Chapter

World's Demand for Food and Water: The Consequences of Climate Change

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Abstract

This study focused on analysis of global food demand and supply situation by 2030 and 2050, water demand-availability, impact of climate change on world water resource, food security and desalination challenges and development opportunities. The population of the world will be 8.6 billion in 2030 and 9.8 billion in 2050; Africa will be the major contributor. World cereal equivalent (CE) food demand is projected to be around 10,094 million tons in 2030 and 14,886 million tons in 2050, while its production is projected to be 10,120 million tons in 2030 and 15,970 million tons in 2050 having a marginal surplus. India and China are capturing large share of global food demand. The developing country will demand more animal origin foods due to income growth in the future. The growth rate of world demand for cereals will decline till 2050. Global water demand is projected to increase by 55% between 2000 and 2050 from 3500 to 5425 km^3. Evidence showed that climate change will have adverse impact on world water resources and food production with high degree of regional variability and scarcity. A number of options are suggested for development of global water resource and food production.

Keywords: demand for food and water, food security, climate change, global, water resources, challenges and opportunities

1. Introduction

Food and water are important for life. Global population increased many folds in the last century and will further boost by 2030 and 2050 [1]. Such large world population will be demanding for more food and water in the future. Despite the fact that agricultural growth has been higher than the rate of population growth concerns has been raised whether the land mass of world is actually capable of supporting its expanding population by 2030 and 2050. Food security remains a relevant and priority of many nations with special emphasis on developing countries. There is growing concern on the future demand for and supply of food in the world. The global food system is experiencing an unprecedented confluence of pressures that may increase over the years 2050 [1]. Increased food production will require greater inputs-land, water or energy, or a combination of these inputs. Thus, required increase in food production will intensify competition for land, water and energy [2, 3]. The global agriculture is evolving with food demand of people, availability of technology and climate change. Could the future growth of supply of food of a country match with its increased demand for food as a result of population pressure and rising income? A number of studies attempted to answer this and projected demand for and supply of key food items in various countries and assessed gap [4–6].

There are growing concerns on the impact of climate change on the water resources. A number of studies assessed such impact at various country levels and food security challenges [7]. An ever increasing amount of evidence suggests that the continual increase in greenhouse gas emissions is affecting the global climate and altering the local precipitation and temperatures [8, 9]. Climate change is expected to produce significant effects on global water resources and freshwater ecosystems [10, 11]. The effects and intensity of climate change will vary from region to region [12]. Impact of climate on global water storage capabilities and hydrologic functions will have significant implications for water management and planning as variability in natural processes increases.

This study was carried out with the objectives to examine and assess global food demand and supply situation by 2030 and 2050, world water demand- availability scenario, impact of climate change on global water resource, food security challenges of the globe, identify challenges and development opportunities. The study is completed based on extensive review and analysis of relevant information and literature available across various regions of the globe.

2. Outlook of world population

Population of the world reached to 7.3 billion by mid-2015 and the extent of increase was approximately 1 billion people during the period of last 12 years. The vast majority of the global population (60%) lives in Asia (4.4 billion), the second highest (16%) in Africa (1.2 billion), third portion (10%) in Europe (738 million), the 4th one (9%) in Latin America and the Caribbean (634 million), and the remaining 5% in rest of the world (**Table 1**). China (1.4 billion) and India (1.3 billion) that belong to Asia are the two largest countries of the world, covering 19% and 18 per cent of the world's population, respectively [8].

2.1 Projected growth of population

The growth rate of global population increased slowly during 1700–1950 and then accelerated rapidly until the mid-1960s, peaking at just over 2% per year before descending to 1.1% per year in 2017. World population size increased seven fold during the period 1800–2011.

Currently, the world population is growing approximately by 83 million people annually. Growth rates are slowing to various extents within different regions with

Major region	***Population (millions)***			
	2015	2030	2050	*2100*
World	7 349	8 501	9 725	11 213
Africa	1 186	1 679	2 478	4 387
Asia	4 393	4 923	5 267	4 889
Europe	738	734	707	646
Latin America and the Caribbean	634	721	784	721
Northern America	358	396	433	500
Oceania	39	47	57	71

Table 1.
Population of the world by region.

result of the overall population growth rate decreasing from 1.55% per year in 1995 to 1.10% in 2017. The median estimate for future growth shows that the world population is projected to increase by more than 1 billion people within the next 15 years, reaching 8.6 billion in 2030, further increase to 9.8 billion in 2050 and 11.2 billion by 2100 assuming a continuing decrease in average fertility rate from 2.5 births per woman in 2010–2015 to 2.2 in 2045–2050 and to 2.0 in 2095–2100 (**Figure 1**). With the main driver of future population growth is the evolution of the fertility rate [9].

More than half of global population growth between now and 2050 will occur in Africa. Africa has the highest rate of population growth among major regions, growing at a pace of 2% annually in 2010–2015 (**Figure 2**). An additional 2.4 billion people projected to be added to the global population between 2015 and 2050 of which 1.3 billion will be added from Africa and 0.9 billion people from Asia. Asia is the second largest contributor to future global population growth followed by Northern America, Latin America and the Caribbean and Oceania, which are projected to have much smaller increments. In the medium variant, Europe is projected to have a smaller population in 2050 than in 2015.

There is link of population growth with economic growth and food demand. According to Malthus, population growth responds to a wage or income signal that

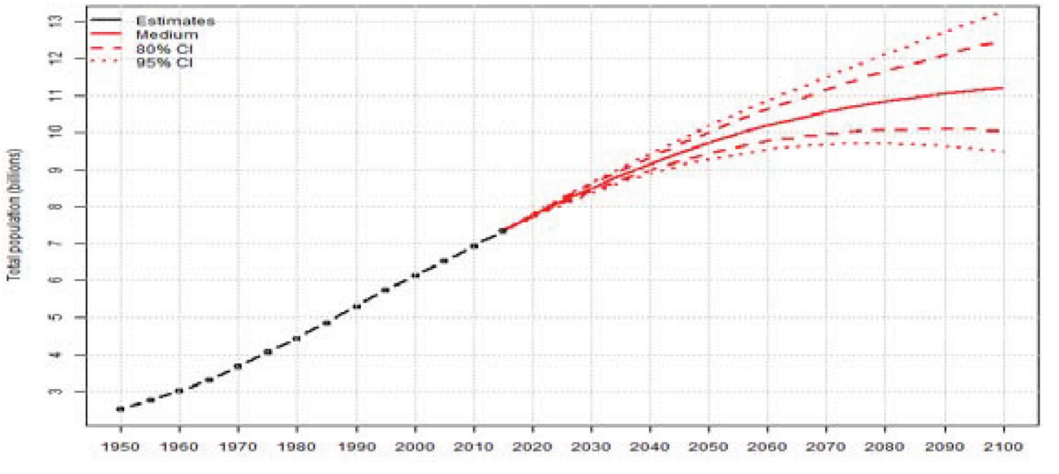

Figure 1.
Median variant projections of world population 2015–2100. Source: Ref. [8].

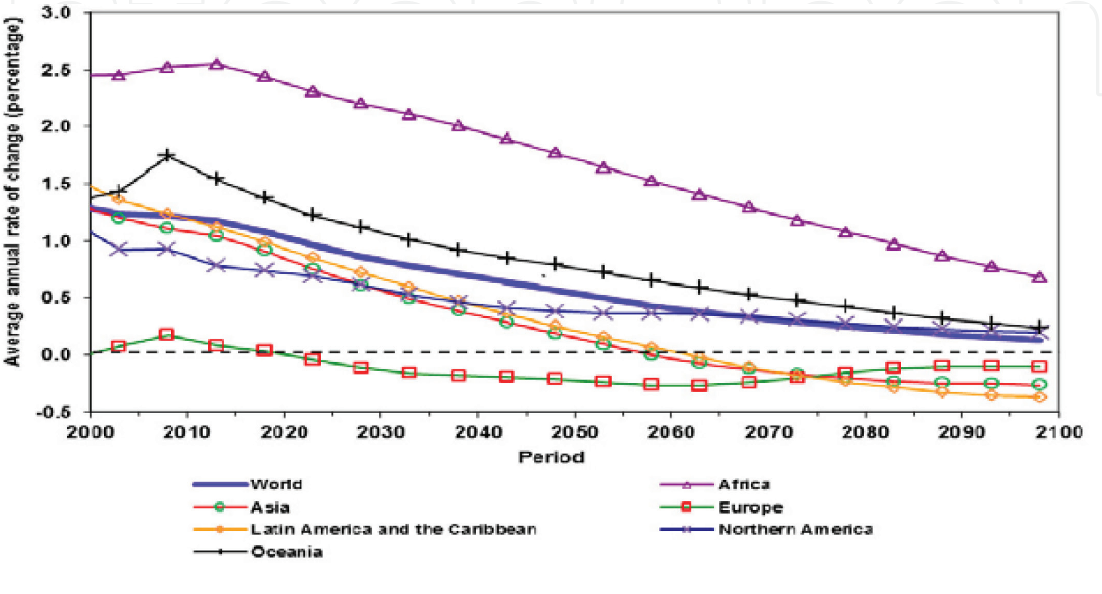

Figure 2.
Medium-variant projection of population growth by major region, 2015–2100. Source: Ref [8].

depends negatively on the size of the population in relation to the economy and its resource base [8]. Population growth is positively related with incidence of poverty. With economic growth incidence of poverty is reduced and population growth declines as result of declining fertility rates. For example, incidence of poverty is high in Africa and growth rate of population is also high.

3. Projections of global food demand and supply

The projected large world population in 2030 and 2050 discussed above has received a great deal of attention as an influence on world food demand [8]. Besides population growth, income growth also becomes an important driver of food demand. According to Bennett's law the proportion of the food budget spent on starchy-staple foods declines while spending on animal-based products increases as incomes grow in developing countries [10]. This dietary change puts pressure on agricultural resources since animal-based food requires disproportionately more agricultural resources including water in production [11]. This relationship between food demand and income, established by Engel's and Bennett's laws, implies that income distribution matters for aggregate food demand.

Substantial efforts have been made in modeling to forecast the global supply and demand for food to the middle of the century, typically using large global agricultural models [12–14]. However, the projections for food output and prices vary widely across the models, depending on their underlying supply and demand specifications, choices of key parameters such as price and income elasticities and their treatments of technical change. For instance, reviewing modeling approaches from 12 global agricultural economic models, It is reported that modelers' projections for increases in global crop output between 2005 and 2050 range from 52 to 116%, while estimated changes in crop prices vary from a decline of 16% to a rise of 46% [15]. Another study projected an increase of 95% in consumption of animal-based food, as against an 18% increase in demand for starchy staples, with the latter being largely driven by population growth toward 2050 [16].

For simplicity of estimation of projected world food demand all food items were converted to cereal equivalent food (CE) [17]. The drivers of cereal equivalent (CE) food demand are growth rate in per capita CE food consumption and population growth rate. **Table 2** shows that world CE food demand increased from 2999 million tons in 1980 to 6360 million tons in 2009. Decade wise analysis of growth rate shows that annual growth rate of CE food demand declined from 2.3% in 1980s to 1.87% during 2001–2009 while per capita food demand increased from 0.55 to

	Evolution of CE food demand 1980-2009					
	CE Food demand			Annual growth rate in CE food demand		
	Change (mil. Tons)	Initial year (mil. Tons)	Last year (mil. Tons)	Total (%)	Per capita (%)	Population (%)
1980-1991	864	2999	3863	2.3	0.55	1.75
1992-2000	817	4590	5407	2.05	0.69	1.36
2001-2009	905	5455	6360	1.87	0.72	1.15
Projected change in CE food demand 2009-2050						
	CE Food demand			Annual growth rate in CE food demand		
	Change (mil. Tons)	Initial year (mil. Tons)	Final year (mil. Tons)	Total (%)	Per capita (%)	Population (%)
2009-2050	7049	6360	14886	1.72	1.03	0.68

Table 2.
Evolution of world food demand during 1980–2009 and Projections in 2050.

0.72% and population growth rate declined from 1.75 to 1.15% (**Table 2**). World CE food demand is projected under strong convergence scenario to be around 10,094 million tons in 2030 and 14,886 million tons in 2050 [17]. On the supply side, CE food production is projected to be 10,120 million tons in 2030 and 15,970 million tons in 2050. The world CE food demands would change by 134% from the base year of 2009 while CE food production would change by 151% and thus food production would grow slightly faster than demand yielding a positive gap of 7%.

The regional decomposition shows that developing countries as a group dominate the increase in food demand and that their income convergence does matter. It was that convergence by middle-income countries, especially such populous countries as India, China, Indonesia and Nigeria, is particularly important for global food demand. This is partly due to the inverted-U shaped pattern of income elasticities for aggregate food demand, with middle-income countries experiencing the largest income elasticities due to their dietary upgrading toward more resource demanding products [10]. **Table 3** shows top 20 countries contributing around 77.5% of total world CE food demand.

India has the largest share of world food demand (24.3%) followed by China (16.7%). Although Bangladesh is small country but densely populated and stood 8th with a share of 2% of world food demand (**Table 3**). **Table 4** shows projected food demand and supply of Bangladesh by 2030 and 2050. Bangladesh is self-sufficient in rice now. Rice production was 5% less than the demand in 2005 and 2000, but there was a marginal surplus of 5% in 2010.The projections show that Bangladesh will have a surplus rice production of 1.2 million tons (MT) and maize production of 1.8 (MT) by 2030. On the other hand, the country will have deficits productions of wheat, potato, pulses, vegetables, meat, egg and fresh water fish amounting 0.5, 0.8, 0.7, 1.0, 0.1 and 0.7 MT. The country is also highly deficit in well seed production. It is projected that Bangladesh will have a surplus production of rice, maize, potato, vegetable and milk by 2050 and will have deficit production of wheat, pulses, fruits, meat and fresh water fish in 2050.

	Change (million ton)	Share (%)	Cumulative (%)
1. India	1715.9	24.3	24.3
2. China	1176.6	16.7	41.0
3. Nigeria	357.6	5.1	46.1
4. Indonesia	301.0	4.3	50.4
5.United States	241.0	3.4	53.8
6. Pakistan	217.9	3.1	56.9
7. Brazil	178.5	2.5	59.4
8. Bangladesh	140.1	2.0.	61.4
9. Egypt	139.8	2.0	63.4
10. Mexico	133.8	1.9	65.3
11. Philippines	128.8	1.8	67.1
12. Ethiopia	105.1	1.5	68.6
13. Turkey	91.8	1.3	69.9
14. Vietnam	91.2	1.3	71.2
15. Tanzania	81.1	1.2	72.4
16.Russian	76.0	1.1	73.4
17. Sudan	74.5	1.1	74.5
18. Iran	73.5	1.0	75.5
19. Uganda	73.4	1.0	76.6
20. Thailand	67.7	1.0	77.5

Table 3.
Top twenty countries contributing to world CE food demand changes.

Year	Rice	Wheat	Maize	Potato	Pulses	Vegetable	Fruits	Meat	Egg	Milk	Fish
Food supply											
2030	38.7	1.6	2.9	11.8	0.4	6.4	3.6	0.9	0.4	4.3	3.2
2050	46.5	2.1	2.9	18.7	0.4	8.3	3.3	1.2	0.5	5.2	3.9
Food demand											
2030	37.5	4.2	1.1	12.3	1.2	7.0	3.2	1.9	0.5	4.2	3.9
2050	41.3	4.5	1.2	13.3	1.3	7.6	3.5	2.1	0.5	4.6	4.2
Surplus(+)/deficit(-											
2030	1.2	-2.6	1.8	-0.5	-0.8	-0.7	0.4	-1.0	-0.1	0.1	-0.7
2050	5.2	-2.4	1.7	5.4	-0.9	0.7	-0.2	-0.9	0.0	0.7	-0.3

Table 4.
Projections of food supply and demand in Bangladesh by 2030 and 2050 (Based on estimates of ARIMA model, quantity in million tons).

Still cereals constitute major portion of world food demand (49%) and will remain so till 2050. The growth rate of global demand for cereals declined continuously during 1969–2007 from 2% per annum to 1.3% and projected to fall further to 1.2% in 2030 and to 0.9 in 2050 while world cereal demand would have a significant rise from 940 million tons from the base year 2005/2007 to 3 billion metric tons by 2050. Almost all the increases in the consumption of cereals will come from the developing countries. The developing countries surpassed developed ones in total cereals consumption in the early 1980s and account now for 61% of world consumption, a share that will increase to 67% by 2050. They also surpassed them in total production in the early 1990s: they now account for 56% of world production and the share will increase to 60% in 2050 [18].

Like other developing countries with income growth food consumption in Bangladesh is slowly diversifying. Cereals still provide a major part of the calorie intake, but their share in total calorie supply has decreased from 92% in 1990 to 89% by 2010. Auto Regressive Integrated Moving Average (ARIMA) projections show that it will further decrease to 86.6% by 2030 and 85.8 by 2050 (**Figure 2**). The contribution to calorie intake from potato, vegetables, and animal products gradually increased between 1990 and 2010 and will continue to increase between 2030 and 2050 (**Figure 3**). The share of rice will decrease from 82% in 2010 to 79% in 2030 and to 78.6% in 2050 and absolute consumption decrease by 24.5 kcal/person/day from 2010 level (**Figure 3**). The share of wheat will slightly decrease from 7% in 2010 to 6.8% in 2030 and 6.7% in 2050 and absolute consumption decrease by15.1 kcal/person/day (**Figure 3**). The share of calorie intake from cereals seems to be reaching a level of saturation. However, as far as rice consumption is concerned, there is no room for significant increases in average consumption even with income

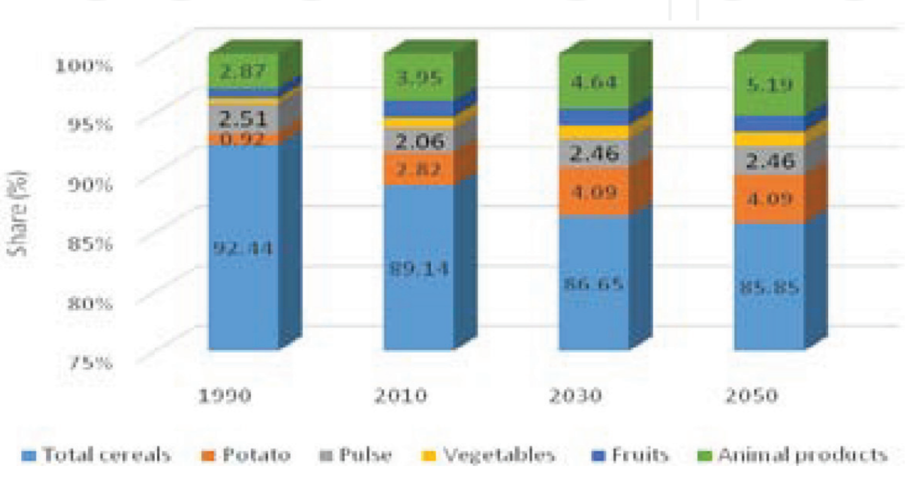

Figure 3.
Share of major food items in total calorie intake per capita. Source: Author's estimation.

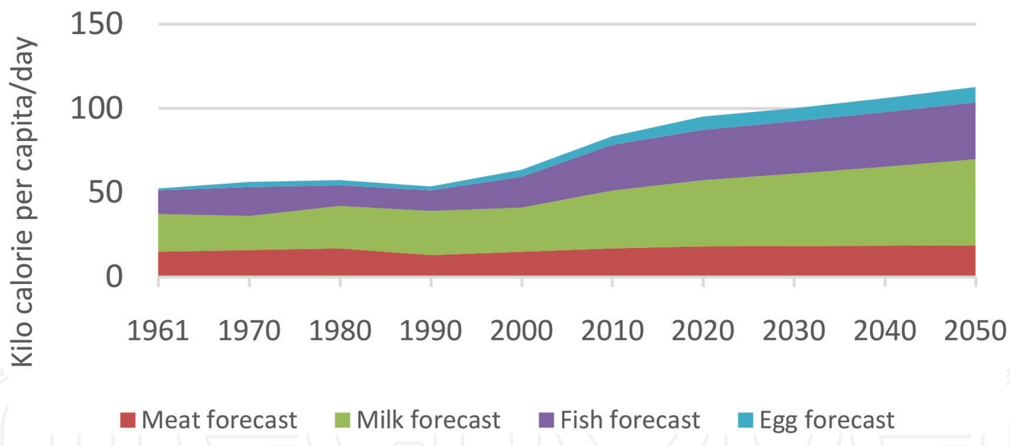

Figure 4.
Projection of per capita calorie intake from animal products. Source: Author's estimation, Per capita calorie intake up to 2013: FAOSTAT and forecasts up to 2050 are authors' estimates.

growth; in fact, it even started decreasing as in countries with similar consumption and economic growth patterns in Asia [19].

World average per capita rice consumption has declined after late 1980s, following mild declines in several countries of East and South Asia and small increases in other regions. These trends are projected to continue and the average of the developing countries may fall from the present 64 to 57 kg in 2050 [18]. It is striking to note that the per capita wheat consumption has also declined in both the developing and the developed countries. Food consumption demand of coarse grains as staple food in several countries in sub-Saharan Africa will increase in the next decades.

With the growth in income in developing countries demand for food from livestock origin increased in the past two decades and projected to grow further by 2030 and 2050. The ARIMA forecasts show that the consumption of animal origin food (meat, milk, egg and fish) and non-cereal food (potato, vegetables and fruits) in Bangladesh will have increasing trend during 1990–2030 (**Figure 3**). Beyond 2030 the consumption of animal products will further increase (**Figure 4**).

4. Global water demand-availability analysis for 2030 and 2050

The demand for water originates from four main uses- agriculture, energy production, industrial uses and human consumption. Production of crops and livestock is water-intensive as a result agriculture is the largest water user accounting 70% of global water withdrawal and rest 30% is used by municipal, energy and industrial sectors. The global booming demand for livestock products is increasing the demand for water as well. The global demand for food is expected to increase by 70% by 2050 [20]. Over the past half century, the area equipped for irrigation has more than doubled, total livestock production has more than tripled and inland aquaculture has grown more than 20-fold.

Global water demand is projected increase by 55% between 2000 and 2050 from 3500 to 5425 km^3 (**Figure 5**). In addition to demand from the agricultural sector, large increases are predicted for industry (400%), energy production (140%) and domestic use (130%) [21, 22]. Accelerated urbanization and the expansion of municipal water supply and sanitation systems would also contribute to the rising demand. Changing consumption patterns, including shifting diets toward highly water-intensive foods such as meat (i.e. 15,000 liters of water are needed for 1 kg of beef) will worsen the situation. While a person may drink 2–4 liters of water a day, it takes 2000–5000 liters of water to produce a person's daily food. Water is important for food security, crop growth, livestock, and food markets. Lack of water can be a major cause of famine and undernourishment, especially in areas where people depend on local agriculture for food and livelihoods. OECD projected that 3.9 billion people - in total over 40% of the world's population - are likely to be living in river basins under severe water stress by 2050 (**Figure 6**). Near East/North Africa and Northern China are water scarce regions.

The world net-land under crops predicted to increase by some 70 million ha by 2050. The area harvested may increase by almost twice that amount as a result of increased multiple cropping and reduced fallow lands. The projected 70 million ha increase is the result of an expansion in the countries of sub Saharan Africa and Latin America [18]. Irrigation has been an important contributor to cereal yield growth over the past decades. World irrigated areas are currently 300 million ha, more than twice the level of the early 1960s. World total irrigated area is projected to expand to 322 million ha in 2050. This expansion of around 22 million ha will be mainly in developing countries. The potential for further expansion of irrigation is limited.

Many water sources of the world are degrading and creating water scarcities. Most of the world irrigated agriculture is today in developing countries, accounting 60% of their cereals production. Nearly one half of the irrigated area of the developing countries is in India and China. One third of the projected increase will likely be in these two countries. The renewable water resources that would underpin the expansion of irrigation are extremely scarce in several countries. Irrigation water withdrawals from such resources are only 6.6% globally and even less in some regions. However, in the Near East/North Africa and in South Asia they already account for 52 and 40%, respectively, in 2005/2007. For some countries of Central America and the Caribbean these percentages are higher. Any country using more

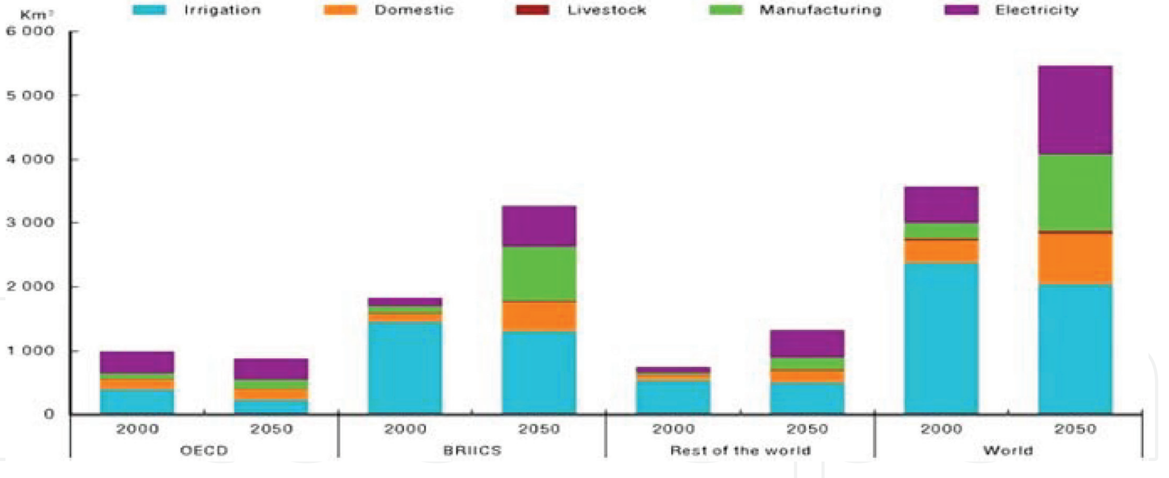

Figure 5.
Projection world water demand in 2050. Source: Ref. [22].

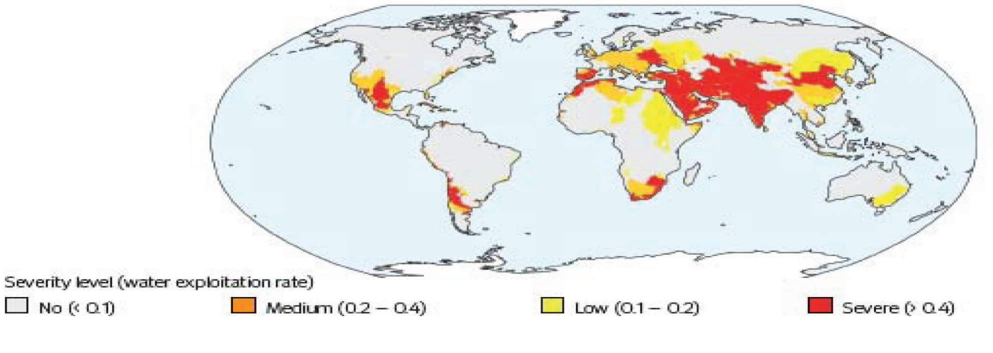

Figure 6.
Population projected to living in river basin under severe water stress. Source: Ref. [22].

than 20% of its renewable resources for irrigation is considered as crossing the threshold of impending water scarcity. There are already 22 countries (developing but including some in the Central Asia region) that have crossed this threshold, 13 of them in the critical over 40% class. Libya, Saudi Arabia, Yemen and Egypt use volumes of water for irrigation larger than their annual renewable resources [18].

Rice production accounted for 93% of the total consumptive water use (CWU) and 90% of the total irrigation CWU in Bangladesh in 2015. Boro rice alone occupies the largest share of irrigation water. We have projected that water demand for Boro rice would increase from 16.5 Billion meter^3 (BM^3) in 2010 to 17.23 BM^3 in 2030 after that it will stabilize and would remain at 17.23 BM^3 in 2050 (**Table 5**). Surface water availability in Bangladesh is alarmingly declining due to more water withdrawal in the upper riparian countries, silting up of major rivers and adverse impact of climate change. Salinity front in the south is also penetrating more inlands of the country due to shrinking of surface water. Thus the groundwater is the major source for more than 75% of the irrigated area in Bangladesh, it amounts 13 BM^{3}of irrigation water in 2010. The projected 17.23 BM^3 water for Boro rice production in 2030 mostly would come from groundwater.

The sources of water in Bangladesh can be classified as surface water, rainfall and ground water. Bangladesh, being the lower most riparian country in the Ganges-the Brahmaputra-the Meghna basins and crisscrossed by around 700 rivers including 57 transboundary rivers, shares its trans-boundary water resources with the upper riparian countries like Bhutan, China, India and Nepal. In the past few decades reduction of dry season flows in Bangladesh due to increasing upstream withdrawal is causing severe water shortage across the country. [23]. For instance, due to withdrawal of water from the transboundary Teesta River through construction of multi-purpose barrage and dams by the upper riparian countries, water availability in Bangladesh portion of the river gradually reduced to 6500 cusec in 1997and it drastically reduced over the years to 250 cusec in 2015 against Bangladesh's requirements of 8000 cusec. Teesta already silted much due to low flow of the river and its branches of many small rivers have dried up. Moreover, the reduced stream flow is also accelerating salinity intrusion and environmental degradation, particularly in the South West region. Again, excessive release of water from upper catchment during monsoon season causes flooding and river bank erosion in Bangladesh [24].

Already there has been much stress on ground water level of Bangladesh due to excessive withdrawal. Given the falling groundwater tables and water quality issues in Bangladesh, it will be extremely difficult to exploit groundwater resources sustainably to meet projected demand. Evidence showed that some districts of North, South and Central regions of Bangladesh already crossed the sustainable thresholds of groundwater use. Groundwater withdrawals for irrigation in these regions may exceed the usable recharge limit [4].

Global water scarcity is growing severe recent years. Recent research has demonstrated that two-thirds of the world's populations currently live in areas that experience water scarcity for at least 1 month a year. About 50% of the people facing this level of water scarcity live in China and India. About 500 million people live

Year	Boro irrigated area (million ha)	Water demand (CWU in billion meter^3)
2010	4.5	16.5
2030	4.7	17.23
2050	4.7	17.23

Table 5.
Irrigation water demand for rice production in Bangladesh in 2030 and 2050.

in areas where water consumption exceeds the locally renewable water resources This includes parts of India, China, the Mediterranean region and the Middle East, Central Asia, arid parts of Sub-Saharan Africa, Australia, Central and Western South America, and Central and Western North America. In these regions groundwater continue to decrease and become highly vulnerable [25].

The availability of water resources is inherently linked to water quality. The pollution of surface water and groundwater may prohibit its different uses due to absence of pre-treatment. The deterioration of water quality is expected to increase further in the coming decades which will further endanger human health and the environment as well as constraining sustainable economic development. The release of untreated wastewater from expanding human settlements and increasing industrial production generates physical, chemical and biological pollution that negatively impact human health and ecosystem. Findings from the global water quality monitoring program showed that severe pathogen pollution affects around one third of all river surface waters in Africa, Asia and Latin America, putting the health of millions of people at risk [26].

Intensive use of fertilizers, agrochemicals and animal waste can accelerate the eutrophication of freshwater and coastal marine ecosystems and increase groundwater pollution. Most of the largest lakes in Latin America and Africa have seen increasing anthropogenic loads of phosphorus, which can accelerate eutrophication processes. Increased discharges of inadequately treated wastewater, resulting from economic and industrial development, intensification and expansion of agriculture, and growing volumes of sewage from rapidly urbanizing areas are contributing to the further degradation of water quality in surface and groundwater around the world. As water pollution critically affects water availability, it needs to be properly managed in order to mitigate the impacts of increasing water scarcity [26].

The municipal and industrial wastewater treatment in high-income, upper middle-income, lower middle-income and low-income countries are about 70, 38, 28 and 8%, respectively. Globally over 80% of all wastewater is discharged without treatment. In high-income countries, the motivation for advanced wastewater treatment is either to maintain environmental quality, or to provide an alternative water source when coping with water scarcity. Recently, the situation of water security in the most populous and rapidly developing mega cities of Asia is worsening because of major challenges resulting from overexploitation of groundwater, skewed water supply and demand due to population explosion and negative impacts of climate change [27].

In addition to hydrologic and climatic impacts, the non-climatic drivers of freshwater systems are changes in population, food demand, economic growth, technology, living standard and societal values of freshwater ecosystems. Land use change, construction and management of reservoirs, pollutant emissions, water treatment and water management influence availability and quality of freshwater at the national and international level.

5. Impact of global climate change on water resources

A large volume of data base is now available on impact of climate change of global water resources. According to IPCC World temperature, humidity and precipitation will change significantly by 2030 and 3050 due to climate change [36]. The variations in the changes in precipitation in a warming is complex across the regions due to climate change will not be uniform (**Figure 7**). The high latitudes and the equatorial Pacific are likely to experience an increase in annual mean precipitation by the end of this century. In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease, while in many mid-latitude wet regions,

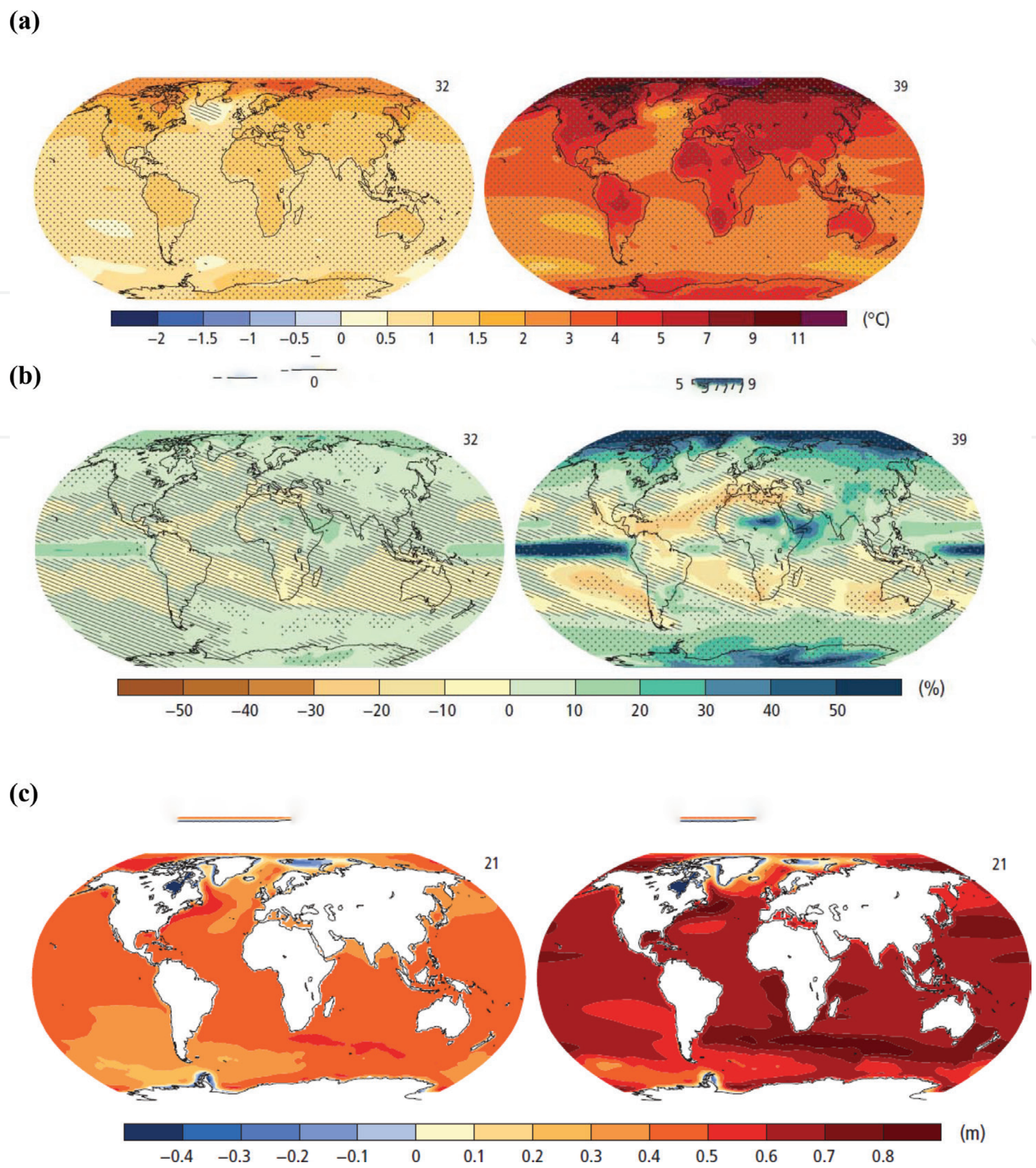

Figure 7.
Projections for the 2081–2100 period under the scenarios for figure (a) change in annual mean surface temperature and figure (b) change in annual mean precipitation, in percentages, and figure (c) change in average sea level. Changes are shown relative to the 1986–2005 period. Source [36].

mean precipitation will likely increase. Extreme precipitation events over most mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent as global mean surface temperature increases. Globally, it is likely that the area encompassed by monsoon systems will increase and monsoon precipitation is likely to intensify and regional variability [28]. Analysis of historical time series on the occurrence of hundred-year floods in large-scale river basins around the world with the relationship of climate change showed that intensity of flood due to climate change will continue to grow in the future [29].

Continuous increase in greenhouse gas emissions is affecting the global climate that altering the local precipitation, temperatures and atmospheric composition [29, 30]. The global temperature increased by 0.85°C during 1880–2012, and will further increase by 0.3–4.8°C until 2100 [31]. Such global warming will produce significant effects on water resources and freshwater ecosystems [31, 32]. The effects and intensity of climate change will vary from region to region [33].

5.1 Regional variability

Asia: Arid and semi-arid regions in northwestern China are very vulnerable to the effects of climate change due to their fragile ecosystems and scare water resources [34–36]. This region characteristically experiences an extremely dry desert climate with low amounts of infrequent rainfall and strong potential evaporation [34]. Many studies indicated that this region is especially sensitive to climate change because the main water sources in this region come from high elevation glaciers and snowmelt through the largest inland Tarim River which flows through the arid and semi-arid region of northwestern China. [33].

The effects of climate change on water resources of the Hotan River Basin in Xinjiang of China was assessed using hydrological models to evaluate responses of discharge, extreme events, evapotranspiration and snowmelt accumulation with the effects of changing climate [37, 38]. The precipitation is projected to experience an overall increase with rates ranging −1.2 to 32.7%. The dry season is predicted to have relatively higher increases than the wet season while a slightly decreasing trend was predicted for July (August and September). The projected average temperature was expected to increase by 1.60–2.61°C. The projected maximum temperature increased slightly during summer and autumn, which represents the predicted warmer daytime temperatures. Discharge will increase with an increase of precipitation. With an increase in temperature, the discharge significantly decreased. The evapotranspiration rate will increase significantly by 7.4–31.3%. Climate change is predicted to lead to stronger changes in peak flow. Stream flow is generally predicted to increase, while the shrinking of snow storage and a reduction in the snowpack will sharply reduce the solid water storage capacity of the landscape. The increasing frequency of extreme events and a spatiotemporal redistribution of water resources will produce great challenges related to agricultural water allocation and management in this region.

Climate change could have a significant impact on drought in North Korea. Drought characteristics in the Hwanghae Plain of North Korea were analyzed from 1981 to 2100 [28]. The results indicated that severe drought is more likely to occur in future as a result of climate change. The seasonal drought conditions were also significantly influenced by climate change.

In a high density populous country like Bangladesh, the effects of climate change on the surface and ground water resources is severe. Changes to water resources and hydrology could lead to adverse impact on the country's economy, where the population is dependent on the surface water for irrigation, industrial production, navigation and various other activities.

Water resources of Bangladesh would be severely affected due to adverse impact of climate change will the most critical for Bangladesh – largely related to coastal and riverine flooding and also enhanced possibility of winter (dry season) drought in northern areas. Both coastal flooding (from sea and river water), and inland flooding (river/rain water) are expected to increase. Flood prone area constitutes about 30% of the land mass and is spread throughout the country. The areas adjacent to major rivers and chars or riverine islands are expected to experience higher intensity flooding. Droughts will be prevalent in the north-west zone of Bangladesh and predicted to reach out into the mid-western region and in the south Cyclones, floods, coastal erosion, and salinity problems may intensify and become more frequent in the 19 districts situated in the coastal zone of Bangladesh. Salinity intrusion from the Bay of Bengal already penetrates 100 kilometers inside the country during the dry season while climate change in its gradual process is likely to further deteriorate the existing scenario. There are 13% areas are with salinity in the southwestern coastal districts of Bangladesh at present, which will increase 16% in 2050 and 18% in 2100 [23].

Europe: The main climate change consequences in Europe related to water resources are increases in temperature, shifts in precipitation patterns and snow cover, and a likely increase in the frequency of flooding and droughts.

Depending on the region, climate change will have widely differing effects on Europe's water. Higher temperatures will generally intensify the global hydrological cycle. Annual precipitation trends in Europe indicate that northern Europe has become 10–40% wetter over the last century, whereas southern Europe has become up to 20% drier. Over the last century annual river discharge increased in some regions, such as Eastern Europe, while it has fallen in others, such as southern Europe.

Climate change may also markedly change the seasonal variation in river-flow. Higher temperatures will push the snow limit upwards in northern Europe and in mountainous regions. This, in conjunction with less precipitation falling as snow, will result in a higher winter run-off in northern European and mountain-fed rivers. Moreover, earlier spring melts will lead to a shift in peak flow levels. As a result of the declining snow reservoir and decreasing glaciers, there will be less water to compensate for the low flow rates in summer.

Climate change tends to increase the frequency and intensity of rainfall; there may be an increase in the occurrence of flooding due to heavy rainfall events. Groundwater recharge may also be affected with a reduction in the availability of groundwater for drinking water in some regions.

In the long-term most climate change scenarios predict that northern and Eastern Europe will see an increase in annual average river flow and water availability. In contrast, average run-off in southern European rivers is projected to decrease. In particular, some river basins in the Mediterranean region, which already face water stress, may see marked decreases of water availability.

The change in temperature is generally more pronounced in higher latitudes, and the air temperature over the European continent has warmed more than the global average, with a 0.8–0.95°C increase since 1900. Important are the regional characteristics of temperature change: the warming has been greatest in Northwest Russia, northern Scandinavia and western Mediterranean. Other parts of Europe, especially central Europe and the eastern Mediterranean coast, show lower increases in temperature or even some decreases (Southeast Germany, Northeast Italy, Macedonia and northern Greece).

The observed higher temperatures stimulate the global hydrological cycle (more evapotranspiration leads to more water vapor in the atmosphere and to more precipitation). Consequently, the average atmospheric water vapor content has increased since at least the 1980s over 10 land and ocean as well as in the upper troposphere [39]. Large areas in the Mediterranean region and in central and eastern Europe experienced a decrease in precipitation over the last century. The observed precipitation trends for the period from 1900 to 2000 show a contrasting picture between increases in northern Europe by 10–40%, and decrease in southern Europe with up to 20% less precipitation, especially in the winter season [40, 41].

River discharge decreased considerably in some southern European river basins and increased in some rivers of Eastern Europe. Extreme floods occurred during the last decade in Germany, Austria, the Czech Republic, Hungary and Poland. A long-term trend toward shorter duration of ice cover has been reported for lakes in Finland and Switzerland. Changes in Europe's water resource will have consequences for several economic sectors. Low water and droughts have severe consequences on most sectors, particularly agriculture, forestry, energy, and drinking water provision. Moreover, wetlands and aquatic ecosystems will be threatened.

Africa*:* The major effects experienced in different African countries are summarized in **Table 6**. Countries in sub-Saharan Africa are likely to suffer the most devastating impacts of climate change. Effects of climate change on water resources in Africa include: flooding, drought, change in the frequency and distribution of rainfall, drying-up of rivers, melting of glaciers, receding of water bodies, landslides, and cyclones among others. Much of Africa is vulnerable to flooding: flood is the most prevalent disaster in North Africa, the second most common in East, South and Central Africa, and the third most common in West Africa [42].

Latin America and Caribbean: Climate change is an important agenda in Central America. This region, together with the Caribbean, is highly vulnerable to the effects of climate change in Latin America. Climate change is manifesting itself through higher average temperatures and more frequent droughts that result in higher water stress, and through the rising frequency of extreme weather events such as tropical storms, hurricanes, floods and landslides, all of which pose significant challenges in the water supply and sanitation sector [43].

Results showed that the regional 16 countries of South America from North West, Central, Northern, Southern and NW Central regions could experience a range of runoff changes depending on whether and how climate change affects precipitation and temperature patterns over the continent [44]. The water availability in the region will be negatively affected by climate change in the next century. Climate change impact assessment indicates that water availability, as reflected by the projected water balance, will likely decrease in most of Nicaragua's basins [45, 46]. The three future scenarios analyzed earlier are in agreement that by 2050 the water

Country	Climate change related effects
Algeria	Mountainous areas subject to severe earthquakes; mudslides and floods in rainy season
Angola	Locally heavy rainfall causes periodic flooding on the plateau
Botswana	Periodic droughts; seasonal August winds blow from the west, carrying sand and dust across the country, which can obscure visibility
Burkina Faso	Recurring droughts
Burundi	Flooding, landslides, drought
Cameroon	Volcanic activity with periodic releases of poisonous gases from Lake Nyos and Lake Monoun volcanoes
Central African Republic	Hot, dry, dusty winds affect northern areas; floods are common
Chad	Hot, dry, dusty winds occur in the north; periodic droughts; locust plagues
Cote d'Ivoire	Coast has heavy surf and no natural harbors; during the rainy season torrential flooding is
Democratic Rep. of the Congo	Periodic droughts in the south; Congo River floods (seasonal); in the east, in the Great Rift Valley, there are active volcanoes
Egypt	Periodic droughts; frequent earthquakes, flash floods, landslides; hot, driving windstorm occurs in spring; dust storms, sandstorms
Ethiopia	Geologically active Great Rift Valley susceptible to earthquakes, volcanic eruptions; frequent droughts
Gambia	Drought (rainfall has dropped by 30% in the last 30 years)
Ghana	Dry, dusty, northeastern winds occur from January to March; droughts
Glorioso Islands	Periodic cyclones
Kenya	Recurring drought; flooding during rainy seasons
Mali	Hot, dust-laden haze is common during dry seasons; recurring droughts; occasional Niger River flooding
Morocco	Northern mountains geologically unstable and subject to earthquakes; periodic droughts
Mozambique	Floods
Namibia	Prolonged periods of drought
Niger	Recurring droughts
Nigeria	Periodic droughts; flooding
Senegal	Lowlands seasonally flooded; periodic droughts
Somalia	Recurring droughts; frequent dust storms over eastern plains in summer; floods during rainy season
South Africa	Prolonged droughts, floods
Sudan	Dust storms and periodic persistent droughts
Swaziland	Drought
Tanzania	Flooding on the central plateau and south-eastern coastal areas during the rainy season;
Zimbabwe	Recurring droughts; floods and severe storms are rare

Table 6.
Climate change-related effects on water resources in Africa.

balance will be reduced in many areas of the country. A reduction in surface water will cause a reduction in groundwater levels and the amount of water available for agriculture, potable water supply and other uses. Current flood-prone areas on Nicaragua's Pacific and Atlantic coasts will likely be exposed to higher runoff than what they are experiencing today.

North America: Climate change is expected to alter hydrologic processes in the Pacific Northwest region of North America, thereby affecting key resources and processes including water supply, infrastructure, aquatic habitat, and access. A warmer climate will affect the amount, timing, and type of precipitation, and the timing and rate of snowmelt which will in turn affect snowpack volume, stream temperature. Altered precipitation patterns would also affect vegetation which would in turn affect water supply [47–50]. There is some indication of increased drought severity and duration in the western and southwestern United States. There is a trend toward reduced mountain snowpack and earlier spring snowmelt runoff peaks across much of the western United States. This trend is very likely attributable at least in part to long-term warming may have substantial impacts on the performance of reservoir systems.

Australia: Plenty of studies have been carried out on the quantitative analysis of the influence of climate change on the hydrological processes. Analysis showed that in 22 basins in Australia will have a change of precipitation and potential evapotranspiration by 1% would cause a change of runoff by 2.1–2.5% and 0.5–1.0%, respectively [51]. Water quality is sensitive to both increased water temperatures and changes in precipitation.

Thus, it appeared from above discussions that climate change will change the world of the present situation of the hydrologic cycle, and cause the redistribution of water resources in time and space.

6. Challenges

6.1 Food security challenges in the globe

The prevalence of undernourishment (POU) in the globe declined considerably in the past decades and reached to 10.9% in 2017. It is projected that POU will have increasing trend beyond 2017 due to persistent conflicts in regions, adverse climate events and economic slowdowns that had affected more peaceful settings and worsened the food security situation. Evidence confirms that lower levels of per capita food consumption in some countries and increased inequality in the ability to access food in the populations of developing countries are contributing to increasing trend in POU [52, 53].

Africa has highest proportion of population (20.4%) having suffering from PoU (more than 256 million people). The prevalence of undernourishment in Africa and Oceania has been increasing for a number of years. This trend is observed in all sub regions of sub-Saharan Africa except for Eastern Africa. A further slight increase is seen in Southern Africa, while a significant uptick is seen in Western Africa, possibly reflecting factors such as droughts, rising foods prices and a slowdown of real per capita Gross Domestic Product (GDP) growth (**Table** 7).

Asia has the highest number of people undernourished (515 million, 11.4% of population). Although In the past decades Asia had decreasing trend in POU until recently it is ended now. Western and South-eastern Asia are among those contributing to this slowdown in the decreasing trend, reflecting the fact that countries in South-eastern Asia have been affected by adverse climate conditions with impacts on food availability and prices, while countries in Western Asia have been affected by prolonged armed conflicts [52].

	Prevalence of undernourishment (%)					
	2005	2010	2012	2014	2016	2017
WORLD	14.5	11.8	11.3	10.7	10.8	10.9
AFRICA	21.2	19.1	18.6	18.3	19.7	20.4
ASIA	17.3	13.6	12.9	12.0	11.5	11.4
LATIN AMERICA AND THE CARIBBEAN	9.1	6.8	6.4	6.2	6.1	6.1
OCEANIA	5.5	5.2	5.4	5.9	6.6	7.0
NORTHERN AMERICA AND EUROPE	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5

Table 7.
Prevalence of undernourishment in the world.

South America has relatively low level of undernourishment, and the situation on POU is deteriorating. POU has increased from 4.7% in 2014 to a projected 5.0% in 2017.

The growth in global food production was higher than the population growth due to adoption of high yielding variety seed, fertilizer and irrigation technology (**Figure 8**). Over the past 50 years, the amount of food available per person has increased by 20%. During the second half of the twentieth century, global food availability and access developed rapidly enough to supersede population growth. As a result, many countries improved their food security and made impressive achievements in reducing hunger and malnutrition by 2015. With the existing technology it will be difficult to boost food production further in the future, specifically during 2030 and 2050. Breakthrough in technology should include new varieties of (rice and wheat) with much high yield ceiling, efficient resource management, faster mechanization and developing high skilled farmers with wider employments of women would be need to transform global agriculture to feed the increased population in the coming decades.

Promoting sustainable agricultural productivity growth is the key to ensuring food availability at affordable prices. While it is likely to become increasingly difficult to push yield frontiers at a constant percentage rate of growth, there is great scope for developing countries to close the yield gap between actual and potential. There is much less scope for increasing cultivated land area of the world.

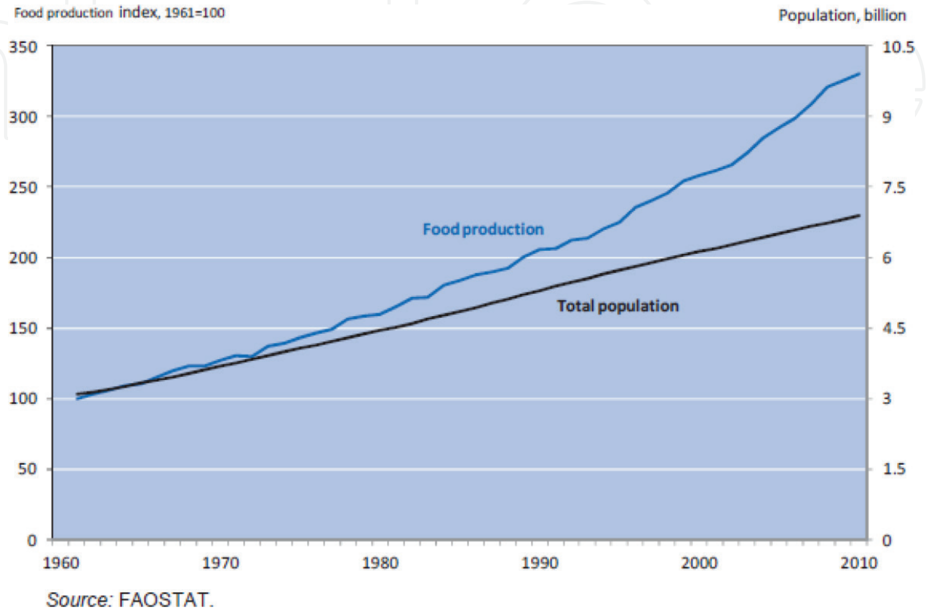

Figure 8.
Global food production and population growth.

So, it is necessary to improve yields of food grains rather than expanding cultivated area. Moreover, a large share of the world's agricultural production is based on the unsustainable exploitation of water resources. There is a need for policies to manage both land and water resources sustainably.

In the coming decades food security threatened due to the fact that climate variability and extremes are negatively affecting agricultural productivity globally. Rising temperature and variability in precipitation would bring changes in global cropping areas, cropping intensity and crop yields. A number of studies shown evidences that both cropping intensity and cropped areas are negatively affected by climate variations and extremes. For example, in the Viet Nam Mekong Delta, variations in the timing and extent of flooding in the wet season and salinity intrusion in the dry season are affecting rice cropping cycles. Recent occurrence of severe floods in Bangladesh in 2018 led to failure of Boro rice crop and threatened its food security. Of course, climate impacts vary between regions, countries, and within a given country due to the diversity and complexity of agricultural systems.

Crop yields in many countries have suffered from changes in temperature and precipitation, which have affected global aggregate rice, wheat and maize yields. A number of studies indicated that heat and water stress resulting in significant global inter annual variability of yields for rice, wheat and maize. Global Synthesis of 144 studies across all regions showed that yield of maize and wheat could be reduced by 20.6 and 39.3% due to drought [54]. Evidences shows that yields of rice, wheat and maize will be declined by a significant amount (roughly one fourth) toward the end of this century due to climate factors (**Box 1**). IPCC Fifth assessment report projected a negative yield impacts for all crops for 3°C of local warming without adaptation across the globe, even with benefits of higher CO_2 and rainfall. South Asia and southern Africa in the absence of adaptation, would suffer the most negative impacts on several important crops [7].

The existence of large numbers of undernourished people is correlated with reduced yields due to increased climate variability and extremes. For instance sub-Saharan Africa has a high level of undernourished people, a region that already has the lowest crop yields globally; increasing temperatures reduced yields for

By the end of this century, the average global temperature is predicted to rise due to the increasing release of greenhouse gases into the atmosphere. Different predictive models inferred that climate change would reduce yields of major cereal crops across different regions of the globe due to rising temperature, resulting in food insecurity challenges.

Rice

Various researchers have shown that global warming can have a negative impact on the yields of paddy produced around the world [55]. It is projected that paddy yield will decrease by 10–15% [56, 57]. In Malaysia that a 2°C temperature increase could reduce paddy yields by 0.36 t ha^{-1} [58]. Temperature increase more than 4°C reduced rice yield in Bangladesh by 36% [59].

Maize

Maize yield in Malawi will decrease 14% by mid-century, and 33% by the century's end because of climate change, in China in maize yield will decline by 35% in 2030 [60], in USA corn yields are projected to decrease further by 20–50% by 2050 [61], in Africa maize yield will decrease by 20% [62], In France, USA, Brazil, and Tanzania, maize yields reduced by about 0.5 t ha^{-1}per 1°C raise in temperature [63].

Wheat

Global climate changes and extreme weather events will have a huge impact on the production of wheat, one of the most widely consumed cereals. In France wheat yield would be reduced by 3.5–12.9% in the medium term from 2037 to 2065, it will further decline by 14.6–17.2% by the end of the century [64]. In China, researchers reported that wheat production rates would be reduced by 3–10% due to a 1°C [65]. In Turkey wheat production would decline by 8–23% by the end of 2100. In Bangladesh 2% increase in winter season temperature wheat yield will reduce by 20 [59] and 4% increase in temperature reduced its yield by 31% [59].

Box 1. *Reduction in cereal yields due to climate change* maize, sorghum and groundnuts. In semi-arid climate regions such as Central Asia, the Near East, and Northern Africa, cereal production is also highly dependent on climate variability Drought is one of the most important climate events that have been shown to have a negative impact on production. For many countries, there is a high negative correlation between drought indicators and food production. The highest correlations occur in semi-arid countries or drought-prone continental climates (example. Central Asia). In rural India, higher numbers of hot days during the agricultural season are leading to lower crop yields. The impact of drought on decreasing crop yields is widely documented [58].

Apart from production side, post-harvest loss in food is huge and reducing food availability which accounting around one-third of all production in developing countries. Food availability could be enhanced and made sustainable through reducing post-harvest loss with increased investments in market infrastructure, value addition and food processing.

The principal cause of food insecurity is poverty and inadequate incomes. Although globally there is enough food available but many people are too poor to afford it. Tighter world food markets could not quickly respond to supply shocks due to natural calamities causing less food available associated with a price hike reducing affordability of the poor people. For instance incidence of devastating cyclone Sidr in 2007 and Aila in 2009 caused food shortage of Bangladesh and created soaring food prices that hit hard the poor people. Therefore, broad-based income growth is the key to lasting reductions in global hunger. Moreover, promoting international trade could contribute much toward global food availability. Food deficit countries would be able to import food from the surplus countries. Functioning of flexible world food markets would reduce volatility in food prices and consumers will be benefited during food crisis with ample supply at affordable price. Moreover, export promotion would increase income of the small farmers producing exportable fresh commodities. For instance large numbers of small farmers are linked in production system of fresh vegetables, fruits and shrimp in Bangladesh and export chains. The small farmers are getting higher prices with the promotion of export of these produces and their income and purchasing power are improving.

6.2 Challenges of desalination

We have discussed earlier about scarcity of fresh water in the globe. Only 2.5% of the Earth's water is fresh non-salty and major portion of it is ice and glaciers (97.2%) contained within the Earth's Polar Regions. In addition, another 1.8% of that exists below ground in the form of underground rivers and aquifers. This means that the amount of water that exists as groundwater, rivers, lakes, and streams which is immediately accessible for drinking and irrigation is just 0.7%. The remaining 97.5% is salt water available from oceans.

Because of population growth, industrialization and climate change, water scarcity has become one of the most pervasive problems afflicting people throughout the world. Presently, over one-third of the world's population lacks access to safe drinking water and suffers the consequences of unacceptable sanitary conditions [66, 67]. According to the International Desalination Association (IDA), in June 2011, 15,988 desalination plants operated worldwide, producing 66.5 million cubic meters per day, providing water for 300 million people. However, the vast majority of this production took place within countries where access to freshwater is limited and cheaper alternatives (such as drilling for aquifers) are not available.

The researchers have been seeking cost-effective ways of turning sea water into drinking water for decades. Development continued and in the 1970s, commercial membrane processes - such as reverse osmosis (RO) and electro dialysis (ED) - began to be used more extensively. Since 1980 reverse osmosis (RO) desalination technology is commercially used in regions and municipalities all around the world where fresh water supplies were limited. At present, reverse osmosis (RO) accounts for approximately 60% of installed capacity. Desalination is an energy intensive technology, and its future costs will depend much on the price of energy Hence it is necessary to develop more cost-effective processes and use renewable energy for desalination plants.

Environmental considerations are also a going concern for desalination of water plants. There was a rapid growth in the installation of brackish water reverse osmosis (BWRO) desalination facilities in the past decade. Nations, spanning from Australia to Spain, from the United States to China, all have BWRO desalination projects accomplished and construction of new plants is expected to increase in the near future. These plants produce a waste concentrate stream in the vicinity of 38,000–57,000 m^3/day. Since these plants are placed far from the coast, direct discharge of the brine will easily affect the surrounding ecosystem. So, the issue is to develop energy efficient desalination minimizing discharge of brine and making environment friendly. More research is needed to develop cost effective and environment friendly desalination technology [68, 69].

7. Development opportunities

Pressures on water resources are increasing with the expanding scale of global development. Impacts from these pressures range from ecological and hydrological consequences of over-allocation of river basins and groundwater aquifers, to public health consequences and ecological damage arising from water quality deterioration [70].

The core concern is that demand for food and water is increasing across globe. Scarcity of future freshwater generation capacity and escalating costs of exploitation are great challenges. The problem would be further aggravated due to the effect of climate change and environmental impact. Thus, the fundamental policy and management concerns are how the available water resources could be managed more sustainably to enhance the efficiency of food production and to safeguard environmental systems and their provision of goods and services. In the face of the growing scarcity of water resources and the need for better management emphasis should be given on increasing current water use efficiency.

When considering economic efficiency of water resource use from a sustainability point of view as 'Scarce natural capital' it is important that water must be managed in such a way as not to reduce the opportunities for potential use by future generations. In this context, in addition to water use efficiency, it is much important to consider water withdrawal and use for irrigation purposes can have negative impacts on wetlands, aquatic ecosystems and corresponding ecological functions. Negative impacts also include external costs, such as those from water logging, salinity intrusion and soil erosion, which are also not usually incorporated into the economic price of irrigation water. Furthermore, even though water is being used more efficiently, the ecological limits to water use must be considered.

Water resources and effects are often non-marketed. It is much important to ensure that the 'true' economic values of such resources are accounted for making decisions on investment for water linked with environmental issue. Water productivity will have to be enhanced significantly in the coming decades via efficiency gains enabled through economic measures such as valuation, pricing and trading, as well as through technological innovation.

Unsustainable development pathways and governance failures have generated immense pressures on water resources, affecting its quality and availability, and in turn compromising its ability to generate social and economic benefits. The

Objective	Strategy	Actions
1.Balancing water supply and demand for sustainable inclusive growth	1. Water supply management	(i) Additional surface irrigation development from rivers improvement, (ii) Augmentation of surface water supply to Municipality of Dhaka, (iii) Deep ground water development, (iv) wastewater reuse
	2. Water demand management	(i) Adopt less water demanding crops, (ii) Irrigation water saving, technologies, (iii Domestic and industrial water saving
	3. Resource planning and protection	(i) River basin management, plans, (ii) Water resource development and protection in river basin
2. Maintaining water quality for health, livelihood and ecosystem	1. Enhancing fresh water flow	(i) Off take stabilization of the river Jamuna and flow augmentation in the north and central region, (ii) River management and smart dredging
	2. Pollution control and treatment	(i) Expansion of clean industrial production technologies, (ii) Low impact agriculture and aquaculture, (iii) Urban wastewater master plan, (iv) Monitoring permitting and control, (v) River basin environmental management plan

Table 8.
Development Strategies formulated in Bangladesh Delta Plan 2100.

planet's capacity to sustain the growing demands for freshwater is being challenged, and there can be no sustainable development unless the balance between demand and supply is restored and water quality is maintained for health, livelihoods and ecosystem which is addressed in the recent Fresh Water Development Strategies formulated in Bangladesh Delta Plan 2100 [23] (**Table 8**).

A number of options could be suggest for developing global water resources, enhancing water use efficiency and mitigate adverse impact of climate change on water availability and increasing agricultural productivity in the globe: (1) Augmentation of surface water through excavation of rivers, water bodies, development of water reservoirs, improved drainage, saline intrusion control, flood management and recharge of ground water. (2) Use water saving technology for improving efficiency of water and install facilities to reduce distribution losses in the crop field. Activities should include: (i) Reduce water losses in existing schemes through improved water management (capacity building of water management organizations), development of water saving techniques or rehabilitation of existing schemes.(3) Reduce impact of saline water intrusion in the main land and enhance river water flow. The focused activities are management of embankment and tidal river; expansion of surface water irrigation with construction of reservoir for monsoon water; and improved brackish water resource management practices. (4) Development of less water consuming and drought tolerant crop varieties, (5) Conservation of water resources for future use, (6) Wastewater treatment for reuse (7) Development and utilization of cost effective environment friendly desalination technology. (7) Development of climate smart and water precision agriculture and (7) Research on technology generation and dissemination.

8. Policy and institution

Favorable policy and institutional climate is needed for enhancing efficiency, conservation and sustainability of global water resource and increased food production in 2030 and 2050. The prospects for the implementation of sustainable water management policies to reverse degradation trends and conserve resources for the future will be effective if appropriate institutional set up could be established. Collaboration would be needed among the national and international water institutions and governments.

Institutional and political measures are further important building blocks for improved water management. In many regions, water is seriously under-valued, especially in the agricultural sector. This is one major reason for over-use and wastage. There is often a lack of well-defined property rights or are not implemented.

A range of technical and institutional solutions might be available to increase food production by almost 70% by 2050; to feed the increased population, reduce hunger and improve livelihoods for the poorest; and to minimize or mitigate degradation of land and water and of the broader ecosystems. They need to be adapted to local conditions and socio-economic contexts. Improved planning, linked to smart incentive packages, can then establish a framework for investment that assigns agreed values to natural capital. On this basis, land and water management that is efficient, equitable and sustainable can be encouraged at all levels. Some of the institutional development options could be suggested are: (1) Capacity development of farmers 'water associations, (2) Capacity development of municipal water distribution agency and water development institutions, (3) Adapting participatory water resource development planning for sustainable water management at local, regional and global. At all level, financing is required for increased levels of investment, and (4) Promoting Public Private Partnership in water sector.

Policies, institutions and implementation strategies should be adjustment at global, national and local levels to develop capacities of organizations and farmers with the knowledge and financial resources. Knowledge sharing at local, national and global levels focusing on land and water systems development will foster socio-economic growth across the globes reducing food insecurity and poverty.

9. Conclusions

World population will be 8.6 billion in 2030 and 9.8 billion in 2050. An additional 2.4 billion people projected to be added to the global population between 2015 and 2050 of which 1.3 billion will be added from Africa and 0.9 billion people from Asia. The growth rates of population and income are the important drivers of world food demand.

As income grows in developing world consumption of starchy-staple foods will decline while spending on animal-based products increases. It implies that income distribution matters for aggregate world food demand.

World cereal equivalent (CE) food demand is projected to be around 10,094 million tons in 2030 and 14,886 million tons in 2050. On the supply side, CE food production is projected to be 10,120 million tons in 2030 and 15,970 million tons in 2050. The world CE food demands would change by 134% from the base year of 2009 while CE food production would change by 151% and thus food production would grow slightly faster than demand yielding a positive gap of 7%. India is first leading country creating largest share of world food demand (24.3%) followed by China (16.7%). Although Bangladesh is small country but densely populated and stood 8th with a share of 2% of world food demand.

The growth rate of global demand for cereals declined continuously during 1969 to 2007 from 2% per annum to 1.3% and projected to fall further to 1.2% in 2030 and to 0.9% in 2050 while world cereal demand would have a significant rise from 940 million tons from the base year 2005/2007 to 3 billion metric tons by 2050. Almost all the increases in the consumption of cereals will come from the developing countries. The developing countries surpassed developed ones in total cereal production in the early 1990s: they now account for 56% of world production and the share will increase to 60% in 2050.

Agriculture is the largest water user accounting 70% of global water withdrawal and rest 30% is used by municipal, energy and industrial sectors. Global water demand is projected increase by 55% between 2000 and 2050 from 3500 to 5425 km^3. In addition to demand from the agricultural sector, large increases are predicted for industry (400%), energy production (140%) and domestic use (130%) Changing diet toward meat would enhance global water demand for growth of livestock sector and would cause scarcity of fresh water in many areas of the world. The potential for further expansion of irrigation is limited. There are plenty of renewable water resources globally; but they are extremely scarce in regions such as the Near East/North Africa, or Northern China, where they are most needed. Global water scarcity is growing more severe recent years. Research has demonstrated that two-thirds of the world's populations currently live in areas that experience water scarcity.

The availability of water resources is intrinsically linked to water quality. Evidence show that severe pathogen pollution affects around one third of all river stretches in Africa, Asia and Latin America. Release of agrochemicals, animal waste and anthropogenic activities are polluting fresh water, marine ecosystem and ground water.

Climate change will have adverse impact on world water resources through changing temperature, precipitation, melting snow, river flow, flood and drought. There are wide range of variability of these climatic events and vulnerability across various regions of the globe. Climate variability and extremes are negatively affecting agricultural productivity globally. With the existing technology it will be difficult to boost food production further in the future, specifically during 2030 and 2050. A technological breakthrough will be needed with introduction of climate resilient HYVs of wheat and rice to transform global agriculture to feed the increased population in the future.

Post-harvest loss in food is huge accounting around one-third of all production in developing countries. Food availability could be enhanced and made sustainable through reducing post-harvest loss with increased investments in market infrastructure, value addition, and food processing and promoting international trade.

Over one-third of the world's population lacks access to safe drinking water. Currently large number of desalination plants are operating worldwide and providing water for more than 300 million people. These desalination remains an energy intensive process and future costs will continue to depend on the price of both energy and desalination technology. These plants release daily huge brine whose disposal is costly and adversely affect surrounding eco-system.

With rising global water demand the policy and management concerns are manage water resource more sustainably to enhance the efficiency of food production and safeguard environmental systems. Emphasis should be given on increasing water use efficiency and conservation of water resources and ecology. A number of options are suggested for developing global water resources, enhancing water use efficiency and mitigate adverse impact of climate change on water availability in the globe and enhancing food production.

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