Water-Energy-Food Nexus: A Basis for Sustainable Agricultural Development in SAARC Region

Tayan Raj Gurung

SAARC Agriculture Centre
South Asian Association for Regional Cooperation

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Edited by
Tayan Raj Gurung
Senior Program Specialist (NRM)
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Foreword

The SAARC Region is predominantly agrarian region and fast emerging as a major player in the global economy, which is supported by agricultural and non-agricultural industrial expansion. SAARC Region is also home to the largest number of people living below the poverty line in the world. Besides, it is also reported that about half of this region's population is food-energy deficient. Food production in SAARC region has become increasingly water and energy intensive. Tremendous increase in the demand for food, water, and energy in the region is taking place at such a time when land, water, and other natural resources are depleting at a faster pace. Under this scenario, the increased food production can only be achieved from the same or even less land. About 20% lack access to safe drinking water. In the wake of growing water stress, these countries are faced with a common challenge of as to how to grow more food with the same or less land, less water, and increased energy costs.

The interconnectedness and interdependence between food, water, and energy security, especially in the regional context, emphasizes the urgency for ascertaining inter-sectoral integrated solutions. Water-Energy-Food Nexus assumes a significant importance in the region to achieve food and energy security. The process of sustainable development is basically dependent on adequate access to these resources and their sustainable management. The inter-connectedness between the water, energy, and food systems is traditionally characterized by the three bilateral interfaces of energy-water, energy-food, and food-water, which comprises linkages representing resource supplies, end-use demands and requirements, and natural and human engineered technologies, processes, and infrastructures necessary to produce, supply, and deliver the resource to meet the end-users' requirements. The water-energy-food nexus approach is extremely relevant to South Asia, which has just 3% of the world's land, but has to feed 1.6 billion people, which account for about one-fourth of the world's population. Rice and wheat, the staple foods in this region, need huge amounts of water and energy. Freshwater, once abundant, is under growing stress due to the increased demand for competing uses, and climate change is creating additional uncertainties. In view of the growing water stress and shortage of energy, there is a big challenge of how to produce more food with less land, less water and less energy. In this backdrop, WEF nexus approach is increasingly seen as a viable option to meet these challenges in the SAARC region.

Foreword

The SAARC Region is predominantly agrarian region and fast emerging as a major player in the global economy, which is supported by agricultural and non-agricultural industrial expansion. SAARC Region is also home to the largest number of people living below the poverty line in the world. Besides, it is also reported that about half of this region's population is food-energy deficient. Food production in SAARC region has become increasingly water and energy intensive. Tremendous increase in the demand for food, water, and energy in the region is taking place at such a time when land, water, and other natural resources are depleting at a faster pace. Under this scenario, the increased food production can only be achieved from the same or even less land. About 20% lack access to safe drinking water. In the wake of growing water stress, these countries are faced with a common challenge of as to how to grow more food with the same or less land, less water, and increased energy costs.

The interconnectedness and interdependence between food, water, and energy security, especially in the regional context, emphasizes the urgency for ascertaining inter-sectoral integrated solutions. Water-Energy-Food Nexus assumes a significant importance in the region to achieve food and energy security. The process of sustainable development is basically dependent on adequate access to these resources and their sustainable management. The inter-connectedness between the water, energy, and food systems is traditionally characterized by the three bilateral interfaces of energy-water, energy-food, and food-water, which comprises linkages representing resource supplies, end-use demands and requirements, and natural and human engineered technologies, processes, and infrastructures necessary to produce, supply, and deliver the resource to meet the end-users' requirements. The water-energy-food nexus approach is extremely relevant to South Asia, which has just 3% of the world's land, but has to feed 1.6 billion people, which account for about one-fourth of the world's population. Rice and wheat, the staple foods in this region, need huge amounts of water and energy. Freshwater, once abundant, is under growing stress due to the increased demand for competing uses, and climate change is creating additional uncertainties. In view of the growing water stress and shortage of energy, there is a big challenge of how to produce more food with less land, less water and less energy. In this backdrop, WEF nexus approach is increasingly seen as a viable option to meet these challenges in the SAARC region.

This book “Water-Energy-Food Nexus: A basis for sustainable agricultural development in SAARC Region” is a collection of papers from the SAARC Regional consultation where each Member States try to bring a comprehensive overview of potentials and challenges in WEF Nexus in the region. I would like to take this opportunity to express my sincere appreciation to Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAARC Agriculture Centre who succinctly put together the manuscript. I am confident that this compilation will facilitate further research and development in Water-Energy-Food in SAARC Region.

Dr. S.M. Bokhtiar

Director

Abbreviation

AIBP	Accelerated Irrigation Benefit Programme
AICC	Agriculture Information and Communication Centre
AICRP	All India Coordinated Research Project
APDP	Accelerated Pulses Development Programme
BADC	Bangladesh Agriculture Development Corporation
BARI	Bangladesh Agriculture Research Institute
BCM	Billion Cubic Meter
BGREI	Bringing Green Revolution in Eastern India
BMI	Body Mass Index
BPC	Bangladesh Petroleum Corporation
BRRI	Bangladesh Rice Research Institute
BUET	Bangladesh University of Engineering and Technology
CARP	Council for Agricultural Research Policy
CCVI	Climate Change Vulnerability Index
CED	Chronic Energy Deficiency
CEGIS	Center for Environmental and Geographic Information Services
CP	Cropping Pattern
CWC	Central Water Commission
DAC	Department of Agriculture and Cooperation
DAE	Department of Agriculture Extension
DAM	Department of Agricultural Marketing
DoLR	Department of Land Resources
EMRD	Energy and Mineral Resources Division
ESCAP	Economic and Social Commission for Asia and the Pacific
FCI	Food Corporation of India
FIAC	Farmer’s Information and Advisory Centre
FPMC	Food Planning and Monitoring Committee
FYP	Five-Year Plan
GAP	Good Agricultural Practices
GDP	Gross Domestic Product

GHG	Green House Gas
GIS	Geographic Information System
GLOF	Glacial Lake Outburst Flooding
GNH	Gross National Happiness Philosophy
GoB	Government of Bangladesh
GSHS	Global School Health Survey
ha	Hectare
HYV	High Yielding Variety
ICAR	Indian Council for Agricultural Research
ICIMOD	International Centre for Integrated Mountain Development
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPC	Irrigation Potential Created
IPM	Integrated Plant Protection
IPU	Irrigation Potential Utilized
IRENA	International Renewable Energy Agency
ISOPOM	Integrated Scheme of Oilseeds, Pulses, Oil palm and Maize
IWM	Integrated Water Management
IWMP	Integrated Watershed Management Programme
kTOE	Thousand Tonnes of Oil Equivalent
LCMP	Land Cover Mapping Project
M ha	Million Hectare
MA	Million Acre
MAF	Million Acre Feet
MCM	Million Cubic Meters
MEE	Ministry of Environment and Energy
MET	Maldives Meteorological Service.
MGNREGS	Mahatma Gandhi National Rural Employment Guaranty Scheme
MoAD	Ministry of Agricultural Development
MoFA	Ministry of Fisheries and Agriculture
MoWR	Ministry of Water Resources

MoWR	Ministry of Water Resources
MRV	Monitoring, Reporting and Verification
MT	Metric Tonne
MTOE	Million Tonnes of Oil Equivalent
MW	Mega Watt
NAPCC	National Action Plan on Climate Change
NARS	National Agriculture Research Systems
NDMA	National Disaster Management Authority
NEEP	Nepal Energy Efficiency Program
NEPRA	National Electric Power Regulatory Authority
NFP	National Food Policy
NFSM	National Food Security Mission
NGO	Non-Government Organization
NIWRMP	National Integrated Water Resources Management Plan
NMMI	National Mission on Micro Irrigation
NMSA	National Mission for Sustainable Agriculture
NMSA	National Mission for Sustainable Agriculture
NRESA	Natural Resources, Energy and Science Authority
NRM	Natural Resource Management
NSB	National Bureau of Statistics
NWPo	National Water Policy
OFR	Onfarm Research
OFWM	On Farm Water Management
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PPD	Policy and Planning Division
PPP	Public-Private-Partnership
RADP	Rainfed Area Development Programme
RD&GR	River Development & Ganga Rejuvenation
RGoB	Royal Government of Bhutan
RNR	Renewable Natural Resources
RWSS	Rural Water Supply Scheme
RYGM	Rice Yield Gap Minimization

SAARC	South Asian Association for Regional Cooperation
SDG	Sustainable Development Goals
SLLC	Sone Low Level Canal
SPS	Sanitary and Phytosanitary
SWAP	Soil Water Atmosphere Plant
UIP	Ultimate Irrigation Potential
UN	United Nations
UNFCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
WAPDA	Water & Power Development Authority
WEF	Water–Energy–Food
WHO	World Health Organization

Executive Summary

Food production in SAARC region has become increasingly water and energy intensive. Tremendous increase in the demand for food, water, and energy in the region is taking place at such a time when land, water, and other natural resources are depleting at a faster pace. Under this scenario, the increased food production can only be achieved from the same or even less land. The interconnectedness and interdependence between food, water, and energy security, especially in the regional context, emphasizes the urgency for ascertaining inter-sectoral integrated solutions. Lack of appropriate incentives, paucity of capacity building and other policy and institutional mechanisms has already culminated jeopardizing the food, water, and energy security in the region. Water-Energy-Food Nexus assumes a significant importance in the region to achieve food and energy security.

Water, energy and food related challenges facing South Asia can be tackled via WEF nexus because, "The nexus approach provides a framework for better understanding of the interdependencies of the food, water, and energy sectors and linkages between upstream and downstream countries as well as better insights into how to address such challenges by maximizing synergies and managing trade-offs" (Rasul, 2014). Asserting that each component of the nexus is fundamental to human life and wellbeing, understanding of the connections among these components can help promote efficiency in their use, greater equity in their distribution, and greater national security for the resource-stressed countries in the region. Irrigation is fundamental to food security and hydropower is fundamental to energy security in South Asia. Sustainable farms and cities require water security. Using the nexus can help define some of these interrelationships (Scott, 2015).

In the wake of emerging shift in global thinking towards sustainable futures and resilient ecosystems, a change in direction has seemingly begun based on holistic systems thinking, which has engendered a new understanding of the complex linkages in human and environmental interactions, leading to the development of the idea of Sustainable Development Goals, in which the WEF nexus can be a useful tool in pursuit of this new way of framing development goals. For instance, WEF nexus has a potential role to play in the realization of the SDGs, especially the SDG-1, SDG-2, SDG-6, SDG-7 and SDG-13 along with the objectives envisaged in the Paris Agreement on Climate Change adopted in December 2015.

This reinforces the fact that WEF nexus is imperative for SAARC Region to ensure all-round growth and speedy realization of the SDGs.

A regional consultation meeting was organized in Bhutan during 3-5 July 2017 with the objectives of (i) documenting the best-policy practices in Water-Energy-Food to harmonize the policies, and (ii) preparing strategic policy brief for

regional integration of WEF Nexus for submission to SAARC Summit and Regional Forums

Agriculture – Current Situation

Bangladesh

Agriculture is the driving force of Bangladesh's economy. Favorable agro-climate that generally prevails throughout the year is very much suitable for crop production. Agriculture is operated in 8.20 million ha with 62% of the population engaged in farming. Agriculture sector contribute 14.79% to the GDP (2016-2017FY). Agriculture in the country is predominated by irrigated agriculture which represents 53%. Rice is the dominant staple food crop and occupies over three-fourths of crop area. This has been a major development success of Bangladesh and a key contributor to poverty reduction and hunger eradication. Other prominent crops are jute, wheat, potato, maize, pulses, oilseeds, spices, vegetables, sugarcane, cotton and tea. In recent years, the cropped area under boro rice, maize, potato, fruits and vegetables are increasing mode. Under HYV, 70% of cropped area today, with current rate of conversion, almost all suitable land is expected to come under HYV within the next decade or so. Bangladesh has made significant progress in improving food security and nutrition in the last twenty-five years. Driven mainly by the expansion in boro rice, total rice production has more than tripled in the last three decades while the population increased by only about 60%.

Bhutan

Agriculture provides livelihoods to 62.2% of the country's population and contributes 16.8% of the GDP, 4.3% of exports, and remains the key source of employment (58% of the employed) and driver for poverty reduction. However, agriculture in Bhutan is dominated by small and marginal farmers with per capita agriculture landholding of only 1.2 ha/household. They occupy most of the country's arable land and produce most of the crop and livestock products. More than 31% of agriculture land is on slopes greater than 50%. Of the total arable/cultivated land of 112,556 ha (LCMP 2010) about 18% is under irrigation. The amount of agriculture produce that is currently produced by the farmers is not enough for Bhutan's domestic consumption resulting in high annual imports. The agricultural trade deficit has been increasing over time. While exports of agricultural products grew in value at an average rate of 15% per annum from 2008 to 2014, imports of agricultural products over the same period grew by 16% per annum.[1] The absolute value of the agricultural deficit rose from Nu 2.3 billion in 2008 to nearly Nu 6 billion in 2014, representing a 17% annual increase.

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1 The use of an annual increase percentage is only indicative since the use of different baseline years would result in a change in the number quoted.

India

India has net sown area of 140.88 M ha and with a cropping intensity of 138.67 its gross sown area is 195.25 M ha. It has increased 50% more agricultural and 200% more horticultural production in last two and half decades. As surface water resources are quite important for crop cultivation through development of large or medium irrigation projects, rainwater harvesting and groundwater recharge, the distribution of annual rainfall is given in Table 2. The net irrigated area is 65.26 M ha with gross irrigated area is 91.53 M ha. As per the latest available statistics (2011-12), irrigated and rainfed area of the country is estimated at around 46 and 54 % of the net sown area, respectively The distribution of cropped area in different category based on rainfall received clearly indicates prospect of bringing at least 70% area under assured irrigation by developing various means of water resource development.

Maldives

There are only 7,000 people registered as farmers (MoFA, 2017). Most of the registered farmers are practicing subsistence farming and backyard cultivation is a common practice. Betel leaves, pumpkin, luffa, passionfruit, collard greens, mango, guava, bilimbi, sweet potato, cassava, stone apple, custard apple, pond apple, wax apple, bread fruit are some of the major crops found in compounds of many islands. Crops grown larger scale on the field includes papaya, watermelon, banana, chili (local githeyo mirus), taro, cucumber and eggplant. Cultivation of traditionally grown crops like sorghum, millets and maize has declined over the past few decades. Apart from these crops, coconut is cultivated extensively throughout the country and it is the only product not being imported.

Nepal

Agriculture in Nepal is dominated by subsistence and small holder agriculture. Over 80% of the population is involved in agriculture, which constitutes 36% of GDP. In general the majority of Nepalese farmers are subsistence farmers and do not export surplus; this does not prevent a minority in the fertile southern Tarai region from being able to do so. Most of the country is mountainous, and there are pockets of food-deficit areas. Rice based and maize based cropping systems are dominant in terai and hills respectively. Cattle, buffalo and goat and poultry are major livestock. The difficulties of transportation make it far easier to export across the border to India than to transport surplus to remote mountain regions within Nepal. A considerable livestock population of cattle, goats, and poultry exists, but the quality is poor and produces insufficient food for local needs.

Pakistan

Agriculture is the lifeline of Pakistan. As per the Economic Survey of Pakistan, 2016-17, agriculture accounting for 19.5% of the gross domestic product, employing 42.3% of the labour force and providing raw material for several value-added industries. It thus plays a central role in national development, food security and poverty reduction. During 2016-17, the agriculture sector achieved growth of 3.46% against the target of 3.5%. The government achieved its growth target in Agriculture due to its supportive policies. Besides, the agriculture credit disbursements were raised to Rs. 700 billion in 2016-17 from Rs 600 billion in 2015-16. Pakistan's agricultural production is closely linked with the availability of irrigation water. During 2016-17, the availability of water for Kharif 2016 stood at 71.4 million acre feet (MAF) showing an increase of 9.0% over Kharif 2015 and 6.4% more than the normal supplies of 67.1 MAF. During Rabi season 2016-17, the water availability remained at 29.7 MAF, which is 9.7% less than Rabi 2015-16 and 18.4 percent less than the normal availability of 36.4 MAF.

Sri Lanka

The agricultural land use in Sri Lanka has increased from 45 % in 1956 to 60 % in 2007. The sparsely used crop lands, homesteads and paddy occupy the highest land area in the agricultural sector. The homestead lands are the home gardens where many tree crops are grown. Among the plantation crops, the land extents under tea and rubber plantations have been decreased since 1956. It indicates these lands have become sparsely used lands. There is nearly 2 % increased of mixed and perennial crop lands and 1 % increased in the coconut plantations. Sri Lanka receives food from three sources namely plants grown in farming systems in the country, plants harvested from natural ecosystems in the country and crop produce brought from other countries. At present, about 106 food crops are grown in the country which includes cereals, yams, pulses, vegetable, fruits, spices and condiments, beverages, oil crops and other crops (Agricola, 1978 and Technoguide, 2016).

Food and Nutrition Security Situation

Bangladesh

Bangladesh has made significant progress in improving food security and nutrition in the last twenty-five years. The improvement in food security has come about through progress in both availability of and access to food. Crop production has accelerated, especially since the late 1980s, when the Green Revolution—based on new seed, fertilizer, and irrigation technologies finally took off. Driven mainly by the expansion in boro rice, total rice production has more than tripled in the last three decades while the population increased by only about 60 percent. Non-crop agriculture has grown at an even faster rate than crop production, with the result that its share in total agricultural gross domestic product (GDP) has gone up from 35% to 45% in the past three decades. At the aggregate level Bangladesh has attained food self-sufficiency as far as calorie availability is concerned. This is evidenced by a dramatic decline in import dependency for rice which declined to less than 1% in 2013–14.

Bhutan

The renewable natural resources (RNR) sector in Bhutan which comprises agriculture, livestock, and forestry is the primary food sector. Bhutan's two main food crops are maize and rice the production of which is 82,035 MT and 83,332 MT respectively (Agriculture Statistics 2016). The other cereals like buckwheat, wheat, barley and millet have also shown a decline in production. Most cereals are consumed domestically, but domestic production is in sufficient and Bhutan imports sizeable amounts of rice (79,306 MT) and wheat (23,264) MT. The availability of food in Bhutan depends mostly on its own agricultural production, supplemented by some food imports. Bhutan has traditionally been self-reliant in cereal production, though the agricultural area under cereal cultivation has been declining since the mid-1990s. Bhutan does not face chronic food insecurity, there are pockets of hunger within the country, particularly in eastern and southern parts. Bhutan imports 34 % of its cereal needs, and close to one-third of the population suffers from food insecurity. Poor nutrition, food insecurity, and malnutrition pose major risks to Bhutan's population. Despite the country's economic growth, nearly 27 % of Bhutanese households consume less than the daily minimum calorific requirement of 2,124 kcal. About 35 % of households face yearly food shortages.

India

A total of 77% of the 1.3 billion population is estimated as poor and vulnerable. Further, in the recently released Global Hunger Index of 2016, India ranked 97 out of 118 countries which is a matter of deep concern as India is one of the largest producers of food in the world. The International Food Policy Research Institute (IFPRI, 2013) classified India into alarming category out of five categories - low, moderate, serious, alarming and extremely alarming. It has been observed that the consumption of food, in terms of nutrition and quantity, is lacking far behind in the country. According to National Institute of Nutrition, the minimum per capita food grain required for an adult is 182.5 kg/year whereas in India, the availability is only 173.6 kg/year and as far as the protein requirement is concerned, the daily intake should be 50 mg but the situation seems to remain stagnant, the per capita daily intake is only 10 mg. According to Food and Agricultural Organisation, 225 million people i.e. 23% of population are undernourished and 260 million people fall under the category of above the poverty line.

Maldives

Maldives was food sufficient about fifty years ago depending mainly on finger millet, maize, coconut, breadfruit, tubers such as sweet potato, taro, cassava and fish. Food habits and main staple foods of locals drastically changed to rice and wheat during 1970s. Studies (GSHS 2009) show that around 7% of students (13-15years) go hungry because there is inadequate food at home; students (7.6%) from Atolls are slightly more likely than students (5.2%) from Male' to go hungry most of the time or always (Moosa, 2010). There is a growing concern on malnutrition among reproductive aged women. MDHS showed that 46% of women aged15-49 years are overweight or obese and only 8% are too thin with BMI less than 18.5. Moreover 61% women do not engage themselves in any kind of physical activity in any day of the week (MOHF and MACRO, 2010). While overweight and obesity is common, micronutrient deficiencies are also common in this age group. Food security interventions are directed by the policies of agriculture sector specified in the Strategic Action Plan.

Nepal

Nepal's food security has been getting high priority in each development plan of Nepal but the situation has not improved significantly. The interim constitution of Nepal has also mentioned "food sovereignty as fundamental right of Nepalese people. Still, 15% of the total population are undernourished in Nepal. According to WHO, among the under five years old children, 40% are stunted, 29% are underweight, and 11% are wasting.

Pakistan

In 2015-16, Pakistan harvested 25.5 million MT of wheat and 6.5 million MT of rice. Limited food access remains the main constraint of food security. It is reported that 66.7% of household are unable to afford the nutritious diet with their food expenditure. The Ministry of Planning reports that every four out of ten Pakistanis live in multidimensional poverty.

Sri Lanka

In 1980, when the Mahaweli river diversion was completed, Sri Lanka achieved significant improvement in food security. At present food and nutrient security status is good in Sri Lanka. For instance, Sri Lanka is self sufficient in rice and produces 19% more than the requirement. The production of pulses, vegetables and fruits are lower than the domestic requirement. The vegetable self sufficiency level is 64.4%, fruits at 71% and pulses at 28%. Maize production is at 59% of the domestic requirement. It reveals the need of enhancing production of such crops in order to strengthen food and nutrient security and self sufficiency. In this regard, water-energy-food nexus plays a significant role. In addition at present, significant fraction of crop produce of particularly fruits and vegetable is lost due to damages from wild animals (Kendaragama, 2015) and while transport.

Water Resources and its Policies

Bangladesh

Water use in Bangladesh is dominated by irrigation with estimated annual use varying from 25 to 33 km^3 of which 80 % is from groundwater. Domestic and industrial demand is estimated at about 2.7 km^3 per year, which is projected to increase to about 4.1 km^3 by 2050. Groundwater is overused in the Barind and around Dhaka, and there are concerns about the level of use elsewhere. Bangladesh is the largest delta in the world – located at the confluence of three of the world's major rivers the Ganges, the Brahmaputra and the Meghna and their tributaries and distributaries. Besides these three major rivers, Bangladesh also shares 57 trans-boundary rivers with her neighbours (54 with India, and 3 with Myanmar). These river systems carry between 1.0 and 1.6 trillion cubic meters of freshwater and 1.0 billion tons of sediments annually, the status of which is dynamic and considered as the lifeline of Bangladesh. Irrigation water for cropland in Bangladesh is available from two sources i.e. surface water and ground water. Irrigation through surface water and groundwater covers 22.45% and 77.55% i.e. 1.21 and 4.19 Mha irrigated area, respectively (BADC, 2014). Bangladesh has adopted the National Water Policy (NWPo) at the end of 1999 was a milestone towards the good governance of water resources (Gain & Schwab, 2012) to ensure progress towards fulfilling national goals of economic development, poverty alleviation, food security, public health and safety, a decent standard of living for the people and protection of the natural environment (MoWR, 1999). The NWPo recognizes the interaction of water and food security. To ensure food security, emphasis is given to the development of groundwater irrigation and conjunctive use of surface and groundwater. Bangladesh Water Act 2013 also has given emphasis on agriculture, aquaculture and power generation.

Bhutan

Bhutan has the highest annual per capita water resource availability in the world with 94,500 cu.m/capita/annum. The total annual water availability stands at 70,576.02 cu.m which works out to average flow of 2,238 cu.m/sec in 2015. Water resources are mainly in the form of rivers, streams, springs and lakes. Most of the river system is fed by rainfall, glacial melt (2-12%) & snow melt (2%). The major river basins are Amochu, Wangchu, Punatshangchu, Mangdechu & Drangmechu. All flows north to south draining into Indian plains. Water quality of rivers & streams are in good conditions except at localized urban areas. Deep groundwater is virtually unexplored in Bhutan. Despite the availability of surface water sources in abundance at national level, there are many localized and seasonal water shortages with settlements on the mountain slopes and the rivers in the valleys. These localized and seasonal water shortages affect drinking water supply and irrigation for agricultural purposes. The reason is that Bhutan is not immune to climate change and been experiencing localized changes in environment such as drying up of river sources, rising temperatures and glacial floods. Availability, access and utilisation are also factors in water security. In particular, water security is about affordable access to clean water for agricultural, industrial and household use. By this definition, it can be said that Bhutan is not water insecure.

The principal policy framework on water is the “Bhutan Water Policy” which emphasizes on adequate water allocation for sustainable agriculture development to achieve national food security goal. It also emphasizes higher water use efficiency through adaptive and applied research on surface water, ground water and rainwater harvesting to address seasonal and local water shortages. While the Water Act of Bhutan enacted in 2011 gives second priority to water for agriculture, the Water Regulation of Bhutan 2014 enforces that water abstraction for irrigation is in line with the National Integrated Water Resources Management Plan (NIWRMP). Other water related policy frameworks are RWSS Sector Policy, National Irrigation Policy, Revised 2012, National Integrated Water Resources Management Plan 2016, and National Irrigation Master Plan 2016.

India

India is divided into 20 river units, 14 of which are major river basins, while the remaining 99 river basins have been grouped into six river units. The leading rivers of India can be classified into four groups: the Himalayan rivers, the rivers of the Deccan plateau, the coastal rivers and the rivers of the inland drainage basin. The Himalayan rivers (Ganges, Brahmaputra, Indus) are formed by melting snow and glaciers as well as rainfall and, therefore, have a continuous flow throughout the year. The spatial imbalance of water resources distribution can be appreciated by the fact that the Ganges-Brahmaputra-Meghna basin, which covers 34 percent of the country’s area, contributes about 59 percent of the water resources. The west flowing rivers towards the Indus cover 10 percent of the area and contribute 4 percent of the water resources. The remaining 56 percent of the area contributes 37 percent to the runoff. India’s annual renewable groundwater resources are an estimated 432 km3, of which around 90 percent or 390 km3 are considered overlap between surface water and groundwater. Annual internal renewable surface water resources (IRSWR) have been estimated as 1 446.42 km3, of which 1 404.42 km3 surface water, 432 km3 groundwater and 390 km3 overlap.

India receives an average annual rainfall of 119.4 cm amounting to about 4000 billion cubic meter (BCM) of water that generates an average annual runoff of 1869 BCM. Due to various constraints about 1123 BCM of water can be put to beneficial use of which 690 BCM is through surface water and 433 BCM by groundwater (CWC, 2015). Out of 690 BCM of surface water, so far about 253.4

BCM of storages are built through major and medium irrigation projects. Another 51 BCM of storage are under construction / consideration. Similarly, out of 431 BCM of groundwater resource, about 360 BCM of groundwater is expected to be available for irrigation, out of which present usage is about 222 BCM. The per capita water availability in the year 2005 was 1703 m3 which is projected to further reduce to 1401 and 1191 m3 by the years 2025 and 2050, respectively.

The projected total water demand of the country is estimated at 1447 BCM by the year 2050 which is more than the present availability of utilizable water resources (CWC, 2010). In that the share of agriculture itself will be 1072 BCM. Thus, there is a need for proper planning, development and management of water resources. Further, the availability of water for agriculture in India is projected to decline from 84% in 2010 to 74% by 2050. Therefore producing 350 M t food grain from shrinking water resources would put existing water sources under immense pressure. It has been estimated that about 1% annual increase in water productivity (quantity per unit consumptive water use) would meet additional water demand for grain production and its further increase to 1.3% would satisfy all crops water demand. Present low crop water productivity provides enough scope for improving present crop water productivity through scientific agricultural water management practices, and the demand of water from other sector can be met with present water resources.

Irrigation development has received high priority in the successive five year plans and has the second largest irrigated area in the world. The ultimate irrigation potential of the country through major, medium and minor irrigation projects has been assessed at 139.9 M ha by conventional storage and diversion works. A record food grain production of 265 M t was achieved in 2014-15. About 60% of country's food grain production is contributed from irrigated agriculture. A total irrigation potential of 113.53 M ha, against 22.6 M ha at pre-planning period, has been created by the end of XI Plan. Total water use in agriculture at current level of development is of the order of about 525 BCM which is about 83% of total present water use in the country. This may get progressively reduced to about 75% in future due to increased demand of other sectors. Groundwater played a major role in the success of green revolution and contributes about 60% of the total irrigated area of the country. Over exploitation of groundwater has reached at alarming levels in Punjab, Haryana, Rajasthan and Tamil Nadu. The Punjab-Haryana region could lose its production potential in a few decades if current patterns of groundwater extraction and pollution, soil salinization and rice-wheat monoculture persist.

Maldives

The only available natural fresh water resources in Maldives are rainfall and a thin layer of fresh water in the groundwater lenses accumulated in the porous coral sands of the tiny islands. Water lens are shallow and is accessible within one to two metres below from ground surface. People harvests rainwater from rooftop for daily use as ground water in inhabited islands is not suitable for consumption purposes. The alternative desalinated water is available in few islands. The average rainfall remains within the range of 2000-2500 mm during the past decade (MET, 2006 to 2016). The highest rainfall is from May to September while the rest of the year is considered as dry period during which the demand for water is the highest. To meet the water shortage, government transports desalinated water to vulnerable islands in ships. The number of islands vulnerable to water scarcity is rising each year and sea transportation of desalinated water is becoming a challenge. Despite pollution and salinity and the high cost of other water resources, farmers are forced to keep on using ground water. It clearly indicates the importance of improving water security across Maldives particularly in those vulnerable islands. Since water is available freely by simply digging a shallow well, farmers often consider it as an unlimited resource. Farmers usually keep hose watering and modified, handmade sprinkle irrigation techniques that have a tendency to waste. Commercial varieties of fruits and vegetables preferred by farmers are higher yielding at the same time require more fertilizers and are more prone to pest and diseases. Therefore farmers often use excessive amounts of fertilizers and pesticides with no hesitance to what is going to happen as it leaches into the ground water resources.

The National Water and Sewerage Policy (NWSP) provide a framework to coordinate action for the provision of adequate water for human consumption and sewerage services and for the proper management of water resources in Maldives.

Nepal

In Nepal, About 15% of the total populations in do not have access to electricity and about 16 % people still use fuels like wood, charcoal, coal and dung for cooking and heating (World bank 2017). Major energy resources in Nepal can be broadly classified into three categories by Pokhrel: traditional, commercial and renewable. Traditional sources include biomass mainly firewood, agriculture residues, and animal dung. Commercial sources of energy are petroleum, coal, and electricity. Renewable energy sources include mini- and micro-hydro, solar, biogas, briquettes, improved cooking stoves, and wind-power. Firewood and animal dung is the major source of cooking fuel in the villages in Nepal basin as majority of households does not have an access to modern sources of energy. Very few people rely on fossil fuels and bio gas. The country does not have its own reserves of gas, coal or oil. Although it's most significant energy resource is water, less than one percent of the potential 83,000 megawatts of hydropower is currently harnessed. Firewood is the predominant energy carrier, counting for more than 70 per cent of consumption. However, its use is inefficient and poses a threat to the country's forests. At the same time, the indoor pollution caused by open hearths in homes presents a hazard to health. Mains electricity is generally only available in urban areas and some 60 percent of the populations do not have access to it. Biomass is by far the most utilized primary energy source and the electrification rate of the population is only about 55%, with approx. 43% in rural areas. Nepal's average annual per capita electricity consumption is about 130 kWh – one of the lowest consumption in South Asia. Despite its vast hydropower potential, Nepal continues to suffer from a severe and long-lasting electricity supply crisis.

Pakistan

Pakistan is blessed with 3rd largest reservoir of freshwater in the shape of over 7000 glaciers to the North, and the snow-melt water passes through the plateau and plains of Indus river and its tributaries and provide water to its rich fertile land for agriculture. Monsoon is the also a major source of fresh water in Pakistan. Besides, about a million tube wells augment the supply of freshwater from underground to make up for the scarcity of water primarily for agriculture, drinking, and sanitation. Per capita surface water availability was 5,260 Cubic Meters per year in 1951, which has reached to alarming value of 1,000 Cubic Meters per capita in 2016. This position is worsening and with rapidly increasing population, this may further drop to about 800 Cubic Meters by 2025 representing acute water short conditions' (WAPDA Annual Report, 2016). As per the Pakistan Water & Power Development Authority (WAPDA), about 104 Million Acre Feet (MAF) out of 144 MAF of surface water is being, annually, diverted to the Indus Basin Irrigation System. This provides irrigation facilities to 48 Million Acre (MA). Hence, the irrigated land base at present corresponds to 55.30 % of the total cultivable area 86 MA. Around 50 MAF is pumped from groundwater. Direct rainfall contributes less than 15 % of the water supplied to crops.'

In Pakistan, over ninety % of the water is used by Agriculture. Water is also a crucial source of electricity generation in Pakistan. About a third of Pakistan's electricity comes from hydropower. The identified potential of hydropower in Pakistan is more than 120,000 MW; whereas, the economically viable hydropower is more than 60,000 MW. However, at present, Pakistan taps only about 7,000 MW from hydropower. Pakistan's first draft National Water Policy is at the final stage of approval. Its overarching objective is to impart Water Security in Pakistan.

Sri Lanka

Sri Lanka is a country with 103 rivers. Of these river basins, about 20 comes under perennial while the rest belonging to the category of seasonal rivers. The magnitude of the river basins varied depending on the extents which range from 10 to 10,000 km^2. Geographically, the extent of land belonging to river basins is about 90% of the total land area of the country. It is also endowed with very high rainfall which is the primary water source of the country. Annual average rainfall over the country is 1940 mm which is equivalent to 132,000 million cubic meters (MCM) of water. Considerable fraction of this surface water stored in the man-made reservoirs. The estimated runoff: rainfall ratio is 40.5 % (NAP, 2014). The ancient tanks are categorized in to 3 groups namely minor tanks (command area less than 80 ha), medium tanks (command areas ranging from 80 to 100 ha) and major tanks (command area more than 100 ha). Groundwater resources also play a vital role in this country for domestic uses extracting mainly through shallow dug wells and to a limited extent through tube wells. It has some limited uses in crop irrigation and industries.

Sri Lanka has diverse water resources in both blue and green water domains. Priority has been given to develop policies for the water resources in the blue domain in the past decades. A National Policy on Protection and Conservation of Water Sources, their Catchments and Reservations in Sri Lanka exists at draft stage.

Way Forward for Sustainable Development

The SAARC Regional consultation meeting on SAARC Regional Expert Consultation Meeting on Water-Energy-Food Nexus: A basis for sustainable agricultural development during 3-5th July 2017 in Thimphu, Bhutan deliberated elaborately and identified areas of common concerns and way forward which are categorized in two parts under Policy & Research & Collaboration/Linkages.

Policy

1. Establish policy framework on WEF-Nexus Including ground water in the SAARC Region for equitable sharing and broadening the horizon of benefit
2. Establish SAARC Water Center/Water Management Centre
3. To integrate the policy tools/mechanism to strengthened the WEF Nexus.
4. To enhance the regional cooperation of water right/resource/share.
5. Create “One Window Services” to coordinate WEF Nexus interconnections. (Like special economic zones/export processing zones)
6. To enhance the road/rail transportation/connectivity to strengthened the food security and reduce the energy use.
7. Develop regional institutions under the aegis of SAARC for transboundary resource management (eg – water drainage data, food surplus/shortage data)

Research and Collaboration/Linkages

1. Establish the mathematical Model for WEF Nexus for forecasting and decision support.

2. To consider Land and Social aspect to address WEF Nexus.
3. To conduct the study of spring-water of SAARC region (w.r.t climate change & natural disaster)
4. To give emphasize on renewable energy for promoting WEF nexus interconnections.
5. To give incentives to the PPP/NGOs to create awareness & promotion of using sustainable renewable energy.
6. Promote people to people and business to business linkages.
7. To introduce and promote of alternative and efficient crop production technologies (e.g Hydroponic in the area where unavailability of fertile land and water shortage)
8. To find out the way forward for optimal use of surface water to minimize over exploitation of ground water.
9. Inclusion of WEF nexus in the curriculum of technical universities in SAARC region.
10. Establish multi-stakeholder platforms in the region for WEF nexus dialogue amongst policy maker/scientists/stakeholders
11. Strengthen institutional linkages for research collaboration/technology transfer/capacity building/exchange of data & information

It is evident from the country report that about half of this SAARC region's total population is food-energy deficient and about 20% lacks access to safe drinking water. All the country in the region is challenged with production of food from limited land, water and increased energy cost. Agriculture and food production is the largest user of water regionally and globally. It is responsible for 80–90% of consumptive water use from surface water and groundwater. Food production and supply chains also consume substantial amount of energy. Apart from agriculture use, water is also used to generate electricity. The ability of existing water, energy and food systems to meet this growing demand, meanwhile, is constrained given the competing needs for limited resources. It is inevitable that an integrated approach like WEF Nexus is necessary to ensure food security, access to safe drinking water and modern affordable energy.

Chapter 1

Water-Energy-Food Nexus- Basis for Sustainable Agriculture in Bangladesh

Md. Hemayet Hussain[1] and Mohd. Sher Ali[2]

[1]Joint Secretary, Ministry Agriculture, Bangladesh
[2]Deputy Secretary, Energy and Mineral Resources Division, Ministry of Power, Energy and Mineral Resources, Bangladesh

mhh1863@gmail.com

Introduction

Of all natural resources, water, food and energy are the most critical to sustaining life. Given the rise in the human population, economic development and the inevitable consequences of climate change, the challenges for achieving secure and sustainable supplies of water, energy and food are onerous. The WEF nexus view acknowledges these links in management, planning and implementation, and proposes to integrate management and governance across sectors and scales to improve water, energy and food security. This is a new concept, generally recognized as having its origins in the Bonn 2011Nexus Conference. Given the interconnectedness across sectors (water, energy and food), space and time, a reduction of negative economic, social and environmental externalities can increase overall resource use efficiency. Compared with other management approaches, the nexus approach can better transition societies towards a green economy and the wider goal of sustainable development (Benson et al., 2015; Hoff, 2011). Water, energy and food resources are crucial to drive economic growth and pull several million remaining people out of poverty in Bangladesh. The water, energy and water policies consider security concerns of these resources without considering their integration.

With over 150 million people in an area of 147,570 km^2, Bangladesh is one of the most densely populated countries in the world. Although its economy has grown rapidly in recent years, agriculture dominates employment, about 46% of the population involved directly or indirectly in agricultural activities. The share of agriculture in gross domestic product (GDP), however, has fallen below 20% as service sectors have grown to employ 52% of the workforce.

Agriculture in Bangladesh: Current Situation

Agriculture is the principle activity and driving force of Bangladesh's economy. Achieving food security, increasing self-employment and the gradually increasing role of agriculture in the export business is greatly speeding up Bangladesh's economic development. Favorable agro-climate that generally prevails throughout the year is very much suitable for crop production. Considering the favorable agro-climate condition the modern varieties and technologies developed by researchers are being extended to the farmers' level. The country's agricultural research organizations are continuously developing varieties of different crops that are high yielding, insect and disease resistant, and tolerant to salinity, drought, heat, cold, and submergence with the development of new varieties. There has also been success in new cropping patterns and water use efficient technologies. Through IPM, quality safety food and pesticide free vegetables are being produced. Through the increase of distribution of high-yielding variety seeds and quality hybrid seeds and surface water use irrigation leading to increase in area of irrigation, productivity is increasing further. Apart from these, efforts are continuously being made to ensure agricultural inputs, equipment, farm machineries and fertilizers are available at subsidy price and a balanced fertilizer use is being maintained. Farmers hampered by natural disasters are being rehabilitated and damage compensated through government subsidy programme. Steps have been taken to make e-agriculture more popular among farmers. Rubber dams are being constructed to increase irrigation area by using surface water. Due to the application of agricultural mechanization and appropriate modern technologies, the country's traditional agriculture is on the verge of transforming into commercial agriculture. Agriculture has started to transform from subsistence mode in the past to semi-commercial level at the current stage. The recent crop sector development shows transformation from subsistence agriculture into semi-commercial agriculture.

Rice is the dominant staple food crop and occupies over three-fourths of crop area. This has been a major development success of Bangladesh and a key contributor to poverty reduction and hunger eradication. Overt time there has been some degree of diversification from this 'mono crop' agriculture with increased production of non-cereal crops and commercial high-value crops. Other prominent crops are jute, wheat, potato, maize, pulses, oilseeds, spices, vegetables, sugarcane, cotton and tea. In recent years, the cropped area under boro rice, maize, potato, fruits and vegetables are increasing mode. Under HYV, 70% of cropped area today, with current rate of conversion, almost all suitable land is expected to come under HYV within the next decade or so. While additional land could be brought under crops through increase in actual area cropped (conversion of non crop or non-agricultural land and restoration of degraded land) and increases in cropping intensity in terms of cropping intensity, while the present rate of 1.9 compares favorably with other Asian countries.

Table 1. Sectoral Share of GDP at Constant Prices (Base Year: 2005-06)

Sector/ Sub-sector	Production (%)		
	2005-2006	2011-2012	2015-2016
1. Agriculture and Forestry	15.33	13.70	11.68
a) Crops and horticulture	11.10	10.01	8.32
b) Animal Farming’s	2.38	1.90	1.66
c) Forest and related services	1.86	1.78	1.69
2. Fishing	3.67	3.68	3.65
Total (Agriculture+ Fisheries)	19.00	17.38	15.33

(Source: Economic Review 2016**)**

Food and Nutrition Security Situation

Bangladesh has made significant progress in improving food security and nutrition in the last twenty-five years. The improvement in food security has come about through progress in both availability of and access to food. In the early 1970s, Bangladesh was a food-deficit country with a population of about 75 million. Today, the population has more than doubled to over 160 million, but food production has more than kept pace with population growth—so much so that at the aggregate level the deficit no longer exists. Crop production has accelerated, especially since the late 1980s, when the Green Revolution—based on new seed, fertilizer, and irrigation technologies—finally took off. In the 1980s, the government liberalized the input markets, gradually eliminated subsidies on agricultural inputs, and removed bans on private-sector imports of agricultural machinery. These policy changes induced private investment into small-scale irrigation, such as shallow tube wells and power pumps, all of which has contributed to the faster growth of dry-season irrigated rice (boro). Driven mainly by the expansion in boro rice, total rice production has more than tripled in the last three decades while the population increased by only about 60 %. Non-crop agriculture has grown at an even faster rate than crop production, with the result that its share in total agricultural gross domestic product (GDP) has gone up from 35 % to 45 % in the past three decades. There are still shortfalls in the production of certain non cereal crops as well as some non-crop foods relative to demand, but overall it is fair to say that Bangladesh has attained food self-sufficiency at the aggregate level as far as calorie availability is concerned. This is evidenced by a dramatic decline in import dependency for rice, which is still by far the most important source of calories in Bangladesh (around70 %): from 4.7 % in 2007–08, the import ratio has declined to less than one % in 2013–14.

Until the mid-1990s, Bangladesh, along with other countries in South Asia, had a persistently high level of under nutrition. The rate of stunting (low height-for-age) among children under five, which is a good indicator of the state of chronic under nutrition in the population as a whole, remained stubbornly above 50 %. More intriguingly, Bangladesh's stunting rates, along with those of the rest of South Asia, were significantly higher than those of Sub-Saharan Africa, where people were both poorer and less educated than in South Asia. UNICEF christened this anomaly as the "Asian Enigma" (Ramalingaswamy et al. 1997).

Since then, Bangladesh has achieved a great deal by way of improving the state of nutrition. So much so that a recent cross-country study by Headey (2013) concluded that from 1997 to 2007 Bangladesh had recorded one of the fastest prolonged reductions in child underweight and stunting prevalence in recorded history, narrowly behind the more celebrated case of Thailand in the 1980s and just ahead of several success stories identified in the nutrition literature, such as Brazil, Mexico, and Honduras. The trend of improvement observed up to 2007 has continued to this day. The rate of stunting, which reflects a state of chronic under nutrition, has come down from55 % in 1996–97 to 36 % in 2014. The rate of wasting (low weight-for-height), which reveals the state of acute malnutrition, has not, however, improved much. Indeed, it showed hardly any improvement from 1996–97 to 2007, the period for which Bangladesh was being acclaimed as a star performer; it is only recently that a modest improvement has been evident. Finally, the rate of underweight (low weight-for-age), which reflects the combined effect of chronic and acute malnutrition, has improved in roughly the same manner as stunting. Given the stubborn nature of wasting, it is not surprising that this has been the slowest to change.

There are also other indicators of significant improvement in nutritional status over the last two decades. A good example is maternal under nutrition, as measured by "low" body mass index (BMI)—meaning a BMI of less than 18.5—which is taken as a symptom of chronic energy deficiency (CED). According to this measure, under nutrition among women of reproductive age has declined sharply from 52% in 1996–97 to 33% in 2007 (NIPORT et al., 1997, 2009), and further to 17% by 2014 (HKI /JPGSPH, 2015). Yet another indicator is child mortality. Although many different factors can influence the level of child mortality, under nutrition is known to be one of the major factors: international evidence suggests that almost half (45%) of all under-five deaths in the developing world can be attributed to under nutrition (Black et al. 2013). According to DHS data, under five mortality has declined in Bangladesh from 133 per thousand in the mid-90s to 46 in recent years (NIPORT et al. 1997, 2015). The credit for a large part of this decline must go the improvement that has occurred on the nutritional front, although health interventions may have played an even bigger role.

Water Resources and its Management

Agricultural practices in Bangladesh are controlled by the hydrological-cycle. Farmers need protection against flood in wet season, irrigation in dry season, supplementary irrigation even in wet season, protection against saline water intrusion in coastal area, proper drainage both in wet and dry season, protection against river erosion, protection against the water related hazard (storm surge/cyclone) in coastal belt. Besides these natural phenomena, the man-made interventions both within and outside the country are adding challenges in the water sector development and management of the country. Under these circumstances, water resource planning in Bangladesh has to take into account a variety of geographic, economic and environmental factors. Bangladesh is the largest delta in the world – located at the confluence of three of the worlds' major rivers the Ganges, the Brahmaputra and the Meghna and their tributaries and distributaries. The river systems drain a total area of about 1.72 million Km^2 in India, China, Nepal, Bhutan and Bangladesh. Besides these three major rivers, Bangladesh also shares 57 trans-boundary rivers with her neighbors (54 with India, and 3 with Myanmar). These river systems carry between 1.0 and 1.6 trillion cubic meters of freshwater and 1.0 billion tons of sediments annually, the status of which is dynamic and considered as the lifeline of Bangladesh. This has a decisive significance and challenge, with around 93% of the total basin actually lying outside Bangladesh. Being the lower most riparian country, Bangladesh alone cannot undertake any meaningful and comprehensive water resources development programmes to harness the waters that flow over its territory, as it is largely dependent on the upper riparian countries for water availability and use.

Yearly rainfall distribution in Bangladesh is uneven. About 89.52% of the total annual rainfall occur during wet months (May to October) and the remainder occurs during dry months (November to April). The efficacy of rainfall for crop production is dependent on its adequacy, certainty and distribution. Amount of rainfall is very little for crop production in dry season. On the other hand, it is quite abundant in wet season. Bangladesh, as a lower riparian country of the Ganges-the Brahmaputra-the Meghna basin, continued development of upstream basin increases the disadvantages of lower riparian region as abundant surface water in the wet season and lean water flow in the dry season face the paradoxical situation. Reduction of the dry season flows due to increasing upstream withdrawal causes severe water shortages across the country and particularly southwest region. Reduced stream flow also aggravates salinity intrusion and environment degradation (Ahmed and Roy, 2007). Also surface water of the country is unprotected from untreated industrial effluent, municipal waste water, runoff pollution from chemical fertilizers, pesticides, oil, lube spillage in the coastal area and is polluted from point and non-point sources. Ground water is the major source of irrigation water and plays a very vital role during dry season and drought periods. But the availability of ground water resources has become a problem in the recent days and the reasons are arsenic in ground water, excessive dissolved iron, salinity of the shallow aquifers in the coastal areas, ground water mining and rock/stony layers in hilly areas (BUET, 2004).

Irrigation water for cropland in Bangladesh is available from two sources i.e. surface water and ground water. Irrigation is one of the key components of increasing crop production and expansion of ensured irrigation facilities is also one of the vital agriculture strategies of the Government. Presently, about 62.96% of total cropped area has been brought under irrigation. Rice covers about 76.70% in which aman rice covers 10.89% and boro rice covers 65.80%, wheat covers 4.77%, potato covers 5.28%, vegetables covers 4.69%, sugarcane covers 0.84%, cotton covers 0.29% and others covers 7.42% of the total irrigated area (DAE). Crops are irrigated mainly by two systems i.e. surface water irrigation and groundwater irrigation system. Irrigation through surface water and groundwater covers 22.45% and 77.55% i.e. 1.21 and 4.19 Mha irrigated area, respectively (BADC, 2014).

Water Resources Policies and its Link to Agriculture

The government of Bangladesh has adopted national water and food policies. The adoption of the National Water Policy (NWPo) at the end of 1999 was a milestone towards the good governance of water resources (Gain and Schwab, 2012). The stated goal of the NWPo is "to ensure progress towards fulfilling national goals of economic development, poverty alleviation, food security, public health and safety, a decent standard of living for the people and protection of the natural environment" (MoWR, 1999). The NWPo recognizes the interaction of water and food security. To ensure food security, emphasis is given to the development of groundwater irrigation and conjunctive use of surface and groundwater. Bangladesh Water Act 2013 also has given emphasis on agriculture, aquaculture and power generation.

The National Food Policy (NFP) was endorsed by the Food Planning and Monitoring Committee (FPMC) and thereafter approved by the cabinet in August 2006. The policy provides strategic guidance on addressing the key challenges facing Bangladesh in achieving food security in all its dimensions. It clearly recognizes the linkages between water and food. To increase food production, the key priorities of the NFP are to extend irrigation coverage by improving delivery and the efficient use of safe irrigation water, to reduce dependency on ground water, and to reduce costs of irrigation water (MoFDM, 2006).

Water Resource Use Competition

Water use in Bangladesh is dominated by irrigation with estimated annual use varying from 25 to 33 km^3 of which 80 % is from groundwater. Domestic and industrial demand is estimated at about 2.7 km3 per year, which is projected to increase to about 4.1 km^3 by 2050. Groundwater is overused in the Barind and around Dhaka, and there are concerns about the level of use elsewhere. However, maintaining and increasing food production for the growing population without increasing (and probably reducing) the use of land and water for agriculture will be an immense challenge, particularly in view of the concerns about overuse and the possible impacts of climate change. Bangladesh is already increasing crop yields and there is good potential for further increases.

Energy Security

Ensure energy security for irrigation is a precondition for sustainable agriculture. Considering the importance of agriculture development Government of Bangladesh (GoB) is ensuring fuel supply to agriculture for irrigation with subsidized price. Different steps are taken by the concerned departments/ organizations/companies regarding import, stock, supply to the door steps of the farmers on time. Energy and Mineral Resources Division (EMRD) is mandated to energy security.

Energy is the most essential factor for the bumper production of 'Boro' rice and also for other agriculture products. Fuel plays unlimited role in the socio-economic development of the country. So, a lion share of our hard-earned foreign currency is spending to fuel import. It is a challenge to ensure supply of imported fuel to the door step of rural remote area people at the rate fixed by the Government on time. Government of Bangladesh ensures fuel supply that increases the rate of economic growth of the country.

Diesel is mostly used to the pumps for irrigation. Irrigation season is mainly considered five months from December to April. But in some year summer (draught) prolong to May. In this time the daily demand for diesel and some other fuel increases several times than normal season in the irrigation areas. Oil marketing companies, in this time considering probable demand make sufficient stocks at main installation situated at the eastern port city Chittagong, regional depots in different parts of the country and sales or supply centers to ensure energy /fuel security for agriculture.

Irrigation machines, power pumps for surface water use or deep or shallow tube well for underground water lifting are operated by using oil mostly diesel or electricity. Renewable energy like, solar and wind is not still mentionable. Energy and Mineral Resources Division (EMRD) is mandated of gas and fuel supply. Bangladesh Oil, Gas & Mineral Corporation (Petrobangla) and Bangladesh Petroleum Corporation (BPC) under EMRD are solely assigned to gas and oil supply respectively through its related companies. About 40% lifted gas is supplied to power generation companies at subsidized rate by the gas distribution companies under Petrobangla ensuring electricity supply. To ensure energy security, state owned BPC imports oil; and distributes throughout the country. For the long time Government of Bangladesh has given subsidy on imported fuel for keeping price lower to benefit the mass people. To ensure irrigation facilities the rate of subsidy to diesel was higher than other fuel. But in the recent years subsidy is withdrawn, due to the price down of fuel in the international market.

Normally, Irrigation season starts from December that prolong to May. Every year, in favor of GoB, BPC opens two tiers control cells, Central Control Cell at headquarter and Regional Control Cells throughout the country for intensive monitoring of fuel (especially diesel) supply for irrigation. Responsible senior officials are involved in control cells. These control cells monitors daily stocks, sales, supply situation and continues at the end of irrigation season. Honorable Prime Minister’s Office oversees the situation and local administration involves sometimes. Sometimes inter-ministerial meetings are arranged involving concerned ministries, departments, stakeholders, organizations etc.

To ensure fuel supply for irrigation different steps has to take. Transportation is one of the important factors of safe fuel supply to irrigation. Three ways-water, railway and road are used. 90% fuel is transported by using water way. Costal tankers, shallow draft tankers, bay crossing shallow draft tankers and mini oil tankers are engaged in oil/fuel transportation. Depots that are not connected with river but railway facility is available, fuel is transported by railway. Bangladesh Railway transports fuel from the main installation to northern and southern parts of Bangladesh. Bangladesh Railway makes special arrangement for quick transportation at irrigation season. Though only 8% fuel is transported by railway but it carries a bulk amount at a time. The third way of fuel transportation is by road with tank lorry. Only 2% fuel is transported by road. But it is possible to reach fuel specially diesel direct to the agents/farmers at the time of need. Oil marketing companies plan to meet the farmers demand for irrigation fuel earlier considering agriculture production.

Making diesel supply available for irrigation is another initiative to ensure agriculture productivity. In 2014-15 fiscal year (July-June) 3,396,061 metric ton diesel was supplied to all over the country (of which 664,179 metric ton used at northern area). The demand for diesel was 6.19% higher in 2015-16 fiscal year that reached at 3,606,404 metric ton (729,677 metric ton used at northern areas). In 2014-15 fiscal year at the irrigation season (December-May) 925,085 metric ton diesel was applied for irrigation and in 2015-16 fiscal year that amount was 944, 055 metric ton. It shows that demand of diesel for irrigation is increasing year after year. Considering the increasing demand BPC estimated diesel demand as 3,850,000 metric ton at 2016-17, 4,000,000 metric ton at 2017-1,842,00,000 metric ton at 2018-1,9 44,00,000 metric ton at 2019-204,600,000 metric ton at

2020-21, and 4,800,000 metric ton at 2021-22 fiscal year. We can look back that after independence in 1972 demand for diesel was 109,000 metric ton only.

Agriculture is always one of the top priority sector of government. To increase cropping intensity modernization is needed that support increase rate of productivity. Fuel is the important factor of production to support mechanical irrigation. EMRD is mandated to ensure fuel supply.

Way Forward for Sustainable Development

a. Water resource management

The vision, goals, objectives and targets of the water sector have been defined in conformity with the vision 2021. One of the root-cause for rural poverty is river erosion. The number of people losing everything i.e., land, shelter (home), livelihood means, due to river erosion is significant numbering to 60,000 people per year. River management, commonly understood as dredging**,** would be given top most priority with feasibility assessment in case by case. Another priority is to take measures to reclaim land in the coastal areas. The following strategies would be followed:

1. **River dredging:** Dredging would be carried out in a systematic and comprehensive way in combination with riverbank protection for non-destructive, easy and smooth passage of flood flow of the river system. Such a planned activity would arrest river erosion, which is also a major factor of rural poverty. While making plans for river dredging, priority may be given for rivers of Khulna, Jessor, Shatkhira and Bagerhat to mitigate the perennial water logging and intrusion of saline water to Sundarbans.

2. **Dry season water scarcity:** In the wake of continued stress on surface water especially during the dry period, top-most priority would be given on water sharing of the Common/trans-boundary Rivers with the neighbouring country/countries following the model of the Ganges Treaty-1996. Efforts should also be made to excavate/re-excavate the natural canals as that can help small scale surface water irrigation.

3. **Basin-wide water resources development initiative:** Initiative would be started immediately to enter into agreements with co-riparian countries for sharing the waters of international rivers, data exchange, resource planning and long-term management of water resources under normal and emergency conditions of flood, drought and water pollution. While moving towards the attainment of basin-wide plans in the long run, it will also be necessary for Bangladesh to concentrate on the development of individual hydrological areas to meet short and intermediate term requirements.

4. Ganges barrage project with ancillary infrastructure: The feasibility study of the Ganges Barrage Project has been done during Sixth Plan period, where Pangsha of Rajbari district is selected for the construction of the main Barrage. Total length of the Ganges is 2,200 km of which 240 km lies inside Bangladesh. Total area of Bangladesh dependent on the Ganges for water is 46,000 square kilometer. The proposed Barrage is 82 km away from Bangladesh-India border & 52 km from Hardinge Bridge/Pakshi Bridge and Rooppur atomic energy center downstream. As per feasibility study, Ganges Barrage Project has contained 78 Spillways with 2.10 km barrage length, 3 Offtake Structures, 8 Regulators, 265 km embankment improvement, 1,116 km river/khal re-excavation etc. The project will require a period of 7 years for its completions. In 7th FYP period, government will pursue to (i) harness properly the benefits of the Ganges Water Treaty 1996 (ii) to save the Sundarbans and the south-west region of the country from salinity intrusion and (iii) to utilize the surface water in the wake of wide-spread arsenic contamination in groundwater.

5. **Reducing climate change induced internal migration and reclamation of agricultural land through river channelization:** Channelization and morphological prediction of major rivers reducing river erosion, thereby helping reduce internal migration caused by such erosion, and reclamation of agricultural land will be pursued under the plan. Major rivers of Bangladesh like the Brahmaputra, the Jamuna, the Meghna use up huge lands, which can be effectively managed through channelization using Remote Sensing, based morphological prediction information. Furthermore, river dredging can enhance the functionality of rivers. The dredging volume, in turn can be used for productive purposes. CEGIS has gained experience in assessment and optimum use of the dredged volume for various productive purposes; and this knowledge and experience will be used for river channelization. This will, thus, be facilitating the navigability, land reclamation, and riverbank protection.

6. **Participatory water management:** The approach would be followed in all water resources sector projects right from the identification up to monitoring & evaluation. The approach is mandatory for all public sector institutions.

7. **Maintenance of completed projects:** The completed projects of water resources sector especially the flood control, drainage and irrigation project would be properly operated and maintained with the participation of stakeholders so that the targeted benefits of the projects are ensured. Dedicated fund for operation and maintenance may need to be created for all projects.

8. **Command area development for food production:** BWDB would continue to pursue command area development activities in surface water irrigation project and to explore expansion of irrigation, river protection and embankments.

9. **Coastal zone management:** Coastal Zone is the zone of prosperity and at the same time most vulnerable place within the country. The area would be treated as a special zone.

10. **Public private partnership:** As water resources development interventions are costly initiatives, public-private partnership model has to be explored whenever possible.

b. Agriculture development

Agricultural research: The National Agricultural Research System (NARS) institutes generate the demand-led agricultural technologies (varieties and management practices) and information. It also covers scaling-up the developed technologies including validation trials. The major researchable areas by NARS institutes are:

- Research thrust on yield and quality improvement of rice, wheat, maize, pulses, oilseeds, tuber crops, vegetables, fruits, cotton, jute, seaweeds, aquatic plants, spices and stress tolerant, climate change resilient variety development and improved management practices; post-harvest management, processing and value addition of agricultural commodities; pest and disease management for crop; natural resource management (NRM); biotechnology & bio-diversity; farm mechanization etc.;
- Development & extension of hybrid/genetically modified crops and biotech/transgenic crop through strengthened capacity on this sectors and initiate basic research to support applied and adaptive research;
- Address the problem areas (like hills, coastal, haor, bills, char land and barind areas) that are more prone to climate;
- Research on climate SMART agriculture, breeding and introduction of climate resilient varieties for saline and drought tolerant, heat & cold tolerant, submergence etc.;
- Develop and refine technologies that will bridge yield gaps and promote diversification, sustainable natural resources management, rain & river water harvesting for agricultural production, disease and pest management, etc.;
- Research on IPM, on-farm water management, high value commodities, safe food and quality food, Good Agricultural Practices (GAP); and market intelligence;
- Breaking yield ceiling with genetic gain, development of super hybrid rice, incorporation of yield stabilization traits through conventional & innovative approaches,
- Crop management, post-harvest handling, crop protection, cultural management, soil and nutrient management, irrigation water management

and pest & disease management technology development and agri-machineries development,

- Emerging technologies like information technology, use of super-efficient Geographic Information System (GIS), biotechnology, gene management, IPR, bio-safety, laser technology,
- Development & extension of high yielding varieties of wheat, maize, vegetables, off season fruits, pulses, oilseeds, tuber and spices crops with nutrient enriched varieties.
- Emphasis on research and development work on multiple cropping, stress management through agronomic practices with conservation agriculture.
- Intervention of biotechnology like genomics, proteomics, micromics and double haploid research will be enhanced for developing biotic and abiotic stress tolerant variety.
- Selection & up scaling of suitable crop varieties and management practices (soil & water) according to land elevation and hydrology for increasing cropping intensity.
- Strengthening Research & dissemination of horticultural field crops technology in char land and hilly areas.

Agricultural extension: Transfer of technologies and diversification and intensification of crop production programme through appropriate extension services are of crucial importance. The following priority strategy will be adopted for extension services:

- Strengthening research–extension-farm linkages;
- Expansion of small scale irrigation technology and surface water for irrigation;
- Different stress tolerant varieties of rice should be extended;
- Extension of saline tolerant variety of crops in the coastal region;
- Diversification to high value crops, i.e. cotton crops in Barind area, Hilly areas, southern coastal region and char land areas with appropriate extension strategy.
- Development and promotion of environmentally sound farming practices;
- Promote mechanization of farming operations;
- Promote community seed production, storage and distribution, build up seed SME;
- Promotion of Rice Yield Gap Minimization (RYGM) techniques;
- Promotion of green growth agriculture by intensifying IPM, IDM, ICM, AWD and organic farming;

- Replace Tobacco cultivation with Maize & Chewing type sugarcane farming;
- Strengthening MIS (ICT) based knowledge management system and e-agriculture;
- Establishing more Agriculture Information and Communication Centre (AICC) at village level;
- Establishing more Farmer's Information and Advisory Centre (FIAC) at union level;
- Strengthening human resources development programme of extension agencies through higher education, training and exposure visit;

Agricultural Inputs- Seeds and Fertilizers

As per seed policy 1993 the concerned agencies under the MoA will be further strengthened in order to ensure production of quality seeds/quality planting material at all stages of its production- breeder, foundation and certified seed and encouraged farmer to produce quality seed and farmer to farmer seed exchange. Emphasis has been given to Public & Private sector involvement in research and development of hybrid and HYV seed.

- BADC and Horticulture Centers of DAE, BRRI, BARI, SCA will be further strengthened in order to ensure production of quality seeds/quality planting material at all stages of its production- breeder, foundation and certified seed
- Encouraged farmer to produce quality seed and farmer to farmer seed exchange.
- Farmers will be given training and technical assistance to extend improved methods of seed production, testing, storage and post-harvest management.
- Ensure timely supply of fertilizers to meet the increasing demand.
- Emphasis/support will be given for the production of bio-fertilizers and facilitating their increased use.
- Adopt pragmatic measure to encourage farmers using balanced fertilizers, integrated plant nutrition system, crop rotation, compost, vermi compost, green manure, bio-fertilizers.

Use of Water Resources and Water Economy

Water is a very essential input for increasing crop production and sustainable agriculture. A well planned irrigation management system is essential for gradual increase of cropping intensity as well as yield. In order to ensure water efficiency and for best utilization of water resources following strategies will be adopted:

- Rain water harvesting for irrigation, discouraging the use of deep tube well for irrigation and discouraging the cultivation of high water demand crop in Barind Area
- Large scale adaptation of water saving technologies such as drip irrigation, sprinkler irrigation, furrow irrigation, alternate furrow irrigation, and deficit irrigation, dug well etc. at farmer's level will substantially increase the water use efficiency.
- Development of cropping pattern based irrigation scheduling will increase the WUE. Replacing of high water consuming crops with low water requirement crops.
- Use of alternate water resources for crop irrigation such as saline water, municipal waste water will reduce the pressure on other fresh water resources.
- Expansion research program will be taken for mechanizing conservation agriculture and efficient water lifting devices (axial flow pump and solar pump) and development and Extension of aerobic & water saving crops.
- Extension of small scale irrigation technology for using surface water by construction of Rubber dam, Crick dam, Drains & Irrigation channel etc.
- Increase water use efficiency through improved on-farm water management technologies such as AWD, Buried Pipe, Hose Pipe, Raised Bed rice irrigation, Drip & Sprinklers irrigation, Hand Shower irrigation, Mulching etc.
- Expanding Aus area by conjunctive use of underground and rain water in northern and Kushtia and Sylhet region.

Minimizing Yield Gaps

Yield gaps in crops between potential and farmers' yields are still substantially high due to the combination of constraints, such as poor management and economic conditions of farmers and lack of resources, especially credit and knowledge. Efforts should, therefore, be made to minimize the yield gaps and increase and sustain production and productivity of crops by properly addressing the constraints. It is also essential to promote collaboration among research, extension, NGOs, and private sector to develop appropriate technologies, Promotion of integrated crop management, adequate input and credit supplies and Policy support with a view to narrowing yield gaps.

Farm Mechanization:

Mechanization creates employment opportunities; provide dignity to agriculture profession and better livelihood and increase gross income. Energy input on the farm in Bangladesh (about1.09 kW/ha) is much less compared to Japan (8.75 kW/ha), Italy (3.01 kW/ha), France (2.65 kW/ha), UK (2.50 kW/ha), and India (1.50 kW/ha). This indicates that Bangladesh has ample opportunity in mechanizing agriculture and increasing productivity. The Government will, of course, have to play its pro-active role in popularizing the use of selected demand-led agricultural tools and machinery, and facilitating use of renewable energy including solar power in agriculture production through give subsidy.

Creating Opportunities for Sustainable Agriculture and Green Growth:

Sustainable agriculture will be built on current agricultural achievements while adopting new approaches that can maintain high yields and farm profits without undermining their resource conservation on which the agricultural system depends. Green growth strategy will pave a sustainable pathway towards a prosperous, inclusive and climate resilient future for Bangladesh.

- Development and extension of bio-rational based Integrated Pest Management (IPM)/IDM approaches for sustainable pest management system instead of existing chemical pesticide based system. These programmes will be intensified and expanded in order to safeguard crops from pest and combat environmental degradation due to pesticide uses.
- Organic farming along with use of crop residues, compost, vermi-compost and animal waste has been popularized but need more effort.
- Increased use of rural & urban organic wastages, waste water and crop residues for renewable energy (biogas) and bio-pesticides instead of chemical pesticides.
- Plant protection activities are largely in the private hands. However, the public sector programmes are confined to qualitative and quantitative aspects of plant protection.
- Develop crop modeling based on carbon trading.

Introduction and Popularization of Good Agricultural Practices (GAP):

Protocol development for Good Agricultural Practices (GAP) suitable for Bangladesh agro-ecological and socio-economic conditions should be the major priority. There are four pillars of GAP: economic viability, environmental sustainability, social acceptability, and food safety and quality. Research and extension will put effort jointly to promote the process. Good Agricultural Practices (GAP) and Sanitary and Phytosanitary (SPS) measures will also have to be popularized and promoted.

Climate Change Adaptation:

New technology generation for vulnerable areas e.g. stress tolerant varieties and management practices, quality improvement of major crop varieties, pest and disease management, resource conservation, and climate smart technologies are needed to combat climate change.

- Environmental, climate change and disaster risk reduction considerations are integrated into project design and address the problem areas (like hills, coastal, haor, bills, char land and barind areas) that are more prone to climate. Long term and holistic project formulation is essential;
- Research on climate SMART agriculture, breeding and introduction of climate resilient varieties for saline and drought tolerant, heat & cold tolerant, submergence etc.;
- Seed multiplication and dissemination of stress tolerant crop varieties are very much required;
- Developing GIS and Remote Sensing Awareness System for farmers about production risks and improving farmers' knowledge in carrying out agricultural activities to avoid risks of climate change;
- Strengthening Integrated Pest Management system in Haor agriculture;
- Strengthening e-Agriculture & Management Information System (MIS);
- Afforestation and Reforestation in Coastal Areas through Homestead Fruit tree Plantation is required (Specially Palm, Date palm, Coconut, Dwarf Coconut, Nut);
- Extension of Saline Tolerant crop/Varieties in Saline Prone Areas;
- Strengthening micro nutrient management for sustainable crop production;
- Extension of less water consuming crops in drought areas;
- Rain water harvesting technologies required to be included in project formulation;
- Floating agriculture technology, Sorjan methods etc. are being piloted by DAE;
- Timely dissemination of Agro-Meteorological services for the farmers and real time and translated early warning and forecasting for the farming community.

Commercialization of Agriculture:

Agriculture has started to transform from subsistence mode in the past to semi commercial level at the current stage. In the wave of globalization, small holders need to be enabled to integrate in the markets to effectively contribute to the production of high value crops. To this effect, they need better access to credit and other agricultural services - such as extension, information and local market infrastructures and services. Most importantly there needs to be more private participation and investments in the agriculture value chain development. Fair price and market access to encourage farmers will be ensured to further intensify crop production in order to satisfy domestic and export demand.

Boosting Agro-Processing Industries and Minimizing Postharvest Loss:

Bangladesh experiences seasonal surpluses in several agricultural commodities of perishable nature. Development of agro-processing facilities can prevent postharvest losses and enhance farmers' income. Food processing e.g. fruits canning, fruit drinks, mushroom growing and processing, processing of vegetables, and dried food production also has considerable potential, provided quality control can be ensured. To ensure that their production and export potential are fully realized, the government needs to continue its current commitment to investing in manufacturing and infrastructure, but more so in facilitating private participation in different aspects of those value chains. Agricultural research institutes, especially BARI will carry out research on technology development for post-harvest management. In this regard the agro processing research facility of BARI, BRRI will be strengthened. Nevertheless, the Public-Private-Partnership (PPP) should be encouraged to export processed fruits and vegetables to domestic as well as overseas market. The process of supporting agro-business will be continued and strengthened.

Value Chain Development:

The main effort will be to improve the efficiency of agricultural marketing to reduce market distortions and the cost of marketing, and to ensure that farmers get proper price for their produce and consumer gets quality products. For quality control and ensuring traceability, sanitary & phytosanitary requirements, Department of Agricultural Marketing (DAM) will need to be involved and its capacity developed. For value chain development augmentation of required technological support services should also be strengthened.

Crop Zoning and Land Use Planning:

Considering the increasing demand for food production, it is an essential task to promote optimum land use and its conservation.

1. Production programme will be organized based on crop zoning.

2. Development and Extension of location specific varieties & ecosystem specific production packages.

3. Special attention for Haor area-

- Development & extension of cold tolerant short duration Boro variety(s)

- Early/double transplanting method practice for long duration variety to maximum harvest

4. Special attention for Coastal Zones-

- Selection & up scaling of suitable crop varieties and management practices (soil & water) according to land elevation and hydrology for increasing cropping intensity.
- Replacement of local varieties by BRRI dhan76 and BRRI dhan77 in the non-saline tidal areas
- Cover crop during dry season

Promoting agricultural diversification and expansion of Horticultural Crops:

Agricultural diversification will allow shifting from cereal-cereal cropping patterns to cereal and non-cereal based high value cropping patterns with value added product, including expansion of horticultural crops, promoting sugar beet production and processing it as sugar crop. Agricultural diversification will also achieved by further development of jute, cotton, quality tea production for local consumption and exports as well as that of aromatic rice and commercial flower cultivation, their marketing, and development of associated value chains. Through diversification, food habit can slowly be changed and nutritional security will be better achieved.

Technology based weather prediction and forecasting:

Weather plays an important role in agricultural production. Due to climate change the sufferings to crop agriculture in Bangladesh are very high. There are several international and national studies including those by CEGIS which show that crop yield improves by 10-15% through reduced crop damage by providing localized weather information to farmers. Research work need to be conducted to generate technology based timely, accurate and well-organized weather forecasting system in the context of climate change and crop production. In addition to that research for producing crop varieties in considering climatic variability, crop-cultural practices to minimize the effects of hazardous weather, medium range weather forecasts with a validity period that enables farmers to organize and carry out appropriate operations will be tried out.

Agriculture in the Newly Accreted Coastal Land and Marine Islands:

Bangladesh has acquired or in the process of acquiring a sizeable land area in the Bay of Bengal. Advance planning should be adopted to utilize the land for agriculture expansion. In order to make best use of this land, following measures should be undertaken:

- Research work will be initiated to utilize marine and coastal resources.

- Strengthening research and establishment of research-extensions linkage for development and disseminating saline tolerant varieties and for introduction of new profitable cropping patterns in the newly accreted coastal land and marine islands.
- Steps will be taken to cultivate crops like Khesari, Mugbean, Water melon, Vegetables, Cowpea, Sesame, Sunflower, Groundnut, Sweet gourd, Chilli, Sweet Potato, Barley, Soybean, Sorghum, Chewing varieties of Sugarcane, Sugar beet and Coconut etc. in the coastal area and marine islands.

  Mixed fruit (saline tolerant fruit trees) orchards with intercropping and coconut/dwarf coconut and betel nut cultivation will be promoted.

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Chapter 2

Water-Energy-Food Nexus-A Basis for Sustainable Agriculture in Bhutan

Kinlay Tshering

Director, Department of Agriculture. Bhutan
kinlaytshering@moaf.gov.bt

Introduction

Bhutan is a landlocked country located high in the eastern Himalayan mountain range in an ecologically fragile area and with the total population of around 768,577 people. It is a country that wants its agriculture to become totally organic, measures happiness as well as economic growth, and wants to bring its citizens into the 21st century while retaining its traditional culture. The country is divided into three altitude zones: the sub-Himalayan foothills, the inner Himalayas, and the greater Himalayas. Altitudes range from about 150 meters in the south to about 7,000 meters in the north. Bhutan's forests cover approximately 70% of the country's land area (38,394 km^2), which is the highest proportion of forest cover of any Asian country. Only 7.8 % of the total land area is arable, and the area under cultivation is only about 2.93%.

Bhutan is unique in the world for its Gross National Happiness philosophy (GNH), which has been the guiding set of principle for the Royal Government of Bhutan since the late 1980s. It is a philosophical approach to policy based on the four pillars of equitable socio-economic development; conservation of the environment; preservation of culture; and promotion of good governance. The development philosophy of GNH articulated the idea and vision of a just, equal and harmonious society, and all policies have to be screened using a GNH screening tool. The government takes a holistic approach to the social, environmental, economic, and development challenges it faces. This includes the food, energy and water nexus of issues facing the country. Bhutan provides an interesting illustration of how these issues can be addressed holistically, in a relatively socially responsible, economically beneficial and environmentally sustainable way.

Poverty has declined significantly, falling from around 23 % in 2007 to 12 % in 2012. According to the Bhutan Poverty Assessment (2014), the primary drivers for the rapid reduction of poverty have been: (a) accelerating commercialization of agriculture, (b) rapid development of rural infrastructure (roads, schools, health centers, and electrification), and (c) spillovers from the recent construction of massive hydro-electric projects. Poverty in Bhutan is largely a rural phenomenon. Rural poverty is 16.7%, while urban poverty is 1.8%.

Current Situation of Agriculture in Bhutan

Agriculture is the main driver towards achievement of the national goal of food self-sufficiency and inclusive green socio-economic development. The sector provides livelihoods to 62.2% of the country's population and contributes 16.8% of the GDP, 4.3% of exports, and remains the key source of employment (58% of the employed) and driver for poverty reduction. As a result of proximity and the free trade agreements that Bhutan enjoys with India and Bangladesh, exports of commercial crops have also increased sharply. However, agriculture in Bhutan is dominated by small and marginal farmers with per capita agriculture landholding of only 1.2 ha/household. They occupy most of the country's arable land and produce most of the crop and livestock products.

The country's size and mountainous terrain present numerous constraints, especially in the agriculture sector. More than 31% of agriculture land is on slopes greater than 50%. Development of the renewable natural resources sector, which comprises agriculture, livestock, and forestry, has been relatively slow in the past plan period. The key reasons are low levels of technology adoption, predominance of subsistence farming, large tracts of fallow land, and lack of market access. The slow growth of agriculture has led to heavy reliance on imports of farm products and inputs from India. The Royal Government of Bhutan (RGoB) has therefore assigned significant priority to agricultural development in the 11th Five-Year Plan (FYP). The RGoB considers agriculture to be one of the country's five jewels, recognizing the importance of the farm sector to the national economy, and its significant role in meeting food and nutrition security, poverty reduction, and equitable and sustainable economic development goals.[1]

Of the total arable/cultivated land of 112,556 ha (LCMP 2010) about 18% is under irrigation. The sector faces the recurring challenges of decreasing public investment, loss of agriculture land for other development, underdeveloped infrastructure and services (irrigation, farm road, post-harvest storage, transport services, marketing network), rural urban migration particularly by youth and men which leads to labor shortages and excessive time burdens on women who remain behind on the farm, low yields and high comparative production costs for many commodities, , human wildlife conflict, inadequate credit opportunities, general scarcity of traders/wholesalers and cultural attitudes towards the production of livestock for meat. The amount of agriculture produce that is currently produced by the farmers is not enough for Bhutan's domestic consumption resulting in high annual imports. The agricultural trade deficit has been increasing over time. While exports of agricultural products grew in value at an average rate of 15% per

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[1] *"The Five Jewels of Economy: Dzongdas' Roles"* Speech from Lyonchhoen Tshering Tobgay, Prime Minister of Bhutan during the Conference of Dzongdas, Kuensel, August 12, 2014

annum from 2008 to 2014, imports of agricultural products over the same period grew by 16% per annum[2]. The absolute value of the agricultural deficit rose from Nu 2.3 billion in 2008 to nearly Nu 6 billion in 2014, representing a 17% annual increase. Ongoing challenges in Bhutan pose additional constraints to improving rural livelihoods.

As a mountainous country, Bhutan is particularly vulnerable to climate change. Climate change is having destructive impacts on the agriculture sector as well as on the necessary infrastructure to support it. Increases in temperatures, rainfall variability, shifts in seasonal patterns and increased incidence of extreme events (e.g. flash floods, landslides) have resulted in declines in crop yield, soil fertility loss due to erosion of top-soil and runoff. Further, increased flooding, landslides and extreme events have caused damage to the road network which is critical for market access by farmers and thus livelihoods. These increasing climate challenges to agriculture production place at risk the livelihood of more than 60% of the country's population in rural areas. Therefore, increasing resilience to the impacts of climate change on water security and climate-resilient agriculture to achieve food and nutrition security is therefore a major priority.

Furthermore, shortage of irrigation water is a serious challenge to increasing food production. Most irrigation channels are not functional. Out of a total of 79,740 target acres under the 11th FYP, only 47,424 acres are currently irrigated. Some irrigation channels have begun to experience competing uses from non-paddy and cereal crops. In an increasing number of cases, this has led to fallowing or under-utilization of irrigation channels, which in turn has resulted in decreases in domestic rice production. Lack of irrigation was cited as one of the major reasons that 16.3 % of farmers left land idle according to the Agriculture Census of 2009. Approximately 23% of rural households report that some of their land is fallow. Of the total cultivable land of 94,903 hectares, 26.3% of the agricultural land is left fallow (24,975ha)[3]. Unless the resilience of the agriculture sector to climate change is enhanced, livelihood and food security in Bhutan will be severely undermined.

The agriculture sector has a significant role in the current 11th Five Year Plan (FYP) and the upcoming 12th FYP. The Ministry of Agriculture and Forests has a mandate to improve food security and nutrition, improve rural livelihoods to overcome poverty, and promote sustainable management and utilization of natural resources. In addition to this, the Royal Government of Bhutan's strategy for the Agriculture Sector includes: (a) a targeted and commodity focused approach which reduces imports and promotes exports; (b) a transition from subsistence to

2 The use of an annual increase %age is only indicative since the use of different baseline years would result in a change in the number quoted.

3 RNR Sector 11th FYP (MoAF, 2014)

commercial agriculture that generates income and attractive employment opportunities, particularly for youth; (c) an enabling policy and legal framework; and (d) the promotion of private sector and contract farming.

Food and Nutrition Security Situation of Bhutan

Food security is assessed on food availability (production and supplies), access to food (both physical and economic access), and utilization (ability of individuals to productively use their caloric intake). In the case of Bhutan, there is in general wide availability of food, sufficient access, and adequate utilization. While on the whole Bhutan does not face chronic food insecurity, there are pockets of hunger within the country, particularly in eastern and southern parts.

Notwithstanding economic gains made in the 10^{th} Five Year Plan (2008-2013) and the current 11^{th} Five Year Plan (2013-2018), sector's growth remained insufficient to adequately address poverty and attain food security. Bhutan imports 34 % of its cereal needs, and close to one-third of the population suffers from food insecurity. Out of a total of 205 gewogs (blocks), 51 gewogs (25%), mainly in the east and south, were classified as "vulnerable" to food insecurity. Poor nutrition, food insecurity, and malnutrition pose major risks to Bhutan's population. Despite the country's economic growth, nearly 27 % of Bhutanese households consume less than the daily minimum calorific requirement of 2,124 kcal. About 35 % of households face yearly food shortages.

The renewable natural resources (RNR) sector in Bhutan which comprises agriculture, livestock, and forestry is the primary food sector. Agriculture (Crops) sector was the main driver of the primary sector's growth, which contributed 2.82%. Agriculture and livestock, supplemented by collection and utilization of non-timber forest products (NTFPs), dominate livelihood, employment, and income in the farming community. Bhutan's two main food crops are maize and rice the production of which is 82,035 MT and 83,332 MT respectively (Agriculture Statistics 2016). The other cereals like buckwheat, wheat, barley and millet have also shown a decline in production. Most cereals are consumed domestically, but domestic production is in sufficient and Bhutan imports sizeable amounts of rice (79,306 MT) and wheat (23,264) MT.

The availability of food in Bhutan depends mostly on its own agricultural production, supplemented by some food imports. Bhutan has traditionally been self-reliant in cereal production, though the agricultural area under cereal cultivation has been declining since the mid-1990s. Overall, Bhutan still has a subsistence agrarian economy, but its domestic food production has been declining and failing to meet the increasing food demand while imports have risen (Figure 1).

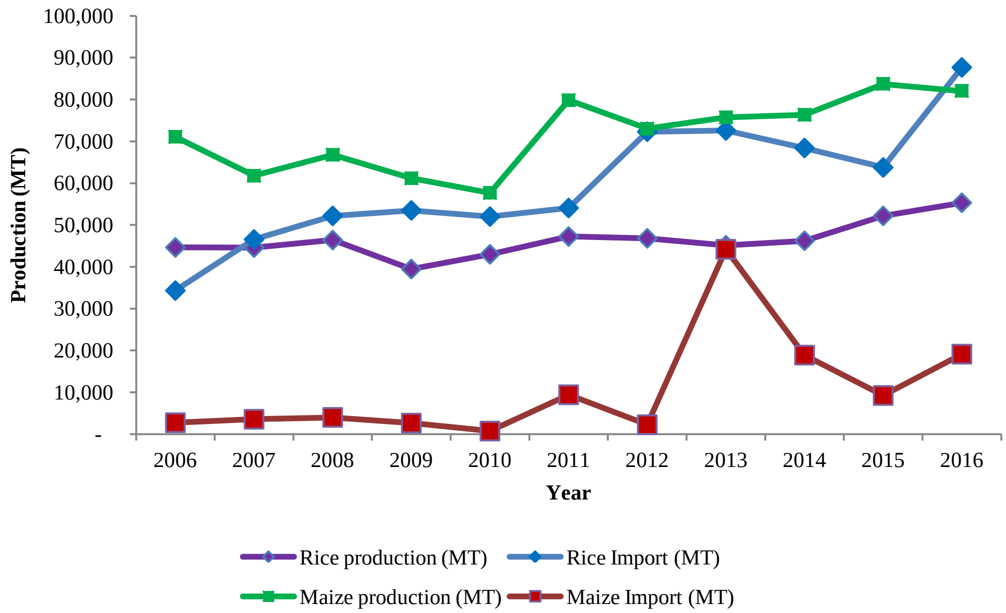

Figure 1. Rice and Maize Production and Import (MT)

Rice is the major food commodity imported into Bhutan, and it is rice consumption that dominates food utilization. Religious principles against the slaughter of animals, as well as inadequate processing and cold storage facilities, and the high transport costs of taking meat to market mean that there is no large-scale meat production in Bhutan. While poultry is more or less self-sufficient, dairy and other meat products are largely imported. Bhutan also produces horticultural commodities such as apples, mandarin oranges, arecanut and vegetables. Overall, Bhutan is a net exporter of fruit, mainly to India and Bangladesh.

There is a seasonal food deficit in Bhutan, which usually coincides with periods of intensive agricultural operations, including tilling and planting, when the food need of the workers are higher than in other times of the year. This limits food availability during specific periods, in particular to certain segments of the population. The most vulnerable groups for food insecurity, therefore are landless farmers, or farmers without sufficient land or livestock holdings. Food shortages are usually linked to food and agricultural productivity because a large proportion of the population depends on subsistence agriculture.

In terms of access to food, remoteness affects access to markets for both consumers and producers within Bhutan. More than half the Bhutanese population lives more than an hour away from a food market. Moreover, steep topography is a hindrance to the expansion of road networks, which would allow easier access to markets for producers and consumers. In rural areas, food access is predicated on extreme topographical variation, and difficulties in subsistence farming arise from inconsistent access to land and water. Crop damage by wild life and pests affects food availability in rural areas, as do rural to urban migration patterns which remove labour from farmland. In urban populations, access to food is linked with unpredictable employment opportunities. The urban population consumes 37% of food intake but constitutes slightly less than a third of the overall population. However, unlike many developing countries, Bhutan's advantage in stemming food insecurity is its controllable population size. In other words, Bhutan has so far been able to afford to import food to fulfill the growing demand from its modestly growing population.

The utilization of food in Bhutan is relatively equitable. However, around 5% of Bhutanese suffer from food poverty, i.e., consume less than 2,124 calories a day. The average national daily calorie intake average, however, is estimated at 2,555 calories per person, and is therefore above food poverty criterion.

In rural areas, rice constitutes a greater share of daily food intake than in urban areas, indicating a potential risk for protein and micronutrient deficiencies in rural households. Meat consumption in Bhutan is also minimal, due in part to religious beliefs and the GNH principles. The utilization of food in Bhutan is strongly linked with Buddhist principles, which are also reflected in the GNH priorities. For example, a farmer might be reluctant to use pesticides that will kill pests on their crops, even if this will benefit crop production, because the killing of animals, even pests, is contrary to Buddhist beliefs. Natural and organic farming methods are therefore given a priority by the government in the production of safe, healthy, nutritious and environmentally friendly food with sustainable and optimum usage of resources. Moreover, the government's approach to addressing food security issues falls under the policy of balanced and equitable development enshrined in the GNH.

Although Bhutan has made good progress in socio-economic development in recent years, within the agriculture sector, the most concerning issue is the general decline in the production of major food commodities such as rice and wheat despite the Government's policy to maintain wetlands for rice cultivation. In the absence of proportionate increase in food grain production versus the increase in population and income, it implies declining per capita food grain production and its adverse impact on food security. Challenges therefore also persist in Bhutan in ending food shortage and poverty, and ensuring food and nutritional security, an adequate standard of living, access to modern energy, water and healthy lives without degrading the natural resource base.

Water Resources and its Management

Availability, access and utilization are also factors in water security. In particular, water security is about affordable access to clean water for agricultural, industrial and household use. By this definition, it can be said that Bhutan is not water insecure. Bhutan has the highest annual per capita water resource availability in the world with 94,500 cu.m /capita/annum. The total annual water availability stands at 70,576.02 cu.m which works out to average flow of 2,238 cu.m/sec in 2015. Water resources are mainly in the form of rivers, streams, springs and lakes. Most of the river system is fed by rainfall, glacial melt (2-12%) & snow melt (2%). The major river basins are Amochu, Wangchu, Punatshangchu, Mangdechu & Drangmechu. All flows north to south draining into Indian plains. Water quality of rivers & streams are in good conditions except at localized urban areas. Deep groundwater is virtually unexplored in Bhutan.

Despite the availability of surface water sources in abundance at national level, there are many localized and seasonal water shortages with settlements on the mountain slopes and the rivers in the valleys. These localized and seasonal water shortages affect drinking water supply and irrigation for agricultural purposes. The reason is that Bhutan is not immune to climate change and been experiencing localized changes in environment such as drying up of river sources, rising temperatures and glacial floods.

Agriculture consumes the highest percentage of water, and the importance of the food-water nexus is expressed in the Bhutan Water Policy, that *"Adequate water allocation to this [agricultural] sector is indispensable for achieving overall national food security"*. The understanding of the interdependence of food and water for the country's growth is enshrined in its management of these resources. Part of the RGoB's vision statement for water resources in Bhutan is that *"Water will continue to be available in abundance to pursue socio-economic development in Bhutan"*. These policies are backed by interlinked visionary statements and approaches such as the maintenance of 60% forest cover at all times, which is extremely crucial to maintaining the watersheds and biological corridors in the mountain eco-system.

Agriculture in Bhutan is mainly rain-fed for dryland crops that include maize, wheat, oilseeds, buckwheat, minor cereals, fruit crops, vegetables and potato, while for rice, substantial amount of water is required for irrigation. Bhutan is blessed with good water sources and therefore free and subsidized water for drinking and for agricultural use in the rural areas is still being adopted. Government provides and puts in place irrigation channels for rice production to increase the sufficiency levels and substitute imports. Irrigation and water use technologies are slowly being extended by the government and being adopted by farmers for use in other crops as well as to increase productivity per unit area of land.

Also, the link between water and energy in Bhutan is inextricable, and due to Bhutanese topography with altitudes varying from 100 meters to over 7500 meters above sea level, the four major rivers draining out of Bhutan provide the ideal conditions for hydropower development. Water users in Bhutan draw water from three distinctively different sources; main rivers provide water for hydropower generation, tourism/recreation and ecology, tributary river provide sources for all water uses mainly irrigation and domestic water supply and sub-surface water in the form of springs and aquifers provide water for domestic water supply and small-scale irrigation.

With regards to the existing institutional setup, National Environment Commission is entrusted with the responsibility of coordinating water resources management in the country as an apex body on water resources. the Ministry of Agriculture and Forests is entrusted with the responsibility of coordinating land-use and irrigation, watershed management, water resources in forests, wetlands and protection of catchment areas. The Ministry of Works and Human Settlement and Municipal Bodies are responsible for ensuring safe, adequate and potable water supply in the urban areas and the Ministry of Health for ensuring safe, adequate and potable water supply in the rural areas. The Ministry of Economic Affairs is responsible for hydro-power development.

Water Resource Policies and its Links to Agriculture

In Bhutan, there are number of policies, acts, regulations, management plan, master plan, etc to manage and utilize the water resources properly. The most prominent ones and their links to agriculture are as follows:

(a) Bhutan Water Policy emphasizes on adequate water allocation for sustainable agriculture development to achieve national food security goal, adopt higher water use efficiency (“more crop per drop”) systems through adaptive and applied research and promote other sources of water like groundwater and rainwater harvesting to address seasonal and local water shortages.

(b) Water Act of Bhutan 2011 gives second priority to water for agriculture after water for drinking and sanitation and specific requirements and water use on irrigation water is clearly articulated.

(c) Water Regulation of Bhutan 2014 ensures that water abstraction for irrigation is in line with the National Integrated Water Resources Management Plan (NIWRMP), identify cost effective irrigation technologies and encourage their implementation, ensure a reliable and efficient water supply system for the intensification and diversification of irrigated crop productions, promote cropping patterns and land use management suitable to water availability in respective locality and explore alternative water resources like rain water harvesting and possible linkage to hydropower reservoirs.

(d) RWSS Sector Policy

(e) National Irrigation Policy, Revised 2012

(f) National Integrated Water Resources Management Plan 2016

(g) National Irrigation Master Plan 2016

Water resource use competition

The total irrigation water demand in 2010 was estimated at 460 million m^3/year. This constitutes about 90% of the country's total consumptive water use. With increase in crop production (cropping intensity) to keep pace with food demands of a growing population, the demand is projected to reach 911.80 million m^3/year in 2030 (Table 1).

Pressure on water resources is mounting due to competing demands from different users. New demands from other sub-sectors such as hydropower and industries are emerging due to market demand, growth in population and change in lifestyle caused by rapid socio-economic development, thereby increasing the competition for water resources.

Table 1. Water demand projection for different user types (in MCM/yr)

Demand Type	2015	2030
Drinking water	36.09	77.68
Industry and other	74.39	218.35
Irrigation	666.90	911.80

Irrigation water supplies near major urban centers like Thimphu, Paro, Wangdue and Punakha are already affected by competing from the Municipals and the industries. The increase in cash crops like vegetables, mandarin, apple, cardamom which are currently dependent on rainfall will further increase the demand for water as farmers begin to appreciate and understand the benefits of irrigation. While the water demand is projected to increase in the future the impact of climate change on water availability will require irrigation systems and water management to be robust and resilient to extreme effects.

Energy Requirement for Agriculture

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 inter linkages pose significant management challenges. Water and energy are 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. Agriculture also contributes to energy; biomass and crop residues are traditional sources of rural energy, and energy crops are used to produce biofuel.

Bhutan's water abundance and topography contribute to the country's energy situation, namely hydro-electric power production. Bhutan's hydropower potential is estimated at 23,760 MW out of which 1,465MW capacity has been installed. Bhutan's hydroelectric dam projects have been developed with foreign aid, primarily from India and it is India that is the largest customer of Bhutanese hydro-power. Production and export of hydroelectricity comprise the bulk of Bhutanese economic activity. Export revenues from hydro-electricity transfers constitute more than half of Bhutan's total revenue.

Because of the hydro energy surpluses being exported, Bhutan is able to significantly subsidize domestic electricity consumption. Bhutanese customers pay the cheapest rate in the world for electricity. In terms of sectoral utilization, the residential sector consumes about 48.7% of the total energy consumed within Bhutan. However, most people in Bhutan, particularly in rural areas, still rely primarily on wood for their immediate energy requirements. Indeed, more than three quarters of all energy consumed in Bhutan comes from wood fuel, and per capita fuel wood consumption in Bhutan is one of the highest in the world. Expanding electricity networks in rural areas has decreased some of this deforestation pressure and enhanced the living standard. It has also helped Bhutan stay a carbon-neutral country.

Most of the hydropower within Bhutan is run-of-the-river type projects. This has a lesser environmental footprint than other types of hydro power generation, but results in wide seasonal variation in the production of power, classifying Bhutan's power exports as 'non-firm'. Bhutan actually imports power from India during the dry season when river flows decline and reduce run-of-the-river power generation. Therefore Bhutan's energy security and development programmes is largely linked to its natural resources-Water and the need of the hour - climate adaptation and mitigation measures through a holistic approach towards sustainable management of the natural resources and working collaboratively with all relevant sectors for common long-term goals.

Way Forward for Water and Energy Resource Management and Sustainable Agriculture Development

Framing independent policies and interventions in each sector will have impacts on other sectors. For example, agricultural policies may influence water and energy demand. It is also imperative to be conscious of the future challenges of decisions enhancing one area of security while compromising other areas will prove unsustainable. Therefore, policies and strategies to enhance food, water, and energy security must be looked at holistically and therefore support the following:

- Adoption of Integrated Water Resources Management principles and approach
- Restoration of natural water storage capacity in the watersheds through conservation of soil, ice, wetlands, permafrost, lakes, and aquifers; and expand water monitoring stations.
- Adoption of Bhutan Water Security Index as a national key result area of 12 FYP
- 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;
- Introduce regulatory mechanism for managing demand for water and energy
- Provision of adequate investment for management of watersheds, wetlands, and biodiversity;
- Establishment of successive river basin committees and implementation of river basin management plan
- Construction of water storage structure/reservoir, improvement in conveyance efficiency of irrigation systems, development of high efficiency irrigation systems and exploration of ground water sources.
- Development of regional multipurpose reservoirs (combination of mini hydropower, irrigation and drinking water) and cost effective water supply delivery system.
- Institute mechanisms for providing incentives to mountain communities for managing mountain ecosystems
- Provision of appropriate incentives for the ones who produces food security crops, and utilize/manage available water and energy resources judiciously for food production
- Promotion of climate smart agriculture production technologies

- Introduction and promotion of water and energy saving devices and technologies
- Enhancing the capacity of people to understand the interconnectedness and interdependence between food, water and energy sector and linkages between upstream and downstream region

As population in Bhutan are concentrated in rural areas (70% in rural areas and 30% in urban areas), the interventions should focus on the challenges of rural poor people in securing enough food, modern energy and clean water; worsening water quality in poor rural areas with significant health implications; and addressing challenges of water availability.

The strategies and programs on WEF Nexus should promote (i) Water, Energy and Food security for all, (ii) Equitable and sustainable growth, and (iii) Resilient and productive environment.

Conclusion

Bhutan at this juncture does not suffer chronic food insecurity, and its water availability is not only sufficient for domestic household and industrial consumption, it is abundant for non-consumptive uses, primarily hydroelectric energy production. The export of the vast majority of Bhutan's hydro power constitutes most of the country's revenue, and facilitates the import of food, especially rice, to satisfy growing food demand, particularly for the urban population. The GNH and strong Buddhist beliefs ensure a socially equitable, economically beneficial, and environmentally sustainable approach. However, Bhutan should not be complacent about its rich natural water resources but need to look into various ways of sustaining them through proper research, cross-sectoral coordinated efforts and optimal and efficient usage particularly in view of global warming and climate change issues. Bhutan must be prepared at all times to maintain and sustain the natural resources to fulfill the holistic development approaches for co-existence with nature.

Like many other countries, Bhutan has also set ambitious targets and accordingly provided policy support to increase crop production, including incentives by subsidizing water, energy, agricultural production inputs, and marketing support. While such incentives have increased crop production, they have also increase the demand for water and energy, degradation of the resource base, and contribute to an increase in water-related disease. With limited land resources, untapped energy and growing water stress due to not being able to tap the water resource potential, Bhutan faces the challenge of providing enough water and affordable energy to grow enough food for the increasing population. Many researchers have analysed that the issues and challenges in the food, water, and energy sectors are interwoven in many complex ways and cannot be managed effectively without cross-sectoral integration to improve the resource-use efficiency and productivity of the three sectors.

Despite the inherent interconnections between food, water, and energy production, agencies often work in a fragmented and isolated way. Poor sectoral coordination and institutional fragmentation have triggered an unsustainable use of resources and threatened the long-term sustainability of food, water, and energy security, and also pose challenges to achieving the Sustainable Development Goals.

It was found that land and water are the two pre-requisite natural resources to develop and sustain agriculture. With growing populations, declining agricultural land, increasing stress on water and energy resources, rising standards of living, climate variability and resource management constraints due to sustainable environmental practices, Bhutan also faces the challenge of how to produce more quality food with the same or less land, less water, and increased energy prices, while conserving resources and maintaining environmental sustainability. 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. Hence, policy makers should look into the challenges of water, energy and food together rather than looking at it independently by maximizing synergies and managing tradeoffs. One should understand that irrigation is fundamental to food security and hydropower is fundamental to energy security. Sustainable farms and cities require water security. There is a need to understand, discuss, revisit and scope through the future on how best the synergies can be built among different resource and harmonize policies on water, energy and food sectors, keeping in view the inter-relatedness and interdependencies of resources across both sectors and scales, upstream and downstream, as well as the role of regional ecosystems in long-term security of water, energy and food.

Ensuring resource use efficiency, however, will not be sufficient to sustain food, water, and energy security in the long-run unless natural resources and ecosystems are conserved and used sustainably. Like the food, water, and energy nexus, the SDGs are closely interlinked. Thus food, water, energy security, and the SDGs need to be addressed in an integrated way. It is vital for a country to come up with common goals and visions for inclusive development and sustainability collaboratively. The nexus approach is vital to address food, water, and energy security in a holistic way, taking all the interlinkages into account through a nexus approach, which is a system-wise approach, rather than a sectoral approach.

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Chapter 3

Water, Energy and Food Security Nexus: An Indian Perspective

S.K. Ambast

Director, ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha, India.
director.iiwm@icar.gov.in

Introduction

Water and energy are the key determinants of agricultural production and food security of a nation. Rapid economic development, expanding populations and changing lifestyle are driving up demand for water, energy and food, especially in developing countries. It is estimated that, globally, the demand for energy will nearly double whereas water and food demand are estimated to increase by over 50% by 2050 (IRENA, 2015). Water, food and energy resources are tightly interconnected, forming a policy nexus (Vogt et al., 2010). The nexus perspective describes the interconnectedness among the use of water in energy and food production, use of energy in food production and improved water supply and food security in generating energy production and water supply by economic development. A joint solution for exploiting the synergies and reducing the risks of trade-offs in the WEF nexus is necessary, as neglecting the inter-connectedness of the three components and focusing only on a single part may lead to sub-optimal outcomes (World Economic Forum 2011). Food production is the largest user of water globally. It is responsible for 80–90 per cent of consumptive water use from surface water and groundwater. Water, however, is also used to generate electricity, and about 8 per cent of global water withdrawal is used for this purpose. Energy, in turn, is needed to transport and fertilize crops. Food production and supply chains are responsible for around 30 per cent of total global energy demand. Crops can themselves be used to produce biofuels (Hoff, 2011). It is widely recognized that water, energy and food sectors have strong interconnections and interdependencies (Hoff, 2011). The ability of existing water, energy and food systems to meet this growing demand, meanwhile, is constrained given the competing needs for limited resources. The challenge of meeting growing demand is further compounded by climate change impacts. Based on a better understanding of the interdependence of water, energy and climate policy (UN, 2013), this new approach identifies mutually beneficial responses and provides an informed and transparent framework for determining trade-offs and synergies that meet demand without compromising sustainability (Figure 1).

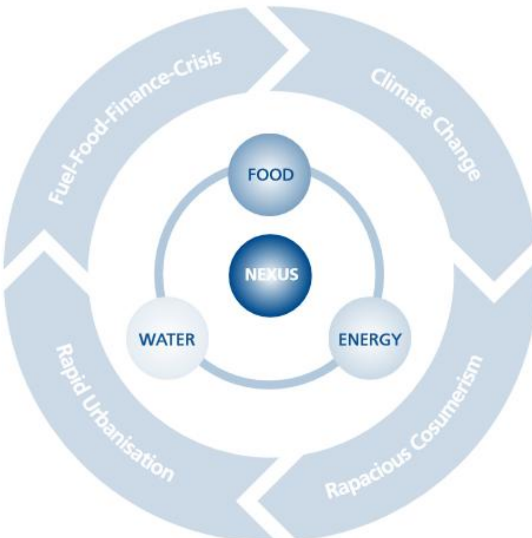

Figure 1. The water-energy-food nexus and its drivers

Population Growth and Economic Development in India

India supports 17 % of the human and 15 % of the livestock population of the world with only 2.4 % of the land and 4 % of the water resources. The population of India as per 2011 census was 1.21 billion (Figure 2). It added 0.18 billion to its population since 2001. Of the 1.21 billion Indians, 0.38 billion stay in urban areas whereas 0.83 billion (68.84%) live in rural areas. The current population of the country is 1.3 billion which is projected to increase to 1.7 billion by 2050 (Figure 3).

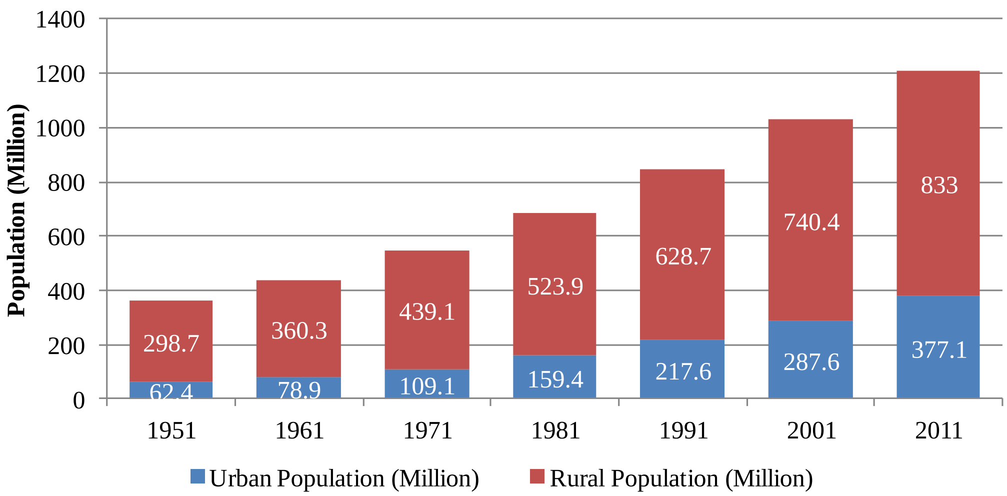

Figure 2. Population growth and rural-urban population in India (1951-2011)

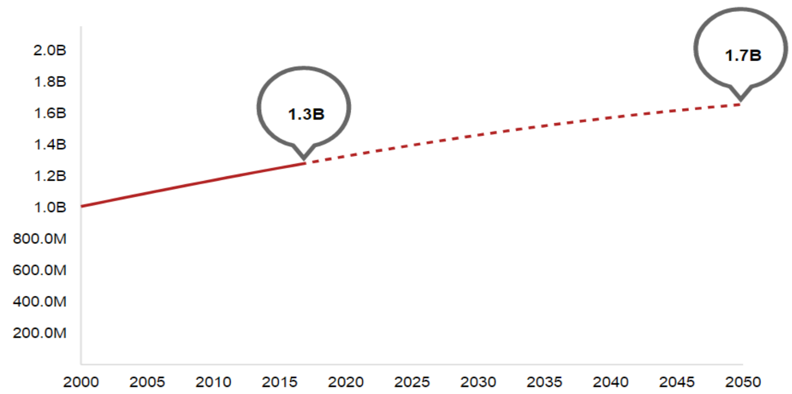

Figure 3. Current and projected population along with age with sex ratio in India by 2050

India is the 7th largest economy of the world. According to International Monetary Fund (2016), India's nominal Gross Domestic Product (GDP) in 2016 at current prices is $2.25 trillion. The economy is classified in three sectors i.e., Agriculture & allied, Industry and Services. In terms of contribution to GDP, services sector is the largest sector, followed by industry and agriculture (Figure 4). Agriculture contributed 17.9% to the national GDP whereas Industry contributed 24.2% and Services contributed 57.9% to national economy in 2014 (GoI, 2016). India is the 2nd larger producer of agriculture product with 7.68 % of total global agricultural output. On the basis of GDP of Industry sector, it is ranked 12th in the world whereas it ranked 11th in the services sector. Contribution of Agriculture sector in Indian economy is much higher than world's average (6.1%) whereas contribution of Industry and Services sector is lower than world's average 30.5% for Industry sector and 63.5% for Services sector. The real GDP at constant (2011-12) prices in the year 2016-17 is likely to attain a level of 121.65 lakh crore INR, with growth rate of 7.1 % over the GDP for the year 2015-16.

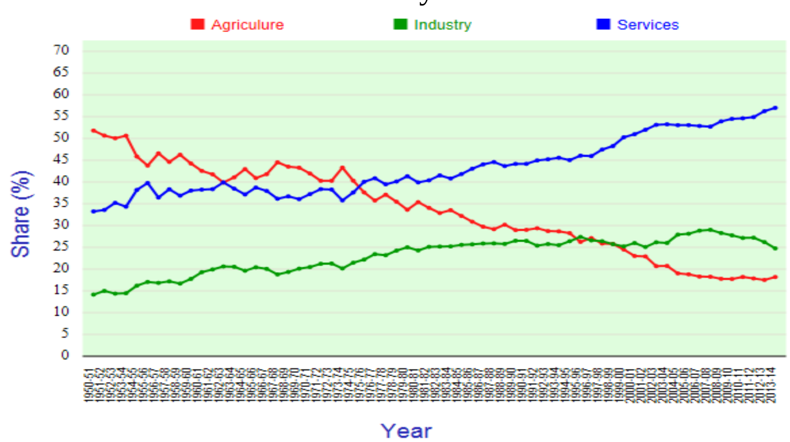

Figure 4. Sector wise GDP contribution in India

Water Availability and Demand

India receives an average annual rainfall of 119.4 cm amounting to about 4000 billion cubic meter (BCM) of water that generates an average annual runoff of 1869 BCM. Due to various constraints about 1123 BCM of water can be put to beneficial use of which 690 BCM is through surface water and 433 BCM by groundwater (CWC, 2015). Out of 690 BCM of surface water, so far about 253.4 BCM of storages are built through major and medium irrigation projects. Another 51 BCM of storage are under construction / consideration. Similarly, out of 431 BCM of groundwater resource, about 360 BCM of groundwater is expected to be available for irrigation, out of which present usage is about 222 BCM. The per capita water availability in the year 2005 was 1703 m^3 which is projected to further reduce to 1401 and 1191 m^3 by the years 2025 and 2050, respectively.

The projected total water demand of the country is estimated at 1447 BCM by the year 2050 (Table 1) which is more than the present availability of utilizable water resources (CWC, 2010). In that the share of agriculture itself will be 1072 BCM. Thus, there is a need for proper planning, development and management of water resources. Further, the availability of water for agriculture in India is projected to decline from 84% in 2010 to 74% by 2050. Therefore producing 350 M t food grain from shrinking water resources would put existing water sources under immense pressure. It has been estimated that about 1% annual increase in water productivity (quantity per unit consumptive water use) would meet additional water demand for grain production and its further increase to 1.3% would satisfy all crops water demand. Present low crop water productivity provides enough scope for improving present crop water productivity through scientific agricultural water management practices, and the demand of water from other sector can be met with present water resources.

Table 1. Sector wise projected water demand in India (in BCM)

Sector/Year	2000	2010	2025	2050
Irrigation	541	688	910	1072
Domestic	42	56	73	102
Industry	8	12	23	63
Energy	2	5	15	130
Others	41	52	72	80
Total	634	813	1093	1447

(Source: Central Water Commission, 2008 & 2010)

Irrigation scenario: In India, irrigation development has received high priority in the successive five year plans and has the second largest irrigated area in the world. The ultimate irrigation potential of the country through major, medium and minor irrigation projects has been assessed at 139.9 M ha by conventional storage and diversion works. A record food grain production of 265 M t was achieved in 2014-15. About 60% of country's food grain production is contributed from irrigated agriculture. A total irrigation potential of 113.53 M ha, against 22.6 M ha at pre-planning period, has been created by the end of XI Plan. Total water use in agriculture at current level of development is of the order of about 525 BCM which is about 83% of total present water use in the country. This may get progressively reduced to about 75% in future due to increased demand of other sectors.

Groundwater played a major role in the success of green revolution and contributes about 60% of the total irrigated area of the country. Over exploitation of groundwater has reached at alarming levels in Punjab, Haryana, Rajasthan and Tamil Nadu. The Punjab-Haryana region could lose its production potential in a few decades if current patterns of groundwater extraction and pollution, soil salinization and rice-wheat monoculture persist. A recent estimate reveals that in 16% of the blocks (Mandals / Talukas), the annual extraction of groundwater exceeds annual recharge. In 3% of the blocks, it is more than 90% but within 100% of net annual groundwater availability (critical units). Groundwater extraction in such blocks needs to be better regulated. Conjunctive use of surface and groundwater is desirable to fulfill the irrigation requirements of crops by judiciously utilizing the water from both the sources. The optimal conjunctive use of the region's surface and ground water resources would help in minimizing the problem of water logging and groundwater mining. The conjunctive use also facilitates the use of highly saline groundwater which can't be otherwise use without appropriate dilution. Strengthening of knowledge base on geology and aquifer characteristics, hydrology of surface' and groundwater, and existing surface and ground water facilities is required to develop appropriate conjunctive use system.

Energy Availability and Demand

The energy policy of India is largely defined by the country's expanding energy deficit and increased focus on developing alternative source of energy, particularly nuclear, solar and wind energy. India ranks 81 position in overall energy self-sufficiency at 66% in 2014. The primary energy consumption in India is the third biggest after China and USA with 5.3% global share in 2015. The total primary energy consumption from crude oil (27.91%), natural gas (6.50%), coal (58.13%), nuclear energy (1.23%), hydro-electricity (4.01%) and renewable power (2.21%) is 700.5 Mtoe (excluding traditional biomass use) in 2015.

In India, 578957 inhabited villages constituting 96.9% out of a total of 597464 inhabited villages (as per 2011 census) have been electrified and 20.1 million pump sets have been energized (Figure 5). It is observed that 15 States namely Andhra Pradesh, Telangana, Madhya Pradesh, Goa, Gujarat, Himachal Pradesh, Karnataka, Haryana, Kerala, Maharastra, Punjab, Sikkim, Tamilnadu, Uttarakhand and West Bengal have almost achieved 100% (more than 99%) village electrification and all UTs except Andaman & Nicobar islands have also achieved 100% village electrification (Figure 6). 4 States namely Jammu & Kashmir, Rajasthan, Tripura & Uttar Pradesh have achieved more than the National Average of village electrification (96.9%). 10 States namely Arunachal Pradesh, Assam, Chhattisgarh, Bihar, Jharkhand, Manipur, Meghalya, Mizoram, Nagaland and Odisha are lagging behind the National Average of village electrification: The charts showing the Plan wise and State wise progress of village electrification and pump sets energisation as on 31.03.2015 are enclosed.

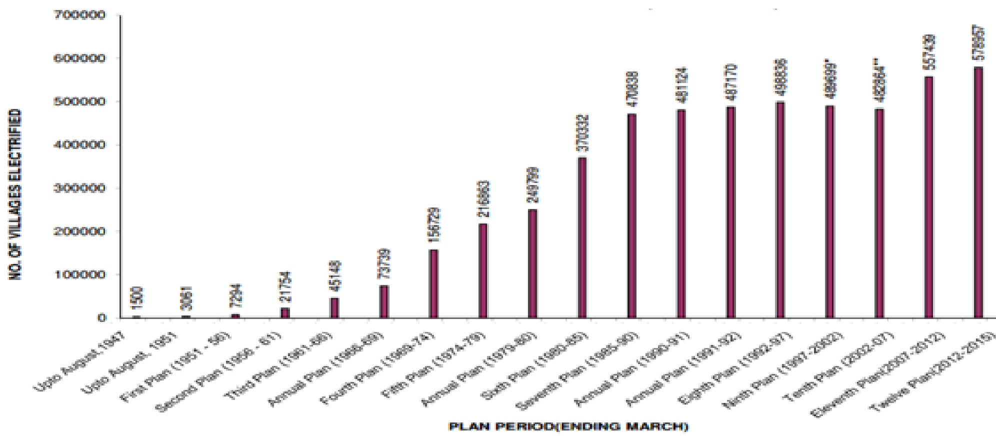

Figure 5. Plan wise number of villages electrified (CEA, 2016)

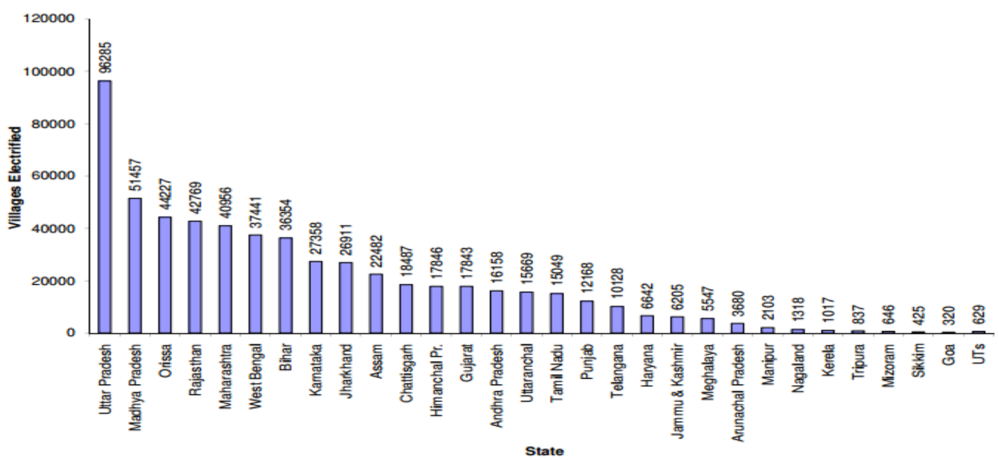

Figure 6. State wise number of villages electrified in India (CEA, 2016)

An overview of power supply position in terms of energy and peak demand for the period from 1997-98 to 2014-15 is presented in Figs.7-8, respectively.

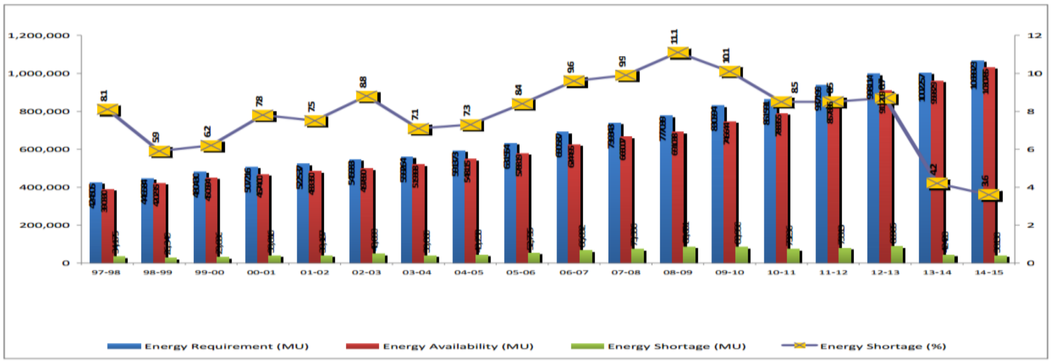

Figure 7. Power supply position in terms of energy demand (1997-98 to 2014-15)

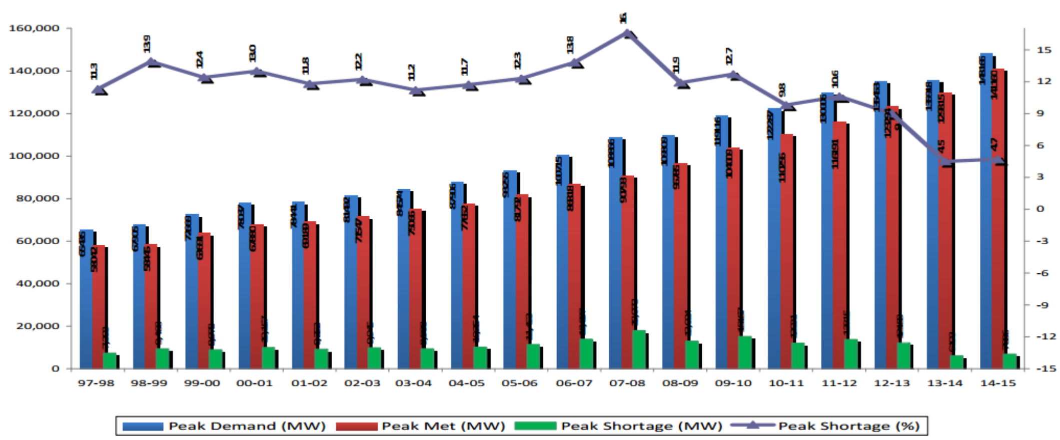

Figure 8. Power supply position in terms of peak demand (1997-98 to 2014-15)

Synergy with irrigation water pumping and hydro power stations: The plan wise and state wise numbers of pumps energized are given in Figure 9 and 10. The major disadvantage of solar power (PV type) is that it cannot produce electricity during the night time and cloudy day time also. In India, this disadvantage can be overcome by installing pumped-storage hydro-electricity requirement for river water pumping (excluding ground water pumping) is 570 billion kWh to pump one cubic meter of water for each square meter area by 125 m height on average for irrigating 140 million hectares of net sown area (42% of total land) for three crops in a year. This is achieved by utilizing all the usable river waters by interlinking Indian rivers water pumping stations would also be envisaged with pumped-storage hydroelectricity features to generate electricity during the night time. These pumped-storage stations would work at 300% water pumping requirement during the day time and generate electricity at 33% of its total capacity during the night time. Also, all existing and future hydro power stations can be expanded with additional pumped-storage hydroelectricity units to cater night time electricity consumption. Most of the ground water pumping power can be met directly by solar power during daytime. To achieve food security, India needs to achieve water security which is possible only by energy security for harnessing its water resources.

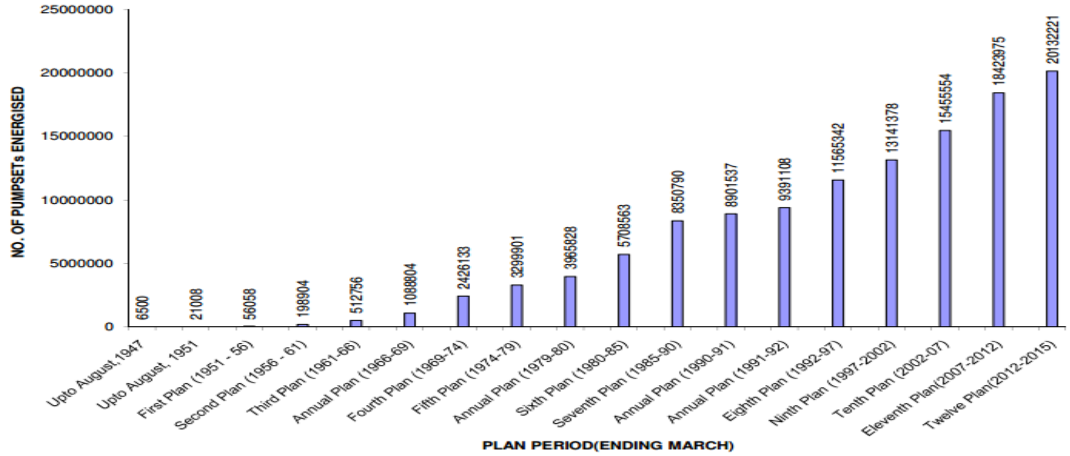

Figure 9. Plan wise number of pumps energized

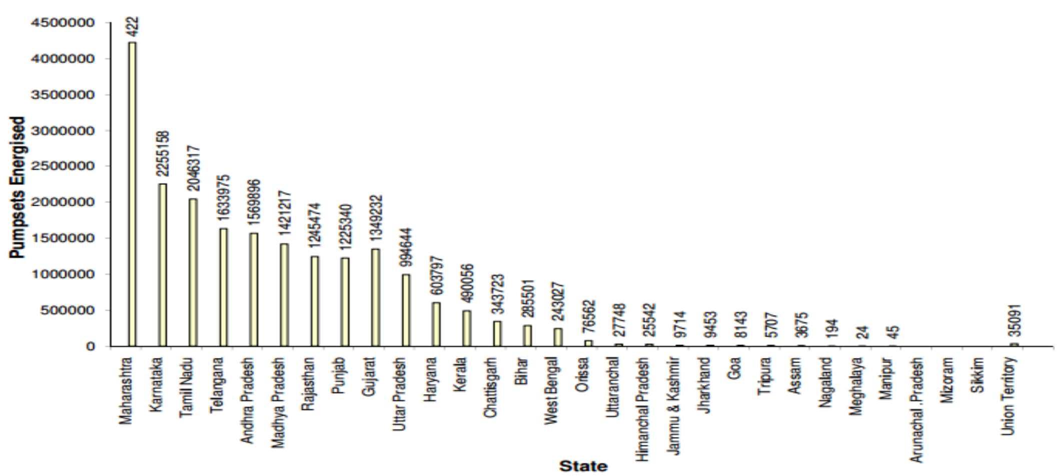

Figure 10. State wise number of pumps energized

Food Security

Food security has three dimensions, (i) food availability i.e. total food production in the country plus the imported food plus buffer stocks maintained in govt. granaries like FCI in previous years, (ii) food accessibility i.e. food should be within the reach of every person and (iii) food affordability i.e. an individual should have enough money to buy proper, safe and nutritious food to meet his dietary needs. In India, it is estimated that out of 1.3 billion population, a total of 77% are considered poor and vulnerable. Further, in the recently released Global Hunger Index of 2016, India ranked 97 out of 118 countries which is a matter of deep concern as India is one of the largest producers of food in the world.

The International food policy research institute (IFPRI, 2013) classified India into alarming category out of five categories - low, moderate, serious, alarming and extremely alarming. It has been observed that the consumption of food, in terms of nutrition and quantity, is lacking far behind in the country. According to National Institute of Nutrition, the minimum per capita food grain required for an adult is 182.5 kg/year whereas in India, the availability is only 173.6 kg/year and as far as the protein requirement is concerned, the daily intake should be 50 mg but the situation seems to remain stagnant, the per capita daily intake is only 10 mg. According to Food and Agricultural Organization, 225 million people i.e. 23% of population are undernourished and 260 million people fall under the category of above the poverty line.

Agricultural Scenario: India has net sown area of 140.88 M ha and with a cropping intensity of 138.67 its gross sown area is 195.25 M ha. It has increased 50% more agricultural and 200% more horticultural production in last two and half decades (Figure 11). As surface water resources are quite important for crop cultivation through development of large or medium irrigation projects, rainwater harvesting and groundwater recharge, the distribution of annual rainfall is given in Table 2. The net irrigated area is 65.26 M ha with gross irrigated area is 91.53 M ha. As per the latest available statistics (2011-12), irrigated and rainfed area of the country is estimated at around 46 and 54 % of the net sown area, respectively The distribution of cropped area in different category based on rainfall received clearly indicates prospect of bringing at least 70% area under assured irrigation by developing various means of water resource development (Table 3).

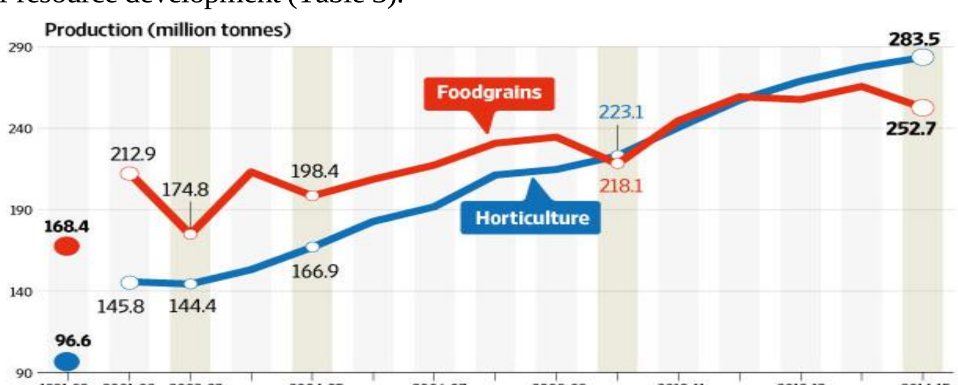

Figure 11. Total food grain and horticultural production in India

Table 2. Distribution of annual rainfall in different season

Season	Duration	Rainfall (%)
Pre-monsoon	March - May	10.4
SW Monsoon	June - September	73.7
Post-Monsoon	October - December	13.3
NE Monsoon	January - February	2.6

Table 3. Distribution of cropped area according to rainfall

Rainfall (mm)	Category	Area receiving rainfall (%)
0-750	Dry	30
750-1150	Medium	42
1150-2000	High	20
Above 2000	Very High	8

Water and Food Security Nexus

Assured irrigation in conjunction with other technological and policy factors has played a catalytic role in the growth of Indian agriculture over the years. Various estimates point to a substantial contribution from irrigated agriculture to overall agricultural production of the country. For example, the contribution from irrigated agriculture to total agricultural production in India ranged from 55% (World Bank, 1991) to 58% (Planning Commission 1999) to 60% (Seckler and Sampath 1985). Because of the yield augmenting impact, irrigation development has always been the priority area of the national agricultural development strategy in the successive five year plans with massive financial support. Consequently, the gross irrigated area in the country has increased from 22.6 in 1950-51 to 86.4 M ha in 2009-10 (CWC, 2012). The positive impact of irrigation development was realized in the form of increased food grains production (from 51 to 252 M t) and cropping intensity (from 111 to 138 %) during the same period. However, the irrigation sector in the country is suffering from several pitfalls. The utilization of already created irrigation potential is only 74% and the gap between irrigation potential created (IPC) and its utilization (IPU) is increasing over the years. For the country as a whole, about 88 per cent of the ultimate irrigation potential (UIP) has already been developed through different major, medium and minor irrigation schemes, which limits further large scale expansion of irrigation infrastructure. Thus, improving the utilization of already created irrigation infrastructure by removing existing operational and maintenance inefficiencies will contribute positively for the agricultural growth in the country. Most of the irrigation projects are operating at an overall efficiency of only about 30 to 35 % against the achievable efficiency of more than 50%. Thus, there is enormous scope to improve the productivity and efficiency of irrigation systems which can be achieved both by technological as well as social interventions. It is estimated that with 10% increase in the present level of efficiency in irrigation projects, an additional 14 M ha area can be irrigated from the existing irrigation capacities which would involve a very modest investment compared to what is required for creating equivalent potential through new schemes. The social and environmental costs involved will be an additional factor to be reckoned with this respect. Further, measures to alleviate the degradation of natural resources due to over-irrigation have to be taken in an economic and optimal manner.

Managing W-E-F Nexus through Agricultural Water Management

As the total projected demand for irrigation sector will be 324 BCM more than the present level of utilizable water resources, the challenge will be (i) more production from less water by efficient and productive use of utilizable water resources in irrigated areas, (ii) increased production from sub-productive challenged ecosystems, *i.e.*, rainfed and water logged areas, and (iii) making use of grey water (waste water) for agriculture production. In addition, there is need for improving productivity of two sub-productive challenged ecosystems rainfed and flood prone/waterlogged areas through efficient irrigation and drainage network development in rainfed areas and combined approach of engineering, crop selection, crop management and aquaculture practices in waterlogged areas would be critical. Moreover, the water resource is fast undergoing change due to increasing population, industrialization, urbanization, pollution, deforestation and above all climate change, which will alter the paradigm of natural resources in which our production system operates. Certainly the business as usual will not suffice. Thus it is essential to visualize the future scenario and prepare strategies for equipping ourselves with technologies which will provide solution for maintaining our food and nutritional security in changing/projected scenarios. This will give us an idea of institutional, technological and financial path to be followed to achieve the national objectives without endangering the sustainability of our production systems.

Water Scarce Rainfed Area

Rainwater management is the most critical component of rainfed farming. Rainfed areas accounts for 56% of total cultivated area and contributes only 47% to national food basket. But rainfed farming will remain the main stay for the livelihood support of millions of small and marginal farmers across the country.

Under current practices, yield under irrigated agriculture almost reached a plateau and nearly 40% of total cultivated area of the country would remain rainfed even after achieving the ultimate irrigation potential. The successful production of rainfed crops largely depends on how effectively surplus runoff is harvested, stored and recycled for supplemental irrigation and soil moisture is conserved in situ. Further the climate change is posing a major challenge for rainfed agriculture and the constraints in further expansion of irrigated area in the country. The rainfall extremes and high intensity rain events witnessed in recent years are likely to cause large spatial and temporal variations in the amount of surplus runoff available for harvesting. In some areas, there could be increased runoff and more potential for harvesting, while in other areas it might decrease.

Watershed management / On-farm reservoir (OFR): Rainwater harvesting and efficient water use are inevitable options to sustain rainfed agriculture in future (Ambast et al., 1998). Different states have initiated special programmes OFR in order to ensure the sustainability and to improve the livelihoods of people. Despite these experiences, the adoption of OFR at the individual farm level has been very low, particularly for drought proofing through life saving irrigation of kharif crops. Renovation of old and silted community ponds for water conservation as well as ground water recharge and monitoring of the effectiveness of OFR constructed under various watershed development programmes will be helpful to strengthen rainwater conservation in the country. Crop diversification with low water requiring crops like pulses, oilseeds along with in-situ soil moisture conservation. Several promising soil and water conservation measures for various rainfall zones in India are listed in Table 5.

Tank cum well system: A tank cum well system was conceptualized for micro-level water resources development on watershed basis for plateau areas with slope of 2 to 5%. This involves construction of tanks and wells in series along the drainage line in a watershed. The excess runoff water is stored in the tank and this can be used for meeting the irrigation requirement in the post monsoon season and supplemental irrigation requirement in the monsoon season (Srivastava et al., 2009). The economic analysis of the system in the first 3 years of its existence revealed 97.75% of investment recovered in three years by adoption of improved package of practices, taking up additional cropping and multiple use of tank.

Rainfed agriculture is complex, diverse and risk-prone and is mostly affected by climate change and variability of rainfall, so each rainfed farmers should be covered under Pradhan Mantri Fasal Bima Yojna. Some of the conservation practices listed above are temporary in nature and can be implemented by the farmers every year before the onset of monsoon, cost being nominal. Few measures such as contour and graded bunding, continuous, contour or staggered trenches, water harvesting structures and drainage line treatment are already covered under the Mahatma Gandhi National Rural Employment Guaranty Scheme (MGNREGS) scheme. Some soil and water conservation programme can also be linked with recently launched Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) where other ongoing schemes of the governments like Accelerated Irrigation Benefit Programme (AIBP) of the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR), Integrated Watershed Management Programme (IWMP) of Department of Land Resources (DoLR) and the On Farm Water Management (OFWM) of Department of Agriculture and Cooperation (DAC) were merged.

The National Mission for Sustainable Agriculture (NMSA), which is one of the eight Missions under the National Action Plan on Climate Change (NAPCC) also seeks to address issues regarding sustainable agriculture in the context of risks associated with climate change by devising appropriate adaptation and mitigation strategies for ensuring food security, particularly in dry and rainfed areas, equitable access to food resources, enhancing livelihood opportunities and contributing to economic stability at the national level. The main interventions are in the areas of improved crop seeds, livestock and fish cultures, improving water use efficiency, soil health management, agricultural insurance, credit and market support and access to information. National Food Security Mission (NFSM), Rainfed Area Development Programme (RADP), National Mission on Micro Irrigation (NMMI), Accelerated Pulses Development Programme (APDP), Integrated Scheme of Oilseeds, Pulses, Oil palm and Maize (ISOPOM), Bringing Green Revolution in Eastern India (BGREI) are some of the other important programmes of the central Government which can be linked to provide boost to agriculture sector in rainfed areas. National Mission for Sustainable Agriculture (NMSA) has also four major programme components e.g., rainfed area development, soil health management, on-farm water management and climate change and sustainable agricultural modeling and networking.

Waterlogged and Flood Prone Rainfed Areas

The management of waterlogged areas depends on drainage points availability and suitability for crop/aquatic crop/fish production. For understanding waterlogging situation, it is essential to understand concept and definition of waterlogging. In general term stagnation/pooling of water on the land surface for significant duration is normally understood as waterlogging. However, from agriculture point of view, it is described as a situation of adverse air-water proportion in subsoil root zone, with respect to a crop due to water stagnation or high water table along with its acceptable level of productivity response. A more comprehensive definition of waterlogging was suggested by National Commission on Agriculture (1976). On the other hand, floods and surface waterlogging are the most common problems in eastern India. The heavy southwest monsoon causes all the rivers to overflow their banks, often flooding surrounding areas. Among Eastern States, Bihar is highly prone to floods (about 70% area is flood affected, particularly north Bihar). West Bengal, a part of Bengal Delta, also has a long recorded history of floods. About 42.3% of total area of the State is susceptible to flood, and spread over 110 blocks in 18 districts. Likewise, Odisha has a history of recurring natural disasters; especially the coastal districts of Odisha are exposed to floods and cyclones. Flood problem is also acute in Brahmaputra and Barak basins and other smaller river sub-basins in the floodplains of Assam. The approach to the problem should be to mitigate waterlogging during monsoon period, increase productivity of the waterlogged areas by crop diversification, and create irrigation potential for increasing the cropping intensity. The following action plan is suggested to deal the issues:

(i) Waterlogging due to water congestion during monsoon to a great extent can be solved by construction of micro-reservoirs along low order streams to intercept runoff, reduce peak flow, enhance ground water recharge and create irrigation potential for increasing agricultural production.

(ii) Large perennial water bodies such as Chaur, Taal etc. can be turned very productive with proper planning for alternative/multiple use of water. A multipronged strategy should be developed for development of these water bodies for its multiple utilization as sink during monsoon and water source during post monsoon for pisciculture, duckery and cultivation of aquatic crops viz., makhana (*Euryale ferox),* water chestnut *(Trapabispinosa)* and swamp taro *(Colocasiaesculenta).*

(iii) Micro-water resources can be developed in coastal waterlogged areas with installation of very shallow tubewells up to a depth of 10 m, filter point wells, and small sub surface water harvesting structure. The project on land shaping-cum-fresh water reservoirs can be undertaken in these areas to store rainwater and harvest subsurface water through small ponds, to develop land to mitigate/reduce water congestion within the mini catchment and to promote diversified cropping by irrigation.

(iv) Multiple uses of water can enhance productivity of seasonally waterlogged lands in canal commands, secondary reservoir fed by canal seepage and supplemented by tube well, fish trenches-cum-raised bed for fish-horticulture production and rice-fish culture using nylon-pen under waterlogged area. At ICAR-RCER, Patna, secondary reservoir concept with two reservoirs (control and reservoir with water exchange due to routing of water) was constructed in the seasonal waterlogged area. Multiple uses of water by fish culture in reservoir, horticulture (two tiers: banana/guava/lemon and vegetables) on bunds, routing water to cereal crops, and duck rearing were evaluated (Sikka et al., 2008).

Agricultural water productivity for multiple water use based farming systems was analysed taking account of water diverted into the pond to replenish water in the seepage fed pond during the lean season and valuation of outputs from crops, vegetables fruits, eggs, and fishes for the year. The results indicate about 2.7 to 6 fold increase in water productivity by integrating different components over the traditional rice-wheat system. Water productivity was maximum (Rs.15.02/ m^3) in the secondary reservoir (with exchange of water) where fish + fruits + vegetables + duckery were integrated with rice and wheat, as against Rs.2.42/ m^3 in rice-wheat system alone. The economic analysis indicates that integrating fish in rice-wheat system gave net income of Rs. 29,694 per ha, 6% higher over the traditional rice-wheat system yielding Rs. 27,965 per ha per year. Under seasonally waterlogged areas up to 1 m depth, a system of fish trenches-cum-raised beds based horticulture + fish system generated a net income of Rs.80,951/ha/year, 189% higher over traditional rice-wheat system. Under seepage-fed secondary reservoir with ground water, a system of horticulture on bunds+fish+duckery yielded net returns of Rs.132,590/ha/year, 374% higher over traditional rice-wheat system.

Multiple water use based farming system approach with on–dyke horticulture and fish-prawn-poultry system in farmers' field in Odisha provided an excellent opportunity to productively use water logged area. The farmers converted 2.47 ha waterlogged area into 1.64 ha of pond and 0.83 ha of raised embankment. While pond area was utilized for fish and prawn culture, 21 m wide embankment was used for planting mango, teak, aeronaut, coconut, banana, papaya, pineapple, mushroom etc. Net water productivity of multiple use system was estimated to be Rs.7.5/m^3 against Rs.0.95/m^3 for low land rainfed paddy alone and Rs.6.0/ m^3 with vegetable production (Samra et al., 2003).

Canal Irrigated Areas

Assured irrigation in synergy with other technological and policy factors has played a catalytic role in the growth of Indian agriculture over the years. The contribution from irrigated agriculture is more than two third to overall agricultural productions. Because of yield augmenting impact, irrigation development has always been the priority area of national agricultural development strategy of the government with massive financial support. Consequently, the gross irrigated area in the country has increased and the impact of irrigation development was realized in the form of increased food grains production.

Performance evaluation of irrigation systems: Space-borne remote sensing measurement can provide information on agricultural and hydrological conditions of the land surface for vast areas at regular intervals. An application of remotely sensed data in the Sone Low Level Canal (SLLC) system in India for assessing irrigation system performance have been used to evaluate the extent of cultivated area, water availability and its distribution, crop yield performance and water productivity for each branch canal and distributaries of the SLLC system for comparative evaluation (Ambast et al., 2008). Even though the capability of satellite remote sensing to monitor agricultural and hydrological conditions of the land surface has undergone major improvements in the past decade, it remains under-utilized by practicing water resource managers.

Conjunctive use of canal and groundwater: In the arid and semi-arid regions, where canal water availability is scarce and groundwater quality is marginally poor, conjunctive use of waters is quite common. Earlier studies for conjunctive use of canal water with saline water were conducted for well-designed treatments of cyclic and blending mode of irrigations under controlled conditions (Sharma and Rao, 1998). However, canal water supply is highly unreliable and inadequate in the region that leaves limited scope for application of recommendations emerged from earlier studies. In another study SWAP model has been calibrated and validated in the Kaithal irrigation circle, Haryana in the northwest India (Mandare et al., 2006) to accommodate farmers' fields observation on canal water availability and groundwater applications to suggest (i) water management options for improving productivity of wheat crop during rabi season. Further, there is a need to assess long term impact of various combinations of saline water applications in different wheat based crop rotations feasible in the region.

Irrigation scheduling: Judicious use of water resources is sine-qua-non for enhanced productivity, improved economy and environment. It becomes all the more critical when water supply is scarce. How productive and safe is the water use, largely depends on the quality of the land leveling accomplished by the farmers. Precision land leveling becomes even more important when both the quality and the quantity of available water are limiting. Such a situation exists in the northwest India, where protective canal irrigation supported by good/marginal quality groundwater is in vogue. In such situations, use of saline/alkaline water supplies often requires the application of smaller depths at relatively more frequent intervals (Mandare et al., 2006). Since the total depth water applied per irrigation is greatly influenced by the quality of land leveling, it is important to achieve precision land leveling for efficient irrigation. Salinity and non-uniformity in irrigation water have much the same effect on the yield-water response function and both result in consuming larger volumes of irrigation water to produce the same yields as can be obtained with non-saline water and uniformly applied water.

Deficit irrigation supplies: In order to improve irrigation system performance, a policy guideline for SLLC system has been prepared. In this, the impact of various possible rotational schedules is analysed and a suitable rotation schedule is suggested (Ambast, 2001). The alternative cropping patterns have been evaluated for their water productivity and economic returns. After the modernisation of the SLLC system and release of Government of Bihar share of water from Bansagar project, it is expected that an additional parallel canal will run during *kharif* season, whereas the existing canals will run with designed capacity of water throughout the *rabi* season. The proposed cropping pattern after modernization (which is quite close to the existing cropping pattern) and the alternative cropping patterns during *rabi* season CP1-CP2-CP5 have increased cropping intensity, however, CP3-CP5 have the maximum intensity (100%) with increased area for the wheat crop due to deficit irrigation practiced. Therefore, cropping patterns CP3-CP5 can be adopted depending on the farmer's choice. However, economic analysis indicated CP5 as the best cropping pattern on the basis of enhanced water productivity and farm returns.

Groundwater Irrigated Areas

Presently, groundwater is the largest source of irrigation. The strategies for accelerating the development of groundwater within the replenishable limits of groundwater for its sustainable use can be drawn based on supply management or demand side are described below:

Ground water Augmentation by artificial recharge: The augmentation of groundwater can be done by maximizing surface ponding for groundwater recharge, rejuvenation of traditional surface water bodies and enhancing incentives for water conservation and artificial recharge. The artificial recharge of ground water needs to be undertaken in areas where ground water levels are declining on regular basis, where substantial amount of aquifer has already been desaturated, where availability of ground water is inadequate in lean months and where salinity ingress is taking place. The artificial recharge techniques can be broadly categorized as (i) direct surface techniques such as percolation tanks, flooding, stream augmentation, ditch and furrow system and over irrigation, (ii) direct sub surface techniques such as recharge pits and shafts, injection wells or recharge wells, dug well recharge, bore hole flooding, natural openings and cavity fillings, (iii) combined surface-sub-surface techniques such as basin or percolation tanks with pit shaft/wells and (iv) indirect techniques such as induced recharge from surface water source and aquifer modification. The existing village tanks which are normally silted and damaged can be modified to serve as recharge structure. In alluvial as well as hard rock areas, there are thousands of dug wells which have either gone dry or the water levels have declined considerably. These dug wells can be used as structures to recharge. The ground water reservoir, storm water, tank water, canal water etc. can be diverted into these structures to directly recharge the dried aquifer. By doing so the soil moisture losses during the normal process of artificial recharge, are reduced. In Urban areas, the roof top rainwater can be conserved and used for recharge of ground water. This approach requires connecting the outlet pipe from rooftop to divert the water to existing wells/ tubewells or specially designed wells. The urban housing complexes or institutional buildings have large roof area and can be utilizing for harvesting roof top rainwater to recharge aquifer in urban areas.

Reducing crop water demand: The reduction in crop water demand can be done by promoting innovative techniques and uses such as conjunctive use of surface and groundwater, promoting precision irrigation and water-saving crop production technologies, system of pricing aligning incentives for ground water use with goal of sustainability, need to create appropriate laws / regulatory mechanism and governance and priotization of uses.

Conjunctive use of canal and groundwater: It provides a greater control on timeliness of irrigation and should be encouraged by making adequate energy available to farmers at a reasonable cost. In order to ensure sustained availability of groundwater, average annual withdrawals should not exceed average annual recharge. Where fresh water is in short supply, groundwater of marginal quality could be advantageously used in combination with good quality water or for alternate irrigations. Recommendations concerning use of saline and sodic water prescribed by All India Coordinated Research Project on Management of salt affected soils and use of saline water of Indian Council of Agricultural Research from field experiments are now available and should be used. Development of conjunctive use system requires knowledge regarding geology of groundwater basin and aquifers, hydrology of surface and groundwater, existing surface and groundwater facilities and storage and transmission characteristics of the basins. Although, efforts have been made to model groundwater use, optimization and build future scenario using simulation models in the country, these needs to be further strengthened.

Pressurized irrigation system: The water use efficiency under conventional flood method of irrigation, which is predominantly practiced in Indian agriculture, is very low due to substantial conveyance and distribution losses. Recognition the fast decline of irrigation water potential and increasing demand for water from different sectors, a number of demand management strategies and programme have been introduced to save water and increase the existing water use efficiency in Indian agriculture. One such method introduced relatively recently in Indian agriculture is pressurized irrigation system, which includes both drip and sprinkler method of irrigation. Since, these methods need water under pressure; they are classified as pressurized irrigation system. Pressurized irrigation system is proved to be an efficient method in saving water and increasing water use efficiency as compared to the conventional surface method of irrigation, where use efficiency is only about 35-40 %.

The field experiments conducted across the country under All India Coordinated Research Project on Water Management have indicated saving of irrigation water depending upon the soil type, e.g., in clay, the saving is from 30 to 48 %, leading to increased area by 1.4 to 1.9 times, in sandy loam, from 40 to 50 % saving with 1.7 to 2.0 times increased irrigated area, in silt loam, from 55 to 61 % water saving with 2.2 to 2.6 times enhanced irrigated area, in silty clay loam 38 to 47 % water saving leading to 1.6 to 1.9 times enhanced irrigated area and in clay loam from 21 to 39 % with 1.3 to 1.6 % irrigated area (Table 4). Also, the water saving in sugarcane was maximum with silt loam soil, followed by sandy loam and least in clay loam soil. This indicated that the drip irrigation was more effective in the soil with poor water retention and higher drainage rate (AICRP-IWM, 2015).

Table 4. Water saving and increase in cultivated area with drip irrigation

Centre & State	Test Crops	Soil type	Water saving (%)	Increase in area (times)
Dapoli (MS)	Brinjal	Lateritic	38	1.6
Navsari (Guj)	Onion	Clay	30	1.4
	Turmeric		32	1.5
	Brinjal		40	1.7
	Chillies		48	1.9
Bhawanisagar (TN)	Jasmine	Sandy loam	50	2.0
	Sugarcane		40	1.7
	Tomato		42	1.7
	Banana		48	1.9
Madurai (TN)	Sugarcane	Clay loam	21	1.3
	Red Gram		39	1.6
Kota (Raj)	Onion	Clay loam	23	1.3
	Garlic		22	1.3
	Turmeric		23	1.3
Faizabad (UP)	Sugarcane	Silt loam	59	2.4
	Marigold		55	2.2
	Cowpea		61	2.6
Palampur (HP)	Broccoli	Silty clay loam	47	1.9
	cauliflower		38	1.6

Drip irrigation along with fertilizer (fertigation) reduces the wastage of water and chemical fertilizers, subsequently optimizes the nutrient use by applying them at proper place and time, which finally increases the water and nutrient use efficiency (Table 5). Moreover, the efficacy of water soluble fertilizers will be affected directly by soil moisture in the root-zone depth. The restricted root development with drip irrigation also shows preference for fertigation over conventional method. The initial experiments conducted across the country have indicated superiority of fertigation over conventional method depending upon soil type. In sandy loam soil, the increase in yield due to fertigation was from 47 to 50 %, in clay loam from 32 to 87 %, in silty clay loam around 14%, in silt loam around 34% and in clay from 28 to 59 % over conventional fertilizers.

Table 5. Fertigation vs. conventional method of fertilizer application

Centre & State	Test Crop	Soil type	Yield (kg/ha)		Yield increase over conv. method (%)
			Conventional method	Fertigation	
Dapoli (MS)	Brinjal	Lateritic	1876	3234	72
Jorhat (Assam)	Assam Lemon	Sandy Loam	10100	14880	47
Palampur (HP)	Broccoli	Silty clay loam	7400	8440	14
Navsari (Guj)	Onion	Clay	28740	45690	59
	Turmeric	Clay	13100	16800	28
	Round melon	Clay	12000	15300	28
	Sugarcane	Clay	140000	183000	31
	Tomato	Clay	48000	68000	42
Bhawanisagar (TN)	Coconut	Sandy loam	10974 nuts	16461 nuts	50
	Sugarcane		115300	171700	49
Madurai (TN)	Red Gram	Clay loam	1108	1515	37
Kota (Raj)	Onion	Clay loam	16350	24960	53
	Cabbage	Clay loam	17756	23373	32
	Garlic	Clay loam	6953	10575	52
	Turmeric	Clay loam	14670	27360	87
	Bitter Gourd	Clay loam	21226	30139	42
Faizabad (UP)	Marigold	Silt loam	161	216	34

Conservation practices: Strong policy is needed to disseminate water efficient agricultural practices like laser land leveling, conservation agriculture, short-duration rice varieties and to diversify cropping patterns, bed planting and alternate furrow irrigation, underground pipeline conveyance of irrigation water, appropriate tillage systems including resource conservation technologies and surface retention of crop residues for mulching etc. Moreover, the practice of flood irrigation should be discouraged and priority incentive be given for micro-irrigation since the latter greatly enhanced the water use efficiency. Such practices need to be extended through extension services so that large areas are covered within a reasonable time.

Ground water governance: The Punjab Preservation of Sub-soil Water Act-2009 is an effort to conserve ground water resource by mandatory delay in the transplanting paddy beyond 10th June to escape periods of high evapo-transpiration demands. Analysis showed that implementation of the Act saved about 172 m kWh of electricity and about 7.2% of annual ground water draft. State of Haryana also passed similar act for mandatory delay in transplanting rice.

Resource conservation technologies: In the post-green revolution era, the issues of conservation have assumed greater importance in view of widespread resource degradation problems and the need to reduce production costs, increase profitability and make agriculture more competitive. The new challenges demand efficient resource use and conservation receive high priority to ensure that earlier gains are sustained and further enhanced to meet the emerging needs. There are many resource conservation technologies like zero tillage, bed planting etc which has shown promise in enhancing water productivity.

Conclusions

The major factor deciding the water demand will be governed by changes in the socioeconomic status of the population and the extent of urbanization and industrialization. In recent years, there have been significant changes in the consumption pattern and the share of non-food grain items in food consumption is increasing. Due to this, there is sharp increase in the demand of such items, i.e., milk, eggs, meat, vegetables and fruits. It is expected that this condition will continue and the gaps will further widen in the next 40 years unless corrective measures are taken to enhance production.

As indicated earlier, about 375 BCM of water will be required for uses other than agriculture, i.e., domestic, industrial, power and others. Considerable proportion of this requirement is non-consumptive and is discharged with varying level of pollution. All these sectors through water use generate large amount of wastewater containing varying levels of contaminants, making them unfit for most of the uses. In the large peri-urban areas, these wastewaters are used either without treatment or partial treatment for growing horticultural crops, with potential health hazard to farmers as well as consumers. Similarly fodder grown (to meet demand of livestock, another prominent activity in peri urban areas) with wastewater increases the chances of entry of heavy metals and other undesirable substances into the food chain. With water availability shrinking further, these instances are going to increase both in number and magnitude. This component of operating environment has to be investigated to create a data base on generation of wastewater and its quality (segregating in four classes: marginally poor, poor, highly degraded, unusable) to develop technologies for their reuse along with identification of sectors where it can be used.

Rising cost of energy and competing demands from other sectors will make it prudent to make agriculture more energy efficient. Irrigation is the second most energy intensive input after tillage operations and therefore the cost and availability of energy will be a guiding factor in future research programmes from both fossil as well as renewable sources. Declining ground water table will add further consumption and cost of energy. A one % fall in ground water table will increase energy consumption 1.25-1.5%. Similarly an increase of 5% pumping efficiency will reduce the energy requirement in similar proportion. Both these factors will have to be accounted for in future research programme.

Drudgery in agricultural operations is a major cause of low preference of agriculture among labourers. Although there have been a lot of research efforts to reduce drudgery of agricultural operations, very little has been done in water application sector to enhance the convenience and comfort level in operations. Few reports suggest that the cost of irrigation labour varies from 30 to 50% of total cost. Increased aspiration of labour as well as competing opportunities of labour in other sectors will further aggravate this problem. Thus there is an urgent need to intensify research efforts to improve technology of surface irrigation system which requires less labour and is more efficient. This can be achieved by introducing some level of automation including estimating irrigation requirement through field sensors.

Climate change scenario will influence all our estimates and projections. The studies have suggested that rainfall in the tropical region will increase by 10-15%, and the extreme rainfall events will be more frequent leading to increased runoff, higher number of dry days and longer dry spells. Rising sea levels will increase salinization of coastal aquifers, as well as waters of rivers in the delta zone. These factors will affect our whole irrigation and drainage systems. Thus we will have to evaluate whether our existing irrigation and drainage systems are robust enough to cope up with expected changes in rainfall pattern. Further, what should be the changes in design and construction codes of soil and water conservation structures, irrigation and drainage systems so that they can withstand the unpredictability of weather during their expected life period.

The increased food grain demand to 38 Mt in 2025 and 111 Mt in 2050 will provide an opportunity of more productive utilization of our land resources in the ecosystems challenged either by quality of water or by soil and land resources.

This will require identification of non-conventional feed resources which can be grown in these challenged ecosystems. This approach has a potential of altering the landscape of these ecosystems which will be more climate resilient as well as would prevent/reverse degradation of natural resources base.

Water governance in some part of the country has moved from totally government controlled system to participatory mode, PPP mode and private sector. While surface water sector governance is largely in public control (*i.e.* government), ground water sector is almost in private sector. There has been a significant shrinkage in public investment in water sector, which has declined from 23% to 8-10% of plan budget. It is expected that the government will further withdraw from this sector in the coming years, while empowered regulatory authorities would be expected to monitor the water resource system in next decades.

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Chapter 4

Water-Energy-Food Nexus – A Basis for Sustainable Agriculture in Maldives

Ali Amir

Director, Ministry of Fisheries and Agriculture, Male, Maldives.
ali.amir@fishagri.gov.mv

Introduction

Maldives consists of 1192 islands lying in the Indian Ocean to the south-west of Sri Lanka and India. As of census 2014 the population of Maldives is 344,023 (NBS, 2014). Almost a quarter of total population resides in the capital city Male' while the rest are dispersed among 200 inhabited islands. Maldives being one of the world's most famous touristic attractions makes tourism sector the driving force of the economy. Vast oceans surrounded by the islands rich in abundant resource of fish, makes fisheries the second major economic sector of the country. Due to limited land, poor soil condition, transportation constraints, potential agriculture islands being dispersed and various other reasons, agriculture sector is further down the line of country's economic contribution. Therefore, the country relies on imported food and food makes up the highest percentage of total imports until 2015. According to the Annual Statistics Report of Maldives Customs Service for the year 2016, machinery and electronics imports have surpassed food imports by 1% (Table 1). This is an exception as the increased imports of bulk machineries is mainly due to the construction of the China-Maldives Friendship Bridge that connects Male' City and Hulhule' (Airport).

Table 1. Major imports 2016.

Major Categories	% of Total Imports
Machinery and Electronics	19
Food Items	18
Fuel	11
Vessels, Aircraft & parts thereof	7
Miscellaneous Infrastructure Articles	6
Wood, Articles of wood, Wood charcoal, Cork & Articles	4
Plastic &Articles thereof, Rubber & Article	4
Textile & Textile Articles	2
Vehicles and Vehicles Parts and Accessories	1
Products of Chemical or Allied Industries	5
Base Metal & Articles of Base Metal	8

Source: Year Summary at the end of November 2016, Maldives Customs Service

Agriculture – Current Situation

Despite the challenges in agriculture development, more than 7,000 people are registered as farmers (MoFA, 2017). Most of the registered farmers are practicing subsistence farming and backyard cultivation is a common practice. Betel leaves, pumpkin, luffa, passion fruit, collard greens, mango, guava, bilimbi, sweet potato, cassava, stone apple, custard apple, pond apple, wax apple, bread fruit are some of the major crops found in compounds of many islands. Crops grown larger scale on the field includes papaya, watermelon, banana, chili (local githeyo mirus), taro, cucumber and eggplant (Table 2). Cultivation of traditionally grown crops like sorghum, millets and maize has declined over the past few decades.

Table 2. Agricultural Products Traded In Male' Market 2016

Produce	Total in Kgs
Watermelon	437,685
Coconut (young)	1,600,833
Papayas	573,983
Pumpkin	142,639
Cucumber	126,990
Banana	589,280
Brinjal	127,885
Coconut	272,294
Chilies	74,421
Bottle gourd	24,920
Butternut	21,670
Chinese Cabbage	75,985
Mango	47,684
Wax gourd	67,679
Betel leaves	43,568
Others	501,451
Total	**4,728,967**

Source: Agriculture Data Management Unit/Min. Fisheries and Agriculture

Apart from these crops, coconut is cultivated extensively throughout the country and it is the only product not being imported. Consistent supply of locally produced coconuts has sustained the retail price below MVR 2 until 2010. Over aging and infestation of pests like coconut hispid beetle *Brontispa longissima* and Rhinoceros beetle *Oryctes rhinoceros* and lack of management lowers the yields. Therefore, the supply of coconut has reduced and the retail price has reached to

MVR 30 in June, 2017. At the same time the demand for tender coconuts has drastically increased with the growing number of tourists.

Food and nutrition security situation

About fifty years ago all food items consumed in the nation was produced locally. Main staple food at that time was finger millet, maize, coconut, breadfruit, tubers such as sweet potato, taro, cassava and fish. Food habits and main staple foods of locals drastically changed to rice and wheat during 1970s (Butany, 1974).

Adolescents are generally on suboptimal diets. Survey results of Global School Health Survey (GSHS 2009) shows that around 7% of students (13-15years) go hungry because there is inadequate food at home; students (7.6%) from Atolls are slightly more likely than students (5.2%) from Male' to go hungry most of the time or always (Moosa, 2010).

Less than half of the students (46%) had breakfast most of the days while only 3% indicated that this is due to unavailability of food at home. Among the students, fruit and vegetable consumption tends to be low. Only 22.7% of students ate a fruit two or more times a day and male students (26.4%) are more likely to eat fruits compared to female students (19.3%). 10.1% of students ate a vegetable three or more time a day. Male students (12.6%) are more likely to eat vegetables compared to female students (7.7%). The consumption of fruit and vegetables in Male' is much lower compared to Atolls; 24.7% and 11.2% in atolls and 5.2% and 7.5% in Male' for fruit and vegetable intake respectively (Moosa, 2010).

Only 24% of students engaged in physical activities for at least an hour for 5 days a week while 42% spend more than 3 hours per day engaged in sedentary behaviour. Students (46.2%) from Male' are more likely to be engaged in sitting activities than students (39.6%) from Atoll. Also, about one third of the students eat less to lose weight (Moosa, 2010).

There is a growing concern on malnutrition among reproductive aged women. MDHS showed that 46% of women aged15-49 years are overweight or obese and only 8% are too thin with BMI less than 18.5. Moreover 61% women do not engage themselves in any kind of physical activity in any day of the week (MOHF and MACRO, 2010). While overweight and obesity is common, micronutrient deficiencies are also common in this age group. Food security interventions are directed by the policies of agriculture sector specified in the Strategic Action Plan.

Programs guided by the SAP and implemented by the stakeholders can be classified into:

1. Promotion of commercial agriculture

2. Target on reducing imports of specific crops by cultivating and marketing them locally in a commercial scale
3. Strengthening institutional capacity

Water resources and its management

The only available natural fresh water resources in Maldives are rainfall and a thin layer of fresh water in the groundwater lenses accumulated in the porous coral sands of the tiny islands. Water lens are shallow and is accessible within one to two metres below from ground surface.

Due to untreated domestic waste water being disposed into the ground, the shallow fresh water lenses are more susceptible for pollution. The lack of safe ground water led people to rely on stored rainwater which is often inadequate to meet the total household water demand in many islands.

People harvests rainwater from rooftop for daily use as ground water in inhabited islands is not suitable for consumption purposes. The alternative desalinated water is available in few islands. The average rainfall remains within the range of 2000-2500 mm during the past decade (MET, 2006 to 2016). The highest rainfall is from May to September while the rest of the year is considered as dry period during which the demand for water is the highest. To meet the water shortage, government transports desalinated water to vulnerable islands in ships.

The number of islands vulnerable to water scarcity is rising each year and sea transportation of desalinated water is becoming a challenge. Despite pollution and salinity and the high cost of other water resources, farmers are forced to keep on using ground water. It clearly indicates the importance of improving water security across Maldives particularly in those vulnerable islands.

During 1980's, as part of the government's effort to better manage water resources and to provide safe water for drinking and household consumption purposes, concrete/cement tanks were placed in public places like mosques and schools where the whole community can access easily. Until 2004 the capacity of water tanks has been increasing with the demand.

After the 2004 Asian tsunami, each household in the Maldives was supplied with a 2500L high-density polyethylene (HDPE) rainwater tank used for water storage. Later, a network of integrated water supply with a combination of harvested rain water and desalinated water has been established in islands that are most vulnerable for water shortage (MEE, 2016).

Water Resource Policies and its Links to Agriculture

The National Water and Sewerage Policy (NWSP) provide a framework to coordinate action for the provision of adequate water for human consumption and sewerage services and for the proper management of water resources in Maldives. The policy proposes to adopt financially, technically and environmentally sustainable approaches along with protection, conservation, sustainable use and efficient management of water resources to meet the present needs as well as the needs of the future generations. The policy intends to bring public and private sector together encouraging maximum participation of water and sewerage stakeholders.

Though the policy goals of NWSP are not clear enough for more strategic approach in using ground water for irrigation purposes, the following policies and strategies have some linkages both directly and indirectly to the supply and management of water resources in irrigated agriculture.

NWSP policy goal 2: “Adopt cost effective, environment friendly, appropriate technologies in developing water supply and sewerage systems”,

NWSP policy goal 8: “Promote Research and development for sustainable use of water resources, water supply and sewerage system” and

NWSP policy goal 8: “Protect and conserve water resources” (MEE, 2016)

Water resource use competition

The diversification of tourism industry from a luxurious to a more affordable and accessible tourism further adds demand for water as guesthouses are becoming popular in inhabited islands. A remarkable progress has been made in this sector and the demand for fresh fruits and vegetables by tourists’ results in expansion of irrigated agricultural plots that utilize more water.

Moreover, the Government’s goal to double the arrivals to 500,000 in the guesthouse sector by 2020 would further increase the demand for fresh fruits and vegetables ultimately straining the water resource (Shifneen Rasheed & Daha Shuaib, 2017).

Other industries like construction that utilizes water in bulk quantities has been booming in the past few years further raising the demand for water. To prevent depletion of water resources, the government has introduced new rules and regulations that prevent construction businesses from using ground water resources.

Since water is available freely by simply digging a shallow well, farmers often consider it as an unlimited resource. Farmers usually keep hose watering and modified, handmade sprinkle irrigation techniques that have a tendency to waste. Commercial varieties of fruits and vegetables preferred by farmers are higher yielding at the same time require more fertilizers and are more prone to pest and diseases. Therefore farmers often use excessive amounts of fertilizers and pesticides with no hesitance to what is going to happen as it leaches into the ground water resources.

Way Forward for Sustainable Development

Water resource management

Water is one of the most essential resources that is not only limited to individual or household consumption but also is used for agricultural and industrial purposes. Sustainable management of this valuable resource is a responsibility of each and every person. Significant areas that need to be addressed in managing water resources are:

1- Strengthen legal framework

2- Integrated water management addressing all use of water in the policy

3- Capacity building of stakeholder and create public awareness

4- Promote research and introduce financial models to develop the sector

Agriculture development

With the poor soil condition and water retention capacity, the agriculture sector in the island nation would be more challenging to develop in a sustainable manner for sustainable development unless the latest technologies are made available to farmers at an affordable rate. The responsibility lies on both farmers and government to ensure that water resource is used in a sustainable manner. Some of the areas that are essential to focus on the sustainable development of agriculture sector include:

1- Strengthen legal framework and empower local councils and NGOs operating at island levels

2- Aware farmers on eco-friendly farming techniques through extension and training programs

3- Invest on infrastructure development in main agricultural islands like establishing proper irrigation networks in main agricultural islands with integration of rainwater harvesting and other mechanisms

4- Promote low cost, waste less, eco-friendly irrigation systems and make it accessible to farmers

5- Introduce financial models and operate irrigation activities in a more harmonised and systematic manner

6- Provide technical and financial support to form and operate farmers' cooperatives

7- Build technical capacity of farmers through extension support services and trainings

Conclusion

Several limitations encountered in the Maldives agriculture sector has caused the country to heavily rely on food imports. Despite the challenges faced in the sector, farmers grow a variety of crops including betel leafs, banana, cassava and coconut. Coconut trees are extensively grown across the country and there is a huge demand for coconut as they are popular among the growing number of tourists. The supply of coconuts has decreased due to pest infestation which has caused a significant rise in coconut prices. Research shows that adolescents generally practice suboptimal diets and those from Atolls are more likely to starve when compared with that of in Male'. Also, there is a high prevalence of malnutrition, overweight and obesity among the reproductive aged women. Interventions of food security are guided by the policies of agriculture sector outlined in the SAP. Furthermore, rainfall and a thin layer of fresh water in the groundwater lenses are the only natural fresh water resources available in the Maldives. The disposal of untreated domestic waste water into the ground, pollutes the groundwater and hence people are depend on stored rainwater which is usually insufficient for use in islands. During the dry season, the government ships water to the islands to meet the water shortage. A network of integrated water supply with a combination of harvested rain water and desalinated water has been established in islands that are most vulnerable for water shortage. The NWSP provides a framework that coordinate action for the provision of adequate water and sewerage services and for proper management of water resources in the country. Diversification of tourism to guesthouse sector further increases the demand for water in inhabited islands. Finally, significant areas like strengthening legal framework and capacity building of stakeholders need to be addresed for sustainable use of water resources. In order to promote a sustainable agricultural development in the country, latest technologies are to be made available to farmers at an affordable price.

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Chapter 5

Water-Energy-Food Nexus – A Basis for Sustainable Agriculture in Nepal

Bashu Dev Lohanee

Director General, Department of Irrigation, Kathmandu, Nepal
lohanibasu@yahoo.com

Introduction

Nepal is a mountainous country an area of 147,181 square kilometer and it a home of 28.5 million population. About 66% of economically active population is engaged in agriculture and agriculture still provides 34% of the gross domestic products (GDP). Geographically, Nepal is divided into three major ecological zones, Terai, Hills in the mid and Mountains in the North. Terai shares its southern border with India in the south. It has 23% of the total land area of Nepal which accommodates about 47% of the population. It has very fertile land producing maximum of the food grown in the whole country. It produces about 55% of the nation's food grain supply. Major crops here are paddy, wheat, jute, tobacco, pulses, fruits, sugarcane, and vegetables. The hills occupy 42% of the area of Nepal inhabited by 45% of the total population. Major crops are maize, paddy, barley, potato, pulses, fruits, vegetables. Cattles and buffalos are raised both in terai and in the hills for milk and draft power. The mountain cover of the country is 35% of the land but on 8% of the people reside in the mountain. Maize and potato are the major crops while the other crops are millet, barley and temperate fruits. Agricultural yield in Nepal is low in comparison to regional and global standards.

Food and water are essential for human existence and energy is the key to human development. Access to these resources and their sustainable management are the basis for sustainable development. In Nepal, more than 90 % of water withdrawal comes from agriculture sector. Further increase in population increase will exponentially increase agricultural output, requiring more water and energy through fertilizers, harvesting and processing.

Food demand not only increases only due to increase in population because rising population but also because higher incomes enabled consumers to buy more and better food. The poorest people typically have to buy the cheapest available carbohydrates. But, with more money, they can buy more fruits and vegetables, along with meat, dairy goods, and eggs. As a result, much of the region has been changing from a traditional diet based on carbohydrates and vegetables to one richer in fat and protein.

Water, energy and food are inextricably linked. Access to these resources and their effective management underpin development progress. The persistence of sectoral approaches to policy-making, however, has led to key resource constraints and policy responses being considered in isolation due to segmented planning and decision-making frameworks, with inadequate attention to the complex interactions that exist between sectors and resource systems. The nexus among water, energy and food (WEF) has gained increasing attention in research and policy spheres in Nepal though it is very noble context which is mostly available in literature with limited operationalization in the ground. WEF has risen up as an appropriate concept to describe and address the complex and interrelated nature of our global resource systems. It presents a conceptual approach to better understand and systematically analyze the interactions between the natural environment and human activities, and to work towards a more coordinated management and use of natural resources across sectors and scales (FAO, 2014a and FAO, 2014b).

Poverty, food insecurities, access to electricity, access to water are the key issues of Nepal (Table 1). To address the above key issues through optimizing the synergies and minimizing the tradeoffs, an integrated approach can support a transition to sustainability, by reducing trade-offs and generating additional benefits. This can lead to many opportunities like increased productivity of resources, development of multiuse system, governance, institutions and policy coherence, capacity building and awareness raising, promoting green economy (Hoff, 2011a and Hoff, 2011b). UNEP has defined green economy as an economy that results in improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities.

Table 1. Key Indicators of Water-Energy-Food Nexus in Nepal

Indicators	Value
Population (million)	28.5
Urban Population (% of total population)	19%
Agriculture land area (000ha)	2113.7
Land under cereal production (000ha)	3480
Agriculture irrigated land (% of total agricultural land)	30
Economically active population in Agriculture	66
Poverty headcount (%)	25.2
Undernourished population (%)	15
Annual fresh water withdrawal in agriculture(% of total fresh water withdrawal)	98.14
Decadal growth in livestock population (2001-2011) %	52

Sources: Economic Survey, Ministry of Finance, GoN (2016), World Bank, 2017

It is increasingly clear that effective and sustainable solutions to climate change and achieve the SDGs goal, will require greater understanding and consideration of the linkages and inter-dependencies between sectors such as water, energy and food (Rasul, 2014; Rasul and Sharma, 2016).The nexus approach is new in Nepalese context. Understanding different aspects of the nexus at various levels and is necessary for effective operationalizing of the nexus. It is needed an adequate deliberations on its rationale, trade-offs and opportunities at different levels at frequent interval. It helps all the related stakeholders to get operationalize the nexus in policies and practices. This paper tries to explore and contextualize the water energy food (WEF) nexus in Nepalese context and discuss how WEF can be an option for the solution.

Water, Energy and Food Dimensions in Nepal

Water resources in Nepal

Nepal is very rich in water resources. Rivers are the main sources of water in Nepal. The rivers in Nepal originate from Himalayas in the north flowing to south draining all its water to the Ganges river system. Nepal has about 6000 rivers draining an average of 225 billion cubic meters (NWP). The major river basins of Nepal are Koshi, Narayani, Karnali and Mahakali rivers having total catchment areas of 60,400 sq. km. (46% of the catchment area in Nepal), 34,960 sq. km. (90% of the catchment area in Nepali territory), 43,679 sq. km. (94% of the catchment area in Nepal) and 15, 260 sq. km (34% of the catchment area in Nepal) respectively. The Koshi is the largest basin with average runoff of 45 billion cubic meters per annum at Chatara, a station at the lowlands with the altitude of 115m MSL. The total discharge in the rivers of Nepal is an average of 225 billion cubic meters per annum. Along with, there are also medium size river basins, namely Kankai, Kamala, Bagmati, West Rapti and Babai with total catchment area of 17,000 sq km. these rivers are mainly rain-fed so the discharge varies a lot during rainy and dry seasons.

With such huge water availability in Nepal and wider topographic variability ranging from 8,848m in north to 64m in south, Nepal has a huge potential of hydropower production (Bajracharya et. al., 2011). Nepal has theoretically potential of 83,000MW of hydroelectricity power among which 43,000MW is considered to be theoretically and technically viable. But currently only 686MW of electricity is being generated which is only 1% of the total estimated potential (Gurung, 2011). Major energy resources in Nepal can be broadly classified into three categories by Pokhrel: traditional, commercial and renewable. Traditional sources include biomass mainly firewood, agriculture residues, and animal dung. Commercial sources of energy are petroleum, coal, and electricity. Renewable energy sources include mini- and micro-hydro, solar, biogas, briquettes, improved cooking stoves, and wind-power.

Agricultural Water Use in Nepal and Issues of Food Security

The agriculture sector dominates the economy providing about 34% of the GDP and employs more than the manufacturing, service and tourism sectors combined. Agriculture absorbs about 66% of Nepal's labour force. About two-thirds of agriculture GDP comes from the crops sub-sector with the remaining from the livestock sub-sector. Close to 16% of the country is arable land. The average household owns 0.8 ha of land but the majority of households (45%) own less than 0.5 ha with a decreasing average household farm size trend over the last several decades. Most agricultural holdings can be classified as subsistence family farms (64%) with only 3.1% classified as actual commercial farming operations.

Agriculture has a dual role as an energy user and as an energy supplier in the form of bioenergy. Sustainable agricultural practices such as actions to avoid land loss or degradation save water by increasing soil water storage and groundwater recharge. They also save energy, for example, by reducing the use of energy-intensive fertilizers. Agriculture and food production have a further impact on the water sector through their effects on land condition, runoff, groundwater discharge, water quality, and availability of water and land for other purposes such as natural habitat (Alauddin and Quiggin 2008).

Agriculture sector is the most dominant sector in Nepal which uses more than 90 % of total water withdrawal. Nepal has 2.64 million ha of cultivable land out of which 1.76 million ha is irrigable (66%) and remaining depends on monsoon rainfall (Irrigation handbook, 2016). Terai has more area under irrigation facilities in comparion to hills and mountain as the construction of irrigation infrastructures are really a challenges in later two ecological zones. As a result, crop yield varies significantly along the three ecological zones of Nepal.

Nepalese agriculture is heavily dependent on monsoon rain. The northern parts of the Mid-West region receive little rain throughout the year. The use of improved seeds is low (Paddy 5.4%), and wheat (5.6%) (MoAD, 2014). About one-half of the farmers use fertilizer on wheat and two-thirds of farmers use fertilizer on paddy but not always the correct type and amount and availability is a problem. In spite of availability of abundant water resources, havening comparative advantages of growing high value crops in diversified agro climatic zones, Nepalese agriculture is not performing well. As a result, food security is an issue.

Food insecurity is a burning issue of Nepal. Nepal is struggling to produce an adequate supply of food from a long time. Nation's food security has been getting high priority in each development plan of Nepal but the situation has not improved significantly. The interim constitution of Nepal has also mentioned "food sovereignty as fundamental right of Nepalese people. Still, 15 % of the total population is undernourished in Nepal (Table 2). According to WHO, among the under five years old children, 40% are stunted, 29% are underweight, and 11% are wasting. The figure shows the problem of food insecurity is one of the key challenges in Nepal. The one of the reason behind the persistence of the problem is the sectoral approach taken for the solution.

Table 2. Population Undernourished in Nepal

	1990-1992	1995-1997	2001-2003	2003-2005
Undernourished population (%)	20	26	17	15
Number of undernourished (000)	3,900	5,600	4,100	4,000

Source: ESAP (2009)

Energy Security

Access to energy is essential to reduce poverty and food security. In Nepal, About 15 of total population in Nepal do not have access to electricity and about 16 % people still use fuels like wood, charcoal, coal and dung for cooking and heating (World Bank 2017). Access to affordable, reliable, sustainable and modern energy (SDG 7) is vital to achieving Sustainable Development Goals (SDGs) and the best adaption options of climate change.

Major energy resources in Nepal can be broadly classified into three categories by Pokhrel: traditional, commercial and renewable. Traditional sources include biomass mainly firewood, agriculture residues, and animal dung. Commercial sources of energy are petroleum, coal, and electricity. Renewable energy sources include mini- and micro-hydro, solar, biogas, briquettes, improved cooking stoves, and wind-power. Firewood and animal dung is the major source of cooking fuel in the villages in Nepal basin as majority of households does not have an access to modern sources of energy. Very few people rely on fossil fuels and bio gas.

Nepal's economic and social development is being hampered by its inadequate energy supply. The country does not have its own reserves of gas, coal or oil. Although the most significant energy resource is water, less than one % of the potential 83,000 megawatts of hydropower is currently harnessed. Firewood is the predominant energy carrier, counting for more than 70 per cent of consumption. However, its use is inefficient and poses a threat to the country's forests. At the same time, the indoor pollution caused by open hearths in homes presents a hazard to health. Mains electricity is generally only available in urban areas and some 60 % of the populations do not have access to it. Biomass is by far the most utilized primary energy source and the electrification rate of the population is only about 55%, with approx. 43% in rural areas. Nepal's average annual per capita electricity consumption is about 130 kWh – one of the lowest consumption in

South Asia. Despite its vast hydropower potential, Nepal suffers from a severe and long-lasting electricity supply crisis (NEEP, 2014).

Energy use in Irrigation

Nepal also has a huge potential for groundwater resources especially in the southern Terai region. It is very productive as it contains thick sediments of alluvial and colluvial origin from the Siwalik hills which are the lower hills. The aquifers are unconfined and the sediments are quite coarse making the permeability very high 100-150 m/d (NWP). In Nepal, about 19.2 % of total irrigated area is irrigated through groundwater (FAOSTAT, 2017). There is a huge potentiality of groundwater use for agriculture in the Terai region of Nepal as this reason is considered as the saturated zone and studies have shown withdrawal of groundwater to certain limits have positive impact on flood moderation in Nepal. Pumping for irrigation is energy intensive. Improving energy access may improve the water availability and accelerate the agriculture intensification in Terai of Nepal. The further development of hydropower projects in Nepal may improve the groundwater withdrawals and agriculture intensification in Nepal. But the precaution should be taken to avoid the over exploitation and groundwater recharge should be considered during the monsoon months. Nepal should learn the lesson from the overexploitation of groundwater due to subsidized electricity from Gujarat, India.

Box1: How lift irrigation is contributing for improving irrigation water availability and food security in Nepal?

Out of total cultivable land (2.641 million hectares) only 1.766 million hectares could be irrigable. This difference of 875 thousand hectares can be made irrigated through the energy use either electric or solar power. Currently around 200 electric lift irrigation system covering around 10000 ha of terrace land which excludes large lift irrigation system of flat land known as terai. Few solar power lift system has been implemented as pilot sites. In these areas, cereals and vegetables are produced which ultimately reduces the food insecurity of the area specially hills of Nepal.

Conclusion and Suggestions

The water, energy, and food sectors are traditionally considered in isolation, but there is a need of cross-sectoral integration on these issues to encourage effective resource management. To achieve food security, we need to use water and energy more efficiently and minimize the negative impacts on the water supply. Better water resources management, sustainable and equitable access to water and use of improved, energy-efficient technologies are the steps to achieve food, energy and water securities in Nepal.

A Nexus approach helps us to better understand the complex and dynamic interrelationships between water, energy and food, so that we can use and manage our limited resources sustainably. It forces us to think of the impacts a decision in one sector can have not only on that sector, but on others. Anticipating potential trade-offs and synergies, we can then design, appraise and prioritize response options that are viable across different sectors.

Bridging the yield gap in Nepalese agricultural in a sustainable through better management of water and energy resources is achievable. Devising agronomic practices which may reduce the water and energy use in agriculture such as promotion of conservation agriculture practices such as zero tillage, bed planting, residue management and crop rotation. Improving energy use efficiency in agriculture by efficient machinery and implement suitable for small holder farmers. Agriculture diversification can reduce the energy and water use in Agriculture.

Enabling environment for a nexus approach include the capacity building and awareness raising programs (Biggs et al., 2014). Informing the public, policymakers and practitioners of the mutual benefits of reducing water and energy use would create mutual trust among stakeholders and therefore creates enabling environment to operationalize the nexus. The environment should encourage collaboration between water and energy expertise for developing innovative synergistic solutions. The additional enabling environment consists promotion and investment in water and energy infrastructures, promote innovation to identify technological choices and investments that explore water-energy synergies and could be implemented to achieve desired changes on the ground.

The horizontal and vertical policy coherence is the one of the key pillars to operationalize nexus in the ground in a sustainable way. Coherence in institutions helps improve governance. For example, it would be easy to operationalize water, food energy nexus in Nepal if two ministries i.e. Ministry of Irrigation and Ministry of Energy work closely or may unite as one Ministry in Nepal.

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Chapter 6

Water-Energy-Food Nexus – A Basis for Sustainable Agriculture in Pakistan

Sajjad Haider Yaldram

Deputy Secretary, Ministry of Energy, Pakistan
yaldramsajjad@yahoo.com

Introduction

The Islamic Republic of Pakistan is the sixth-most-populous country of the world and home to about 195.5 million people. Located in South Asia and an active member of SAARC, Pakistan has a total area of 796,095 Km^2. It has an Exclusive Economic Zone of 240,000 Km^2 and an additional Continental Shelf area of about 50,000 Km^2. Bordering China, India, Afghanistan and Iran, Pakistan is one of the key countries of the region with unique geo-strategic and socio-economic realities.

Pakistan's population growth rate is 1.89% per annum and it's expected to swell up to 275 million by 2050. Pakistan is the 2nd most rapidly urbanizing country of South Asia with 36 % urban population. Current gross domestic product (GDP) of nearly US$ 300 billion and average GDP growth of 4.9% since 1952 classifies Pakistan as a lower middle-income country. Pakistan is predominantly an agrarian country with 42.3% of the population directly employed by the agriculture sector and its contribution to the overall GDP is around 19.8 %. Pakistan is famous all over the world for its geographical uniqueness and climate variability. Its legendary Northern Areas are often referred to as Switzerland of Asia. Over fifteen thousand square kilometer of glacial area and 7,000 glaciers, often referred as third pole of the world, make it the most glacially populated region outside the polar region. It also boasts some of the highest peaks of the world, such as, K2 (8611 m), Nanga Parbat (8126 m), Gasherbrum I (8080 m), Broad Peak (8,051m) etc. The deserts, about eleven million hectares, make up fourteen % of the land. The Arabian Sea in the South provides about nine hundred and ninety kilometers coastline. The subtropical arid zone is where Pakistan is situated and it is mostly subjected to a semi-arid climate. The main climatic regions of Pakistan include the subtropical continental plateau, the subtropical continental highlands, the subtropical continental lowlands, and the marine tropical coastland.

Climate Change and its Ensuing Insecurities of Food, Water, and Energy in Pakistan

Pakistan is worst hit by climate change and global warming. It has imparted widespread insecurities of food, water and energy in Pakistan. "The super floods of 2010 alone displaced twenty million people from their homes in just one stroke, making it by far the biggest human displacement caused by any climate induced single event in the history of human memory," (Pakistan's National Climate Change Policy 2012).

Glaciers are widely considered as stabilizers against climate change and global warming. However, in Pakistan which is predominantly dependent on its glaciers for fresh water resources, the glaciers are melting at 2.3 % per annum, which is one of the fastest in the world, resulting in frequent flooding.

Pakistan's National Disaster Management Authority (NDMA) has carried out multiple studies which show that the flood events from 2010 to 2014 have caused monetary losses of over US$ 18 billion with 38.12 million people affected, 3.45 million houses damaged and 10.63 million acres of crops destroyed. Pakistan has been estimated to suffer to the tune of US$ 4 billion per annum due to climate-induced catastrophes between 1994 and 2013.

Recently carried out Pakistan's Intended Nationally Determined Contribution (Pak-INDC) to the United Nations Framework Convention on Climate Change, 2016, for Paris Agreement on Climate Change, "Despite Pakistan's diminutive contribution to global GHG emissions, it is among the top ten most climate-affected countries of the world, as indicated by the Global Climate Risk Index developed by Germanwatch."

The Pak-INDC reported the Climate Change Vulnerability Index 2016 (CCVI) suggesting "an increase in precipitation and rainfall pattern will happen during the summer season, resulting in riverine and flash floods over different areas of Pakistan. On the other hand, lack of capacity for flood management and wetlands results in discharge of extra water into the sea in less than a month's time, leaving the country in water-stressed situation for the large part of the year, with serious implications for food and energy security. Other hydro-meteorological hazards such as glacial melt, glacial lake outburst flooding (GLOF), avalanches, storms, cyclones, desertification and heat waves are becoming more common, putting lives, property and the allied socio-economic features of country at great risk."

Agriculture – Current Situation in Pakistan

Agriculture is the lifeline of Pakistan. *The country has a large cultivable land base of 86 Million Acre (MA)* (WAPDA, 2016). As per the Economic Survey of Pakistan, 2016-17, agriculture accounting for 19.5 % of the gross domestic product, employing 42.3 % of the labour force and providing raw material for several value-added industries. It thus plays a central role in national development, food security and poverty reduction. During 2016-17, the agriculture sector achieved growth of 3.46 % against the target of 3.5 %.

The government achieved its growth target in Agriculture due to its supportive policies. Besides, the agriculture credit disbursements were raised to Rs. 700 billion in 2016-17 from Rs 600 billion in 2015-16. Lastly, the Prime Minister's Agriculture Kissan Package has also proved beneficial. As per the Agriculture Year Book 2015-16, a three yearly comparison of major food crops of Wheat, Sugarcane, Rice, and Maize is as follows:

Table 1. Comparison of Production of Wheat, Sugarcane, Rice, and Maize (Million Tons)

Crop	2013-14	2014-15	2015-16	Growth %
Wheat	25.979	25.478	25.48	0.01
Sugarcane	67.46	62.65	65.48	4.52
Rice	6.798	7.005	6.811	-2.77
Maize	4.944	4.695	4.920	4.79

Agriculture Year Book 2015-16 states that the "*Livestock contributed approximately 58.6 % to the agriculture value added and 11.6 % to the overall GDP during 2015-16 compared to 56.4 % and 11.7 % during the corresponding period last year, respectively. Gross value addition of livestock at constant cost factor of 2005-06 has increased from Rs. 1247 billion (2014-15) to Rs. 1292 billion (2015-16).*"

For the Year 2015-16, the livestock population (cattle, buffalo, sheep, goats, camels) shows 2.4% growth whereas equines (horses, asses, mules) grew at 1.4%.

Millions.

Table 2. Livestock Population (2013 to 2016)

Species	2013-14	2014-15	2015-16
Cattle	39.7	41.2	42.8
Buffalo	34.6	35.6	36.6
Sheep	29.1	29.4	29.8
Goat	66.6	68.4	70.3
Camels	1.0	1.0	1.0
Horses	0.4	0.4	0.4
Asses	4.9	5.0	5.1
Mules	0.2	0.2	0.2

Food and Nutrition Security Situation in Pakistan

Long before the division of Sub-Continent and creation of Pakistan in 1947, the Province of Punjab was famously called the ‘Bread Basket” of Sub-Continent. The fertile planes of the Punjab generously irrigated by the largest and modern irrigation infrastructure of its time used to produce plentiful quantities of food and nutrition for the entire Sub-Continent.

However, after the partition of the Sub-Continent and creation of Pakistan, the requisite up gradation and improvements in the Agriculture, Food and Nutrition could not keep pace with the rapid growth in Population and Urbanization. The gap between supply and demand starts widening gradually.

The advent of 21st Century added to the murky waters of uncertainty another powerful variable in the form of Climate Change. The last two decades have seen climate induced calamities and catastrophes playing havoc with Agriculture, Food and Nutrition with increased frequency and alarming ferocity in Pakistan. Long and depressing droughts in some parts, destructive and widespread yearly or biennial floods in other parts become a norm rather than an exception is Pakistan. The Pak-INDC report says that the single event of 2010 Flooding, according to the World Bank calculations, eroded away 6 % of Pakistan’s GDP.

The resultant national food and nutritional security situation has been summed up by the Pakistan’s Food Security Assessment Survey 2016, which says that about 18 % of its population is undernourished.

As per the World Bank report, 2017, “*Pakistan has an extraordinarily high and persistent level of child under nutrition. To effectively tackle the problem, the design of public policies and programs needs to be based on evidence.”* Pakistan is aiming for Food and Nutrition Security for some time now. Lately, Pakistan’s National Climate Change Policy while describing Climate Change as Threat Multiplier vows to achieve Food Security through various measures of Climate Change Adaptation across Agriculture and Water sectors.

Pakistan did make noticeable progress in food production owing to agriculture supportive policies of the present Government, however, the high rate of population growth; urbanization and climate change have eaten into the visible gains in food production. Pakistan did get surpluses in Wheat, Rice and Sugar consecutively for the last 6 years, however the high cost of production make them uncompetitive in the international market which is passing through a phase of depression and as per the ‘Future Outlook’ of United Nations FAO, the situation is likely to remain depressed for a few more years. Given the present scenario Pakistan needs to gear up its efforts to diversify its food products for vegetables, fruits, nuts, oilseeds, pulses, livestock which make up about half of the dietary energy.

Pakistan, however, is mindful of the gigantic challenge of Food and Nutrition Security for the two hundred million people of Pakistan. Under Policy and Institutional response, Pakistan set up a full-fledged Federal Ministry of National Food Security and Research (MNFSR) in 2011. Since then the Ministry is in the process of devising an overarching, comprehensive and responsive Food and Nutrition Security Policy for Pakistan.

A considerable amount of effort and hard work have gone into the process of historic national, regional and international data collection, comparison, and future demand projections of the food and nutrition needs and requirements of the Nation. Based on the historic lessons learnt in food and nutrition production, provision, access and affordability, policy, institutional and legal measures have been further refined to match them with the enormity of the Food and Nutrition Security challenge in Pakistan.

Further, the emerging regional and international food and nutrition markets have been analyzed and taken into consideration for any future agriculture and food exports. Given the fact that about 65 % of Pakistan's exports are agriculture related, the extent and spectrum of the future avenues of food and agriculture exports to the regional and international markets are crucial for the viability and profitability of the Agriculture, Food and Nutrition in Pakistan.

Apart from historic data and empirical based evidence, the process of National Food and Security Policy formulation have also benefited from the institutional research on Food and Nutrition carried out by national, sub-national, regional and international institutions. Lastly, the Federal Ministry of National Food Security and Research (MNFSR) have ensured robust stakeholder consultations all across all segments of society. Starting with the basic tier of the agriculture spectrum the stakeholder consultations have gone on to the meaningful participation of Tehsils, Districts, Provinces and National tiers. Resultantly, Pakistan has succeeded in the completion of its first National Food and Nutrition Security Policy. Now the draft Policy is at the final stage of Governmental approvals.

The timing of the Pakistan's first National Food and Nutrition Policy can't be more fortunate, as it coincides with the launch of the Global Sustainable Development Goals (SDGs) and their adoption by Pakistan Parliament as Pakistan Development Goals (PDGs). In the instant case, the SDGs-1 and 2 about Poverty and Zero Hunger are of crucial significance.

Government of Pakistan's avowed mission is a Food Secured Pakistan through modern and efficient food production and distribution system that can best contribute towards food nutrition security. Under the umbrella guidance of United Nations' Food and Agriculture Organization the key elements of Food and Nutrition Security, such as, timely availability, universal access, strong utilization and all across stability are being intertwined into the Policy, Legal and Institutional Frameworks.

According to some Food and Nutrition Security estimates the growth potential of Agriculture Sector in Pakistan is 7% if its sub-sectors' development is carried out holistically and synergistically. However, under the present technical and technological constraints coupled with the availability of finances for the Agriculture Sector, Government is making a concerted effort to raise the agriculture growth to 4%, which, as per some statistics bare minimum growth to support the requisite Food and Nutritional Security to Pakistan.

In this regard, the Government of Pakistan is exploring options for innovations in the Food System. Programs, such as 'Zero Hunger', 'Kitchen Gardening', and 'Rural Poultry' are gaining enhanced recognition at national and sub national levels. Innovative livelihood practices, such as, medicinal plants, fisheries, bee-keeping and fruit orchard nurseries are gaining currency.

Likewise, the Cluster Approach for farm level food processing and value addition through public private partnership mode is gaining popularity.

Further, the Government is keen to exploit the full potential of the exportable entities in Food, Agriculture and Nutrition spectrum. Ways and means of enhanced exports of food, horticulture, aquaculture and fish are being vehemently explored and tapped. Government is also being increasingly cognizant of the low farm gate prices, high price fluctuations and inadequate market infrastructure.

Water Resources and its Management in Pakistan

Pakistan is blessed with 3rd largest reservoir of freshwater in the shape of over 7000 glaciers to the North, and the snow-melt water passes through the plateau and plains of Indus river and its tributaries and provide water to its rich fertile land for agriculture, and then end up in the Arabian Sea to the South of Pakistan. Monsoon is the also a major source of fresh water in Pakistan. Besides, about a million tube wells augment the supply of freshwater from underground to make up for the scarcity of water primarily for agriculture, drinking, and sanitation.

Pakistan has about a century old largest man-made canal system of the world. As Pakistan Water & Power Development Authority (WAPDA), 2015-16 states that '*About 104 Million Acre Feet (MAF) out of 144 MAF of surface water is being, annually, diverted to the Indus Basin Irrigation System. This provides irrigation facilities to 48 Million Acre (MA). Hence, the irrigated land base at present corresponds to 55.30 % of the total cultivable area 86 MA. Around 50 MAF is pumped from groundwater. Direct rainfall contributes less than 15 % of the water supplied to crops.'*

Pakistan's burgeoning population and lack of adequate water storage facilities pose serious threats of water shortage and food insecurity. *'Per capita surface water availability was 5,260 Cubic Meters per year in 1951, which has reached to alarming value of 1,000 Cubic Meters per capita in 2016. This position is* *worsening and with rapidly increasing population, this may further drop to about 800 Cubic Meters by 2025 representing acute water short conditions'* (WAPDA Annual Report, 2016).

Since Pakistan predominantly depend on glacial melt for its fresh water, climate change and global warming have far reaching implications for water security in Pakistan. As per ICIMOD's recent studies the rate of glacial melt in Himalayan-Hindukush region is one of the fast in the world.

The changing pattern of monsoon due to climate change has also worsened the already precarious situation in Pakistan. The incidents of flash floods and Glacial Lake Outburst Floods (GLOFs) have become increasingly common in Pakistan during the last decade or so.

Water is also a crucial source of electricity generation in Pakistan. About a third of Pakistan's electricity comes from hydropower. The identified potential of hydropower in Pakistan is more than 120,000 MW; whereas, the economically viable hydropower is more than 60,000 MW. However, at present, Pakistan taps only about 7,000 MW from hydropower. Pakistan's first draft National Water Policy is at the final stage of approval. Its overarching objective is to impart Water Security in Pakistan.

Water Resource and its Linkage to Agriculture

In Pakistan, over ninety % of the water is used by Agriculture. The Economic Survey of Pakistan 2016-17 rightly states that "*Pakistan's agricultural production is closely linked with the availability of irrigation water.'* Further, in Pakistan, the development of additional resources has the potential of bringing over 20.30 MA of virgin land under agriculture, (WAPDA Annual Report, 2016).

However, lack of water storage facilities during the summer season and climate change induced weather patterns have added unpredictability to the already fragile balance of water availability during Kharif and Rabi seasons. '*During 2016-17, the availability of water for Kharif 2016 stood at 71.4 million acre feet (MAF) showing an increase of 9.0 % over Kharif 2015 and 6.4 % more than the normal supplies of 67.1 MAF. During Rabi season 2016-17, the water availability remained at 29.7 MAF, which is 9.7 % less than Rabi 2015-16 and 18.4 % less than the normal availability of 36.4 MAF',* Economic Survey of Pakistan (2016-17).

Pakistan is a witness to reduced productivity of agricultural products in a number of instances due to unpredictability of water availability during cropping seasons, which results into enhanced food insecurity in Pakistan.

Water Resource Use Competition

Pakistan recognizes priority of the consumptive and non-consumptive uses of water of the following sectors:

a. Drinking (including livestock) and sanitation

b. Irrigation including land reclamation

c. Hydropower

d. Industry

e. Environment, river system, wetlands, aquatic life

f. Forestry including social forestry

g. Recreation and sports

h. Navigation

Way Forward for Sustainable Development in Pakistan

The Water-Enegy-Food Nexus Approach is the way forward for sustainable development in Pakistan. The Nexus Approach provides a new prism to understand the complex interactions amonst water, energy, food and agriculture sectors, and then applying this understanding to managing complex nexus amongst them. It’s a newly developed, focused, very thoughtful and vigorous Approach, which if equipped with practical tools and uniform data sets, can upgrade the mechanics of sectoral planning, meaningful stakeholder consultation, shrewd decision making, timely mobilization of requisite investments, brisk execution and pursposeful monitoring of sectoral developments for the overall benefits of sustainable development.

The Nexus Approch Nexus through working areas of evidence collection, scenario development, and response options provide a headstart to Policy Makers, Policy Implementers, Academia, Civil Society Organizations and other relevant stakeholders alike. Accurate and reliable data collection and generation in mutually acceptable standard formats, and data sharing platforms and such as data banks, provide the crucial backbone for meaningful scenario development and consequential policy options.

Conclusions

Water-Energy-Food-Nexus is an important concept for sustainable agriculture due to the cross-sectoral connectedness and inter-reliance of water, energy, food, and agriculture sectors. The Nexus concept is a practical concept, already practiced somewhat less systematically and methodologically, however, given its enhanced significance, it can be practiced more systematically, and new tools and data systems may be developed to help Policy Developers, Policy Makers and Policy Implementers to formulate, approve, implement and monitor informed and synergistic policies all across the water, energy, food and agriculture sectors

SAARC has an important responsibility and enhanced role to play in regional sustainable agriculture as the South Asian region has to feed about one fifth of the world population from far less corresponding share of natural resources in the form of land, water, and energy.

The Nexus Approach has fortunately coincided with the era of Sustainable Development Goals (SDGs). It's high time that the Nexus Approach may be transformed into practical tools and bankable indicators for larger synergy of the overall system that governs the sustainability of agriculture. In this way, the Nexus Approach, apart from serving the synergistic needs and necessities of the agriculture sector, may be helpful in developing an otherwise robust Monitoring, Reporting and Verification (MRV) System for other sectors as well.

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Chapter 7

Water-Energy-Food Nexus – A Basis for Sustainable Agriculture in Sri Lanka

K.M.A. Kendaragama

Principal Agriculture Scientist (NRM), Natural Resources Management Center
Department of Agriculture, Sri Lanka

kendarag@sltnet.lk

Introduction

Sri Lanka as an island has a total land extent of 6.5 million hectare and a population of about 22 million people. It consists of a mountain mass known as central highlands located towards south central part of the country and an area surrounded by the central highlands which is a plain mass. Major human settlements were first established in the plain mass in areas such as Anuradapura, Polonnaruwa and Kurunegala and few minor settlements were existed in valley bottoms in the central highlands. Hills in the central highlands were remained unexploited. The lands in central highlands have been characterized by flat, rolling, hilly and mountainous and extremely steeply topographic features while undulating to flat terrain in the plain mass. Major streams in the country originate from central highlands with a potential for hydropower generation. With the establishment of the Kandyan kingdom, major human settlements were expanded to central highlands particularly on flat to rolling lands. Later, with the introduction of commercial plantations of tea and other crops, the forest cover in central highlands dropped down. In contrast, agriculture and human settlements were expanded to hilly areas. Agriculture sector inclusive of food crop farming, plantation industries and homesteads occupied 65 % of the land mass (National Land Use Policy of Sri Lanka) and about 20 % of this land extent has irrigation facility. Per capita land availability in this country remains at 0.3 ha (Dimantha, 1992). Machinery use has been satisfactorily confined to paddy farming. Biomass, hydropower and petroleum products have been the major conventional energy resources of which the later has been imported from other countries. The country has been self sufficient in the staple food, rice and most of minor food crops. Local production of most of major food crops remains below the requirement, the balance being imported and needs production enhancement. Few crops such as wheat, lentil, chick pea, pigeon pea, garlic, barley, oat, corriander, fennel, cumin seed, fenugreek and apple have been totally imported from other countries. All these factors collectively revealed that food production in the country needs intensification towards sustainable agriculture development. In this regards, a potential exists for water and energy based intensification. Thus, the aim of this review paper was to discuss the present status of food crop agriculture, food and nutrient security, availability of water and energy resources for agriculture, water resource policies and its links to agriculture and water resource use competition. Further, this paper will discuss the way forward for sustainable agriculture through water resources management and agriculture development.

Agriculture

The land in the country has been used for wide range of agricultural and non-agricultural uses as shown in the table 1. It also shows the land use changes since 1956. The extent of agricultural lands has increased from 45 % in 1956 to 60 % in 2007 while land extent under various forest types has decreased from 44 % to 28.8 % during the period. The dense and open forest area of the country during this period decreased from 44 % to 23 %. The sparsely used crop lands, homesteads and paddy occupy the highest land area in the agricultural sector. The homestead lands are the home gardens where many tree crops are grown. The sparsely used croplands are the lands where the agricultural crops are grown but not properly managed and maintained. The sparsely used crop lands have been increased during this period indicating poor management of agricultural lands in the country. Among the plantation crops, the land extents under tea and rubber plantations have been decreased since 1956. It indicates these lands have become sparsely used lands. There is nearly 2 % increased of mixed and perennial crop lands and 1 % increased in the coconut plantations.

Sri Lanka receives food from three sources namely plants grown in farming systems in the country, plants harvested from natural ecosystems in the country and crop produce brought from other countries. The first has been the main source of foods. At present, about 106 food crops are grown in the country which include cereals (rice, maize, sorghum, finger millet, meneri, and thanahal), yams (cassava, sweet potato, large leaved yams, dioscoreas, chinese potato, elephant yam, edible canna and jerusalem artichoke), pulses (green gram, black gram, cowpea, soybean, groundnut and horse gram), vegetable (potato, cabbage, carrot, lettuce, bell paper, broccoli, brussle sproute, beet, reddish, leak, peas, beans, winged bean, vegetable cowpea, brinjal, elabatu, thibbotu, capsicum, tomato, okra, snake gourd, ridge guard, bitter gourd, thumbakarawila, cucumber, sweet pumpkin, ash pumpkin, konl-khol, ash plantain, jak and breadfruit), leafy vegetable (Kathurumurunga, murunga, spinach, thampala, gotukola, mukunuwenna, kankun, and Kohila).

Table 1. Land Use Types and Extents in Sri Lanka

Main land use type	Sub land use type	Land extent			
		1956		2007	
		000' ha	%	000' ha	%
Agricultural lands	Homesteads	586.3	9.0	1,028.6	15.7
	Tea	257.5	4.0	189.8	2.9
	Rubber	227.4	3.5	183.2	2.8
	Coconut	250.5	3.8	313.7	4.8
	Mixed perennial crops	90.0	1.4	164.3	2.5
	Paddy	510.7	7.8	844.0	12.9
	Sugarcane	0.3	0.0	13.8	0.2
	Sparsely used crop lands	1,008.1	15.4	1,439.5	22.0
	Other crop lands	4.3	0.1	76.8	1.2
Forest lands	Dense forest	1,656.8	25.2	1,123.7	17.1
	Open forest	1,222.6	18.6	404.0	6.2
	Forest plantations	20.6	0.3	86.9	1.3
	Scrubs	100.9	1.5	138.6	2.1
	Grasslands	324.9	4.9	90.6	1.4
	Mangroves/marsh	32.8	0.5	43.5	0.7
Other	Urban and barren lands etc.	267.3	4.1	420.0	6.4
Total		6,561.0	100.0	6,561.0	100.0

Source: Adapted from National Land Use Policy of Sri Lanka (http://www.luppd.gov.lk/web/images/content_image/downloads/pdf/national_land_use_policy.pdf).

Similarly fruits (banana, passion fruit, pineapple, mango, papaw, sweet melon, cashew, grapes, orange, lime, strawberry, dragon fruit, star fruit, apple, peach, pear, guava, avocado, sapodilla, anonas, pomegranate, rambutan, mangosteen and durian), spices and condiments (cinnamon, pepper, cardamom, clove, nutmeg, vanilla, chilli, hot chilli, kochchi chilli, red onion, big onion, turmeric, ginger, rampe, and curry leaves), beverages (tea, coffee and cocoa), oil crops (coconut and sesame) and other crops (sugarcane and mushroom) (Agricola, 1978 and Technoguide, 2016). In addition, considerable number of plants have been naturally grown in lands are also used as food. Furthermore, few crops which are not grown in the country and are totally imported from other countries in order to meet consumer needs. Some of them are wheat, lentil, chick pea, pigeon pea, garlic, barley, oat, corriander, fennel, cumin seed, fenugreek and apple.

Food and Nutrient Security

With the completion of the Mahaweli river diversion, the largest water-energy-food nexus in the country, in 1980s, Sri Lanka achieved significant improvement in food security. At present, about 106 food crops are grown in the country which include cereals, yams, pulses, vegetable, leafy vegetable, fruits, spices and condiments, beverages, oil crops and other crops such as sugarcane and mushroom. In addition, edible parts of many naturally occurring plants in natural vegetations are also consumed mainly as vegetable and fruits. Therefore, food and nutrient security status is good in this country. However, some short duration shortages in food supply appear hardly due to spatial and temporal variations in food production and market. Making necessary improvements for food transport and storage help address this issue. The annual production in 2014 and the requirement for 2015 for 11 crops or commodity groups are given in the Table 2. Among them, rice, vegetable and fruits are the major crop produce which have an annual requirement of more than one million tones. Among the above 11 crops or commodity groups, rice has a production with a marginal surplus, green chilli production meets the annual requirement but all the other crops and commodity groups, the present annual production remains below the annual requirement. It reveals the need of enhancing production of such crops in order to strengthen food and nutrient security and self sufficiency. In this regard, water-energy-food nexus plays a significant role. In addition at present, significant fraction of crop produce of particularly fruits and vegetable is lost due to damages from wild animals (Kendaragama, 2015) and while transport. Adoption of appropriate packing and transport technologies help minimize transport related crop losses but the damages from wild animals namely Elephant (*Elephas maximus*), Boar (*Sus scrofa*), Deer (*Axis axis*), Monkey (*Rhesus macaque*), Porcupine (*Hystrix indica*), Palm civet (*Viverricula indica*), Squirrel (*Callosciurus prevostii)*, Indian palm squirrel (*Funambulus palmavum*), Peacock (*Pavo cristatus*), Indian star tortoise (*Geochelone elegans*) are to be properly addressed in the future.

Table 2. National Food Crop Production and Requirement

Crop produce	Annual production (2014) (tones)	Annual requirement (2015) (tones)
Rice	2,710,000	2,270,000
Maize	235,000	400,000
Groundnut	21,516	26,000
Green gram	12,000	26,000
Soybean	22,500	220,000
Red onion	78,000	90,000
Green chilli	30,000	30,000
Dry chilli	9,237	50,000
Potato	80,000	160,000
Vegetable	1,011,683	1,500,000
Fruit	916,527	1,300,000

Source: Adapted from National Food Production Program of Sri Lanka (2015).

Energy Resources

Based on National Energy Policy & Strategies of Sri Lanka (http://www.energy.gov.lk/sites/default/files/files/Energy%20Policy%20%26%20Strategies%20-%20English.pdf), energy supply in the country is mainly based on three primary resources, namely, biomass, petroleum and hydroelectricity. Use of biomass energy has been the conventional source in the country. Hydroelectricity has been a local energy source exploited sine 1950s. Petroleum is the main energy source at present which is totally imported from other countries. In 2004, hydro-electricity production in the country accounted for 706.9 kTOE (thousand tonnes of oil equivalent) while the biomass-based energy supply was 4,494.4 kTOE. Approximately 4,304.2 kTOE was provided by imported crude oil and finished petroleum products such as diesel and liquefied petroleum gas. Additionally, the non-conventional resources (mainly wind) provided 3.5 kTOE of primary energy, giving an aggregate primary energy supply of approximately 9,509.1 kTOE. In 2004, primary energy contributions to national energy supply were 47.3% from biomass, 45.3% from crude oil and petroleum products and 7.4% from hydroelectricity. The use of other energy resources in Sri Lanka is of a relatively smaller scale and therefore its contribution is presently of low significance in the macro energy picture. The other resources include solar energy captured from solar cells and used to dry agricultural produces, wind energy; draft power commonly used in farming and transport goods particularly in rural areas. The primary energy contributions in 1991 were 70% from biomass, 10% from hydroelectricity and 20% from crude oil and petroleum products (NARESA, 1991). It shows an increasing demand with time for crude oil and petroleum products as energy resources.

With the increasing demand for energy to provide for the country's economic and social development, total primary energy demand is expected to increase to about 15,000 kTOE by the year 2020 at an average annual growth rate of about 3%. Electricity and petroleum sub-sectors are likely to record higher annual growth rates of about 7-8%. Hydro electricity production and biomass-based energy supplies, which are the only large-scale indigenous primary energy resources available in Sri Lanka, are expected to increase only marginally in the near future. This is mainly due to limitations in further hydropower development owing to lower economic viability of exploiting the remaining large hydropower sites and limited use of biomass with gradually increasing standard of living of the population. This means that the country's incremental primary energy requirements need to be supplied mainly by imported fossil fuels in the medium term. In the longer term, possible development of indigenous petroleum resources and accelerated development of non-conventional renewable energy are likely to make a significant change in primary energy resources.

In farming, energy is widely used in paddy cultivation in this country and has been mainly coupled with farm mechanization. Major machinery being used in paddy sector include two-wheel tractors, four-wheel tractors, mould board ploughs for two-wheel tractors, mould board ploughs for four-wheel tractors, rotary ploughs for two-wheel tractors, nine tine tillers, transplanters, weeders, power sprayers, knapsack sprayers, paddy reapers, paddy threshers, combine harvesters and winnowing fans. Petroleum products are used as the energy source in most of above cases. Hence, intensification of agriculture through farm mechanization results enhancing imported energy sources but it is significantly cost effective.

Water Resources and its Management

Sri Lanka is endowed with very high rainfall which is the primary water source of the country. Annual average rainfall over the country is 1940 mm which is equivalent to 132,000 million cubic meters (MCM) of water. Part of this rain water infiltrate in to the earth and enter in to underground aquifers as groundwater. Another part as surface water flows to the ocean through 103 rivers and streams which are drained from different catchments in the country. Considerable fraction of this surface water stored in the man-made reservoirs. The estimated runoff: rainfall ratio is 40.5 % (NAP, 2014). Reservoirs have been built to store part of runoff fraction of surface water. These reservoirs, classed as ancient tanks and modern reservoirs are multipurpose and provide services such as domestic needs, crop irrigation, hydropower generation and fresh water fishery. The reservoirs also contribute to ecological services such as groundwater recharge, maintenance of aquatic ecosystems and biodiversity conservation. The ancient tanks are categorized in to 3 groups namely minor tanks (command area less than 80 ha), medium tanks (command areas ranging from 80 to 100 ha) and major tanks (command area more than 100 ha). The modern reservoirs have been built during the last 6 decades using advanced engineering technologies and are large in water storage capacity and having features for hydropower generation. The storage capacity of these reservoirs is 375, 2425 and 5720 MCM, respectively for medium, major and modern reservoirs. The total storage capacities of minor tanks are not known but there are over 7,600 tanks in operation in the country.

Groundwater resources also play a vital role in this country for domestic uses extracting mainly through shallow dug wells and to a limited extent through tube wells. It has some limited uses in crop irrigation and industries. Most of groundwater resources are found in shallow aquifers and deep groundwater aquifers are confined to a limited area in the northwestern part of the country. With the expansion of agriculture in the dry and intermediate zones particularly in 1980s, hard metamorphic rock areas of the Central and North Western provinces, farmers have begun extraction of shallow ground water through large diameter shallow dug wells, popularly known as agro-wells among farmers, for cultivation of high value food crops such as chili, onion, vegetable, fruits etc. This has become an extremely popular among farmers. Consequently, there has been a rapid and haphazard increase in the number of agro-wells without adequate scientific backing. As estimated in 2000, the number has expanded up to around 50,000 in an unprecedented manner as those were meant to serve as sources of water for irrigation of agricultural crops during the much drier Yala season as well as during the water stress times of the Maha season (Kikichi, et al., 2002).In addition, natural springs scattered around the country help meet the domestic water needs of the people.

Watersheds also play a vital role in sustaining water resources in the country. Most of watersheds have been habituated by people and are used for multiple purposes leading to degradation of them as watersheds. The situation has been worsened by spatial and temporal changes of rainfall characteristics such as amount, distribution and intensity due to recent climate change effects. At present, despite the fact that Sri Lanka has been blessed by with plentiful of water, regular water shortages have impacted seriously on development activities in the country. Very wide temporal and spatial variation in water availability has been observed and it has been aggravated by quality deterioration and degradation of watersheds due to mismanagement of lands. Both surface and ground water resources have been subject to this fate. It is reported that groundwater in intensively farming areas such as Kalpitiya and Jaffna have been polluted due to contamination of chemical fertilizers, organic manures and agro-chemicals and intensively populated areas such as Colombo, Kandy, Kurunegala and Jaffna have been polluted due to contamination of domestic and industrial wastes. Many studies have shown that water use efficiency is also low in all water use sectors. Making attempts to increase water use efficiency in all sectors is an urgent requirement in order to meet the future water demands by all sectors.

Water Resource Policies and its Links to Agriculture

Sri Lanka has diverse water resources in both blue and green water domains. Priority has been given to develop policies for the water resources in the blue domain in the past decades. Table 3 presents the diverse fields in the blue water domain for which policy development is needed.

Table 3. Major Sectoral and Sub Sectoral Water Resources Use in Sri Lanka

Domain	Policy level	
Blue water	Sectoral	Sub sectoral
	Domestic use	Urban community
		Rural community
	Irrigation	Major reservoir system
		Cascade system
		Anicut system
	Hydropower generation	Major hydropower
		Mini hydropower

At present, a National Drinking Water Policy has been developed (http://waterboard.lk/web/images/contents/organization/policies/national_drinking_water_policy.pdf). A National Policy on Protection and Conservation of Water Sources, their Catchments and Reservations in Sri Lanka has been developed (http://www.landmin.gov.lk/web/upload/downloads/english-national-policy-on-protection-and-conservation-of-water-sources.pdf) and it exists at draft stage. A framework for groundwater policy for Sri Lanka was proposed by Gunawardena and Pabasara (2016). A brief description on above policy documents is given below.

National Policy on Protection and Conservation of Water Sources, their Catchments and Reservations in Sri Lanka

A National Policy on Protection and Conservation of Water Sources, their Catchments and Reservations in Sri Lanka exists at draft stage. It says that water is one of the main natural resources in Sri Lanka and it is the main factor which contributes to the country`s economic development since the past. Sri Lanka being an agricultural country, the irrigation has had a unique contribution towards country`s agro economy from history to this date. In spite of that, the water resource has become a prominent source in industry, supply of services, consumption (drinking) as well as recreation activities and tourism and hydro power generation. The requirement of a new strategic approach on water resources management in Sri Lanka has been included in the National Development Plans and agendas.

Sri Lanka is a country with 103 rivers. Of these river basins, about 20 comes under perennial while the rest belonging to the category of seasonal rivers. The magnitude of the river basins varied depending on the extents which range from 10 to 10,000 km^2. Geographically, the extent of land belonging to river basins is about 90% of the total land area of the country. Though there are no large scale natural reservoirs in Sri Lanka, the country is rich with a number of manmade tanks and an irrigation canal system, some of those tanks had been constructed centuries back and had been rehabilitated to the present condition. By now, about 12,000 tanks have been spread in Dry Zone areas of which the extent ranges from 01 to 6500 hectares. However the most of those tanks are less than 300 hectares in extent.

The cascade system created by interconnection of several tanks in the Dry Zone area is also an important component in water resources conservation in the country. In addition to the water sources described above, a large number of springs exists all over the island. For instances, there are about 1,544 such water sources in Nuwara Eliya district while 204 in Kandy district, 319 in Kurunegala District, 210 in Monaragala district and 288 in Mathale district. The number of water sources identified in the entire island is 3,540.

In addition, the aquifers laying within the inner limestone layers in the dry zone areas of the country are prominent in this country. These aquifers play a major role in fulfilling drinking and agricultural water requirement of the country.

In general, but widely considered the definition of the term “Water Sources” contains; not only the rivers, streams, reservoirs, and their catchments, springs and wet lands but also the glaziers, ice caps, atmospheric vapor, clouds and Tornados. However, three main components related to conservation and Protection of water sources in Sri Lanka have been taken into account when formulating this Policy depending on its importance. (a) Micro catchments which include rivers and streams, their reservations and their spouts and flood plains of the rivers. (b) Natural or manmade tanks and reservoirs and shallow lakes (villu), their reservations and "immediate catchments" of those tanks and irrigation canals and their reservations. (c) Existing underground or surface springs or spouts or such sources which are potentially available for common use and necessary land extent to ensure their existence and protection.

The contribution of the catchments, source areas and reserves play a vital role in ensuring the sustainability of the water sources described above. Especially the micro- catchments in high altitudes by which the rivers are fed, tanks and catchments of reservoirs, reservations of rivers and streams and flood planes are the sources of water resources of Sri Lanka and also they are the sources that balance the flow regime and sustainable existence. Considering the utilization pattern of the country's water resource, it appears that the protection of the above mentioned sources is a fundamental requirement for the sustainability of both the surface water bodies and ground water aquifers. For instance, the capacity of the shallow aquifers in Kalpiytiya peninsular could have fulfilled the drinking water requirement of a large population. But such waters have been contaminated to a level which could not be purified due to the excess adding of chemical fertilizer, agro chemicals and insecticides to the soil. The adverse effects on land by population pressure and the use of land for various complex economic activities are being increased at an alarming rate day by day, which directly affect not only the existence of the water resources and their reservations but also the water quality.

The soil is polluted due to the excess use of chemical fertilizer in agricultural land use and high use of agro chemicals and pesticides in intensively farming areas which resulted in water pollution. It has already been reported that the water use for drinking purposes and for agriculture has been disturbed due to the pollution in such areas.

The catchment areas are being rapidly waned as a result of inappropriate constructions by unplanned clearing of the forest cover in micro catchment areas and improper cultivations. Due to this reason the annual flow regime of rivers and streams or their capacity reduction, causing a major problem of drinking water and scarcity of water for agriculture.

In spite of the above, excavation of soil, clay or sand and also mining in the lands reserved for rivers, streams and tanks and reservoirs have adversely affected the water resource at a greater extent. Furthermore, the capacity of the springs and water spouts with common use is being deteriorated and gradually being destroyed due to misuse of land.

Today Sri Lanka is badly experiencing the threat of silting in reservoirs which generate hydro power and supply irrigated water due to the clearance of catchment areas in high altitudes and inadequate water and soil conservation practices. For instance, 38 % of the capacity of Rantambe reservoirs has been silted within 09 years of its construction while Polgolla and Rantambe reservoirs are being silted annually by 2.52% and 6.95% respectively.

Protection, conservation and sustainable existence of water sources, their reservations and catchments grant a great support not only to the country's socio – economic development but also to maintain the environment equilibrium and protect the bio diversity.

When it is generally considered, water is not a scarce resource in Sri Lanka. But not only the unequal geographical distribution of water resources, the fluctuations in the rainfall pattern but also the inequality of water use have caused water a scarce resource while granting a high economic value. Accordingly, if the sustainable existence of water is not ensured, it would result in social, economic as well as environmental adverse effects, though it is "a resource not ended by use." Therefore this policy on protection and conservation of water resources has been formulated based on the below mentioned principles.

- All the water sources would be treated as a public natural resource belonging to Sri Lanka.
- The public has the right to receive and consume clean and quality water for the well being of the human being as well as the environment.
- The role of all the communities and responsible agencies shall be to ensure sustainable existence of the water resource with common Public Consumption as well as in all sorts of other uses.
- The common responsibility of each and every citizen shall be to protect and conserve the water sources and their source areas for the future protection and preserving the quality of the water resource.
- Water sources and their source areas shall be protected and conserved without considering their location or the ownership. Conservation strategies and mechanisms shall be prepared based on the nature of the ownership.
- Water users of all levels, planners and the decision making personnel and institutions shall contribute for the protection conservation and management of water sources with Participatory Planning Approach.

National Drinking Water Policy

The National Drinking Water Policy for the country has been developed. It provides a framework for addressing the key issues and challenges facing the countries water supply sector in the provision of safe water supply to the people of Sri Lanka. Safe water is an essential prerequisite for better health and socio economic development. Increasing demands from a growing population, competing uses of water in an expanding economy, mounting evidence of environmental degradation, rising costs of development of new supplies, increased pollution from urbanization, lack of policies and institutional constraints, diverse public perceptions about the value of water and increasing cost of development are critical issues in meeting targets in the water supply sector. The policy aims at addressing these issues through inclusive strategies and broader vision. It has following principles.

- Access to safe drinking water is a basic right with commensurate responsibilities on the recipients.
- Planning and development of water supply will follow people centered, participatory and demand responsive approaches.
- Abstraction of water from rivers and streams for domestic purposes will be carried out in recognition of downstream needs.
- The Government will act as the custodian of the water resources and manage such resources on behalf of the people in an effective efficient and equitable manner, consistent with the social, economic and environmental needs of present and future generations.
- Water for domestic purposes will receive priority over other uses, subject to implementation of any previous agreement for other uses.
- Investment in drinking water supply development will be based on priority needs regardless of social standing or geographical location.
- Pipe-borne water supply option will only be considered when all other cost effective options are not feasible.
- The operational responsibilities will be decentralized to the lowest appropriate level with due consideration to management capacity.
- Safety of drinking Water supplied to the people need to be ensured at all times by all water service agencies through adoption of appropriate instruments.

The rural water supply & sanitation policy comprehensively addresses the rural water supply aspects coming under the purview of mainly the provincial councils and Pradeshiya Sabhas. The drinking water services for this sub sector is mainly by way of dug wells, tube wells, rain water harvesting and small scale rural piped water supply systems. The urban water supply services focuses mainly on provision of piped borne water supply to urban areas as defined by towns, cities, urban centers, industries and some suburban areas. Urban water supplies will be under the purview of the ministries responsible for such services and for their operation by the relevant local authorities.

Groundwater Policy

A framework for groundwater policy for Sri Lanka was proposed by Gunawardena and Pabasara (2016). It says that except in the Jaffna peninsula, groundwater has never been used on a large scale in the past. From late 1970's, various government and non-government agencies have been involved in groundwater development. In 1989, with a subsidy scheme, financial aid was given to farmers for construction of agro-wells leading to expansion of the use of groundwater for irrigation. In addition, groundwater has been exploited by industries in the recent past as well. As at present intensive irrigation practices and the over use of agrochemicals has caused deterioration of groundwater quality in many parts of the country. Water quantity issues have arisen with uncontrolled digging of wells, over abstraction and construction of agro-wells without following the recommendations. There are numbers of existing regulations and recommendations to address the issues regarding the sustainable groundwater usage in Sri Lanka. Some recommendations are suggested and some are already applied. But those problems still remains unsolved primarily due to inconsistent and ad-hoc approach which does not address the problem in a coordinated manner. When consider other countries and the way they deal with issues of groundwater, implementing of a coherent policy can be a better option. Before developing a policy it is necessary to identify how other countries address each of their major groundwater issues through such policies. In this respect, groundwater policies of South Africa, Goa and Tamil Nadu in India, California, Scotland, New South Wales in Australia and China were reviewed in addition to the existing groundwater regulation in Sri Lanka. Based on the review, a framework for groundwater policy for Sri Lanka was drafted. It has 12 principles which as listed below.

Groundwater Development

- The WRB (or a delegated authority by the WRB) shall have the power to develop, control, regulate and administer the groundwater resource.
- Employ the principles of ecologically sustainable development and should be directed at achieving sustainable use of the resource.
- Develop an agreed nationally consistent definition and approach to sustainable groundwater yield.
- Activities should be compatible with the long-term protection of water resources. This will ensure the protection of dependent ecosystems and the availability of good quality groundwater.
- A national classification system for water resources, including groundwater and determine a management class for each resource.

- Determine the “Reserve,” which includes the basic human needs reserve (water for drinking, food preparation and personal hygiene) and the ecological reserve, which must be determined for all or part of any significant water resource such as rivers, streams, wetlands, lakes, estuaries, as well as groundwater.
- Set resource-quality objectives which represent the desired level of protection of a water resource.

Registering and Licensing

- Register all the existing wells and get permissions for new wells from an authorized agency.
- All the bore wells will be drilled through bore well agencies registered with the Water Resources Board.
- Local Authorities, delegated by the WRB, have the authority for issuing approvals, including licenses for groundwater extractions (in granting licenses or permits consider the impacts of those developments on the associated groundwater resource).
- Licensing of all high yielding wells (specified in the Act) will be undertaken by the WRB.
- Registering of wells of subsistent or small farmers (Subsistent or Small Farmer means a farmer who holds lands less than 1 ha) needs to be undertaken by the Agrarian Development Department in liaison with the WRB.

Groundwater Abstraction

- All the withdrawals of the groundwater from “high yielding wells “should be metered.
- The meters and withdrawals will be checked periodically.
- Monitor the groundwater levels, especially in highly sensitive areas identified by the WRB.
- Maintain a sustainable balance between abstraction, the water needs of dependent ecosystems and surface waters and the recharge of groundwater.
- Non-sustainable resource uses should be phased out and should not be permitted to continue.
- Encourage the efficient use of groundwater to improve preservation of the available resource.
- Prevent changes in flow direction of groundwater resulting from groundwater abstractions.

- Ensure that new abstractions do not compromise the resources available to existing abstractors.
- The agencies should develop strategies to reduce abstractions to sustainable levels within time frames that minimize permanent damage to the resource.
- All the transportation carriers, especially the tankers should be registered by the authorized officers (a permit will be issued).

Water Quality Management

- Policy principle of "Groundwater quality management is integral to optimizing groundwater resources. It must be science-based and include improved data management, basin assessments, monitoring, reporting, protection and, where appropriate, remediation.
- Water quality of groundwater should be assessed and monitored on a regular basis.
- Water should be checked by the owners, at regular intervals (preferably twice a year), with the help from laboratories registered with the WRB.
- All the parameters should be within the prescribed limits.
- The protection of groundwater from contamination is primarily governed by the National Environmental Act.
- Maintain the quality of groundwater such that there is, no harm to human health, including harm by pathogens, no harm to the quality of aquatic ecosystems or terrestrial ecosystems dependent on groundwater, no impairment or interference with amenities or other legitimate uses of the environment, no deterioration in status of the water environment and no significant damage to aquatic ecosystems.
- Encourage a progressive reduction of discharges of contaminated groundwater via base flow of groundwater into surface waters of priority substances and cessation or phasing out of discharges of priority hazardous substances into surface waters via the groundwater pathway.
- Standards to regulate the quality of waste discharges to water resources (end-of-pipe quality, already identified by the Central Environment Authority (CEA)).
- Requirements for on-site management practices (e.g. to minimize waste at source and to control diffuse pollution (already identified by the CEA)

Pricing and Cost Recovery

- The cost of direct management activities should be recovered from users.

- Explore means for meeting the indirect costs of groundwater management.
- Stricter water use quotas in combination with differential water pricing for high water consumption industries and the service industry.
- Management costs from domestic users and marginal farmers shall be borne by the State.

Groundwater Restoration

- Secure restoration of groundwater bodies which are at poor status because of over-abstraction or pollution.

Conjunctive Use

- Where appropriate, the management of surface and groundwater resources should be integrated.
- In canals or flow irrigation, conjunctive use of groundwater along with surface water resources should be adopted to prevent wastage and conserve water.

Institutional Arrangement

- Water Resources Board (WRB) is the main institution responsible for implementing the Groundwater Act and manages the resource as per the stated policy.
- The WRB shall liaise with relevant institution in implementing the Groundwater Act
- The responsibilities of the WRB shall be delegated to the local and provincial government authorities.
- WRB, line ministries, local authorities should develop and implement organizational arrangements and processes which specifically eliminate conflict of interest situations in groundwater assessment and management.
- Mechanism should be developed to facilitate community participation, such as Water User Associations (WUAs), Community Based Organizations (CBOs) etc.

Integration with other Policies

- Groundwater management should be integrated with the wider environmental and resource management framework, and also with other policies dealing with human activities and land use, such as urban development, agriculture, industry, mining, energy, transport and tourism.

Environmental/Social Values

- Maintenance of intrinsic environmental value, particularly where groundwater dependent ecosystems support threatened species, populations and communities, or critical habitat.

- Conservation of special areas.
- Maintain unique social or recreational amenity. Where village/town water supplies are wholly or partially derived from groundwater, strategies may be required to ensure other land use activities do not adversely affect the quality of the groundwater.
- Environmentally degrading processes and practices should be replaced with more efficient and ecologically sustainable alternatives.
- Where possible, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.
- Groundwater management should be adaptive, to account for both increasing understanding of resource dynamics and changing community attitudes and needs.

Awareness

- Assess the opportunities for increasing public awareness of the value of groundwater, its vulnerability to over-use and damage through other activities and the need for groundwater management.
- Encourage the development of appropriate awareness programs through various organizations including schools and universities.

Research and Capacity Building

- The state should promote and sustain groundwater research by allocation of funds.
- The collaborative research among line ministries and universities should be encouraged and promoted.

National Energy Policy and Strategies of Sri Lanka

The National Energy policy and strategies of Sri Lanka remains at draft stage. Primary objective of the energy policy is to ensure that energy is available through economically viable supplies that are clean, secure, sustainable, and reliable, to provide convenient, affordable energy services to support socially equitable development of Sri Lanka. This policy is founded on ten pillars, rooted in the broad areas impacting the society, economy and the environment.

1) Assuring Energy security: Primary and secondary energy supplies of the country will be secured to ensure continuity, adequacy and reliability.

2) Providing Access to Energy Services: Access to reliable, convenient, affordable, equitable and quality energy services will be provided to all citizens to improve their living standards and to engage in gainful economic activities.

3) Providing Energy Services at the Optimum Cost to the National Economy: Energy services will be provided at the optimum long term cost, to lower the burden on the national economy and to achieve competitiveness of locally produced goods and services in international markets.

4) Improving Energy Efficiency and Conservation: Efficient use of energy will be promoted in all sectors and across the energy value chain, engaging both the suppliers and users.

5) Enhancing Self Reliance: Indigenous energy resources will be developed to the optimum levels to minimize dependence on imported resources, subject to resolving technical, economic, environmental and social constraints, with the objective of minimizing the vulnerability of energy supplies to external situations.

6) Caring for the Environment: A meaningful response to climate change will be made by further reducing the low carbon intensity of Sri Lankan energy sector. Adverse environmental and social impacts of energy services to be minimized to care for the global and local environment.

7) Enhancing the Share of Renewable Energy: Indigenous renewable energy resources will be developed to the optimum level to attain sustainability and a higher degree of resilience in the energy sector.

8) Strengthening the Good Governance in the Energy Sector: Governance of the energy sector to be strengthened to realize accountability, fairness and transparency to achieve investor and consumer confidence. A stable policy environment will be ensured and a regulatory framework will be further strengthened to assure good governance in the energy sector.

9) Securing Land for Future Energy Infrastructure: Strategic locations for establishing energy facilities and corridors which interconnect such facilities will be acquired early and developed speedily as a national priority.

10) Providing Opportunities for Innovation and Entrepreneurship: Considering the vastness of the sector, opportunities available for R&D and local value addition in advanced technologies, Sri Lankan business and research community will be actively engaged in the sector to develop local entrepreneurship and research capacity.

Sri Lanka National Agriculture Policy

The Sri Lanka National Agriculture Policy has been formulated (http://www.agrimin.gov.lk/web/images/docs/1252389643AgPolicy4.pdf). It has many sections addressing all sectors of agriculture inclusive of seeds and planting materials, fertilizers, pesticides, agricultural machinery, irrigation and water management, land use, soil conservation, agricultural credits, agricultural insurance, agricultural research, agricultural extension and education, post harvest technology, marketing, agro based industries, traditional agricultural crops and technologies, home gardening, investments in agriculture, institutional development, utilization and sharing of plant genetic resources, youth involvement in agriculture and agricultural exports. The section on irrigation and water management covers the issues related to water-energy-food nexus towards sustainable agricultural development in the country and the provisions available under above sections are summarized below.

- Encourage the use of efficient water management and moisture retention techniques to achieve high productivity in agriculture.
- Conserve the existing water resources for sustainable agricultural development.
- Improve efficiency of rain-fed agriculture through water harvesting, mulching and other appropriate techniques.
- Promote participatory irrigation management in maintaining and improving irrigation and drainage systems.
- Safeguard irrigation reservoirs, canals and drainage systems and other structures from damage by natural calamities and usage.
- Prevent pollution of water from agriculture and industries.
- Promote conservation of rainwater and groundwater.
- Increasing the water use efficiency and promote modern and intensive irrigation techniques for water conservation.

Almost all provisions in the section on irrigation and water management provide necessary policy level support for strengthening water-energy-food nexus towards sustainable agricultural development in the country.

Water Resource use Competition

A competition exists in water resource use in the country and the Government has given first priority for domestic needs inclusive of drinking and thereafter other needs such as agriculture, hydropower generation, industry, supply of services, navigation, recreation activities, tourism and hydro power and maintaining ecosystem services.

a. Domestic use

The domestic needs include drinking, food preparation, bathing, washing and home gardening. Based on the National Drinking Water Policy of the country, provision of drinking water supply is a government priority and targets have been set periodically with regards to population access to safe drinking water. On a nation- wide basis, piped water systems and protected wells deliver safe water to almost 90% of the urban population and 60% of the rural population. Piped water is supplied to 31% of the population at present which is over 6 million people. Tube wells provide water to a population of more than 2 million (10%). In addition, 27 % of the population living in rural areas has been provided with safe drinking water through protected dug wells. Accordingly, 90 % of the urban population and 60 % of the rural population are provided with safe drinking water facilities. The proportion of households with access to an improved water supply is about 76% at present which was 71 % in 2004. However, disparities in service coverage across regions are still prominent, despite the massive investments made during the last few decades in the water sector.

b. Agriculture

Water use in agriculture includes crop irrigation, livestock rearing and fish rearing. In crop irrigation, out of the total land extent of the country (6.56 m. ha), an extent of 4.25 m ha has been used for the agriculture sector (Table 1). Among lands in the agriculture sector, irrigation terraces have been established to harvest rainwater or to receive irrigation water in an extent of 0.844 m ha of paddy lands and therefore only about 20 % of agricultural lands are irrigable at present. Water requirements of major crops grown in this country are given in the Table 4. Compared to crop irrigation, the quantity of water use for livestock rearing and fish rearing remain at a relatively low level.

Among the crops grown with supplementary irrigation, rice needs extremely high levels of irrigation water as conventional flood irrigation is being practiced in this crop. On the other hand, among the food crops grown in the country, rice has occupied the largest extent of about 844,000 ha (Table 1). Hence, greater fraction of water available for irrigation is being used for rice as it is the staple crop of the country.

Table 4. Water Requirements of Selected Food Crops in Sri Lanka

Commodity group	Crop	Duration (days)	Water requirement (mm)	
			Maha (Wet season)	Yala (Dry season)
Cereals	Paddy (Long duration)	135	1,180	1,650
	Paddy (Medium duration)	105	910	1,250
	Paddy (Short duration)	80	750	1,000
	Maize	115	460	825
Pulses	Soybean	105	390	710
	Green gram	75	245	460
	Cowpea	90	370	770
	Peanut	110	395	735
Condiments	Chilli	150	590	920
	Big onion	95	--	700
Oil crops	Sunflower	130	460	930
Vegetable	Bean	90	310	530
	Cabbage	120	445	--
	Carrot	100	330	--
	Redish	60	200	--
	Tomato	135	490	860
	Cucumber	130	--	790
	Brinjal	130	490	825

Source: Adapted from CARP, 2011.

c. Hydropower generation

In the country, hydropower generates through major hydropower stations and small scale hydro power projects (mini hydropower stations). Hydroelectricity has played a very significant role in the national installed power capacity since it was introduced in the 1950s, with over 50% of the total grid capacity met by hydroelectricity 2000–2010. The major power stations in the country, their capacities and month of commissioned is given in the table 3. During the period from 1950 to 2017, 20 hydropower stations have been commissioned in the country with a total power generation capacity of 1439.7 mv (Table 4). In 1980s, out of 20 stations, 7 stations have been commissioned with a power generation capacity of 740.2 mv. It was 51 % of the total capacity and therefore the 1980s can be considered as the master decade in hydropower generation in this country.

As the potential for establishment of mega hydropower stations has been fully exploited during past 6 decades, the Sri Lankan Government is giving high priority for developing its remaining hydro-power resources in the island to reduce dependence on costly fuel imports as well as for their potential to earn carbon credits in the initiative to reduce the effects of global warming. Private sector developers are to be encouraged to launch mini hydro power projects under an ambitious plan of the Ceylon Electricity Board (CEB). Around 600 small scale hydro power projects have been identified which are capable of adding around 500 MW of power to the national grid. Of this total, both CEB and private sector developers have developed 148 MW and provisional approvals to develop the remaining capacity had been already issued. Potential hydro power sites have capacities ranging from a few hundred kW to 40 mv.

Table 5. Major Power Stations in the Country, their Capacities and Month of Commissioned

No	Power station	Capacity (mv)	Month commissioned
1	Old Luxapana	50	December, 1950
2	Inginiyagala	11	1951
3	Wimalasurendra	50	January, 1965
4	Udawalawe	6	April, 1969
5	Polpitiya	75	February, 1974
6	Ukuwela	40	July, 1976
7	Bowatenna	40	January, 1981
8	New Luxapana	100	March, 1983
9	Canyon	60	March, 1983
10	Victoria	210	October, 1984
11	Kotmale	201	April, 1985
12	Randenigala	126	July, 1986
13	Nilambe	3.2	July 1988
14	Rantambe	52	January, 1990
15	Samanala	124	October, 1992
16	Kukuleganga	80	July, 2003

No	Power station	Capacity (mv)	Month commissioned
17	Upper Kotmale	150	July, 2012
18	Deduruoya	1.5	November, 2014
19	Moragahakanda	25	July, 2016 (under construction)
20	Broadlands	35	2017 (under construction)

Source: Adapted from wikipedia.org/wiki/List_of_power_stations_in_Sri_Lanka.

d. Other uses

In water resource use, this country has given priority for domestic needs inclusive of drinking, crop irrigation in agriculture and hydropower generation. In spite of that, the water resource has become a prominent source in industry, supply of services, navigation, recreation activities, tourism and hydro power and maintaining ecosystem services. The maintaining ecosystem services include maintaining the stability of ecosystems, preserving the quality of the environment and maintaining wildlife.

7. Major water-energy-food nexus in the country

The country has a greater diversity with respect to topography and four topographic classes namely flat, rolling, hilly and mountainous, and extremely steep have been identified in the country (Table 5). It has provided the way for developing three major types of water-energy-food nexus which are:

a. Hill agriculture in the wet zone-mini hydropower generation-domestic uses-paddy farming (Anicut system in the central hills).

b. Upland farming in the dry zone- domestic use-paddy farming (Cascade system).

c. Hill agriculture in the wet zone-mega hydropower generation-domestic uses-paddy farming (Major reservoir system).

Table 6. Major Topographic Classes in Sri Lanka

Topography class	Slope range (%)	Land extent (‘000 ha)	Fraction of total land extent (%)
Flat to undulating	0 – 8	4300	67
Rolling	8 – 30	730	11
Hilly and mountainous	30 – 60	1370	21
Extremely steep	> 60	80	1

Source: Adapted from Dimantha, 1992.

a. Anicut system in the Central Hills

This traditional anicut system has been emerged as an earliest attempt in irrigation and made through diversion canals from perennial rivers (Goonasekara and Gamage, 1999). The diversion canal runs along a contour and spills into a natural drainage canal. It has been confined to rolling, hilly and mountainous terrain in the wet and intermediate zones of the country. In this nexus, hill agriculture (tea, rubber and vegetable) is practiced in hilly upper elevations with the use of rainwater, runoff and subsurface flow is collected to natural streams, hydropower is generated from mini power plants fixed to few of those natural streams, part of outgoing water from power plants is used for community purposes in the middle elevations, water draining from power plants and community areas is used for paddy farming in lower elevations through the river diversion canal system. This nexus includes rain water harvesting in hilly watersheds, hydropower generation through mini power plants and food crop production.

b. Cascade System

The traditional cascade system has been developed as organization of small tanks into a cascading sequence within micro catchments and it allows greater efficiencies in water use (NARESA, 1991). This system has been confined to undulating terrain in the inland dry and intermediate zones of the country. In this nexus, rain-fed upland farming is practiced in tank catchment areas, runoff and subsurface flow is collected in to village tanks for community use, excess water is used for paddy farming in the tank command area. Drainage of the paddy fields in the upper part of the cascade flowed into a downstream tank for reuse in paddy fields below. In this nexus, power generation is not included but strong link exists in between water use in an efficient manner and food crop production.

c. Major Reservoir System

In addition to village tanks in the traditional cascade system, major reservoirs have been built to retain water draining out from watersheds in the country. These major reservoirs are multipurpose and provide services such as domestic use, irrigation, hydropower generation and fresh water fishery (NAP, 2014). In this nexus in central hills in the country, hill agriculture (tea, rubber, export agricultural crops, fruits, vegetable and other field crops) is practiced in hilly watersheds in the upper elevations with the use of rainwater, runoff and subsurface flow is collected to major power generation reservoirs, hydropower is generated from power plants fixed to the reservoirs, part of outgoing water from power plants is used for community purposes in the middle elevations, water draining from power plants and community areas is used for rice and other field crop farming in lower elevations in the dry zone. This nexus includes water harvesting, power generation in mega power plants and food crop production. It has been confined to all climatic zones (wet, intermediate and dry zones) of the country. In this nexus in the low country, upland agricultural crops (Other field crops and vegetable) are grown in watersheds in undulating terrain with the use of rainwater, runoff and subsurface flow is collected to major reservoirs and outgoing water from reservoirs is used for domestic use and paddy and other seasonal crop farming. Hydropower is not generated.

d. Lift Irrigation Systems

In addition to above described major water-energy-food nexus, minor nexus exists scattered in the country in the form of lift irrigation in which power is used for lifting purpose. Shallow ground water is used for irrigation with few exceptions where stream water is lifted. For example, groundwater extraction for seasonal crop farming in the Kalpitiya peninsula, dug well farming in the Jaffna peninsula and agro-well farming in the central dry and intermediate zones significantly contribute for a water-food nexus where external energy is used for water lifting purpose. The external energy comes from petroleum and hydroelectricity and to a lesser extent solar energy. In crop irrigation, conventional flooding is being practiced in most cases and steps have been taken to promote efficient technologies such as sprinkler, drip, spray jet and tricle irrigation mainly for sustainable use of groundwater resources.

8. Way Forward for Sustainable Development

In this section, way forward for sustainable development is discussed below as three sections namely water resource management, agriculture development and sectoral coordination.

a. Water Resource Management

De-siltation of reservoirs

Land related agricultural and non agricultural activities in reservoir catchment areas lead to siltation of reservoirs and it has resulted reduction of hydropower generation and crop irrigation. For instance, 38 % of the capacity of Rantambe reservoirs has been silted within 09 years of its construction while Polgolla and Rantambe reservoirs are being silted annually by 2.52% and 6.95% respectively. De-siltation of reservoirs is practiced to a certain extent and it needs expansion in order to control this situation to a satisfactory extent. Various de-siltation techniques are available and partial de-siltation has become more common in this country. In addition in case of farming areas in reservoir catchments, country has taken steps to promote soil and water conservation technologies in order to reduce sediment transport to reservoirs. The steps include conducting research, development of appropriate soil and water conservation technologies, demonstration of generated technologies on selected farmer fields, training field agriculture extension officers and farmers, providing financial and material subsidies to resource poor farmers, taking legal actions against violators under the

Soil Conservation Act 1951 of the Ministry of Agriculture and creating awareness among general public. Awareness creation include conducting television and radio programs, organizing field events for school students, erecting display boards on roadsides and railway stations, holding exhibitions and publishing printed materials.

In addition to farming, non agricultural activities also contribute for sediment loading to reservoirs. The non agricultural activities include earth excavation in road construction, road expansion, laying telecommunication cables and water conveying tubing in roads, establishment of housing settlements, tree felling, establishment of mini hydropower stations, mining of soil resources (clay, sand, metal, gem and graphite) and establishment of large buildings (tourist hotels, schools, hospitals, factories). In the case of non agricultural activities, under the Soil Conservation Act 1951, a soil conservation and storm water management plan should be prepared and necessary approval should be obtained from the Natural Resources Management Center of the Department of Agriculture prior to commissioning of construction. Thereafter, entire construction process is monitored by a technical team appointed by the Central Environmental Authority of the Ministry of Environment.

Exploiting potential sites for construction of new reservoirs

Still considerable fraction of rain water passes to the ocean without being used for hydropower generation and crop production particularly in the wet zone of the country. Therefore, it is necessary to explore sites for construction of new reservoirs with the use of modern technologies in civil engineering for expanding hydropower generation and crop production capacities. It will further strengthen the water-energy-food nexus in the country.

Need of a national water policy

Sri Lanka needs a comprehensive water policy. At present few organizations are involved in water resources management which includes Irrigation Department, Department of Agrarian Development, Mahaweli Authority of Sri Lanka, National Water Supply and Drainage Board, Water Resources Board, Central Environmental Authority, non government organizations and community based farmer organizations. The Irrigation Department, established in 1900, is the principal organization responsible for the regulation and control of inland water inclusive of major reservoirs. The Department of Agrarian Development is the principal organization responsible for the regulation and control of inland water inclusive of minor reservoirs. The Mahaweli Authority of Sri Lanka, established in 1979, is responsible for water and related infrastructure development in designated basins inclusive of Mahaweli river basin. The National Water Supply and Drainage Board is the regulator for drinking water and operator of integrated urban and small town schemes. The Water Resources Board, established in 1968, is responsible for hydro-geological Investigations. The Central Environmental Authority is responsible for environmental quality standards and environmental impact assessment procedures (tolerance limits for discharge of effluents into inland waters). It is timely important to develop comprehensive national level water policy for Sri Lanka having a very close collaboration, active participation and significant contributions from water related institutions inclusive of above listed organizations. In this regard, it is suggested to first develop comprehensive sectoral and subsectoral policies and then to compile a national level water policy.

At present, priority is given to provide water first for drinking and other domestic needs particularly in the dry zone of the country where a bimodal rainfall pattern and therefore two major dry periods exists. In the wet zone, particularly in the rural areas, most of community people use water extracted from dug wells in their home gardens. Pipe born drinking water facility is available in urban areas both in the dry and wet zones. The second priority is given to agriculture in water supply and it is much more remarkable in the dry zone. The third priority is given to hydropower generation. This arrangement can be developed for a sound water policy for the country. Since 4 decades back, water quality related community issues have been appeared in the dry zone of the country (Kendaragama, 2016b) and as a result, priority has been given to provide water diverted from wet zone for dry zone communities. It should also be taken into consideration in the policy development process.

b. Agriculture development

Increasing water use efficiency in farming

Presently flood irrigation is being practiced in most cases in irrigated agriculture inclusive of rice farming which has low water use efficiency. Hence, it is suggested to promote efficient irrigation systems such as drip, sprinkler, spray jet and tricle irrigation systems particularly among upland crop farming. High cost and high technology involved in above micro irrigation systems has restricted its wider application in Sri Lanka among small scale farming sector. It is suggested to provide loan and subsidy schemes for them to address installation cost related issues. Creating awareness and providing appropriate training help solve high technology related issues. In this regard Kendaragama (2016a) suggested an approach for promotion of micro irrigation technologies among rural small holder farms in Sri Lanka.

Providing irrigation facility to existing rain-fed farming systems

At present, irrigation facilities are available for about 20 % of agricultural lands in the country. Research is in progress to introduce rainwater, roof water and runoff water harvesting technologies in order to provide irrigation facility for existing rain-fed farming systems.

Solar energy as an alternative energy source

Being a tropical country, Sri Lanka is in a region where substantial solar energy resources exist throughout much of the year in adequate quantities for many applications, including water lifting for farming and domestic use, water heating and electricity generation. Many applications of solar energy have currently been in use for meeting remote electrical loads throughout much of the non- electrified regions of Sri Lanka. The potential exists for significant expansion of the use of this renewable energy. The highest resources are in the dry zone of the country which is the principal areas for food crop production. Therefore, a potential exists to explore solar energy for food crop production in the country and to strengthen water-energy-food nexus towards sustainable agricultural development.

Wind energy as an alternative energy source

There are many potential sites to capture wind energy in the country along with the financial and economic viability of establishing wind driven power generation plants (MOPE, 2015). According to a study by Elliott et al. (2003), there is nearly 5,000 km2 of windy area with good to excellent wind resource potential in Sri Lanka out of which 4,100 km2 is in inland and 700 km2 is in the costal belt. Therefore, the land extent with wind energy potential is around 6% of the total land area (65,610 sq km2) of Sri Lanka. Some of intensively farming areas fall into windy areas in the country and a potential exists to use wind energy as a supplementary source for crop irrigation and food crop production.

C. Sectoral Coordination

The three nexus sectors – water, energy and food – are executed by different organizations in the country. For example, main organizations involved in water sector are Irrigation Department, Department of Agrarian Development, Mahaweli Authority of Sri Lanka, National Water Supply and Drainage Board, Water Resources Board, Central Environmental Authority, Engineering based universities, non government organizations, private sector organizations and community based farmer organizations. The main organizations involved in energy sector are Ceylon Electricity Board and private sector organizations. In the food sector, Department of Agriculture, Provincial Departments of Agriculture, Department of Agrarian Development, Department of Export Agriculture, Department of Animal Production and Health, Mahaweli Authority of Sri Lanka, Crop Research Institutions, Agriculture based universities, non government organizations, private sector organizations and community based farmer organizations are involved. Hence, there should be a national level body to integrate activities of above organizations towards strengthening water-energy-food nexus in the country. It will facilitate maximizing synergies, create more opportunities, facilitate upstream downstream cooperation, and share data for mutual benefit. There is also need to overcome mistrust between organizations to facilitate cooperation.

Conclusion

The energy supply in the country is mainly based on three primary resources, namely, biomass, petroleum and hydroelectricity. Use of biomass energy has been the conventional source in the country. Hydroelectricity has been a local energy source exploited sine 1950s. Petroleum is the main energy source at present which is totally imported from other countries. The land in the country has been used for wide range of agricultural and non-agricultural uses. The agricultural uses include tea, rubber, coconut, mixed perennial crops, rice, homesteads, sugarcane, sparsely used crop lands and other crops. At present, the country receives food from three sources namely plants grown in farming systems in the country, plants harvested from natural ecosystems in the country and crop produce brought from other countries. The first has been the main source of foods. Therefore, food and nutrient security status is good in this country. However, some short duration shortages in food supply appear hardly due to spatial and temporal variations in food production and market. The country has a greater diversity with respect to topography and it has provided the way for developing three major types of water-energy-food nexus which are hill agriculture in the wet zone-mini hydropower generation-domestic uses-paddy farming, upland farming in the dry zone- domestic use-paddy farming, hill agriculture in the wet zone-mega hydropower generation-domestic uses-paddy farming. Among the steps to be taken to strengthen the water-energy-food nexus, de-siltation of water resources, exploiting potential sites for construction of new reservoirs, the need of a national water policy, increasing water use efficiency in farming, providing irrigation facility to existing rain-fed farming systems, solar and wind energy as alternative energy sources are significant measures to strengthen water-energy-food nexus towards sustainable agriculture development in Sri Lanka.

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Proceeding of the Meeting

The Meeting was sanctified by the solemn prayer and ceremony "Marchang" offered by the Director, Ministry of Agriculture and Forests. Dr. Tayan Raj Gurung, Senior Program Specialist (NRM) extended a warm welcome to all the delegates from SAARC Member States representing agencies and institutions. He also expressed appreciation to Hon'ble Secretary, Ministry of Agriculture and Forests, Bhutan for gracing the Inaugural Session despite his busy schedule. He also explained the purpose and objectives of the meeting. In the inaugural session two keynote remarks was delivered by Dr. Shoaib Ahmad, Deputy Director (SEC) and Dr. Golam Rasul, Theme Leader (ICIMOD). While Dr. Shoaib discussed about the Energy security and need for holistic policy framework to ensure energy security, Dr. Golam highlighted the overall scenario of Water-energy-food nexus in SAARC Region. Dasho Rinzin Dorji, Secretary, Ministry of Agriculture and Forests inaugurating the meeting extended warm welcome to the delegates from all SAARC Member States and representative of different regional and international institution, expressed the timely intervention of SAARC in convening the regional consultation meeting on W-E-F in Bhutan when we are strategizing the attainment of SDGs. Dasho Secretary reiterated that with more than 60% of people dependent on agriculture is the mainstay of SAARC Region. He also mentioned that about 39% of cropland is irrigated, and irrigated agriculture accounts for 60–80% of food production. Agriculture consumes about 90% of water use and 20% of energy. Groundwater has become the major source of irrigation in the region. The region is also one of the world's most water scarce regions, with less than 5% of the world's annual renewable water resources. He highlighted that with the growing populations, declining agricultural land, increasing stress on water and energy resources, and climate variability, South Asia faces the challenge of how to produce more food with the same or less land, less water, and increased energy prices, while conserving resources and maintaining environmental sustainability. In conclusion he emphasized the need for being mindful of the vital synergy of the three sectors and urged the entire delegate to engage deliberations in developing a middle path in achieving the security in the entire sector.

The Chief Planning Officer, PPD-MoAF expressed appreciation to SAARC and all the associated institutions in organizing the meeting in Bhutan and providing the opportunity for professional interactions among the participants.

Technical Session I: Country Presentation

The first Technical Session was chaired by Mr. Jamil Ahmad, Joint Secretary, Ministry of National Food Security and Research, Islamabad, Pakistan. He explaining the urgency of food and nutrition security in the region and role of water and energy, invited the country focal points to make the presentation.

Mr. Md. Hemayet Hussain, Joint Secretary, Ministry of Agriculture, Bangladesh explained that Bangladesh has 8.56 million hectare of cultivable land with 15.18 million farm holdings. Major crops include Rice, Potato, Wheat, Maize, Jute, Pulses, Oilseeds, Sugarcane, fruits and vegetables with a cropping intensity of 192%. Agriculture is a major sector in the country which contributes 15.33% to the GDP. He explained the factors that have accelerated the enhancement of agricultural productivity in Bangladesh. It was also highlighted that Bangladesh have enormous endowment of water resources. For instance it shares 57 trans-boundary rivers with her neighbors (54 with India, and 3 with Myanmar). These river systems carry between 1.0 and 1.6 trillion cubic meters of freshwater. In addition it has plenty of underground water resources. Water resources are managed under the policy frameworks - National Water Policy 1999, Bangladesh Water Act 2013 and Coastal zone Policy 2005. He concluded his presentation by proposing some pragmatic actions.

Ms. Kinlay Tshering, Director, Agriculture, Bhutan started by giving a general background of Bhutan touching on GNH, small population and small holder agriculture. She explained that agriculture is the main driver towards achievement of food self-sufficiency & inclusive green socio-economic development goal. It provides livelihood to 62.2% of population, contributes 16.8% of GDP, 4.3% of exports, and employment to 58%. She also explained that there is in general wide availability of food, sufficient access, and adequate utilization. Bhutan imports 34% of its cereal needs, & one-third of population suffers from food insecurity. While on the whole Bhutan does not face chronic food insecurity, there are pockets of hunger, particularly in eastern & southern parts. In terms of the water resource, the total annual water availability stands at 70,576.02 cu.m which works out to average flow of 2,238 cu.m/sec in 2015. Bhutan has one of the highest per capita water resource availability in the world with 94,500 cu.m /capita/annum. She informed that National Environment Commission (NEC) is the apex body on water resources, with policies like Bhutan Water Policy, Water Act of Bhutan 2011, Water Regulation of Bhutan 2014, RWSS Sector Policy, National Irrigation Policy, Revised 2012, National Integrated Water Resources Management Plan 2016, and National Irrigation Master Plan 2016. It was highlighted that Bhutan has enormous hydro-power potentials. She concluded her presentation by proposing some way-forward actions.

Dr. S. K. Ambast, Director, ICAR-IIWM, India presented a paper on Water, Energy and Food Security Nexus: An Indian Perspective. He explained that Nexus describes interconnectedness among use of water in energy and food production; use of energy in food production and improved water supply; food security in generating energy production and water supply by economic development. Water and energy are the key determinants of agricultural production & food security. The rapid economic development, expanding populations and changing lifestyle are driving demand for water, energy & food. He introduced India as the 7^{th} largest economy of the world (nominal GDP in 2016 at current prices is $ 2.25 trillion) with 17% of world population, 15% of livestock population of world, 2.4% of the land and 4% of the water resources. He highlighted the water resource situation in the country and its utilization by different sectors. In the energy front, he explained that India ranks 81^{st} position in self sufficiency at 66% (2014) and is the 3^{rd} biggest energy consumer with 5.3% of global share (700.5 Mtoe-2015) is consumed by India. Other energy sources comprise of Crude oil (27.9%), Natural Gas (6.5%), Coal (57.1%), Nuclear (1.2%), Renewable power (2.2%). Dr. Ambast also introduced different initiatives on sustainable water management in India by different agencies. On conclusion he explained that water demand will be governed by changes in the population expansion, socio-economic status of the population and extent of urbanization and industrialization, which needs to be addressed holistically.

Mr. Ali Amir, Director, Ministry of Fisheries and Agriculture, Maldives gave a brief introduction of Maldives as an island country comprising of 1192 islands covering an area of 90000 km^2 and population of 344,023 people. There are about 7,000 registered farmers who practice subsistence farming and backyard cultivation of coconut, chili, papaya and watermelon. 79 islands were under long term lease for agriculture development by the end of 2014. He informed that most food items are imported. Only available natural fresh water resources in Maldives are rainfall. As sea and ground water are salinated, desalinization of water is practiced. Some of the way forward proposed by Mr. Ali is strengthen legal framework, capacity building of stakeholder and create public awareness and promoting research and introduce financial models to develop the sector.

The chairman expressing his appreciation to all the presenters for a comprehensive presentation opened the floor for discussion. Among many points discussed, it was felt the need to apply policy/program screening framework used by Bhutan in such integrated concepts.

Technical Session II- Country Paper - Member States

Dr. Aditi Mukherji, Theme Leader-Water and Air, ICIMOD as the chair of the session invited three country presentations from Nepal, Pakistan and Sri Lanka. Mr. Bashu Dev Lohanee, DDG, Department of Irrigation, Nepal made a brief introduction of Nepal by saying that it has 2.6 million ha cultivable land from a total land area of 14.7 million ha. Roughly 69% of the cultivated land is irrigated. Agriculture is an important sector with 70% of the population engaged in farming. He highlighted that the National Agricultural Policy, 2004 envisions transforming the subsistence oriented farming system into a commercial and competitive farming system, and Irrigation Policy 2013 emphasizes to provide year round Irrigation to all agricultural land. He also explained some of the issues related to farmer managed irrigation systems. He introduced the Integrated Crop and Water Management Program (ICWMP) which aims at coordination between agriculture and irrigation professional in all level, on-farm structure improvement of canal system to enhance efficiency, capacity development of water user association (WUA), and farmer's field school. He concluded by emphasizing the need of harmonized policy for using water, energy and food wisely to make long term sustainability.

Mr. Sajjad Haider Yaldram, Deputy Secretary, Ministry of Water and Power, Pakistan giving a brief introduction of Pakistan explained that it is one of the top ten most vulnerable countries to climate change impacts. For instance, the rate of glacial melt is 2.3% per annum, which is one of the fastest in the world, The flood events from 2010 to 2014 have caused monetary losses of over US$ 18 billion with 38.12 million people affected, 3.45 million houses damaged and 10.63 million acres of crops destroyed. He mentioned that WEF Nexus approach is a useful concept that allows planning, decision-making, monitoring and evaluation based on evidence-based assessments and developed through a continuous process of stakeholder dialogue. Pakistan has 25 million ha of agriculture land out of which 82% is irrigated. Agriculture generates employment for 42.3% of population. As per the Food Security Assessment Survey (2016), 18% of the population is undernourished. In terms of water resources, per capita water availability has drastically declined from <5000 cubic meter in 1951 to 1000 cubic meters in 2016. It is predicted that per capita water availability will further decline to 800 cubic meters by 2025. Concluding his presentation, he informed that Pakistan is developing National Food Security Policy and National Water Policy which will holistically encompass the WEF Nexus and take forward the sustainable development agenda.

K.M.A.Kendaragama, Principal Agriculture Scientist (NRM), Sri Lanka gave a brief background of Sri Lanka stating that there are 66000 Km^2 land area with population of 20 million. He informed that there are diverse energy sources ranging from biomass, hydropower, petroleum and wind. It was highlighted that Sri Lanka has a unique system water resource management with Anicut systems, there are 7600 ancient tanks in operations even today. Dug wells are also common to extract water. Some of the policy instruments that manage water resources are National Drinking Water Policy developed by the Ministry of Water Supply & Drainage (MOWSD), National Policy on Protection and Conservation of Water Sources, A framework for groundwater policy, and National Drinking Water Policy.

Technical Session III- Keynote papers on Policies

Technical Session included three papers on policies under the chairmanship of Dr. Shoaib Ahmad, Deputy Director (Coordination), SAARC Energy Centre, Pakistan. Dr. Golam Rasul, ICIMOD made a comprehensive presentation on "Managing the Food- energy-water Nexus for achieving the SDGs in SAARC Region". His presentation focused on SDGs, Water, energy, food nexus challenges in South Asia, and Connecting WEF nexus perspective in implementing SDGs. He explained the key trends and challenges in WEF Nexus and emphasized that resources are fast depleting and demand for food is escalating. He went on to say the demand for energy is growing 3.2% annually and energy use in agriculture increasing. In achieving the SDGs, Dr. Golam listed the challenges as operationalizing SDGs, achieving multiple objectives, priority setting, cross-sectoral integration & coordination, harnessing potential synergies & complementarities, and managing trade-offs.

Ms. Tenzin Wangmo, Chief Environment Officer, NEC, Bhutan presented a Water security in Bhutan: A Strategic direction. Basically she explained elaborately two of the policies related to water resources: (i) Water Act of Bhutan, 2011 and its Regulation 2014, and (ii) National Integrated Water Resource Management Plan, 2016. She also explained the key challenges and issues related to water resource in Bhutan – some of the issues were high availability and low accessibility, high intervention cost to deliver to highly dispersed population, and high per capita cost.

Dr. Alok Sikka, IWMI, India gave a talk on Sustainable Water management from the perspective of W-E-F Nexus in SAARC Region and informed the meeting that South Asia is challenged with food, water and energy security due to growing populations, incomes, changing life styles, resource degradation and vulnerability to climate change. He also highlighted that with just 3% of the World's land and 5% of the World's annual renewable water resources, it has to support 25% of the World's population. About 40% of cultivated land in SA is irrigated, and contributes 60−80% of food production, agriculture in SA consumes ~ 95% of the total water consumed against world average of 70%. He also explained the intrinsic relationship among water, energy and food in a nexus where water is a unifying thread across this nexus and its efficient use is essential to WEF nexus. He explained different ways to manage water resources efficiently. He reiterated the follow up actions as:

- Mainstream sustainable water management with greater focus on demand side management to save water and energy;
- Incentivization and enabling policies for saving water and energy;
- Solarizing groundwater economy with grid metering and buy back of surplus energy

- Eliminating huge carbon footprint ;
- Optimizing irrigation use ;
- Improved access to GW in water abundant, energy starved areas;

- Integrated and synchronized programs and policies across water, energy and food sectors for greater synergy;
- Strengthening capacity of humans and institutions in managing WEF nexus;
- Regional cooperation for managing WEF nexus

There were many concerns raised on the SDGs and how it can be achieved. There was a shared understanding that integrated and synchronized policies and programs across water, energy and food sector was a need of the hour.

Technical Session IV- Invited papers on Energy

Dr. Sucharita Sen, Executive Director, SaciWATERS, India took the chair and welcome all participants to the Second Day of the program. She announced that the session will focus on energy and invited three presenters. Mr. Ram Gopal Lageju, Research Fellow (Energy Trade), SAARC Energy Centre (SEC), Islamabad made a comprehensive presentation on Sustainable Energy Security in SAARC. He started with introduction of SEC which was established in 2006 to initiate, promote and facilitate cooperation in energy sector of the SAARC Member States. He highlighted the energy consumption in the SAARC region which average at 364 Kgoe/capita and electricity consumption at 48 Kgoe/capita. Among the SAARC countries consumption in Bhutan is the highest. Source of energy, supply of commercial energy and import of energy was also explained. With the enormous resource of energy in the region, he indicated that it is possible to attain energy security in the region through regional cooperation. Some of the initiatives necessary are infrastructure, fair regulatory systems, cross-border inter-connection and transit facility, power market and open access, proper financial model and risk sharing, environment and land acquisition, and resolved water related issues. He concluded his presentation by highlighting the way forward in achievement of energy security in the region. Some of the suggestions are as follows:

- Preparation of Energy Security Master Plan for National & Regional Level
- Implementation SAARC Framework Agreement on Energy Cooperation (Electricity), November 2014
- Regional Hydro Projects Development:
- Increase Regional Cooperation in regional energy projects, technology and information sharing

- Formulate SAARC Framework Agreement for Gas Trade
- Formulated, signed and ratified
- Review SAARC Energy Ring

Dr. Aditi Mukherji, Theme Leader-Energy and Air, ICIMOD gave comprehensive presentation ion - Solar powered irrigation pumps (SPIP) as a solution to WEF nexus in South Asia. She focused on her work done in understanding WEF nexus in South Asia through the irrigation story of India and ground water resources. She explained three typologies of WEF Nexus in South Asia grouped for India, India+Bangladesh+Nepal, and Pakistan. It was highlighted that carefully crafted SPIP policies can facilitate in developing a sustainable agricultural pathway in areas where groundwater is under-utilized and recharge is high, reducing unsustainable groundwater use in rest of South Asia, and reducing emission of SLCPs like BC and help reach INDC goals.

Mr. Ahsan Javed, Research Fellow (Renewable Energy), SAARC Energy Centre, Islamabad gave an elaborate presentation on Sustainable Energy Security: Role of Renewable Energy in SAARC Region covering the areas of current state on renewable energy, application of WEF Nexus and policy recommendation on renewable energy. The presentation was concluded with a set of recommendations as follows:

- Establishing a dedicated authority/institute as “one-window facility” for facilitation and development of private sector investment in Renewable energy projects/ technologies
- Setting up specific targets of RE contribution in Energy/Power/technology mix:
- Renewable Energy Assessment for high potential sites in member states
- Creating a market for Distribution generation technologies for investors and consumers
- Creating a competitive RE market for all stakeholders
- Policies with favorable economic incentives for deploying RE projects

Technical Session V- Gender, Education and Climate change

Technical session V was chaired by Mr. Md. Hemayet Hussain, Joint Secretary, Ministry of Agriculture, Bangladesh who in his opening remarks mentioned that WEF or in that matter agriculture is highly vulnerable to climate change in the region. He mentioned the role of education and enhanced awareness can have a much needed push to mainstream WEF Nexus approach. He invited three eminent researchers to share their ideas on the topic. Dr. Muhammad Zulfiqar, Director, Climate Change Center, University of Agriculture, Peshawar, Pakistan made a very interesting presentation on Water-Energy-Food Nexus in South Asia from the perspective of climate change.

Dr. Sucharita Sen, Executive Director, SaciWATERS, India explained the relevance of gender as a strategic entry point in most interventions which are linked to most SDGs. The need to looks from gender lens is necessary as gendered division of water access- irrigation and drinking water, marginal capacities in terms of decision making, higher in terms of work (relatively), their understanding CPLR, water, land fertility often significant- a knowledge that is very often ignored, and ownership of agricultural land, access to water and energy technology very limited. She also explained that character role of women in agriculture is changing. Under such circumstances, land rights to women become more crucial to bring them back to the fore-front of agriculture, into cultivation with decision making rights. Dr. Sen also gave a perspectives of changing role of State in 1987 when role of the state getting diminished with the involvement of community for water management, to service provider, encouragement for private sector participation in 2002, and as regulator and facilitator- PPP and private models (subsidized) in 2012. Corresponding to these changes in role, she also indicates the change in value of water in 1987- water is a precious natural resource hence it needs to be managed and utilized well, which is treated as an economic good in 2002, and priority for water use is to human consumpation.

Dr. Mohammad Abu Taiyeb Chowdhury, Professor, Geography and Environmental Studies, University of Chittagong, Bangladesh gave a comprehensive presentation on higher education and research on water, energy and food security nexus in the Himalayan University Consortium (HUC). Professor Chowdhury explained the Nexus challenges in South Asia where 3% of world land has to feed 20% of the global population. With over 40% of the world's poor living in South Asia food production needs to be doubled in next 25 years. To maximize food production, water demand for irrigation will increase about 70%. He also highlighted that 63% population have no access to modern energy and Food-energy deficiency in the region accounts to 51%. He also tried to contextualize the Himalayan ecosystem services from the perspective of WEF Nexus. A review on WEF in education system was also presented showing that varying level of curriculum is included in different education levels. He concluded by saying that mountains provide numerous goods and services like fresh water, biodiversity, food, forest, medicinal products and energy while the role of mountains in W-E-F nexus security is not fully understood and recognized. This he associated to exploitation and degradation of scarce natural resources in the mountains.

Technical Session VI

Technical session VI was a break up session which was facilitated by Dr. Golam Rasul and Dr. Tayan Raj Gurung. As a briefing two keynote papers were presented by Dr. John Dore, Senior Water Resources Specialist, Department of Foreign Affairs and Trade. Australian Embassy, Thailand and Dr. Golam Rasul, ICIMOD.

Dr John Dore made a presentation on Nexus Governance of "entwined predicaments"- theory & practice - real examples from Greater Mekong where he explained governance as multi-layered interplay of negotiations, agenda-setting, preference shaping, decision-making, management and administration between many actors (including organisations) in the state-society complex, at and between different levels and scales, vying for authority or influence, and constrained or enabled by evolving norms and institutions. He also elaborated that deliberative nexus governance as constructive engagement in governance arenas through promotion of inclusive, deliberative processes that emphasise different perspectives, critical analysis, learning and institution-building.

Dr. Golam Rasul explained the need of regional cooperation for strengthening water-energy-food security in South Asia. To highlight the regional cooperation in the region, he showed the interregional trade which is very low at 6.4% export and 4.7% import. In terms of WEF security he reiterated that the upstream-downstream interdependence is very high and HKH Mountains Water is an important source of water for agriculture in downstream. He also informed the recent developments on regional cooperation such as (i) BBIN-Motor Vehicle Agreement (MVA)- signed 2015 will facilitate transportation of cargo & passengers, including third country transport, (ii) BIMSTEC to harness shared & accelerated growth through technological & economic co-operation among south Asian & south east Asian countries along the coast of the Bay of Bengal, (iii) Regional energy cooperation, and (iv) Regional road, rail & waterways.

Break up Session

The meeting was divided into two groups assigned with the following topics to deliberate and discuss.

Group 1: What are the challenges/constraints in regional cooperation for W-E-F Nexus security

Group 2: What are the opportunities for promoting regional cooperation for W-E-F Nexus security

Challenges/constraints in regional cooperation for W-E-F Nexus security

General challenges

- SAARC as a Regional Body is not exploring workable mechanisms to forge interactive Regional Cooperation

- Regional issues need to be address in time
- Lack of trust between major players in the region
- Power imbalance
- Self-interest overriding regional interests
- External influence on SAARC countries
- Multi Party Democracy → diverse opinion → lack of consensus
- Global geopolitics
- Mismatch in country prioritization

Water specific challenges

- Lack of data and technology sharing
- Water dialogues are more on a bilateral level than regional
- No established regional institute working for water sector in SAARC
- Ground water is not covered in any of the treaties

Energy specific challenges

- Poor regulatory frameworks in each country
- Lack of common grid cord and standards
- SAARC framework agreement on energy cooperation (Electricity) yet to be ratified by all member countries.
- Lack of financing and technical expertise
- Disparity in energy security
- Lack of multipurpose reservoir project

Food specific challenges

- SAARC Food Bank not functioning effectively
- Resource rich Vs Resource poor countries
- Change in food habit
- Lack of institutional linkages

The group suggested following solutions to address the above challenges

- Expanding the horizon of benefits
- Multi-lateral negotiations to be strengthened and SAARC needs to play pivotal roles
- Multi stakeholder platform form SAARC water energy and food
- Creation of SAARC water centre

- Strengthen Institutional linkages and enhance capacity building in the SAARC region.
- Respect for each other regardless of the size of country
- Establish People to people and business to business linkages
- Harmonization of data processing and sharing in regional level (SAARC)
- Countries need to be forward and progressive looking

Opportunities for promoting regional cooperation for W-E-F Nexus security

Existing opportunities

- Availability of water sources upstream
- Sources of renewable energy
- Seasonal complimentary of energy and food (excess and deficit)
- Upstream and downstream water rights
- Trade potential of energy and food commodities
- Availability of bilateral agreements to build on
- Gravity trade potential
- Availability of successful case studies in some countries/ region

Pathways to take benefit of the opportunities

1. Explore synergistic opportunities for joint water resource development (*Example: Himachal-Punjab – Bhakra dam; Mekong river network)*
2. Promoting cooperation for enhancing regional trade in energy, water and food (*Example: Standardized tariff for water, energy, and food)*
3. Creation of a body for uniform quality control and accreditation for enhancing sustainability of water, energy and food resources (*Example: Food safety)*
4. Developing regional institutions under the aegis of SAARC for trans-boundary resource management (*Example: Water drainage data; food surplus/shortage data)*
5. Standardization of datasets (*Example: Mekong river commission data exchange)*
6. Enhancing societal well-being through regional cooperation and shared learning (*Examples: World happiness report / Human Development Index– Bhutan vs other countries; Sri Lanka's policy based on equity and justice)*
7. Sharing of best practices in sustainable management of water, energy and public policy (*Examples: Sri Lanka's policy based on equity and justice)*

8. Technology transfer (*Examples: Renewable energy technologies (wind, solar) which is has lesser production cost in India can be transferred to other countries)*

9. Resources and training collaboration (*Examples: Initiating joint research programme on assessing potential of WEF security and trade-off amongst SAARC countries)*

Technical Session VII

Considering the larger issue of regional cooperation which has far reaching implications on the WEF sector, a Leadership Panel: Science-Policy dialogue for regional cooperation in WEF Nexus was organized with participation from relevant institutions. The following were the panelist under the chair of Dasho Yogesh Tamang, MP and Chairperson, Good Governance Committee, National Assembly of Bhutan.

1. Mr. Yogesh Tamang (MP), Chairperson, Good Governance Committee, National Assembly of Bhutan **[Governance]**
2. Mr. Dophu Dukpa (MP), Chairperson, Environment and Urban Development Committee, National Assembly of Bhutan **[Environment and Natural Resources]**
3. Mr. Jamil Ahmad, Additional Secretary, Ministry of National Food Security and Research, Pakistan **[Food Security]**
4. Dr. Sunil Kumar Ambast, Director, Indian Institute of Water Management **[Water-Research]**
5. Dr. Aditi Mukherji, Theme Leader, Water and Air, ICIMOD **[Energy]**
6. Dr. Chubamenla Jamir, Assistant Professor, HUC **[Education]**
7. Dr. Shoiab Ahmad, Deputy Director (Coordination), SAARC Energy Centre, Islamabad **[Energy]**

A panel discussion on Science-Policy Dialogue for Regional Cooperation in WEF Nexus was organized as part of SAARC-ICIMOD's Regional Expert Consultation Meeting on Water-Energy-Food Nexus on July 5, 2017. The seven invited panelists were Dasho Yogesh Tamang (MP), Chairperson, Good Governance Committee, National Assembly of Bhutan, Dasho Dophu Dukpa (MP), Chairperson, Environment and Urban Development Committee, National Assembly of Bhutan, Mr. Jamil Ahmad, Additional Secretary, Ministry of National Food Security and Research, Government of Pakistan, Dr. Aditi Mukherji, Theme Leader, Water and Air, ICIMOD, Dr. Sunil Kumar Ambast, Director, Indian Institute of Water Management, Dr. Chubamenla Jamir, Assistant Professor, TERI University, and Dr. Shoaib Ahmad, Deputy Director, SAARC

Energy Centre. The panel session was chaired by Mr. Yogesh Tamang, MP and moderated by Dr. Tayan Gurung and Dr. Golam Rasul. The discussion revolved around different aspects of water, energy food nexus and how to manage trade-offs and harness synergies among the three sectors to improve water, energy and food security in South Asia.

The main themes of the deliberation and discussion are presented below.

Dasho Yogesh Tamang, MP stated that water, energy and food are fundamental for existence of mountain people in remote areas. Dasho shared that Agriculture and food production in different parts of Bhutan is increasingly being challenged due to water shortage. Further, the impacts of climate change are leading to drying up of water sources, which is affecting the lives and livelihoods of mountain people. Dasho also highlighted that water, energy, food nexus are an integral part of Gross National Happiness (GNH), the overriding development philosophy pursued by Bhutan. Furthermore, Bhutan's commitment to maintain 60% of the country under forest cover for all times to come as well remain carbon neutral require coherent policy for governance of water, energy and food nexus for sustainable development, environment conservation and achieving wellbeing and happiness of population, he said. He underscored the need for integrated management of these fundamental resources through multi-sector engagement and partnerships.

Referring Pakistan's determination forzero hunger, **Mr. Jamil Ahmad** highlighted the importance of water and energy for food production and agricultural sustainability in Pakistan. He mentioned that though Pakistan has world's one of the most sophisticated irrigation system in the world, Pakistan agriculture has been facing huge challenges as surface water irrigation is decreasing, while groundwater (and mixed) irrigation is increasing due to shortage and unreliability of surface water. This has further led to increase inthe demand for energy in agriculture in Pakistan. For sustainable development of agriculture, all the three sectors need to be managed in an integrated manner.

Dasho Dophu Dukpa, MP, highlighted theconcern of food security in the entire South Asia. With limited land resources, increasing stress and uncertainty of water, South Asia face a common challenge of feeding the growing population. Dasho alsomentioned that climate change continues to increase the intensity of floods and droughts and thus affect food production and a people's livelihoods. Depleting ground water resources, water pollution such as increasing arsenic in water are emerging challenges. Dasho called for synergy and coherence among multiple sectors so that WEF nexus can be addressed sustainably through collective and coordinated actions.

Drawing relationship between solar power, plant photo-synthesis and food production, Dr. Sunil Kumar Ambast highlighted that water, energy, food nexus relationship can be observed in the nature. He reiterated the importance of resource use efficiencythrough efficient technologies such as precision agriculture, leaser land labelling among others. He, also cautioned that there is trade-offs between water use efficiency and sub-surface water availability, which is important for environment and local ecosystem. He emphasized the need for cooperation among sectors for developing efficient production system and reducing leakages for sustainable agriculture.

Dr. Aditi Mukherji looked at WEF nexus from energy, irrigation, food production perspective. She highlighted the importance of ground water irrigation in plain and Terai area, where adequate ground water is available. With example from Nepal Terai, she shared that making energy available for ground water irrigation can help farmers considerably to increase food production and livelihood improvement. However, due to non-availability of electricity, farmerswere depended on using diesel pump for ground water irrigation, which is economically unviable and environmentally harmful. Thus, use of solar pump for ground water irrigation were innovated to address irrigation water crisis and improve food production without putting further pressure on scarce energy resources. She also highlighted the potential of hydropower resources in HKH region and the importance of benefit sharing in hydropower development so that local people’s ownership increases in hydropower development. She also recommended to consider gender dimensions of water, energy food nexus as women are integral part of the use and management of these three resources.

Dr. Chubamenla Jamir, underscored the importance of system thinking of the three sectors, water, energy and food and raised the question of capability of young researches and scientist as well as planners in dealing with the complexity of thse sectors in an integrated systematic manners. Referring Himalayan University Consortium Program, she therefore urged to build capacity of young scientist and university graduates to promote interdisciplinary and transdisciplinary research to equip them with systems knowledge.

Dr. Shoaib Ahmed described the work of SAARC Energy Centre and highlighted the importance of diversifying energy portfolio as well as increased investment in small and micro-hydro to meet the growing energy demand in the context of water, energy, and food nexus.

Interactive discussion

The interactive session addressed questions and comments around following broad areas:

- How can we sustain water and energy availability for producing adequate food for growing population of South Asia?

- How to enhance efficiency of using water, energy and food resources to ensure its long term sustainability?
- How to break sectoral silos and improve coordination across the sectors and scales- local, national and regional?
- How to make WEF nexus more inclusive and gender sensitive?

Regarding **resource availability** and sustainability, there was general consensus that the public investment in water, energy and agriculture sectors are not in commensurate with the rapid increase in demand for these resources. As such there is an urgent need for policy support to allocate adequate investments particularly in irrigation, renewable energy and agricultural development. Need for innovative projects that integrate multiple use of water, energy and irrigation as well as efficient management of demand and supply for these resources were highlighted. Furthermore, assessing resource potential and development, their inter-linkages and interdependencies, reducing overexploitation and leakages were also outlined.

For enhancing resource use efficiency, experts noted that broad knowledge and sound understanding of inter linkages and interdependencies of water, energy, and food are critical for designing sustainable management regimes. Urgent need for technology improvement was highlighted to improve efficiency in using land, water and energy resources at different scales.

On achieving coherence, participants recognized that there is fragmentation and duplication of efforts among government ministries and departments due to lack of coordination and cooperation in managing these scarce resources. Therefore, efforts are required to break the sectoral silos and strengthen cross-sectoral coordination. This would also requirestrengthening institutional capacity to deal with cross-sectoral issues. Exchange of experience and lessonsamong countries, regional cooperation and collaborative research on transboundary dimensions of nexus issues could facilitate forging partnerships. Also, institutional innovation and mechanisms are required to enhance synergies among multiple sectors and minimize trade-offs.

For ensuing inclusive and gender sensitive WEF nexus approach, experts reminded that women are generally responsible for collection of drinking water, fuel wood energy for energy and for preparing household food. As such women are more involved in managing these resources are also faced with difficulties in accessing these critical resources. Yet understanding on how women are involved in different stages of management and use of these resources as well as factors that constrains them in active participation of decision making are often missing. It is important to look water, agriculture and energy from gender lens, how women are involved in different stages of management and use of these resources, and identify factors that constrains them in active participation of decision making.

Key messages from interactive session

- **Need system thinking and e**mbedding nexus principles in policy making **and actions across the WEF sectors** to better harness synergies and manage trade-offs among the three sectors. Mechanisms for integrated planning across sectors at the county level need to be developed so that nexus perspective are integrated into national policies, programs, research and decision-making process.
- **Develop institutional mechanism** for improving cross-sectoral coordination and nexus decision-making for horizontal and vertical coordination. A framework for coordination among the three sectors is needed. The framework should clarify the role and responsibilities of different government agencies between different sectors and center and local government. A ‘WEF Nexus Committee’ may be established comprising senior experts from different ministries and sectors as well as research and think tank to share information, identify policy gaps, and define priorities.
- **Strengthen institutional capacity** to operate in a more integrated way by adopting nexus approach
- **Nexus has a regional dimensions** as a number of large rivers in South Asia is transboundary. A cooperative management of these river systems via nexus mode is vital to ensuring future demand for water, energy and food security. Improved regional connectivity and trade can also facilitate easy movement of foods, reduces food transportation costs and energy as well as facilitate regional energy cooperation. Regional organization like SAARC and ICIMOD could be entrusted with the tasks of identifying issues which require more regional attention.
- **Inadequate knowledge**, understanding, practical tools hinders implementing nexus approach. It is therefore important to generate interdisciplinary knowledge and develop policy instruments and implementing guidelines for practical application. Knowledge of cross-country interdependencies in WEF sector are also important.
- **Promote gender-responsive planning** for the water-energy-food nexus so that strategic gender needs are well integrated into WEF nexus planning.

Closing Session

Mr. Mohibur Rahman, Research Fellow, SEC-Islamabad presented the draft recommendation of the meeting

Policy:

- Establish policy framework on WEF nexus including ground water in the SAARC region for equitable sharing and broadening the horizon of benefit
- Establish SAARC water center
- To integrate the policy tools/mechanism to strengthened the WEF Nexus.
- To enhance the regional cooperation of water right/resource.
- Create “One Window Services” to coordinate WEF Nexus interconnections. (Like special economic zones/export processing zones)
- To enhance the road/rail transportation/connectivity to strengthened the food security and reduce the energy use.
- Develop regional institutions under the aegis of SAARC for transboundary resource management (eg – water drainage data, food surplus/shortage data)

Research and collaboration/linkages:

- Establish the mathematical Model for WEF Nexus for forecasting and decision support.
- To consider Land and Social aspect to address WEF Nexus.
- To conduct the study of spring-water of SAARC region (w.r.t climate change & natural disaster)
- To give emphasize on Renewable Energy (RE) for promoting WEF nexus interconnections.
- To give incentives to the PPP/NGOs to create awareness & promotion of using sustainable RE.
- Promote people to people and business to business linkages.
- To introduce and promote of alternative and efficient crop production technologies (e.g Hydroponic in the area where unavailability of fertile land and water shortage)
- To find out the way forward for optimal use of surface water to minimize over exploitation of ground water.
- Inclusion of WEF nexus in the curriculum of technical universities in SAARC region.
- Establish multi-stakeholder platforms in the region for WEF nexus dialogue amongst policy maker/scientists/stakeholders
- Strengthen institutional linkages for research collaboration/ technology transfer/capacity building/exchange of data & information

Dasho Rinzin Dorji, Secretary, Ministry of Agriculture and Forests, Bhutan as the Chief Guest in the closing session his personal satisfaction to be closely engaged in this deliberative process on important agenda that cuts across the three vital facets (*environmental, social and economic*) of national development. He mentioned that many ancient civilizations have been closely associated with water, the rise and fall of civilization has indeed been correlated to judicious management and mismanagement of water resources respectively. While we have industrialized and developed, our societal sustenance is directly dependent on water. More so the present trends of development exerts increasing ecological, economic and social pressures on water, energy and food whose effects are visible in different dimensions. He reiterated that such complex dimensions will need integrated assessment approach to better comprehend, frame, and strategize to address challenges. Acknowledging the presentation on the draft recommendations of the meeting, he classified them as pragmatic, forward looking, holistic and most importantly doable. The urgency to address these issues and the commitment of the national delegation and the participants radiates in every recommendation. Secretary also related the recommendations to the development philosophy of Gross National Happiness and promoting Green Economy, he reiterated the need to create synergies between the water-energy-food nexus sectors while reducing trade-offs. He urged all the participants to take forward the collective commitments and translate into actions that will help in sustainable development of agriculture and livelihood in the region.

On behalf of the Royal Government of Bhutan, he also assured the commitment of Bhutan to the shared vision of SAARC - to promote and strengthen collective self-reliance among the countries of South Asia and to promote active collaboration and mutual assistance in the economic, social, cultural, technical and scientific fields. He concluded by saying that many of the recommendations can be an important inputs to the forthcoming 4th SAARC Agriculture Minister's Meeting.

On behalf of the participants, Ms. Niru Dahal, Program Director, Directorate of Agricultural Extension, Ministry of Agricultural Development, Kathmandu, Nepal, Dr. Sucharita Sen, Executive Director, SaciWATERS, Hyderabad, India, and Dr John Dore, Senior Water Resources Specialist, Department of Foreign Affairs and Trade, Ministry of Foreign Affairs, Australian Embassy, Thailand gave a remarks on the program. All expressed their satisfaction

Dr. Shoaib Ahmad, Deputy Director, SEC proposed vote of thanks, where he expressed his gratitude to Honourable Secretary, Ministry of Agriculture and Forests, Bhutan for gracing both the inaugural and closing of this important consultation meeting. He also thanked all the delegates from SAARC Member States in preparation of a comprehensive paper and participation in the meeting.

On behalf of SAARC, he mentioned the very pro-active engagement of ICIMOD in supporting additional participants is highly appreciated by SAARC so that exchange of knowledge and information can be widened. In conclusion he thanked the Ministry of Agriculture and Forests, Royal Government of Bhutan for hosting the meeting and delegations from all SAARC Member States.

Meeting Agenda

SAARC Regional Expert Consultation Meeting on Water-Energy-Food Nexus: A basis for sustainable agricultural development

3-5 July 2017, Thimphu, Bhutan

Day 1 (3/7/2017)

Inaugural Session

8:30	Registration	PPD-MoAF
9:00	Arrival of Chief Guest and Dignitaries	To be received by Dr. Shoiab, Dr. Golam, Mr. Jamyang, and Dr. Tayan
9:15	Marchang	Directorate, MoAF
9:30	Welcome Remarks (Purpose and objectives of the meeting)	Dr. Tayan Gurung, Senior Program Specialist (NRM), SAARC Agri Centre
9:35	Keynote remarks on Energy Sector in South Asia vis-à-vis WEF Nexus	Dr. Shoiab, Deputy Director (Coordination), SAARC Energy Centre
9:40	Keynote remarks on Water-Energy-Food Nexus in South Asia	Dr. Golam, Theme Leader, Livelihood, ICIMOD
9:45	Inaugural Address by the Chief Guest	Dasho Rinzin Dorji, Secretary, Ministry of Agriculture and Forests, Bhutan
9:55	Vote of Thanks	Chief Planning Officer, Policy and Planning Division, MoAF, Bhutan
10:00	Group Photo and Tea Break	ISC-MoAF

Technical Session I- Country Paper **-** Member States

Chairperson	Mr. Jamil Ahmad, Joint Secretary, Ministry of National Food Security and Research, Islamabad.
Rapporteur	Mr. Mohibur Rahman, Research Fellow-SEC and Mr. Ahsan Javed, Research Fellow-SEC

11:00	Water-energy-food nexus – a basis for sustainable agriculture in Afghanistan	Afghanistan.

11:20	Water-energy-food nexus – a basis for sustainable agriculture in Bangladesh	Mr. Md. Hemayet Hussain, Joint Secretary, Ministry of Agriculture, Bangladesh
11:40	Water-energy-food nexus – a basis for sustainable agriculture in Bhutan	Ms. Kinlay Tshering, Director, Agriculture, Bhutan
12:20	Water-energy-food nexus – a basis for sustainable agriculture in India	Dr. SK Ambast, Director, ICAR-IIWM, India.
12:40	Discussion	
01:00	Lunch Break	

Technical Session II- Country Paper - Member States

Chairperson Dr. Aditi Mukherji, Theme Leader-ICIMOD

Rapporteur Mr. Mohibur Rahman, Research Fellow-SEC and Mr. Ahsan Javed, Research Fellow-SEC

2:00	Water-energy-food nexus – a basis for sustainable agriculture in Maldives	Mr. Ali Amir, Director, Ministry of Fisheries and Agriculture, Maldives
2:20	Water-energy-food nexus – a basis for sustainable agriculture in Nepal	Mr. Bashu Dev Lohanee, DDG, Department of Irrigation, Nepal.
2:40	Water-energy-food nexus – a basis for sustainable agriculture in Pakistan	Mr. Sajjad Haider Yaldram, Deputy Secretary, Ministry of Water and Power, Pakistan
3:00	Water-energy-food nexus – a basis for sustainable agriculture in Sri Lanka	K.M.A.Kendaragama Principal Agriculture Scientist (NRM), Sri Lanka.
3:30	Tea Break	

Technical Session III- Keynote papers on Policies

Chairperson:	Dr. Shoaib Ahmad, Deputy Director (Coordination), SAARC Energy Centre
Rapporteur	Mr. Mohibur, SEC and Mr. Jamyang, PPD, MoAF

4:00	Managing the Food- energy-water Nexus for achieving the SDGs in SAARC Region	Dr. Golam Rasul, ICIMOD
4:20	Water security in Bhutan: A Strategic direction	Tenzin Wangmo, Chief Environment Officer, NEC, Bhutan *(TBC)*
4:40	Sustainable Water management from the perspective of W-E-F Nexus in SAARC Region – IWMI	Dr. Alok Sikka, IWMI
5:00	Discussion	
	End of Day 1	

Day 2 (4/7/2017)

Technical Session IV- Invited papers on Energy

Chairperson	Dr. Sucharita Sen, Executive Director, SaciWATERS, India
Rapporteur	Mr. Mohibur Rahaman, SEC and Mr. Ram Gopal Lageju, SEC

9:00	SAARC Energy Centre – Paper 1	SEC

9:20	Renewable energy in Water-Energy-Food Nexus in South Asia	Dr. Aditi Mukherji, ICIMOD
9:40	SAARC Energy Centre – Paper 2	SEC
10:00	Tea Break	

Technical Session V- Gender, Education and Climate change

Chairperson	Mr. Md. Hemayet Hussain, Joint Secretary, Ministry of Agriculture, Bangladesh
Rapporteur	Mr. Mohibur Rahaman and Mr. Jamyang Phuntsho

10:30	Water-Energy-Food Nexus in South Asia – from the perspective of climate change	Dr. Muhammad Zulfiqar, Director, Climate Change Center, University of Agriculture, Peshawar, Pakistan.
10:50	Gender perspective in Water-Energy-Food nexus in South Asia	Dr. Sucharita Sen, Executive Director, SaciWATERS, India
11:20	Higher Education and Research on W-E-F Nexus in the HUC	Dr. Mohammad Abu Taiyeb Chowdhury, Professor, Geography and Environmental Studies, University of Chittagong, Bangladesh. *(TBC)*
11:40	Discussion	
12:00	Briefing on the group work	SAC/SEC/ICIMOD
12:30	Lunch	

Technical Session VI-Regional cooperation for W-E-F Nexus security (Facilitated by ICIMOD, IFPRI, SEC, and SAC)

2:00	**Keynote paper 1**: Governance of Water-Energy-Food Nexus in South Asia including lessons from	Dr John Dore, Senior Water Resources

	Greater Mekong and Australia	Specialist, Department of Foreign Affairs and Trade. Australian Embassy, Thailand.
	Keynote paper 2: Regional cooperation for strengthening water-energy-food security in South Asia	Dr. Golam Rasul, ICIMOD
2:20	Group work (3 groups) - Briefing and Moderation	SAC/SEC/ICIMOD
2:30-5:30	**Group 1**: What are the challenges/constraints in regional cooperation for W-E-F Nexus security	
	Group 2: What are the opportunities for promoting regional cooperation for W-E-F Nexus security	
	Group 1a and 2a: How can we address the challenges and harness the opportunities for regional cooperation for W-E-F Nexus security	

Day 3 (5/7/2017)

9:00	Presentation by the 3 Groups (10 minutes each+5 minutes for discussion)	
9:45	Tea Break	

Technical Session VII-Leadership Panel: Science-Policy dialogue for regional cooperation in WEF Nexus (*Facilitated by SAC, SEC, ICIMOD*)

10:15 to 12:15	**Panelist**: Policy Maker and Expert from SAARC Countries, (*Moderated session*) - ***Water–energy–food nexus and sustainable development: Policy mainstreaming***	ICIMOD/SEC/SAC
	1. Mr. Jamil Ahmad, Joint Secretary, Ministry of National Food Security and Research, Pakistan **[Food Security]**	Moderator: *Dr. Golam and Dr. Tayan*
	2. Mr. Dophu Dukpa (MP), Chairperson, Environment and Urban Development Committee, National Assembly of Bhutan **[Environment and Natural Resources]**	

3. Mr. Yogesh Tamang (MP), Chairperson, Good Governance Committee, National Assembly of Bhutan **[Governance]**
4. Dr. Sunil Kumar Ambast, Director, Indian Institute of Water Management **[Water-Research]**
5. Dr. Aditi Mukherji, Theme Leader, Water and Air, ICIMOD **[Energy]**
6. Dr. Chubamenla Jamir, Assistant Professor, HUC **[Education]**

Closing Session

12:20	Presentation of the Draft Recommendations	Rapporteur (SEC)
12:30	Remarks by the Participant *(TBC)*	*(Max 3)*
12:35	Remarks by the Chief Guest	H.E Yeshi Dorji, Minister, Ministry of Agriculture and Forests, Bhutan
12:45	Vote of Thanks –	Deputy Director, SAARC Energy Centre

1:00	Lunch Break
2:30	Field visit in Thimphu/Paro

Day 4 (6/7/17)	Delegates return to their home country

Organizing Committee

1.	SAARC Agriculture Centre (*Coordinator*)	-	Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), tayangurung@yahoo.com
2.	SAARC Energy Centre	-	Dr. Shoaib Ahmad, Deputy Director, ddcoord@saarcenergy.org
3.	ICIMOD	-	Dr. Golam Rasul, Theme Leader, Livelihoods. Golam.Rasul@icimod.org
4.	SAARC Energy Centre	-	Mr. Mohibur Rahman, Research Fellow, rftt@saarcenergy.org
5.	MoAF-Bhutan (*Local Facilitator*)	-	Mr. Jamyang P Rabten, Planning Officer, jphuntsho@moaf.gov.bt

Rapporteurs: Mr. Mohibur Rahman, SEC, Mr. Kailash Pradhan, Specialist, DOA-Bhutan; Mr. Ram Gopal Lageju, Research Fellow, SEC-Islamabad, and Mr. Jamyang Phuntsho, PPD, Mr. Ahsan Javed, Research Fellow (RE)

Participants List

A Focal Points from SAARC Member States

1.	Bangladesh	Mr. Md. Hemayet Hussain, Joint Secretary, Ministry of Agriculture, Bangladesh Secretariat, Dhaka, Bangladesh. +8801711784979. mhh1863@gmail.com
2.		Dr. Mohd. Sher Ali, Deputy Secretray, MoPEMR. Sherali93@yahoo.com
3.	Bhutan	Ms. Kinlay Tshering, Director, Department of Agriculture, Thimphu, Bhutan. kinlaytshering@moaf.gov.bt
4.	India	Dr. SK Ambast, Director, ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha, India. +916742300060. director.iiwm@icar.gov.in
5.	Maldives	Mr. Ali Amir, Director, Ministry of Fisheries and Agriculture, Male, Maldives. ali.amir@fishagri.gov.mv
6.	Nepal	Ms. Niru Dahal, Program Director, Directorate of Agricultural Extension, Ministry of Agricultural Development, Kathmandu, Nepal.
7.		Mr Sagar Raj Goutam, Senior Divisional Engineer, Energy, Nepal
8.	Pakistan	Mr. Sajjad Haider Yaldram, Deputy Secretary, Ministry of Water and Power, Government of Pakistan, Islamabad. yaldramsajjad@yahoo.com
9.		Mr. Jamil Ahmad, Joint Secretary, Ministry of National Food Security and Research, Islamabad. Jamil254@hotmail.com
10.	Sri Lanka	Mr. KMA Kendaragama. Deputy Director, Department of Agriculture, Sri Lanka. +94779436475. kendarag@sltnet.lk

B. ICIMOD officials and ICIMOD supported participants from the region

11.		Dr. Aditi Mukherji, Theme Leader, Water and Air, ICIMOD, Kathmandu, Nepal, aditi.mukherji@icimod.org
12.		Dr. Golam Rasul, Theme Leader, Livelihood, ICIMOD, GPO Box 3226, Kathmandu, Nepal, Tel: +977golam.rasul@icimod.org
13.		Mr. Bashu Dev Lohanee, Deputy Director General, Department of Irrigation, Government of Nepal, Jawalakhel, Lalitpur, Nepal Mobile: 9841277760. lohanibasu@yahoo.com

14. Dr. Sucharita Sen, Executive Director, SaciWATERS, Hyderabad, India. sucharita@saciwaters.org

15. Dr. Muhammad Zulfiqar, Director, Climate Change Center, The University of Agriculture, Peshawar, Pakistan. zulfiqar@aup.edu.pk

16. Dr. Mohammad Abu Taiyeb Chowdhury, Department of Geography and Environmental Studies, University of Chittagong Bangladesh. taiyeb.chy@gmail.com

17. Dr. Neeraj N. Joshi, Himalayan College of Agricultural Sciences and Technology, Founder and Adjunct Professor, Nepal. neerajnjoshi@hotmail.com

18. Dr. Mohammad Nazim Sakandari, Head of Faculty of Agriculture Herat University, Afghanistan. nazimsakandari@gmail.com, nazim.sakandari@yahoo.com

19. Dr. Chubamenla Jamir, Assistant Professor, Department of Energy and Environment, TERI University, New Delhi, India. chubamenla.jamir@teriuniversity.ac.in

20. Ms. Sonam, Lecturer, Department of Agriculture, CNR, Lobeysa

C. Department of Foreign Affairs and Trade. Australian Embassy, Thailand

21. Dr John Dore, Senior Water Resources Specialist, Australia's Department of Foreign Affairs and Trade. Australian Embassy, 37 South Sathorn Road, Bangkok, 10120, Thailand.Cell: +66 (0)8 1732-0364. John.Dore@dfat.gov.au

D. International Water Management Institute (IWMI)

22. Dr. Alok Sikka, Coordinator, IWMI-India, New Delhi, India. A.Sikka@cgiar.org

F. SAARC Energy Centre

23. Dr. Shoaib Ahmad, Deputy Director, SEC. ddcoord@saarcenergy.org

24. Mr. Mohibur Rahman, Research Fellow, SEC-Islamabad. rftt@saarcenergy.org

25. Mr. Ram Gopal Lageju, Research Fellow, SEC-Islamabad

26. Mr. Ahsan Javed, Research Fellow, SEC-Islamabad

G. SAARC Agriculture Centre

27.		Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAC-Dhaka. tayangurung@yahoo.com

H. Participation from Bhutan

28.	PPD-MoAF	Mr. Rinzin Dorji, DyCPO, PPD-MoAF
		Ms. Sonam
29.		Mr. Jamyang Phuntsho, PO, PPD-MoAF
30.	DoA-MoAF	Mr. Kailash Pradhan, Specialist, DoA
31.		Mr. Karma Tshether, Chief Engineer, Irrigation Division, DoA
32.	Department of Power-MoEA	.
33.	NEC	Ms. Tenzin Wangmo, Chief Environment Officer, WRCD, NECS, Water Resource Coordination Division, NEC, Bhutan. twangmo@nec.gov.bt
34.	RSPN	.
35.	National Assembly	Dasho Dophu Dukpa, Environment Committee, NAB
36.	National Assembly	Dasho Yogesh Tamang, Good Governance Committee, NAB
37.	DoA	Sagar Acharya, Agriculture Officer
38.		Chimi, Horticulture Officer
39.	ISC	Coidup, Photo-documentation
40.		Tenzin, Video-documentation

Photo Gallery

Hon’ble Secretary, Ministry of Agriculture and Forests, Bhutan inaugurates the Meeting

Group Photo of participants with the Chief Guest: Hon’ble Secretary-Agriculture and Forests

Joint Secretary, Ministry of Agriculture, Bangladesh presenting the Country Paper

Additional Secretary, Ministry of Food Security and Research,
Pakistan and SAC-GB Member Chairing the Session.