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GIS development to monitor climate change and its geohydrological consequences on non-monsoon crop pattern in Himalaya

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ABSTRACT

The main objective of the study was to assess climate change and its geohydrological impacts on non-monsoon crop pattern at watershed level through GIS development on climate informatics, land use informatics, hydro-informatics and agro-informatics. The Dabka watershed constitutes a part of the Kosi Basin in densely populated Lesser Himalaya, India in district Nainital has been selected for the case illustration. This reconnaissance study analyzed the climatic database for last three decades (1982–2012) and estimates that the average temperature and evaporation loss have been rising with the rate of 0.07 °C/yr and 4.03 mm/yr respectively whereas the average rainfall has been decreasing with the rate of 0.60 mm/yr. These rates of climate change increasing with mounting elevations. Consequently the existing microclimatic zones (sub-tropical, temperate and moist temperate) shifting towards higher altitudes and affecting the favorable conditions of the land use pattern and decreased the eco-friendly forest and vegetation cover. The land use degradation and high rate of deforestation (0.22 km^2 or 1.5%/yr) leads to accelerate several hydrological problems during non-monsoon period (i.e. decreasing infiltration capacity of land surface, declining underground water level, drying up natural perennial springs and streams, decreasing irrigation water availability etc.). In order to that the non-monsoon crops yield has been decreasing with the rate of 0.60% each year as the results suggest that the average crop yield is just about 58 q/ha whereas twenty five to thirty year back it was recorded about 66 q/ha which is about 12% higher (8 q/ha) than existing yield. On the other hand the population increasing with the growth rate of 2% each year. Therefore, decreasing crop yield and increasing population raised food deficiency problem and the people adopting other occupations which ultimately affecting rural livelihood of the Himalaya.

1. Introduction

Intergovernmental Panel for Climate Change-IPCC warns that the progress in human development achieved over the last decade may be slowed down or even reversed by climate change, as new threats emerge to food and livelihood security, agricultural production and access, and nutrition and public health (IPCC, 2007; Rawat et al., 2011, 2012a). Agriculture constitutes the backbone of most developing economies throughout the world and in turn, food and fiber production is essential for sustaining and enhancing human welfare (Rawat et al., 2012b; Rawat, 2013). Consequently, agriculture has been a major concern in the discussions on climate change. Agronomic and economic impacts from climate change depend primarily on two factors i.e. (i) the rate and magnitude of change in climate attributes and the agricultural effects of these changes, and (ii) the ability of agricultural production to adapt to changing environmental conditions. Temperature, precipitation, atmospheric CO_2 content, the incidence of extreme events and rise in sea level are the main drivers related to climate change which impact agricultural production (Fleming et al., 1995). Climate change, however, is considered as posing the greatest threat to agriculture and food security in the 21st century, particularly in many of the agriculture-based countries with their low capacity to cope up with these changes effectively (Darwin, 1999; Adams et al., 1998). Mountain agriculture is already under stress as a result of population increase, industrialization and urbanization, competition over resource use, degradation of resources, and insufficient public spending for rural infrastructure and services. The impact of climate change is likely to exacerbate these stresses even further. The amount of water allocated to agriculture and water management choices will determine, to a large extent, whether societies achieve economic and social development and environmental sustainability (Iglesias et al., 2007; Easterling et al., 1993).

Food security and rural livelihoods are intrinsically linked to water availability and use. Food security is determined by the options people have to secure access to own agricultural production and

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exchange opportunities (Parry et al., 1999). These opportunities are influenced by access to water. Making these water-livelihoods linkages is important for a more complete understanding of the nature of vulnerability of households to climate-related hazards such as drought, and the multi-faceted impacts that water security has on food and livelihood security. In order to highlight such linkages, there has been a move in recent years towards looking at water issues through sustainable livelihood frameworks (Rosenzweig and Parry, 1994; Iglesias et al., 2000).

This article reviews current knowledge about the relationships among climate change, hydrological process, non-monsoon crop production and community food security in Dabka watershed, Lesser Himalaya. The watershed lies between the latitude 29°24′09″–29°30′19″E and longitude 79°17′53″–79°25′38″N in the north west of Nainital Township (Fig. 1). The region encompasses a geographical area of 69.06 km^2 between 700 m and 2623 m altitude above mean sea level. The Geographical Information system (GIS) and Remote Sensing (RS) techniques have recently been widely applied to study land use/land cover changes (Mohanty, 1994; Minakshi and Sharma, 1999; Brahma et al., 2000; Chauhan et al., 2003). In Himalaya, a variety of changes have emerged in the traditional resource utilization structure mainly in response to population growth and resultant increased demand of natural resources, ineffective technology transfer, market forces, inappropriate land tenure policies, faulty environmental conservation programs, irrational rural developmental schemes, and increasing economic and political marginalization, during the recent years (Hamilton, 1987; Tiwari and Joshi, 1997). These emerging negative trends in the socio-economic profile have resulted into rapid exploitation and transformation of land resources and large-scale land use changes in the region. Under the impact of various land use systems, the land and whole environment of a geographical region changes positively or negatively. The impact of some land use changes is limited to the area in which they are operated while that of others reaches far in the surrounding ecosystems (Kostrowicki, 1983; Sharma et al., 2001, 2003; Scheling, 1988). The extensive land use changes in Himalaya have not only disrupted the fragile ecological balance of the watersheds in the region through deforestation, erosion, landslides, hydrological disruptions, depletion of genetic resources, but have also threatened the livelihood security and community sustainability in mountains as well as in adjoining plains ecosystem (Tiwari, 2000; Ives, 1989; Valdiya and

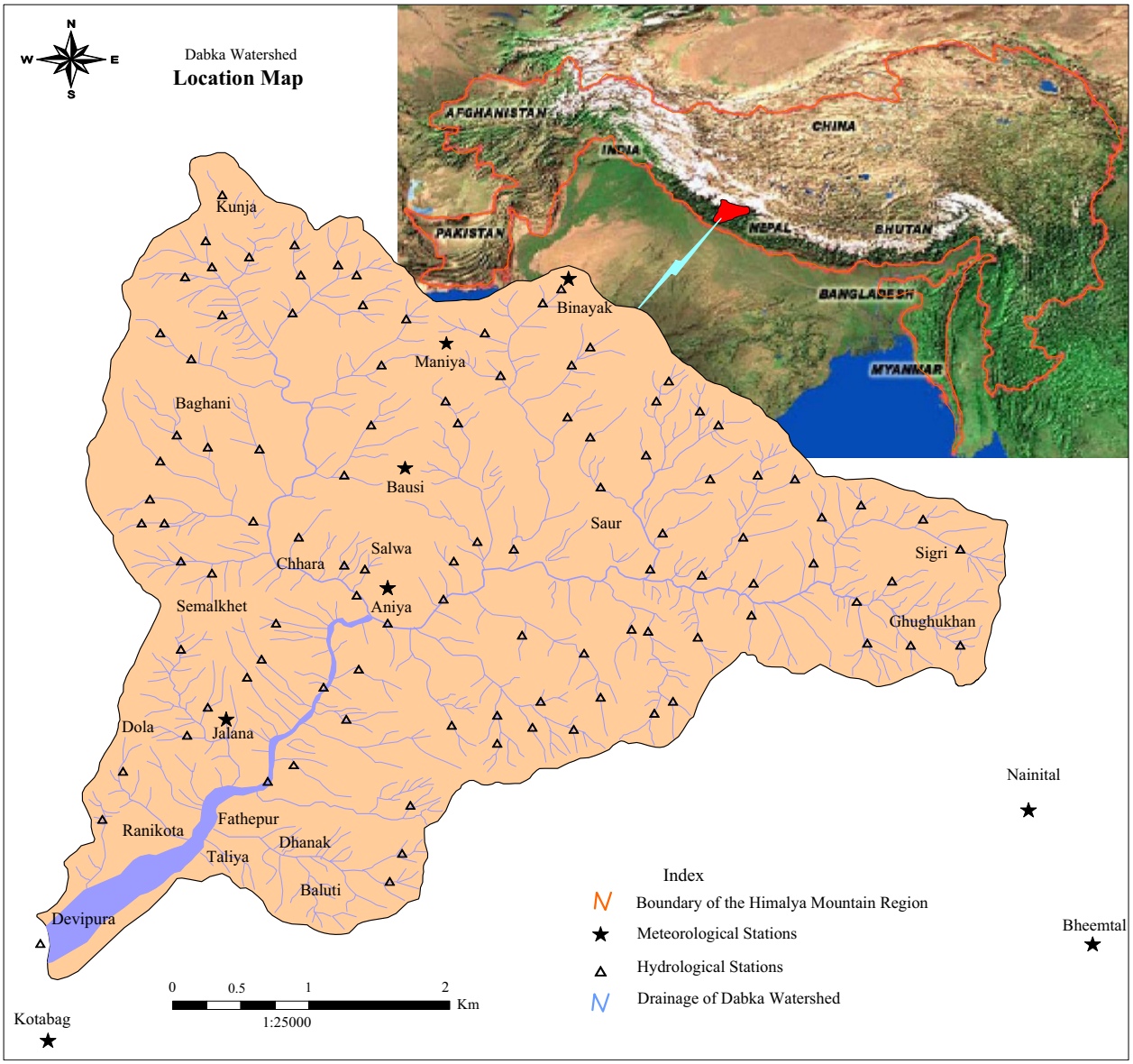

Fig. 1. Location of study area in the Himalaya mountain region (inset).