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Vulnerability and impact assessment of extreme climatic event: A case study of southern Punjab, Pakistan

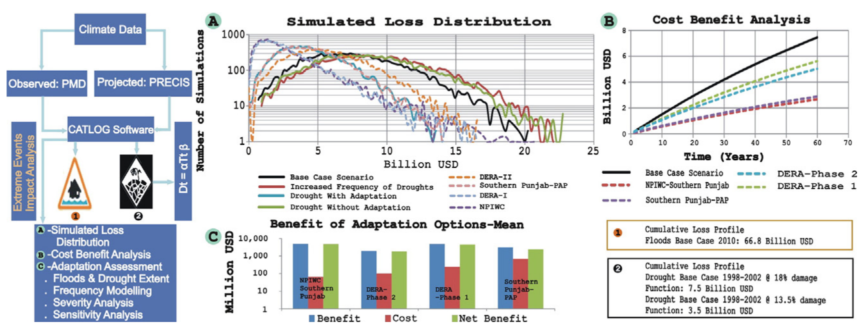
Abdul Qayyum Aslam [a,*], Sajid R Ahmad [a], Iftikhar Ahmad [a], Yawar Hussain [b], Muhammad Sameem Hussain [a]

[a] College of Earth & Environmental Sciences, University of the Punjab, New Campus, Lahore 54000, Pakistan
[b] Department of Civil and Environmental Engineering, University of Brasilia, Brasilia DF 70910-900, Brazil

HIGHLIGHTS

- Climatic extremes including floods and droughts are predicted to increase in coming decades.
- Projected cumulative loss-floods will be USD 66.8–79.3 billion from 2010 base case.
- Irrigation and flood management is least expensive adaptation for floods.
- Droughts loss-A2 Scenario @ 18% damage function ranges from 7.5–8.5 Billion $.
- Drought loss-A1B Scenario @ 13.5% damage function ranges from 3.5–4.2 Billion $.
- Southern Punjab-PAP is high while NPIWC is least expensive adaptation for droughts.

GRAPHICAL ABSTRACT



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ABSTRACT

Understanding of frequency, severity, damages and adaptation costs of climate extremes is crucial to manage their aftermath. Evaluation of PRECIS RCM modelled data under IPCC scenarios in Southern Punjab reveals that monthly mean temperature is 30 °C under A2 scenario, 2.4 °C higher than A1B which is 27.6 °C in defined time lapses. Monthly mean precipitation under A2 scenario ranges from 12 to 15 mm and for A1B scenario it ranges from 15 to 19 mm. Frequency modelling of floods and droughts via poisson distribution shows increasing trend in upcoming decades posing serious impacts on agriculture and livestock, food security, water resources, public health and economic status. Cumulative loss projected for frequent floods without adaptation will be in the range of USD 66.8–79.3 billion in time lapse of 40 years from 2010 base case. Drought damage function @ 18% for A2 scenario and @ 13.5% for A1B scenario was calculated; drought losses on agriculture and livestock sectors were modelled. Cumulative loss projected for frequent droughts without adaptation under A2 scenario will be in the range of USD 7.5–8.5 billion while under A1B scenario it will be in the range of USD 3.5–4.2 billion for time lapse of 60 years from base case 1998–2002. Severity analysis of extreme events shows that situation get worse if adaptations are not only included in the policy but also in the integrated development framework with required allocation of funds. This evaluation also highlights the result of cost benefit analysis, benefits of the adaptation options (mean & worst case) for floods and droughts in Southern Punjab. Additionally the research highlights the role of integrated extreme events impact assessment methodology in performing the

* Corresponding author.
E-mail address: qayyumdhump@hotmail.com (A.Q. Aslam).

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vulnerability assessments and to support the adaptation decisions. This paper is an effort to highlight importance of bottom up approaches to deal with climate change.

1. Introduction

Climate change at the level of governments, business, and community have attained top priority worldwide due to growing understanding of its implications for trade, security, the economy, ecosystems, the well-being of humans and other species (Posas, 2011). There is broad agreement that low-income countries are more vulnerable to current climate variability and future climate change than rich countries (World Bank, 2013). Projected and modelled climate change scenarios show high variability and vulnerability in countries with low economies (Abid et al., 2016). Vulnerability refers to the characteristics and circumstances of exposed societies, systems and assets that make these susceptible to hazards of climate extreme (UNISDR, 2009; Cardona et al., 2012). One of the reason for this vulnerability is the so-called adaptation deficit, that is, limits in the ability of poorer countries to adapt (Fankhauser and Mcdermott, 2014). Adaptation, defined as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects" (IPCC, 2007) is inevitable. Climate change adaptation is crucial for managing risks from extreme events (Hallegatte et al., 2010). Adaptation is a dynamic process by which societies respond continually to changing socioeconomic, technological, and resource regimes (Amaru and Chhetri, 2013). Vulnerability to climate change is subject to the problem of understanding the interaction between multiple climate impacts on water, health, agriculture, prices and non-climate changes (e.g. political, institutional, demographic, economic, social and technological) occurring at different scales (Seaman et al., 2014). In order to explore linkages of food, health and climate change in a typical vulnerability assessment, there is need of a better understanding of the these relations and a greater alignment of policy across these issues (Bradbear and Friel, 2013). Bottom up approaches explore such linkages to deal with extreme event aftermath (Voskamp & Van de Ven, 2013).

To deal with such problem, many researchers practice forms of integrated assessment of climate change, using various modelling and non-modelling approaches (Tol and Vellinga, 1998). Top-down approaches have been stalled on political grounds after Kyoto protocol (1992) and both climate and non-climate actors have shifted their focus to bottom-up approaches (Green et al., 2014). Bottom-up approaches are used to model regional or local level data from sectors to estimate disaster costs and impacts (Van der Veen, 2004). Economic losses from weather and climate related disasters have increased with large spatial and inter-annual variability. There is a lack of data at local level on disasters and disaster risk reduction which can constrain improvements in local vulnerability reduction (IPCC, 2012). Vulnerability and adaptation assessments are bottom-up approaches and can be helpful in generating local level disaster risk reduction data. Climate change loss and damage assessment has achieved considerable importance in United Nation Framework on Climate Change (UNFCC) debates in recent years. Research work on loss and damage assessment using range of approaches has been agreed by the parties during seventeenth session held in Durban, to address impacts related to extreme weather events, taking into consideration experience at all levels (UNFCC, 2012).

Pakistan is listed in the top vulnerable countries to climate change, which experiencing catastrophic climate extreme events and these extreme events are predicted to increase in frequency, intensity and duration. Climate change scenario is alarming the existence of climate change related risks in Pakistan including sea level increase, glacial depletion, high average temperatures, floods, high frequency droughts and half of the country's population is at risk (World Bank, 2013). As per vulnerability index, Pakistan is ranked 12th at global scale with approximately 4.5 billion dollars anticipated economic losses (Ahmed and Schmitz, 2015). Climate change impacts are manifold because major segment of population is dependent on agriculture economy (Asif, 2013). By 2030, there will be high multi-hazard risk to huge population with limited adaptive capacity in Pakistan (ODI, 2013). In Pakistan availability of irrigation water is mainly dependent on rainfall (mostly monsoon driven) and glacier melting, which supply water to rain fed and irrigated agriculture. Due to temperature rise excessive melting of Karakoram glacier is predictable (50% increase) in first half of the century and then will be reduced (40% decrease) at the end of the century (Rees and Collins, 2006). There is high spatial variability in precipitation and surface air temperatures along the tributaries of Indus basin passing from the Punjab province (Qureshi, 2011). These spatial and temporal variations in temperature and precipitation directly influence the hydrological cycles and trigger climatic extremes in the area.

Analysis of mean temperature data of 37 meteorological stations reveals a trend of warmer climate, over past few decades in Pakistan (del Río et al., 2013). Frequency of extreme maximum temperature events is increasing significantly in Northern Areas, Southern Punjab, Sindh and Baluchistan (PMD, 2011). Heat waves of ≥40 °C and ≥45 °C for >5 consecutive days are observed in defined temperature thresholds (Zahid and Rasul, 2012). Heat waves are more frequent over Punjab plains (Saeed and Suleri, 2015). Southern Punjab usually experiences heat index of 41–54 °C from May–September, resulting induced impacts on agriculture yield, public health, livestock yields/performance and ultimately economy of the area. Heat index is a serious threat to health in Southern Punjab, almost all parts of Sindh, South Eastern Balochistan extending up to coast and plains of North Eastern Balochistan of Pakistan during summer (Zahid and Rasul, 2007). Southern Punjab is the 2nd most vulnerable among nine agro-ecological zones with respect to impacts of climate change on human health (Sightsavers, 2010).

Shifting in rainfall is not only at spatial scale but also at temporal scale, early and late onset of monsoon is also resulting in huge losses. Rainfall patterns of 1961–2000 dataset, indicate clear shift towards the northern east and southern west of the province, posing direct impact on agricultural activity (Cheema and Hanif, 2013). Agricultural systems are highly sensitive to climate extremes as environmental conditions of these systems are directly impacted by these extremes. Food production/security is influenced by climate change due to variation in temperature and water availability (Kirby et al., 2016). Higher temperatures have drastically reduced yields in arid, semi-arid and sub-humid zones (Sultana et al., 2009). Cotton production is impacted by climate change across crop's growth cycle. Even 1 °C rise in temperature from normal at various crop growth stages can impact the crop yield. In Punjab1ºC increase in temperature during the sowing period will result in increased yield of 1.65% while same 1 °C rise in temperature during vegetative and flowering-fruiting stages will result in yield reduction by 24.14% (Raza and Ahmad, 2015). In case of wheat crop, 2–4 °C warmer climate than normal in 2006, has accelerated the grain formation phase in Sindh and Southern Punjab. Crop yield is reduced due to earlier grain formation with improper grain size and reduced weight (Rasul et al., 2011). Frequency and duration of monsoon rainfall, onset and departure of precipitation events, total number of rainy days and total amount of monsoon rainfall are the key factors directly influencing socio-economic status (Imran et al., 2014). Spatial and temporal variations in monsoon are directly resulting in higher agriculture losses. Increase