the rice-based systems in Asia (Ginigaddara 2018). Both SI and EI strategies are in accord with the One Health concept: the health of soil, plants, animals, people, ecosystems, and planetary processes is one and indivisible (Lal 2020a). The One Health concept, integrated agriculture, and "agroecology" to go together (Hall et al. 2011), and organic farming is a part of this wholistic approach (Sarker and Itohara 2010). The latter is enhanced by improving the understanding of the food-energy-water-soil (FEWS) nexus (Lal et al. 2017) or the food-energy-water (FEW) nexus (Rasul 2014; Putra et al. 2020). Key strategies for advancing food security in SA include measures to promote big agro-based industries with funding support from both the private and public sectors, increase agricultural productivity (SI and EI), enhance agricultural research and development, and manage food security risks and vulnerabilities (Galishcheva 2018).

2.5.2 Climate-Smart Agriculture (CSA)

Climate change, and especially global warming, is an important factor affecting food insecurity and must be addressed (Mehta et al. 2018). Climate change may aggravate food insecurity in SA (and CA) by reducing crop yield, increasing frequency of drought, adversely affecting the stability of food supply chain, and reducing accessibility of food to the poor. The rice-wheat system (RWS) is practiced on 12.3 M ha in India, 2.2 M ha in Pakistan, 0.5 M ha in Nepal, and 0.8 M ha in Bangladesh (Bhatt et al. 2019), and is feeding 2 B people (Kumar et al. 2019). Being a major production system for the Indo-Gangetic Plains and mid-hills of SA, enhancing and sustaining productivity of the RWS through adoption of integrated crop management is critical to achieving food security in SA (Regmi and Ladha 2005). The RWS is being affected by declining land and water productivity, degrading soil health, increasing micronutrient deficiencies and other resource degradation problems. Furthermore, the RWS affects and is being affected by global warming. The changing climate is affecting soil and natural resources where the RWS is practiced. Thus, conservation agriculture, negative emission farming (Lal 2021), and water footprints of the RWS must be managed/reduced by adoption of CSA technologies by converting water wasted by evaporation to its use for transpiration and for enhancing the grain yield. The goal is to grow more rice from less water by using direct-seeded and aerobic rice (Tuong et al. 2005). Altered rainfall patterns or temperature regimes caused by climate change may significantly affect crop productivity (Gurditta and Singh 2016). The Himalayan glaciers, a major source of waters in many rivers, are melting rapidly. The production of winter crops (rabi) may be more adversely affected by the projected 2 °C of warming. The net cereal production in SA is projected to decline by 10 to 40% by regional warming of 3 °C by the end of the century (Aggarwal and Sivakumar 2011). There are no one-size-fit-all practices for adaptation to climate change, and site-specific factors are important determinant of specific CSA practices, which include management options that adapt and mitigate climate change. Some adaptation strategies may include changes in planting dates, improved varieties, and new crop species (Aggarwal and Sivakumar 2011).

In Pakistan, Shahzad and Abdulai (2021) observed that adoption of CSA practices significantly reduced household food insecurity while also increasing household diet diversity and reducing poverty. CSA practices in Bangladesh include improved varieties for tolerance to salinity, flooding and drought, early maturing varieties, pond side vegetable cultivation, relay cropping, deep urea placement, organic fertilizers, mulching, rainwater harvesting, etc. (Hasan et al. 2018). More than 30% of cultivable area in Bangladesh is coastal area. Out of 2.9 M ha of coastal and offshore lands, 1.1 M ha of croplands are affected by varying degrees of soil salinity (Moslehuddin et al. 2015). Therefore, management of soil salinity is critical to sustaining crop yields in coastal regions, as it is in irrigated lands in SA and CA.

Agroforestry is also a widely used CSA option (Dagar et al. 2014a, b) and can be used in diverse regions by using the region-specific tree species.

2.5.3 Conservation Agriculture

System-based conservation agriculture (CAG) comprises several components: no till, residue mulch on soil surface, ISFM, complex rotations, and cover cropping (Lal 2015). Critical reviews on issues, challenges, prospects, and benefits of using CAG in SA have been widely discussed (ur-Rehman et al. 2015; Jat et al. 2020; Somasundaram et al. 2020). It is widely believed that CAG is specifically suited for cultivation of cereals in SA including rice, wheat, and maize (Kumar et al. 2019), and is an important option for adaptation to climate change (Paudel et al. 2015). However, the success of CAG depends on an effective use of crop residue as a surface mulch, growing a cover crop during the off season and adoption of ISFM. Residue management with a system-based CAG is also pertinent to restoring soil quality in the RWS system (Zahid et al. 2020). In India, Singh et al. (2016) studied the use of CAG for the rice-maize system in northwestern India. These practices involved: early direct seeded rice, no-till and residue retention as mulch and maize seeded through it for the winter (rabi) season. An increase in SOM content in a 0–30 cm layer enhanced grain yield and overall productivity. Singh and colleagues recommended that CAG practices can be adopted on sandy loam and other light-textured soils for sustaining soil and crop productivity in SA. Judicious use of crop residues and agro-wastes can improve soil functions in diverse agro-ecoregions of SA (Dey et al. 2020). A system-based CAG has also been widely researched in CA, as reported by Lal (2007) and exemplified by research reported by Suleimenov et al. (2004, 2006), and Boboev et al. (2019).

2.5.4 Sustainable Water Management

Technology for water saving and improving use efficiency are important to the semi-arid and arid climate of SA and CA and for avoiding water crises created by water scarcity. Asia on the whole accounts for 70% of the world's irrigated area. However, the current state of affairs of these irrigation schemes leaves much to be desired and they need restoration (Mukherji et al. 2012). The strategy is to produce more crop per drop of water by changing flood-based to drip irrigation (Birkenholtz 2017). The primary metric to implement this strategy is the availability of fresh water for agriculture, which is primarily the combination of both surface and ground water. Instead, however, Swatuk et al. (2015) proposed the metric that comprises green water and virtual water with specific reference to Uzbekistan. Swatuk and colleagues argued that shortages in water are often the result of decision-making based on a narrow economic criterion rather than on the satisfaction of basic human needs. A study conducted in the Fergana Valley, CA, showed that replacing alfalfa by wheat can save water in the Syrdarya River basin (Karimov et al. 2018). Crop substitution combined with deficit (rather than full irrigation) can also maintain productivity and yet save water resources (Reddy et al. 2016) in the Fergana Valley and elsewhere. Similarly, substitution of maize and cotton for rice in the RWS may save water and enhance sustainability.

Drought in SA and CA, major constraints to obtaining high yields in rainfed agriculture, are being aggravated by soil degradation and climate change. It is argued that the worst droughts in SA in the future are likely to be more intense and widespread (Aadhar and Mishra 2021). Meanwhile, land equipped for irrigation in SA has tripled since 1950. Over 60% of irrigated land in India is supported by ground water. India's ground water (and that of neighboring countries) is disappearing at an alarming rate (Kerr 2009), and this trend must be halted (Subhadra 2015). While the drip irrigation in India is truly booming (Birkenholtz 2017), India uses 230 Km^3 of ground water annually (Chindarkar and Grafton 2019). Thus, identification of a reliable water supply to farmers is the single most important factor to advance food security in arid regions, such as those in Afghanistan and elsewhere in SA (Walters and Groninger 2014). Improved water management (e.g., bunding, stress-tolerant varieties, mulch farming, and drip irrigation) is also one of the options of CSA as discussed above (Ringler and Anwar 2013). Integrated water resource management for both blue and green water is critical to effectively use every drop of water (Rautanen and White 2013). Innovative water management to adapt to water supply fluctuations is essential to develop resilience against climate change in arid regions of Afghanistan (Salman et al. 2017). Farmers are advised to build water storage reservoirs to store wet year flows and use it during the dry years. Ali et al. (2018) reported that adoption of innovative water management practices improves yield of both rice and wheat.

Water scarcity, already a serious issue in SA and CA, is likely to worsen with climate change. Increase in climate extremes by 1.5 °C and 2 °C may adversely affect agricultural production in CA where ecological problems may become more severe (Liu et al. 2020). Thus, an adaptation strategy must be implemented as a priority to minimize the negative effects of climate change on CA's agriculture. The FEW concept (see the previous section) is also a pertinent instrument to increasing food production in CA. It puts a strong emphasis on cross-sectoral and multilevel interaction and resource interdependencies including those in the Aral Sea Basin (Saidmamatov et al. 2020). In this context, Jalilov et al. (2016) outlined two critical choices: (a) using land and fertilizers for food production or for renewable energy production, and (b) using fresh water for energy or for irrigation. Decreases in water availability for irrigation may reduce cereal production by 37% in downstream countries of CA (e.g., Tajikistan and Uzbekistan).

2.5.5 Salinity Management

Secondary salinization is increasing in irrigated areas of SA and CA. Salinization is also increasing because of the climate change, increasing heat waves, rising ground water levels, deteriorating drainage systems and faulty agrotechnology (Kulmatov et al. 2021). In this regard, sustainable development of water resources for achieving water security in CA (and SA) are critical to achieving food security, and also the political stability of the region (Wang et al. 2020). For example, Kulmatov et al. (2021) observed that saline areas are progressively increasing in irrigated lands of the Aral Sea Basin. As large parts of the former Aral Sea have been dried out, dust storms are affecting the surrounding regions with adverse effects on human health (Shen et al. 2016; Opp et al. 2017). Every year millions of people are suffering from water scarcity for drinking and irrigation (Abdullayev 2010). SA must learn lessons regarding the overuse of water from the Aral Sea, and safeguard its precious and finite surface and ground water resources. Afterall, the mighty Indus Valley civilization perished because of the desertification of the land that supported the once thriving agrarian culture for millennia (Lal 2010).

2.5.6 Nanotechnology

Nanotechnology has specific application to addressing issues related to soil health, fertilizer management, water security, food quality in storage and distribution, and agronomic productivity (Sastry et al. 2011). It is therefore important to identify and prioritize potential areas for nanotechnology applications to advance food security in SA and CA with regards to development of nanotechnology infrastructure. For example, colloidal nano-silica can be used to enhance soil water storage and improve soil structure. Another innovative option is the use of Zeolites as amendment. Zeolites are naturally occurring alumino-silicate minerals, which have large internal and external surface areas and high charge density. Using zeolites as amendments can improve soil structure, enhance soil water storage, and improve fertilizer use efficiency (Liu and Lal 2014). Among numerous applications of nanotechnology in agriculture, using nano-fertilizers is an important option to enhancing nutrient use efficiency and improving soil water storage.

In this connection soilless agriculture (aquaponics, aeroponics, hydroponic, sand culture), and use of artificial/synthetic soils are also important options. For example, Zulfiqar et al. (2020) reported that urban agriculture positively contributed to household food security of urban dwellers and assisted in building livelihood strategies. Sky farming, based on tall glass buildings and recycling of gray and black water are among emerging innovations (Lal and Stewart 2017). Greenhouse agriculture, and specifically solar greenhouses in Himalayas (e.g., Nepal), are among innovative options to advancing food security (Fuller and Zahnd 2012) in SA and CA, as have been the case in eastern and northern Asia.

2.5.7 Improving Use Efficiency of Fertilizers in Central and South Asia

Some countries in SA (e.g., India) use a lot of fertilizers and other agrochemicals. Fertilizers are important, and the balanced use of fertilizer-based elements is essential to enhancing and sustaining productivity and improving nutritional quality of food. However, excessive and indiscriminate use of chemicals can be counterproductive. Rather than focusing on the rate and total amount of fertilizers used, the focus must be on restoring soil quality (e.g., SOM content, soil structure and green water storage in the root zone), which is critical to improving the fertilizer use efficiency so that these chemicals do not leak into the environment (in air as N_2O and in water as NO_3^-). Fertilizer use efficiency, especially that of nitrogen, is low in SA and CA. Restoration of SOM content to above the critical level in the root zone (3–4% in 0–30 cm layer) is essential to improving use efficiency of all inputs (fertilizer, irrigation, pesticides, tillage, etc.). Improving SOM content, and through it the soil health and its functionality, is also essential to realizing the genetic potential of improved varieties. Restoring SOM content can increase green water supply (Lal 2020b). Therefore, ISFM, and use of crop residues (as mulch) and other organic amendments (e.g., cover crops, compost, and biochar), is widely recommended. Biochar combined with manure is an important option in the context of ISFM (Arif et al. 2016). To discourage in-field burning of crop residues, farmers should be rewarded financially (through payments for ecosystem services) for leaving the crop residues as mulch on the soil surface and for restoring SOM content of the soil for advancing security of food, climate, and the environment. Soils of a high SOM content are also disease-suppressive soils and require less pesticides than those with severely depleted SOM content because of the perpetual use of extractive farming practices.

2.6 Conclusions

The number of people is 2 B in SA, and 72 M in CA. Food and nutritional security is a widespread problem in SA, and it also persists in CA. The Green Revolution of the 1960s and 1970s brought about a quantum jump in agronomic yield of cereals (e.g., rice, wheat) and improved access to food. Yet, food and nutritional insecurity persists, and is also being aggravated by climate change and soil degradation, which are mutually reinforcing processes. Soil degradation affects as much as 230 M ha each in SA and CA. Wind erosion, dust storms from the dried-out Aral Sea and degradation of grasslands/rangelands are serious problems in CA. The available data on the extent and severity of soil degradation in SA are obsolete (30 years old). Although country level data exist (e.g., India, Pakistan, Bangladesh), they need to be improved and updated. The most vulnerable areas to soil degradation in SA are grasslands, mountain forest lands, arid and semi-arid regions. The Thar desert is increasing at the rate of 100 ha/yr, which may adversely affect 13,000 ha of agricultural land in India and Pakistan. Food and nutritional insecurity are aggravated by soil and environmental degradation, and there is a strong need to improve the regional database through cooperation among all countries of the region. Food insecurity in these regions is also aggravated by civil strife and political unrest.

There are a wide range of RMPs for soil, crop, and water resources management to protect, manage, and restore soils of these regions. These technologies for the widely used RWS include direct seeded aerobic rice and use of system-based CAG. The CSA technologies involve water conservation and management, complex cropping systems, crop diversification and substitution, ISFM, and nanotechnology. Widespread adoption of the resource conservation and soil restorative options are also important to enhancing and sustaining productivity for advancing food and nutritional security (SDG 2), taking climate action by sequestering SOC content in agroecosystems (SDG 13), and restoring degraded lands and accomplishing land degradation neutrality (SDG 15).

Reducing food waste is important because its loss translates into waste of finite and precious natural resources (e.g., soil, water, energy, fertilizers). Identification and implementation of policies (pro-nature, pro-agriculture, and pro-farmer) are needed to promote adoption of nutrition-sensitive agricultural practices. Achieving food security is the first step to achieving the much-needed peace and tranquility in SA and CA.

Appendix

See Tables 2.21 and 2.22.

Table 2.21 Population trends (M) in South Asia from 1961 to 2018

Year	South Asia	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1961	607.4	9.16	49.4	459.6	10.3	46.1	10.1
1970	742.2	11.2	64.2	555.2	12.1	58.1	12.5
1980	939.3	13.4	79.6	698.5	15.0	78.1	15.0
1990	1189.9	12.4	103.2	873.2	18.9	107.6	17.3
1992	1242.9	14.5	108.0	909.3	19.4	113.9	17.7
1995	1323.0	18.1	115.2	963.9	21.6	123.8	18.2
2000	1456.6	20.8	127.7	1056.6	23.9	142.3	18.8
2005	1588.6	25.7	139.0	1147.6	25.7	160.3	19.5
2010	1712.6	29.2	147.6	1234.3	27.0	179.4	20.3
2015	1827.8	34.4	156.3	1310.2	27.0	199.4	20.9
2018	1895.8	37.2	161.4	1352.6	28.1	212.2	21.2

Table 2.22 Population trends (M) in Central Asia from 1992 to 2018

Year	Central Asia	Azerbaijan	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
1992	51.3	7.5	16.3	4.5	5.5	3.9	21.4
1995	53.2	7.8	15.8	4.6	5.8	4.2	22.8
2000	55.3	8.1	14.9	4.9	6.2	4.5	24.8
2005	58.5	8.5	15.4	5.1	6.8	4.8	26.4
2010	62.8	9.0	16.3	5.4	7.5	5.1	28.5
2015	68.5	9.6	17.6	6.0	8.5	5.7	30.9
2018	72.1	10.0	18.3	6.3	9.1	5.9	32.5

Adapted from United Nations (2019)

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Chapter 3
Water-Food Equation in Central and South Asia

Manzoor Qadir

Abstract Population growth and urbanization converge upon the Central and South Asia region, where water demand is expected to continue rising in order to support food production systems. In contrast, some freshwater resources are likely to be diverted from agriculture to provide water for other increasing demands, such as municipal and industrial activities. In such a context, achieving water and food security has become an entangled challenge in the region where most countries are net importers of major cereals. Ensuring both sides of the water-food equation complement each other needs insights into strategies that promote efficient use of available water resources to support efforts in achieving food security across the region. The following aspects of water resources management are needed in building a water- and food-secure future in the region by (1) promoting water conservation, water recycling and reuse; (2) ensuring sustainable water resources augmentation; (3) supporting productivity enhancement of underperforming land and water resources; and (4) addressing challenges beyond technical solutions accompanied by a call for sustainable intensification of agricultural production systems. Policymakers and water professionals need to recognize and treat water as a highly valuable precious resource for sustainable agricultural production systems and a cornerstone of the circular economy. The key to support efforts in ensuring water- and food-security in the Central and South Asia regions include pertinent political agendas and associated public policies, supportive institutions, strengthening institutional collaborations, and skilled professionals.

Keywords Water conservation · Water reuse · Water augmentation · Water productivity · Agricultural intensification · Food security

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3.1 Introduction

Driven by water scarcity and water quality deterioration, the global water crisis is expected to continue and intensify in arid and semi-arid areas (Damania et al. 2017; UN-Water 2020) common in most countries within the Central and South Asia region. As freshwater resources and population densities are unevenly distributed across the region, countries experience a range of challenges with implications on the achievement of water-related sustainable development at the national and regional levels (Immerzeel et al. 2010).

Renewable freshwater resources are already developed across the Central and South Asia region (FAO-AQUASTAT 2020). Climate change may increase or decrease water supplies (Bates et al. 2008; Buytaert and De Bièvre 2012) with uncertain net impacts on freshwater availability, depending on a complex mix of precipitation and evaporation trends across the world. The same applies to Central and South Asia. The actual impact of climate change on total renewable freshwater resources is hard to predict as projections of climate change effects on the hydrologic cycle are often diverse. However, there may be temporary changes in precipitation in some parts of the region, such as in the upper Ganges, Brahmaputra, and Mekong basins, as well as changes to snowmelt patterns with impacts on water supply in the upper Indus Basin (Lutz et al. 2016). There are also differences between basins in the extent to which climate change is predicted to affect water availability and food security. For example, the Brahmaputra and Indus basins are most susceptible to reductions in water flow, threatening the food security of an estimated 60 million people (Immerzeel et al. 2010).

The population in the region continues to grow, albeit at a slower pace than at any time since the 1950s, with some countries' population still increasing rapidly according to the latest population forecasts (UN-DESA 2019). The projected population growth indicates with reasonable confidence that freshwater available per capita will decrease in the region no matter how climate change affects precipitation and evaporation patterns (Buytaert and De Bièvre 2012).

In contrast to uncertain impacts of climate change, growing population and urbanization converge upon the Central and South Asia region where water demand is expected to continue rising over the next decades (Boretti and Rosa 2019). Sustainable food production systems are vital to feeding the growing population, which currently stands at 26% of the global population (UN-DESA 2019).

As water scarcity intensifies, freshwater resources are likely to be diverted from agriculture to provide water for other demands, such as growing urban populations and industrial activities (Strzepek and Boehlert 2010). Simultaneously, to meet higher food demands for a growing population, agriculture will have to expand to new areas or become more productive, leading to a further increase in water demand.

Amid competitive water needs, water allocations for environmental flows are also needed to ensure functional and sustainable freshwater ecosystems (Smakhtin et al. 2004). In this context, achieving water and food security have become entangled challenges in the region. Understanding the scale and impact of such challenges will necessitate analysis of the status of water resources per capita vis-à-vis the status of food security at the national and regional levels—the water-food equation. Ensuring both sides of the water-food equation complement each other will need insights into the strategies promoting the efficient use of available water resources and water resources augmentation to ensure food security, where applicable in the region. These aspects are essential to explore the interface between water and food security in the Central and South Asia region and are the focus of this chapter.

3.2 Water Resources

While linked to food security and freshwater availability, the initial quantifications of the annual renewable water resources (ARWR) per capita considered the number of people in a country that compete for total renewable water resources[1] (TRWR) in a year at the national level (Falkenmark 1986), i.e., TRWR in m^3 divided by the number of people in a specific year in the same country (m^3/capita/year).

Water resources assessments for potential uses suggest that beyond human needs, water is essentially needed to ensure the functionality of ecosystems, which support and help maintain the Earth's natural balance. Balancing the requirements of freshwater ecosystems and other uses has become critical in many of the world's river basins due to an increase in population and associated water demands (Smakhtin et al. 2004). The water needed to support freshwater ecosystems, i.e., environmental flows requirement (EFR), is referred to as "the quantity and timing of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and wellbeing" (FAO 2019). Thus, sustainable water management needs to ensure enough water resources for ecosystems and human use of those ecosystems. The ARWR reported in this chapter are based on Eq. 3.1.

$$\text{ARWR} = \frac{\text{TRWR} - \text{EFR}}{\text{Population}} \tag{3.1}$$

where ARWR expressed as m^3/capita/year, TRWR and EFR in m^3/year at the national level and 'Population' refers to the number of people in a specific year in the same country. The values of TRWR and EFR at the national are based on (FAO-AQUASTAT 2020) while country-specific population statistics stem from UN-DESA (2019).

Analysis of the status of renewable freshwater resources in the Central and South Asia region suggests that the ARWR stand at 1173 m^3 per capita, indicating that the region, in general, does not have enough water resources, i.e., less than 1700 m^3

[1] Total Renewable Water Resources (TRWR) is the volume of water based on the sum of internal renewable water resources and external renewable water resources and corresponds to the maximum theoretical yearly amount of water available in a country (FAO-AQUASTAT 2020).

Table 3.1 Annual renewable water resources (ARWR; m^3 per capita) at the national level in 2015 and projected for 2030 and 2050 based on freshwater availability data (FAO-AQUASTAT 2020) and population estimates for 2015 and population projections for 2030 and 2050 (UN-DESA 2019)

Country	ARWR (m^3 per capita)			Change over 2015 level (%)	
	2015	2030	2050	2015–2030	2015–2050
Afghanistan	1076	728	441	−32.4	−59.0
Bangladesh	4011	3476	3167	−13.3	−21.0
Bhutan	32,835	28,165	25,942	−14.2	−21.0
India	743	645	583	−13.2	−21.6
Iran	1456	1233	1117	−15.3	−23.3
Kazakhstan	4103	3466	2857	−15.5	−30.4
Kyrgyzstan	2585	2044	1578	−20.9	−38.9
Nepal	4229	3390	3139	−19.9	−25.8
Pakistan	817	604	424	−26.1	−48.2
Sri Lanka	682	647	650	−5.2	−4.7
Tajikistan	1793	1291	847	−28.0	−52.8
Turkmenistan	3489	2828	2284	−18.9	−34.5
Uzbekistan	1127	923	773	−18.1	−31.4

per capita, a universal threshold value for water scarcity as proposed by the Third Assessment Report on Hydrology and Water Resources of the Intergovernmental Panel on Climate Change (IPCC 2001). However, such levels of ARWR do not prevail in all countries of the region, as freshwater resources and population densities are unevenly distributed across the region. There are significant differences among the region countries with Bhutan having the highest ARWR (32,835 m^3 per capita) while Sri Lanka (682 m^3 per capita), India (743 m^3 per capita) and Pakistan (817 m^3 per capita) having the lowest ARWR (Table 3.1).

Considering population growth projections and assuming little or no change to renewable freshwater resources in the Central and South Asia region, the ARWR are expected to decrease to 991 m^3 per capita by 2030 and 853 m^3 per capita by 2050, i.e., a drop of 15.6% and 27.3% in ARWR m^3 per capita in the region by 2030 and 2050, respectively.

As the indicator ARWR defines population-driven physical availability of water, the rate of decrease in ARWR varies across countries. For example, ARWR in Afghanistan (1076 m^3 per capita) are expected to decrease to 728 m^3 per capita by 2030 and 441 m^3 per capita by 2050, i.e., a drop of 32.4% and 59.0% in ARWR m^3 per capita by 2030 and 2050, respectively.

Following Afghanistan, the country with a significant decrease in ARWR is Tajikistan with ARWR of 1793 m^3 per capita, dropping to 1291 m^3 per capita (28.0% decrease) and 847 m^3 per capita (52.8% decrease) in 2030, and 2050, respectively. The third most affected country regarding the drop in ARWR would be Pakistan with ARWR of 817 m^3 per capita, decreasing to 604 m^3 per capita in 2030 (26.1% decrease over 2015 level) and 424 m^3 per capita in 2050 (48.2% decrease).

Currently, Sri Lanka, India, Pakistan, Afghanistan, Uzbekistan, and Iran have ARWR less than 1700 m^3 per capita. By 2030, the additional country with ARWR reaching below the water scarcity threshold (1700 m^3 per capita) will be Tajikistan. The ARWR would be further decreased in these countries by 2050, while Tajikistan will also join them with ARWR less than 1700 m^3 per capita by the same year (Table 3.1).

With large populations, most countries in the Central and South Asia region would face the associated challenge of achieving food security amid drops in ARWR per capita and possible reallocation of some water currently allocated to the agriculture sector to other competing sectors such as municipal and industrial activities. This situation questions the status of food security in certain parts of the region, which is expected to become food-insecure in the absence of concerted efforts based on appropriate response options (Rasul 2014).

3.3 Food Security

Food security analysis in the Central and South Asian countries, translated through dependency on cereal imports, reveals a wide range of dependency ratio, a measure of a country's reliance on cereal imports to fulfill its domestic needs. Based on the data on cereal production, import and export between 2014 and 2017 at the national level (FAO-STAT 2020), the cereal crops included in estimating the cereal import dependency ratio were rice, maize, wheat, barley, rye, oats, millet, sorghum, and their associated products. The cereal crop choice is made because of the direct consumption of rice, wheat, and maize. To a lesser extent, the use of sorghum and millets. Such cereal consumption patterns correspond to 50% of world global caloric intake and play a critical in people's diets (Awika 2011) in major regions, including Central and South Asia.

Synthesis of the cereal dependency data in the Central and South Asian countries at the national level reveals that India, Pakistan and Kazakhstan are three countries from the region, which are net exporters of cereals. Except for Bhutan and Uzbekistan, other countries from the region are net importers of cereals with Sri Lanka, Tajikistan, and Turkmenistan having above 40% dependency on cereal imports. There is no cereal dependency data available for Bhutan and Uzbekistan (Table 3.2).

In addition to cereal dependency assessment and the status of water resources in the region, employment in the agriculture sector is a relevant factor in the water-food equation. Higher dependency on cereal imports and increasing scarcity of water resources would result in complicated impacts in countries where a large percentage of the labor force is employed to support activities in the agriculture sector (Table 3.2).

Based on the employment status in agriculture at the national level, expressed as the percentage share of total employment in 2015 (ILO-STAT 2020), more than

Table 3.2 Average cereal import dependency ratio between 2014 and 2017 at the national level in Central and South Asian countries (based on data on the production, import, and export of cereals—rice, maize, wheat, barley, rye, oats, millet, sorghum, and their associated products; FAO-STAT 2020) and employment status in agriculture at the national level, expressed as the percentage share of total employment in 2015 in a country (Based on employment data; ILO-STAT 2020)

Country	Cereal import dependency ratio[a]	Employment in agriculture (%)
Afghanistan	36	47
Bangladesh	15	43
Bhutan	NA[b]	58
India	−5	46
Iran	35	18
Kazakhstan	−69	18
Kyrgyz Republic	20	29
Nepal	14	67
Pakistan	−13	41
Sri Lanka	57	29
Tajikistan	46	48
Turkmenistan	42	22
Uzbekistan	NA	27

[a]The cereal import dependency ratio is expressed as a percentage. The higher the positive value of the cereal dependency ratio for a given country, the higher is its dependency on cereal imports. Negative values of the dependency ratio indicate that the country is a net exporter of cereals
[b]NA refers to data 'not available'

half of the countries in the region—Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, and Tajikistan—have more than 40% employment in the agriculture sector. The livelihoods of the communities associated with agriculture would suffer as water scarcity intensifies across the region.

3.4 Response Options

In the 2030 Agenda for Sustainable Development, the challenge of water scarcity and water quality deterioration is addressed through Sustainable Development Goal (SDG) 6, which aims to ensure water and sanitation for all by 2030. The inter-connected challenge of ending hunger and achieving food security and improved nutrition is the focus of SDG 2. There are other SDGs where the achievement of specific targets is needed to ensure water- and food-secure countries in the SDG era and beyond. Five years into the SDG era, the latest assessments suggest that the world is not on track to achieve SDGs by 2030 (UN 2018). The same applies to the Central and South Asia region. The following aspects of water resources management are needed in building water- and food-secure future in the region by (1) promoting water conservation, water recycling and reuse; (2) ensuring sustainable water resources augmentation; (3) supporting productivity enhancement of underperforming land and water resources; and (4) addressing challenges beyond technical solutions.

3.4.1 Promoting Water Conservation, Water Recycling, and Reuse

In arid and semi-arid areas of the Central and South Asia, where rainfall is limited and subject to high intra-and inter-seasonal variability, much of the rainwater that does fall is lost through surface runoff and evaporation. Such loss of water is further aggravated in areas with sparse vegetative cover and shallow and crusting soils. These factors provide a strong impetus for strategies that conserve even small amounts of rainfall and runoff water through micro-catchment rainwater harvesting systems for crop production and local needs of the associated communities (Oweis 2017). Such systems for agriculture production involve collecting rainwater that runs off a catchment area in a reservoir or in the root zone of a cultivated field, which is usually smaller than the size of the catchment area (Box 3.1). Owing to the intermittent nature of runoff events, the maximum amount of rainwater during the rainy season should be stored for later use (Thomas et al. 2014).

Box 3.1 Community based micro-catchment rainwater harvesting systems for crop production in Pakistan

Different forms of micro-catchments can be used for agriculture. Contour bunds consist of earth or stone embankments placed along the contours of a sloping field or hillside to trap rainwater behind them and allow more significant infiltration. Semicircular, trapezoidal, or 'V'-shaped bunds are generally placed in a staggered formation, allowing water to collect in the area behind the bunds. Excess water is displaced around the edges of the bund when the 'hoop' area is filled with water. These systems are mostly used for growing fruit trees and shrubs (Qadir et al. 2007). Another type of water harvesting system involving micro-catchments is the meskat-type system. Instead of alternating catchment and cultivated areas, the field is divided into a distinct catchment area located directly above the cropped area. The catchment area is often stripped of vegetation to increase runoff. The cultivated area is surrounded by a 'U'-shaped bund to hold the runoff. Such systems are suitable for productivity enhancement of plant species such as olives, which are usually grown under rainfed conditions, have low water requirements, and produce higher yields than rainfed areas when irrigated with small applications of water. A similar system, '*Khushkaba*,' is used in the Baluchistan province of Pakistan for growing some field crops, which require low volumes of irrigation water (Oweis et al. 2004).

Recycling and reusing 'used water' are crucial in water-scarce areas (Qadir et al. 2020). Currently, 32.8 billion m^3 (m^3 = 1000 L) of municipal wastewater are produced annually across the Central and South Asia region. Of this volume, 10.2 billion m^3 of wastewater are collected, i.e., 31% of the wastewater produced. The remaining amount of wastewater (22.6 billion m^3) is not collected and is released to the environment untreated, i.e., 69% of the wastewater produced. In terms of wastewater treatment, only 23.4% of the collected wastewater undergoes treatment, ranging from primary treatment to advanced treatment. The remaining volume of collected wastewater is not treated. The release of such large quantities of untreated wastewater carries health and environmental impacts. There is also a missed opportunity of not capturing and reusing the valuable resources—water, nutrients, and energy—embedded in wastewater.

In terms of use as a source of irrigation in agriculture, 32.8 billion m^3 of water could be used to irrigate 2.73 million ha, considering two crops per year and water requirements of both crops[2] around 12,000 m^3 per ha. The reclaimed water could be used to irrigate new areas or replace valuable freshwater where crops are already irrigated. Although such reuse of wastewater is already happening in the region, it is far from what could be offered by the actual potential of wastewater. The farmers use treated, inadequately treated, and untreated wastewater directly for irrigation or indirectly when it is discharged into freshwater bodies where it becomes diluted and diverted to the agricultural farms. There is a need to promote fit-for-purpose use of treated wastewater based on its quality and pertinent guidelines. Such reuse of treated wastewater needs to intensify as more volumes of wastewater are collected and treated as sources of irrigation water in the region.

While irrigated agriculture plays a significant role in supporting food production in the Central and South Asia region, adequate drainage is a prerequisite if irrigation is sustainable, particularly when salts in groundwater and high-water tables or waterlogging may damage the crops. A fraction of the water used for crop production results in drainage water. To maintain an appropriate salt balance in the root zone, the salinity of the drainage water percolating below the root zone must be higher than the salinity of the irrigation water applied (Qadir et al. 2007). The decreased allocation of freshwater to agriculture necessitates the reuse of agricultural drainage for irrigation. Contingent upon the levels and types of salts present, and the use of appropriate irrigation and soil management practices, research and practice (Oster and Grattan 2002; Linneman et al. 2014) have demonstrated that agricultural drainage water can be used for different crop production systems (Box 3.2).

[2] Based on the average crop water requirements of 13 crops: maize, wheat, barley, sorghum, cotton, soybean, sugar beet, cabbage, tomato, potato, onion, pepper, and watermelon (http://www.fao.org/land-water/databases-and-software/crop-information/en/).

Box 3.2 Crop diversification options under irrigation with saline drainage water in the Indian Sub-continent

Saline drainage water produced by irrigated agriculture can be used for growing a range of salt-tolerant crops, which may be grouped into (1) fiber and grain crops, (2) forage grass and shrub species, (3) medicinal and aromatic plant species (4) biofuel and multipurpose species, (5) fruit trees, and (6) agroforestry systems. Among grain crops, barley—at soil salinity levels around 12 dS/m—can produce 80% of the yield potential anticipated from non-saline conditions. Sugar beet can tolerate moderate levels of salinity in irrigation water (4–8 dS/m). Once established adequately under saline conditions, the sugar content in the crop increases compared to non-saline conditions. It is a deep-rooted crop that can use water stored in the soil profile missed by other crops. Quinoa is a salt-tolerant crop of high nutritional value. It has been recognized as a potential alternative crop for salt-affected areas and is expected to play an important role in ensuring future food security (Manaa et al. 2019). Forages produced by irrigation with saline water provide additional income sources for farmers in marginal lands. The promising forage species irrigated by saline water in the Indian sub-continent include, but are not limited to, Kallar grass or Australian grass, para grass, Bermuda grass, kochia, sesbania, purslane, and shrub species from the genera *Atriplex* and *Maireana* (Qadir et al. 2008).

The major river basins with irrigation systems in the region are the Aral Sea Basin (Amu-Darya and Syr-Darya River Basins) in Central Asia, the Indo-Gangetic Basin in India, the Indus Basin in Pakistan, and the Karkheh River Basin in Iran. Despite the importance of reusing agricultural drainage water for irrigation, most irrigated land is either without a drainage system or the available drainage system is not functional. For example, the drainage infrastructure installed during the Soviet era in the Aral Sea Basin does not function well due to weak institutions and lack of funding. This vast infrastructure network includes over 80 storage reservoirs, 47,000 km of partly lined main and secondary irrigation canals, 270,000 km of tertiary irrigation canals, 145,000 km of collector drains, 8000 vertical drainage wells, and hundreds of large pumping stations and water control structures. Irrigation in the absence of functional drainage system has caused large-scale land degradation and water quality deterioration in downstream parts of the Aral Sea Basin (Qadir et al. 2009) as well as in other major river basins in the region (Qureshi et al. 2008; Minhas et al. 2019).

By recycling agricultural drainage water until it is no longer usable for any economic activity, a significant contribution to food production could be achieved without expanding the production area and preventing the associated challenges that this brings. There is a need for a paradigm shift towards the *reuse* of saline water until it becomes unusable for any economic activity rather than its *disposal*. Thus, saline drainage water cannot be considered redundant and, consequently, neglected, especially in areas heavily dependent on irrigated agriculture where significant investments have already been made in infrastructures such as water conveyance and delivery systems to supply water for irrigation and food security.

3.4.2 Ensuring Sustainable Water Resources Augmentation

As water scarcity is expected to continue and intensify in dry and overpopulated areas of Central and South Asia, countries with such areas need a radical rethinking of water resource planning and management. Creative exploitation of a growing set of viable but unconventional water resources for food production, livelihoods, ecosystems, climate change adaption, and sustainable development need to be included. There are many of unconventional water resources that can be tapped (Djuma et al. 2014). Sources of such water resources range from the earth's seabed to its upper atmosphere. Capturing these resources requires a diverse range of technological interventions and innovations. Harvesting water from the air consists of rain enhancement through cloud seeding and the collection of water from fog; such techniques address local water shortages. On the groundwater front, tapping offshore and onshore deep groundwater and extending sustainable extraction of undeveloped groundwater are appropriate options in areas where there is potential for additional groundwater resources. Other opportunities to develop water resources exist in the form of desalinated potable water. Physical transport of water, such as towed icebergs and ballast water held in tanks and cargo holds of ships, is receiving attention, but corresponding practices remain in infancy (UN-Water 2020).

Some unconventional water resources are relevant to specific areas in Central and South Asia. The scope of harnessing the potential of unconventional water resources varies and depends on the water needs for purposes and associated policy and institutional support, human resources, and scale of investments required. For example, some resources such as fog water produce small volumes compared with other unconventional water resources, including desalinated water which produces large quantities. Still, fog water systems provide critical support to the associated communities for addressing local water shortages (Schemenauer et al. 2016). Engaging local institutions and related communities and ensuring gender mainstreaming are critical drivers for ensuring the sustainability of fog water collection systems.

Another form of harvesting water from air is rain enhancement. The amount of water vapor present in the atmosphere is an inexhaustible freshwater source and an opportunity for rain enhancement. Under pertinent conditions, cloud seeding could be used to enhance rainfall in a target area. Cloud seeding is a system that involves dispersing particular glaciogenic or hygroscopic substances into clouds or in their vicinity that allow water droplets or ice crystals to activate on heterogeneous nuclei through water vapor condensation-freezing processes (Flossmann et al. 2019). Subsequent collision-coalescence growth between artificial and natural water droplets and ice crystals leads to the formation of large rainy hydrometeor (drops, graupels, hailstones, snowflakes, etc.) that fall as precipitation (UN-Water 2020).

Desalinated water is a valuable water resource, which can extend water supplies beyond what is available from the hydrological cycle, providing a climate-independent and steady supply of high-quality water (Jones et al. 2019). A steady downward trend in desalination costs is expected to accelerate the current trend of reliance on the ocean as an attractive and competitive water source. These trends are likely to continue and to further establish seawater desalination as a reliable drought-proof alternative for coastal communities worldwide in the next 15 years (World Bank 2019).

More than 150 countries use desalination in one form or another to meet sector water demand, supplying over 300 million people with potable water (Mickley and Voutchkov 2016). Despite declining costs, most desalination facilities are in high-income countries and account for 71% of the global desalination capacity. Conversely, less than 0.1% of the desalination capacity occurs in low-income countries (Jones et al. 2019). The production of desalinated water in the Central and South region stands at 5.0 million m^3 per day (1.8 billion m^3 per year), about 5% of the global volume of desalinated water produced (Jones et al. 2019).

There is a need to identify and promote bright spots of functional systems of unconventional water resources in the Central and South Asia region that are environmentally feasible, economically viable, and support the achievement of water-related SDGs (UN-Water 2020).

3.4.3 Enhancing Productivity of Underperforming Land and Water Resources

In dry areas of Central and South Asia, agriculture is based on both *rainfed* and *irrigated* production systems. Both systems have specific challenges to achieve optimal agricultural productivity. In *rainfed* systems, retaining moisture in the root zone and utilizing it for crop growth is a significant challenge due to crust formation on soil surfaces resulting from raindrops. Consequently, significant rainwater runoff from the crusted agricultural fields leaves less moisture in the root zone and poor crop growth. In *irrigated* systems, salt-induced land degradation is common and affects several soil properties and crop productivity negatively.

The cost of "inaction" on underperforming degraded lands is estimated to be a 15 to 69% loss in revenues: depending on variables such as the crops grown, the intensity of land degradation, and the level of water quality deterioration, among others (Qadir et al. 2014). These estimates do not account for additional costs such as loss of employment, increased human and animal health problems, reduced property values, and associated environmental costs. In comparison, there are costs associated with "action" for investing in preventing or reversing land degradation or restoring degraded landscapes. Such "action" costs are likely to be much less than the costs associated with allowing land degradation to continue. The same applies to marginal-quality water resources. Recognition of the economic impetus for reversing land degradation and productive use of marginal-quality water resources by farmers, governments, development donors, and the private sector alike could be an essential step to support efforts in achieving food security in dry areas of the region.

Salt-affected and waterlogged soils are a significant impediment to the optimal utilization of agricultural production systems in the Central and South Asia region (Vyshpolsky et al. 2008). The most significant part of salt-affected soils and saline waters exists in the lower reaches of Amu-Darya and Syr-Darya Basins, where salinity is one of the main factors threatening food production. Salinization is exacerbated by the lack of safe disposal of large volumes of agricultural drainage water, deep drainage promoting salt mobilization, a mismatch between demand and supply of irrigation water, and lack of adequate maintenance of irrigation and drainage networks. Such factors have also triggered waterlogging in irrigated areas (Qadir et al. 2009). Like Central Asia, salinization of land resources is a significant impediment to the sustainability of irrigated agriculture in other major river basins of the region, such as the Indo-Gangetic Basin in India, the Indus Basin in Pakistan, and the Karkheh River Basin in Iran (Qureshi et al. 2008; Minhas et al. 2019).

Amid food insecurity, scarcity of freshwater and productive land in dry areas of the region, there is a need to focus on the productivity enhancement of underperforming land and water resources. Such resources include marginal-quality water resources, crusted soils in *rainfed* areas, and salt-affected soils in *irrigated* areas (Vyshpolsky et al. 2008; Oweis 2017; Minhas et al. 2019). These land and water resources cannot be neglected, especially in areas where significant investments have already been made in developing infrastructure (Box 3.3).

Box 3.3 Productivity enhancement of salt-affected soils in Central Asia

High-magnesium waters and soils are emerging environmental and food security constraints in South and Central Asia (Qadir et al. 2018). Excess levels of magnesium in irrigation waters and/or in soils in combination with sodium or alone result in soil degradation through impacts on soil physical properties. More than 30% of the irrigated area in southern Kazakhstan alone is represented by magnesium-affected soils. With low infiltration rates and hydraulic conductivities, these soils form large dense clods during the drying post-irrigation phase, which impact the water flow rate. Several farmers participatory studies have been undertaken on productivity enhancement of high-magnesium soils and waters in Kazakhstan and other countries in Central Asia. Vyshpolsky et al. (2008) carried out a 4-year study in southern Kazakhstan where they applied phosphogypsum as a soil ameliorant to enhance cotton productivity. The application of phosphogypsum improved soil structure and caused an increase in nutrient (phosphorus and sulfur) availability, which resulted in beneficial effects on crop yields. The cotton yield in fields with no phosphogypsum application remained 1.4 t/ha, while cotton yields were 2.7 t/ha in the phosphogypsum applied fields. This multi-year study demonstrated that farmers could improve their livelihoods by applying phosphogypsum to degraded lands resulting from high levels of magnesium in soils and irrigation waters rather than compromising on low crop yields. They were able to receive high net profits and made independent decisions on purchasing farm inputs and operational expenses and sale of harvested crop in the open market. In addition to increase in crop yields, there are common gains from such phosphogypsum-led interventions, such as environmental gains through carbon sequestration in soils, increase in land value, and livelihood resilience of the associated communities (Vyshpolsky et al. 2008).

3.4.4 Addressing Challenges Beyond Technical Solutions

There is a need for a radical rethinking of the public policy agenda by prioritizing water conservation, water recycling, and reuse; ensuring sustainable water resources augmentation; and supporting productivity enhancement of available land and water resources, particularly those underperforming. Such policy actions should be accompanied by a call for sustainable intensification of agricultural production systems. The increases in crop yields have fallen substantially below the growth observed from the 1960s through the 1990s. Skilled professionals, supportive institutions, and strengthening institutional collaborations would be the key to support the implementation of such policy actions.

Pertinent policy actions and strategic investments in support of agricultural production systems can reduce poverty, generate economic benefits, and ensure equitable social development for smallholders and marginalized groups. Although it is high time to consider strategic options for sustainably increasing agricultural output, policymakers may be tempted to ignore long-term sustainability aspects and focus on some cosmetic solutions for short-term benefits. For example, the political agenda and associated policies may tend to favor expanding the irrigated area over providing effective drainage systems to existing irrigated lands. Such steps will help farmers temporarily maximize current net revenues, while delaying the necessary investments in salinity and drainage management. Such policies and practices result in short-term benefits, followed by salt build-up, and productivity declines over the long run.

The valuation of the benefits of “action” or valuation of the costs of “inaction” is necessary to justify suitable investments in harnessing the potential of water resources in the Central and South Asia region. For example, the perceived high costs of technology for using some unconventional water resources without undertaking comprehensive economic analyses and innovative financing mechanisms restrict developing such water resources and scaling up their use (Hanjra et al. 2015). Such economic analyses do not consider the costs of alternate water supply options and the resources needed for them in the long run (UN-Water 2020).

With stagnant or declining agricultural productivity, the associated human resources such as farmworkers, communities, and businesses closely connected with agricultural production remain potentially at risk (Vyshpolsky et al. 2010). Such risks are particularly crucial in countries where a large percentage of the labor force is employed in the agriculture sector (Table 3.2). The business sectors at risk may deal with primary resources (forestry, wood, pulp, and paper), food and beverage, construction and materials, industrial goods and services (transportation and packaging), utilities (water and electricity), personal and household goods (clothing, footwear, and furniture), leisure and travel (hotels and restaurants), and real estate (ELD Initiative 2013). Such a situation paves the way to encourage the private sector's involvement and collaboration in addressing agricultural productivity enhancement targets and expanding market access to agricultural produce.

The challenge for achieving a sustainable increase in agricultural production systems lies with the planned and well-coordinated actions at the national and inter-regional levels. Water professionals and policymakers need to consider the urgency around building a water- and food-secure Central and South Asia region where water is recognized and treated as a precious, highly valuable resource for sustainable agricultural production systems and as a cornerstone of the circular economy.

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Chapter 4
Water-Energy Equation in Central and South Asia: A Perspective from Tajikistan

Sulton Rahimzoda

Abstract Central and South Asia are connected in many ways. Water and energy have the potential to further strengthen these links. South Asia needs energy to fuel its development, while the waters of Central Asia can be used to produce the clean and sustainable energy needed by South Asia. The major rivers of both regions are transboundary in nature, and bilateral and multilateral cooperation is essential to tap their full potential. In Central Asia alone, the annual economic benefits of cooperation were estimated at 5% of regional GDP. Hydropower is a sector where potential for cooperation is high, both within Central Asia and between Central Asia and South Asia. The capacity of Central Asian hydropower generation capacity can transform the energy market in both regions; the chapter analyzes the specific needs of Afghanistan, Pakistan and India and the potential for further cooperation. Finally, this chapter discusses the main challenges along the water-energy nexus in both regions, particularly climate change and population growth, suggesting ways forward.

Keywords Central Asia · South Asia · Hydropower · CASA-1000 · Water-energy nexus · Transboundary water resources

4.1 Introduction: Where Water and Energy Meet

Water and energy have always been, are and will be interconnected. If water is needed for generating electricity in hydropower plants and steam turbines of thermal power plants, as well as for use in the cooling systems of power plants, then electricity is needed to pump water from underground sources, to pump water to high buildings for drinking needs, to high-altitude fields for irrigation, as well as for water treatment and desalination systems.

The countries of Central and South Asia are rich in water and energy resources. Ensuring the necessary water and energy equation is extremely important for their

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Table 4.1 Formation and use of surface waters in the Aral Sea Basin (SIC ICWC 1996; SIC ICWC 2019)

Countries	Water formation		Water withdrawal	
	km^3	%	km^3	%
Afghanistan	6.18	5.35	3.50	3.01
Kazakhstan	4.50	3.89	18.73	16.09
Kyrgyzstan	29.30	25.35	5.53	4.75
Tajikistan	64.00	55.36	12.31	10.58
Turkmenistan	2.78	2.40	25.38	21.80
Uzbekistan	8.84	7.65	50.95	43.77
Total	115.60	100.00	116.39	100.00

further development. Moreover, this applies not only to the development of each of them separately, but also to their joint development, because the main rivers of these countries are transboundary and use by one country may impact others. At the same time, energy resources are also unevenly located and close cooperation among countries is needed to meet energy needs.

An example of this situation is the Aral Sea basin, covering the territories of Central Asian countries and, within the Amu Darya river basin, northern Afghanistan. The majority of the water resources in this basin have their origin in the territory of two upstream countries: Tajikistan and Kyrgyzstan (more than 80%) and partially in Afghanistan; however, their main users are the downstream countries: Kazakhstan, Uzbekistan, and Turkmenistan (more than 80%) (Table 4.1).

Meanwhile, the fossil fuel resources in this region are also unevenly distributed. Tajikistan and Kyrgyzstan do not have significant oil and gas resources and their coal resources are located in high mountain areas, which makes their extraction difficult and expensive. At the same time, rich water resources and convenient geographical conditions provide them with the opportunity to use water to generate hydroelectric power. Downstream countries (i.e., Kazakhstan, Turkmenistan, and Uzbekistan) have large oil and gas reserves, which are the main source of energy generation in these countries. Consequently, the share of hydropower in the total electricity generation in downstream countries is very low (Table 4.2).

If water and energy resources are sufficient to meet the needs of the population and the economy of the region, as it seems, this should not cause any concern. However, the problem lies in the different interests of the upstream and downstream countries. Thus, Tajikistan and Kyrgyzstan, lacking large reserves of fossil energy, need to accumulate water and use it in the autumn-winter period, when electricity demand is high. At the same time, Kazakhstan, Turkmenistan, and Uzbekistan are interested in the maximum use of water resources in the summer for irrigated agriculture.

During the Soviet period, when all these countries were united, there was a scheme, according to which downstream countries provided energy upstream during winter, while upstream countries stockpiled water and released it during summer to meet the needs of irrigation downstream. Unfortunately, this practice ceased to exist after the

Table 4.2 Structure of electricity production in Central Asian countries in 2018, including hydropower

Countries	Electricity generation in total, billion kWh per year	Hydropower generation, billion kWh per year	% of hydropower in total generation
Kazakhstan	107.10	10.4	9.7
Kyrgyzstan	15.60	13.47	86.3
Tajikistan	19.70	18.40	93.4
Turkmenistan	21.20	0.00	0.00
Uzbekistan	62.80	6.5	10.3
Total	226.40	48.77	21.5

Source SIC ICWC (2019)

collapse of the Soviet Union, when these countries became independent and began to advance policies based on national interests. This policy basically consisted in the principle of self-sufficiency and independence from each other, which disrupted the water and energy balance.

Unfortunately, all countries involved pay the consequences of such policy. In 2006, the region's losses from inefficient cooperation in water resources management accounted for USD 1.75 billion in lost agricultural yields or 3.6% of GDP (UNDP 2005). By 2017, this cost had gone up to an estimated USD 4.59 billion per year (Pohl et al. 2017).

Meanwhile, the benefits of regional cooperation only in the field of water and energy cooperation are enormous. In 2006, the annual economic benefits of cooperation were estimated at 5% of regional GDP (UNDP 2005).

The Central Asian region so far uses only about 10% of its existing cost-effective hydropower potential and the share of hydropower in the total electricity generation in the region is just over 21%. Meanwhile, Tajikistan alone has a hydropower potential estimated at 527 billion kWh (Abdullaeva et al. 1965), which is 2.3 times higher than the current needs of the countries of the region. And today this potential is used only by 4–5%, which indicates the huge potential for further development, which could contribute to a comprehensive solution to many current and future problems in the region (Ministry of Energy and Water Resources of Tajikistan 2016).

First of all, it is the production of relatively inexpensive and overall environmentally friendly electricity, which could cover the growing demands not only of Tajikistan, which recurrently faces acute shortage of energy in wintertime, but also of neighboring countries. In total, two million households in the region experience heating and electricity shortages in winter (World Bank 2016a). Second, the construction of reservoirs for hydropower plants allows improved regulation of river flows over several years and seasonally, which will ensure water security and water supply for irrigation in all Central Asian countries in dry years. Third, the generation of inexpensive hydropower would save oil, natural gas, and coal reserves, which are intensively used by some countries in the region to generate electricity. Thus, hydropower contributes to a significant reduction of CO_2 emissions in the region. Thus, development of hydropower is consistent with the need for a transition to renewable energy, which is a target of Sustainable Development Goal (SDG) 7 to "ensure access to affordable, reliable, sustainable and modern energy for all". Finally, reservoirs of hydropower plants contribute to the prevention of extreme hydrometeorological phenomena such as drought, floods, and mudflows, which annually cause huge economic damage to almost all countries in the region.

Thus, timely and joint efforts would allow the countries of the region to combat today's challenges and find ways to solve existing and emerging problems. Regional approaches to the use of water and energy resources in Central Asia would also contribute to greater efficiency, water security, and economic growth, improving the welfare of the population and achieving sustainable development.

4.2 The Significance of the Rogun Hydropower Plant for Central Asia

An example of the importance of water and energy for the region is the construction of the Rogun hydropower plant (HPP) in Tajikistan. The potential benefits from the construction of the Rogun HPP for the region will be USD 1.48 billion (Pohl et al. 2017).

After completion, the Rogun HPP will be the biggest HPP in Central Asia, with a total capacity of 3600 MW. The average annual electricity generation of the HPP will be more than 17.0 billion kWh per year. The dam of the Rogun HPP will be the tallest rockfill dam in the world, with a height of 335 m. It will form the Rogun reservoir, with a total volume of 13.3 km^3 and a useful volume of 10.3 km^3.

The construction of the Rogun HPP began in 1976; however, after the collapse of the Soviet Union, the project was suspended. In 2007, the Government of Tajikistan restarted the project. The Rogun HPP is planned to be used as a multi-purpose dam, including generating electricity, regulating water for purposes such as irrigation and environmental protection, reducing the risk of dangerous floods and mitigating droughts.

The Rogun HPP will be the biggest producer of clean energy in Central Asia and the surrounding regions. The affordable, environmentally friendly, and renewable energy produced will fully satisfy Tajikistan's electricity demand and will increase the country's export of electricity to neighboring countries, which mostly use fossil fuels to produce electricity and cover the needs of their own economy and population.

Hydropower cuts greenhouse gas emissions by reducing the amount of fossil fuel necessary to produce electricity in thermal power plants, and thus CO_2 emissions. To produce the same amount of electricity as Rogun HPP, coal-fired power plants would emit 13.67 million tons of CO_2 per year, while oil-fired ones would emit 9.95 million tons and LNG-powered 6.71 million tons (OSHPC "Barki Tojik" 2014). Thus, Rogun HPP will significantly contribute to reduce CO_2 emissions.

One of the most important features of the Rogun dam is its capacity to manage water resources in a sustainable manner in the context of climate change. Water shortages regularly causes severe problems in dry years, especially in the lower reaches of Central Asian rivers. This situation could worsen in the future with the impact of climate change. Rising temperatures will lead to an increase in evapotranspiration; consequently, higher irregularity in precipitation could lead to an increase in the number of extremely wet and extremely dry years; moreover, earlier snow melt will mean more water in spring and less in summer. In this situation, resource management will be even more important than it is today (OSHPC "Barki Tojik" 2014).

The Rogun dam also planned for adding regulating capacity to the entire system, especially in dry years, by making additional water available under such conditions. Jointly with the Nurek reservoir, whose total volume is of 10.5 km^3 and useful capacity 4.5 km^3, the Rogun reservoir will provide additional water for irrigation and other needs in dry years. According to the Ministry of Water Resources of the Soviet Union (1987), "for the Amu Darya basin, the commissioning of the Rogun reservoir is of great importance, since starting from 1986 the requirements of water consumers for the Amu Darya River will exceed the capacity of its seasonal regulation in dry years. Therefore, the period of development of the basin's water resources prior to the commissioning of the Rogun reservoir can be stressful with an unfavorable combination of dry years." This describes the importance of the speedy completion of the construction of the Rogun reservoir in the Master Plan for the use and protection of the water resources of the Amu Darya. Rogun will provide guaranteed water for irrigation of about 4 million hectares of land in the Amu Darya basin in water scarce and dry years, as well as for the development of more than 300 thousand hectares of new lands for irrigation. So, the Rogun HPP could benefit all downstream water users in the Amu Darya basin.

Rogun HPP with its big reservoir also offers flood control benefits, with positive effects on the entire downstream area. For the last decades, floods and mudflows increased in the magnitude in Central Asia. Adding Rogun to the cascade will reduce risks related to high magnitude floods (e.g., Probable Maximum Floods) and also reduce risks of floods of lower magnitude, but higher probability of occurrence, thus offering the potential to reduce inundation downstream (OSHPC "Barki Tojik" 2014).

Designed to generate electricity and manage water resources, Rogun HPP will also address climate change and a number of climate-related issues such as floods and droughts. It will contribute to both adaptation and mitigation and will also make a valuable contribution to reduction of CO_2 emissions, in line with 2015 Paris Agreement.

In addition to this, producing affordable electricity, Rogun HPP will provide an opportunity to create new industrial enterprises providing jobs and helping to develop economic and social conditions. It will help Tajikistan as well as other neighboring countries to make significant progress to achieve a number of SDGs.

4.2.1 Connecting Central Asia Hydropower Supply and South Asia Energy Demand

Meanwhile, the Rogun project is a component of the CASA-1000 project, connecting Central and South Asian countries with a 1300 MW high-voltage power transmission line, through which the surplus electricity from Tajikistan and Kyrgyzstan will be transmitted to energy-demanding Pakistan and Afghanistan during the summer. This project was initiated by the World Bank and is currently being implemented with power transmission expected to begin in 2024.

An important point in the initiation of this project was that Tajikistan and Kyrgyzstan have a very large surplus of electricity in the summer period, which is associated with an increase in river flow at this time of the year due to snow and glacier melt. At the same time, the electricity market in Central Asia is limited. Tajikistan alone releases from 3 to 5 billion m^3 of water annually through spillways, i.e., without generating electricity, while this water can generate from 2.5 to 4.0 billion kWh of electricity per year.

In the framework of the CASA-1000 project, the total surplus of the two countries was estimated at 6.0 billion kWh per year. At the same time, a 2035 development scenario was also considered. Even in this case, with no generation expansion and an annual increase in demand from 1.6 to 2.6%, Tajikistan and Kyrgyzstan can export up to 1 billion kWh of electricity per year to Afghanistan and Pakistan (SNC Lavalin 2011). Meanwhile, the electricity shortage in these countries is estimated at 10,000 MW for Pakistan (SNC Lavalin 2011) in 2030 and 3500 MW for Afghanistan in 2032 (Ministry of Energy and Water of the Islamic Republic of Afghanistan 2013).

The Rogun project with an annual output of 17 billion kWh per year is expected to be completed by 2030 and therefore can cover this deficit. Moreover, the first and second units of this station were launched in 2018 and 2019 respectively and the station is already producing electricity. Kyrgyzstan is also building up its potential. The Kambarata-2 HPP is being built with 360 MW capacity. The launch of its second unit is planned for the near future. Investments in new plants is currently sought: Kambar-Ata-1 HPP (1860 MW), Verkhne-Narynsky HPP cascade, etc. (Kyrgyzstan 2018).

Thus, the CASA-1000 project is a key element in the electricity transmission between the countries of Central and South Asia. The countries involved will reap important benefits. Tajikistan and Kyrgyzstan will be able to export surplus electricity and receive economic benefits, while Afghanistan and Pakistan will be able to cover their needs with environmentally friendly and affordable electricity. Ultimately, this project will improve the development prospects of both regions.[1]

At the same time, the downstream countries, Kazakhstan, Turkmenistan, and Uzbekistan, will also benefit from this situation. By exporting electricity to the countries of South Asia in the summer, Tajikistan and Kyrgyzstan will use water

[1] See the website of the CASA-1000 project www.casa-1000.org.

resources for generation. This is important for downstream countries, since it is during the summer period that water is most needed for irrigation.

Electricity transmission from Central Asia through the CASA-1000 is designed to solve the problems of Afghanistan and Pakistan in the short and medium term, since the needs of these countries are growing rapidly, and the available resources and capacity are insufficient to meet such demand.

4.2.2 Afghanistan: Water and Energy for Peace

In fact, both countries have their own hydropower potential. In addition to the CASA-1000 project, this potential can help resolve energy supply issues in the long-term period.

For example, Afghanistan has 23,000 MW of hydropower potential, of which only 270 MW is currently utilized, which makes only 1.17% of the available potential.[2] But in general the total installed generation capacity in Afghanistan is about 520 MW, including 254 MW (49%) from hydropower resources; 200 MW (39%) from thermal sources (furnace oil, diesel, natural gas); and 65 MW (12%) from distributed generators. Imports constitute nearly 80% of the total power balance. This situation persists despite the fact that Afghanistan is among the countries with the lowest in electricity usage per capita in the world, about 100 kWh per year with 30% of its population connected to the grid (ADB 2019). At the same time, the demand for electricity is growing annually. According to the Afghanistan Power Sector Master Plan, the gross demand for the whole of Afghanistan, i.e., the dispatched electricity, will increase in the baseline scenario by 5.7% or 8.7% per annum on average from its current level to 18,400 GWh in 2032. Total peak demand in 2032 is expected to stand at around 3500 MW (Ministry of Energy and Water of the Islamic Republic of Afghanistan 2013).

By developing its hydropower potential, Afghanistan will also be able to improve management of water resources. One of the important directions in this context will be the irrigation of new land. After all, HPP reservoirs provide an opportunity for gravity irrigation, which represents a competitive advantage for agricultural production. On the other hand, affordable electricity will make it possible to irrigate new land using pumping stations, where gravity irrigation is impossible.

The potential area for irrigation in Afghanistan is of 7.9 million hectares. At the end of the 1970s, the irrigated land in the country amounted to 3.3 million hectares, but today only about 2 million hectares remain available (Mahmoodi 2008). Irrigated agriculture makes a worthy contribution to the development of agriculture, which provides up to 50% of the country's GDP, as well as to employment, with more than

[2] See the presentation by Abdul Jamil Musleh, Acting Director of the Renewable Energy Department of the Ministry of Energy and Water of the Islamic Republic of Afghanistan at the SAARC Workshop On Application of on-grid Biogas Technology, held in Kabul on 16–17 May 2016: www.saarcenergy.org/wp-content/uploads/2016/07/Afghanistan%20presentation.pdf.

75% of the Afghan population living in rural areas, mainly engaged in agriculture (King and Stürthewagen 2010).

On this basis, the return of land to agriculture to the level of the 1970s, as well as the development of new land in the long term will be important for further economic development and addressing social problems of Afghanistan. In this regard, both the regulating capacities of HPP reservoirs, as well as the HPPs themselves, by generating electricity, will play a crucial role.

The surface water resources of Afghanistan are estimated at 57 billion m^3 per year. However, they are unevenly distributed: the Amu Darya river basin covers approximately 15.68% of the total land area but holds about 57% of the water flow; whereas Helmand with 45.35% of area holds only 11% of the water flow. The Kabul river basin in the east of the country covers an area of approximately 13.3% and holds about 26% of the water flow. The northern basin holds 12.26% of the area and drains about 2% of the discharge, while the Harirod-Murghab basin has a coverage area of 13.41% and holds 4% of the discharge (Alim 2006).

From 2008 to 2013, the Afghanistan National Development Strategy (ANDS) had a special focus on water and noted that "certainly, contributions to the Water Sector will remain key to the success of this strategy in particular, and of the ANDS in general" (Islamic Republic of Afghanistan 2008). Undoubtedly, sustainable management and efficient use of water resources in Afghanistan is important for reducing poverty, ensuring employment, preventing internal and external displacements, as well as ensuring security and political stability.

It should be noted that the majority of Afghanistan's river basins are transboundary, which highlights the need for cooperation with neighboring countries. Despite this, the only formalized instrument for bilateral or multilateral dialogue on water resources management to date is the agreement on the Helmand River (King and Stürthewagen 2010). Meanwhile, the main water resources of Afghanistan, as mentioned above, are part of the Amu Darya river basin, which also unites Kyrgyzstan, Tajikistan, Uzbekistan, and Turkmenistan. These countries are members of the International Fund to Save the Aral Sea (IFAS) and its water commission the Interstate Commission for Water Cooperation (ICWC). Afghanistan has not yet joined this institutional mechanism. The need for increased regional cooperation in the field of water resources is obvious, first to assist Afghanistan's use and protection of its water resources, without prejudice, and at the same time, the rights of downstream countries (King and Stürthewagen 2010).

One of the important projects for Afghanistan's water and energy equation is the joint construction of the 4000 MW Dashtijum HPP with Tajikistan on the Pyanj River, which is the main tributary of the Amu Darya River. The annual output of this power plant will be 15.6 billion kWh, which will meet the growing needs of not only Tajikistan and Afghanistan, but also other countries of Central and South Asia. The total volume of its reservoir will be 17.6 billion m^3 with a useful volume of 10.2 billion m^3, which will ensure, in addition to generating electricity and irrigating lands, effective protection against flooding (Petrov and Akhmedov 2010). According to preliminary estimates, the construction of the Dashtijum HPP will provide 1.5 million hectares of land in the region with irrigation water.[3]

4.2.3 *Pakistan: Tapping in Energy Deficit with Hydropower Development*

Pakistan also has a large hydropower potential. According to Pakistan's Water and Power Development Authority (WAPDA), there is 60,000 MW of hydropower potential in the country, of which only 9732 MW or 16.22% has been developed so far. In general, the power capacity of Pakistan today is of 35,924 MW. The share of hydropower accounts for 26.7%; thermal is 63.96%; nuclear is 4.14%; and solar, wind, and bagasse make up 5.2% (NEPRA 2019).

At the same time, Pakistan is currently amid an energy crisis. Some 51 million Pakistanis lack access to electricity, while a further 90 million suffer from unreliable power supply and daily load-shedding. This is having a serious impact on the economy. Over-reliance on imported fuel for thermal generation subject to price fluctuation is at the core of the energy crisis. The government remains under significant pressure to address an annual average power deficit of 4000 MW. Hydropower once underpinned the country's power sector, accounting for 45% of power generation in 1991. However, this share has dropped to around 28%, as short-term planning preferred thermal power plants. However, hydropower is poised for a resurgence and will play a significant role in addressing this power deficit. The proportion of hydropower in the total electricity generation may increase to more than 40% by 2030.[4]

Nevertheless, the preparatory process of the CASA-1000 project determined that over 90,000 MW of generation capacity will be required by 2030. Even with the existing identified potential plants, there will be about a 10,000 MW deficit in 2030 (SNC Lavalin 2011).

One of the grandiose projects to develop hydropower potential according to the plans of the Government of Pakistan will be Diamer-Bhasha HPP, the construction of which is planned on the Indus River. Upon completion, Diamer-Bhasha Dam would, first, produce 4800 MW of electricity through hydro-power generation; second, store an extra 10.5 billion m^3 of water that would be used for irrigation and drinking; third, extend the life of Tarbela Dam, created downstream 35 years ago; and finally, it would control flood damage by the Indus River downstream during high floods.[5]

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[3] See the news item, https://tj.sputniknews.ru/energetics/20160106/1018154932.html. Accessed 27 July 2020 .

[4] See the Pakistan country profile on the website of the International Hydropower Association, www.hydropower.org/country-profiles/pakistan. Accessed 5 Aug 2020.

[5] See the Diamer-Bhasha entry on Wikipedia, https://en.wikipedia.org/wiki/Diamer-Bhasha_Dam. Accessed 5 Aug 2020.

The live storage capacity of the reservoir will be 7.9 billion m^3. It is obvious that the Diamer-Bhasha Dam project will have a multi-purpose impact: generating electricity, regulating water resources, reducing the risk of floods, and controlling sedimentation.

This project will contribute to the regulation of the country's water resources, important in the context of climate change and increased water consumption, especially considering that in terms of water availability, Pakistan is at risk. Over the last six decades, the amount of per capita water resources has decreased from 5300 m^3 to 1000 m^3, which corresponds to the international definition of water stress (World Bank 2016b). The National Water Policy 2018 estimates the annual water resources of the Indus River system at 170.65 billion m^3, which corresponds to 804 m^3 per capita, with a population of 212.2 million people in 2018. Pakistan needs to build at least 13 dams having a water storage capacity equivalent to the Kalabagh Dam, whose total capacity is 17.22 billion m^3, including 7.52 billion m^3 of active capacity (UNDP 2016). It is projected that by 2025, per capita water availability in Pakistan will be reduced to less than 600 m^3, which would mean a 32% shortfall, which would in turn result in a food shortage of 70 million tons of crop (Qureshi 2011).

One of the main water consumers in Pakistan is agriculture, which accounts for more than 90% of total water withdrawals. Irrigated agriculture and, consequently, water have always played an important role in the economic development of Pakistan and are likely to continue to do so in the future. Agriculture accounts for around one quarter of the country's GDP and employs 44% of the labor force. It supports 75% of the population and accounts for 60% of foreign exchange earnings. In Pakistan, agriculture is dependent on irrigation, perhaps more so than anywhere else in the world. Irrigation is used on 80% of all arable land and produces fully 90% of all food and fodder (Pakistan 2008).

However, as with Afghanistan and Central Asian countries, transboundary water cooperation is an important component of water management in Pakistan. Moreover, Pakistan is a downstream country in relation to both India and Afghanistan. New plans for the development of water resources in upstream countries will have an impact on Pakistan.

The 1960 Indus Basin Treaty between India and Pakistan regulated the relationship between the two countries over the use of the water resources of the Indus River, but over the last few years serious differences have emerged between Pakistan and India. Neighboring Afghanistan is also conducting feasibility studies to make new dams on the Kabul River, the right tributary of the Indus River with an annual average of 25 billion m^3. The short-term possible uses by Afghanistan on the Kabul River would be 10 billion m^3. Therefore, starting negotiations with Afghanistan to reach an agreement on water sharing is considered urgent (Qureshi 2011).

4.2.4 India: Fast Growing Water and Energy Ambitions

The largest country in this region is India. With a population of 1.34 billion inhabitants, India is one of the largest countries and consumers of water and energy in the world. It is among world's top ten countries with the most renewable freshwater resources and the world's top ten energy consumers. Having 1869 km^3/year renewable freshwater resources, India accounts for about 4% of the world's freshwater resources. Due to various constraints of topography and uneven distribution over space and time, India uses about 1123 billion m^3 or 60.08% of its renewable freshwater (India. Ministry of Water Resources 2019).

The main water consumer in India is agriculture, which in its turn has an important role in the socio-economic development of the country. Agriculture employs 50% of the workforce (Dhawan 2017) and accounts for 15.4% of India's GDP.[6] The main contributor to agriculture in India, as in many other countries and regions of the world, is irrigated agriculture. The irrigation area from 12.9 million hectares in 1951 increased to 126.73 million hectares in 2018. The overall irrigation potential of the country is estimated at 139.89 million hectares (India. Ministry of Water Resources 2019). At present, irrigation consumes about 84% of total used freshwater (Dhawan 2017, 13). Since agriculture is the main sector for food security and given that it provides more than 50% of the population's employment and about 13% of exports,[7] the Government of India plans to irrigate new lands, which will lead to an increase in water consumption. Many large and medium irrigation projects are being considered or implemented (India. Ministry of Water Resources 2019).

It is expected that the increase of irrigated land will be partially solved through the construction of new reservoirs and the development of hydropower potential. For 2019, the total volume of reservoirs in India was 253 billion m^3 and the estimated additional likely live storage available due to projects under construction/consideration is 155 billion m^3 (India. Ministry of Water Resources 2019).

Hydropower in India also has great potential, which is estimated at 148,700 MW. The country ranks 5th in the world in this regard.[8] 134.89 billion kWh of electricity or 10.5% of the total generation (1249.34 billion kWh) was generated at the country's HPPs (India. Ministry of Power 2019a). The capacity of all hydropower plants in India amounted to 45,399 MW or 12.75% of the total capacity of the country's energy system (356,100 MW) (India. Ministry of Power 2019b, 17). By April 2020, the capacity of HPPs increased by 300 MW and amounted to 45,699 MW.[9]

India has ambitious plans to develop its hydropower potential. In 2018, a National Electricity Plan was adopted, according to which at that time the capacity of hydropower schemes under construction was 10,848.5 MW, and the capacity of those that were under consideration and approval by the Central Electricity Authority of the Ministry of Power was 25,160 MW. In general, this Plan envisages bringing the

[6] See the Economy of India entry on Wikipedia, https://en.wikipedia.org/wiki/Economy_of_India. Accessed 5 Aug 2020.

[7] Ibid.

[8] See the AQUASTAT figures for India, www.fao.org/nr/water/aquastat/countries_regions/IND/IND-CP_eng.pdf. Accessed 5 Aug 2020.

[9] See the webpage, https://powermin.nic.in/en/content/power-sector-glance-all-india. Accessed 5 Aug 2020.

total capacity of India's HPPs to 110,393.3 MW (India. Ministry of Power 2018). Although this document does not indicate a timeframe for implementation, India aims at increasing the installed capacity of non-fossil fuel power plants to 40% by 2030.[10] The development of hydropower will play a key role in this regard, both in terms of increasing capacity and for balancing the energy system. The National Electricity Plan also describes the importance of hydropower development for achieving sustainable development and energy security in India, as well as the development of remote and backward regions of the country (India. Ministry of Power 2018).

The development of water and hydropower resources in India is also related to transboundary issues. The three major river systems of India–Ganges, Brahmaputra, and Indus–cross international borders. Because India's unexploited hydropower potential is also mainly along these three river systems, India has several international issues across them[11]

In addition to the abovementioned 1960 Indus Basin Treaty between India and Pakistan, India signed a number of agreements and memorandums with China, Nepal, Bhutan, and Bangladesh, which regulate their relationship on various issues, including the exchange of hydrological data, forecasting and flood management, joint research, control and monitoring of water resources, development and implementation of joint multi-purpose projects, and allocation and management of water resources. In the cases of Nepal and Bangladesh, the India-Nepal Joint Committee on Water Resources and Indo-Bangladesh Joint Rivers Commission were also established (India. Ministry of Water Resources 2019).

One of the key projects of such cooperation is the Saptakosi High Dam Multipurpose Project, which aims at building a 269 m high dam, a HPP with a capacity of 3000 MW, and at irrigating 1.522 million hectares of new lands. The field investigation for preparation of the Detail Project Report (DPR) is still under progress. India and Nepal also jointly undertook investigations and studies and prepared a DPR for the Pancheshwar Multipurpose Project with a capacity of 6480 MW and a dam height of 315 m. The total volume of its reservoir will be 12.26 billion m^3, while the useful volume will be of 6.56 billion m^3,[12] which will allow irrigation of about 430 thousand hectares of new land,[13] as well as to manage the flow and reduce the risks of flood from the Karnali and Mohan rivers.

Indeed, such multi-purpose projects can bring great benefits in terms of generating electricity, irrigating new lands, and regulating water flow thus reducing the risk of flood. Another feature of these projects is their contribution to reducing greenhouse gas emissions to the atmosphere, which could be very high if the same amounts of electricity were produced using fuel resources. However, both of these

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[10] See the news item, www.thehindubusinessline.com/opinion/indias-true-hydropower-potential-remains-untapped/article31580979.ece. Accessed 6 Aug 2020.

[11] See AK Verma's opinion piece, entitled "India's true hydropower potential remains untapped, www.thehindubusinessline.com/opinion/indias-true-hydropower-potential-remains-untapped/article31580979.ece. Accessed 6 Aug 2020.

[12] See the website, www.pmp.gov.np/index.php. Accessed 6 Aug 2020.

[13] See the news item, https://india.mongabay.com/2018/05/the-strategic-pancheshwar-project-comes-back-in-focus/. Accessed 6 Aug 2020.

projects and other plans for the development of water and hydropower resources are progressing with difficulty. Well-established transboundary cooperation would help and contribute to the achievement of sustainable development in these countries.

4.3 Conclusion: Future Challenges to the Water and Energy Equation

The above analysis of the situation in the countries of Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) and South Asia (Afghanistan, Pakistan, and India) shows how closely interconnected water and energy are and how many benefits their balanced use can bring. Meanwhile, the above examples prove once again that mutually beneficial international cooperation is one of the key factors in the development of water and hydropower resources due to the transboundary nature of many rivers, as well as the regional dimension of many energy markets.

However, there are other challenges that impact both the current situation and future development, among which the most important are climate change and population growth. While climate change leads inter alia to an increase in temperature, change in the hydrological cycle, increase in droughts, and other hydrometeorological phenomena, a reduction of river flow, as well as, at these latitudes, an increase in the use of electricity, population growth will lead to an increase in demand for water, food, energy, and other vital necessities, including employment. Moreover, the countries of Central and South Asia are considered highly vulnerable to climate change impacts and have high rates of population growth.

Until the 2000s population growth in the countries of Central Asia, as well as India, Pakistan, and Afghanistan was even higher. For example, during the Soviet Union period, the annual population growth of the countries of Central Asia was more than 3%, which stabilized at about 2% by 2000.[14]

Population growth in the region will probably continue in the future. It is expected that the population of Central Asian countries will reach 83.8 million by 2030 and 100.25 million by 2050. In the same timeframe, Afghanistan is expected to reach 48.1 and 64.7 million; Pakistan 262.96 and 338.01 million; India, 1.50 and 1.64 billion, respectively.[15] According to these estimates, India will surpass China in terms of population by 2027.

Regarding the impact of climate change, the average air temperature in the region has already increased by 0.5 °C and, by 2030–2050, will reach 1.6–2.6 °C respectively (World Bank 2009). Obviously, this situation will increase the melting of glaciers, which are the main source of river runoff in the region. Over the past 50–60 years,

[14] SIC ICWC Diagnostic report on the rational use of water resources in Central Asia as of 2019 (draft for discussion and comments), p. 13.

[15] See the following webpage, https://population.un.org/wpp/Download/Standard/Population/. Accessed 7 Aug 2020.

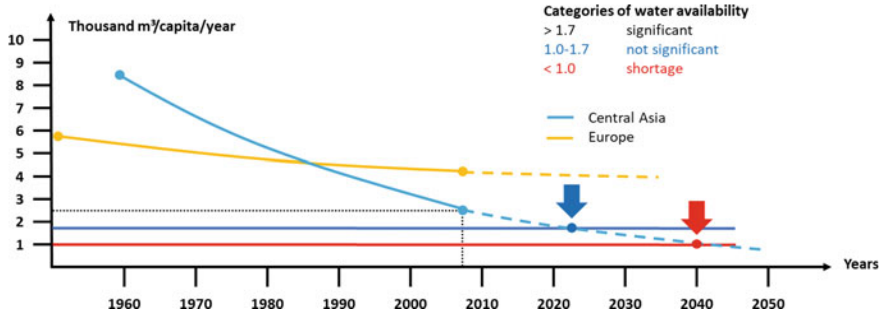

Fig. 4.1 Change of water availability in Central Asia[16]

the Tien Shan and Pamirs glaciers in Central Asia shrank from 6 to 40% in both volume and surface (UNEP 2017).

During the second half of the twentieth century the glacial resources of Central Asia decreased by more than three times and continue to decline with an average intensity of about 0.6–0.8% per year in terms of surface and about 0.1% in volume (Seversky and Tokmagambetov 2004). So far, this trend has not led to a significant change in river flow. A comparison of data for the period of 2001–2018 showed a runoff reduction in the Amu Darya basin by 0.51 km^3 and in the Syr Darya basin by 0.9 km^3. As a whole, in the Aral Sea basin, the runoff reduction amounted to 1.41 km^3 or 1.2% (SIC ICWC 2019). However, the available estimates show that "harsh" climate scenarios, such as doubling the concentration of carbon dioxide in the atmosphere, the flow of the Syr Darya river can drop from 15 to 30%, while the Amu Darya would observe a reduction from 21 to 40% (Chub 2000, 2007; Sorokin 2016; SIC ICWC 2019). The milder scenarios, however, predict a reduction in the river flow in the range of 6–10% for the Syr Darya and 10–15% for the Amu Darya by 2050 (EDB 2009).

According to the various scenarios, the river flow is expected to decrease in the mid- and long-term. Taking into account population growth, the availability of water resources, irrigated land, and hydropower per capita will gradually decrease. This is clearly seen in the case of Central Asia, where over the past 40 years the annual water supply per capita dropped from 8.4 thousand m^3 to 2.5 thousand m^3. At current rates of population growth, it is expected to reach the critical value of 1.7 thousand m^3 by 2025. By 2040 the region will become completely water-scarce, reaching a water availability of 1.0 thousand m^3 per capita (Fig. 4.1). Moreover, it will still be necessary to annually provide an additional 500–700 million m^3 of water to sustain the population of Central Asia even at very low levels of consumption (World Bank 2016b).

The same situation is observed in the countries of South Asia. For example, the water availability (surface water) per capita in India at the time of its independence (1947) was more than 5000 m^3/person per year and it is expected that by 2025 this

[16] Redrawn from World Bank (2016b) (data: EC IFAS).

figure will drop to 1500 m^3/person, which is more than three times less (Chatterjee 2002). In Pakistan, this indicator decreased from 5260 m^3/person in 1951 to 1000 m^3/person in 2016. By 2025, it is expected to drop to 860 m^3/person, which is 5.8 times less (Pakistan 2018). This moves Pakistan from water stressed into water scarce country. In Afghanistan, water availability per capita decreased from 5042 m^3/person in 1962 to 1412 m^3/person in 2014. By 2025, this indicator is expected to reach 1105 m^3/person, which is 4.5 times less (Lal et al. 2011).

Population growth will lead to an increase in the demand for food, one of the main suppliers of which is agriculture, including irrigated agriculture. Accordingly, the irrigated area per capita will also play an important role in this context. In the 1960s, this indicator in Central Asia was 0.32 ha/person, while today it has reached 0.14 ha/person, which is 2.3 times less.[17] The same phenomenon can be observed in South Asian countries. This indicator will keep dropping because of high population growth and the need for large financial resources for the cultivation and, where required, irrigation of new land.

However, advanced water and energy-saving technologies, new irrigation methods, as well as other achievements in the agriculture sector, due to the progressive development of science and technology, including the introduction of new adaptive, resilient, and high-yielding plants, provide the opportunity to achieve the desired results with less energy, water, and land to compensate. Thus, countries must focus on the efficient use of energy, water, and land resources, as well as increase the productivity of their use relying on new technologies and innovative techniques.

Thus, the above analysis shows that ensuring the water-energy equation in the countries of Central and South Asia under the impact of current challenges, including the increasing demand for water, energy, and food, is one of the key tasks for achieving sustainable development. The solution to this equation, considering the transboundary nature of many rivers, as well as the need for electricity export/import, transportation of necessary material and equipment for infrastructure development, as well as minimizing negative environmental and social impact, requires well-established cooperation between neighboring countries, which ultimately leads to a win-win situation for all parties.

The main objective of this analysis was to demonstrate the existing interdependency between water and energy in these countries. Water is the basis of life, and that energy is the basis of development. This means a lot. However, they are also directly involved in solving social problems and promoting economic development, contributing to the efforts of countries to achieve sustainable development.

The events of the first half of 2020, when the COVID-19 pandemic swept the whole world, once again put issues of sanitation and hygiene, which are closely interconnected with water, at the top of agendas. The ongoing changes in economic activity will have a direct impact on the energy sector. The expected shocks and changes in the world in connection with COVID-19 will be a great test for many countries, including the countries of Central and South Asia. Ensuring the water

[17] Data: ICWC.

and energy equation certainly is of great support for these countries in this difficult period.

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Part II
Regional Issues

Chapter 5
Towards the Deployment of Food, Energy and Water Security Early Warning Systems as Convergent Technologies for Building Climate Resilience

Asim Zia

Abstract The goal of designing convergent technologies, such as food, energy, water, energy security early warning systems (Nexus-EWS), is driven by societal need to adapt to increasing frequency and intensity of extreme hydro-meteorological events (e.g., floods, droughts, heatwaves) differentially distributed across the planet due to accelerating global climate change. Deployment and continual improvement of such convergent technologies may enhance social understanding of coupled food-energy-water systemic interactions, couplings, and processes, which in turn are critically needed for forecasting and managing the social ecological risk accentuated by climate change-induced extreme hydro-meteorological events. This chapter presents a brief review and discussion of Nexus-EWS as convergent technologies and provides promising examples of Nexus-EWS applications with specific focus on Central and South Asian countries, both within countries and across regional scale entities. The scientific and technical challenges for deploying, sustaining, and improving Nexus-EWS to generate accurate early warnings about the risks to secure and safe provision of food, energy, and water and identify early action capabilities are also explored. The growing role of open-sourced big data, such as remotely sensed satellite data and artificial intelligence, and their intersection with traditional security dimensions are discussed. Geopolitical and ethical issues arising from the deployment of convergent technologies such as Nexus-EWS are presented to inform the future research and policy action needs and goals.

Keywords Nexus-EWS · Extreme hydro-meteorological events · Central and South Asia · Early warning systems · Food · Energy · Water · FEW

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5.1 Introduction

In a landmark report on global risks, the World Economic Forum (WEF 2011) highlighted the need for a synergistic, convergent understanding of the food-energy-water nexus by emphasizing that a rapidly rising global population and growing prosperity are putting unsustainable pressures on resources, and that any strategy that focuses on one part of the food-energy-water nexus without considering interconnections risks serious unintended consequences. The interconnections and couplings in food, energy, and water systems have been recognized in recent literature (Bazilian et al. 2011; Hoff 2011; ICIMOD 2012; Endo et al. 2015; Scott et al. 2015). However, computational modelling that reflects those convergent and divergent interconnections and can inform policy development and risk management requires far more research and resource investments (Bizikova et al. 2013; Howells et al. 2013; Biggs et al. 2015; Zhang and Vesselinov 2017). In addition to human population growth and income disparity, the degradation in ecosystem services also poses a monumental risk at the nexus of food energy and water systems (Hoff 2011; Rasul and Sharma 2016).

In the face of these exogenous and endogenous drivers of change in the nexus, the central role of the changing risk from extreme hydro-meteorological events, such as extreme temperature and rainfall variability, poses a fundamental scientific and policy challenge for managing risk. Poor understanding of biogeochemical, landscape and policy responses to "primary" extreme events typically leads to "consequent" extreme events such as floods, droughts, wildfires, and water contamination events, which in turn pose monumental challenges for secure provision of food, energy, and water in the affected regions. The "antecedent" conditions in a landscape, e.g., soil moisture content, riparian buffers, and tree density, can play a critical role in mitigating the effects of primary extreme events and the emergence of "consequent" natural hazards and disasters such as widespread floods, droughts, and wildfires (Field et al. 2012). Further, there is an active community of research investigating the attribution of global climate change to the shifting trends in the frequencies, intensities, and durations of "primary" extreme events (e.g., see NAS 2014). There is widespread consensus in the scientific community that global climate change will very likely change the frequency, intensity, and duration of two primary extreme events (temperature and rainfall variability) from watershed to basin to regional scales under different Greenhouse Gas (GHG) forcing scenarios (Field et al. 2012). However, there is considerable uncertainty surrounding the projection of the changing frequencies and intensities of these events at multiple scales (e.g., see Yang et al. 2016a; Zia et al. 2016). Large uncertainty about changes in extreme events hinders local- to regional-scale efforts to incorporate the risk from extreme events in the decision-making processes of critical actors engaged in the production and consumption of food, energy, and water.

Broadly, the first generation Early Warning Systems (EWS) with varying levels of forecast accuracy have been deployed for a variety of natural hazards including sudden-onset events such as earthquakes, tsunamis (Taubenböck et al. 2009; Liu et al.

2007; Thomalla and Larsen 2010; Spahn et al. 2010), landslides (Intrieri et al. 2012), and flooding from rivers and tsunamis (Basher 2006; Thieler et al. 2009), as well as more gradual processes like drought (Pozzi et al. 2013; Pulwarty and Sivakumar 2014) and malaria transmission that result from climate variability (Thomson et al. 2006). As such, EWS are established to mitigate hazards and can act on a multitude of temporal and spatial scales. The temporal scales (early warning lead times) range from minutes in the case of earthquake and tsunamis, to hours in the event of river flooding, and at times months and even years in the case of drought. Food, energy, water security early warning systems must encompass lead times from hours to decades and perhaps even centuries in the face of global climate change. Short- to medium-term lead time forecasts can be used by policy makers, managers, and citizens for both operational and tactical decision making for adapting to the risk of extreme events, while long term lead time forecasts are generally usable for strategic decision making (Zia and Hammond Wagner 2015) and increasingly critical for building resilient and sustainable planetary systems (Zia 2021). Effective communication of uncertainty embedded in Nexus-EWS and improved understanding of synergies and trade-offs in the nexus due to differential sources, processes, and output of a social ecological system were enunciated as desirable goals in a UNFCCC COP24 side-event focused on mainstreaming Nexus-EWS for adaptation to climate change (Zia 2018).

The goal of designing convergent technologies, such as Nexus-EWS, is thus driven by critical global environmental policy need to adapt to increasing frequency and intensity of extreme events differentially distributed across the planet (e.g., see IPCC 2021). Deployment and continual improvement of such convergent technologies may enhance stakeholder understanding of nexus interactions, couplings, and processes, which in turn are critically needed for forecasting and managing the social ecological risk accentuated by climate change-induced extreme events (e.g., see Howarth and Monasterolo 2016). This approach hypothesizes that convergent risk management interventions through Nexus-EWS reduces risk from extreme events and builds resilience against internal and external extreme events by increasing food, energy, and water security across different eco-hydrological regions. *A central hypothesis is that Nexus-EWS could be harnessed as convergent resilience technologies that can project, under different climate change, socio-economic, and land-use scenarios, the shifting risk from extreme events on safe and secure provision of food, energy, and water for the affected populations at national and regional scales, including but not limited to communities in the Central and South Asia.* Ultimately, the promise of a Nexus-EWS as a convergent technology is to facilitate both the private and public decision making by enabling transparent understanding of synergies and trade-offs embedded in managing complex interactions of the nexus.

Widespread deployment of convergent Nexus-EWS have strong potential to build resilience against extreme events and improve adaptive capacity of vulnerable human and ecological populations exposed to extreme events. While different conceptual notions of vulnerability and resilience have been explored in multiple disciplines (e.g., ecology, political ecology, human ecology, disaster management, climatic impacts, human dimensions of global change) and theories (e.g., pressure and release), which have been reviewed by Liverman (1990), Dow (1992), Ribot et al. (1996), Eakin and Luers (2006), Pelling (2003), Füssel and Klein (2006), Adger (2006), Cutter (2003), Ionescu et al. (2009), and Janssen et al. (2006), this chapter considers vulnerability and resilience as properties of a coupled natural and human system, as elaborated by Turner et al. (2003a, b) in the context of a social-ecological system. Previously, the system-level frameworks for vulnerability and resilience have been applied in a range of empirical assessments (Luers et al. 2003; O'Brien et al. 2004; Schröter et al., 2005; Ionescu et al. 2009). Despite the promising conceptual developments about the system-level notions of vulnerability and resilience in sustainability science and social ecological systems community, there are significant challenges in assessing vulnerability and resilience of coupled natural and human systems (e.g., see Adger 2006; Luers et al. 2003; Luers 2005). In the long run, the proposed approach of designing, deploying, and iteratively evaluating the performance of convergent technologies, such as Nexus-EWS, presents a monumental opportunity with increasingly widespread availability of open-sourced socio-environmental data and advancements in artificial intelligence (AI), yet there are many scientific and technological challenges, as well as ethical and geopolitical governance challenges that impede the realization of Nexus-EWS.

Section 5.2 of this chapter presents a brief review and discussion of Nexus-EWS as convergent technologies. Section 5.3 provides promising examples of Nexus-EWS applications with specific focus on Central and South Asian countries, both within countries and across regional scale entities. The scientific and technical challenges for deploying, sustaining, and improving Nexus-EWS to generate accurate early warnings about the risks to secure and safe provision of food, energy, and water and identify early action capabilities are discussed in Sect. 5.4. The growing role of open-sourced big data, such as remotely sensed satellite data and AI, and their intersection with traditional security dimensions are explored in Sect. 5.5. Geopolitical and ethical issues arising from the deployment of convergent technologies such as Nexus-EWS are presented in the concluding Sect. 5.6.

5.2 Nexus-EWS as Convergent Technologies

In this chapter, we follow Pahl-Wostl (2019) definition to characterize convergent understanding of the nexus: "Addressing security from the perspective of the Water-Energy-Food nexus refers to reducing trade-offs to acceptable levels and to enhancing synergies between efforts to simultaneously increase water, energy, and food security, respectively, to sustain human-wellbeing, economic production and environmental integrity and to enhance the resilience of the human-environment-technology system as a whole (Pahl-Wostl 2019: 361)." In the face of multiple, yet highly uncertain exogenous and endogenous drivers of change in the nexus, the changing risk from primary and secondary extreme events plays a central role and poses a fundamental scientific and policy challenge for building climate resilience. Poor understanding of biogeochemical, landscape, policy, and behavioral responses to "primary" extreme

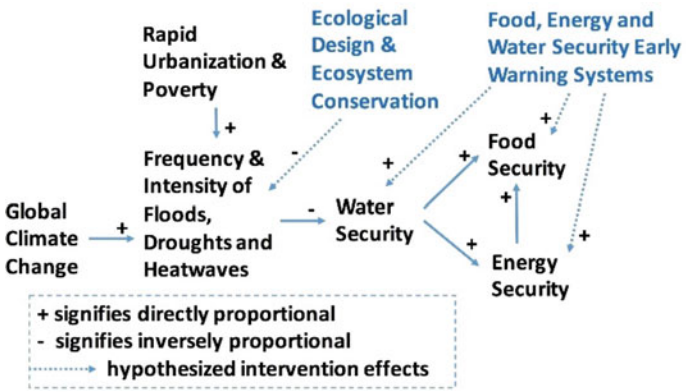

Fig. 5.1 A conceptual overview of the hypothesized intervention effects induced by convergent technologies such as Nexus-EWS, Ecological Design & Ecosystem Conservation in promoting food, energy, and water security

events may lead to "consequent" extreme events such as floods, droughts, and water contamination events, which in turn pose monumental challenges for secure and safe provision of food, energy, and water in the affected regions, as shown in Fig. 5.1.

The food, energy, and water early warning systems (Nexus-EWS) approach is embedded in social ecological systems theory (Gunderson 2001; Ostrom 2009) and complex adaptive systems theory (Holland 1992) that explicitly models the interconnections and dynamics of various nexus components and drivers of change across consistently defined eco-hydrological regions. In this tradition, many climate risk assessments and nexus studies have highlighted the need to develop regional/river basin scale social ecological systems models for improved understanding and the management of risk posed by both endogenous and exogenous drivers of change (NAS 2014, 2016). Complexity science-informed research has demonstrated that when exposed to exogenous shocks (e.g., climate change-induced extreme events) or endogenous surprises (e.g., ecological collapse or a geopolitical conflict), social ecological systems do not necessarily go through gradual change, but rather critical transitions (tipping points and thresholds) may abruptly change the trajectory of state variables (e.g., Scheffer 2010). It is hypothesized that a loss of resilience can trigger critical transitions that induce the state variables in the system to be abruptly tipped into a different state (Carpenter et al. 2005; Folke 2006; Holling 1973). In the context of the social ecological systems approach to design convergent technologies for building resilience against the extreme events, resilience refers precisely to the *magnitude of disturbance that can be absorbed before a system changes to a radically different state, as well as the capacity to self-organize and the capacity for adaptation to emerging circumstances* (e.g., Carpenter et al. 2001; Folke 2006; Berkes et al. 2008).

However, many resilience and vulnerability assessments of the nexus to the extreme events, lack a critical dimension that concerns the control and adaptive management of complex adaptive systems, such as river basin social ecological systems (Zia 2021). Inadequate understanding of non-linear processes and threshold effects pose fundamental challenges in distinguishing controllable from non-controllable processes in social ecological systems (Zia et al. 2022b). In particular, the controllability in the decision-making processes at micro-scale levels, such as households and firms (farmers, utilities, etc.), is poorly understood. It is recognized in the complexity science literature that the properties of complex adaptive systems, such as emergence, adaptation, and self-organization of heterogeneously interacting components, do not necessarily lend to top-down control and dynamic optimization (e.g., see Holland 1992; Levin 1998). Tipping points, thresholds, non-linearities, and irreversibilities in ecological and biogeochemical systems need to be adequately accounted for to effectively model social ecological resilience and vulnerability to extreme events. Similarly, tipping points in social systems induced by poor governance and infrastructure planning may lead to maladaptation and vicious social traps. Conventional engineering economic models of system optimization and top-down control do not necessarily work in managing the risk and trade-offs in multi-scale social ecological systems beset with thresholds and tipping points (e.g., Zia et al. 2011, 2014; Blair and Buytaert 2016; Chaffin et al. 2016). Polycentric governance systems balance bottom-up and top-down (multi-level) and lateral (inter-sectoral) pathways of influence (Ostrom 2010; Pahl-Wostl et al. 2012; Pahl-Wostl and Knieper 2014). They are assumed to have high performance with respect to integration across issues and scales and regarding adaptive capacity (Ostrom 2010; Folke 2006; Pahl-Wostl et al. 2012; Pahl-Wostl 2009; Blomquist and Schlager 2005).

In the nexus domain, potentially increasing frequencies and intensities of extreme events are likely to increase socio-political and ecological stresses with growing demand for food, energy, and water. Novel, bottom-up approaches to model the interconnections and control in the nexus are needed for generating transformative and actionable science (e.g., Liu et al. 2015). Such bottom-up computational approaches may provide novel contrast to top-down, constrained linear programming approaches for assessing resilience and control in the nexus. Zhang and Vesselinov (2017) developed a Water Energy Food Security Optimization model, an example of a top-down approach, that minimizes cost of energy supply, water supply, electricity generation, food production, and CO_2 mitigation for a given socio-economic demand in a stipulated timeframe. Similarly, Karabulut et al. (2016) used the Soil and Water Assessment Tool integrated with a variety of food and energy indicators, to assess water scarcity scenarios in the Danube sub-basins. Damerau et al. (2016) present a globally scaled, top-down optimization model of five regions to investigate the global water demand under three future food preference scenarios and two scenarios of future resource preferences for electricity and transport fuels. These top-down, integrated assessment approaches assume global control of societal preferences for food, energy, and water demand and typically specify convenient objective and constraining functions to identify optimal pathways for minimizing risk from extreme events.

While top-down approaches provide useful baselines to explore the nexus interactions and couplings, bottom-up approaches informed by social ecological systems theory have the potential to generate actionable convergent technologies for managing risk at spatially distributed scales that account for non-linear interactions of social, ecological, and technological components in complex adaptive systems. Bottom-up, computational modelling of resilience and control in the nexus has the potential to generate novel, interdisciplinary insights for managing the risks posed by multi-scale drivers of change, ranging from global-scale, climatic shifts to local-scale, land-use and land-cover changes induced by demographic and socio-economic shifts. In particular, the landscape design, which requires a bottom-up modelling, can play a critical role in differentiating resilient from non-resilient scenarios in the nexus, particularly in the face of changing frequency, intensity, and duration of extreme events. A global controller cannot necessarily predict or steer a landscape in an optimal direction in the face of large uncertainty about potential risks from endogenous and exogenous drivers of change, yet a well-defined objective function is typically assumed in constrained, linear programming approaches to assess resilience in the nexus. In fact, the locus of control in deciding the evolution of landscape typically rests with the decision-making and learning processes of landowners/land users, whether they are homeowners, farmers, businesses/firms, or local towns, both in response to and in anticipation of extreme events. Higher-level governance entities may develop land planning guidelines and rule structures, induce or coerce decision-making processes at household and firm levels, but the implementation of these rules and inducements typically takes place at the local, distributed scales of households and firms. Box 5.1 shows the positive social impacts that can be derived from nature-based solutions and ecological design approaches to reduce the risk from extreme events from increasing urbanization and build resilience in the nexus. Similar resilience enhancing benefits derived from the potential Nexus-EWS applications are presented in Sect. 5.2.

Box 5.1 Emerging role of nature-based solutions and ecological design approaches in reducing the risk from extreme events in the nexus

The recent nexus research has highlighted the need for future research to assess the differences between "business as usual" urbanization scenarios versus natural infrastructure landscape design scenarios in terms of their ability to modulate and buffer the impacts of extreme events. In the business-as-usual urbanization scenario, the growth and decline of cities can be modeled with urbanization models, such as UrbanSIM (Waddell 2002), and complexity science tools, such as cellular automata and agent-based models (e.g., see Batty 2007). Urbanization typically results in decimation of lower-valued forest lands, wetlands, riparian buffers, and even agricultural lands near urban lands (Grimm et al. 2000, 2008). In contrast, in a natural infrastructure landscape design, nature-based solutions for food and energy production and conservation of water are explicitly designed and implemented on the landscapes (Mitsch

1992; Lyle 1999; Makhzoumi and Pungetti 2003). Such nature-based solutions may include: agro-ecological practices for food production, wetland and riparian buffer conservation for flood mitigation, rooftop gardens and vertical gardens in urban areas, micro-hydro power generation projects, biomass and biowaste projects that "complete the loop" from waste to source, cover crops and conservation tillage in the face of drought, and constructed wetlands and ponds for slowing down nutrient run off (Makhzoumi and Pungetti 2003; Steiner 2014; Van der Ryn and Cowan 2013).

5.3 Applications of FEWS-EWS

The operational and tactical scale deployments of Nexus-EWS will likely take place in a few decades, or perhaps a few years henceforth, the strategic scale development of Nexus-EWS has recently seen an uptick in research and development (R&D) investments. Two specific initiatives are highlighted here: (1) Under the World Bank funding, a top-down *hydro-economic modelling approach* was used to ascertain the synergies and trade-offs induced by water, energy, and food management decisions on the future of nexus security under alternate climate change scenarios in the Indus (Yang et al. 2016a) and Brahmaputra (Yang et al. 2016b). (2) Under the funding from the US State Department's Fulbright Commission, I am working with a Transboundary Water-In Cooperation Network (TWIN) to develop a bottom-up *Integrated Regime Shift Assessment Model* to build tactical and strategic Nexus-EWS capacity for anticipating the impact of hydro-climate regime shifts on food, energy, and water security and designing multi-governance mechanisms for building resilience in transboundary Indus, Jordan, Mekong, and Amazon basins. Both the application approaches highlighted in this section are extendable to all the regions of the world, including Central and South Asia.

5.3.1 Hydro-Economic Approach

Yang et al. (2016a) evaluates the nexus in the Indus River of Pakistan using a hydro-agro-economic model extended with an agricultural energy use module. Impacts of a range of climate change scenarios on the nexus in the Indus Basin were modeled and then the potential of different alternative water allocation mechanisms and water infrastructure developments to address growing water, energy, and food security concerns in the country were assessed. Results show growing water and energy use under hotter and wetter climate conditions (Fig. 5.2). While more flexible surface water allocation policies can mitigate negative climate change impacts on agricultural water and energy use allowing for larger crop and hydropower production, such policies might also increase the inter-annual variability of resource use. Moreover, a more flexible surface water allocation policy would increase surface water use in the basin, while groundwater and energy use would be lower (Fig. 5.2). This project recommended that integration of a groundwater model and an energy market model was needed to further refine the longterm nexus projections under alternate climate scenarios. Explicitly addressing changes in food and energy demand as a result of demographic dynamics are also needed in future extensions of this model.

Using similar hydro-economic approach, Yang et al. (2016b) explores trans-boundary management implications of water diversions by upstream Chinese and Indian riparian partners on the downstream Bangladeshi regions of Brahmaputra basin. Development of new hydropower projects, upstream water diversions, and possible climate changes have introduced concerns among riparian countries about future water supply for energy and food production in this basin. Yang et al. (2016b) present details of this calibrated hydro-economic water system model of the Brahmaputra basin that is coupled with *ex-post* scenario analysis under the "nexus thinking" concept to identify and illustrate where development paths are in conflict. Results indicate that the ability of future development to remain free of conflict hinges mostly on the amount of precipitation falling in the basin in the future. Uncertain future precipitation along with uncertain future temperature and the unknown amount of

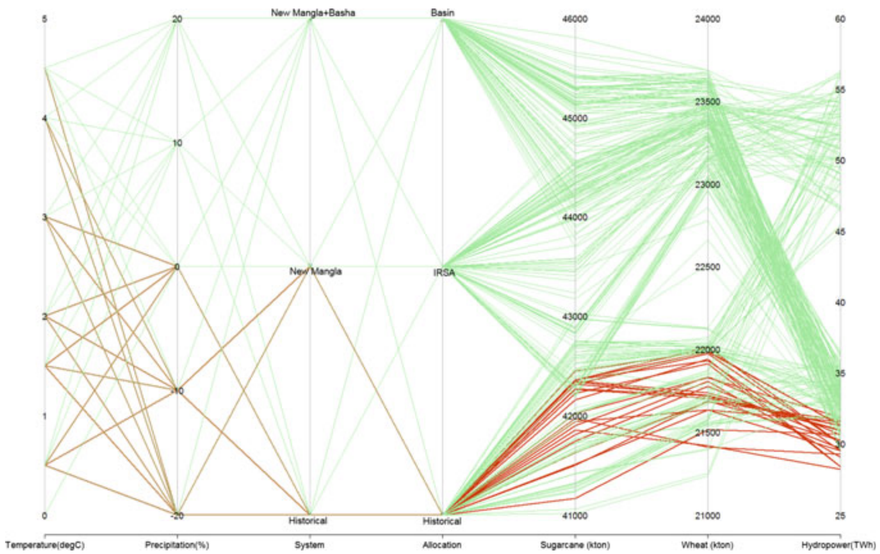

Fig. 5.2 Indus basin annual crop and hydropower production under the impacts of climate change (first two axes), dam development (third axis), and alternative water allocation scenarios (fourth axis). Green lines represent scenarios that satisfy thresholds and red lines represent scenarios that cannot satisfy threshold. In this figure, scenarios that result in sugarcane production, wheat production, and hydropower generation all below historical condition are labeled as red lines. *Source* Yang et al. (2016a)*

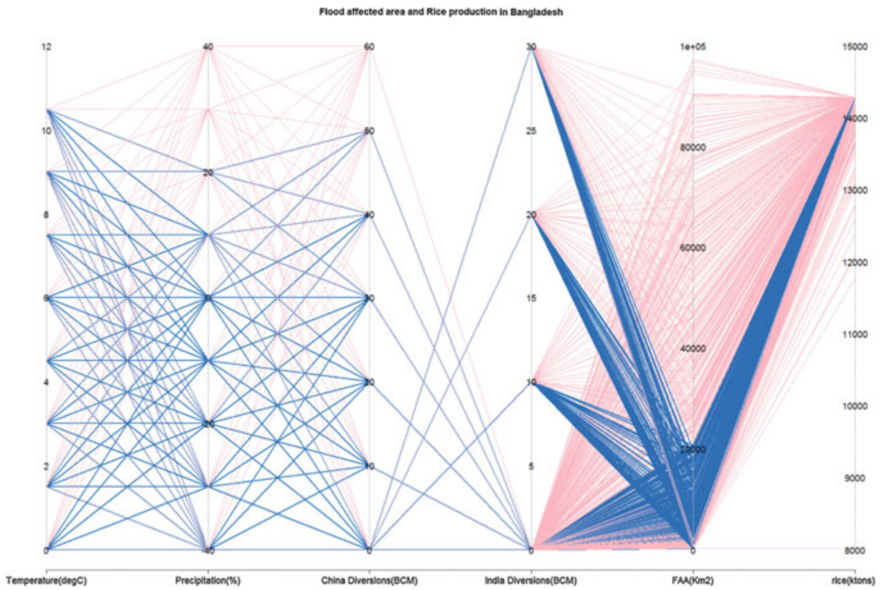

Fig. 5.3 Nexus modelling in Brahmaputra basin. Flood affected area (FAA) and rice production in Bangladesh under the impacts of climate change and upstream diversions. Blue lines represent scenarios within thresholds and pink lines represent scenarios outside of thresholds. Precipitation change and Chinese diversion cause tradeoff between FAA and rice production in Bangladesh. While positive precipitation change benefit rice production, it results in more FAA. *Source* Yang et al. (2016b)*

upstream water diversion combine to strongly influence future water, energy, and food production in the basin. Specifically, decreases in precipitation coupled with large upstream diversions (e.g., diversion in the territory of China) would leave downstream Bangladesh unable to secure enough water to produce their desired energy and food (Fig. 5.3).

5.3.2 *Integrated Regime Shift Assessment Modelling (IRSAM) Approach*

Coarse resolution climate impact assessments in the upper Indus basin suggest the likelihood of radical shifts in its eco-hydrological regime initiating a cascade of downstream impacts on its nexus (Immerzeel et al. 2010; Rasul 2014). More accurate projections at finer space-time resolution are direly needed for proactive policy and planning interventions to mitigate impending flood and drought risks. More accuracy requires the development of calibrated eco-hydrological models at the basin scale, and their integration with socio-economic models to estimate the risk posed by climate change-induced extreme events and to help identify leverage points for policy makers and planners to identify strategic interventions that account for couplings and critical transitions. Previous research discussed in Zia and Glantz (2012), Zia (2013), Zia and Hammond Wagner (2015), Ali and Zia (2017), and Zia et al. (2022a) suggest that uncertainties about monsoon variability and glacial melt timing pose daunting infrastructure design planning and nexus challenges. In the upper Indus basin, the melting of glaciers in the Tibetan delta is expected to result in significantly decreased water availability (e.g., see Immerzeel et al. 2010).

After simulating mean upper Indus discharge for the baseline (2000–2007) and future climate for A1B SRES scenario (2046–2065), Immerzeel et al. (2010) projected a mean 8.4% decrease in the upper Indus water supply for this mid-century scenario. Upstream water supply is crucial to sustaining water storage capacity in Tarbela dam, which in turn regulates the largest irrigation network in the downstream Indus. High-resolution models are needed to understand different glacial melt scenarios and shifts in the Monsoon to better predict long-term water supply issues in the Indus basin beyond mid-century scenarios (Ali and Zia 2017). Hanif et al. (2013), using the Pakistan Meteorological Department (PMD) dataset has found significant shifts in Monsoon direction from Gilgit-Hunza basins in the upper Indus towards the Hindukush mountains. By relating changes in upstream water availability to net irrigation requirements, observed crop yields, caloric values of the crops, and required human energy consumption, Immerzeel et al. (2010) estimated that 26.3 ± 3.0 million fewer people in the Indus basin will be fed. There is however a lot of uncertainty embedded in these projections, and Immerzeel et al. (2010, Fig. S3) found that the model projections are sensitive to glacial melt timing, while monsoon shifts were not incorporated in these projections. Further, the impacts of extreme events, such as the mega-floods of 2010 in the Indus basin, on food and energy production were ignored as well. Reduced water quantity in the upper Indus will also affect the ability of hydropower dams to operate at their maximum capacity, especially during winter months. Another serious concern arises due to the flood induced massive movement of sediments in the upper Indus that may shorten the lifespan of three critical dams (Tarbela, Diamir-Bhasha, and Bunji), consequently adversely affecting the energy security situation in Pakistan.

Lack of information on modelling feedback within and between social and ecological systems has hampered policy makers' and watershed managers' capacity to use the outputs of simulation models to develop effective adaptive management responses (Ostrom 2010). This approach builds upon Filatova (2015) proposed integrated approach by combining multiple modelling approaches—statistical analysis, system dynamics, equilibrium models, and agent-based models, which are typically used for detecting regime shifts in social ecological systems. Integrated modelling approaches can account for cascading interactions between coupled human and natural systems in the form of two-way feedback loops in the simulation models (e.g., see *Ecology and Society* special issue, Hull et al. 2015). Utilizing such an integrated model would potentially allow for tracing cascading effects when crossing a threshold in a subsystem, or the social ecological system may affect another threshold in the other subsystem, or emergence of the moving thresholds.

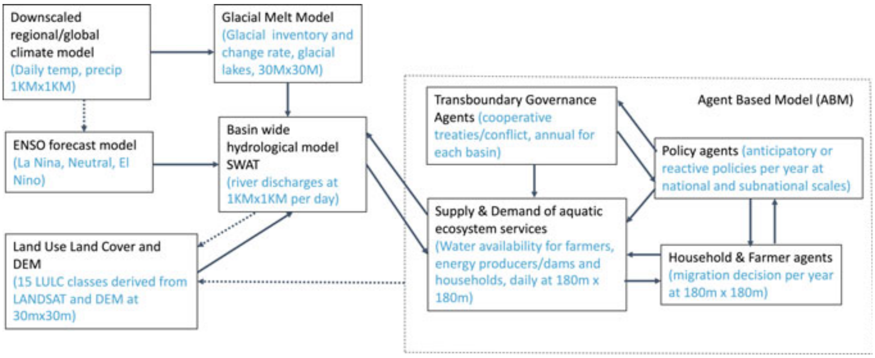

Fig. 5.4 Computational structure of a bottom-up Integrated Regime Shift Assessment Model (IRSAM) under development for the Indus basin

The integrated regime shift assessment modelling (IRSAM) (Fig. 5.4) will integrate a hydrological model, e.g., SWAT with an Agent Based Model (ABM) to simulate endogenous dynamics of (1) water, energy, and food availability and socio-economic stability in the entire river basin under alternate interacting regime shifts induced by global climate change and El Nino Southern Oscillation (ENSO) at global scales, (2) transboundary governance at basin scales and reactive versus anticipatory water, energy, and food policy regimes at national and subnational scales (Fig. 5.4). The IRSAM will have the ability to simulate the emergence of socio-economic stability regimes (e.g., mass migrations or not, conflict or cooperation) under different anticipatory and reactive scenarios co-designed with stakeholders in focal riparian countries spanning Indus and other focal river basins in this project. The computational workflow of the IRSAM described in Fig. 5.4 will be implemented in a workflow management system such as the Pegasus Workflow Management System, similar to Zia et al. (2016, 2022b) for transboundary Missisquoi river in the Lake Champlain basin.

5.4 Scientific and Technological Challenges in the Region

Given the novelty of Nexus-EWS as an emergent concept, a variety of fragmented early warning systems are deployed at various scales, community to sub-national to national to transboundary systems. These fragmented EWS do not necessarily account for the nexus, rather the EWS are operational in separate domains, e.g., flood early warning systems, drought early warning systems, and famine early warning systems. The US-AID and NASA have invested considerably in advancing EWS in both Central and South Asia.

In 2010, NASA and US-AID SERVIR program was expanded to Hindu Kush Himalaya, covering most of the mountainous terrain in the Central and South Asia.

SERVIR maintains a large, diverse collection of user-tailored geospatial services that use Earth observations and NASA data to inform resilient development. In Hindu Kush Himalaya, with respect to the nexus, SERVIR team has set up a regional drought monitoring and outlook system for South Asia. A prototypical drought monitoring and early warning system for Nepal has been developed under this program, and this prototype is being expanded to other countries Central and South Asia spanning Hindu Kush Himalaya.

Another project under the SERVIR program focuses on enhancing flood EWS. This project aims to build the resilience of vulnerable communities in the Hindu Kush Himalaya region by increasing flood forecast lead times and hosting the information on an interactive web platform. Once fully developed, the service will include an operational 15-day flood forecast based on the downscaled Global Flood Awareness System using a hydrological routing model at designated locations in Bangladesh and Nepal. In addition, this flood EWS will issue warnings on 24 to 48-hour high intensity rainfall events and flash floods. Similar flood EWS is being developed for the Indus basin by BlueEarth and Deltares.

Famine Early Warning Systems Network (FEWS NET), which was initially launched by US-AID and NASA in Africa, was expanded to Afghanistan. The FEWS NET issues monthly reports and maps detailing current and projected food insecurity and alerts on emerging or likely crises. The FEWS NET also issues special reports on factors that contribute to or mitigate food insecurity, including nexus factors pertaining to weather and climate changing induced water variability, as well as markets and trade, agricultural production, conflict, livelihoods, nutrition, and humanitarian assistance.

While SERVIR program inspired drought and flood EWS and FEWS NET generated famine alerts are steps in the right direction, these initiatives have only recently been piloted; and their scaling up across the Central and South Asia will require considerable investments in local capacity to process earth observation data and forecasting models. Bajracharya et al. (2021) provide a decadal synthesis of SERVIR program inspired monitoring and EWS applications in the Hindu Kush Himalaya region. As discussed above, either water (e.g., flood and drought) or food (e.g., famine) related EWS have been piloted; however, no nexus EWS application has yet been derived from the SERVIR program. Nevertheless, the SERVIR program has set up earth observation data capacity in the mountainous region of Central and South Asia to develop Nexus-EWS in the next few years.

Effective design and deployment of Central and South Asian region wide Nexus-EWS still faces considerable scientific and technological challenges. Many of these challenges pertain to the lack of cooperation in data sharing and management planning among riparian partners in transboundary river basins (e.g., Indus and Brahmaputra discussed above). Considerable benefits from scientific and technical cooperation could be potentially drawn by both upstream and downstream riparian partners in transboundary river basins in Central and South Asia; however, narrower geopolitical and compartmentalized policy goals (e.g., energy securitization without regard to water or food security) hamper scientific and technological cooperation. Financial and human resource challenges also compound design and deployment of Nexus-EWS.

5.5 Satellite Data Revolution and Its Intersection with Traditional Security Dimensions

Widespread availability of satellite and social media data has opened up the possibilities for the design and deployment of convergent technologies such as Nexus-EWS. Yet, a major challenge for quantifying and reducing the uncertainty in the projections of Nexus-EWS concerns the calibration and validation of underlying models against the field scale data. The drought and flood EWS piloted under the SERVIR program and famine EWS piloted under FEWS NET are limited to local scales. Both their scaling up at the Central and South Asian regional scales and their continuous improvement through assimilation of field data (e.g., supply and demand of food, energy, and water across sectors and countries) requires regional cooperation. Due to ongoing geopolitical conflicts in Central and South Asia (e.g., Kashmir, Afghanistan), field data on nexus being collected by national level agencies is not yet shared with scientists working on developing EWS. Without concurrent assimilation of field data in the nexus forecast models, the forecast reliability and accuracy cannot be readily determined. One of the major hurdles in field data sharing concerns the powerful role of traditional energy (e.g., hydropower), water and food securitization lobbies in many Central and South Asian countries.

Furthermore, the satellite data could be limiting due to limits in their spatial, temporal, radiometric, and spectral resolutions. Satellites with higher spatial resolutions tend to have lower temporal resolutions and vice versa. Spectral resolutions of satellites, e.g., Landsat (NASA) and Sentinel (ESA), are driven by science goals of western agencies and not the needs of convergent technologies in developing countries of Central and South Asia. Private sector satellite data could be cost prohibitive. Challenges associated with cloud cover limit the accuracy of Nexus-EWS. To account for gaps in spatial, temporal, radiometric and spectral resolutions, field scale in situ data on water (e.g., stream data), food (e.g., crop data) and energy (e.g., hydropower, wind data) must be made available at the regional scale for developing high resolution operational and tactical scale Nexus-EWS. Traditional securitization approaches, current in Central and South Asia, are certainly unable to stop the information that can be gleaned from open-sourced satellite data, yet the uncertainty of the forecast information derived from the satellite data can be considerably reduced if traditional securitization approach is made more flexible towards scientific and technological cooperation in transboundary river basins. Adoption of open science and data transparency principles in the Central and South Asian countries may eventually be one way to add flexibility in the traditional securitization approach.

5.6 Geopolitical and Ethical Issues

Widespread design and deployment of convergent technologies such as Nexus-EWS can provide critical and timely information for building resiliency and sustainability. Through mainstreaming Nexus-EWS projections in food, energy, water, and land use planning, ecosystem service management and disaster management at the river basin scales, the risk from extreme events can be potentially reduced and lives saved. Food and energy insecurity are destabilizing factors and increase the likelihood of international crises and conflict. The deployments of Nexus-EWS could support long-term land use and infrastructure planning as well as enable dissemination of early warnings for the near-real time impacts of floods and droughts on food and energy provision. In the face of the risks posed by global climate change, the migration and starvation implications of vulnerable people exposed to food, water, and energy insecurity in Central and South Asia are staggering; and provide strong motivation for future investments in Nexus-EWS. Novel science and environmental diplomacy approaches to build scientific cooperation could also pave the way for deployment of Nexus-EWS.

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Chapter 6
Climate Change Impacts

Fiona Rochholz, Tobias Matusch, Jens Wunderlich, and Alexander Siegmund

Abstract The all-embracing impact of human-made climate change is widely visible in both Central and South Asia, areas highly susceptible to climate related risks. From rising atmospheric and oceanic temperatures, rising sea levels, shifting precipitation regimes, and glacier melt related floods, no area is spared by climate change. A high vulnerability to climatic extremes is a consequence of the region's natural climate and geography and each country's sociological and political structure. Natural disparities are amplified by inequalities in educational and cultural opportunities. Additionally, low climatic resilience exists in densely populated areas with high poverty rates, which exacerbates the exposure to climate extremes and to accumulation of natural catastrophic events. Economic and social sectors dependent on water, energy, and food resources will experience increasing stress, risking wealth and economic standards of the countries and communities under a changing climate. This chapter outlines the most significant changes in climate for the region and the impact of these changes on water, energy, and food resources. Most countries in Central and South Asia have already included important steps in their policies or have implemented a series of strategies and projects (e.g., climate change adaptation). However, full implementation of sustainable adaptation projects presents a number of difficulties, all of which can be addressed on national and transregional scales to improve resilience against climate related threats.

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Keywords Climate change · Adaptation · Biosphere reserves · Water resources · Agriculture · Local communities

6.1 Introduction

The global climate crisis brings significant consequences for Central and South Asian countries. The region is characterized by highly complex geographic and climatic regimes, as well as a low resilience against climate related threats due to each country's own sociological and political structures. Despite similarities in high exposure to climate impact, the specific consequences on each country and society include various aspects and should be addressed on both regional and transnational scale.

The first part of this chapter addresses the natural geographic patterns and defines climate regimes across the different regions of Central and South Asia. The second part covers the most important climate change impacts, including both known and observed impacts, as well as expected changes in the near and distant future. While there are certainly differences in each region's specific challenges to a shifting future, which we address separately, intersectoral approaches through the nexus between water, food, and energy have the potential to address transnational challenges and risks for all regions and are covered in the third part.

The necessity to support both societies as well as the natural habitat to balance sustainability despite changing climate regimes will be addressed in the last part of this chapter. As a possible approach to the expected climate changes in both Central and South Asia, we introduce the concept of UNESCO's biosphere reserves as models for sustainable development which combine different aspects of climate adaptation, whilst serving natural conservation efforts.

6.2 Natural Spatial Patterns in Central and South Asia

Central Asia with an area of about 4.0 million km^2 and South Asia with about 6.9 million km^2 cover roughly 7.3% of the Earth's terrestrial surface. Following (Olson et al. 2001), Central Asia belongs to the Palearctic biogeographic realm, whereas South Asia is part of the Indo-Malay region. Central Asia is characterized by four biomes, (1) deserts and xeric shrublands; (2) temperate grasslands, savannas, and shrublands; (3) montane grasslands and shrubs; and (4) boreal forests/taiga (Olson et al. 2001). The region comprises different climate regimes, varying from arid deserts to mountain ranges with high precipitation rates. The strong influence of the Pamir and the Tien Shan mountain ranges is particularly evident by the available water resources in the main rivers of Amu Darya and Syr Darya (Magin 2005). Both rivers are fed by melting glaciers in the high mountains and are of utmost importance for the agriculture and energy sector, especially in Kyrgyzstan and Tajikistan. With the

Aral Sea, one of the most prominent examples of man-made environmental disaster lies between the two countries Kazakhstan and Uzbekistan (White 2013).

South Asia comprises mainly (1) tropical and subtropical moist broadleaf forests; (2) tropical and subtropical dry broadleaf forests; (3) tropical and subtropical grasslands, savannas, and shrublands; (4) deserts and xeric shrublands; and (5) mangroves (Olson et al. 2001). Large regional climate differences exist due to a variety of climatic factors such as altitude, proximity to the sea, and the influence of the monsoon. The glaciers of the Himalayas form the basis for the most important river systems in the region, in particular the Ganges, the Indus, and the Brahmaputra (Rasul 2012). The coastal regions have not only a high ecological value, among others due to the mangrove ecosystems, but also a high economic importance. However, these regions are particularly vulnerable to climate change, e.g., due to their low elevation and ongoing degradation of their natural protective mechanisms such as the mangrove ecosystems (Barbier 2015; Giri et al. 2015). Due to the high population density in large parts of South Asia and the increasing pressure on land use, multiple environmental challenges exist, ranging from deforestation and degradation to erosion, pollution, and loss of biodiversity (Barbier 2015). These challenges are addressed i.e., by the growing network of UNESCO Biosphere Reserves, model regions for sustainable development (see Box 6.1).

Box 6.1 The Global Biosphere Reserve Network—Model Regions for Sustainable Development

The Agenda 2030 under the Sustainable Development Goals (SDGs) provide clear targets, while keeping it to the respective national decision-making bodies on how to achieve them. A common approach for breaking new ground in testing and finding answers to ecological challenges under climate change conditions are biosphere reserves. The Dresden Declaration on biosphere reserves and climate change states that “Biosphere reserves are an effective instrument for mitigating climate change and serve as models for adaptation to the impacts of this change” (UNESCO 2011) and call for action on policy level, practical level, and UNESCO level. Biosphere reserves shall also function as climate change observatories and monitoring entities (UNESCO 2016a).

After the initiation of the Man and Biosphere (MAB) Program in 1971, only a few biosphere reserves were established in Central Asia during Soviet times. The perception of biosphere reserves in the Soviet Union was a certification of a high-quality standard of strict nature protected areas (zapovednik, IUCN Category Ia), rather than a complex concept for sustainable development. The modern understanding of biosphere reserves aligns with the Seville Strategy (UNESCO 1995), Madrid Action Plan (UNESCO 2008), and most recently, the Lima Action Plan (UNESCO 2016b). Biosphere reserves, after these conceptions are global model regions for conservation, sustainable use, and environmental research and education.

For testing innovative approaches on sustainable agriculture for example, ecosystem-based adaptation and nature-based solutions communication, education, and networking are important. It belongs to the key principles of the MAB Program that biosphere reserves also function as ambassadors for Education for Sustainable Development (ESD). "The crucial role of MAB reserves is to increase human capacity for climate action. Education and raising awareness are key to strengthen locals' role as actors in early warning, mitigation, adaptation, and resilience. The more people are aware of climate change issues and about the way they can contribute, the more efficient these processes will be" (Meggle 2015). This concept includes diverse aspects of lifelong learning, testing, and communicating best practices, and linking and connecting with other biosphere reserves under the umbrella of the World Network of Biosphere Reserves (WNBR).

Both Central Asia and South Asia are characterized by large demographic and socio-economic differences. Central Asia is sparsely populated (18.4 person/km^2) with primarily small differences between countries, e.g., Kazakhstan (6.8 person/km^2) and Uzbekistan (75 person/km^2). Contrary to this, with 278.9 person/km^2, South Asia is one of the most densely populated regions worldwide, where countries such as India, Bangladesh, and the Maldives face a particularly high population pressure (World Bank, https://data.worldbank.org, data from 2019). In addition, large socio-economic inequalities, not only between countries but also within individual countries, affect the vulnerability and adaptive capacities to projected climate change (Brooks and Adger 2005). For example, outdated and inefficiently operated irrigation infrastructure already became a significant problem in some Central Asian countries (Abdullaev and Rakhmatullaev 2016; Xenarios et al. 2018, p. 131). The biophysical and socio-economic vulnerability is especially high in the coastal areas of South Asia, despite their fast-growing economies (Siddiqui and Hossain 2020).

6.3 Observed and Projected Climate Change in Central and South Asia

The complex geographical location of Central and South Asia creates diverse climatological and environmental conditions and impose various challenges and threats to the Central and South Asian countries.

Impacts climate change that is already occurring are felt in all facets and regions of Central and South Asia. These changes indicate the magnitude of impact that is expected under progressing climate change.

6.3.1 Observed Changes

For many regions of Central and South Asia, current climate change is marked by an increase in mean surface air temperature (i.e., 1.1–1.8 °C in South Asia [Aadhar and Mishra 2020] and 0.7 °C in Central Asia [Hong et al. 2017]) and more frequent warm days, while the numbers of cold days have decreased consistently (Hijioka et al. 2014). Precipitation frequency and intensity in South Asia, especially in the tropical countries has changed towards more heavy rainfall events with decreased frequency of light rain events and extension of dry periods (Hijioka et al. 2014). The drying trend in the tropical areas also affects the South Asian summer monsoon in the seasonal mean (June–September) (Neelin et al. 2006; Bollasina et al. 2011; Hijioka et al. 2014) and is associated with the interference of atmospheric and oceanic circulation patterns by rising concentrations of greenhouse gases and aerosols (Ramanathan et al. 2005; Bollasina et al. 2011; Hijioka et al. 2014). Next to the above-mentioned mechanisms, increasing sea surface temperatures are proposed to be causing a spatial shift of monsoonal rainfall, enhancing the regional climate change impact (Annamalai et al. 2013).

Similar to the terrestrial Earth's surface, climate change has already affected the adjacent ocean basin of the Indian Ocean. The sea surface temperature of the tropical Indian Ocean has increased, on average, about 1 °C from 1951 to 2015 and is significantly higher than the global mean increase of 0.7 °C. In addition to a warming of the ocean, there is a notable increase of the sea level in the North Indian Ocean of around 1.06 to 1.75 mm per year from 1874 to 2004 and an increased rate of 3.3 mm per year, from 1993 to 2017 (Hijioka et al. 2014; Krishnan et al. 2020).

In the Pacific and Indian Ocean, some of the recorded sea level rise is likely due to an intensification of winds (trade winds in the eastern tropical Pacific and enhancements of Hadley and Walker cells in Indian ocean). Thermostatic extension of the warming ocean in the future may add to the sea level change, which has already accounted for around 80% of the sea-level rise in the nearby region of Gulf of Japan between 1993 to 2010 (Hijioka et al. 2014).

Next to the threat of sea level rise, since the 1970s coastal areas have been increasingly endangered by a weak upward trend of tropical cyclones in the western North Pacific. Whereas the Indian Ocean experiences fewer tropical cyclones, it is facing a very recent increase (2000–2018) of severe cyclic storms, usually in the post-monsoon season (Hijioka et al. 2014; Krishnan et al. 2020). A tropical storm describes a rapidly rotating storm system which forms over tropical seas. It is termed a severe cyclonic storm if this happens in the Indian Ocean or South Pacific. Coastal areas are extremely vulnerable to their impacts of heavy rain within a short time, strong winds, waves, and storm surges.

With the lack of a broad recording network, the data for Central Asia is not sufficient to draw specific conclusions on changes in annual precipitation trends over the past century (Hijioka et al. 2014) and regional observations are too scarce for universal descriptions. However, available records show not only mean temperature changes and precipitation values, but also generally, more frequent heat waves and heavy rainfall events since the mid-twentieth century in large parts of Asia (Hijioka et al. 2014). Heatwaves have had significant impacts in India and eastern Pakistan in 2015 and 2010 (Ullah et al. 2020) and have similarly become more frequent in Central Asia since the 1960s (Yu et al. 2020). Other climate extremes, such as floods had devastating effects in Bangladesh in 2018 and 2019 (Rahman and Islam 2019; Ullah et al. 2020). Long lasting heat spells and overdue rainfall have caused droughts over Pakistan and some parts of Afghanistan, India, and Iran (Ullah et al. 2020).

6.3.2 Projected Climate Change

As heavy weather events have significantly increased in frequency, duration, and strength in the past decades (Mirza and Monirul 2011; Ullah et al. 2020), the need for reliable climate predictions for the near and distant future has increased.

Climate model projections are used to assess future climate change impacts on both regional and transregional scales. For adequate projections of future development, emission and climate scenarios are described which represent possible fossil fuel emissions, their effect on the radiative forcing (cumulative measure of human emissions of greenhouse gases from all sources expressed in watts per square meter), and the subsequent effect on future climate conditions (Nakicenovic and Swart 2000; Moss et al. 2010). A low emission scenario is, for instance, the RCP 2.6 (RCP—Representative Concentration Pathway), which assumes the peak of radiative forcing at around 3 W/m^2 before 2100 and a decline afterwards. An extreme example of high emission scenario is the RCP 8.5, which assumes rising radiative forcing up to 8.5 W/m^2 in the same period.

Model capacity has significantly improved on all scales and simulations of recent years offer decreasing uncertainties about future climate projections. However, the reliability about regional results decreases with progressing time and increasing uncertainty about future emission trends, which requires deliberate interpretations of the projections. Despite uncertainties in the models themselves, knowledge about future climate trends on a regional scale can help to integrate measures for climate change adaptation specialized on regional needs and impacts (Dessai et al. 2009).

Model simulation of the IPCC AR5 Chapter 24—Asia (Hijioka et al. 2014) suggests a future increase of temperature relative to the late twentieth century, over all Asian land areas until the end of the twenty-first century. For low emission scenarios, this ranges around 2–3 °C and 3–6 °C in a high emission scenario, depending on the latitude. Under high emission scenarios, temperature increased significantly well into the future.

Robust temperature increase is also projected for the ocean surface in all emission-scenario cases, which indicates a strong vulnerability of the ocean. This implies significant issues for coastal countries in South Asia, where regional sea level rise is likely to exceed the global mean, as projected for the northern Indian Ocean under the higher emission scenarios (Krishnan et al. 2020). The frequency of tropical cyclones is difficult to determine and even if there is some confidence in a shift of North

Pacific storm tracks, there is low certainty about the projection of impacts from tropical cyclones (IPCC AR5). However, there are some indications for an increase of tropical cyclones in the northern Indian Ocean under a warming climate (Krishnan et al. 2020).

Predictions are also difficult for consistent future precipitation changes especially on regional levels. While directions for change are robust (Hijioka et al. 2014; Zhang et al. 2019), precise values are hard to forecast. This includes the impact of precipitation changes on parameters like runoff, water availability, and impact of water availability on the stability of the ecosystem under changing temperatures (Zhang et al. 2019).

Overall, precipitation is likely to increase in high latitudes, while at low latitudes, there is high uncertainty about precipitation changes. This is especially true for the low-CO_2 emission scenario RCP 2.5. In this scenario, changes in the monsoon system will increase precipitation in South Asia, with both mean and extreme precipitation increasing during the Indian summer monsoon (Mirza and Monirul 2011; Hijioka et al. 2014), whereas observations and predictions agree with a decreasing trend of mean precipitation during the summer monsoon (Ashfaq et al. 2009).

6.3.3 Regional Climate Change in South Asia

The current global warming trend and the geographical location with its topography and various climatological conditions make South Asia very vulnerable to climate change and one of the hotspots of future climate change (i.e., Byers et al. 2018; Mirza and Monirul 2011; Ullah et al. 2020).

Regional modelling studies for South Asia indicate increasing warming under all proposed scenarios; however, concrete effects vary with region and scenario, indicating additional effects coming from, for example, population density and/or land use. Stronger warming effects are expected in higher latitude areas than in mid to low latitudes, as well as in highly climate sensitive mountain areas (Pepin et al. 2015; Ullah et al. 2020).

Early season melting of snow and glaciers in high mountain areas of Asia affects the potential of the large rivers of South and Southeast Asia, such as Brahmaputra, Yellow, Yangtze, Indus, and Mekong, in particular to buffer water resources for drier seasons (Zhao et al. 2014). The development of glaciers of this area is not only affected by rising atmospheric temperatures. A regional study on glaciers of the northern Karakorum region illustrates how a smaller group of glaciers of the Karakorum seem to be preserved by a combination of enhanced cloudiness from monsoon moisture and an increase in debris cover over the glaciers (Zhao et al. 2014; Zafar et al. 2016). This development seems to be unique for the Karakorum, while the majority (~75%) of Asia's high mountain glaciers will significantly lose in extent (Zhao et al. 2014). However, unregulated discharge may cause flooding in melting seasons and endanger deltaic regions of Indus and Ganga–Brahmaputra Rivers (Ullah et al. 2020). For particularly vulnerable population groups with low adaptive capacities to climate change, this means additional burdens (Aadhar and Mishra 2020).

Results of future precipitation modelling for South Asia are quite variable and range from increasing amounts (Maldives, Sri Lanka, India, and Bangladesh) to decreasing amounts (Nepal), or very small changes (Bhutan), but in most cases with very low confidence or poor agreement across model simulations (Bhutan, Nepal, Sri Lanka) (Ahmed and Suphachol 2014).

Regional simulations for changes in the monsoon system in the near and distant future still lack certainty and model agreement on small scale changes. Turner and Annamalai (2012) review model weaknesses and difficulties when simulating the key processes of the monsoon system and discover large discrepancies in reconstructions of present and future interannual variability across models. They summarize arguments for an increase of aerosol forcing over South Asia, leading to reduced monsoonal rainfall from observations of the twentieth century. This might hinder a climate change induced increase of monsoon intensity over South Asia in the future that would be expected from rising atmospheric temperatures alone (Turner and Annamalai 2012). The key to lighten the expected changes to the monsoon system will be an improvement of the monsoonal processes in the general circulation models (GCMs) used to simulate future climate change in Asia.

Coastal areas are especially affected by climate change related sea-level rise. Observations already indicate a yearly sea level rise of about 1.0 mm (Vivekanandan and O'Brien 2016) in the Bay of Bengal. While regional differences exist, sea level will rise at all coasts across South Asia and pose threats for human life especially in densely populated areas. For instance, calculations show that 1 m sea level rise would displace 7.1 million people in India (Vivekanandan and O'Brien 2016). Another study simulated that around 18% of the land area in Bangladesh would be lost by an increase of only 1 m, threatening the life of millions of people and the economy of an entire nation with more than 160 million inhabitants (Minar et al. 2013).

The main cause of sea level to rise is thermal expansion of the warming ocean and this trend follows global observations and future simulations (Unnikrishnan and Shankar 2007; Vivekanandan and O'Brien 2016). Additional difficulties and threats are those in those coastal areas, formed by large river deltas. Here, reduced sediment delivery by drying rivers hinders deltas to keep up with the sea level rise and maintain a certain elevation. These coasts are highly vulnerable to erosion hazards and salt-water intrusion in fresh-water ground water sources (Oppenheimer et al. 2019).

6.3.4 Regional Climate Change in Central Asia

Temperatures in Central Asia likewise depend on the global emission scenario. These scenarios show with considerable certainty an increase in temperature by 2071 to 2099 of about 2.5 °C in the low-emission scenario and as much as 6.5 °C higher in the high emission scenario, relative to 1951 to 1980 (Reyer et al. 2017). Warming is especially pronounced in the southern part of Central Asia, indicating a potential to shift the climate regime towards a new one by the end of the century under the assumption of high emission scenario (Hijioka et al. 2014; Reyer et al. 2017). This comprises heat extremes, such as hot days and nights and warm spells, which will notably appear more frequently in Central Asia, with the length of warm spells being prolonged.

For northern regions of Central Asia, warming and specifically summer warming will be less intense. Most studies conclude that climatic change in high altitudes is less pronounced than in lower elevation plains (Unger-Shayesteh et al. 2013; Reyer et al. 2017), whereas there are indications for strong warming in winter in higher elevations in Tien Shan mountains (Kriegel et al. 2013; Reyer et al. 2017).

Atmospheric warming significantly contributes to melting of the regions' most valuable fresh-water source—high mountain glaciers of Tien Shan (Kyrgyzstan) and Pamir (Tajikistan) and smaller glaciers in Kazakhstan and Uzbekistan (Reyer et al. 2017), which feed, among others, the large rivers of Amu Darya and Syr Darya. These freshwater resources provide the livelihood for communities in arid and semiarid regions of Central Asia. These communities strongly depend on the water supply coming from these rivers for agriculture and hydropower. The largest freshwater source of the arid Central Asia area, the Aral Sea, is likely to continue to shrink under decreasing inflow of tributary rivers, already endangered by increased water evaporation and precipitation changes (Cretaux and Bergé-Nguyen 2013; Reyer et al. 2017). Increased runoff from glacier and snow during warming spring seasons may time the spring flood earlier in the year, while shrinking glaciers imply water scarcity the Syr Darya and Amu Darya rivers in the future (Reyer et al. 2017 and references therein).

Both developments of temporal change and runoff rates are strongly dependent to climate change projections, as well as water usage upstream (Bernauer and Siegfried 2012; Reyer et al. 2017). The glacier area loss is projected to be anywhere from 50 to 80% (2 °C and 4 °C global temperature increase, respectively) by 2100. The exact future development of changes in meltwater fluxes and glacier area loss are difficult to assess, owing to the lack of consistent observational data. While attempts are made to improve glacier models and understanding of glacier processes, inconsistent measurements in High Mountain Asia imply gaps in datasets needed for explicit spatial glacier models (Reyer et al. 2017; Miles et al. 2021).

While the results for regional warming are relatively robust and higher relative to the global mean, future development of precipitation lacks certainty and agreement throughout the model ensembles, largely due to incomplete data coverage as a basis for reliable future simulations (Hijioka et al. 2014; Reyer et al. 2017).

Precipitation projections show a drier Southwest and wetter Northeast, with changes more pronounced in the winter than during summer, depending on the intensity on the scenario. In a 2 °C world, models disagree about direction, but indicate changes. In a 4 °C world, there would be less rain in Turkmenistan, parts of Tajikistan, and Uzbekistan, with a stronger decrease in summer. However, accuracy of seasonal changes with present reconstruction of precipitation is still difficult (Bhend and Whetton 2013; Hijioka et al. 2014; Reyer et al. 2017).

Water stress will not only be amplified by decreasing precipitation, but also enhanced evaporation under warming temperature. In a 2 °C world, hyper arid or arid land area would increase by about 6% in a 4 °C world, it would be 20% more, relative to the reference period.

Increase melt of glacier ice and snow may counteract the loss of precipitation, as projected in some studies; however, a shift in the spring peak flow will limit water availability in dry summers (Hagg et al. 2013; Reyer et al. 2017).

6.4 Impact of Climate Change on the Water, Food, and Energy Sectors

With water and food resources being directly shaped by temperature and freshwater availability, climatic changes will heavily affect these sectors under the observed and simulated climate changes. Economic and social sectors dependent on natural resources will experience increasing stress, risking wealth and economic standards of the countries and communities.

6.4.1 Water

Central Asia is one of the driest areas in the world and water scarcity is going to become more frequent under a changing climate. Observed and proposed changes in water availability due to changes in meltwater discharge will not only directly affect freshwater availability from large rivers, but also food availability, due to the strong dependency of agriculture on irrigation (Schlüter et al. 2010).

On one hand, increasing runoff from glaciers and snowfields feeding the two largest rivers (Amu Darya and the Syr Darya) can occasionally substitute the lack of rainwater, and are already in use for irrigational agriculture (Xenarios et al. 2019). On the other hand, increasing water flow in those meltwater-fed rivers in warm months may pose threats to the environment and people if river flow is not regulated.

A contrast to this is South Asia, whose countries receive significant amounts of rain through monsoon seasons (Mishra et al. 2012). Some simulations suggest that in the future, there will be higher intensity and higher frequency of heavy rain events. However, this will pose high risk from heavy rain fall, runoff, and flooding events, especially dangerous in densely populated coastal areas. Rising damage and higher frequency of flood events has already been documented (Mirza and Monirul 2011).

Although climatically different developments will dominate the future of Central and South Asia, associated risks and inevitable impacts to the water, food, and energy sectors pose considerable threats to urban and rural communities and areas.

Regional impacts of climate change might even hold similar implications for both regions. Increasing heavy rain fall and glacier/snow field melt may improve freshwater supply in rivers for arid and semi-arid areas of the Amu Darya and Syr Darya as transboundary rivers of Central Asia. The same effect appears at the large delta areas of Indus and Ganges–Brahmaputra in South Asia. Though, if the glaciers of Tien Shan, Pamir-Alay, and Himalaya lose their water storage capability, flooding in melting seasons can negatively impact deltaic regions downstream (Mirza and Monirul 2011; Reyer et al. 2017; Aadhar and Mishra 2020; Ullah et al. 2020).

Securing water resources and ensuring equal management of river water resourced among all riparian countries requires transnational efforts. While five different countries, Kyrgyzstan, Tajikistan Uzbekistan, Turkmenistan, and Kazakhstan depend on the water resources of Syr Darya (Siegfried et al. 2010), four countries are involved in water management of the Indus and Ganges–Brahmaputra-Meghna basins: Bangladesh, India, Nepal, and Pakistan (Uprety and Salman 2011). Integrated management across borders can allow communities to use river discharge for irrigation or energy production and preserve water resources in a drier and warmer future. Current efforts in Central Asia to manage demands over water resources of the Syr Darya still reveal disputes between Kyrgyzstan and Uzbekistan and will become more complicated with decreasing water resources under climate change (Bernauer and Siegfried 2012).

For those areas in Central and South Asia, where modelling studies predict decreasing precipitation, increased glacier melt might counteract seasonal water deficits in the medium-term. However, increasing runoff in the melt season might be thwarted by an increasing demand for water for agriculture in dry and hot seasons and associated evapotranspiration (Reyer et al. 2017; Zhang et al. 2017, 2019).

6.4.2 Agriculture

Climate change impacts on agriculture, and as a result food availability, are closely tied to water availability. Difficulties for adequate risk assessment arise from uncertainties in model simulations for exact regional temperature and precipitation development, as well as the link between water availability and excessive water use for irrigation methods in agriculture.

Some regions in Central Asia currently experiencing year-round cool weather might benefit from climate change, with increased crop yields under lengthening growing seasons. However, droughts might hinder the growth if not compensated by irrigation methods. But to preserve water resources, changes in agriculture methods need to be employed under the consideration of sustainable development (see Box 6.3).

For large parts of South Asia, the monsoonal seasonal precipitation from June to September is the most important freshwater resource (Mishra et al. 2012), for which significant changes are forthcoming. While heavy and unpredictable rainfall events endanger crop yield by water excesses, the frequency of longer dry spells and monsoon break periods increase water stress on plants and crops. This results in losses in yield, hardly compensated by the growth increase during a lengthened growing season. While higher CO_2 and temperature might force plants to grow faster, studies showed decreased biomass production in fast growing plants, reducing the total yield in the end (Aryal et al. 2020).

Additional threats in coastal areas are salt-water intrusions into the rivers and river-flooding areas under rising sea levels (Sivakumar and Stefanski 2010), which can only be overcome in the longterm by either abandoning these areas for agricultural use or coastal protection measures to prevent increased salinity (Aryal et al. 2020). However, in countries with huge pressure on land use such as Bangladesh, it is questionable whether the highly valuable resource of land and its use will be abandoned especially by poor households with a lack of alternative income sources.

In many regions reduced crop yield can exacerbate problems of communities purely relying on agriculture for their living. While heat (excess) and water (lack, or excess of) pose the largest stress on crops of all kinds, heavy rain events and salinity intrusions in coastal and low-lying areas call for agriculture plans that provide more stability to these various threats.

6.4.3 Energy

Both Central and South Asia are widely applying hydropower for energy production and regulation of river flow. Changes in Central Asia's river flow throughout the year and water in pulses poses difficulties for solving conflicts about water use in agriculture and hydropower, as well as increase risk of floods and destruction of hydropower plants (Reyer et al. 2017). In South Asia, additional danger is posed by flooding of power plants on islands, low lying countries, or coasts, and hydropower, as well as heavy heatwaves or droughts (Ahmed and Suphachol 2014).

The various impacts of climate change on the energy and food sectors illustrate the nexus between water, food, and energy in Central and South Asia and the threats to life and wealth in poor or vulnerable communities.

Access and security of resources of energy, water, and food are closely connected and strongly depend on the wealth of each sector. Securing these resources is the overall aim at the political and social level to guarantee access for all communities. Collaborative efforts and projects need to be designed to adjust to new climatic conditions and guarantee sustainable use of resources, especially under increasing climate change and reduced resource capacity.

6.5 Future Perspective: Climate Change Adaptation Between International Strategies and Local Projects

To reduce the future impact of climate change on resources and social structures in Central and South Asian countries, collective efforts for climate change mitigation are undoubtedly the most urgent actions to be undertaken globally. However, global greenhouse gas emissions have risen since industrialization, and we are now experiencing irreversible changes in climate and long-term impacts because system feedbacks and thresholds are expected to accelerate this change climate.

While uncertainty about small scale climate change impacts hamper regional predictions, measures can be undertaken to attenuate the impact of heavy weather events, droughts, and heat spells and to protect disaster prone regions.

Climate change adaptation can reduce vulnerability to climate change induced threats, support local communities, and secure their resilience against climate change. It may also yield opportunities to create nationwide projects or collaborate across countries and borders, increase economic conditions, for example, by assuring food or energy independence (Sovacool et al. 2012), and help to implement Sustainable Development Goals (SDGs) in respective countries (see Box 6.2).

Box 6.2 Impact on Implementation of the Sustainable Development Goals (SDGs)
The legally binding Paris Agreement, adopted in December 2015, as an international response to global warming, is already far behind its targets. As part of the 2030 Agenda, the global community has set up 17 Sustainable Development Goals (SDGs) for a sustainable development. The implementation of these targets is deficient in both regions. According to the Sustainable Development Report, Kyrgyzstan performed best, ranking 52nd out of 166 countries rated. According to Sachs et al. (2020), Central Asian countries implemented the SDGs better than South Asian countries (average country rank 75 compared to 102) (Sachs et al. 2020). However, focusing on SDG 13—Climate Actions individually, several countries are already on track to achieve specified targets, ranging from strengthening resilience and adaptive capacity up to policies, planning, and capacity development measures. On the other hand, the climate change vulnerability monitor shows that countries such as Bangladesh, India, Iran, and Tajikistan are particularly exposed to potential impacts of global warming (Lafortune et al. 2018).

According to United Nations Development Program (UNDP), most of the countries of Central and South Asia have established, or are in development of a National Adaptation Plan (NAP) with partly massive support by the UNDP and the Green Climate Fund (GCF) as part of the historic Paris Agreement (Ahmed et al. 2019).

Various reports summarize current implementation of national adaptation plans and projects in South Asian countries (e.g., in Sterrett 2011; Sumit Vij et al. 2017; Ahmed et al. 2019). They provide a review of political strategies and outline the existing difficulties prohibiting nationwide efforts for adaptation plans often in close relation to disaster risk management. This includes prohibiting factors such as the lack of widespread financial support and lack of integration of adaptation into climate change policies (in addition to mitigation) or the lack of clear institutional structures to initiate and supervise adaptation projects.

Several reports on adaptation projects in Central Asian countries reveal similar fundamental difficulties when it comes to implementing adaptation in policies and institutions (Schlüter and Herrfahrdt-Pähle 2007; Pollner et al. 2008; Sutton et al. 2009; Novikov et al. 2009; UNDP 2018; GIZ 2020a, b).

To meet country specific requirements and vulnerability, a combination of different approaches can meet climate change related need for adaptation.

The Adaptation Committee (AC) of the United Nations Framework Convention on Climate Change (UNFCCC) describes different approaches to meet adaptation to climate change in the longterm, whilst integrating SDGs of various sectors (Adaptation Committee 2019). Among the suggested methods, two approaches stand out to support integration of sustainable development as part of climate adaptation: (1) community-based adaptation, an approach which focuses on strengthening the community by integrating them into the adaptation process, and (2) ecosystem-based adaptation, where nature-based solutions for adaptation are integrated to reduce vulnerability of the ecosystem and the local community to climate risks (Colls et al. 2009; Adaptation Committee 2019; GIZ 2020b).

In order to implement and evaluate the above-mentioned and other approaches (find more in Sterrett 2011; UNDP 2018), the network of UNESCO biosphere reserves can serve as examples and model regions for sustainable development. Biosphere reserves in Central and South Asia can facilitate changes towards sustainability and adaptation, serve nature conservation efforts, as well as support local communities in their desire for socio-economic development (see Box 6.3). In nearly all research and development projects education strategies about climate change adaptation and the implementation of natural conservation are integrated. These innovative and tested ideas are of utmost importance when facing climate change.

Box 6.3 Examples of Biosphere Reserves from Central Asia

There are three biosphere reserves whose location and ecological interconnectedness makes them representative for the major ecosystem types along the inner Asian watershed of Amu Darya and Syr Darya.

The Tian Shan mountains are represented by the *Biosphere Reserve Issyk-Kul* (Kyrgyzstan), established in 2001. Here, glacier meltdown and a changed water regime of the high mountain glaciers have been observed for decades (Narama et al. 2010; Hagg et al. 2013; Kriegel et al. 2013; Unger-Shayesteh et al. 2013). The surplus meltdown, but also the hydropower stations and dams that have been built affect water availability in the lowlands and have caused a shift in the annual water cycle pattern, with considerable implications for livelihoods (Lioubimtseva 2015).

This can exemplarily be shown in the *Lower Amu Darya State Biosphere Reserve* (Uzbekistan), established in 2011. The biosphere reserve is located in the lowlands adjacent to the estuary system of wetlands of the southern Aral Sea region. Agriculture in the region is mainly crop and cotton oriented and depends on timely and sufficient water supply (Conrad et al. 2010; Dubovyk et al. 2013). A change in agricultural practices is necessary to adapt to the changing water regime and to ensure food security and energy supply in this densely populated region of Central Asia. Correspondingly, the ecosystem is severely hit by sinking water table, and insufficient or absent flooding events (Kuz'mina and Treshkin 2012). The results are lacking natural rejuvenation and descending riparian forests including the complete species composition. Alternatives are sufficiently investigated and available for upscaling in the transition zone of the biosphere reserve and beyond (Khamzina et al. 2006, 2012; Lamers and Khamzina 2008; Gupta et al. 2009).

Another pearl of this necklace of biosphere reserves along the hydrologic lifelines of Central Asia is the *Barsakelmes Biosphere Reserve* (Kazakhstan), established in 2016. Barsakelmes is a true witness of man-made ecosystem change within less than half a century. An island in the formerly 4th biggest lake worldwide, the Aral Sea, is nowadays a tiny hilly ridge with steep cliffs within the most recent desert in the world—the Aralkum. It is among the worst ecological disasters of mankind. The biosphere reserve status may leverage the necessary national and international attention and resources to implement the changes needed for the adaptation to climate change.

To tackle the various targets of the SDGs, inter- and transdisciplinary efforts are vital. All kinds of approaches, which are designed, developed, and implemented according to the needs of the specific region and local communities can support local structures and increase resilience against climate change impacts in a sustainable way. Nevertheless, the fight against climate change remains a global task and support from other regions of the world, whether through research and development, support for the network of biosphere reserves and the establishment of global learning networks, efficient use of resources and emission reductions, or through financial contributions, is absolutely necessary to limit the most harmful consequences.

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Chapter 7
Gender Mainstreaming and the Nexus

Nimita Pandey and Neha Midha

Abstract Central and South Asia together form 26 per cent of the global population and are rich in biodiversity. Many of the ecosystems, however, are vulnerable to climate change which has the potential to disrupt the availability of and access to water, energy, and food. In these regions, women constitute about half of the population and are stakeholders both as consumers and producers, besides being active agents of change. Needless to say the issues of gender and the associated nexus are critical for addressing challenges emanating from climate change and biodiversity losses. Hence, it is essential to examine and ensure participation of more women in policy planning and implementation around the nexus of water, energy, and food security, including in agriculture. This chapter provides an overview of the challenges and issues existing in the food, water, and energy nexus, through a gender lens. Taking note of the existing status of women in Central and South Asia across the three sectors, the chapter highlights various promising practices of different stakeholders to enhance capacities and financial resources, provide adequate infrastructure, and a work environment conducive to encourage gender-balanced processes and strategies. Highlighting the issues and challenges, the chapter concludes that gender mainstreaming needs to be an intrinsic aspect of policies and processes, across the three sectors. Challenges related to assessing and institutionalizing gender inclusion need utmost attention and require transformative and unique solutions. With the right balance of training, education, enabling environment and policy planning, as well as implementation, the nexus will become more gender inclusive and sustainable.

Keywords Gender mainstreaming · Science policy · Sustainability · South Asia · Food security · Energy · Water

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7.1 Introduction

With the growing demands for food, water, and energy amidst escalating impacts of climate change, developing countries are facing serious challenges to effectively adapt towards the efficient use of limited resources. In this regard, the policies and interventions put in place are generally sectoral in nature with limited interconnections and interdependence among the three sectors—water, energy and food. In the recent past to facilitate greater climate change adaptation, the concept of a water–energy–food nexus (Rasul and Sharma 2016) has gained momentum. It is realized that a nexus approach is a potent tool to enhance resource optimization and encourage greater policy coherence for food, water, and energy security (Coghlan et al. 2022). Access to land, water, energy resources, technology, training avenues, and financial services ensures livelihood security and acts as a safeguard against economic shock (FAO 2017).

Central and South Asia together form 26 per cent of the global population and are rich in biodiversity. Many of the ecosystems, however, are vulnerable to climate change which has the potential to disrupt the availability of and access to water, energy, and food. In these regions, women constitute about half of the population and are stakeholders both as consumers and producers, besides being active agents of change. Needless to say the issues of gender and the nexus are critical for addressing challenges emanating from climate change and biodiversity loss. Hence, it is essential to examine and ensure participation of more women in policy planning and implementation around the nexus of water, energy, and food security, including in agriculture. Their limited adaptive capacities and restricted access to resources arise from prevailing socio-economic inequalities, patriarchal culture and gender stereotypes, which are manifested through differences in property rights, lack of employment and unequal access to information and resources. The constrained roles and undervalued positioning of women in resource governance and production, are hindrances to achieving gender equality in society.

This chapter provides an overview of the challenges and issues existing in the food, water, and energy nexus, through a gender lens. Taking note of the existing status of women in the three sectors, the chapter highlights various promising practices of different stakeholders to enhance capacities and financial resources, provide adequate infrastructure, and a work environment conducive to encourage gender-balanced processes and strategies.

7.2 Background

7.2.1 On Water

Globally, women and girls spend an estimated 200 million hours a day collecting water (WHO and UNICEF 2017). In Asia, on a daily basis, women and children walk an average of 6 km to access water. The economic cost of women's unpaid work as water collectors is enormous with the figure for India alone equivalent to a national loss of income of about $160 million (ADB 2014).

7.2.2 On Energy

It has been realized that energy consumption patterns and impacts of 'energy poverty' differ between men and women and both benefit differently from recent increased access. Women spend more time in unpaid energy intensive labor, which include cooking and laundry, whereas men consumed more energy in outside activities like transportation and dining. In developing countries, women spent nearly 1.4 h a day collecting fuel wood and water, and nearly four hours are spent cooking. Indoor air pollution from using combustible fuels for household energy caused 4.3 million deaths in 2012, with women and girls accounting for six out of every ten deaths. In rural households in Central and Southern Asia, the proportion of households with reliance on solid fuels is as high as 89 per cent (UN Women 2018). Innovative approaches, for example in Nepal, having access to solar-powered irrigation for women has increased cropped areas by close to 30% and significantly reduced dependency on costly diesel pumps (Fauconnier et al. 2018).

7.2.3 On Food

In South Asia, 69% of the women are engaged in agriculture. The proportion ranges from 28 per cent in Sri Lanka to a far higher 74 per cent in Nepal, with more than 50 per cent in India, Bangladesh, Pakistan, and Bhutan. Despite the crucial role played by women across all regions they still face constraints that limit the equality in terms of access to resource and its governance and thus undermine their productive potential and capacity.

Asia reports the highest gender-gap in terms of land holding by women. Female land ownership is 16.3 per cent in Sri Lanka, 4.6 per cent in Bangladesh, 12.4 per cent in Kyrgyzstan, 8.1 per cent in Nepal and 11.7 per cent in India (FAO 2015). Bhutan is the only country in South Asia where 70 per cent of farmland is owned by women. Women participate in agriculture as unpaid or low paid seasonal laborers, without much recognition as agents of production and are therefore likely to be left out of social protection systems (Rapsomanikis 2015; OCED 2021).

In Central and South Asia, there exists a gender gap due to food security; the gender gap in prevalence of food security is measured as the difference in percent of males who are food insecure to the percent of females; it is highest in Pakistan at 11.5 per cent and lowest in Bhutan at 0.2 per cent (UN Women 2018). The data in UN Women Report (2018) also highlights gender disparity in access to finance. In countries like Bangladesh, Pakistan, and Turkey, the gender gap in owning a bank account is nearly 30 per cent, though smaller gaps are found in economies like Sri Lanka and India (The Global Findex Database 2017). A gap is also prevalent in leadership position at all levels of national, municipal, and local governance. A study of female water professionals revealed that in South Asia technical posts occupied by women is only 5 per cent, and that almost all women interviewed felt that their skills were highly underutilized (Grant et al. 2017). In Kazakhstan, only 20 per cent of the paid positions in local water governance institutions (e.g., water users' associations) are held by women (UNESCO WWAP 2021).

7.3 Challenges

On average, only 35 per cent of countries had gender focal points in their ministries linked to natural resource management. Among those, the ministries of agriculture recorded the highest and ministry of water resources is recorded the lowest score (Fauconnier et al. 2018). These gender inequalities in accessing and controlling assets not only undermine women's economic potential and capacities, but also impose high costs on the economy. If women have the same access to productive resources as men, they could increase yields on their farms by 20 to 30 per cent. These gains in agricultural production alone could lift some 100–150 million people out of hunger (FAO 2017; World Bank 2017). Further, a study carried out by the International Water and Sanitation Centre across 15 countries found that projects that ensured the full participation of women at all stages were more sustainable and effective (van Wijk-Sijbesma 1998; OCED 2021).

Evidence from 121 rural water supply projects studied by the World Bank shows that the projects are six to seven times more effective than others when women are involved (World Bank 1995; OCED 2021). A UNDP research on 44 water projects across Asia and Africa shows that communities use water services more sustainably when both men and women are engaged in policy-design. When faced with scarcity in these communities, women are key in ensuring equity and justice in resource management, as well as peace and stability (Trivedi 2018; OCED 2021). Thus, opportunities for women's participation in all levels of natural resource governance should be advanced.

7.4 Gender Mainstreaming: A Concerted Approach

In order to tackle issues, gender mainstreaming is considered a plausible way for developing nations to ensure gender equity, particularly in natural resource management (Tantoh et al. 2021). Gender mainstreaming can be instrumental in helping countries address other national and global challenges (poverty, inequalities, social justice, climate change, etc.), and should thus be integrated into holistic and cross-cutting national policies which contribute to the achievement of the many related SDGs (GWP and UNEP-DHI 2021). In this chapter, some of best practices, mechanisms, and tools have been highlighted, which are existing in Central and South Asian countries, to mainstream gender in the nexus—water, energy, and food. Drawing inspiration from the report by GWP and UNEP-DHI (2021), some of the gender mainstreaming mechanisms and practices can be grouped into 4 categories:

1. **Enabling Environment—Political Will and Legislative Framework**. A clear commitment by government can drive the process of mainstreaming gender equality and inclusion in national management plans and national development policies. More often than not, these efforts are inspired by the targets of Agenda 2030, international commitments, and/or by requirements related to funding opportunities provided by international financial institutions.
2. **Women's Participation in Governance**. Women should seriously participate in the whole value chain of resource governance including policy formulation and not just as end-users. This requires a balanced number of women to be at leadership positions within central government and private organizations. At local government levels, women participation and leadership can support transformation of social norms and can lead to greater investment in public services by the local government.
3. **Effective Monitoring and Planning**. Monitoring and evidence-based planning are the key pillars of any gender mainstreaming strategy. To meet the development priorities of a country, policy planning and monitoring are to be based on evidence-informed inputs, derived out of sex-disaggregated data. Furthermore, gender monitoring in each sector shall be integrated in national monitoring frameworks, rather than executed as separate processes.
4. **Awareness Raising, Capacity Building, and Education Activities**. There is a need to challenge gender stereotypes, which have caused limitations to women's roles in planning, management, and decision-making. These clichés are often significant barriers to gender mainstreaming. It requires a change of mentality through awareness, capacity development, and education.

The proceeding section attempts to identify and examine the aforementioned dimensions across the three sectors—water, energy, and food. The discussion draws upon extensive review of literature and secondary data, available in public domain.

7.5 Promising Practices and Interventions

7.5.1 Enabling Environment—Political Will and Legislative Framework

In context to the policy landscape in the water sector, while efforts are being made in some countries to encompass gender inclusion as an integral part, there is still a long way to go. In **India**, The National Water Policies of 1987, 2002, and 2012 are not reflective of any gender-related element; they neither provide any concrete guidelines or recommendations to make gender-inclusive policies and practices. However, the National Policy for Women 2016 recognizes that the lack of the availability of water puts additional burden on women; it recommends that the design of programs and projects must be implemented while keeping women in mind as significant water users. It also suggests the need for involvement and training of women in initiatives on conservation and utilization of water (GWP and UNEP-DHI 2021). In **Nepal**, the national irrigation and drinking water policies are relatively progressive in terms of gender and social inclusion. As a result of concerted efforts, gender mainstreaming has improved the gender and social inclusion (GESI) units in most ministries and line departments. The National Water Policy (1999) and the Coastal Zone Policy (2005) of **Bangladesh** include gender considerations, and the National Women Development Policy (2011) provides an overarching framework for gender mainstreaming (GWP and UNEP-DHI 2021).

The energy sector has some unique interventions in the region. In **Sri Lanka**, some of the development processes are driven by '*Mahinda Chintana*'—a collaborative effort by the National Development Programme (NDP), the Regional Development Programme of the Ministry of Economic Development and the Ministry of Women's Affairs. *Mahinda Chintana* identifies women as pioneers of development, prioritizes empowering women and reducing inequalities between men and women. The key elements are promoting quality and productive employment as well as gainful economic activities for women, the equitable representation of women in decision making, and recognizing women as heads of households, with equal rights of access to useful resources, finance and infrastructure. The phenomenon has considerable impacts on enhancing women's position in energy access and governance.

Likewise, **India's** Integrated Energy Policy (IEP) Report prepared by the Planning Commission, provides the broad framework for guiding national energy policies (Norad 2011). The report paves the way for more gender-aware energy policies. The IEP report makes a number of recommendations that are of relevance. The chapter on energy recognizes that women, being the main energy users and primary energy suppliers, are most affected by restricted liquified petroleum gas (LPG) supply, and that this poses one of the most difficult barriers to the empowerment of women. **The chapter on energy recognizes that women, being the main energy users and primary energy suppliers, are most affected by restricted liquified petroleum gas (LPG) supply, and that this poses one of the most difficult barriers to the empowerment of women.** To address this aspect, India's flagship program, the

Pradhan Mantri Ujjwala Yojana (PMUY) aims to improve access to clean cooking energy in the country by providing free LPG connections to poor households. Women have been the biggest beneficiaries of the smokeless kitchen initiative (Norad 2011).

Nepal has also developed sector-specific policies: (1) The Rural Energy Policy of Nepal (2006) recognizes the role of women in the collection and management of traditional fuel. It outlines the implications of traditional fuel on their health as well as on children's education. The policy promotes women's participation in community management of renewable energy systems, and links energy with other sectors, to be supportive of women. (2) The Nepalese Renewable Energy Subsidy Policy is another example of a detailed and focused document targeting the disadvantaged sections of society, including women. In 2013, the Renewable Energy Subsidy Policy recognized and addressed income-related barriers and aimed to enable low-income and remote, rural households to use renewable energy technologies and attract private sector entrepreneurs.

The food and agriculture sector have been witnessing some national level interventions in this context. In **India**, the Ninth Five-Year Plan (1997–2002) called for the removal of gender discrimination in property ownership, advocated for women's land ownership, and suggested changes to bring in gender inclusiveness in land-related laws. India's National Policy on Farmer Producer Organizations and the *Mahila Kisan Sashakthi Karan Pariyojana* are examples of policies that provide scope for developing gendered agricultural value chains in the country. Promotion of state—supported land leasing by women's collectives, has empowered landless women agricultural laborers to participate in the agricultural value chain (Manjula 2021).

In **Bangladesh**, joint ownership of land by husband and wife is promoted by the Khas Land Management and Distribution Policy (Manjula 2021). On similar lines, the government of **Nepal** have been issuing Joint Land Ownership Certificates, to enable translation of men's exclusive land rights to joint ownership with their wives (Manjula 2021). Nepal has approved the Agriculture Development Strategy (ADS) (2015–2035), with emphasis on the integration of Gender Equity and Social Inclusion throughout the ADS process. It recognizes women farmers as independent farmers and ensures adequate budget provision, women's access to and control over agricultural resources and produce as well as women's leadership, among others.

In **Sri Lanka**, a chapter on women's rights has been included in the National Human Rights Action Plan (2017–2021) which led to the formulation of the National Action Plan on Women-Headed Households. It addresses the livelihood and food security needs of this vulnerable population group (FAO 2017).

The design and implementation of a national gender policy is generally coordinated by the line ministry responsible for gender equality. There are very few countries in the world where a single dedicated ministry for gender equality exists. An example is **Kyrgyzstan**, with a gender unit, which is the main national gender machinery that operates under the Ministry of Labour and Social Development. The ministry has established a gender policy department, the primary tasks of which are to make proposals defining priorities, formulating national gender policies, and to conduct analysis of gender issues and to monitor policy implementation across sectors. Another example is **Nepal**, as already discussed.

7.5.2 Women's Participation in Governance

With regard to women's participation in water-related governance processes, some countries are actively involving them in decision making bodies in the three sectors. For instance, in context to water, **Nepal** has established a legal quota for women's participation in official community water management groups, like Water User Associations. The 33% quota is of particular interest as it is the country's most central policy measure on gender equality, cutting across the irrigation, water, sanitation, and hygiene (WASH) sectors. In relation to the transboundary cooperation on the use of water resources is the sharing of the Chu and Talas River basins in **Kazakhstan** and **Kyrgyzstan**, it was observed that the country offices of the secretariat are headed by women, and the Working Groups under the Secretariat of the Commission are also dominated by women (OSCE 2020).

Women at leadership positions have made considerable impacts in mitigating issues of climate change. In **India**, one-third of seats on the gram panchayats (village councils) are reserved for women. This has led to more investments in drinking water infrastructure and better availability of public goods (Klugman et al. 2014). Nevertheless, urban municipalities are yet to realize equitable representation of women.

The Agriculture Development Strategy (2015–2035) of **Nepal**, targets that farmland ownership by women, individually or through joint ownership, shall reach to 50 per cent by 2035, from 10 per cent in 2010. It recommends equal wages for women in agriculture, encourages equitable representation of male and female farmers in agriculture development programs, as formulated in the Gender Equity and Social inclusion (GESI) section[1] within the Division of Food Security, Agribusiness Promotion and Environment (FAO 2019).

In **India**, the government clearly specifies that all beneficiary-oriented schemes under the Ministry of Agriculture should ensure inclusion of a minimum of 30 per cent women farmers and spend at least 30% of funds on the same group (Manjula 2021).

In **Sri Lanka**, the new constitution of 2015 guarantees women's representation in an unprecedented manner via various government structures and at the leadership level. The new Local Authorities Election Amendment Act, 2017 has made it mandatory to have a woman as the chair or vice-chair of the village councils, municipalities, and district coordination committees (Krishnamohan 2018). The Act states that half

[1] In Nepal, as the Gender Equity and Social Inclusion (GESI) section within the Division of Food Security, Agribusiness Promotion and Environment under the Ministry of Agriculture and Livestock Development acts as a focal point for the gender disaggregated database management and gender responsive budget allocation and utilization.

of each four-member ward committee members should be women. At the national level, The Ministry of Women and Child Affairs and Social Security is the nodal agency responsible for promoting gender equality and women's empowerment. The 2018 budget highlights '*Enterprise Sri Lanka*', a government program designed to support entrepreneurs by providing credit and interest subsidies. The credit plan, which has been allocated nearly USD 5 million, will specifically support small- and medium-scale enterprises owned by women. The budget document suggests the assistance will be mainly directed to rural women and youth. The approach is female-targeted rather than gender equitable (FAO 2018b).

7.5.3 Effective Monitoring and Planning

In the context of water, the Groundwater Resources Governance in the Transboundary Aquifers project in Central Asia collected and assessed sex-disaggregated data and developed an inventory of policy instruments that affect gender equality in science. The gender analysis tool is currently used to improve the socio-economic and legal assessment of groundwater use (UNESCO WWAP 2021).

In **India**, the 'Uttarakhand Decentralized Watershed Management' Project identified gender-sensitive indicators for monitoring and evaluation of the project. A midterm review of these indicators identified a need for amendments, leading to the expansion of support for women and other vulnerable groups beyond self-help groups to include entrepreneurial activities. The results showed significant benefits for and empowerment of women. Fifty per cent of the beneficiaries of livelihood development activities were women. Also, women's overall annual workdays for firewood collection decreased from 120 to 35 days. Moreover, 50 per cent of the Gram Panchayat representatives were women (while the national average was 33 per cent). In the Panchayat elections, 304 village level project staff and project-formed self-help groups (and farmer interest group members) were elected for various positions in Panchayat Rai Institutions and 73 per cent of those elected were women (World Bank 2016).

The **Kyrgyz** Republic Rural Water Supply and Sanitation Project demonstrates effective use of gender-sensitive indicators and monitoring for assessing development outcomes, while promoting the involvement and empowerment of women in water governance. A qualitative socioeconomic assessment carried out in each village documented the role of women and children in household water collection and management. The decrease in women's workload was identified as a key intermediate outcome. According to an impact evaluation study, 66 per cent of women claimed their workload was now "much easier and less" and 31 per cent claimed that it has improved. Further, the evaluation data showed that more than 60 per cent of water union leaders were female, and two or three women were on each water union board (World Bank 2016).

In **Nepal**, as the Gender Equity and Social Inclusion (GESI) section within the Division of Food Security, Agribusiness Promotion and Environment under the

Ministry of Agriculture and Livestock Development acts as a focal point for the gender disaggregated database management and gender responsive budget allocation and utilization. In 2014, the Ministry established a five-member Gender Responsive Budget Committee chaired by the Joint Secretary of Planning for the promotion of gender equality, to implement policies, plans and programs under GESI (FAO 2019; Adhikary 2019).

Some countries have a common model, encompassing all sectors, to monitor gender inclusion. For example, the National Statistical Committee of the Kyrgyz Republic supervises the collection of gender-sensitive data and compiles statistics in relation to the implementation of the law (FAO 2017). The FAO's AQUASTAT database includes specific gender-related indicators that support the collection of reliable and comparable data on gender and agricultural water management, giving more visibility to women's roles and potential in sustainable water governance, which are often underestimated. This information is also used for advocating for equitable water governance in existing policies and projects and for addressing the specific constraints of female farmers in gaining access to and control over water resources (UNESCO WWAP 2021).

7.5.4 Awareness Raising, Capacity Building, and Education Activities

The 'Tajikistan Drinking Water Supply and Sanitation Sector Improving Social Accountability' (TWISA) program established Community Advisory Boards to hold local water service providers accountable and to set up complaint and feedback mechanisms. Women were encouraged to participate, and they received targeted trainings on their rights as consumers. While it was challenging to maintain equal levels of female and male participation, it was beneficial to have women leaders involved (Oxfam 2020).

In Nepal, under the Trans-boundary Rivers of South Asia (TROSA) program, Oxfam has promoted similar opportunities for women's leadership in water governance to increase social accountability. Oxfam established Women Empowerment Centres (WECs), which host regular community meetings run by trained social mobilizers. The Centres aim to sensitize women on their rights around riverine water resources, and to involve them in transboundary water resources planning and decision making (Oxfam 2020).

The World Bank Group's Central Asia Knowledge Network, under the Central Asia Water and Energy Program (CAWEP), aims to promote gender equality in water resource management in Central Asia and Afghanistan by raising awareness and promoting knowledge exchange on gender issues among academic and expert communities in the region. The Central Asia Knowledge Network has partnered with the Kazakh-German-University to implement a project supporting young academics at universities and research institutes in Central Asia and Afghanistan who are conducting research in the fields of water and energy conservation and/or climate change, particularly those with a strong focus on the gender aspects of water resource management.

In Bangladesh, The Blue Gold Programme found that leadership of women (and men) developed within water management groups (WMGs), empowering them to stand as candidates for local government (Union Parishad) elections. In 2016, 20 women from Blue Gold-supported WMGs were elected (GRF 2017).

While looking at the energy sector, some initiatives have made attempts to enhance capacities of women at the grassroots level. One such interventions is of Barefoot College in India, that provides training to middle-aged women from villages worldwide to become solar engineers. The trainers are illiterate or semi-literate grandmothers who maintain strong roots in their villages and play a major role in bringing sustainable electricity to remote, inaccessible villages. In the last decade, over 2,500 women solar engineers have reached over 1 million people in 1,300 villages worldwide in Latin America, Africa, the Middle East, Asia, and the South Pacific islands (Ministry of Agriculture and Farmers Welfare 2021). Similarly, the Sakhi Unique Rural Enterprise (SURE) by Swayam Shikshan Prayog (SSP), a non-profit organization in India, engages rural women in the supply chain to bring clean energy products—such as improved cookstoves, water purifiers, and solar products. The rural women entrepreneurs are called Sakhis, meaning “friend” in Hindi. Across various sectors, the work of SSP has reached 145,000 women across 6 states, and set up 97,000 micro-enterprises that are catering to clean energy and basic health services (Bhandari 2019).

In **Nepal**, The Women Network for Energy and Environment (WoNEE) is a national-level network of grassroots women working on policy advocacy, capacity building and awareness raising for economic empowerment in the energy sector (Namati 2020).

The KAZENERGY Women Energy Club in **Kazakhstan** is a dialogue platform for female workers of the oil, gas, and energy sector to share experiences and facilitate the development of talents and skills necessary for professional and personal growth. It includes representations from different institutions including National Commission for Women, the Council of Business Women of Atameken (NCERK), state authorities, major international organizations, as well as representatives of oil, gas, and energy companies of national and international reputes.

Certain organizations have a regional focus in capacity building and developing collectives. International networks such as the Clean Energy, Education and Empowerment Initiative (C3E), Women of Renewable Industries and Sustainable Energy (WRISE), Women in Solar Energy (WISE), Entrepreneurial Women in Renewable Energy (EWiRE) and the Global Women’s Network for the Energy Transition (GWNET) are also spreading ideas, mobilizing support and providing encouragement, to build a cadre of women leaders in the energy sector, particularly in Asian regions.

Even in sectors related to food and agriculture, efforts are being made to enhance the capacities of women farmers and spread awareness about their legit rights. In Kyrgyzstan and Tajikistan, drawing on Article 16 of the “UN Convention on the

Elimination of All Forms of Discrimination Against Women", awareness and sensitization of local officials was undertaken and linked with protecting women's rights as well as improving the effectiveness of related interventions. Through this initiative, women were provided with legal advice and logistical support for land claims. The media has been actively involved, widely broadcasting the message "Land in the Right Hands!" to support women's equal rights. As an outcome, the proportion of women owning family farms in Tajikistan rose from 2 to 14% between 2002 and 2008 (FAO 2017).

Since 2014, a joint United Nations initiative for accelerating progress towards the economic empowerment of rural women was undertaken in seven countries including **Kyrgyzstan** and **Nepal**. Based on an integrated approach, it targets the same group of female farmers to build capacity and provide technical support, in order to promote gender-responsive rural institutions and policies. By the end of 2017, the program reached over 50 000 beneficiaries. As a result, the participating groups were able to increase their agricultural productivity and the nutritional level of their families. Furthermore, they had access to credit and started their own businesses, thereby improving their incomes (FAO 2017).

In **India**, to improve agricultural productivity and water-use efficiency, the FAO collaborated with the Uttar Pradesh Department of Agriculture to establish a project called "Farmer Water School (FWS)". It organized training to enhance the capacity of farmers and improve farming practices related to water management, soil nutrients and pests, and make informed decisions at crucial stages of the crop production cycle. As per FAO (2018a), a total of 6720 women were trained to take on leadership roles in the future FWS, which are to be exclusive for women.

A regional conference Promoting Socially Inclusive Rural Development in Europe and Central Asia (2017) helped share experiences, build networks, and strengthen political commitment for reducing gender gaps in agriculture. The conference brought together high-level officials from more than 20 countries and resulted in a Joint Call for Action, a unique framework for addressing rural gender issues in Europe and Central Asia (FAO 2018a).

7.6 Conclusion

In the present paper, discussions revolve around gender-related issues and challenges in water, energy, and food related sectors. Efforts have been made to present some of the best practices, mechanisms, and tools that exist in different countries in order to advance gender mainstreaming initiatives in the given sectors. While there are initiatives at different levels across geographies, the major challenge is to scale them up, and have them adopted and implemented elsewhere. Although there are methodological and practical issues and challenges, a beginning has been made, at micro level, particularly in cases where rural–urban and metropolitan cities/states/provinces have climate/water/energy/agriculture policies.

Some of the issues highlighted in this chapter, align with the larger discourse on women in science. Suggestions drawn from some of the relevant research and publications will also help in gender mainstreaming in the three sectors. One such document is UNESCO's latest publication, entitled 'A Braided River: The Universe of Indian Women in Science' (2022)—an insightful document providing practical recommendations, to encourage, promote and retain women in science in the Indian context. Some suggestions which hold significance for this chapter include:

- Institutionalize counselling and training initiatives that target young, vulnerable, poor, and underprivileged women.
- Promote mentorships and strengthen professional networks to advance the status of women to leadership positions.
- Encourage relevant stakeholders to incorporate gender-inclusive benefits and work time arrangements in their employment policies.
- Support more studies and the collection of sex-disaggregated data for evidence-based decision-making.
- Vigorously implement state and national policies supporting women in their choice of education and careers.

It is needless to say that SDG 5 as a touchstone, is crucial for the sustainable transition and transformation to achieve other SDGs, particularly those linked with energy, water, and food security. It is essential to have a better understanding of linkages between SDG 5 and the Water-Energy-Food Nexus, in the context of Central and South Asia. In order to ensure effective gender mainstreaming, an integrated and collaborative approach is required to reap the benefits of on-going interventions as well as to develop new frameworks. Capacity building, coupled with access to funding, infrastructure, and other vital resources can effectively enhance the positioning of women and provide them with equitable opportunities, in order to contribute to climate change mitigation and adaptation.

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Part III
Cross-Cutting Themes for Nexus Security

Chapter 8
Gendered Food and Water Insecurity in South Asia

Vrushti Mawani

Abstract Women in South Asia, like women across the world, face disproportionate water and food insecurity. Aspects such as access to education, income, gender roles, and land ownership are cross-cutting themes influencing women's water and food insecurity. However, country- and region-specific issues, premised in diverse political, economic, cultural, and environmental conditions, also shape differential water and food insecurity for particular groups of women. Understanding the complex and multidimensional aspects of differential gendered water and food insecurity is a core concern for scholars and policymakers. In this chapter, I review the common aspects as well as country- and region-specific issues impacting women's water and food insecurity in South Asia. A nuanced understanding of how diverse groups of women are impacted by food and water insecurity is important for developing nuanced and targeted interventions towards achieving SDGs 2 and 6.

Keywords Gender · South Asia · Education · Income · Systemic Injustice · Food Insecurity

8.1 Introduction

Women and girls in South Asia are disproportionately impacted by food and water insecurity in multiple direct and indirect ways. Food insecurity is higher among women than men, and the gender gap in accessing food has increased from 2018 to 2019 in the *moderate or severe* and *severe* categories, not just in Asia but also globally (FAO, IFAD, UNICEF, WFP and WHO 2020, see Fig. 8.1). The link between food insecurity and income insecurity and/or poverty is a major reason that women and girls experience unequal food insecurity (Asian Development Bank 2013). Women's

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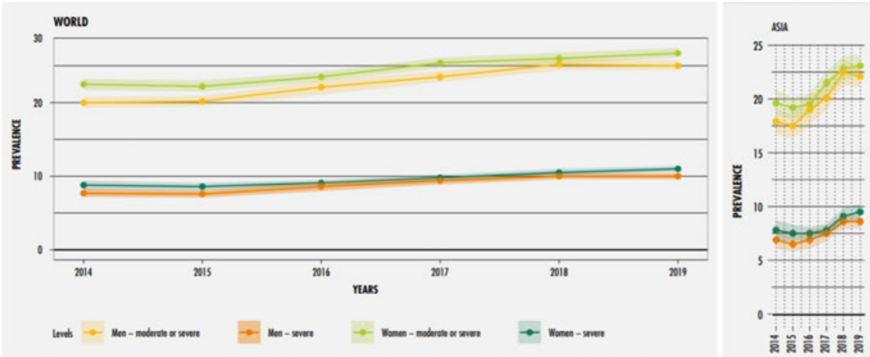

Fig. 8.1 Prevalence of food insecurity in women versus men, 2014–2019. *Source* FAO, IFAD, UNICEF, WFP and WHO (2020)

income insecurity in turn is premised in patriarchal land ownership and inheritance patterns, gender roles that have historically kept women tied to unpaid care-work, and unequal access to education, technology, and jobs (Jung et al. 2016; Asian Development Bank 2013). Additionally, and as a consequence of these myriad inequities, climate change also has gendered impacts (Lambrou and Nelson 2010).

The impacts of water insecurity experienced by women are similarly complex and multidimensional. Women often compromise their own water security, restricting their personal drinking and washing needs, to provide more for their family members (Truelove 2019). Confronting realities such as fetching polluted water—sometimes the only water available—for the family, despite knowing the risks this entails, are additional burdens that women disproportionately shoulder (Sultana 2011). Furthermore, the consumption of contaminated water increases the incidence of water-borne diseases, in turn increasing women's care-giving responsibilities, further confining them within their homes, and limiting their ability to pursue income-generating opportunities (Corcoran-Nantes and Roy 2018; Kher et al. 2015). The responsibility of fetching water from far distances in Central and South Asia falls disproportionately on women and girls, which in addition to being a physical burden in itself, also increases their risk to sexual violence while traveling back and forth (UNICEF 2018). Figure 8.2 illustrates the scale of this burden for the women and girls of Nepal, Afghanistan, India, and Bhutan (adapted from WHO 2017). In Nepal and India for instance, in 53% and 40% cases respectively, the primary responsibility of fetching water from off premises falls on women over the age of 15. This is in sharp contrast to 2 and 6% men over the age of 15 in the same countries.

On account of these multidimensional aspects constituting gendered food and water insecurity, scholars have urged the need to disentangle insecurities experienced by women individually from household-level insecurities (Broussard 2019; Truelove 2019). The Food Insecurity Experience Scale (FIES) used by the FAO since 2014 to record people's experiences of constrained access to food offers the possibility of recording individual issues impacting women's food insecurity. Studies separating

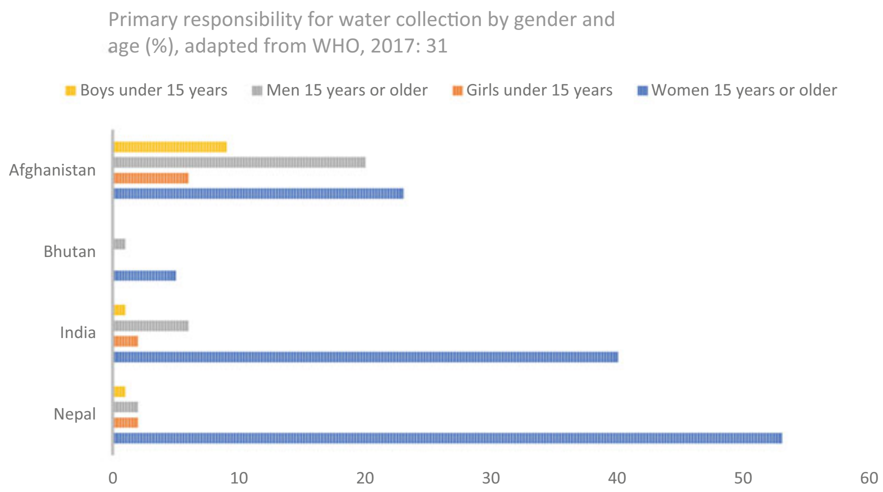

Fig. 8.2 Primary responsibility for water collection by gender and age, as a percent. Adapted from WHO (2017)

individual insecurities from those of the household have highlighted certain issues as cross-cutting themes impacting food and water insecurity for women in South Asia. These include patriarchal land ownership, access to education and employment, income inequality, differential access to social networks, geospatial factors, stereotypical gender roles, time spent making food and water available for the family, and additional care-giving burdens from caring for family members suffering malnutrition and water-borne diseases. Yet, country- and region-specific political, economic, cultural, and environmental conditions also differentially impact particular groups of women. For instance, more women face water and food insecurity in conflict-ridden areas of Pakistan, in rural, drought-prone areas of Nepal, Bangladesh, and Bhutan, particularly if they are Dalit,[1] indigenous, and/or poor.

Recognizing these common themes and differences is important for grasping vulnerabilities experienced by different groups of women. Such disaggregation is crucial for meaningfully grasping interventions towards achieving the Sustainable Development Goals relating to women's food and water security. SDG 6.1 aims to "*… achieve universal and equitable access to safe and affordable drinking water for all*", while SDG 2.1 is geared *to* "*end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round*" (UN 2015). Given the culturally, politically, economically, spatially, and environmentally specific issues impacting women, achieving the SDGs is impossible without careful attention to the specific dynamics of food and water insecurity pertaining to different groups of women. In

[1] The term "Dalit" refers to people assigned by the traditional Indian caste system as part of the lowest caste.

the absence of more grounded and nuanced understandings, interventions to achieve women's water and food security will remain inappropriately conceived and targeted.

In this chapter, I review existing literature on women's food and water insecurity in South Asia, highlighting common themes and specific aspects impacting particular groups. I draw on recent studies that shed light on the multidimensional nature of food and water insecurity. For instance, violence across scales—household as well as region—is a cause, as well as effect of women's food and water insecurity, and is entangled with the impacts of climate change. As well, where relevant, I include intra-national/regional differentiation to locate the multi-scalar role of geospatial unevenness—rural/urban, intra-urban, ecologically or politically vulnerable locations, etc. This review is by no means comprehensive. Rather, I simply wish to emphasize some key complexities that characterize the intractable nature of women's food and water insecurity, and the overarching perspectives from which these gendered insecurities have been explored. My intent is to show how enduring gendered inequalities and specific vulnerabilities become pathways through which recursive relationships between food and water insecurity are reproduced.

8.2 Food Insecurity Among Women in South Asia

In 2008, over two-fifths of the women in India and Bangladesh suffered maternal undernutrition[2] (Asian Development Bank 2013: 12; Ahmed et al. 2012). Varying studies suggest that 41.7 to 77.0% of women of reproductive age in Pakistan are affected by anemia (Ali et al. 2020), as are about half the women in Bhutan (Atwood et al. 2014), and almost a third of the women in Sri Lanka (SAPRI 2017). This disproportionate burden of anemia on women can be associated on the one hand with their physiological needs relating to menstruation, childbirth, and breastfeeding, and on the other hand with long-standing histories of gendered malnutrition. In turn, gendered malnutrition might directly stem from men consuming more calories than the women in patriarchal South Asian households (D'Souza and Tandon 2015). But aspects such as income levels, caste, geospatial location within the country, education level, pregnancy and lactation, and marriage also shape unequal access to food for women (Pandey and Fusaro 2020). For instance, a nationally representative survey of 12,862 women of reproductive age[3] in Nepal reported that over half the respondents—56% women—experienced food insecurity (Pandey and Fusaro 2020). Geographically, this survey found that food insecurity was most pronounced among women residing in districts of Nepal's Mid-Western development region, ranging between 83 to 100% across districts in this part. And while women with a 10th grade education emerged over twice as likely to be food secure than women without an education, 76% of the Dalit respondents,[4] irrespective of education and class,

[2] Where a mother's body mass index is less than 18.5 kg per square meter.

[3] Between 15 and 49 years of age.

[4] Dalit women comprised 12% of total survey respondents.

reported food insecurity (Pandey and Fusaro 2020). This association between **caste and gendered food insecurity** is echoed by studies in India, and indeed there might be significant differentiation in women's food insecurity even across lower caste groups (Rao et al. 2017).

Pregnancy and lactation further increase the impact of food insecurity on women, particularly among women who do not have an income. According to the UN World Food Programme, roughly 1.4 million pregnant and lactating women in Nepal were malnourished and 48% suffered from anemia (USAID 2019). These statistics are substantiated by studies such as by Harris-Fry et al. (2018) who show that pregnant women, unless their income matches their spouse's, receive the lowest share of food and nutrients within the household. The continuing prevalence of child marriages in Nepal is another predictor of food insecurity for girls (young pregnant women) and their children (Na et al. 2018). Arguably, while young mothers are inadequately informed about their own or their children's nutritional needs, early motherhood additionally constrains girls' access to education and employment, further compounding food insecurity. **Persistently high rates of teenage pregnancies** are a cause of concern across South Asia. In Afghanistan, a third of all pregnancies reportedly occur in adolescence (Akseer et al. 2018). In 2010, 11 to 15% 15- to 19-year-old girls in Bhutan had already given birth (Atwood et al. 2014), while in 2014 over 30% of 15- to 19-year-old Bangladeshi girls had borne children (Osmani et al. 2016).

These numbers and the implications they carry are particularly worrying given the **chronic domestic violence faced by women in South Asia, and what this implies for their food security**. For instance, over half the women in Bangladesh and Afghanistan reported having experienced physical and/or sexual violence at least once in their lives (Fig. 8.3). The relationship between food insecurity and violence is a complex one. Lentz (2018) insightfully delineates two pathways linking food insecurity and violence: on the one hand, household food insecurity is a trigger for violence against women, on the other, food insecurity (withholding of food) is a mechanism of inflicting physical violence on women. The accounts by Diamond-Smith et al. (2019) for Nepal and by Gibbs et al. (2018) for Afghanistan are instructive of the first pathway, while Ackerson and Subramanian's study (2008) on India[5] illustrates the second pathway. Of the 90,000+ Indian women that Ackerman and Subramanian interviewed, nearly half had anemia and almost a third were severely underweight. Of these respondents, 19% women reported domestic violence, and the authors found chronic malnutrition among the women who reported frequent abuse (Ackerson and Subramanian's 2008).

In addition to being tied to violence against women within households, **food insecurity is also a cause and consequence of regional conflicts**. For instance, food insecurity in Pakistan is highest in its most conflict-ridden areas—such as some parts of Khyber Pakhtunkhwa and Baluchistan (Malik 2010)—and impacts women in multiple ways. To begin with, regional violence in the conflict-ridden areas of Pakistan has been associated with an increase in domestic violence against women (World Food Programme 2010). Women's mobility in these parts is also especially

[5] Even though limited to physical abuse.

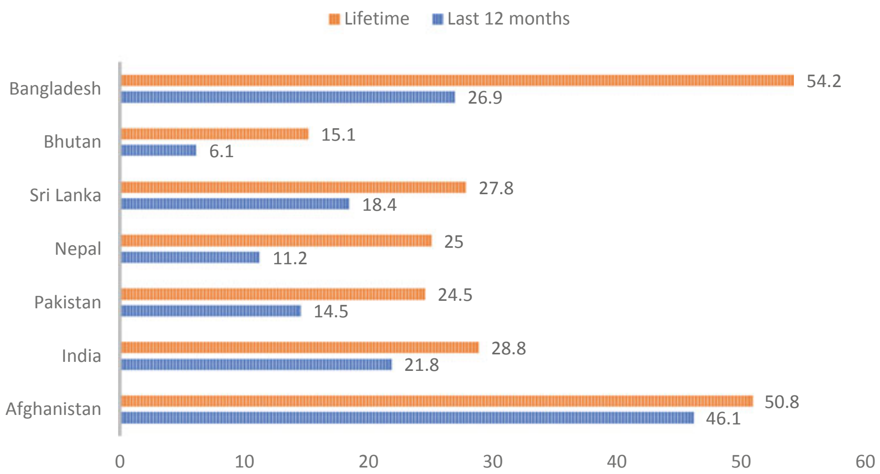

Fig. 8.3 Proportion of women disclosing experiences of violence. Adapted from UNFPA (2019)

restricted and decreases their access to healthcare, schools, and jobs. Violent crises also restrict income-generating activities (poultry farming for instance) that might have been the only source of income for women, in turn compromising their food security. Further, households headed by women in these parts of Pakistan reported disproportionate food insecurity (World Food Programme 2010). This evidence from Pakistan on female headed households (FHHs) being especially food insecure is echoed by findings from Nepal (Pandey and Fusaro 2020), Sri Lanka (Vhurumuku et al. 2012), Bangladesh (Munro et al. 2014), and Bhutan (Aryal et al. 2019). Aryal et al. (2019) suggest that further targeted understandings and interventions need to differentiate between de jure FHHs (i.e., households run by single, widowed, or divorced women) and de facto FHHs (i.e., households with husbands who are not physically present because of their off-farm work). Munro et al. (2014) show further through their work with Bangladeshi Garo women how indigeneity, income, and culture interact to produce disproportionate impacts on the food security of South Asian households headed by women.

Another cross-cutting theme impacting women's food security in South Asia is their **limited land ownership** and relatedly their **constrained role in agricultural decision-making**. Aziz et al. (2021) illustrate through the case of Azad Jammu-Kashmir in Pakistan how women's ownership of land and livestock and their decision-making in agriculture can improve their own as well as their family's food security. This insight is pertinent for other parts of South Asia too, where land ownership and inheritance are largely patriarchal, depriving women of control over assets, income, and decision-making. For instance, in 2002 only 16% of the land in Sri Lanka (FAO 2018) was owned by women, while in 2011, only 12% of agricultural land in India (Rao et al. 2017) was owned by women. Such limited ownership of land limits women's ability to access agricultural subsidies, loans, and other services and benefits, as well as make decisions regarding agriculture. In this regard, Bhutan fares better than its South Asian counterparts. A key differentiating factor here is Bhutan's long-standing Inheritance Act of 1980 which enables female children to have equal inheritance rights as male children (Aryal et al. 2019).[6] India on the other hand has had an equivalent of this law only since 2005 (Rao et al. 2017). However, these statistics are complicated by the fact that land titles in women's names might not always mean that women have power over agricultural decision-making in male headed households (Rao et al. 2017). In other words, the complex relationship between South Asian women owning land and their food security requires more exploration.

Yet another way that South Asian women's role in agriculture impacts their food security is in terms of impacts of the increasing **feminization of agriculture.** For instance, almost a fourth of the total women employed in Sri Lanka were part of the agricultural sector (FAO 2018). Growing engagement of women in agriculture, if in terms of paid employment, can provide women with much-needed incomes. However, it can also burden them with extra work in addition to their domestic care responsibilities, which in turn can impact their food security and nutrition in multiple, contradictory ways (Rao et al. 2019). As well, a number of women engaged in agriculture might be unpaid. For instance, 60% of Pakistan's rural women in 2014 were reportedly unpaid workers on family farms and other enterprises: only 19% of the country's rural women were in paid employment (Zaidi et al. 2018). In Afghanistan in the same year, 5.4 million women of working age—71% of the country's women—were inactive and not seeking employment, and another 1.1 million women in this age group seeking employment were either underemployed or unable to find a job (Zaher 2016). Furthermore, even among paid women workers, there is significant **wage inequality** between men and women. For instance, in Sri Lanka, the estimated earned income per capita per month for rural women stood at Rs 5,379 (~25 USD), as opposed to Rs 17,275 (~85 USD) per capita per month for rural men (FAO 2018).

These enduring inequalities and their impact on women's food security need to be reckoned with against the persistently **low literacy levels** of rural South Asian women. In 2014–2015, the literacy rate among Pakistan's rural women was at 38%, as compared to 63% for rural men, 69% for urban women, and 82% for urban men (Fig. 8.3). Indeed, differential literacy rates between women and men across rural and urban areas is a trend echoed across South Asia. Given that the national government data cited in Fig. 8.3 for India and Pakistan is not current, I have offered a comparison of more recent literacy rates for men and women (not differentiated across rural and urban areas) as estimated by the UNESCO Institute for Statistics (Fig. 8.4). Across all South Asian countries, literacy rates are higher among men, albeit the gender gap in literacy in Sri Lanka for instance is much smaller, while in Afghanistan and Pakistan is much higher (Fig. 8.5).

Together, these persevering inequities have meant that women in South Asia are disproportionately impacted by climate change, and these impacts show up in terms of heightened food insecurity. In drought-prone areas, reduced or untimely rainfall

[6] Yet, in practice, land ownership among women differs across the country. Among the matrilineal communities of Bhutan's central and western regions, women traditionally inherit land and property, while in parts of southern and eastern Bhutan, men usually inherit the property (Aryal et al. 2019).

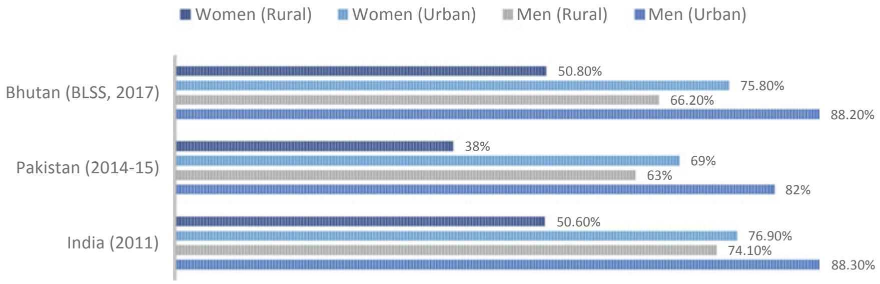

Fig. 8.4 Literacy rates in men and women across rural and urban areas. Compiled from Census of India (2011), BLSS (2017), and PSLM (2016)

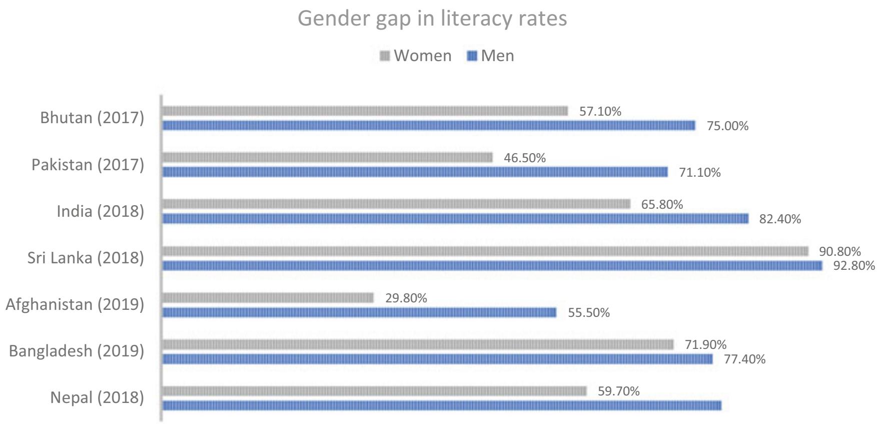

Fig. 8.5 Gender gap in literacy rates in South Asia. Compiled using data from UNESCO (2021)

manifests as water shortages, bore-wells and ponds drying up, and reduced fodder and livestock (Lambrou and Nelson 2010). The gendered impacts of these climate change manifestations on rural South Asian women include increased pressure to provide food for the family, consuming decreased quantities of food as well as eating poorer quality food in relation to men, increased domestic responsibilities, and more health issues (Lambrou and Nelson 2010; Alston and Akhter 2016). Alston and Akhter's (2016) study on gendered climate change perceptions also reports that a greater share of women perceive reduced water availability for agriculture, increased crop damage, increased disease and pests in crops, and increased difficulty in irrigation. Additionally, more women report taking up additional daily wage work than men to meet their families' needs in the face of climate change impacts (Lambrou and Nelson 2010; Bastakoti and Doneys 2020).

8.3 Water Insecurity Among Women in South Asia

Water insecurity among South Asian women has similarly been probed from myriad perspectives, including infrastructure politics and urbanization, geospatial unevenness, caste, religion, income, domestic care responsibilities, wage inequality, land/property ownership, and climate change (Molden et al. 2020). And like issues pertaining to food (in)security, the political, economic, cultural, and environmental conditions across regions mediate the impacts of each of these aspects. These impacts are then unequally experienced by particular groups of South Asian women. As some examples, Dalit women in rural India and Nepal are one such group (Dutta et al. 2018; Wali et al. 2020), so are women living in parts of rural Bangladesh with arsenic-laden groundwater (Sultana 2011), women living in low-income informal settlements in urban areas of India and Pakistan (Das and Safini 2018; Truelove 2019; Anwar et al. 2020; Subbaraman et al. 2014; Mawani 2022), and low-income pregnant women in Afghanistan (Gon et al. 2014).

Caste-based water insecurity can be grasped by contrasting the number of Dalit households in India that have access to water within their premises against the country's total number of households (Table 8.1) Less than a third of India's Dalit households report being able to access water on their premises as compared to the much higher numbers reported nationally (Dutta et al. 2018; Johns 2012). Differentiated water access based on caste has been tied on the one hand to notions of untouchability in the country's rural areas, and to long-standing conflicts and assertions of authority by upper and lower castes on the other (Dutta et al. 2018; Johns 2012). These persevering inequities in turn manifest as uneven access to education, jobs, income, and land/property for Dalit groups. Markedly poor access to water for Dalit households means unequal burdens on Dalit women, who have to fetch water from off-site sources much further away than other women to avoid conflict with upper caste people (Dutta et al. 2018). In addition to the extra time and labor involved in fetching water from further away, discriminatory access to water might even involve Dalit women in rural India being subject to abusive language, and physical violence (Dutta et al. 2018).

An increasing number of studies are illustrating the disproportionate impacts of chronic water insecurity on women's **physical health**. Studies from Nepal highlight that persistent water insecurity is a "gendered physiological stressor" leading to

Table 8.1 Caste-based unevenness in water access in India

	National	Dalit
No. of households	246,740,228	67,601,968
Households with water within premises	114,925,251	20,269,355
Ratio	1 in 2 (approximately)	1 in 3 (approximately)

Data from Census on India (2011)

chronic diseases such as high blood pressure among women (Brewis et al. 2019). For women in poor urban areas that lack household water connections and are dependent on water tankers, tubewells, and/or informal water lines, water insecurity as a physiological stressor acquires additional intensity in the summer (Mawani 2022). In these months, groundwater levels recede, tankers become less frequent, and informal water connections become less reliable. This places additional physical stress on women, especially on pregnant women or women with existing physical challenges, who have to stand in long queues to fill water and carry buckets over long distances (Mawani 2022).

Equally, water insecurity also has **negative psychological impacts** on women (Aihara et al. 2016). The emotional distress reported by the latter study pertains to new mothers being unable to spend time to care for their children given the amount of time that securing water takes up, as well as being unable to maintain hygiene as a result of scarce access to water. These findings from Nepal are echoed by earlier studies from urban India (Subbaraman et al. 2014) and rural Bangladesh (Sultana 2011). In addition to stresses of not being able to maintain hygiene, women are also confronted with trade-offs between paying for water or paying for food: choices that entail yet another set of emotional stresses (Subbaraman et al. 2014). Or, as Sultana (2011) describes in relation to the arsenic waterscape of rural Bangladesh, women might know that they are compromising water quality, yet might have no choice but to use contaminated water for drinking and cooking. Making these choices knowingly—in the absence of water that might be safer to consume—are also stressors that fall disproportionately on women. It is on account of these myriad stresses that Subbaraman et al. (2014) have linked chronic water insecurity with a higher prevalence of general mental disorders among women living in urban South Asian low-income neighbourhoods. Accounts from urban Pakistan add further depth to this understanding by reporting increased domestic violence as a result of chronic water insecurity (Anwar et al. 2020).

8.4 Compounding Impacts of COVID-19 on Gendered Food and Water Insecurity in South Asia

COVID-19 broke out across South Asia in early 2020. And while lockdowns led to a widespread loss of livelihoods, the pandemic too disproportionately impacted women generally, and some groups of women more specifically. Across South Asia, violence against women increased, with over 37% women reporting having experienced intimate partner violence (UNICEF 2020). This increase in violence against women and girls has been critically associated with economic and food insecurity. A study with 2424 women in Bangladesh (Hamadani et al. 2020) confirms this association. According to this study, while 5.6% and 2.7% women reported experiencing moderate and severe household food insecurity before the pandemic, these numbers rose significantly to 36.5% and 15.3% during the lockdown in 2020. The number of participants reporting emotional, physical, and sexual violence also rose through this period, as did the number of women reporting symptoms of depression and anxiety (Hamadani et al. 2020). In Pakistan, along with increased domestic violence, women also reported reduced decision-making and increased domestic responsibilities (The Asia Foundation 2021), which in turn, as discussed in Sect. 8.2, impact gendered food insecurity in multiple ways.

Simba and Ngcobo (2020) show, the uneven impacts of pandemics on women stem from the deep entanglements between enduring patterns of economic and food insecurity, gender-roles, precarious employment, violence, unpaid care work, and access to healthcare. McLaren et al. (2020) analyse these additional and intensifying gendered impacts for Sri Lankan women in terms of the long-standing triple burdens that women have historically experienced as a result of their productive, reproductive and community roles (cf. Moser 1993). As one example of precarious employment, women comprise 70% of the workforce engaged in healthcare and social services globally (Boniol 2019), so the COVID-19 outbreak meant a directly increased risk of infection for women. The case is no different for South Asian women. India for instance has the world's largest all-female community health worker programme, which employs almost a million women as accredited social health activist (ASHA) workers (Ved et al. 2019). And while ASHA workers took on additional work and risk during the pandemic to address new and more intense community health issues across India, these women healthcare workers themselves had to deal with disproportionate economic and social burdens (Kidangoor 2020). Their hours of work increased but their pay remained the same (Kidangoor 2020), and as discussed in Sect. 8.2, women's economic independence or the lack thereof affects food (in)security in multiple ways.

Additionally, long-standing inequalities within households in consumption of nutritious food, and the higher incidence of malnutrition and poor health associated with these patterns, itself also becomes a greater risk for negative outcomes in pandemics for women. Similar patterns have been observed in Bangladesh by Rahman et al. (2021), who draw connections between increased food insecurity among women in the first and second waves of the pandemic and increased gendered mental health impacts. In addition to healthcare workers, unequal impacts of COVID-19 on women's food insecurity have also observed for migrant women workers across India engaged in a range of precarious employment settings (Manral 2021). According to a report by UN Women (2020), "*COVID-19 could cause 25 million jobs to be lost globally, with women migrant workers particularly vulnerable*". A report by the ILO (2020) presents more grim estimates, suggesting that the COVID outbreak has caused a loss of 81 million jobs in just the Asia—Pacific region, of which 32 million are jobs lost by women. This report suggests that the pandemic has led to a loss of 50 million jobs in South Asia alone. Arguably, such sweeping loss of livelihoods will affect women's food and water insecurity in numerous direct and indirect ways. In addition to the loss of livelihoods, the report by UN Women (2020), states the millions of migrant women employed as workers in a range of domestic and healthcare settings also face increased risks of abuse, exploitation, violence, loss of shelter and in close connection, I suggest, food and water insecurity.

Some clear pathways for improving gendered food and water security in South Asia then involve providing better access to education for girls, and targeted interventions relating to women's livelihoods. Similarly, comprehensive sexuality education and family planning among men, boys, girls, and women, and increasing awareness of the disproportionate burdens girls and women face is important to increase attention to women's food and water security at household and community levels. Further, the uneven impacts of COVID-19 on the food and water insecurity experienced by South Asian women given their specific health, social, and economic contexts and conditions are only beginning to be understood. Inquiring into how enduring patterns of food and water insecurity make women more susceptible to disproportionate impacts of pandemics, and how pandemics in turn exacerbate gendered food and water insecurity for specific groups of women are crucial research directions for government and policy organizations. The pandemic has had a profound impact on the lives and livelihoods of already marginalized South Asian women. A disaggregated understanding of gendered food and water insecurity in light of the pandemic is crucial for developing nuanced and targeted interventions towards achieving SDGs 2 and 6.

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Chapter 9
Poverty Reduction and Inclusion in Central and South Asia

Bishwa Nath Tiwari

Abstract The concept of poverty evolved over time moving beyond the confines of income to non-income dimensions consisting of the concept of vulnerability and inclusion. The present chapter is an attempt to briefly look into how poverty can be eradicated through addressing exclusion so that no one is left behind—the pledge of 2030 Agenda for Sustainable Development. The chapter is organized in five sections. Section 9.1 is an introductory one that sketches background for a much broader discussion in the latter sections. Section 9.2 presents the income and multidimensional poverty status which provides a basis for Sect. 9.3 to further explain the deprivation in water, energy, food, and their relationship with the multidimensional poverty. Section 9.4 advances social exclusion as the driver of inequality. Finally, some policy suggestions are advanced on how poverty can be addressed through promoting inclusion. The central message of the chapter is that Central and South Asia have been making significant progress on poverty reduction over time. However, vulnerability and inequality are rising in most countries of the two sub-regions. This is mainly due to exclusion. Therefore, measures should be adopted to promote inclusion and to share the gains fairly across all population groups. This requires reforming existing policies, introducing new policies and legislations, as well as implementing effectively redistributive policies with a reform in existing fiscal policy, wage policy, in addition to making social protection inclusive and shock responsive.

Keywords Horizontal inequality · Human Development Index · Multidimensional poverty · Non-income deprivations · Social exclusion

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9.1 Introduction

9.1.1 Justification and Framework

Poverty is a complex, multidimensional phenomenon encompassing both income and non-income deprivations. Apart from paucity of income, various non-income deprivations that can affect people's well-being are inadequate education, lack of health care, low-quality housing, lack of water, sanitation and energy, or working in a hazardous environment (Tiwari 2020b).

The concept of poverty evolved over time moving beyond the original focus on income poverty. Although income continues to be a widely used poverty measure, it cannot truly reflect people's well-being and happiness. Monetary measures are therefore not enough to guide policies to eradicate poverty as envisaged by Sustainable Development Goals (SDGs), in particular SDG 1 on ending all forms of poverty everywhere (Tiwari 2020b).

Poverty and vulnerability remain a stark reality in the Central and South Asian region. With modest economic growth, the two sub-regions have made progress on poverty reduction and human development. However, they are nonetheless highly vulnerable. A larger proportion of people are living just above the poverty line, therefore, a shock can push them back into poverty.

Exclusion and discrimination still prevail (Senapati 2021; Thapa et al. 2021; Tiwari 2010a). This situation constrains achieving SDG 1 of 'No Poverty'. Still tens of millions of people are devoid of drinking water, energy, food in world, and a large proportion of them live in South Asia and some in Central Asia. These are generally the population groups which are left behind and are excluded on various grounds such as belonging to certain castes and races or being a woman. The exclusion makes them vulnerable to any shock including rising health threats like COVID-19. Promoting inclusion and improving their access to basic services including water, energy and food is therefore necessary for eradicating all forms of poverty, as well as contributing to the achievement of the SDGs.

9.1.2 Objectives and Methods

The chapter presents status of income and non-income deprivations with the objective of assessing how inclusion can be an effective approach for removing disparities, and eradicating poverty. In order to fulfill the objective, the chapter uses poverty and inequality data of the World Bank, multidimensional poverty data of United Nations Development Programme (UNDP), and the Oxford Poverty and Human Development Initiative (OPHI). It also draws on several other secondary literature to build its arguments and to draw policy implications.

9.1.3 Chapter Outline

The chapter is divided into five sections. Following this introductory section, Sect. 9.2 presents the status of income or consumption-based poverty, as well as multidimensional poverty and human development.[1] This description provides a good basis for leading the discussion of Sect. 9.3 which focuses on the deprivation of water, energy, and food. Section 9.4 advances social exclusion as the driver of inequality, building on which the final section ends with some policy implications.

9.2 Poverty and Inclusion: Status and Trends

This section explains the status and trends of both monetary and non-monetary or multidimensional poverty. It presents deprivations at sub-regional and country levels. But before moving on to this, it briefly outlines human development status and trends.

9.2.1 Human Development Status and Trends

Human development is the expansion of freedom and choices of people. The concept builds on Amartya Sen's Capability approach (Sen 1980; Alkire 2010). UNDP has advanced several indices to measure it, chief among them is the Human Development Index (HDI). HDI is a summary measure of achievements in three key dimensions of human development: a long and healthy life, access to knowledge and a decent standard of living. The 2020 Human Development Report (HDR) presents HDI ranking of 189 countries including 5 countries of Central Asia and 8 countries of South Asia for the year 2019 (UNDP 2020a).[2]

The status of human development varies widely across the 13 countries of Central and South Asia. This is evident from their ranks and values. In terms of HDI ranking, Kazakhstan stands at the 51st, with Afghanistan at the 169th position out of 189 countries and territories.[3] In terms of HDI value, Kazakhstan lies in the Very High Human Development Group, and all other countries have high or medium levels of development, excluding Afghanistan which is in the Low Human Development

[1] Poverty incidence is estimated generally using consumption rather than income data. Consumption aggregates are used to measure welfare for at least two reasons: (i) income data is generally underreported in household surveys, (ii) consumption is more stable than income and represents welfare properly.

[2] HDI values and rankings are presented only for 13 countries of Central and South Asia which have data to measure the HDI.

[3] In fact, Kazakhstan's HDI value is 61.4% higher than that of Afghanistan. During 2014–2019, HDI ranking of Kazakhstan rose by seven positions, whereas that of Afghanistan went down by five positions. Excluding Afghanistan all other countries of South Asia did not record a fall in the HDI ranking, but two of the five countries from Central Asia moved down to the HDI ladder.

Table 9.1 Human Development Index trends, 1990–2019

		Human Development Index (HDI)					Change in HDI rank
2019 HDI rank	Country	1990	2000	2010	2014	2019	2014–2019
Very high human development							
51	Kazakhstan	0.690	0.685	0.764	0.798	0.825	7
High human development							
70	Iran (Islamic Republic of)	0.565	0.658	0.742	0.774	0.783	1
72	Sri Lanka	0.629	0.691	0.754	0.773	0.782	0
106	Uzbekistan	–	0.599	0.669	0.696	0.720	4
111	Turkmenistan	–	–	0.666	0.689	0.715	4
Medium human development							
120	Kyrgyzstan	0.640	0.620	0.662	0.686	0.697	−4
125	Tajikistan	0.617	0.555	0.638	0.652	0.668	−2
129	Bhutan	–	–	0.574	0.618	0.654	1
131	India	0.429	0.495	0.579	0.616	0.645	1
133	Bangladesh	0.394	0.478	0.557	0.579	0.632	8
142	Nepal	0.387	0.453	0.537	0.576	0.602	0
154	Pakistan	0.402	0.447	0.512	0.530	0.557	2
Low human development							
169	Afghanistan	0.302	0.350	0.472	0.500	0.511	−5
	Developing countries	0.517	0.571	0.642	0.668	0.689	–
	World	0.601	0.644	0.699	0.720	0.737	–

Source UNDP (2020a)

Group. Two of the four countries belonging to the High Human Development category are also from South Asia (Table 9.1). On the whole, Central Asian countries have a higher level of human development, and South Asian countries are making faster progress.

9.2.2 Current Status of Poverty and Vulnerability

The HDI depicts country level development status, whereas poverty reflects individual's deprivations. A negative association appears between the two measures across countries. Central Asia has a higher level of human development and lower poverty than South Asia.

The World Bank had devised three poverty lines—$1.9, $3.2 and $5.5 a day—for measuring monetary poverty in low income, lower middle income, and upper

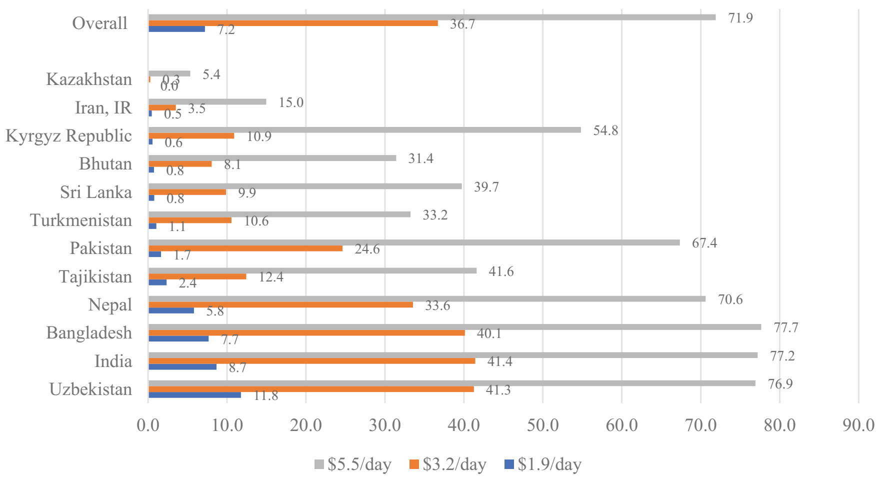

Fig. 9.1 Poverty headcounts (%) in Central and South Asian Countries, in 2018. *Source* World Bank PovcalNet. Last accessed 30 December 2020. Poverty rate for Afghanistan is not available

middle-income countries, respectively. Extreme poverty (PPP$1.9 a day poverty) is low in Central and South Asia. It ranges from no poverty in Kazakhstan to as high as 11.8% in Uzbekistan, 8.7% in India, and 7.7% in Bangladesh.[4] The aggregate poverty rate in the two sub-regions is 7.2% (Fig. 9.1).[5]

Using a poverty line of $3.2 seems to be more appropriate to measure poverty, as most countries are lower middle-income countries in the two sub-regions. At this threshold, the poverty incidence ranges between 0.3% in Kazakhstan to as high as 41.4% in India, 41.3% in Uzbekistan and 40.1% in Bangladesh (Fig. 9.1). Altogether, 708.2 million live below $3.2 a day; of which 560.5 million or four-fifths (79.2%) are in India alone. When three other South Asian countries (Bangladesh, Nepal, and Pakistan) are included, South Asia becomes home to almost all the impoverished people in the two sub-regions, implying that eradicating income poverty requires a special focus in South Asia.

South Asia is more vulnerable than Central Asia because a large share of the population is living just above the poverty threshold. When the threshold is raised from $3.2 to $5.5 a day, the aggregate poverty rate jumps from 36.7 to 71.9% in the two sub-regions (Fig. 9.1). Thus, 35.2% or 680.7 million people are living between $3.2 and $5.5 a day in the two sub-regions. Out of them as many as 661.3 million people are in South Asia and 19.4 million are in Central Asia. However, that does not mean that Central Asia is not vulnerable. The following section shows an increase in poverty in the past before setting to decrease.

[4] Poverty data for Afghanistan is not available.

[5] Altogether, there were 139.5 million extreme poor in Central and South Asia out of 665.2 million in the world in 2018. About 97% of the 139.5 million extreme poor are in South Asia alone. India shares more than four-fifths (84.1%) of the total extreme poor in the sub-region.

9.2.3 *Trends of Income Poverty*

Central and South Asia reduced poverty significantly during 1990–2018. In total, the proportion of people living below $3.2 a day decreased from 64.7 to 36.7%. However, the decreasing trends differ between the two sub-regions.

The number of people living in poverty in Central Asia first doubled in 2000 from 1990 (67.2% vs. 33.2%), and then subsequently declined, reaching 22.2% in 2018. Unlike Central Asia, South Asia has consistent falling pattern. Overall, poverty decreased from 69.9 to 37.2% between 1990 and 2018; however, poverty occurs at a much higher rate than Central Asia. Out of all countries, Bhutan recorded the fastest decrease by 66.8% points (PP) followed by Pakistan (61.4PP), Nepal (57.7PP), India, (41.3PP), and Bangladesh (39.7PP) (Figs. 9.2 and 9.3).

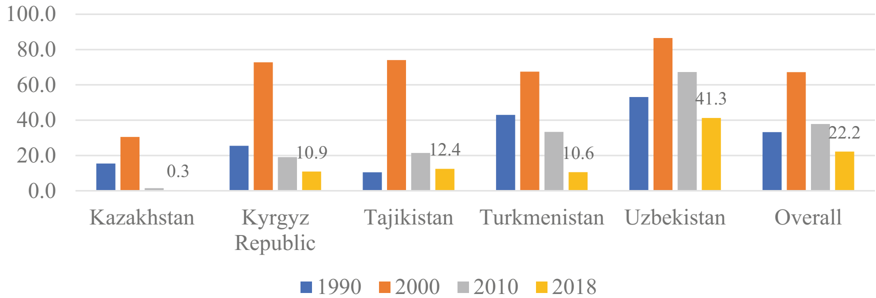

Fig. 9.2 Poverty trends (%) in Central Asian Countries from 1990 to 2018 (PPP$3.2/day). *Source* World Bank PovcalNet. Last accessed 30 December 2020

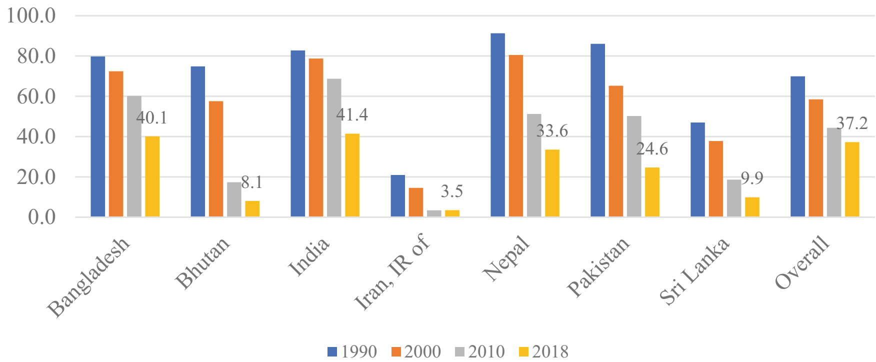

Fig. 9.3 Poverty trends (%) in South Asian Countries from 1990 to 2018 (PPP$3.2/day). *Source* World Bank PovcalNet. Last accessed 30 December 2020

9.2.4 Multidimensional Poverty

UNDP and OPHI launched multidimensional poverty index (MPI) in the 2010 Human Development Report to measure multidimensional poverty across countries. Several countries have subsequently adapted the MPI to their national context. Thus, there are two versions of MPI: global MPI and national MPI. While the definition and measurement of national MPI varies across countries, the global MPI is measured using a fixed set of 10 indicators in three dimensions: health, education, and standards of living (Tiwari 2020a). The 10 indicators are nutrition, child mortality, years of schooling, school attendance, drinking water, sanitation, cooking fuels, electricity, housing, and assets.

The MPI has two components: headcount and intensity. The headcount is the proportion of multidimensional poor who are deprived in one-third or more of the 10 (weighted) indicators. Intensity is the proportion of indicators in which poor people are deprived (Tiwari 2020b). Thus, MPI adjusts multidimensional poverty headcount with the intensity of poverty. The following section presents global MPI in order to facilitate country comparison.

9.2.4.1 Status of Multidimensional Poverty

Global multidimensional poverty is measured using data from national household surveys such as Demographic Health Survey and Multiple Indicators Cluster Survey. These surveys are rolled out in different years for different countries; therefore, it becomes difficult to provide MPI results for all countries for the same year. However, as most countries of the two sub-regions have MPI poverty headcount between 2015/2016 and 2017/2018, they have been compared here.[6]

A comparison shows that poverty headcount is highest in Afghanistan (64.1%) and lowest in Kazakhstan (0.5%). India shares the largest proportion of the world's multidimensional poor, where 27.9% of its population are poor (Fig. 9.4).

9.2.4.2 Trends of Multidimensional Poverty

The trend of multidimensional poverty headcount is available for 9 out of 13 countries of Central and South Asia. The average annual reduction between the two survey years is higher in South Asian countries than Central Asian countries. Excluding Pakistan, the four South Asian countries have annual reduction between 2.4 and 2.7%, whereas the annual reduction in Central Asian countries ranges between 0.1% in Kazakhstan to 1.0% in Tajikistan. Average annual reduction of the multidimensional

[6] Two countries have data out of the 2015/2016 and 2017/2018 range. Kyrgyzstan has 2014 data and Bangladesh has 2019 data.

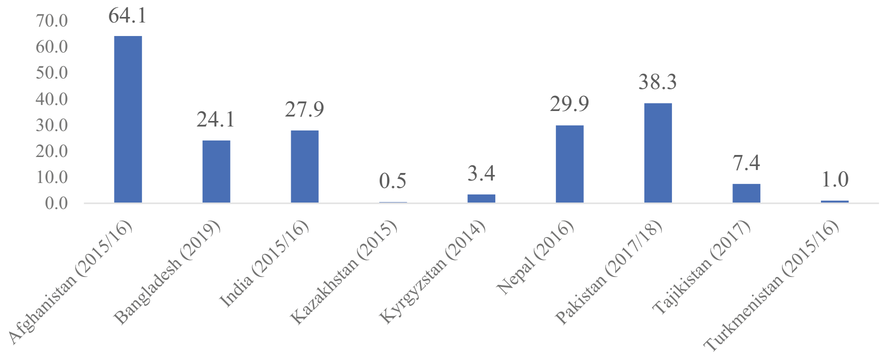

Fig. 9.4 Multidimensional poverty headcount in countries (%). *Source* UNDP and OPHI (2020)

Table 9.2 Trend of multidimensional poverty headcount

Country	Year 1	Year 2	Poverty headcount		Average annual change (% points)
			Year 1	Year 2	
Afghanistan	2010/2011	2015/2016	76.0	64.1	−2.4
Bangladesh	2014	2019	37.6	24.1	−2.7
India	2005/2006	2015/2016	55.1	27.9	−2.7
Kazakhstan	2010/2011	2015	0.9	0.5	−0.1
Kyrgyzstan	2005/2006	2014	9.3	3.4	−0.7
Nepal	2011	2016	43.3	29.9	−2.7
Pakistan	2012/2013	2017/2018	44.5	38.3	−1.2
Tajikistan	2012	2017	12.2	7.4	−1.0
Turkmenistan	2006	2015/2016	3.4	1.0	−0.2

Source Alkire et al. (2020)

poverty headcount ranges between 0.1% points in Kazakhstan and 2.7% points in Bangladesh, India, and Nepal (Table 9.2).[7]

In summary, Central Asia has a better status than South Asia both in terms of human development and poverty incidence. Between the two sub-regions, South Asia is home to most of the poor. This is also because it has a much larger population apart from higher poverty rate. However, South Asia is progressing faster than Central Asia, which is evident from the rapid decrease in poverty, as well as increase in human development.

[7] The two annual data points across countries are of different years, therefore, the MPI measurements need to be interpreted cautiously while making inter-country comparison.

At the country level, Kazakhstan has highest level of human development and Afghanistan has lowest across the countries of two sub-regions. Conversely, Kazakhstan has the lowest multidimensional poverty and Afghanistan has the highest poverty incidence. Within Central Asia, Uzbekistan has the lowest human development and highest poverty rate.

9.3 Linkage Between Water-Energy-Food Nexus and Poverty

9.3.1 Water, Energy, and Food Deprivation: Components of Multidimensional Poverty

Food, drinking water, and energy are basic human needs and are essential for survival. South Asian countries lack adequate access to these basic needs despite the sub-region having achieved higher economic growth and human development than Central Asia. The subregion remains a global hotspot for poverty, hunger, and other deprivations. This is evident from the status of the MPI which consists of food, drinking water, and energy related indicators. Out of the ten MPI indicators, four are related to food, water, and energy.

A positive association appears between the deprivation in food, energy, and water and the multidimensional poverty rate. Multidimensional poverty is generally higher in South Asian countries; and is highest in Afghanistan, followed by Pakistan, Nepal, India, and Bangladesh. These are also countries where deprivation of food, water, and energy is higher. More than 27% of population are undernourished in Nepal and Pakistan, and almost 21% in India. They also have higher deprivation in drinking water and energy. Of the four countries where multidimensional poverty is higher, Afghanistan is the most deprived where more than 30% of people are deprived of drinking water and 24% are deprived of electricity (Table 9.3). The high correlation of deprivation in nutrition, water and energy with the multidimensional poverty head count, implies that improving access to these services could decrease poverty in these countries.

Low human development status persists among the excluded population groups including women, and growing inequality is the result of economic growth that has excluded much of the population. Gender inequality in South Asia is of prominent concern although the situation is improving over time. Millennium Development Goals (MDGs) have played a significant role in enhancing gender parity in primary school; however, gender differences are still high in the higher levels of education. Moreover, a wide wage gap prevails by gender with higher positions in various occupations mainly held by men.

Table 9.3 Percentage of people who are poor and deprived in food, water, and energy

Country	Survey year	Nutrition	Drinking water	Cooking fuel	Electricity
Afghanistan	2015–2016	–	30.2	49.4	23.7
Bangladesh	2019	9.5	1.4	23.3	4.6
India	2015–2016	20.5	6.1	25.8	8.5
Kazakhstan	2015	0.5	0.1	0.0	0.0
Kyrgyzstan	2018	0.4	0.1	0.3	0.0
Nepal	2016	27.5	4.5	33.9	7.8
Pakistan	2017–2018	27.0	7.9	31.2	7.1
Sri Lanka	2016	2.0	1.2	2.7	0.7
Tajikistan	2017	6.2	3.6	3.5	0.1
Turkmenistan	2015–2016	0.4	0.1	0.0	0.0

Source Alkire et al. (2020)

9.3.2 *Impact of COVID-19 on Poverty*

UNDP and the World Bank have projected that COVID-19 will increase both income and multidimensional poverty, as well as exclusion and inequality. As presented in the preceding section, inadequate access to food, water and energy can further amplify deprivation and increase poverty.

A 2020 UNDP study conducted with the Pardee Center for International Futures assessed the potential negative impacts of COVID-19 by 2030 under 'baseline' and 'high damage' scenario. The estimated number of new extreme poor due to COVID-19 ranges between 44 and 251 million in the world. However, the study also finds that a focused set of SDG investments over the next decade in social protection, governance, digitalization, and a green economy could prevent the rise of extreme poverty. The SDG interventions suggested by the study combine behavioral changes by both governments and citizens, such as improved effectiveness and efficiency in governance and changes in consumption patterns of food, energy, and water (UNDP 2020b).

Using January 2021 forecasts of economic growth, the World Bank expects that COVID-19-induced new poor in 2020 will rise between 119 and 124 million. This range of estimates is in line with other estimates based on alternative recent growth forecasts (Lakner et al. 2021).[8]

[8] The number of people living in extreme poverty worldwide has fallen by more than 1 billion people in the two-decades since 1999. Part of this gain in poverty reduction will be reversed due to the COVID-19 pandemic. For the first time in 20 years, poverty is likely to significantly increase. The COVID-19 pandemic is estimated to increase extreme poverty in the range of 88 million (baseline estimate) and 93 million (downside estimate) in 2020. Considering those who would have otherwise escaped extreme poverty but will not due to the pandemic (i.e. 31 million in 2020), the total COVID-19-induced new poor in 2020 is estimated to be between 119 and 124 million (Lakner et al. 2021).

Apart from income poverty, the COVID-19 pandemic has threatened the progress in reducing multidimensional poverty. A substantial rise in multidimensional poverty is anticipated through two multidimensional poverty indicators that are being severely affected by the pandemic—nutrition, and school attendance of children. With a prolonged crisis it is likely that children from vulnerable households will be out of school and/or become undernourished due to lack of adequate nutrition. This could push those households into multidimensional poverty.

9.4 Drivers of Poverty: Social Exclusion and Horizontal Inequality

People are deprived for various reasons including social exclusion and horizontal inequality. Horizontal or group-based inequality refers to the situation when certain population groups are excluded from access to services and/or income earning opportunities, leading to differences in outcomes. The differences in outcome further perpetuate the differences in access to opportunities, thus keeping the horizontal inequality spiral rolling. Perpetuation of inequality is due to power dynamics. Those who are in power intend to maintain the status-quo, always leaving the excluded groups behind (Stewart 2002; Tiwari 2010b; Tiwari et al. 2009; UNDP 2019). Social and cultural factors very often create such an exclusion resulting into horizontal inequality, which is manifested in political and economic dimensions. The lack of participation of the poor and their exclusion in the political system perpetuates the inequality and exclusion.

UNESCAP (2018) used three broad types of inequality: inequality of outcome, inequality of opportunity and inequality of impact. It measured inequality of opportunity through computing 'Dissimilarity Indices' for the five sub-regions of Asia-Pacific including Central, and South Asia using 15 individual or household-based opportunities critical for human well-being.

Some of the highest overall values on the dissimilarity index are found in countries of South and South-West Asia. The countries that stand out as particularly unequal in a wide range of opportunities are Afghanistan, Bangladesh, and India. The opportunities that appeared as most unequally distributed are household access to clean fuels, individual's attainment of secondary and higher education, and household access to a bank account. On the other hand, access to safe drinking water and household access to a mobile phone are the most equally distributed opportunities. Compared to South Asian countries, inequality in Central Asian countries was low. The lowest inequality was found in Kazakhstan followed by Turkmenistan, Kyrgyzstan, and Tajikistan respectively. Among South Asian countries, Iran and Sri Lanka have low inequality. Of all the countries of the two sub-regions the lowest inequality was in Kazakhstan.

Group-based inequality prevails widely in all society. Past experience reveals that the so-called 'conflict entrepreneurs' mobilized such groups who have grievances against discrimination, leading at times to violent conflict (Tiwari 2010b). Therefore, addressing social exclusion and inequality have been central focus of the government policy to maintain peace and stability. Countries have implemented various pro-poor policies and affirmative actions to address exclusion in various dimensions as mentioned in the following section.[9]

9.5 Policy Measures for Addressing Poverty and Exclusion

Underlying reasons for poverty and inequality within a country are lack of empowerment, and exclusion which make poor people deprived of even basic services like food, water, and energy. The population groups which are more deprived are children, women, persons with disabilities, people living with HIV/AIDS, older persons, Indigenous peoples, refugees, internally displaced persons, and migrants. The following are some of the major policy recommendations to reduce exclusion and inequality within countries. Several of these recommendations build on the existing pro-poor policies.

9.5.1 Increasing the Capabilities of the Bottom Population Groups

Progressively achieving and sustaining income growth of the bottom 40% of the population at a rate higher than the national average will help address exclusion. Income is an important means to enhance other capabilities like health and education. But there is a lack of one-to-one correspondence between the two. Therefore, empowering the poor and deprived also requires building other forms of human capabilities like food and nutrition, education, housing, and other services including energy and water.

9.5.2 Addressing Discriminatory Policies and Formulating New Policies

Mere building of income and non-income capabilities will not suffice to end discrimination and poverty. For example, a Dalit in South Asia might have earned higher

[9] Some countries such as Nepal have ensured a fair representation of women in parliament through the provision of quota systems where women should hold at least one third of the seats. Similar progress has also been made in India where quota for the scheduled castes and tribes helped them ensure participation in social and political system, resulting in significant improvement of their current situation.

income but he may not be able to take part in decision making in society. A state legislation is necessary to end the discrimination such as untouchability issues with Dalit which still prevails in rural areas of some South Asian countries.

Some people suffer from multiple deprivations, for example a Dalit woman who is deprived for being Dalit and being a woman. This requires correcting, not only the discrimination between caste and ethnic groups, but also gender discrimination.

Thus, promoting inclusion requires a holistic approach addressing multiple inequalities and exclusions. This can be done by remedying the existing policies and introducing new ones that can empower poor and excluded groups building their capabilities and agency so that they can interact with the state and society more actively.

9.5.3 Role of Redistributive Policies

Inequality in opportunity, and outcome reinforce each other. It is likely that a rich person has a better opportunity of higher and quality education; or a highly educated person can be rich earning higher income. Poor and excluded groups might have higher capabilities but those capabilities may not result in higher outcome because the rich and powerful could serve as barrier in the process of fulfilling their own entrenched interest.

It is a great challenge to ensure inclusion and equality in an unequal society for the reasons that outcome and opportunity are mutually reinforcing. Those who are better off will have higher opportunities and will benefit from higher outcome. In order to break this spiral, countries must also implement some affirmative actions and redistributive policies. Such redistributive policies are progressive fiscal policy, wage policy, and social protection. Progressive fiscal policy has the feature of progressive taxation with pro-poor expenditure, meaning that raising more resources from the better off class and spending on universal social protection will disproportionally be of more benefit to the poor and excluded class of society.

Neo-classical economics held that wages increase with the rise in marginal productivity of labor. However, this does not seem to be the case as advanced by Piketty (2013) who held that the rise in inequality is mainly the result of a higher rate of return on capital than average economic growth. This implies that those who own capital get a greater share of the economy over time. This could also be because wages in countries do not rise at par with increase in labor productivity. This therefore requires addressing labor market institutions including discriminatory wage policies, as well as enhancing voice and participation of labourers through strengthening their trade union and ensuring labor rights.

9.5.4 Social Protection and Inclusion

The 2030 Agenda for Sustainable Development underscores the importance of social protection for the attainment of the SDGs. Target 1.3 addresses the role of social protection in ending poverty in all its forms. Specifically, it seeks the implementation of "nationally appropriate social protection measures and systems for all, including floors."

Social protection is an important instrument to reduce poverty, inequality and exclusion. In fact, few countries have been able to reduce poverty and improve living conditions on a broad scale without comprehensive social protection systems in place. Studies show that a larger proportion of the population will be living in poverty in the absence of social protection transfers (Fiszbein et al. 2014).

The role of social protection is extending over time with increasing shocks, including health risks like COVID-19. It is implemented not only with the aim of smoothening consumption of the poor during a crisis, but also with broader imperatives of promotive and transformative roles. Fostering human capital through investing in education and health of the poor and vulnerable is necessary for making society resilient.

As the social imbalances reinforce planetary imbalance, social protection can play a double role. It can contribute to the reduction of inequality in society, as well as promote green recovery, thus relieving the pressure on the planet. Reduced pressure on the planet could help prevent zoonotic diseases. Some flagship programmes, such as Mahatma Gandhi National Employment Guarantee Programme, also have the intention of green recovery in addition to protecting the poor. A massive investment in social protection with its dual objectives of addressing social and planetary imbalances can be the right approach to recover from current COVID-19 crisis.

9.6 Conclusion

Central Asia and South Asia have been making significant progress over time. Although they are slightly at different stages of development, they have similar challenges that they need to address in order to progress and sustain their development. Vulnerability and inequality are increasing in most countries of the two subregions. This is due to exclusion and inequality. Therefore, holistic measures should be adopted to promote inclusion and to share the gains fairly to all members of society. Reforming existing policies, introducing new policies and legislation are necessary. They need to be complemented by some redistributive policies including reform in fiscal policies, wage policies, and a move towards an inclusive and shock-responsive social protection system.

Addressing social imbalances such as social exclusion and inequality have positive effects on other dimensions. A positive association holds even between higher inequality and higher consumption of natural resources. Thus, addressing social imbalances can also help in addressing planetary imbalances such as climate change. Inequality is a problem of all societies. While domestic policy actions are necessary to attack such imbalances, addressing them also requires a simultaneous effort at both global and regional levels. Countries of Central Asia and South Asia must come together to manage such exclusion and inequality in order to realize the pledge of 'leave no one behind'.

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Chapter 10
Water-Energy-Food (WEF) Nexus and the SDGs in Central and South Asia

Humayoun Akram, Sardar Mohazzam, and Saleem H. Ali

Abstract The international research community has been attracted to the concept of a "water-energy-food" nexus as an approach for more integrated planning for global environmental change. The Sustainable Development Goals may well be approached using such a nexus approach for data gathering and for holistic policy implementation. This chapter considers how Central and South Asia might adopt this approach, particularly in the context of rapid development which is taking place across the region. We focus on energy efficiency and public-private partnerships as two key areas where robust metrics for such a nexus being realized hold promise. We also consider some of the criticism of the nexus approach in terms of research depth and policy implementation and the use of tools such as the Water Energy Food Nexus Index in the context of this region. Overall, we find the concept is appropriate for use in this region, particularly as a means of cross-border and regional development planning.

Keywords Sustainable Development Goals · Central Asia · South Asia · WEF nexus

10.1 Introduction—SDGs and WEFS

Over the past decade, the interface between water, energy and food (WEF), as well as soil has become a recurring theme in global environmental change research (D'Odorico et al. 2018). Figure 10.1 shows the interactions between the three sectors.

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The extraction of water not only requires the input of energy (pumping of groundwater, desalinization of water, and heating and cooling of water), but the water itself is input to the production of energy (hydropower production and cooling processes) and food (irrigation and processing of food). Moreover, incentives for energy generation can sometimes conflict with food production. For instance, hydropower production may occur at those times of the year, where there is less demand for irrigation. Consequently, there is a need to adopt a governance mechanism that is inter-sectoral.

The framework for the WEF nexus provides a holistic approach for addressing the disconnect between the three sectors. Although the interconnection of three sectors was always present, it was formally defined at the Nexus conference in Bonn 2011 (Mahlknecht et al. 2020), recognizing the need for collective governance for these three sectors in particular. Soon thereafter, the United Nations started the process of developing the next set of development planning horizons. The 8 Millennium Development Goals, which had only been instituted for developing countries from 2000 to 2015 were replaced with the Sustainable Development Goals over the 2015–2030 planning horizon. These 17 goals were mandated for all countries, regardless of income, and had a series of very specific targets as well. There was also a tracking mechanism put in place by the United Nations alongside independent tracking platforms supported by donors. A separate civil society platform called the Sustainable

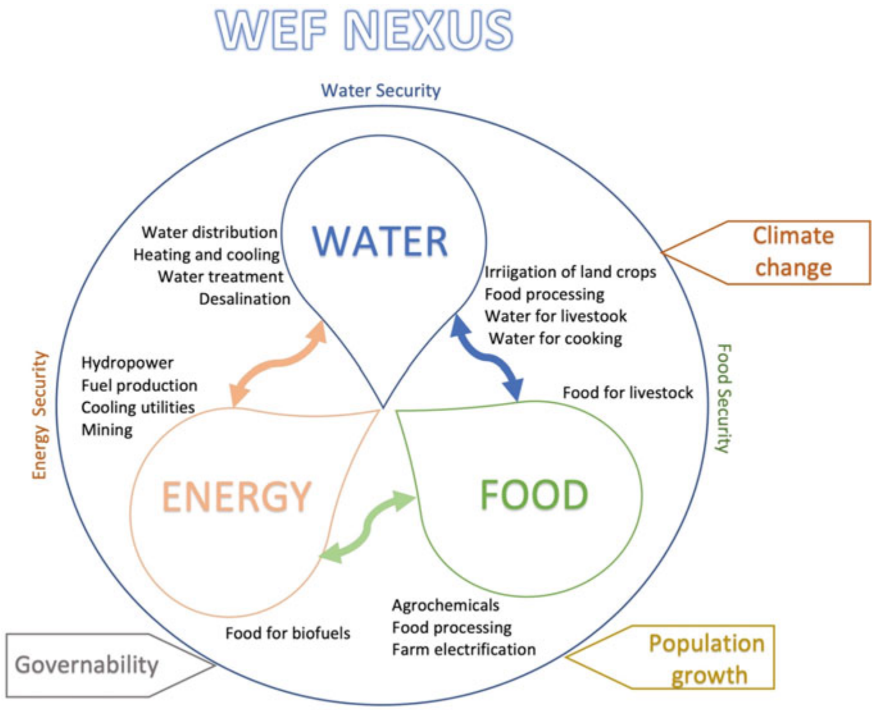

Fig. 10.1 Summary of the WEF nexus. Adopted from Mahlknecht et al. (2020)*

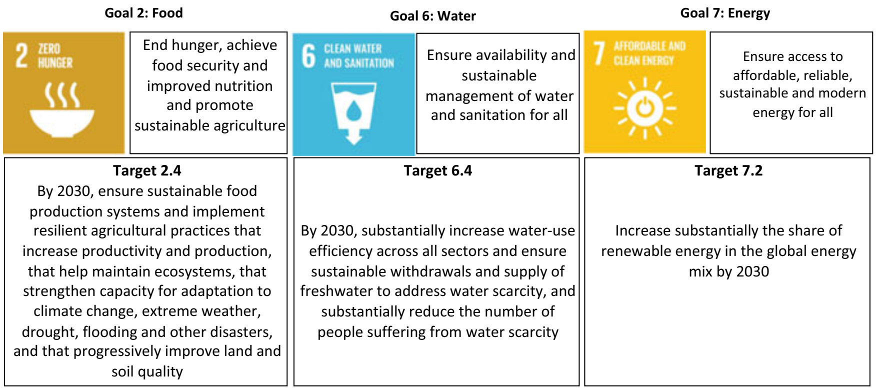

Fig. 10.2 Key connections between the WEF nexus and the SDGs. Adopted from Learn More About the SDGs—SDG Compass (n.d.)

Development Solutions Network (SDSN) was put in place to ensure that the SDGs were not just top-down but also bottom-up in their implementation. Out of the 17 goals, the three which are most directly relevant to the WEF nexus are Goals 2, 6, and 7. Figure 10.2 presents these 3 goals and the most significant targets under each of these 3 which need to be interwoven in a WEF approach to SDG planning (Mohtar 2017).

In order to keep track of the interactions between these factors, there have been attempts to track the relationship and measure discrete variables which can provide us a monitoring mechanism. Criticisms of the WEF approach have come from human geographers and scholars who are concerned about proximate livelihood impacts of securitizing environmental discourse. Calls for linking the WEF approach to a means of prioritizing the SDG agenda have come under considerable scrutiny as well, since they tend to create a hierarchy between the goals (Simpson and Jewitt 2019). However, there is little doubt that ultimately social and economic systems must depend on natural capital. Thus, giving some measure of primacy to optimize interactions between water, energy and food are likely to lead to a more sustainable and resilient outcome for livelihoods as well. The WEF Nexus Index has recently been developed by the European Union and accounts for a range of variables to constitute an index which can measure the degree to which these interactions are synergistic. Figure 10.3 presents the three pillars of this index and what is being measured.

The index was formally launched in November 2020, and an effort was made to also consider the correlation between its indicators and the well-established Human Development Index (HDI) which is regularly published by the United Nations Development Programme (UNDP). HDI focuses on income, education, and demographic health indicators as a composite for development. The correlation plot between the two indices is shown in Fig. 10.4. There is a coefficient of determination (r squared) of 0.6609 which indicates that over 66% of the variation can be explained by the

Fig. 10.3 The WEF Index (EU and German Government project). Figure from https://www.water-energy-food.org/

relationship between the two indices. The WEF Index has been calculated for all countries in the Central and South Asian region, except for Kyrgyzstan (due to data deficiency). As this region urbanizes, there is also growing evidence for the WEF approach to improve sustainable cities development (Arthur et al. 2019). Such targets can be linked to the World Bank's Global Platform on Sustainable Cities and the impact programs for the regions being supported by the Global Environment Facility.

Rather than considering the absolute values of this index,[1] the comparison with the HDI is more instructive as the 45° line suggests divergence between conventional human development metrics and ecological indicators. In this comparative plot of HDI versus the WEF Nexus Index, countries that have data point above the regression line typically have human development that exceed their available domestic natural resource base. In other words, they are able to import materials and resources from outside of their borders to maintain higher human development, while exporting their ecological footprint to other nations. The corollary is true of nations that plot

[1] The exact values for each country are regularly updated and viewable online at https://wefnexusindex.org/.

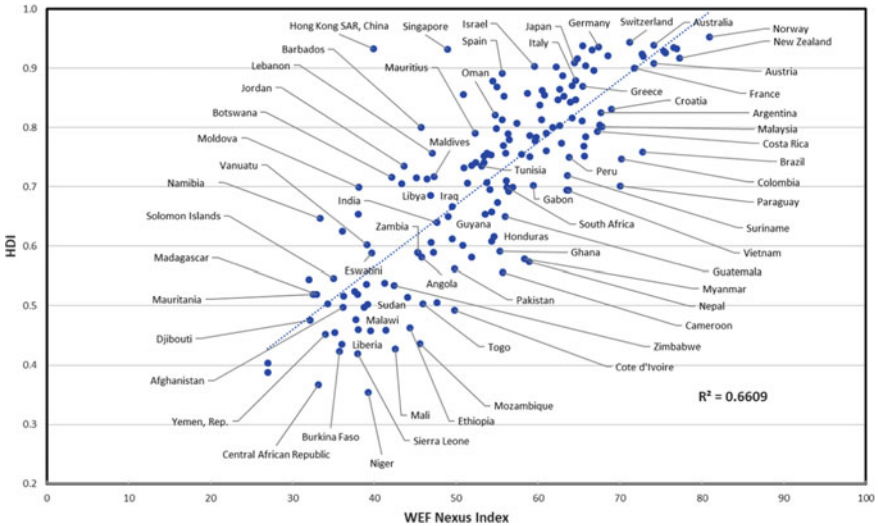

Fig. 10.4 Correlating the WEF Index with the Human Development Index (Simpson et al. 2020)

below the regression line. Noticeably, Afghanistan, which has the lowest score in both categories for the region still falls below the regression line, indicating that it has the WEF nexus base domestically to support itself. A key next step will be to extend this index further through regional cooperation so as to keep overall metrics of planetary sustainability in mind. Thus, water and energy transfer projects in the region (Huda and Ali 2018), as well as food trade which is based on ecological efficiency criteria would be an important way forward towards a more sustainable outcome in the long-term.

10.2 Water-Energy-Food Nexus in Central and South Asia

Central and South Asian countries have vastly different environmental and political histories and yet now require collective governance of their water, energy, and food sectors to have greater overall impact in reaching development outcomes. These nation-states are special because they include some of the least developed countries, and their economies are highly dependent on the waters of transboundary rivers. Kazakhstan and Turkmenistan are outliers in the region because of their fossil fuels wealth which has distorted some of the decision-making process, but here too there is growing pressure to consider more sustainable outcomes based on international environmental agreements. In the past, policies were mainly focused on one of the sectors unknowingly imposing costs on other sectors. Moreover, the environmental impacts of these developments were totally ignored, causing environmental degradation and economic harm. Local actors were frequently left out of policymaking.

This approach was particularly apparent during the Soviet control of the Central Asian region, where top-down policies have resulted in inefficient resource allocation and environmental degradation. The depletion of the waters of the Aral Sea was a particularly stark example of this degradation (Micklin 1988).

As a result of the growing awareness of the need to adopt a Nexus approach in the region, the Regional Environmental Centre for Central Asia (CAREC), in cooperation with the International Fund for Saving the Aral Sea (IFAS), are implementing the Nexus Regional Dialogues Programme activities. There are a number of studies conducted in the region to assess the possibility of the implementation of the nexus framework within the region. Jalilov et al. (2018) conducted an economic analysis by considering the effect of infrastructure development and climate variability for central Asian countries (Tajikistan, Afghanistan, Turkmenistan, and Uzbekistan) sharing the Amu Darya River basin. Infrastructure development in terms of the building of two hydroelectric dams was considered in the study. Climate change scenarios investigated the impact of a 50% reduction of the river flow. According to their analysis, there is a considerable chance of economic gains for the basin countries if they decide to cooperate on collective infrastructure development and sharing the benefits from the development. Economic gains are in the agriculture and energy sector. However, gains are not equally spread between the two sectors: Uzbekistan, being lower riparian, will have proportionately higher gains in agriculture; on the other hand, energy generation gains will be more for Afghanistan and Tajikistan.

This study has not considered the environmental impacts of the development. The Amu Darya is the major supplier of water to the Aral Sea; agricultural developments starting from the 1960s have resulted in the reduction of its water level. Therefore, it is important to see the cost and benefits of further developments and protect and restore the Aral Sea. However, negotiations based on collective but differentiated benefits for the countries of the region will require altering water allocation among different crops, sectors, and locations. Therefore, it is a big challenge and opportunity for effective collective environmental mitigation strategy also. Saidmamatov et al. (2020) provided a meta-analysis of the studies conducted for the water-energy-food-nexus in the Aral Sea basin. Major rivers of the basin are the Syr Darya and the Amu Darya; 70% of the basin area of these rivers is located in just two mountainous countries (Tajikistan and Kyrgyzstan) relying on more than 80% for a hydroelectric generation due to waters of these rivers, while the majority of agriculture consumption is in Uzbekistan and Turkmenistan.

The region's current water infrastructure is based on former Soviet Union central planning, which resulted in massive water withdrawals for irrigation purposes in lower riparian countries and hydroelectric dams for power generation in the upper riparian regions. Soviets were also instrumental in negotiating and supervising the transboundary water management in the region. However, the policy was formulated top-down, resulting in an inefficient allocation of water for agriculture and energy sectors. For instance, cotton cultivation in the dry regions resulted in an over-draw of water from the Amu Darya (the main contributor to the Aral Sea), at the same time contributing to the food security of the region by depriving cultivation area for other food crops.

Although Saidmamatov et al. (2020) highlight the importance of the water-food-energy nexus approach for effective management of water resources of this region, they also bring forward challenges in the form of 'poor market structure, diplomacy, and governance in the region.' Moreover, reliable hydrological data and quantifiable information on the environment are also major hurdles for setting any management and environmental goals.

In South Asia, the Indus basin is one of the most intensively irrigated areas of the world. The Indus basin is located in four countries, of which the largest part in Pakistan, and substantial upstream parts in India, China and Afghanistan. Almost 60% of the irrigated land of the Indus Basin area lies in Pakistan with the remaining in India (37.2%), Afghanistan (1.9%) and a negligible portion in China (Laghari et al. 2012). Inefficient surface irrigation practices result in the loss of surface water and cause salinity of the soils. Moreover, groundwater is pumped to irrigate the crops excessively within the basin resulting in massive energy use.

Further, in Pakistan, hydroelectricity is generated from the dams located on the Indus River, and its tributaries provide about 28% of the total electricity to the country's national grid (NEPRA 2020). Therefore, the importance of the water-energy-food nexus approach cannot be more important than any other place (Siddiqi 2014). Yang et al. (2016) modelled the future climate impacts, different water allocation, and future water infrastructure development scenarios in Pakistan's Indus River basin. They considered different climate projections scenarios—increased precipitation and increased temperatures, reduced precipitation and increased temperature, current water allocation practices at the sub-government level and federal government level through the Water Apportioned Accord, and optimum water allocation based on the marginal value of water in the basin. The model results show that there will be increased water and energy consumption in future higher temperatures and precipitation scenarios. However, better allocation policies can reduce crop water use and increase hydropower production, but it will also cause more variability in the crop's annual water supplies. Additionally, it will also increase surface water use. Furthermore, Pakistan seriously lacks in the governance of all three sectors. Similarly, in case of India, Afghanistan, and China long-term challenges will emerge such as (1) water resource changes due to climate change; (2) increase in population, urbanization, and industrialization will increase demand for water in domestic and industrial processes, energy, and food production; (3) shift from surface water to groundwater which will deplete the groundwater both in Indus and Ganges basin. Overall, countries collectively lack a holistic and integrated governance framework. This problem is added to the top of fragmented policies that have historically taken place in each sector (Bazmi 2018). A regional SDG approach that considers such deficiencies of fragmentation needs to be considered.

Regional projects connecting Central and South Asia through gas pipeline infrastructure or electricity grids remain important (Huda and Ali 2017). However, there are many broader dividends which could be harnessed through a joint SDG agenda approach that considers a regional WEF nexus. There is potential for regional entities such as the Shanghai Cooperation Organization (SCO), comprising China, India, Kazakhstan, Kyrgyzstan, Pakistan, Russia, Tajikistan, and Uzbekistan, that spans both Central and South Asia to play a role in this regard. The Green Belt and Road Initiative Center could be a useful host body for developing a research agenda and further enhancing regional synergies for collective SDG attainment. The Food and Agricultural Organization (FAO) of the United Nations signed a partnership agreement with the SCO in November 2019 to enhance food security efforts in the region (FAO 2019). Such an agreement could be extended to consider the WEF approach and associated SDGs.

10.3 Energy Efficiency as an SDG Operative Metric

There is a general presumption that industrialization leads to a reduction in the percentage of energy used by households. In general, industrial development leads to greater per capita household energy usage as well. Central and South Asia vary dramatically in their industrialization levels but can potentially exchange lessons from each other on energy efficiency as a common means of improving resource access. Central Asian countries, in particular, are still relying on resource extraction rather than orientation toward efficiency improvements—a result of ageing industrial infrastructure from the Soviet era (Rakhmatullaev et al. 2018). The improvement in energy efficiency has slowed down below 2.6 energy intensity per capita rate, which was requisite to attain the SDG Target 7.3 according to the tracking report prepared by the International Renewable Energy Agency (IRENA) in May 2020 (IEA, IRENA, UNSD, World Bank, WHO 2020). Energy efficiency plays a pivotal role in the WEF nexus as it helps to decouple the economy of the country from a range of environmental harms. Developing mechanisms to adapt readily available efficient technologies is one of the most cost-effective way of saving energy while reducing emissions and achieving wider SDGs goals. Globally, there is low investment in energy efficiency which clearly indicates a missed opportunity. However, unlocking the full potential of efficiency would require USD 600 billion for energy efficiency until 2030 (United Nations, n.d.).

In Central Asian countries though there is an abundance of diverse energy resources, but there is an absence of suitable energy services which leads to the use of available natural resources to meet basic energy needs. This heavy reliance on natural resources results in considerable exposure to indoor and outdoor air pollution for women and children (Mehta et al. 2021). On the other hand, in the South Asian region, the role of women in collecting firewood for cooking expose women and children to indoor air pollution ("The Clean Cooking Alliance," n.d.). This links to SDG 5 (gender equality), as well as SDG 8 (decent work and economic growth) and (this connects with SDG 3 on "good health and well-being"). Exposure to indoor air pollution is estimated to "lead to 4 million premature deaths a year, which is 5-6% of global mortality (International Energy Agency and the World Bank 2017). Sustainable Development Goals 7, focused on Energy, explicitly mentions the need to address this risk, and the need to integrate sustainability principles which lower this risk into the goals and objectives of all national and international strategies. In Central

Asia, water issues are the centerpiece and water governance is "water-centric". Electricity use in the region is projected to grow by 87% by 2035. Much of the demand will be met by thermal power plants, of which, fossil fuel and nuclear power plants have a heightened water need for cooling purposes as per unit of energy produced, they are the energy sector's most intensive users of water" ("Data Tables—Data & Statistics" 2018). Much of the sector's water demand would be greatly reduced if the future energy mix is inclined towards sustainable energy resources that are less water intensive. Thus, efficiency metrics would again be useful to incorporate as a corollary for WEF nexus planning. There is a wide diversity of stakeholders involved in the implementation and operationalization of the nexus approach and easy metrics are an important part of ensuring a common vocabulary to link them to SDG targets set forth by each country. According to Asian Development Bank (2018) the most reliable estimates for the Asian region's irrigation requires annual investment of $12.31 billion between 2005 and 2030.

Figure 10.5 provides the illustration of the management of nexus through different scenario development. The resource base is land, labor, and capital, as well as energy and water. The scenarios are developed through stakeholders' dialogues based on evidence and response options to achieve desired goals and interests. The numbers of drivers impact the resource base, as well as goals and interests.

Some of the roadblocks in WEF nexus implementation are (1) the limited information which weakens evidence-based decision-making due to the frequent lack of reliable and updated data on the status of the WEF sectors at the local level, and often also at the national level (Scott 2017), (2) lack of awareness of the benefits of using the WEF nexus approach by relevant stakeholders, (3) negative externalities due to low or no pricing of water and energy use in the region (HICs; Sarni 2015), and (4) an inadequate coordination mechanism by relevant stakeholders, as the perceived transaction costs of coordination seems higher than the benefits (Keskinen et al. 2016).

Central and South Asian regions have multifarious challenges to implement the SDGs. Central Asian states are landlock with greater reliance on agriculture and forestry for livelihood; however, there is an abundance of energy resources (fossil and renewable resources). Central Asia, being the closed drainage basin, is facing significant challenges in water management. The South Asian countries depend on irrigation for food production which consumes immense energy resources—the energy resources are expensive and not abundant. The implementation of WEF nexus needs the policy framework with shared responsibility when there exist shared boundaries among sectors i.e., agriculture/food, water, energy, finance, as well as, municipalities, and other stakeholders locally and globally is a key. The program such as CAREC (Central Asia Regional Economic Cooperation Program) is a good example in this region. Similarly, One Belt One Road (OBOR) through infrastructure development is also addressing the WEF nexus.

However, the need for financing for effective implementation is one of the challenges for SDGs. To this end, partnerships will be an essential part of a success trajectory and the United Nations specifically enshrined SDG 17 (revitalizing global partnerships) to specifically be targeted at establishing such arrangements.

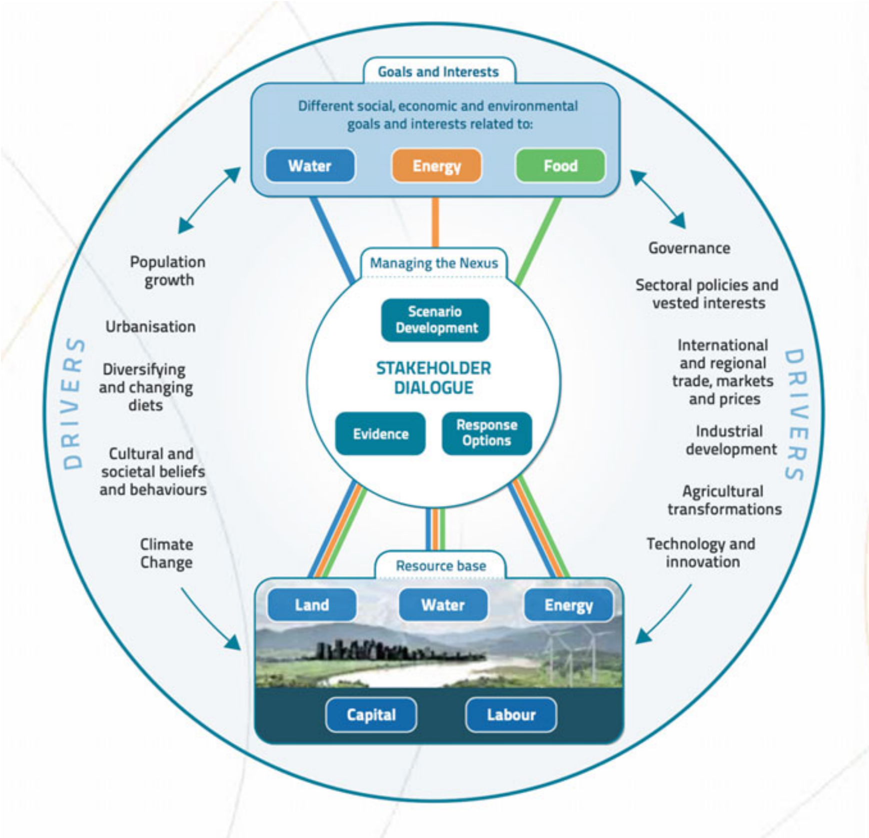

Fig. 10.5 The WEF nexus (FAO 2014)

10.4 Public Private Partnership for SDGs in the Region

Financing requirements for the implementation of SDGs require US$5–7 trillion per year, where in developing countries USD $3.9 trillion per year for basic infrastructure (United Nations 2016). Analysis of the existing public and private sector investment shows an annual gap of around $2.5 trillion to meet the SDGs objectives. The WEF nexus approach under the SDGs subsequently requires the major portion of this investment, which can be translated into future financial savings. The investment requirement of this scale is not possible under constrained public spending or Official Development Assistance (ODA) as experienced in case of Millennium Development Goals (MDGs). Therefore, private finance will be required to fill the gap. Public-Private Partnerships (PPPs) have the potential to attract these additional resources. Within Central and South Asia, the opportunities for partnerships are often constrained in the WEF nexus because of geopolitical rivalries. The Belt and Road

Initiative is a mega-partnership effort, but because of its linkage with China, donors such as the United States and the European Union may perceive it as a threat. The WEF nexus approach has the potential to inject science diplomacy within this context to build trust purely through environmental research linkages.

The private sector is another important potential partner in the WEF nexus, given the salience of utilities for water and energy delivery and the range of companies involved in food production and delivery. However, proactive engagement of the private sector in Central and South Asia has been limited due to limited collaborative incentives, as well as resource nationalism by public sector companies. The water-energy linkages analysis reveals, in most developing countries water is subsidized. Hence, few individuals or municipalities pay the real cost of water and wastewater services. On the other hand, the energy sector's tariffs are based on a full-cost recovery basis which makes it a productive sector with reasonable income on a yearly basis. Contrary to the water sector, the energy sector has more leverage for investments. Establishing the linkages between these two sectors, and other sectors can promote and incentivize private investment for nexus approach (Schuster-Wallace et al. 2015).

Public-Private Partnerships have become even more prominent with the adoption of the SDGs. To achieve the targets set forth for the SDGs, the private sector role has been redefined through PPPs emerging as a recognized financial instrument. However, for PPPs' effectiveness to deliver the important services and infrastructure, it is critical that countries in Central and South Asia have an institutional capacity to create, manage and evaluate PPPs.

The role of these partnerships is thus of "regulatory intermediaries" who are able to share expertise and knowledge, implementation/enforcement capacity, and legitimacy (Abbott et al. 2017). The SDG agenda, coupled with global environmental mechanisms, such as the WEF nexus, can empower PPPs and prevent them from being marginalized by parochial politics that are so prevalent in the region.

One of the examples of a PPP is Central Asia-South Asia Regional Electricity and Trade Project (CASA-1000) which is the first step toward creating the Central Asia-South Asia Regional Electricity Market (CASAREM). There is a strong commitment of countries from Central Asia and South Asia to addressing their challenges together. Through PPP, the private sector is attracted to invest in infrastructure development (electricity transmission).

10.5 Conclusions

In the face of climate change, if Central and South Asian countries choose to cooperate and manage their transboundary resources in the framework of WEF nexus, it will result in the economic benefit to all the nations sharing these resources. There is also growing evidence that the river basins that constitute the most contentious aspect of the resource nexus can be managed to provide maximum economic benefits for all nations in the region. The economic value of regional cooperation across riparian basins to consider a nexus approach in realizing the SDGs is now quite clear, particularly between Afghanistan, Pakistan, and India (Vinca et al. 2020).

In Central and South Asian countries an integrated approach is needed, and a WEF nexus approach is an entry point to capture and operationalize synergies in the implementation of SDGs. A more comprehensive and integrated strategic planning for operationalizing synergies and minimizing trade-offs in WEF among the goals and associated targets would help the region to achieve co-benefits. Therefore, this requires strengthening institutional coordination for mainstreaming SDGs. The 2030 SDG agenda has been assimilated in the governments' policies and program with reasonable financial resource allocations to meet the targets as per regional context. However, there are challenges in governance and management due to predicted political inertia in a lack of trust between countries. First, there is a critical need to create a political will to manage resources in the nexus framework. The upper and lower riparian rights in Central and South Asia region requires a nexus framework not only to address the challenges of water management but also generation of electricity from hydro-electric resources. The WEF nexus approach can definitely build a better political understanding for greater interest of regional stakeholders. Second, historical formation of policies was based on a top-down approach; this resulted in not only inefficient allocation but also an obfuscation of massive environmental harm from international donors. The focus on WEF nexus is this case is a paradigm shift from earlier developed program such as green revolution. Hence, the most effective path towards achieving any cooperation objective is to make policies that involve multi-sector and multi-level engagement with all actors of the shared resource nexus. Regional development organizations need to thus prioritize the linkage between the WEF nexus and the SDG agenda to optimize development outcomes, while also using such an approach for peace-building in this contentious region.

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Part IV
An Integrated Narrative

Chapter 11
The Water-Energy-Food Nexus Approach Towards Long-Term Peace and Stability

Fozia Nazir Lone

Abstract This chapter assesses the ways in which a nexus approach to water-energy-food (WEF) resource management could fulfil the international community's goals of long-term peace and stability. Considering the factors that catalyse conflict, this chapter will explore how a nexus approach incentivizes cooperation, policy coherency, and resource optimisation at domestic, regional, and international levels. This chapter will also explore the significance of regional dialogue (or lack thereof) in impacting the future prosperity of local populations.

Keywords Water-Energy-Food Nexus · Lancang-Mekong Cooperation · Kashmir · China-Pakistan-Iran-Turkey Energy Corridor · Indus Waters Treaty · 1997 UN Watercourses Convention

11.1 Introduction

The water-energy-food (WEF) nexus approach advocates cooperation over shared resources at domestic, regional, and international levels. There is significant positive correlation between WEF resource security and political stability (Abbott et al. 2017; Amorim et al. 2018). Regions in Asia that are "energy-poor, water-stressed, and food-deficient" often experience conflicts between stakeholders (Rasul et al. 2019). The combination of increasing demand and increasing scarcity, climate change, urbanization, poverty, societal inequities and the cross-border nature of key resources show the need for a coherent and cooperative approach to achieve regional peace and stability, as well as meeting development goals, including UN Agenda 2030, i.e. the Sustainable Development Goals (SDGs).

The multifaceted associations and interdependencies between water, energy, and food sectors require a multidisciplinary and integrated approach. Streamlining WEF

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nexus management has myriad of benefits, including the improvement of food security and energy sharing (Mabhaudhi et al. 2020). This coherent approach to management will benefit the achievement of sustainable development and create responsive and harmonized management structures for shared resources, which are necessary for long-term global peace and security. Streamlining WEF nexus interdependencies facilitates negotiations and potential trade-offs for food security, including cross-border trade of food products, energy sharing, and the construction of new energy corridors. These synergies are not only central to sustainable development, but also encourage responsiveness and collaboration, which are beneficial for long-term peace and security (Staupe-Delgado 2020). The strategies taken by parties with the most impact, particularly China (as the upper riparian of the regional major river systems) will be key. China's 'soft path' approach to international relations and openness to global health security in the post-COVID-19 and One Belt One Road era could further extend to the application of a nexus approach to key resource management.

This chapter will take a holistic approach to defining peace and security from the nexus perspective, i.e., in terms of the production, consumption, and distribution of water, energy, and food, and the resolution of conflicts that arise around these resources. Human security involves understanding the impact of broader factors (such as those arising from the environment, availability of resources, economic goals, culture, conflict, etc.) on the well-being of individuals, and aims to change the deleterious trajectory of potential scenarios, creating outcomes that value the well-being of individuals. These achievements were poignantly described as follows: "a child who did not die, a disease that did not spread, a job that was not cut, an ethnic tension that did not explode in violence, a dissident who was not silenced" (Kaul et al. 1994). Human security rests on systems that manage interdependencies, taking a people-centered and protective approach that is preventative (rather than reactionary) in nature. This results in practical benefits at all levels, including cost-effective, integrated project management for governing bodies. The potential for trade-offs also creates incentives that sectoral approaches may not, e.g. for upper riparian cooperation that can be difficult to obtain in water-centric approaches (Zarei 2020).

This chapter further explores these trade-offs and synergies. It considers best practice examples, such as the Lancang-Mekong Cooperation (LMC) and recommendations from the MENA Region Initiative as a model of Nexus Approach and Renewable Energy Technologies (MINARET) (IUCN ROWA Report 2019), to demonstrate how WEF insecurities are symptomatic of turbulent power dynamics in the region, leading to conflict that could be mitigated using the integrated framework of the WEF nexus approach, which can also inform policy in the trans-boundary river basins. This chapter explores how a nexus approach can promote peace, security, and sustainable development in the region through the thoughtful management of water, energy, and food resources.

11.2 Peace and Conflict in WEF Discourse

WEF nexus discourse draws from both the natural sciences and the humanities to apply scientific findings within decision-making bodies (Taniguchi et al. 2017). Human security involves the management of five key resources: land, energy, food, water, and minerals (Khagram et al. 2003). A zero-sum approach to these resources can result in international conflicts (such as in the context of international trade) (Adnan 2013). As articulated at the Bonn 2011 conference, it is possible to make investments in a way that sustains ecosystem services and optimizes resource use, while serving the needs of the poorest and most vulnerable. This Bonn conference report also recognized the need to manage water, energy, and food in the face of increasing demand, and warned of the unintended consequences of sectoral approaches, including the dangers of shortages as causes of political instability, global conflict, and environmental degradation (Adnan 2013).

The failure to integrate these pivotal findings from the Bonn 2011 conference into policy has and will result in egregious unsustainability. This is partly due to the relative political weakness of government departments dealing with water and environmental issues. There is also an overall lack of understanding of the economic value of water and the link between the protection of ecosystems and human security. These factors (among others) lead to insufficient regional investments that take an integrated approach to protecting ecosystem services. There is increased understanding throughout the global community of the security threats posed by the mismanagement of these resources (Krchnak et al. 2011; Chellaney 2011; Klare 2012).

There are geopolitical factors that give the region strategic significance, including the involvement of three nuclear powers (China, India, and Pakistan). The resources necessary for nations to function properly are not distributed along the lines of national boundaries; for instance, in the case of lower-riparian dependence on upper-riparian nations. There is a clear need to address these issues coherently as potential flashpoints exist the world over, including in Southeast Asia, India, the Nile Basin, Saudi Arabia, the Arctic Pole, and the South China Sea (Biba 2013; Ho 2014; Adnan 2013). The situation in Kashmir is an example of how energy, food, and water governance are interlinked. The 2014 floods in the region demonstrate the impact of low stakeholder engagement, and this issue of low stakeholder engagement is also linked to the difficulties that have arisen after the lockdown imposed in 2019 (Lone 2020).

The factors that contribute to resource-related conflict have been widely acknowledged and studied in various parts of the world. In the Middle East, for instance, nexus studies show that the factors driving conflict include the scarcity of water, the occurrence of natural disasters (flooding, droughts, and dust storms) as well as economic and population growth, urbanization, political instability, and poverty (Hameed et al. 2019). The Pardee RAND Food-Energy-Water Security Index tracks the resources contributing to these factors.

There is also increasing understanding of the nexus approach and its contribution to peacebuilding, as evident in the 2019 Mali conference on Water, Peace, and Security regarding the Inner Niger Delta. The positive results of that application have led to proposals for its expansion into other parts of Niger and Chad (Water Energy Food 2019).

This chapter will elucidate how the nexus approach can be viewed in terms of conflict prevention at domestic, regional, and international levels. It will draw from examples of cooperative trends and arrangements, international law frameworks, and lessons from nexus studies regarding conflict prevention.

11.3 A Conflict Prevention and Cooperation Framework

The interlinkages and dependencies among water, energy, and food systems have emerged around the world and conflicts have developed over access, affordability, and ownership rights of water, land and energy, which are highly politicized, at different levels of governance (Keukertz et al. 2018). On the other hand, there have been warnings made against 'de-globalization' as a response to the changing geopolitical situation due to parallels with the historical conditions that resulted in WWII. This section will look at the overall framework for adapting the nexus approach towards conflict prevention at the international, domestic, and regional levels. Examples will include the LMC, China-Pakistan-Iran-Turkey Energy Corridor, the Grand Ethiopian Renaissance Dam, and the South Asian Association for Regional Cooperation (SAARC) and arbitration under the Indus Waters Treaty 1960.

11.3.1 International Approach

At an international level there are ongoing debates regarding the keyways in which WEF security issues can be integrated in international law, and how the nexus approach can be used in a way that reduces political tension. The Sustainable Development Goals (SDGs), which are viewed as an improvement on the Millennium Development Goals (MDGs), have been critiqued for not having integrated a more effective nexus approach (Boas et al. 2016; Kim 2016).

In terms of existing sectoral approaches, studies have found that targeted interventions in water management contribute to peacebuilding and post-conflict recovery processes, as well as to long-term sustainable development and stability (Swain 2016). Transboundary water resources include major rivers flowing from the Greater Himalayan Region to various parts of Asia, as well as shared groundwater resources. There are fears of imminent "water wars" given water scarcity and increasing demand. The domestic development plans, such as hydropower plants, of upper riparian nations are not reflecting regional needs and are failing to address the potentially devastating effects on lower-riparian nations.

The key conventions on water governance are the 1997 UN Watercourses Convention (UNWC) and the 1992 UNECE Transboundary Waters Convention (UNECE). Art. 6 and Art. 4 (customary international law principles of Equitable and Reasonable Utilisation) of the UNWC are key articles that can inform a more holistic approach to water governance. UN Resolution 71/222 on the International Decade for Action, "Water for Sustainable Development", 2018–2028 (adopted by the General Assembly on 21 December 2016) and the UNECE will be valuable for a nexus assessment, integrating human rights (food and water) discourses read through the nexus approach (Belinskij 2015).

The "Potential Conflict into Cooperation Potential" (PCCP) approach is based on transforming the dynamics of such a situation to conform to international law principles (Vinogradov et al. 2003). It advocates a five phase PCCP cycle, beginning with the legal context of applicable international law, finding means to transform conflict to cooperation, creating an agreement, and implementation.

Energy security, as per the International Energy Agency, is "the uninterrupted availability of energy sources at an affordable price" as well as access to energy for individual needs i.e.: "access to clean, reliable and affordable energy services for cooking, heating, lighting, communication, and productive uses" (Belinskij 2015). This requires addressing energy security at both the macro and micro (i.e., individual) levels.

There have been attempts to expand the sectoral approach to energy into a more integrated model. The G8 Gleneagles 2005 Plan of Action, 'Climate Change, Clean Energy and Sustainable Development' was a milestone undertaking of this type of integrated model. There have been recommendations made in existing energy and sustainable development agreements (including attempts to impose liability) for an international convention on energy and the environment through environmental rules and obligations, and calls to address sovereignty issues over energy management/natural resources (Arghand et al. 2018).

The Food and Agriculture Organisation (FAO) has been supportive of an expansive approach to key resources. The right to food and water (Art. 11 and 12 of the ICESCR on adequate standard of living including adequate food, clothing, and housing and to the enjoyment of the highest attainable standard of physical and mental health; Art. 14 and 17 of the ILA Berlin Rules; General Assembly Resolutions) are essential to the nexus approach (Belinskij 2015).

An expanded nexus approach would combine WEF security through a human rights/basic needs perspective tailored to both individuals and ecosystems (Bizikova et al. 2013). Further, there is no single method that fits all situations; rather the approach must be tailored for each unique situation (Simpson and Jewitt 2019). The above noted efforts provide a foundation for this more intensive nexus-driven agenda. Regulations (defined as enforced imperatives that guide human interactions) related to resources are, even within a domestic setup, highly complex (Larcom and Gevelt 2017). Therefore, existing sectoral regulations at the international level can be streamlined into a nexus approach (Zarei 2020).

11.3.2 Domestic and Regional Levels

At the moment, resource utilisation is primarily within the purview of national planning commissions. Some research on the limitations of these domestic practices have demonstrated sectoral approaches being prioritized without trans/cross-sectoral inputs in decision-making (Albrecht et al. 2018); a lack of input into budgetary allocation; and a limited understanding of nexus perspectives in national planning. nexus could help national-level plans and encourage decision-making that promotes "synergies and minimizing trade-offs in resource use and enhancing policy coherence across the three sectors" (Rasul and Sharma 2016).

Institutionalist arrangements (rather than ad hoc) have been recognized as more effective in constraining behaviour and reducing tensions (North 1990). However, as demonstrated by the IUCN ROWA Report (2019) report, it is better to build on existing institutions to create regionally coherent policies with expert input, rather than to focus on creating specific institutions for the WEF nexus. I hold that it is possible to do both: to develop existing sectoral institutions as well as to design new institutional frameworks simultaneously.

The role of China as the upper riparian to the major rivers in the region is a key consideration in this discussion. During the COVID-19 era, rather than retreating from globalization denying about the need for international cooperation, China has stressed the need for international collaboration. President Xi made six points about common global understanding and five pledges for actions (Xinhua 2020). Chinese political approaches are particularly salient to investigate because China is home to many of the rivers vital to the survival of those in the region. In President Xi's speech in May 2020 at the World Health Assembly, he affirmed the idea of common humanity and laid out the areas that should be urgently tackled to fight the epidemic. Xi's willingness to cooperate during the pandemic may open the door to other types of cooperation (such as developing existing regional arrangements) in the post COVID-19 era.

The Chinese approach includes the call for a body of nations to take the lead rather than one country; focusing efforts on the developing world (this shows an understanding of the need to build systems that can tackle a response domestically, in line with the SDGs); planning for the future and strengthening global governance; and the need to restore economic and social development (i.e., international macroeconomic policy coordination should be stepped up and the global industrial and supply chains must be kept stable and unclogged if we are to restore growth to the world economy). President Xi emphasized the need to strengthen international cooperation, stating that 'Mankind is a community with a shared future' (Xinhua 2020).

China's willingness to cooperate over resources is evident in the LMC with its downstream neighbors on the Mekong River, which has involved consideration of ecological impacts in dam projects and has even led to the cancellation of the Mengsong Dam project in 2010 on the Buyuan River (a river vital to fish migration) in consideration of the local ecosystem (He et al. 2014). Another example of development in this area is the China-Pakistan-Iran-Turkey energy corridor. In terms of areas of potential conflict, there have been both criticisms (e.g., regarding the Malacca Strait) and recommended solutions (e.g. opening up new energy channels, greater international cooperation on shared energy, structural developments). Despite these criticisms, overall China is perceived by scholars as strengthening cooperation in policymaking, energy and dispute resolution, and security cooperation (Guo et al. 2019).

In terms of regional security, anti-terrorism, and overall risk reduction, recommendations include joint anti-terrorism centers for intelligence sharing and related cooperation such as joint responses and a regional security cooperation system such as the Shanghai Cooperation Organization (SCO) to strengthen ties between member states for the sake of regional peace, security, and stability. This can also protect investments, projects, and workers and address the causes of terrorism in terms of poor economic development and wealth disparity in line with "the principle of consultation, co-construction and sharing" (Zhang 2016). This improves overall wellbeing, reduces conflict triggers (including poverty), and promotes sustainable economic development.

Looking at examples outside the region, the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile was an example of collaboration that uses a cooperative approach to mitigate tensions. In the past, with the backing of the African Union and with assistance from experts, there had been ongoing diplomatic relations between Egypt, Sudan, and Ethiopia in decision-making over damming the Nile (Mbaku 2020). This included the establishment of a tripartite commission to create an agreement. However, since 2020 a fresh controversy has started over filling and operation of the GERD by Ethiopia. There has been increasingly nationalist rhetoric from Egypt and Sudan, and the UN Security Council has taken up the issue. The US mediated between these countries in concluding a trilateral agreement to control the filling and operation of the GERD on the Blue Nile by Ethiopia. However, Former President Donald Trump sparked diplomatic tensions when he remarked that Egypt could 'blow up' the GERD that Ethiopia is building on a tributary of the Nile. Clearly, this ongoing situation is an illustration of states' reluctance to sign binding agreements and how insensitive remarks from a third country can derail cooperation and incite a diplomatic furore (Chothia 2020).

A recent report on the implementation of the nexus approach in the Middle East and North Africa acknowledges the difficulty of setting up new bodies that specifically deal with nexus management, and advocates expanding the mandate of existing bodies working on areas linked to these sectors (IUCN ROWA 2019). This would involve policy dialogues, methods to periodically evaluate strategies and implementation and, possibly, regular reporting. This section will explore recommendations relating to shared governance mechanisms (with representatives from states and sub-national bodies for stakeholder integration), high level governance mechanisms through an independence bodies, and possibilities for public–private partnerships. Clearly, cooperation and partnerships around water, agriculture, and energy add value to governance and technological measures needed to address these challenges (Borgomeo et al. (2018).

In terms of empowering governing/institutional bodies to support sustainable development through the nexus approach to resource management, we must first examine and understand the existing situation and current limitations, and then use this knowledge to fortify these existing bodies and promote greater regional collaboration.

11.3.3 Critical Reflections

In terms of attempts to integrate the nexus approach through existing structures, the South Asian Association for Regional Cooperation (SAARC) Regional Expert Consultation Meeting on Water, Energy & Food Nexus in 2017 recognized the approach and its benefits in promoting cooperation. However, the increasing militarisation of resource-rich Kashmir shows challenges for comprehensive developments on this front.

Overall, in terms of international water law (IWL) itself, there have been criticisms of the disparity between IWL's guarantee to all riparian states to the fair entitlement of shared waters, and incentives for more powerful states to take unilateral actions that prejudice legitimate competing claims and threaten the wellbeing of those reliant on the water; approaches that call for more flexible management regimes that must be reconciled with the law's long-standing goal of encouraging nations to negotiate fixed entitlement treaties to provide the necessary stability for infrastructure investment; ways in which conservation and environmental issues are subsumed by consumptive short-term approaches; and issues that remain unaddressed in the IWL arena regarding the construction of largescale dams, which often do not achieve their promised deliverables and adversely affect vulnerable groups and ecosystems (Tarlock 2010).

In terms of expanding the interpretative jurisdiction regarding *rationae personae* (jurisdiction based on parties concerned) and *rationae materiae* (jurisdiction over subject matter) of the court through existing bilateral treaties, the jurisprudence of the International Court of Justice (ICJ) in *Gabcíkovo Nagymaros* (1997) is instructive. The ICJ in this case encourages the use of contemporary international laws and standards in treaty interpretation. In the context of the Indus Waters Treaty 1960 framework in the *Kishenganga* (2013) decision, the Permanent Court of Arbitration found that it was "incumbent upon this Court to interpret and apply this 1960 Treaty in light of the customary international principles for the protection of the environment in force today." However, the court also clarified that this could not be used to negate any rights in the Treaty or to go beyond expressed boundaries. Therefore, while existing structures can incorporate elements of nexus thinking, it is evident that there are inherent limitations as well. Furthermore, states generally do not pursue a nexus approach that aims to jointly manage linkages and trade-offs between these water, food and energy systems. For instance, reviewing literature on the WEF nexus with emphasis on irrigation issues, Hamidov and Helming (2020) have observed the increasing importance of the nexus approach in natural resource management in terms of multi-scalar optimization of resource utilisation and trade-offs. However, they point out that there has been limited real-world application, and that sectoral approaches tend to be emphasized. They reflect the increasing consensus that "[t]o address sustainable development, there is a need to fully integrate across research disciplines and thematic dimensions. Such studies are only starting to emerge" (Hamidov and Helming 2020).

A contrast has been drawn between the integrated water management (IWRM) approach and the nexus approach (Rasul and Sharma 2016). It has even been stated that "the equally laudable [IWRM] paradigm … was hijacked by water agencies to prevent radical transformation by focusing on technocratic and procedural solutions" (Gywali 2020). These critiques distinguish the nexus approach from sectoral approaches, advocating against development through existing sectoral models.

Overall, there is a clear need for cross-sectoral expertise and diplomacy. It may be possible for the SDG sectoral goals to be a guide for the meantime until nexus-oriented goals can be collaboratively discussed. As the common saying goes, the perfect should not be the enemy of the good. Progress can be made by studying existing domestic, regional, and global frameworks and making recommendations based on the nexus approach framed through the SDGs and broader goals of the international community to achieve peace, stability, and sustainable development.

11.4 Conflict Reduction—Lessons Learned

As demonstrated above, regional dialogue and foreign policy trends can affect future cooperation with the integration of the WEF nexus approach to promote regional peace and to reflect on recommendations from ongoing efforts to use the nexus approach. Zarei's (2020) model on the ways in which the nexus approach reduces conflict and facilitates cooperation (rather than competition) shows the way in which the nexus provides both flexibility and efficiency. Addressing the primary drivers of tensions: economic and population growth, political disputes, climate change, urbanization, and the need to develop infrastructure through an integrated, human security-centered nexus approach enables cooperation-based outcomes including shared benefits, enhanced livelihoods, resource optimization, good governance, supply meeting demand, and a holistic "win–win" framework, facilitating the achievement of equitable and sustainable growth and saving ecosystems (Zarei 2020).

The recommendations from IUCN ROWA Report (2019) are compelling and widely applicable. They emphasize the role of multi-stakeholder platforms to link scientific expertise to policy and societal understanding, and the development of public sector (including public institutions, politicians and legislators) alongside the private sector and civil society and, where relevant, agencies dispensing foreign aid. The role of civil society is significant, in that it helps to develop inclusive multi-scalar input and dialogue. Private–public partnerships are also key, as are links between research institutions and the private sector. Peaceful and effective mediation eases conflict resolution, as do expert-led movements towards common goals through the nexus approach.

A study of existing national institutional arrangements and multi-stakeholder platforms would create the knowledge base for targeted policies that implement the nexus approach. This would include taking a critical look at existing sectoral approaches and the ways in which systems affecting resource use are designed, as well as identifying potential areas for cooperation within the different domestic systems studied across a given region. The IUCN ROWA Report (2019) also recommended creating a network of experts regionally as a model for the international community to synergize the technical knowledge involved and create understanding around the nexus international law and policy framework.

The establishment/enhancement of coordination mechanisms and institutions would assist in the mainstreaming of the WEF approach in the Asian region as well. This approach, which does not require waiting for new institutions specializing in the WEF nexus, is in line with recommendations to work with existing regulations rather than undertaking a complete overhaul. Understanding the needs of the vulnerable and ensuring outreach to all stakeholders would also help identify nascent conflicts and allow for the development of expansive dispute resolution practices.

Emphasising the importance of learning (knowledge assimilation by stakeholders) to policy coherence and integration, Weitz et al. (2017) identify governance gaps that must be addressed to connect nexus conceptual frameworks and analytical tools with decision-making praxis. Integrative Environmental Governance and other meta-governance literature illuminates how technical information needs to be considered in light of cognitive factors (such as trust), value systems of institutions, ways of informing stakeholders, and the ways in which narratives are framed (Weitz et. al. 2017). Building trust, capacity, and knowledge assimilation goes towards creating a shared understanding that diminishes conflict.

Domestically, conflicts can arise because of a lack of comprehensive and integrated strategies towards water, energy, and food. Regulatory regimes that take a sectoral approach create inefficacies and tensions, as does a lack of private–public partnerships. As found by Fowler and Shi (2016) in the US domestic setting, mediation (with a neutral third party) on disputes that arise in relation to these resources can, through a nexus approach, increase stakeholder engagement and build long-term relationships between civil society, expert communities, and the citizenry at large (Fowler and Shi 2016). That said, Weitz et al. (2017) have pointed out that it is not necessary or even desirable to eliminate conflicting interests. There is increasing consensus that implementing the nexus approach does not require radically overhauling existing regulatory and governance frameworks (Larcom and Gevelt 2017; IUCN ROWA Report 2019). However, there are also warnings to avoid the sectoral approach that ended up narrowing the scope of IWRM. Furthermore, the value-based input of the SDGs and other international points of consensus on shared development and well-being would make such actions meaningful.

Regionally, there is a tendency for states to resist agreements that are binding, even when regional dialogues are established. This can be seen in the back and forth between the Ethiopian and Egyptian governments with GERD. However, progress is being made in the African Union-backed tripartite commission, with experts and observers attending the negotiations.

11.5 Conclusion

The nexus approach is directly aimed at improving human security and addressing the conditions that could otherwise lead to conflict. The potential for conflict is directly linked to scarcity and a lack of cooperative mechanisms, including security threats in major river basins and other water resources. There are also tensions caused by increasing demands for energy and the impact of dam projects on lower riparian neighbours; lower-riparian agricultural concerns (as agricultural use is the highest demand on freshwater); lack of cooperation; and a lack of due consideration for the water-food interface (integrated planning approaches and government strategies) and water-energy interface (e.g., hydropower and cooling for fossil fuel energy). The lack of joint regional responses to environmental crises, disasters, and extreme events increased by climate change leads to zero-sum approaches at national or sub-national levels, which ultimately lead to loss at every level due to mismanagement. Poverty is also a key factor, with rapid urbanisation increasing slum dwellers and increasing energy demands.

Regional approaches have shown some success. It is significant that the Indus Waters Treaty 1960 has lasted despite the ongoing conflict between India and Pakistan. Joint resources incentivise India and China to de-escalate and engage in diplomatic relations vis-a-vis their disputed boundaries. As in these and other examples mentioned above, there is a direct link between cooperating over resource security and overall political stability.

However, there is still a long way to go in terms of integrating and adapting the nexus approach at all levels. WEF management requires a multidisciplinary and integrated approach that streamlines nexus interdependencies, considering the multifaceted associations between these critical sectors. The development of cooperative bodies that take a nexus approach incentivises a joint approach to key resources, and emphasises mutual benefits and human security. It also provides a framework for offering other incentives, such as those related to trade or other elements of foreign policy, like China's One Belt One Road program and other international infrastructure-oriented approaches.

In terms of indirect incorporation, the nexus approach is also being discussed with reference to the regime of the UNECE Water Convention as well as a framework for achieving the SDGs in relevant sectors. The international community's goal setting, while still taking a sectoral approach, is developing. This can be facilitated with reference to SDGs themselves, including SDGs 16 (Peace, Justice and Strong Institutions) and 17 (Partnerships for the Goals). The 2017 SAARC Regional Meeting on the WEF nexus Approach also emphasized the nexus approach's utility in conflict prevention, which also appears to be recognized with respect to the tripartite commission set up to deal with issues arising out of the Grand Ethiopian Renaissance Dam.

As with the IUCN ROWA Report (2019) recommendation to develop existing bodies to further an integrated nexus approach, current international instruments can also be harnessed for this purpose, while developing recommendations for a more synthesized approach and international support for it as a policy goal, given the inherent limitations of existing treaty structures (as seen in the Permanent Court of Arbitration's *Kishenganga* decision).

The growing knowledge base and WEF discourse on strengthening existing cooperative agreements (e.g., Chellaney 2015), along with dispute resolution principles from river basin models, demonstrate that the WEF nexus approach offers a great deal of promise in reducing political instability and mismanagement of key resources vital to human security. If integrated into the changing approach to global governance in the post COVID-19 era, the nexus emphasis on a trans-sectoral, integrated approach could play a key role in reducing conflict in an increasingly globalized and interconnected world that faces challenges that cannot be resolved without a collective and coherent approach.

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Chapter 12
Looking into the Future of the Water, Energy, Food Nexus in Central and South Asia

Zafar Adeel

Abstract This chapter takes a horizontal transect through the book and analyzes the commonalities and divergences in perspectives offered by the various authors. It presents the trends and patterns of the nexus' security in the Central and South Asian region. It also provides an overview of the major drivers and their impacts on development, notably including climate change impacts, urban development and growth, development of new trade corridors, and management of transboundary water resources. Intersection of social issues like poverty reduction, societal inclusion, and gender dimensions of the water, energy, and food nexus are also discussed. This chapter offers some scenarios for how the situation for water, energy, and food security for the Central and South Asian region might evolve in the coming decades. It discusses how regional peace and security are dependent on sustainable availability of water, energy, and food.

Keywords Nexus scenarios · Regional trends · Food insecurity · Land degradation · Energy insecurity · Gender inequities · COVID-19 pandemic · Regional trade · Shared early-warning-systems · SDG framework

12.1 Overview

12.1.1 Objectives and Scope of This Chapter

The primary objective of this chapter is to draw together the diverse perspectives and narratives shared by the book's authors who are leaders in their respective domains, and in so doing identify findings that can be instrumental in understanding the regional challenges and opportunities. There are very few publications that provide a consolidated picture of the Central and South Asian region; most literature focus on either subregion, thus missing some key learning opportunities. It is, therefore,

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critical that a comprehensive and synthetic overview of the book be provided in this chapter.

This chapter first and foremost focuses on the major regional processes that are of significance to the water, energy, food (WEF) nexus in Central and South Asian region: food insecurity, land degradation, energy insecurity, and gender inequities. These regional processes are closely inter-twined, a fact that becomes obvious as we unpack the operative and normative functioning of these processes. The chapter than collates the regional drivers behind these processes, which include climate change, urbanization, population growth, and more recently, the COVID-19 pandemic. This listing of drivers of change is not surprising because the same have been observed in other regions of the world as well.

The chapter goes on to explores the regional opportunities to overcome the challenges embedded in the regional processes and their drivers, describing how the WEF nexus can provide a framing to solve problems. This segment of the chapter specifically analyzes the opportunities that pertain to regional trade, sharing of transboundary water resources, poverty reduction and inclusion, and development of shared early warning systems. The chapter concludes by attempting to forecast future scenarios that might unfold within the Central and South Asian region in the coming decades. These scenarios are influenced by the framing of global development objectives (in the form of United Nations' Sustainable Development Goals, or the SDGs), the role of the international community, and a number of externalities that might influence the future of this region.

In terms of the presentation of information, the content of this chapter draws heavily and exclusively from the chapters within this book; whenever possible, the author or chapter being cited is referenced. If readers of this chapter wish to delve deeper into the specifics of a matter, they are directed to the corresponding chapters which provide the underlying data, a detailed data and information analysis, synthesis of prevailing scientific knowledge, and the cited sources for all pertinent information. To state the obvious, this chapter is not meant to be an exhaustive or all-inclusive summary of all the chapters; rather, it extracts ideas and information that support the overall narrative.

12.1.2 Regional Trends of Water Resources

The countries in the Central and South Asian region have vastly different environmental, social, economic, and political settings; although there is a significant commonality in history and trade. Akram et al. (Chap. 10) argue that the region now requires collective governance of its water, energy, and food resources to have greater overall impact in reaching development objectives.

This region presents a unique situation because it includes some of the least developed countries, and their economies are highly dependent on transboundary water resources. In particular, the availability of water resources has undergone a drastic change in the recent decades. For example, the annual water availability (surface water) per capita in India around 1950 was more than 5,000 m^3/person and it is expected that by 2025 this figure will drop to 1,500 m^3/person (Rahimzoda, Chap. 4). Similarly, this indicator for Pakistan decreased from 5,260 m^3/person in 1951 to 1,000 m^3/person in 2016. By 2025, it is expected to drop further to 860 m^3/person, which will mean Pakistan can be designated as a water scarce country. In Afghanistan, water availability per capita decreased from about 5,000 m^3/person in 1962 to about 1,400 m^3/person in 2014; this will further drop to 1,105 m^3/person by 2025.

Rochholz et al. (Chap. 6) describe that water scarcity in Central Asian is going to be further exacerbated due to climate change. These changes in meltwater discharge will not only directly affect freshwater availability from large rivers, but also food availability, due to the strong dependency of agriculture on irrigation. The situation is somewhat different in South Asia, where countries receive significant amounts of rain through monsoon seasons, for which heavy rainfall events are forecasted to be of higher intensity and higher frequency. This situation in South Asian countries poses a much greater risk of flooding, which can be particularly dangerous in densely populated coastal areas (Rochholz et al., Chap. 6). Over the past decade, there has already been a higher frequency of extreme flood events and higher corresponding damages have been documented. Therefore, it becomes critical to deploy early-warning systems that are enabled with dissemination mechanisms and provide information on near-real time impacts of floods and droughts on food and energy provision (Zia, Chap. 5).

12.1.3 The Water–Energy Nexus

Notionally, the countries of Central and South Asia are rich in potential energy resources, whereas water scarcity prevails at different magnitudes. Therefore, it becomes critical that water and energy equation is balanced in a way that it directly contributes to their social, economic, and human development in a sustainable manner (Rahimzoda, Chap. 4). A major intersection of the water and energy resources is in the form of hydropower generation, which is often couple with provisioning of drinking and irrigation water supplies.

Overall, the potential for hydropower in the region is grossly underutilized. For example, the Central Asian region so far uses only about 10% of its existing cost-effective hydropower potential and the share of hydropower in the total electricity generation in the region is just over 21% (Rahimzoda, Chap. 4). The energy insecurity is discussed in greater detail in Sect. 12.2.3. It is important to point out that the construction of reservoirs for hydropower generation allows improved regulation of river flows over several years and seasonally. Such approaches can become part of the regional water security and sharing of resources for human and agricultural consumption. Additionally, generation of relatively inexpensive hydropower can reduce the reliance on non-renewable energy sources; currently, oil, natural gas, and coal are being used intensively electricity generation (Rahimzoda, Chap. 4).

12.1.4 The Food–Water Nexus

Climate change impacts on food availability are closely tied to water availability (Rochholz et al., Chap. 6); this correlation is robust, even when accounting for uncertainties in model simulations for exact regional temperature and precipitation development. Overall, agricultural production and the food sector tend to be the most significant consumer of water in the Central and South Asian region. For example, agriculture accounts for more than 90% of total water withdrawals in Pakistan (Rahimzoda, Chap. 4). Irrigated agriculture and, consequently, water resources have always played an important role in the economic development of Pakistan and are likely to continue to do so in the future. Agriculture accounts for around one quarter of the country's GDP and employs 44% of the labour force. Similarly, agriculture is also a major water consumer for India and plays an important role in the socio-economic development of the country. The agriculture sector employs about half of the workforce and accounts for about 15% of India's GDP (Rahimzoda, Chap. 4). The correlation between water insecurity and its impacts on food insecurity is discussed in detail in Sect. 12.2.1.

12.2 Major Regional Processes in Central and South Asia

12.2.1 Food Insecurity

There are clear indications at the global scale that climate change impacts are adversely affecting the agronomic yield (Lal, Chap. 2; Rochholz et al., Chap. 6). This finding is also true for the Central and South Asian region; a situation that is further exacerbated by wastage of food—which amounts to 30–40% of grains and even more for fruits and vegetables. This food insecurity hits women particularly hard; it is linked to poverty and is a major reason that women and girls experience unequal food insecurity (Mawani, Chap. 8). It can, therefore, be argued that collective, regional action is critical to addressing the cross-cutting issue of food and nutritional insecurity. These actions must mitigate the risk of declining agronomic productivity and aggravating soil degradation driven by climate change and inappropriate management practices for soil, crop, and water resources (Lal, Chap. 2).

The statistics for food insecurity in Central and South Asian region show some interesting trends, with the Central Asian countries faring better. The number of under-nourished people in Central Asia was 6.5 million 2005 and reduced to 2 million in 2019, with a further decrease projected during this decade (Lal, Chap. 2). Comparatively, the number of food-insecure people in the South Asian region decreased from 328 million in 2005 to about 258 million in 2019; this number is projected to fall further to about 204 million by 2030 (Lal, Chap. 2). It can be concluded that there is a significant trend of reducing the absolute number of undernourished people and increasing agricultural productivity, which can be contrasted by significant reduction in cropland area over the same period of time.

Lal (Chap. 2) outlines a number of strategies than can be adopted to achieve better nutritional and food security in the South and Central Asian region. These include the following approaches: further improving agricultural productivity; enhancing food distribution mechanisms and networks; enhancing access to food; and strengthening public/private sector partnership. For city dwellers, urban agriculture can contribute positively to achieving food security of urban households and assist in developing new livelihoods; sky farming based on tall glass buildings and recycling of gray and black water are among related innovations. Further, there is a need for transformation to climate-resilient and negative emission farming techniques and reversing the widespread problem of soil and land degradation (further discussed in Sect. 12.2.2).

12.2.2 Land Degradation

Land degradation is closely related to soil quality and its degradation, and is a major challenge on the horizon for the Central and South Asian region. Some of the most prominent drivers of soil degradation relate to agricultural practices in the region and include decline of soil structure together with crusting and compaction, accelerated wind and water erosion, excessive water withdrawals causing water contamination, depletion of soil organic matter and plant nutrients by extractive practices, rapid salinization, waterlogging, and acidification of soil caused by flood irrigation (Lal, Chap. 2).

Each of these processes can be addressed through system-wide and comprehensive management approaches (Lal, Chap. 2). Sustainable intensification involves strategies which enhance crop yield but reduce its negative environmental impacts. Similarly, the concept of eco-intensification focuses on enhancing efficient inputs and producing more from less. Some recommended management practices must also be supported in conjunction with intensification approaches: these include restoration of the soil organic matter content, rainwater harvesting, efficient use of water, and integrated soil fertility management. Further, such policies must discourage soil-destructive approaches such as in-field burning of crop residues, scalping of topsoil for brick making, using flood-based irrigation, puddling of soil followed by inundation of rice paddies, and overusing fertilizers.

Lal (Chap. 2) also identifies some emerging technological solutions that can effectively counter land degradation in Central and South Asia. Innovative solutions based on nanotechnology are readily available but will require development of corresponding structures for their implementation. For example, colloidal nanosilica can be used to enhance soil water storage and improve soil structure. Using zeolites as amendments can improve soil structure, enhance soil water storage, and improve fertilizer use efficiency (Lal, Chap. 2).

12.2.3 Energy Insecurity

Rahimzoda (Chap. 4) describes that the fossil fuel resources in Central and South Asian regions are unevenly distributed. Most countries in the region do not have significant oil and gas resources; for Tajikistan and Kyrgyzstan, their coal resources are located in high mountain areas, which makes their extraction difficult and expensive. This situation points to: (a) a present dependency on imported fossil fuels, (b) a high level of energy insecurity because of fluctuations in the international fossil fuels market, and (c) numerous opportunities for introducing renewable energy sources. The most prominent among the renewable energy sources is hydropower—with available water resources and convenient geographical conditions (Rahimzoda, Chap. 4).

Presently, Central and South Asia countries are widely applying hydropower for energy production and regulation of river flow (Rochholz et al., Chap. 6). However, such hydropower generation units are faced with some challenges. For example, changes in Central Asia's river flow throughout the year poses difficulties for solving conflicts about water sharing between agriculture and hydropower generation, while increasing the risk of flooding. Similar risks are posed for the South Asian countries as well, plus the additional risk of prolonged heatwaves and droughts (Rochholz et al., Chap. 6).

Throughout the region, the use of hydropower in comparison to its potential for energy generation remains low (Rahimzoda, Chap. 4). For example, Pakistan's hydropower potential is 60,000 MW, but only about 9,700 MW has been developed so far; this hydropower generation accounts for about a quarter of Pakistan's power generation needs with a vast majority still being produced via thermal power generation. In Afghanistan, the hydropower generation at 254 MW accounts for about half of the installed generation capacity, whereas the total peak demand in 2032 is projected to be about 3,500 MW. The hydropower potential is estimated at 148,700 MW; the country ranks 5th in the world in this regard. Hydropower generation in India accounts for about 10% of its overall energy generation.

12.2.4 Gender Inequities

The Central and South Asian constitute about a quarter of the global population, with women comprising half of the population. Women are stakeholders both as consumers and producers, besides being active agents of change (Pandey and Midha, Chap. 7). It is, therefore, essential to examine and ensure greater participation of women in policy planning and implementation around the nexus of water, energy, and food security. Their limited adaptive capacities and restricted access to resources arise from prevailing socio-economic inequalities, patriarchal culture, and gender stereotypes, which are manifested through differences in property rights, lack of employment, and unequal access to information and resources (Pandey and Midha, Chap. 7; Mawani, Chap. 8). The constrained roles and undervalued positioning of women in resource governance and production, are hindrances to achieving gender equality in society.

These persevering inequities have meant that women in this region are disproportionately impacted by climate change, and these impacts show up in terms of heightened food insecurity (Mawani, Chap. 8). For example, the gendered impacts of these climate change manifestations on rural South Asian women include increased pressure to provide food for the family, consuming decreased quantities of food as well as eating poorer quality food in relation to men, increased domestic responsibilities, and greater health impacts (Mawani, Chap. 8).

Water stewardship is a key factor in the current gender-based inequities: Women and girls spend an estimated 200 million hours a day collecting water (Pandey and Midha, Chap. 7). In Asia, on a daily basis, women and children walk an average of 6 km to access water, which often times is not safe for human consumption. The economic cost of women's unpaid work as water collectors is enormous, with the figure for India alone equivalent to a national loss of income of about $160 million (Pandey and Midha, Chap. 7).

In many developing countries, women spend over an hour each day collecting fuel wood and water, and nearly four hours are spent cooking (Pandey and Midha, Chap. 7). Indoor air pollution from using combustible fuels for household energy caused 4.3 million deaths in 2012, with women and girls accounting for six out of every ten deaths. The proportion of rural households in Central and Southern Asia relying on solid fuels is as high as 89% (Pandey and Midha, Chap. 7).

Food insecurity is a major element of the gendered inequities in Central and South Asia. Ironically, a large fraction of women in this region are engaged in the agricultural sector, with an increasing feminization of this sector (Mawani, Chap. 8). In South Asia, 69% of women are engaged in agriculture; this proportion ranges from 28% in Sri Lanka to a far higher 74% in Nepal, with more than 50% in India, Bangladesh, Pakistan, and Bhutan (Pandey and Midha, Chap. 7). Conversely, Asia reports the highest gender-gap in terms of land holding by women. Female land ownership is 16.3% in Sri Lanka, 4.6% in Bangladesh, 12.4% in Kyrgyzstan, 8.1% in Nepal and 11.7% in India (Pandey and Midha, Chap. 7). Bhutan is the only country in where 70% of farmland is owned by women. Women participate in agriculture as unpaid or low paid seasonal labourers, without much recognition as agents of production and are therefore often left out of social protection systems (Pandey and Midha, Chap. 7). Pregnancy and lactation further increase the impact of food insecurity on women, particularly among women who do not have an income (Mawani, Chap. 8).

Mawani (Chap. 8) argues that there are some clear pathways for improving gendered food and water security in this region, which would entail providing better access to education for girls, and targeted interventions relating to women's livelihoods. Similarly, comprehensive sexuality education and family planning among men, boys, girls, and women, coupled with increasing awareness of the disproportionate burdens girls and women face are important in reducing water and food insecurity faced by women (Mawani, Chap. 8).

12.3 Drivers of Regional Processes in Central and South Asia

12.3.1 Climate Change

It is important to recognize that Central Asia with an area of about 4.0 million km^2 and South Asia with about 6.9 million km^2 cover about 7.3% of the Earth's terrestrial surface (Rochholz et al., Chap. 6). The Central Asia region comprises different climate regimes, varying from arid deserts to mountain ranges with high precipitation rates; there is a strong influence of the Pamir and the Tien Shan Mountain ranges on the available water resources in Amu Darya and Syr Darya (Rochholz et al., Chap. 6). The South Asian region has greater ecosystem diversity and comprises tropical and subtropical moist and dry broadleaf forests; tropical and subtropical grasslands, savannas, and shrublands; deserts and xeric shrublands; and mangroves (Rochholz et al., Chap. 6).

For many regions of South and Central Asia, current climate change is marked by an increase in mean surface air temperature (i.e., 1.1–1.8 °C in South Asia and 0.7 °C in Central Asia). These temperature changes have been accompanied by more frequent warm days, while the numbers of cold days have decreased consistently (Rochholz et al., Chap. 6). Precipitation frequency and intensity in South Asia, especially in the tropical countries has changed towards more heavy rainfall events with decreased frequency of light rain events and extension of dry periods. Early season melting of snow and glaciers in high mountain areas of Asia affects the potential of the large rivers of South and Southeast Asia, such as Brahmaputra, Yellow, Yangtze, Indus, and Mekong, in particular to buffer water resources for drier seasons (Rochholz et al., Chap. 6). The largest freshwater source of the arid Central Asia area, the Aral Sea, is likely to continue to shrink under decreasing inflow of tributary rivers, already endangered by increased water evaporation and precipitation changes.

Climate change forecasts indicate a robust temperature increase for the ocean surface, indicating a strong vulnerability of the ocean. This implies that the regional sea level rise for coastal countries in South Asia is likely to exceed the global mean (Rochholz et al., Chap. 6). Observations already indicate a yearly sea level rise of about 1.0 mm in the Bay of Bengal. While regional differences exist, sea level will rise at all coasts across South Asia and pose threats for human life, especially in densely populated areas. For example, computations show that a 1 m sea level rise would displace 7.1 million people in India (Rochholz et al., Chap. 6). Additional threats in coastal areas are salt-water intrusions into rivers and river-flooding under rising sea levels.

Rochholz et al. (Chap. 6) also offer a commentary on the state efforts in the Central and South Asian region to combat climate change, which primarily focus on mitigation and to a lesser extent on mitigation. The national adaptation plans outline the political strategies adopted, while outlining the existing difficulties that prohibit nationwide efforts towards implementation of these adaptation plans. The prohibiting factors include the lack of widespread financial support and lack of integration of adaptation into climate change policies (in addition to mitigation) or the lack of clear institutional structures to initiate and supervise adaptation projects.

12.3.2 Urbanization

Rapid urbanization and increases in the average income in the Central and South Asian region have resulted in the growing use of energy and consumption that exceeds basic needs, even causing food-, water-, and energy-wastage (Adeel and Böer, Chap. 1). For most of the largest and fastest growing urban centres in the region the supply of food, energy, and water resources is dependent on rural areas and often on transboundary trade. It is argued that the larger the scale of urbanization, the larger its environmental footprint can be found for the surrounding area; such enhanced ecological footprints can cause an increase in natural habitat loss via encroachment of agricultural ecosystems into natural places.

Air quality degradation has emerged as a major side-effect of urbanization, which is exacerbated further by the burning of agricultural by-products, in addition to vehicular emissions and dust (Adeel and Böer, Chap. 1). For example, New Delhi counts as one of the most air-polluted cities in the world. The water-demand of urban places is frequently supplied by water resources further away from the cities, such as dams, rivers, and aquifers, causing significant and ecologically noticeable pressure on the water-source.

Adeel and Böer (Chap. 1) argue that it is very important to implement measures that aim at increasing the efficiency of urbanization and land use, including via good infrastructure planning that supports efficient use of energy, water, and food, considering waste reduction, forest conservation and restoration, as well as evidence-based ecosystem management.

12.3.3 Population Growth

Rochholz et al. (Chap. 6) point out that there are considerable differences in the demographic and socio-economic character between Central Asia and South Asia. Central Asia is sparsely populated (18.4 person/km^2) with primarily small differences between countries, for example, Kazakhstan (6.8 person/km^2) and Uzbekistan (75 person/km^2). In contrast, South Asia is one of the most densely populated regions worldwide, with a population density of about 278.9 person/km^2; where countries such as India, Bangladesh, and the Maldives face a particularly high population pressure (Rochholz et al., Chap. 6). In addition, large socio-economic inequalities, not only between countries but also within individual countries, affect the vulnerability and adaptive capacities to projected climate change.

Further, Rahimzoda (Chap. 4) points out that population growth in the region will likely continue in the future. It is expected that the population of Central Asian countries will reach 83.8 million by 2030 and 100.25 million by 2050. In the same timeframe, Afghanistan is expected to reach 48.1 and 64.7 million; Pakistan 262.96 and 338.01 million; India, 1.50 and 1.64 billion, respectively. According to these estimates, India will surpass China in terms of population by 2027 (Rahimzoda, Chap. 4).

12.3.4 The COVID-19 Pandemic and Related Health Crises

The COVID-19 pandemic started in China in November 2019 and caused the step-by-step partial or complete lock-down of countries around the world. It has caused global havoc and the Central and South Asian region has not been immune to its impacts on the economy, public health, and social structures (Adeel and Böer, Chap. 1). The United Nations Development Programme and the World Bank have projected that COVID-19 will increase both income and multidimensional poverty, as well as exclusion and inequality (Tiwari, Chap. 9). It can be argued that the COVID-19 pandemic threatens many of the development gains already achieved. With a prolonged crisis it is likely that children from vulnerable households will be out of school and/or become undernourished due to lack of adequate nutrition. This could push those households into multidimensional poverty (Tiwari, Chap. 9).

Mawani (Chap. 8) argues that the COVID-19 pandemic has disproportionately impacted women generally, and some groups of women more specifically. It exacerbated some long-standing inequalities within households in consumption of nutritious food, and the higher incidence of malnutrition and poor health associated with these patterns. There is also evidence of increase in violence against women across South Asia, with over 37% women reporting having experienced intimate partner violence (Mawani, Chap. 8). The uneven impacts of pandemics on women stem from enduring patterns of economic and food insecurity, precarious employment, gendered violence, unpaid care work, and poor access to healthcare.

12.4 Major Opportunities in Central and South Asia

12.4.1 Regional Trade Corridors and Geopolitical Considerations

Energy-based trading has great potential in the Central and South Asian region, where a number of energy corridors have been discussed, primarily meant to export oil and natural gas from Kazakhstan and Turkmenistan to rest of the of the world (Adeel and Böer, Chap. 1). A typical example of such a corridor is the gas pipeline project called the Turkmenistan-Afghanistan-Pakistan-India (TAPI) gas pipeline, although this project has been marred because of the uncertainties surrounding natural gas supply in Turkmenistan, the worsening security situation in Afghanistan, and the escalating political tensions between India and Pakistan (Adeel and Böer, Chap. 1).

The CASA-1000 project, that intends to connect the Central and South Asian countries with a 1,300 MW high-voltage power transmission line, is another energy sector initiative. Through CASA-1000 the surplus electricity from Tajikistan and Kyrgyzstan will be transmitted to energy-demanding Pakistan and Afghanistan during the summer (Rahimzoda, Chap. 4); this project was initiated by the World Bank and is currently being implemented.

In terms of general regional trading opportunities, the Chinese Belt and Road Initiative (BRI) offers a platform for infrastructure and economic development, which can in turn facilitate regional trade (Adeel and Böer, Chap. 1). Because of China's immediate proximity to the Central and South Asian region, the BRI has interlinkages to essentially all the countries in that region. Given the scale of China's economic investments, the potential impacts on the developing and intermediate economies in the Central and South Asian region can be very significant. An ongoing analysis of the BRI's influence on the WEF nexus is therefore critical.

12.4.2 Sharing of Transboundary Water Resources

An analysis of the status of renewable freshwater resources in the Central and South Asia region suggests that the annual renewable water resources stand at 1,173 m^3 per capita, which indicates that the region does not have sufficient water resources—that is, less than 1,700 m^3 per capita, a universal threshold value for water scarcity (Qadir, Chap. 3). The water resources are further expected to decrease to 991 m^3 per capita by 2030 and 853 m^3 per capita by 2050.

It can, therefore, be argued that securing water resources and ensuring equitable management of water resources in the Central and South Asian region urgently requires transnational efforts (Rochholz et al., Chap. 6). Such efforts must include exchange of hydrological data, forecasting and flood management, joint research, control and monitoring of water resources, development and implementation of joint multi-purpose projects, and allocation and management of water resources (Rahimzoda, Chap. 4). While five different countries, Kyrgyzstan, Tajikistan Uzbekistan, Turkmenistan, and Kazakhstan depend on the water resources of Syr Darya, four countries are involved in water management of the Indus and Ganges–Brahmaputra–Meghna basins: Bangladesh, India, Nepal, and Pakistan (Qadir, Chap. 3). However, such sharing of water resources is not without its challenges. Current efforts in Central Asia to manage water-resource demands in the Syr Darya basin reveal disputes between Kyrgyzstan and Uzbekistan and will become more complicated with decreasing water resources under climate change (Rochholz et al., Chap. 6).

In view of looming water scarcity, recycling and reusing ‘used water’ become more crucial in water-scarce areas (Qadir, Chap. 3). Currently, 32.8 billion m^3 of municipal wastewater are produced annually across the Central and South Asia region. Of this volume, 10.2 billion m^3 of wastewater are collected, i.e., 31% of the wastewater produced (Qadir, Chap. 3). The release of such large quantities of untreated wastewater carries health and environmental impacts. Importantly, however, there is a missed opportunity of not capturing and reusing the valuable resources—water, nutrients, and energy—embedded in wastewater. The scope of harnessing the potential of unconventional water resources varies in the region and depends on the water needs for purposes and associated policy and institutional support, human resources, and scale of investments required.

Qadir (Chap. 3) argues that there is a need for a radical rethinking of the public policy agenda by prioritizing water conservation, water recycling, and reuse; ensuring sustainable water resources augmentation; and supporting productivity enhancement of available land and water resources, particularly those underperforming. Skilled professionals, supportive institutions, and strengthening institutional collaborations are the key to support the implementation of such policy actions.

12.4.3 Poverty Reduction and Inclusion

It is important to point out that poverty is a complex, multidimensional phenomenon that encompasses both income and non-income deprivations (Tiwari, Chap. 9). That means various non-income deprivations can also affect people’s well-being; these include inadequate education, lack of health care, low-quality housing, lack of water, sanitation, and energy, or working in a hazardous environment. Extreme poverty and vulnerability remain a stark reality in the Central and South Asian region (Tiwari, Chap. 9). With modest economic growth, the two sub-regions have made progress on poverty reduction and human development, but remain highly vulnerable.

A key measure of achievement against poverty reduction is the Human Development Index (HDI), which presents a cumulative picture of achievements in three key dimensions of human development: a long and healthy life, access to knowledge and a decent standard of living (Tiwari, Chap. 9). The 2020 Human Development Report presents the HDI ranking, which varies widely across the 13 countries of Central and South Asia. In terms of this HDI ranking, the Central and South Asian region spans a large spectrum: Kazakhstan stands at the 51st, with Afghanistan at the 169th position out of 189 countries and territories. Overall, Kazakhstan lies in the Very High Human Development Group, and all other countries have high or medium levels of development, excluding Afghanistan. Overall, the Central Asian countries have a higher level of human development, whereas the South Asian countries are making faster progress in poverty reduction (Tiwari, Chap. 9).

Promoting inclusion requires a holistic approach addressing multiple inequalities and exclusions. Tiwari (Chap. 9) argues that progressively achieving and sustaining income growth of the bottom 40% of the population at a rate higher than the national average will help address exclusion. Empowering the poor and deprived also requires building other forms of human capabilities like food and nutrition, education, housing, and other services including energy and water. Similarly, developing social protections is an important instrument to reduce poverty, inequality, and exclusion (Tiwari, Chap. 9).

12.4.4 Shared Early Warning Systems

In the Central and South Asian region heavy weather events have significantly increased in frequency, duration, and strength in the past decades, highlighting the need for reliable climate predictions for the near and distant future (Zia, Chap. 5; Rochholz et al., Chap. 6). There remains considerable uncertainty surrounding the projection of the changing frequencies and intensities of these events at multiple scales (Zia, Chap. 5). This uncertainty about changes in extreme events hinders local- to regional-scale efforts points to the need for adequately incorporating the risk from extreme events in the decision-making processes of critical actors engaged in the production and consumption of food, energy, and water.

In general, early warning systems are established to mitigate hazards and can act on a multitude of temporal and spatial scales (Zia, Chap. 5). The temporal scales of lead times can potentially range from minutes in the case of earthquakes and tsunamis, to hours in the event of river flooding, and often months in the case of drought. This broad range of temporal scales—from hours to decades—must be incorporated into any early warning systems that deal with WEF nexus (Zia, Chap. 5). Zia (Chap. 5) further posits that deployment and continual improvement of such early warning systems may enhance stakeholder understanding of nexus interactions, couplings, and processes, further facilitating the understanding of social and ecological risks. Short- to medium-term forecasts can be used by policy makers, managers, and citizens, whereas long-term forecasts are more suited to strategic investments and related decision making. As Asim (Chap. 5) states, given the novelty of Nexus-EWS as an emergent concept, a variety of fragmented early warning systems are deployed at various scales, community to sub-national to national to transboundary systems. These fragmented EWS do not necessarily account for the nexus, rather the EWS are operational in separate domains, e.g., flood early warning systems, drought early warning systems, and famine early warning systems. In 2010, NASA and US-AID SERVIR program was expanded to Hindu Kush Himalaya, covering most of the mountainous terrain in the Central and South Asia.

It is important to reduce the level of fragmentation often encountered in various domains—notably the divergence between flood early warning systems, drought early warning systems, and famine early warning systems (Zia, Chap. 5). Effective design and deployment such integrated early warning systems in Central and South Asian region faces considerable scientific and technological challenges. The most significant challenge, by far, is the lack of cooperation between a number of countries in data sharing; narrow geopolitical and compartmentalized policy goals that tend towards securitization of water, energy, and food resources hamper scientific and technological cooperation (Zia, Chap. 5). Utilization of open-sourced satellite data can play a role in reducing the fragmentation of early warning systems. This outcome can be achieved if the traditional securitization approaches are relaxed towards greater flexibility in scientific and technological cooperation in transboundary river basins (Zia, Chap. 5).

12.5 Future Directions

12.5.1 Using the SDG Framework

The Sustainable Development Goals (SDGs) adapted by the United Nations General Assembly in 2015 present the global roadmap for addressing economic, social, and environmental challenges facing the world. The various SDG targets and indicators have a bearing on the WEF nexus, and require interdisciplinary and inter-sectoral efforts (Adeel and Böer, Chap. 1; Rochholz et al., Chap. 6). Akram et al. (Chap. 10) posit that a WEF nexus framework provides a holistic approach for addressing the disconnect between the three sectors and address multiple SDG targets.

At present, the implementation of SDG targets remains generally deficient in the Central and South Asian region (Rochholz et al., Chap. 6). Analysis based on national reporting indicates that Central Asian countries implemented the SDGs better than South Asian countries (average country rank 75 compared to 102). For example, Kyrgyzstan performed best in the region, ranking 52nd out of 166 countries rated. Overall, the regions' commitment to take effective climate action (SDG 13) and achieve the land degradation neutrality (SDG 15) do not appear to be on track to achieve the respective targets by 2030 (Lal, Chap. 2). Similarly, stronger investments in agriculture and related transformational changes in policies are needed to achieve SDG 2 (Zero Hunger) (Lal, Chap. 2). Equally, SDG 5 (Gender Equality) is a touchstone and crucial for the sustainable transition and transformation to achieve other SDGs, particularly those linked with water, energy, and food security (Pandey and Midha, Chap. 7).

Akram et al. (Chap. 10) have identified the major roadblocks in implementation of the SDG targets related to the WEF nexus. These roadblocks include: the limited availability of reliable data which weakens evidence-based decision-making; lack of awareness of the benefits of using the nexus approach by relevant stakeholders; negative externalities due to low or no pricing of water and energy use in the Central and South Asian region; and, inadequate coordination between relevant stakeholders because they perceive the transaction costs of coordination to be higher than their benefits.

Mobilizing adequate finances for successful SDG implementation also remains a major challenge (Akram et al., Chap. 10). The finances required for the implementation of SDGs fall in the range of USD 5–7 trillion per year, including USD 3.9

trillion per year for basic infrastructure in developing countries. Analysis by Akram et al. (Chap. 10) shows an annual gap in investments of about $2.5 trillion to meet the SDGs objectives, a major portion of which needs to go towards water, energy, and food security and can be translated into future financial savings. Importantly, the investment requirement of this scale is not feasible under constrained public spending or Official Development Assistance (ODA). Private financing needs to be triggered to fill the financial gap, and Public–Private Partnerships (PPPs) have the potential to attract these additional resources (Akram et al., Chap. 10).

To overcome these challenges, Akram et al. (Chap. 10) proposes that a more comprehensive and integrated strategic planning for operationalizing synergies and minimizing trade-offs in the WEF nexus is needed. Doing so will help the Central and South Asian region achieve some significant co-benefits. Therefore, this requires strengthening institutional coordination for mainstreaming SDGs within countries. There is also a need for regional collaboration and developing approaches and policies than can overcome any political inertia and lack of trust between countries.

12.5.2 Potential for Cooperation or Conflict Prevention?

Lone (Chap. 11) describes that human security involves the management of five key resources: land, energy, food, water, and minerals, and a zero-sum approach to these resources can result in international conflicts. The need for regional cooperation is underlined because of some geopolitical factors that give the region strategic significance, including the involvement of three nuclear powers (China, India, and Pakistan). The distribution of water, energy, and food resources necessary for the countries in the region to function properly are not distributed along the lines of international boundaries. This situation points to a clear need to address these issues coherently as potential flashpoints exist in the Central and South Asian region (Lone, Chap. 11).

The WEF nexus approach generally advocates cooperation over shared resources at domestic, regional, and international levels, particularly because there is significant positive correlation between security of these resources and political stability (Lone, Chap. 11). The combination of increasing demand and increasing scarcity, climate change, urbanization trends, poverty, societal inequities, and the transboundary nature of key resources show the need for a coherent and cooperative approach to achieve regional peace and stability (Lone, Chap. 11).

Akram et al. (Chap. 10) argue that if Central and South Asian countries choose to cooperate and manage their transboundary resources in the framework of the WEF nexus, it will result in the economic benefit to all the nations sharing these resources. There is also growing evidence that the river basins that constitute the most contentious aspect of the resource nexus can be managed to provide maximum economic benefits for all nations in the region. Progress can be made by studying existing policy frameworks and making recommendations based on the nexus approach framed through the SDGs to achieve peace, stability, and sustainable development (Lone, Chap. 11). Multi-stakeholder platforms, established through regional cooperation mechanisms, can be used to link scientific expertise to policy and societal understanding, and the development of public sector (including public institutions, politicians, and legislators) alongside the private sector and civil society and, where relevant, agencies dispensing foreign aid (Lone, Chap. 11).

12.5.3 Gazing into the Crystal Ball: Outlook for the Coming decades

The diversity of perspectives and approaches encapsulated in this book paint a picture that straddles hope and optimism on the one hand, and adverse trends on the other hand can lead to pessimistic conclusions about the state of water, energy, and food resources in the Central and South Asian region. It is indeed challenging to reach definitive conclusions about this topic. The diversity of processes and the underlying drivers have been discussed in this chapter, in view of the contributions made by individual chapters. A number of externalities, such as the geopolitical considerations described by Adeel and Böer (Chap. 1), also play a significant role and will continue to torque any outcomes related to the nexus.

Collectively viewing the trends, it is reasonable to argue that there are some solid reasons for optimism. Those reasons are briefly summarized as follows. First, the economic and political benefits for a shared and holistic management of water, energy, and food resources far outweigh any costs—real or perceived—accrued by following a securitized approach. Second, recent events—such as the COVID-19 pandemic, or the withdrawal of United States' forces from Afghanistan, or the Ukraine–Russia conflict—have shown that historical geopolitical consideration can be set aside to achieve outcomes of common interest. Third, the political leadership in the region has shown that it can come together to take bold action of challenges that are perceived to be a common threat. The China-Pakistan Economic Corridor, a $46 billion initiative as part of the larger Belt and Road Initiative, is an example of such decision making. CASA-1000 energy-sharing initiative is yet another example.