Review on Effects of Climate Change on Water Resources

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Abstract— The primary objective of this study is to determine what drives to plan for the impacts of a changing climate. As the climate continues to change, climate scientists have projected changes in water quantities available for human and other uses. A review of the present study has been taken up to quantify the possible impact of the climate change on the water resources of Indian river systems within the constraints of the uncertainty of climate change predictions. Impacts of climate change and climate variability on the water resources are likely to affect irrigated agriculture, installed power capacity, environmental flows in the dry season and higher flows during the wet season, thereby causing severe droughts and floods in urban and rural areas. Climate change impacts on water resources which are addressed and analyzed in the present study include impacts on annual and inter-annual water availability as well as extreme events of droughts and floods. The analysis has been performed to evaluate the severity of droughts and floods and thus identify the vulnerable hotspots that may require attention in view of the climate change in various parts of the country. The analysis is also performed on the blue and green water so as to identify the climate change impacts on these sub-components of water that are responsible for environmental functions and biomass production. The study determines the present water availability in space and time without incorporating any man-made changes like dams, diversions, etc. The same framework is then used to predict the impact of climate change on the water resources with the assumption that the land use shall not change over time. The analysis has also been extended to the detection of extreme events of droughts and floods that may be triggered on account of the climate change and are of major concern to the local societies. This paper will focus on each and every aspect related to climate change impact assessment of water resources of India.

Keywords: Effects of Climate Change on Water Resources

I. INTRODUCTION

The study evaluates the possible impacts of climate change on water resources of the river basins in India. Figure 1 shows the various regions (according to the Central Water Commission nomenclature) that have been simulated (complete basins ignoring the international boundaries have been taken). Management and protection of the water resources needed to support life and drive the economy is generally left to state governments within the Country. Furthermore, while all disasters are local they tend to be mitigated and managed at the state level. Consequently, planning for and responding to major risks to key resources, especially for water resources, frequently occurs at the state level. In a country that is increasingly politically polarized and drastic changes in weather patterns and water availability increasingly challenge urban and rural areas, how to secure future access to water and mitigating nature based risk has become a significant policy challenge. Twenty-nine out of fifty U.S. states have developed formal water plans to guide their future water supply investments. This means we should also start preparing plans and take factors like climate change into consideration. Although full river systems have been modelled, analyses have been made only for the geographical areas of India. Figure 2 provides the relative proportions of these river systems that fall into the geographical area of India. It may be seen that although the Brahmaputra is a much bigger river system, the two largest systems that cover the geographical area of India are the Ganga and Indus rivers. How future climate change will affect flows in rivers draining from Himalayan headwater tributaries is of serious concern for sustainability of downstream water resources throughout the densely populated Gangetic plain. Runoff from mountain basins is particularly likely to be susceptible to climatic warming as much of such flow is derived from melting of seasonal snow pack and glacier ice. Along the length of the Himalayan arc, however, runoff is influenced not only by snow- and ice-melt but also to varying extents by monsoonal precipitation, the timing, duration and amounts of which are likely to be modified by climatic change.

Most water management strategies are tied to standard operating procedures that prescribe actions based on observed conditions, such as reservoir levels, the time of year, and the amount of snow on the ground. Well, the major reason seen due to which the climate change is occurring so frequently is pollution. Social and economic development depends on the availability and the sustainable management of water resources. Food production also relies on the availability of water at a given place and time, and this availability is also influenced by climatic conditions. Over the last several years, the potential effects of climate variability and change on water availability have received increasing political, social, and economic attention. Despite the levels of uncertainty associated with the magnitude and direction of climate variability and change, they are expected to have impacts on water resources availability, agricultural activities, and human, and ecosystem functions, including tropical region. The anticipated climate variability and change are likely to impact water resources by altering precipitation patterns and intensity, duration and frequency of rainfall events. Such changes in the pattern and nature of rainfall regimes will have effects on surface water and groundwater availability.

Increased fossil fuel use in the past several decades has raised concerns about the depletion of fossil resources in future. This has also raised serious environmental concerns leading to climate change issues. Human activities are responsible for dumping about 8 billion metric tons of carbon into atmosphere every year out of which 6.5 billion tons is from fossil fuel sand 1.5 billion tons from deforestation. Tropical deforestation in Africa, Asia, and South America are thought to be the largest contributors to emissions from land use change globally. Climate change impacts are expected to affect agriculture thus endangering food security, increasing natural disasters, species extinction, spread of vector borne diseases, rise in sea-level and accelerating erosion of coastal zones. The top carbon dioxide (CO_2) emitters are China, United States, the European Union, India, Russian federation, Japan and Canada based on the data which include CO2 emissions from fossil fuel combustion, cement manufacturing and gas flaring [1]. Power plants in the U.S.A cause about one-third of carbon pollution emissions and are the largest drivers of climate change. Recently U.S.A has announced clean power plan which will accelerate the transition to a clean energy in future to reduce its CO2 emissions by 32% by 2030 below 2005 levels [1]. China has also offered to reduce its emissions by 2030 with the increase in the use of non-fossil sources to 20% by 2030. Based on these initiatives U.S. and China's per capita CO2 emissions are likely to reduce to about 12–13% by 2030. India is the fourth largest CO2 emitter in the world with 2000 million tons of emissions with power sector contributing nearly half of the country's carbon emissions. At present India is fifth largest power market in electricity generation in the world which is largely based on fast depleting fossil fuels like coal, gas and oil. The hydro and renewable power generation has a little share in comparison to the fossil fuels. The analyses are carried out over a 20-year period. The major advantage of the current analysis framework is that it investigates the potential impact of climatic assumptions on farmincome, food security, land uses, and water availability within a single framework.

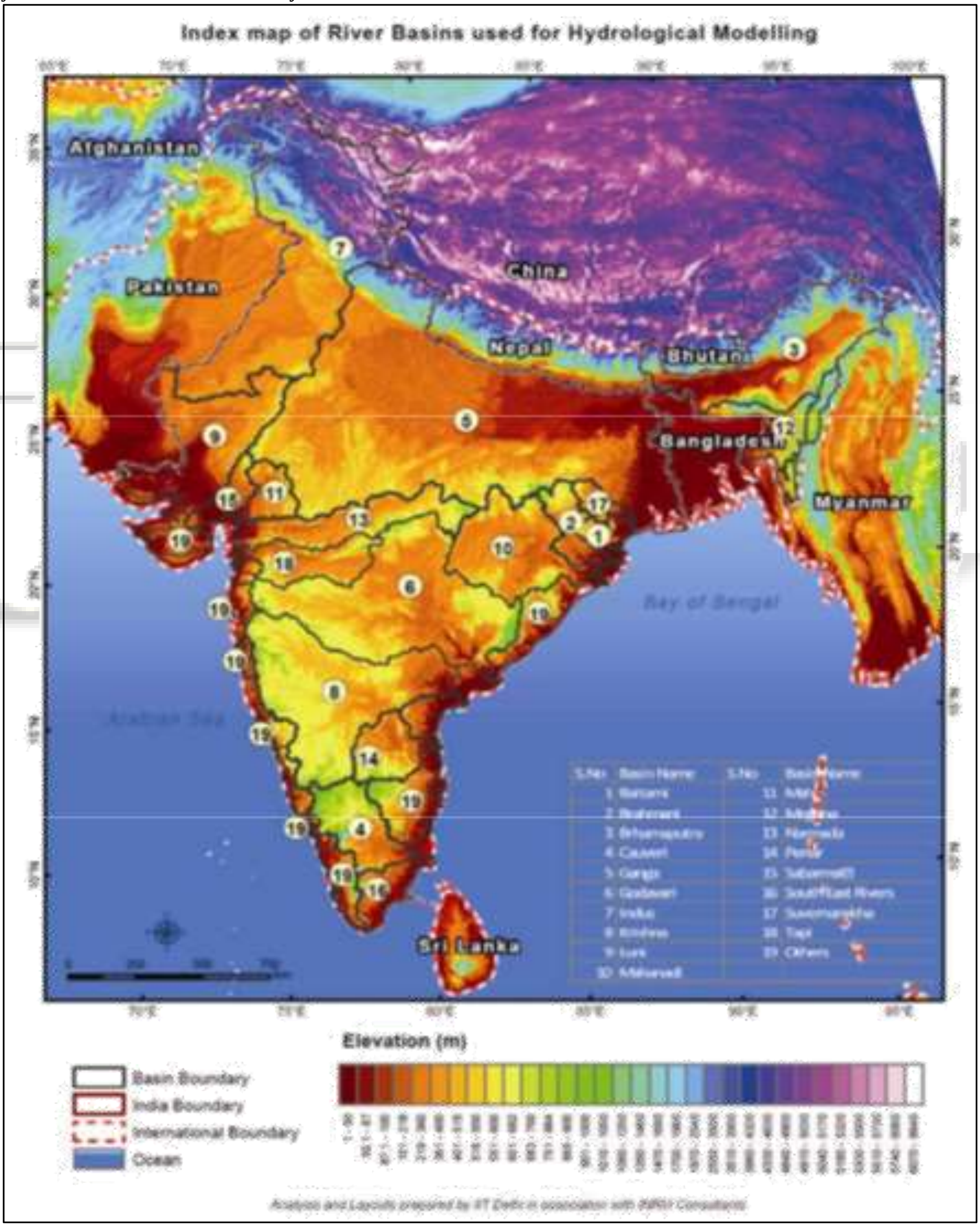

Fig. 1: River basins used for hydrological modelling.

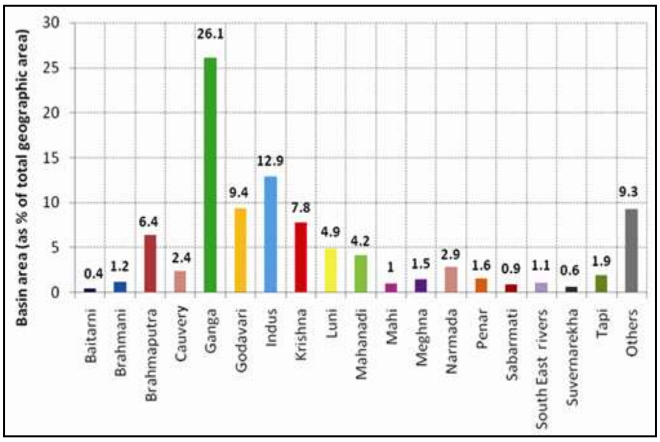

Fig. 2: Areas of river basins of India as percentage of total geographic area.

II. DATA & METHODOLOGY

A. *Data Integration:*

The development and implementation of the framework such as described in this paper required different sets of data, obtained from different sources. The diverse nature of the data sources needed to implement the developed framework required an extensive investment of time in sourcing, preparing, and integrating data. The framework uses climatology data that could be at daily, monthly or yearly timescales, and over different spatial scales such as watershed, sub-basin, basin or region. Farm budget data from the agricultural sector is essential as well. The farm budget data could include crops' water application, crop yields, production cost, crop wholesale prices and groundwater pumping cost in addition to other agronomic data such as cropwater requirements. In addition to agricultural land use, other forms of land usage such as open grassed areas, golf courses, vacant land, residential and commercial land, transportation network land, gullies, and forested areas can be integrated in such frameworks. Information on groundwater characteristics such as aquifer depth, aquifer area, aquifer storativity, and pumping depth were also needed. Climate change projections for India using the Coupled Model Intercomparison Project 5 (CMIP5) ensemble found that, by the 2030s, under a business-as usual representative concentration pathway (between RCP6.0 and RCP8.5) scenario, mean warming in India relative to preindustrial times is likely to be in the range 1.7–2.0 °C while precipitation is projected to increase by 4% to 5% compared to the 1961–1990 (historic) baseline. A trend for increased frequency of extreme precipitation days (e.g. N40 mm/day) is projected for the 2060s and beyond. The climate assumptions in this research refer to projected variability and change in the annual average precipitation. Aggregating the available monthly precipitation data for 24 years from 1989 to 2012, the total annual average precipitation is calculated. Three different hypothetical future climate assumptions have been generated using the normal distribution technique. The fourth climate assumption used is the base climate assumption, which uses the current data without any changes. The average precipitation per unit of land (hectare) is estimated by the following equation where the average precipitation Pr_{lkcst} for any land use classification (l), irrigation technology (k), climate assumption (c), subsidy scheme (s), and time span (t) is a function of the calculated average annual precipitation under climate variability and change assumptions and time period.

$$Pr_{lksct} = N\_ (Pct, sc)$$

Parameter (Pct) refers to the average precipitation in thousand cubic meters (CM) per hectare and (sc) refers to the variance in annual precipitation under climate assumptions.

III. EFFECTS OF CLIMATE CHANGES

A. *Diarrhoeal Disease in India:*

In this paper we discuss the impact of climate change on diarrhoea as a representative of waterborne disease affecting human health, taking the Ganges basin of Northern India. To our knowledge no studies have evaluated the impact of future climate change on diarrhoea incidences in India. And no studies have given an all-inclusive estimate on diarrhoea incidences, including beside temperature other relevant climate factors.

Despite sustained prevention and treatment campaigns, India remains the country with the highest diarrhoeal mortality in the world. There are significant variations by region; diarrhoea mortality rate was higher than 25 deaths per 100,000 children in northeast, east, and central regions of the country and lower than 12 in the north, west, and southern regions. Girls in central India were found to have a four times higher mortality rate compared to boys in western India.

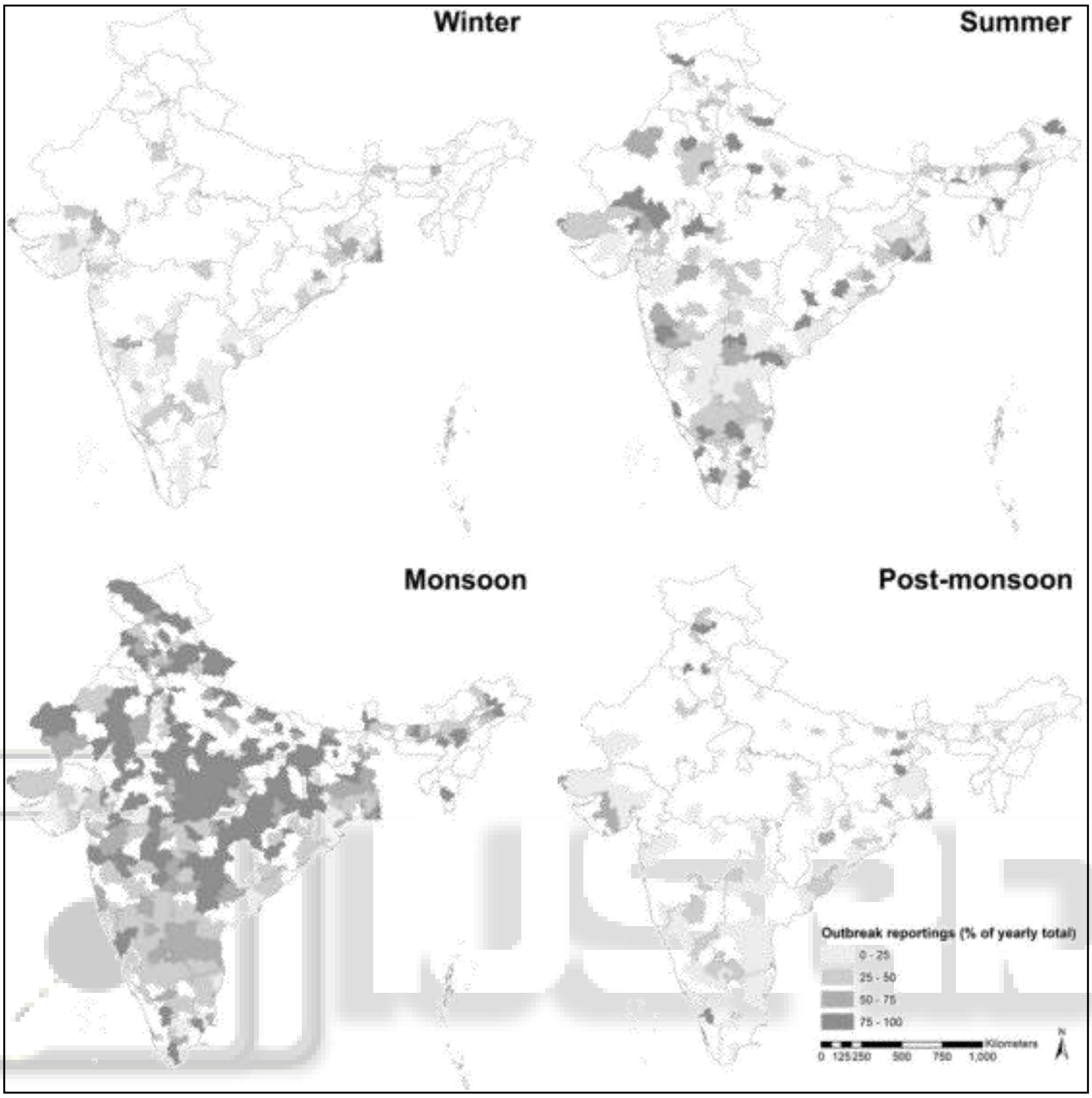

Fig. 3: The relative number of cases of acute diarrhoeal disease outbreaks (waterborne) reported for all districts for the different seasons in India, for the period ofmid-June, 2009–mid-October, 2012. Source: IDSP (http://www.idsp.nic.in/). We defined the relative number of outbreaks per season as the number of outbreaks relative to the yearly total. Winter (December, January, February), Summer (March, April, May),Monsoon (June, July, August, September) and Post-Monsoon (October, November) seasons were determined in correspondence with the division made by the India Meteorological Department.

B. Decreased Precipitation/Droughts:

There are two different types of reasoning on how decreased precipitation or extremes, such as droughts, can affect infectious outbreaks. First, decreased precipitation coupled to water scarcity limits dilution and, thus, increases the concentration level of pathogens in water. Communities relying on these contaminated water resources experience increased outbreaks of water-borne diseases.

C. Rotavirus:

In temperate regions rotavirus peaks during the cooler and dry months between autumn and spring, with winter being the most common for seasonal peaks. The most striking difference between all cause diarrhoea and rotavirus is the opposing effect of increased temperature on the disease. In all-cause diarrhoea bacteria are included as causative agents, which favour warmer temperatures, next to viruses, which have their best survival rates within the ranges of moderate temperatures. Thus, higher temperatures lead to an inactivation of viruses. Regarding temperature increase for rotavirus, the norm is usually an inverse relationship with an impact interval ranging from 0.7%–10%

IV. RESULTS

Climate change impacts on diarrhoea over northern India. Climate impacts on rotavirus over northern India.

A. Adaptive Options:

Actions to improve the health situation are often driven by daily realities and pressures emerging from global challenges and the current development context. However, improvements which are robust on the long term should incorporate future projections of population, economic growth, physical urban expansion, development of infrastructure such as sanitation and health facilities, and climate change. This can pose a challenge at first, but can also generate new incentives and innovations to tackle pressing problems. Here we distinguish three types of measures and make recommendations on their applicability: reactive actions, preventive actions and national policy options.

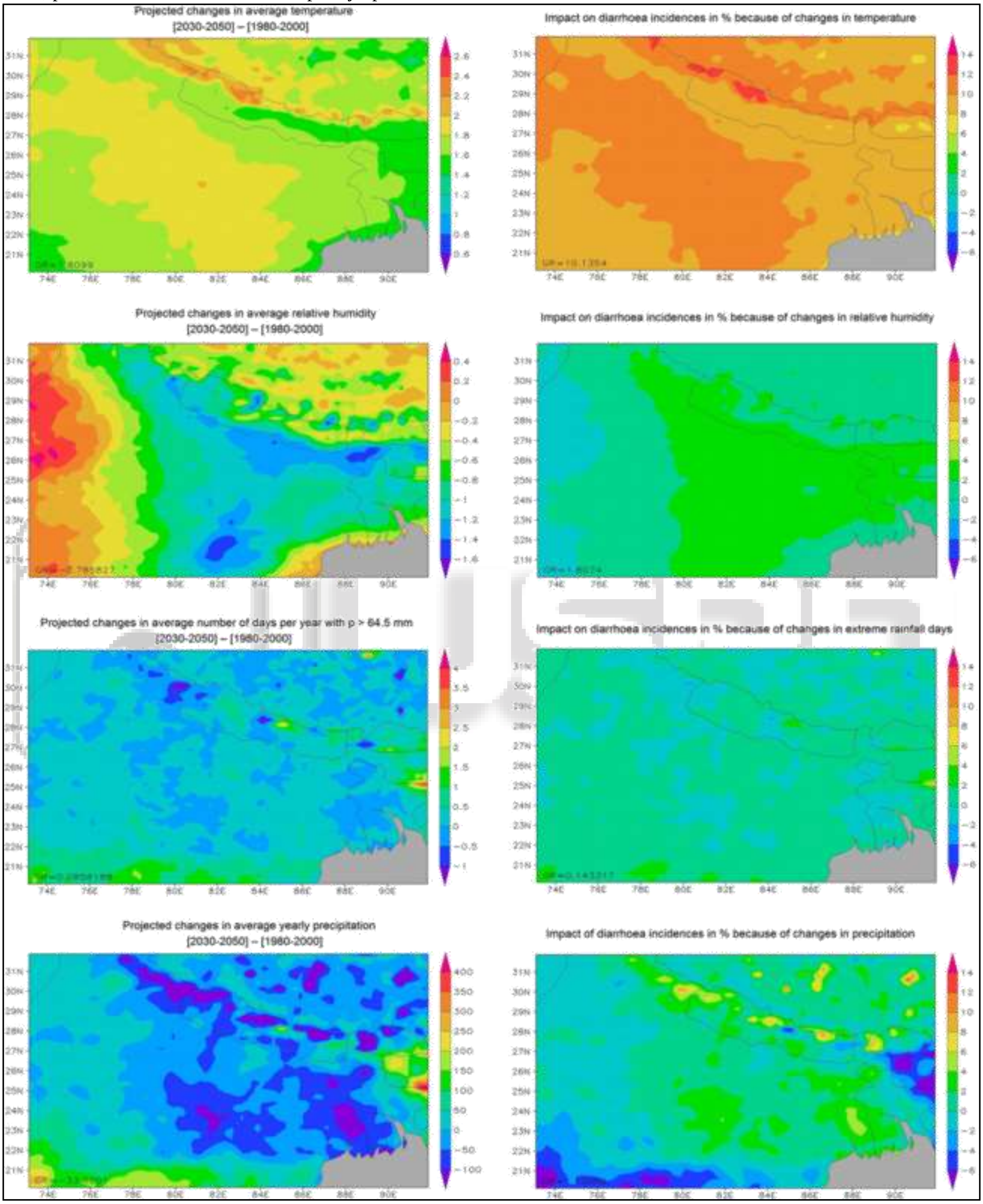

Fig. 4: Projected changes between current and future (2040s) climate for the four relevant all-cause diarrhoea climate factors: increased temperatures, humidity, extreme rainfall, and decreased rainfall (left part of the figure) and their impact on diarrhoea incidences (right part of the figure).

B. Socio-economic changes and impacts on water and food demand, especially in the lowlands:

A pressure on the available water resources only exists if the demand for water at a specific location and at a specific time cannot be met. India is a rapidly changing country where the demand for food and water will change as a result of fast population increase, industrialization and agricultural intensification. Therefore, it is not only important to estimate changes in water availability, but also in water demand caused by these socio-economic changes. Their combined effect will therefore determine the stress on available water resources that would exist across regions in any point of time, and hence which people and areas are vulnerable.

Water demand for irrigation is influenced by different factors like the total extent of irrigated area, the cropping pattern, the efficiency of the irrigation system and the climate dependent evaporative demand. Unfortunately, future scenarios of land use change for India or the Ganges basin (including cropping patterns and irrigated areas) do not yet exist. However, with an increase in the population the demand for food is likely to increase in future. One of the options to meet a growing food demand is increasing crop production by expanding irrigated area. The effect of expanding irrigated area on water demand, sources to extract this water as well as effects on crop yields has been evaluated by using an integrated vegetation and hydrology model.

V. Summary & Conclusion

The results for northern India project an increase in mean annual temperature of 1–4 8C between 2010 and 2050.There is no clear indication of a climatically induced change in annual mean precipitation by 2050, due to strong natural variability. We find that changes in the future water availability are mainly determined by decadal variability, with great uncertainty in the contribution from climate change. The seasonal water availability depends not only on precipitation but also on snow and glacier melt. Through the detailed modelling of the melt from Himalayan glaciers, feeding into hydrological models of the Ganges, an improved assessment of future changes in the seasonality of water is needed. The total water demand mainly depends on the agricultural use. Crop production could see a 90% growth by 2020, if all crops were fully irrigated, 50% above the projected food requirement for the region. However, the available surface water and water from reservoirs will not supply such a demand. Most of the additional water would have to come from ‘‘other sources’’, e.g. groundwater or inter-basin transfers.

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