Contribution of Himalayan Ecosystems to Water, Energy, and Food Security in South Asia: A nexus approach

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FOR MOUNTAINS AND PEOPLE

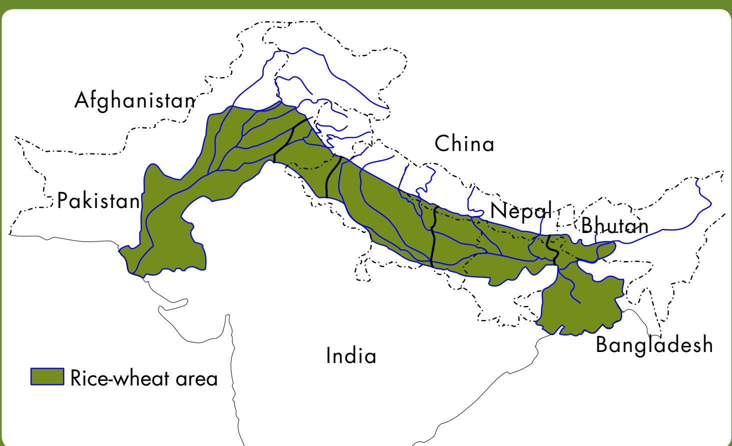
Food, water, and energy security is a common challenge for the countries of South Asia

South Asia,[1] while developing rapidly both industrially and economically, faces difficult challenges to meet the growing demand of its burgeoning population for food, water, and energy in the face of climatic and other socioeconomic changes. Most South Asian countries – having large population, limited land resources, and growing water stress – face a common challenge of how to grow more food with the same or less land, less water, and increased energy prices. Rice and wheat, the staple foods in South Asia, require huge amounts of both water and energy. It is necessary to understand how food, water, and energy are entwined and how these relationships influence long-term agricultural sustainability and food security[2] in South Asia.

More than 40% of the world's poor live in South Asia. Some 51% of the region's population is food-energy deficient – a proportion almost as high as that in sub-Saharan Africa (57%) (Ahmed et al. 2007). About 20% lacks access to safe drinking water (Babel and Wahid 2008). Any large disturbance in grain supply in this region could have global ramifications, for example by increasing world food prices.

The Indus-Ganges-Brahmaputra plain is both one of the most populous areas in the world and one of the largest areas of irrigated agriculture, depending in large part on water from the Himalayas. The plain's rice-wheat system produces the bulk of the sub-region's food grains (Figure 1). The other main farming systems in the region are highland mixed, rice, rain-fed mixed, and dry rain-fed. With high population growth and changes in diet from an increasingly urbanized population, demand for food and water is rapidly increasing.

Figure 1. **The Indus-Ganges-Brahmaputra plain – bread basket of South Asia**



Challenges ahead for South Asian agriculture

- Per capita agricultural land has been declining sharply.
- The ratio of agricultural land to total land is high, varying from 35% in Nepal to 70% in Bangladesh (Rasul 2010).
- Scope for increasing food production by bringing additional land under cultivation is limited, as most of the suitable land is already under cultivation.
- Higher agricultural production has to come from the same amount of land.
- From 1990 to 2025 the population of South Asia will almost double, and cereal demand is expected to increase at least proportionately.
- Water scarcity in much of South Asia limits the potential for additional supply, while water demand is rapidly expanding for food production, for cities, and for energy.

Climate change is a major concern in the sub-region; its impacts include changes in temperature and precipitation, increased climatic variability, altered monsoon patterns, and increased frequency of extreme events such as drought and flood, as well as accelerated melting of Himalayan glaciers, all causing alterations in natural resources and the environment. Future availability of freshwater is uncertain given changes in glacier, snow, and permafrost melt and shifting rainfall patterns. Cereal production is expected to suffer more in South Asia than in other regions; crop yields in South Asia could decrease by up to 30% by 2050 with no change in practices (IPCC, 2007).

[1] In this document, 'South Asia' refers to the mainland countries of Bangladesh, Bhutan, India, Nepal, and Pakistan – a region also referred to as the Indian sub-continent or the sub-Himalayan region.

[2] Although the concept of food security includes both physical availability and economic and social access to food, this document focuses on food production, i.e., the physical availability of food at the national level.

Interlinkages of food, water, and energy security in South Asia: competition for scarce resources

With increasing demand for and scarcity of land, water, energy, and natural resources for competing uses, the challenge is to minimize trade-offs and maximize synergies.

Land is needed for food, for energy (e.g., to grow biofuel crops), for hydropower (reservoirs), and for ecosystem conservation. Water is needed for food and for energy, and energy is needed for water (to secure, deliver, treat, and distribute it). Energy is needed for agriculture and for processing, transport, and cold storage of food. Energy and water resources are also used for the collection, treatment, and disposal of wastewater and solid waste.These interlinkages pose significant management challenges.

Water and energy are inextricably linked with food production. Energy prices influence prices of inputs such as irrigation and fertilizers, transportation of agricultural inputs, and processing and marketing of foods. Many countries in South Asia, by subsidizing energy for irrigation to increase agricultural producation, have contributed to overexploitation of groundwater, paradoxically jeopardizing long-term agricultural sustainability. Moreover, increased energy prices may divert land for energy crops by changing relative profitability of food and energy crops.

Agriculture also contributes to energy; biomass and crop residues are traditional sources of rural energy, and energy crops are used to produce biofuels. However, energy crops can compete with food crops for irrigation water and land. On the other hand, when biofuels are grown on unused or waste land as in India, they may enhance energy security and contribute to food security.

Better agricultural practices can contribute to conservation of ecosystems and watersheds, and hence to water quality and quantity. Good water management, such as enhancing irrigation efficiency, can reduce demand for water and energy.

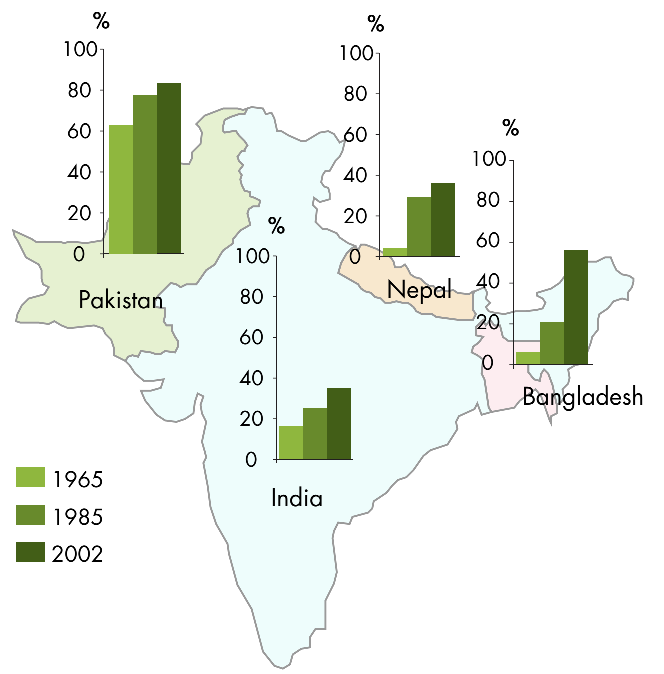
Much of the debate on food, water, and energy is either focused on reducing energy demand for water and agriculture or on policies to enhance energy availability to support growing demand for irrigation. A better understanding of the inherent interlinkages among water, energy and food, in space and time, is essential to formulate policies for more resilient and adaptable societies (Table 1). Policies in each sector have impacts on other sectors (Figure 2). For example, bioenergy and water pricing policies may affect food production, and agricultural policies may influence water and energy demand.

Irrigation: growing and shifting needs

In the past 50 years, irrigated area has increased dramatically in the countries of the Indian sub-continent, both in terms of absolute area and percent of arable land (Rasul, 2010) (Figure).

The source of irrigation has also shifted, from surface to groundwater (Table). Increased extraction of groundwater has lowered the groundwater table in some parts of South Asia.

Trend in irrigated land as percentage of arable land, 1965–2002



Source: Based on Rasul (2010)

Changes in irrigation in South Asia

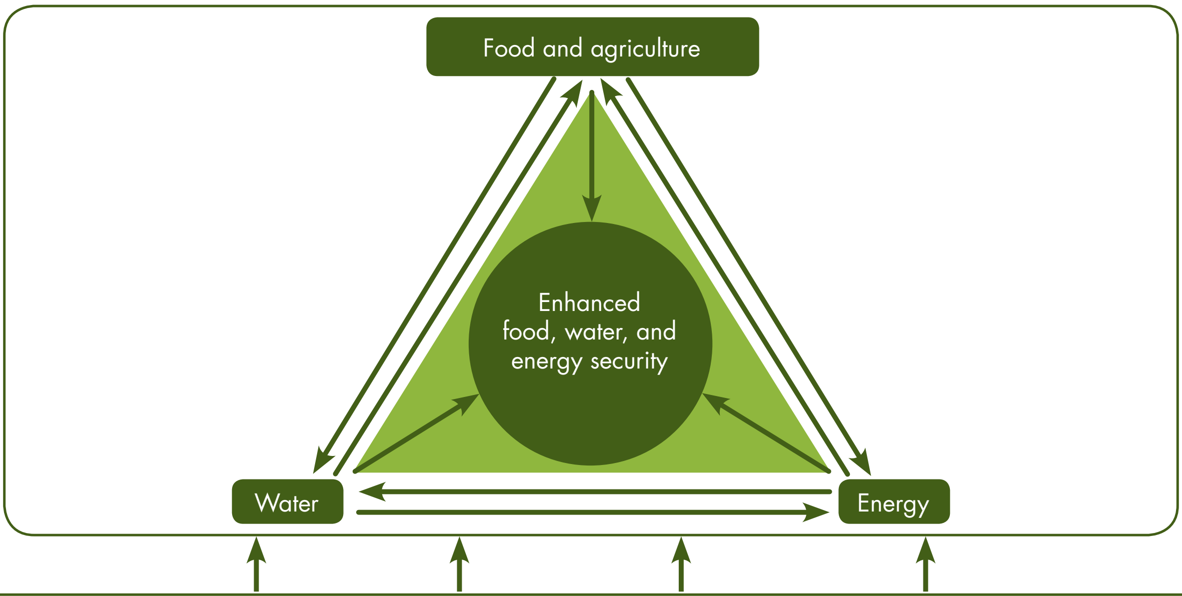
Area or territory	Net irrigated area served by groundwater			Groundwater irrigation as % of surface irrigation, 2000–2001
	1993–1994 ('000 ha)	2000–2001 ('000 ha)	Change (%)	
Key Indian cereal-producing states	17,413	21,760	25	197
Pakistan	8,760	10,340	18	276
Sindh Province of Pakistan	140	200	42.9	
Bangladesh	2,124	3,462	63	721

Source: World Bank 2005

Table 1: **Key features and challenges in food, water, and energy security in South Asia**

Key features	Socio-economic, environmental, and development implications	Future challenges
Food security		
Almost half of the world's hungry and undernourished people; about 446.2 million people living on less than US$ 1 a day, i.e., 46% of the world's poor (Ahmed et al. 2007) 51% of the population food-energy deficient (Smith and Wiesmann 2007) Food production falling short of population growth Cereals' share in total dietary energy consumption ranges from 49% to 80%, mainly rice and wheat (Weinberger et al. 2009) Changing food preferences: more meat, fruit, and vegetables consumed Arable land is low – limited options for expanding crop area Indus-Ganges-Brahmaputra plain is the major food basket of South Asia, and depends on water from the Himalayas	Growing demand for water for agriculture to meet increased food demand from limited land Agricultural growth constrained by shortage of energy and water Increased use of groundwater for irrigation, leading to groundwater depletion Changing food preferences require more energy and water; about 7 kg of grain equivalent energy (Pachauri 2008) and about 3,000 to 10,000 litres of water (Molden et al. 2007) required to produce 1 kg of meat About 2,000 to 5,000 litres of water per day required for one person's diet, depending on food composition – more meat requiring more water (Molden et al. 2007) Intensification of agriculture has led to great dependence on water and energy	To meet the nutritional needs of all, food production needs to double in the next 25 years Increased production of food grain limited by shrinking areas of cultivable land Competition for land for food and bioenergy crops and ecosystem services Increasing need for water and power in agriculture Climate change likely to affect food production
Water security		
Growing water demand for agriculture, energy, industry, and human and livestock use – predicted to increase 55% by 2030 compared to 2005 (ESCAP, 2011) Per capita water availability below the world average (excluding Bhutan and Nepal) Uneven endowment of water resources over time and space Existing water scarcity and large uncertainties about future water availability As much as 90% of the withdrawn water is consumed by the agriculture sector, compared to 70% worldwide (Hooper 2010) About 20% of the population lacks access to safe drinking water 70–80% of India's agricultural production depends on groundwater irrigation (Narayanamoorthy 2007) Demand for water for energy is growing Salinization and water pollution	Environmental stress, ecological insecurity Availability of water is paramount for environmental health, societal wellbeing, and a thriving economy Poor water management is detrimental to energy supplies and agricultural production Water-borne diseases cause poor human health and high child mortality Overexploitation of groundwater is lowering the water table	Growing water stress Challenges in meeting growing demand for competing water uses Decline in water table, posing threats to the sustainability of agriculture Drought and climate change likely to further increase reliance on groundwater Seasonal and spatial variations in hydrology Difficulty of ensuring water quality and providing access to safe drinking water
Energy security		
Widening demand–supply gap Poor access of the poor to modern energy; about 63% of the population lacks electricity (Abeygunawardana 2011) Biomass used as prime source of energy in rural areas; 65% use biomass for cooking Unreliable energy supply and rising energy prices Shortage of energy for agriculture High dependence on traditional sources, fossil fuels, and imported energy	Agricultural production affected by unreliable electricity supply Use of crop residues and animal dung for cooking have affected soil fertility and crop productivity Use of biomass for cooking has serious health, socioeconomic, and environmental implications Shortage of energy impedes economic growth; growth could be accelerated perhaps 2–3 % more if quality energy could be provided (Koch 2012)	Providing access to modern energy for rural people at affordable cost Meeting growing energy demand for agriculture, water, industry, and other economic activities Reducing reliance on fossil fuels and carbon intensity Reducing dependence on imported energy

Figure 2: **Food, water, and energy nexus and the contribution of Himalayan ecosystem services**



Himalayan ecosystem services			
Provisioning	Regulating	Supporting	Cultural
• Food, fodder, fuel • Fresh water • Minerals • Raw materials • Pollination • Genetic resources	• Climate regulation • Water regulation • Biological control • Disturbance regulation • Regulating precipitation, monsoon	• Recharging groundwater • Soil formation • Erosion control • Water retention • Nutrient cycling, movement	• Traditional knowledge and practices of conservation • Recreation • Agro-biodiversity

The nexus approach

It is vital to address food, water, and energy security in a holistic way, taking all the interlinkages into account through a nexus approach (Figure 2). A nexus approach is a system-wise approach, rather than a sectoral approach. It can help in reducing trade-offs and generating additional benefits. In South Asia, such an approach inevitably needs to take Himalayan ecosystem services into account.

How the Himalayas support the water, energy, and food security nexus

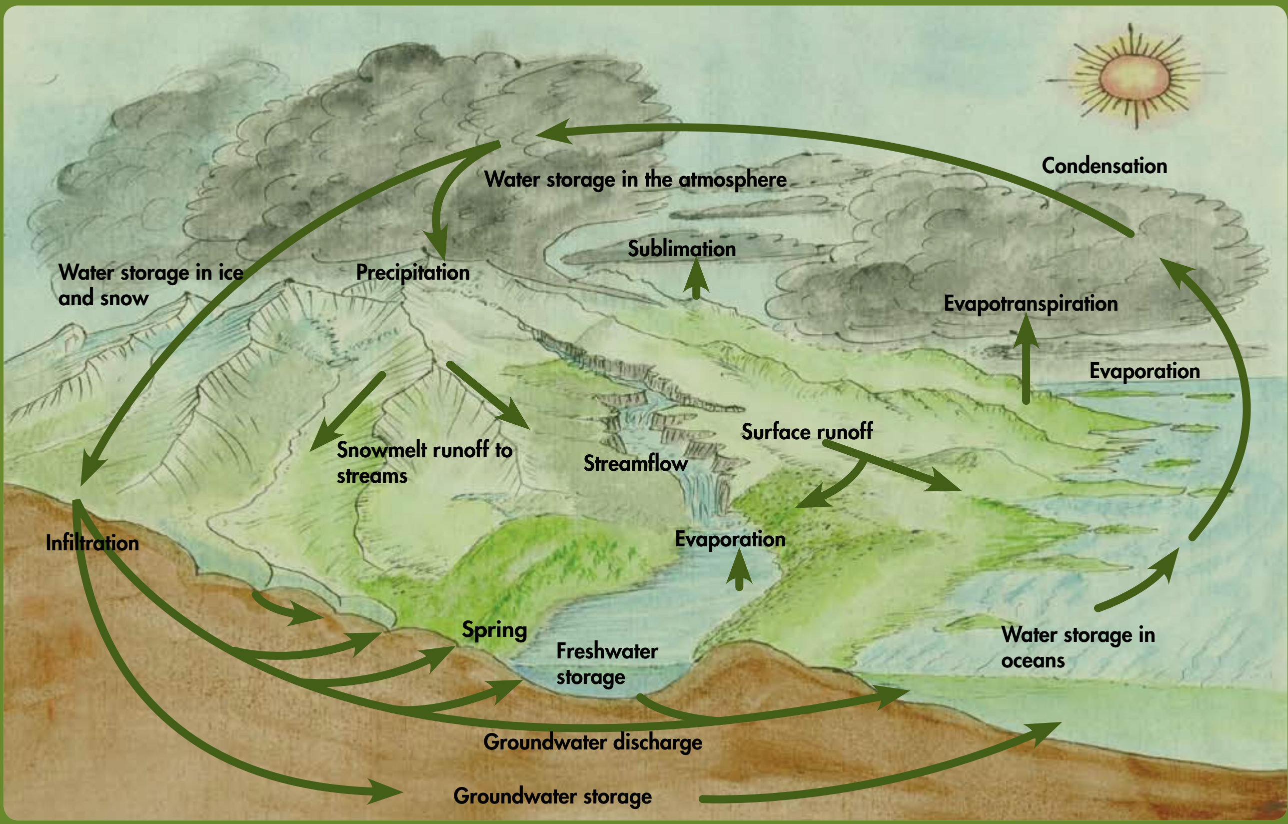
The Himalayan mountain system provides ecosystem services that support agricultural production, water security, and clean energy development downstream. To sustain these services, and to ensure food, water, and energy security in South Asia, management of Himalayan watersheds and their forests, wetlands, and rangelands is crucial.

Source of water – surface and groundwater

The Himalayas – the highest and largest mountain range in the world – has the largest body of ice in the world outside the two polar caps. The region's more than 54,000 glaciers hold ice reserves of about 6,100 km^3, representing huge stocks of water (ICIMOD, 2011).

The glaciers of the Himalayas are the headwaters for ten major river systems in Asia, a lifeline for almost half of humanity. These rivers receive significant contributions from the snow and glacier melt of the Himalayas, which provides the main basis for both surface and groundwater irrigation (Figure 3). The contribution of mountain discharge to dry season water is estimated to vary from 30% to 60% in the humid tropics and from 50% to more than 90% in arid and semi-arid regions (Viviroli et al. 2003).

Figure 3: **The water cycle**



Source: Based on USGS 2012

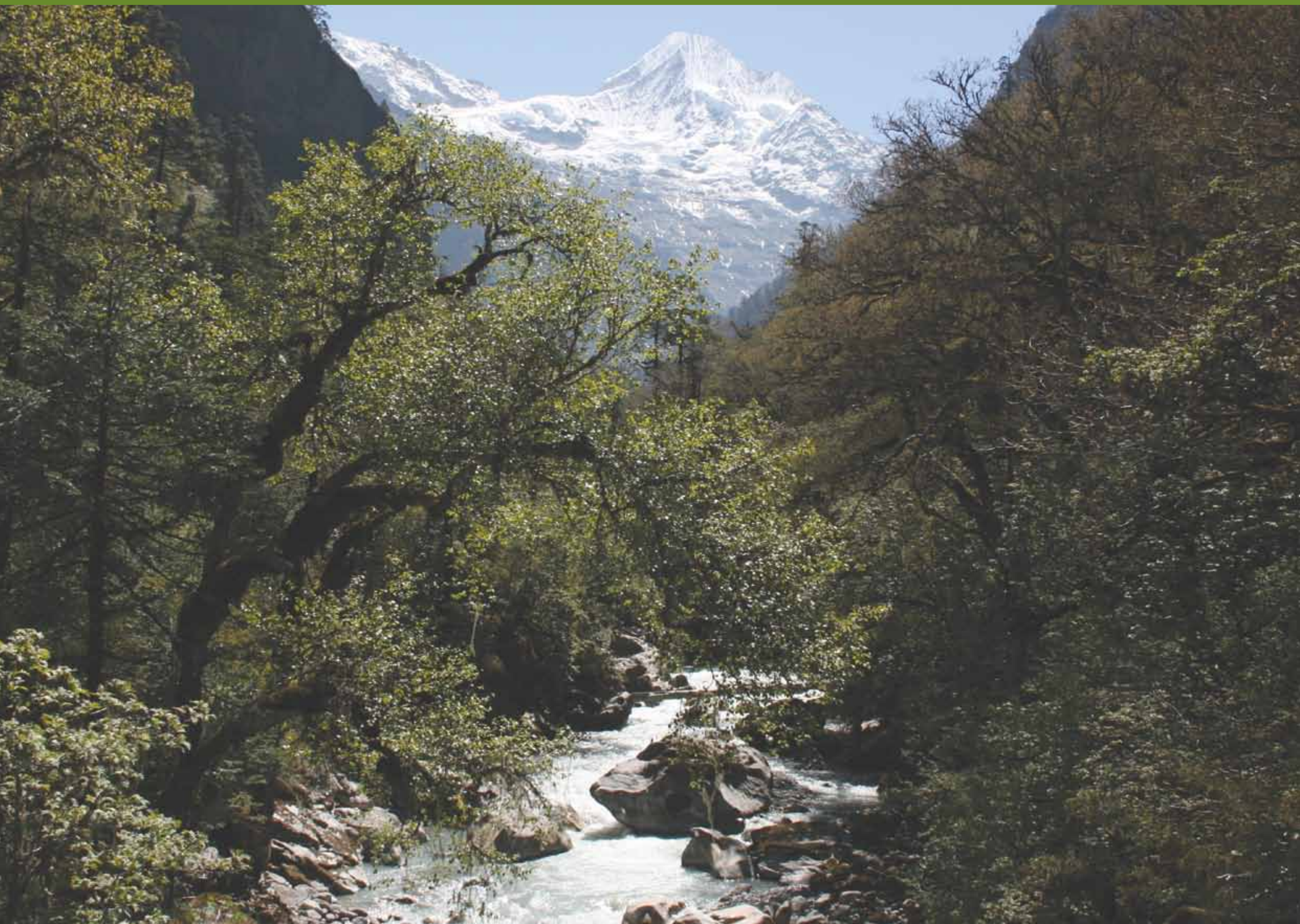
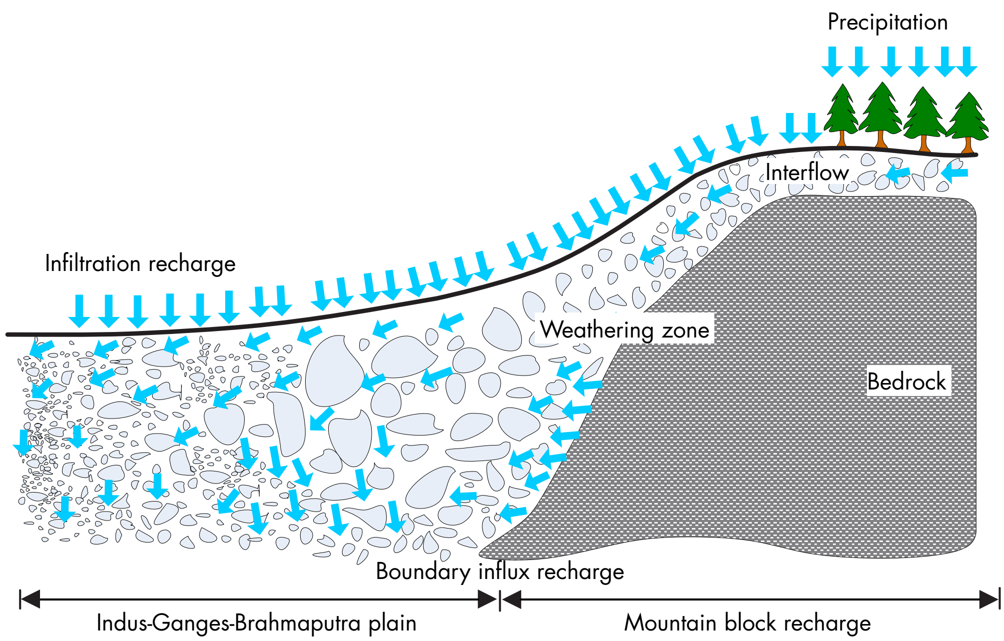


Figure 4: **Groundwater recharge from the mountains to the downstream alluvial plain**



Source: Based on Kao et al. 2012

The Himalayan mountains also store large amounts of groundwater, which contributes to both surface water and groundwater recharge in the downstream basins (Figure 4). The Himalayan watersheds, their forests, shrubs, and vegetation and their rock, soils, and wetlands, are natural reservoirs of water which gradually moves downward underground. Some of it is discharged as surface water or springs at lower elevations, while the rest helps replenish the groundwater system of the Indus-Ganges-Brahmaputra plain.

Groundwater – the invisible ecosystem service of the Himalayas – is vital for irrigation in the entire agricultural landscape of South Asia, in addition to serving other human uses and sustaining wetland ecosystems. Further study is needed to determine the potential role of Himalayan watershed management in reducing runoff and increasing infiltration to ensure groundwater recharge downstream.

Energy security

With increasing levels of industrialization, urbanization, and economic growth, electric power consumption will increase. The Himalayas have the potential to play a vital role in energy security in South Asia; the hydropower potential in the region exceeds 500 GW (Table 2). If properly harnessed, hydropower could provide reliable access to energy for most of the population and reduce use of traditional fuels, thus also reducing atmospheric black carbon, which is a serious problem in the region.

Table2: **Hydropower in the Himalayas**

Country	Hydropower potential (MW)	Installed hydropower capacity	Access to electricity, 2005 (%)	Per capita electric power consumption, 2008 (kWh)
Afghanistan	Not available	Not available	7	Not available
Bangladesh	Not significant	Not available	32	208
Bhutan	23,760	1,465	Not available	Not available
China	272,000	Not available	99	2,455
India	114,398	24,630	56	566
Myanmar	Not available	NA	11	97
Nepal	42,130	658	33	89
Pakistan	46,000	6,608	54	436

Source: Vaidya 2012

Support to food production – climate regulation and agro-biodiversity

In addition to providing surface water and groundwater, the Himalayan mountain system creates conditions conducive to agriculture by regulating micro-climate as well as wind and monsoon circulation in South Asia. Because of its altitude and its location, directly in the path of the monsoon, it influences precipitation as rain or snow, saving northern India from the gradual desiccation that afflicts Central Asia.

The Himalayas are also important storehouses of agro-biodiversity. Over 675 edible plants and nearly 1,743 species of medicinal value are found in the Indian Himalayan region alone (Samant et al. 1998). The genetic diversity in mountains is particularly high, not only because of mountains' geographic isolation, but also because the mountain cultures have long traditions of protecting certain plants and animal species.

Policies to sustain upstream ecosystem services are vital

Food, water, and energy security in South Asia must be understood and addressed in an integrated manner. Sustained Himalayan ecosystem services are vital to both upstream and downstream food, water, and energy security in South Asia. These ecosystems must be managed to ensure their resilience and their support to production of food, energy, and water. Protecting and enhancing ecosystem services will also support livelihoods of people living in the Himalayas and downstream.

Policies and strategies to enhance food, water, and energy security in South Asia must therefore embrace mechanisms for managing Himalayan ecosystems better. They must support:

- restoration of natural water storage capacity in the Himalayan watersheds through conservation of soil, ice, wetlands, permafrost, lakes, and aquifers;
- development of climate smart, environmentally and socially sound infrastructure to provide water for agriculture, hydropower generation, and downstream irrigation as well as to reduce runoff and flood risks to downstream areas;
- adequate investment for management of Himalayan watersheds, wetlands, and biodiversity;
- mechanisms for providing incentives to mountain communities for managing Himalayan ecosystems.

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