Preface

Addressing issues of climate change impacts, adaptation and vulnerability on the ground: Challenges and opportunities

The Paris Agreement – a landmark outcome of the 21st Session of the Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCC) – acknowledges 'enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change' to be a major priority for the developing countries. The agreement will be open for signature on 22 April 2016. Once a country becomes a party to this agreement, planning and implementing adaptation efforts 'as appropriate' will be a requirement. The current juncture is an especially appropriate time to examine the status of knowledge on climate change impacts and adaptation in the vulnerable communities in South Asia, especially India which is home to over 1.2 billion people.

Vulnerability to climate change is 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes', as defined by the Intergovernmental Panel on Climate Change (IPCC). Vulnerability is a function of many factors, ranging from socio-political and institutional factors to biophysical factors, including temperature, precipitation, topography and soil. Variations and changes in these factors occur at multiple spatial scales, which makes it particularly difficult to quantify vulnerability. Similarly, adaptive capacity – defined by IPCC as 'the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences' – is context-specific, and varies among individuals, communities, social groups and over time. Hence adaptation strategies face difficulties in scaling up from case studies, posing limitations for integrating adaptation methods into a policy perspective. While academic researchers and government/non-governmental organizations are working towards achieving this goal independently, they address different facets of the problem. Thus there is a substantial need for collaborative assessment and action to synergistically address these issues.

This special section brings together detailed case-studies of climate change impacts on agriculture and responses from different Indian ecoregions. The papers are an outcome of an Indo-US bilateral workshop entitled 'Adaptation of rural communities to climate change: bridging the gap between academia and community workers and identifying research needs', which was held in Bengaluru, India in February 2014. These papers cover a range of topics related to crop and climate variability, livelihood, and adaptation planning at diverse spatial scales, ranging from households and farms, to villages, districts and states across South Asia (with specific case studies from India, Nepal and Bangladesh). With studies from multiple spatial scales, our goal is to gain a better understanding of how climate change impacts and adaptation options differ across these scales. While the particular context varies in different locations, we expect that the basic challenges and potential solutions to climate change adaptability across communities apply to other parts of the world where vulnerable agricultural communities need to adapt to ongoing and future climate changes.

Saxena *et al*. (**page 1195**) combine a sustainable livelihood framework with cross-scale resilience analysis to demonstrate the relative impacts of government policies and climate change on livelihoods of resource-dependent rural communities. The authors examine the case of rural household livelihoods in six villages of Madhya Pradesh, India and conclude that shifts in policies (e.g. establishment of national park boundary leading to restriction on collecting fuelwood, timber and non-timber forest products) have greater effects on the households compared to the impacts of climate change in this region. They argue that their article demonstrates an approach that provides an improved understanding of the dynamic nature of social–ecological systems, where it is often difficult to disentangle the effects of policies and climate change impacts.

Mathur and Awasthi (**page 1208**) draw from their experience of working with rural communities in Maharashtra, India and propose systematic interventions to move towards carbon neutrality. The authors recommend a suite of actions, including ecosystem management through watershed development, efficient water management practices (such as drip systems and sprinklers), and action plan for low carbon energy in order to reduce greenhouse gas emissions. They find that sustainable agricultural strategies, such as organic manuring, reduced or no tillage farming and water budgeting are critical to adapt to climate variability. They also stress the importance of strengthening the village economy and reducing transport miles by focusing on local producers.

Kumar *et al*. (**page 1216**) examine whether agricultural adaptation strategies (such as improved crop varieties, crop diversification, water and livestock management) to reduce the negative effects of climate extremes affect agricultural profitability. The authors focus on 12 villages in the Indian state of Haryana, and conclude that such adaptation strategies are critical, especially for small and marginal farmers. They find that income diversification can reduce agricultural costs, and increase profitability and adaptability to climate risks; but the outcomes would likely be varied at the community level based on the size of landholding. Specifically, small and marginal farmers have more adaptation costs compared to large farmers, but also have higher profits per unit area; whereas large farmers have lower profits as they tend to focus on cereal cropping system with high agricultural input costs.

Esteves *et al*. (**page 1225**) adopt a multi-scale approach to identify vulnerability to climate variability in 1200 villages in Karnataka, India. The authors show that low levels of education and skills, lack of income diversification and livelihood-support institutions contribute to increased vulnerability at household, village and district levels. They recommend a multi-scale vulnerability assessment in order to prioritize adaptation interventions. They also suggest focusing on the most vulnerable households and villages first for adaptation-related policy implementation, including sustainable water harvesting, improving literacy rates, provision of alternate sources of income and restoration of grazing lands.

Narayanan and Sahu (**page 1240**) use an econometric model to understand the effects of changes in rainfall and temperature on agricultural households in coastal Odisha, India. The authors report that adaptability to weather variability is greatly influenced by the degree of changes in temperature and rainfall, as well as the availability of credit facilities and credit amount through agricultural extension programnes. They recommend that local knowledge be included in direct policies, and village-level non-farm enterprises be promoted.

Khatri-Chhetri *et al*. (**page 1251**) examine if climate-smart agricultural (CSA) practices can provide economic benefits to smallholder farmers. The authors focus on the rice–wheat cropping system in the Indo-Gangetic Plains, specifically in Haryana and Bihar, India. By examining the existing and promoted CSA strategies (such as zero tillage, laser land levelling, crop residue management for soil and water conservation, flood and drought-tolerant crop varieties and site-specific nutrient management practices), they conclude that combinations of the above-mentioned strategies need to be implemented to maximize the efficiency of resource use and crop productivity, and minimize the negative impacts of climate change and variability. In terms of policy implementation, they recommend minimizing farmers' financial burdens to adopt CSA technologies beyond the study region, since the farmers tend to hesitate in investing in risky activities despite potential economic benefits.

McDermid *et al*. (**page 1257**) utilize a multi-climate and crop modelling approach to examine the impacts of climate variability on maize yields across 60 farms in Tamil Nadu, India. The authors consider observed changes in climatic parameters as well as projected climate changes for the mid-21st century, and evaluate adaptation strategies (earlier sowing date, more fertilizer and supplemental irrigation) for their capacity to provide maize yield improvement. They report that maize yield in this region is associated positively with total rainfall and negatively with daily maximum temperature. Their findings indicate that the current adaptation strategies might not be efficient to improve yield, hence additional and alternate strategies (such as using improved varieties, planting different crops, or building more rainwater harvesting and irrigation infrastructure) are warranted.

Bhatta *et al*. (**page 1272**) explore the relative importance of climatic and non-climatic factors in influencing farmers' decision to change their farming practices over time. The authors report findings from a household survey of 2660 farm-families in the Indian state of Bihar, Terai of Nepal, and coastal Bangladesh. Irrespective of the agro-climatic zone, the findings indicate that market-related forces (e.g. higher yielding crop types/varieties and better market opportunity) and resource issues (e.g. declining soil fertility, labour shortage and pest/disease outbreaks) are stronger drivers of changes in farming practices compared to the climatic factors. While food-sufficient families are likely to better adapt to changing climate, marginal and smallholder households need social protection measures and targeted policies for new agricultural practices in order to be less vulnerable to climate and market shocks.

It is evident from the case studies in this special section that climate change is one of many factors (such as policy, market and biotic factors) affecting vulnerability. Sustainable water management, reduced or no-tillage farming, planting flood and drought tolerant high-yielding crop varieties, and crop diversification were identified as the most promising adaptation strategies across spatial scales. At household levels, however, restrictions on the use of natural resources, lack of income diversification, and low levels of education and skills will specifically limit adaptability of smallholder farmers who typically own less than 2 ha of farmland. Thus majority of these studies highlight the critical importance of targeted policies for smallholder farmers, including availability of credit facilities and social protection measures to minimize farmers' financial burdens. In order to be efficient, such policies must consider various axes of vulnerability, such as environmental, economical and social, and prioritize adaptation efforts accordingly. Effective integration of all these components requires trans-disciplinary collaboration, which is often non-existent in many climate change studies, thus prohibiting a successful science-to-policy translation. The 2014 Indo-US bilateral workshop is unique in that it brought together practitioners and scientists from the physical and social sciences, in an effort to bridge the gap between academia and community workers. We hope this special section will encourage a continued dialogue between physical scientists, social scientists and community workers/practitioners on addressing vulnerability and adaptation issues at multiple scales.

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