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RESEARCH PAPER

Communication and capacity building to advance adaptation strategies in agriculture in the context of climate change in India

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Abstract Climate change is perhaps the most serious issue that affects food security of a very large number of human beings and animals. Impacts of climate change will be particularly significant in South Asia where most of food production comes from smallholder farms. Vulnerability in this region is twofold: production of important food crop varieties may be affected by developments such as rise in temperature; smallholder farmers have low economic resilience when large variations in crop outputs occur. Both adaptive and anticipatory measures based on research in agricultural sciences are being proposed. What is also important is to build the capacity of smallholder farmers to cope with the impact of climate change-induced phenomena. Key guides to large-scale actions such as the UN Framework Convention for Climate Change propose integrated action for capacity building involving both top-down and bottom-up inputs. In this paper, we provide an overview of accepted impacts of climate change on agriculture and food security in South Asia, and the proposed and ongoing agronomic adaptation strategies in India. Our focus is on capacity building at a micro-level which can augment adaptation efforts. We offer two case studies that provide pointers for integrating novel communication and capacity building processes for smallholder farmers that can considerably improve their ability to engage in action for adaptation.

Keywords Climate change · Capacity building · MOOC · Mobile phones · Energy · Drought

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Introduction

South Asia as a whole is vulnerable to the impacts of global climate change (Carabine and Lemma 2014). According to the Intergovernmental Panel on Climate Change (IPCC), impacts are and will be multi-dimensional, affecting human and animal communities as well as natural ecosystems. Both the fourth and the fifth assessments of IPCC (Cruz et al. 2007; Porter et al. 2014) have concluded that there is adequate evidence about the potentially adverse impact of climate change on crop and livestock production in South Asia. This region is expected to experience extreme temperature, extreme rainfall on the coasts, sea level rise, drought, and significant variability in rainfall everywhere. All models and all scenarios project an increase in both the mean and extreme precipitation in the Indian summer monsoon. Coastal areas are more vulnerable than other areas. Historically in this region, climate-related disasters are among the main drivers of food insecurity. South Asia is already home to most of the under-nourished individuals in the world. Climate change is likely to exacerbate food insecurity in less than a generation. The Indo-Gangetic Plain (IGP) covering four countries (Pakistan, India, Nepal and Bangladesh) is a major food-producing region of the world. All available evidence indicates that agricultural production in the IGP is prone to adverse impacts of climate change.

Adaptation is a globally recognized response to climate change and consists of several measures and practices. Examples are changes in agronomic practices, or control of emission of greenhouse gases (GHG). Apart from such measures, communication and capacity building have significant roles in fostering very large scale and effective adaptation to climate change. During the early phase of the green revolution in the IGP, new crop varieties were adopted by farmers on a mass scale in a relatively short span of time. Analysis of the experiences then shows that expert communication with smallholder farmers and building their awareness and capacities on large scale through field demonstrations played a very important role. New channels of communication such as mobile phones and ICT-based rural information access points have become available in recent times. They can be used for communication and large scale capacity building among smallholder farmers in helping them to adapt to climate change. We shall offer two case studies after presenting an overview of climate change impacts with a special reference to the IGP. We will look at ways to foster preparedness to adapt to or mitigate the impacts of climate change among the vulnerable communities and consider how a recent development in learning technology, the massive open online course (MOOC), can be a support tool in fostering preparedness.

Impact on agriculture and food security

Intergovernmental Panel on Climate Change assessments of impact of climate change are considered the most acceptable statements among all stakeholders for they have been arrived at through consensus-oriented negotiations among groups of experts from different regions of the world. Impacts are formulated in these assessments in “likely” rather than in certain terms, and the strength of evidence is simultaneously provided. Estimates of severity of impact over a period of time are stated with reference to a baseline (no adaptations to climate change) and to different scenarios for short term and long term based on different types of adaptations. Using this manner of formulation of impacts, we will present an overview of the impact of climate change developments on agriculture and food security in the South Asia, especially in the IGP.

Agriculture in the IGP directly contributes to food security of almost a billion human beings. About 14–15 % of global wheat production occurs in this area. Rice is an important cereal crop produced in the IGP. There could be a significant decrease in non-irrigated wheat and rice yields for a temperature increase of greater than 2.5 °C which could lead to a loss in farm-level net revenue (Cruz et al. 2007).

More than 28 million hectares (Mha) in South and East Asia will require a substantial increase in irrigation for sustained productivity. Furthermore, the demand for agricultural irrigation in arid and semi-arid regions of Asia is estimated to increase by at least 10 % for an increase in temperature of 1 °C. In the IGP, there could be a decrease of about 50 % in the most favorable and high-yielding wheat area in one scenario (Cruz et al. 2007). Sea level rise will inundate low-lying areas and will especially affect rice growing regions.

There is a consensus among experts that high temperatures tend to reduce animal feeding and growth rates. Existing challenges of supplying water for an increasing livestock population will be exacerbated by climate change in many places. Climate change will alter potential losses to many pests and diseases. Changes in temperature can result in geographic shifts through changes in seasonal extremes, and thus, for example, overwintering and summer survival. Elevated CO_2 can lower the nutritional quality of flour produced from grain cereals (Erbs et al. 2010). The overall impact of climate change on food security is considerably more complex and potentially greater than projected impacts on agricultural productivity alone.

Impact on smallholder farmers

Experts agree that in many rural areas, smallholder farmers in particular do not have the capacity to adjust consumption in the face of climate shocks, especially those that affect a majority of households in the same location (Porter et al. 2014; Prakash 2011). Any increases in climate extremes will exacerbate the vulnerability of all food-insecure people, including smallholders [robust evidence, high agreement in IPCC (Cruz et al. 2007; Porter et al. 2014)]. Currently, smallholder farmers rely to a large extent on increasing labor off-farm where possible (Porter et al. 2014). Furthermore, some evidence also suggests that poorer households are more likely to reduce consumption, while wealthier households liquidate assets to cover current deficits (Carter and Lybbert 2012). Reductions in food consumption and sales of productive assets can lead to long-term losses in terms of income generation and thus to future food security. Increased uncertainty of future climate conditions and increases in climate extremes will increase food insecurity, generally speaking.

Agronomic adaptation strategies in India

Adaptation is primarily an act of risk management. IPCC takes adaptation to mean reductions in risk and vulnerability through the actions of adjusting practices, processes, and capital in response to the actuality or threat of climate change. Autonomous adaptations are incremental changes that include coping responses and are reactive in nature. Planned adaptations are proactive and can either adjust the broader system or transform it (Nelson et al. 2013). Adaptations can occur at a range of scales from field to policy.

Globally, many potential adaptation strategies are being practiced and proposed. On an average, agronomic adaptation improves yields by the equivalent of ~15–18 % of current yields but the effectiveness of adaptation is highly variable ranging from negligible to very substantial. Projected benefits of agronomic adaptation are greater for crops in temperate, rather than tropical, regions.

Reduction of greenhouse gases emission from agriculture

Emission of GHG into the atmosphere is a known contributing factor in climate change. Control and reduction of emission of GHG is a critical measure in adaptation in general. In India, among the three large economic sectors producing more than 95 % of GHG, agriculture has the least share at 17 % (the others being energy (58 %) and industry (22 %) (Indian Network for Climate Change Assessment 2010). India: greenhouse gas emissions 2007). For the period 2001–2010, the largest source in agriculture, forestry and land uses (AFOLU) emissions was agriculture (50 %), followed by net forest conversion (38 %) and peat degradation (i.e., cultivation of organic soils and peat fires) (11 %). However, AFLOU activities are also known sinks of carbon. For example, forest (forest management and afforestation) contributed 100 % of AFOLU removals by sink, and represented a 20 % offset of total AFOLU emissions by source (Tubiello et al. 1990). In India, contribution of the agriculture sector to the total emissions declined from 27.6 % in 1994 to 17.6 % in 2007 in spite of the fact that the agricultural production recorded positive growth during this period. Total production of food grains in India increased from 184.26 million tons in 1993–1994 to 230.78 million tons in 2007–2008.

Thus, among three core contributing sectors, agriculture is the only sector which has shown improvement in mitigation share from 1994 to 2007 but the emissions remained more or less constant with the figure of 334.41 million tons CO2 equivalent in 1994–2007. From the XI Plan period (2007–2012) onwards, there has been considerable growth in agriculture but data on GHG emissions are not available to evaluate further impact of mitigation and adaptation measures.

A recent review on the status of climate change adaptation and mitigation strategies in India focused on rainfed agriculture which is highly vulnerable (Venkateswarlu and Singh 2012). This review has covered crop-based approaches (suitable crops and varieties, development of varieties for heat stress, drought, and submergence tolerance, evolving varieties that augment nutrient use efficiency or can tolerate coastal salinity and sea water inundation, and judicious intercropping). Strategies based on resource conservation and management include technologies such as in situ moisture conservation, rainwater harvesting and recycling, efficient use of irrigation water, conservation agriculture, energy efficiency in agriculture, watershed management, plantation of multipurpose trees for carbon sequestration, and use of poor quality water (such as reuse of urban waste water).

Site-specific nutrient management (SSNM) strategies demonstrated benefits in terms of higher rice yields, increased CO_2 net assimilation and nitrogen use efficiency. *Neem* oil coated urea tailored to enhance nitrogen use efficiency has become very popular leading to reduction of GHG emissions and ground water pollution of nitrate (Anonymous 2015; Devakumar 2005). Amelioration of phosphorus (P) deficiency regulates CH_4 emissions. Judicious fertilizer application through SSNM approach ensures twofold benefits, i.e., reducing greenhouse gas emissions and concurrently improving yields under high CO_2 levels. In irrigated areas, zero tillage in particular has reduced the demand for water in rice–wheat cropping system of the IGP along with some mitigation effects in terms of enhancing soil carbon content, reducing energy requirement, and improving water and nutrient use efficiency. This technique is scalable. Rice–wheat cropping system in the IGP of India produces substantial quantities of crop residues. These residues can be pyrolyzed producing *biochar* as soil amendment, increasing soil fertility and crop yields while sequestering carbon. In India, it has been projected that about 309 MT of *biochar* could be produced annually, the application of which might offset about 50 % of carbon emission (292 Tera gm C per year) from fossil fuel (Lal 2004). Besides identification of specific practices, there is a promotion of research and policy advocacy. Through the recently concluded National Agricultural Innovation Project (2007–2014), investments have been channeled into mitigation of GHG emissions and in climate smart agriculture. The National Academy of Agricultural Sciences, New Delhi (NAAS-India) has brought out several policy papers to guide the implementation of activities within the twin agenda of mitigation and adaptation.

Communication and capacity building as supporting factors in adaptation

The AFOLU systems are not only emitters of GHG. They have enormous capacities for carbon sequestration. Thus, this aspect of agriculture has to be mainstreamed into policies on good practices to highlight multiple benefits of promoting land and water conservation, choice of appropriate climate resilient crops and their sustainable production. This would ensure sustainable and wider livelihood opportunities for communities. Here is where participatory processes of cross-learning and multi-stakeholder cooperation become critical. Local communities and their organizations need support for developing their capacities to adapt to local manifestations of climate change-related developments. There is an increasing recognition that effective adaptation will often require changes in institutional arrangements and policies including investment in new technologies, infrastructure, information, and engagement processes. Building adaptive capacity at all scales is an important part of the adaptation. Disaster preparedness on a local community level could include a combination of indigenous coping strategies, early-warning systems and adaptive measures.

Global experience in drought management shows that preparedness at all levels, certainly at the community level, is better than relief. Information sharing and capacity building are at the core of preparedness. This is also emphasized in a different way in the capacity building approaches endorsed and promoted by the UN Convention to Combat Desertification and the UN Framework Convention on Climate Change (UNEP 2012). Since socially and economically vulnerable sections of human communities are known to bear disproportionate burdens of disasters induced by climate change, it is important to bolster preparedness and capacities at that level as well. This will contribute to advancing and sustaining agronomic adaptation processes and strategies as well as to reducing vulnerabilities. Away from agriculture but in India, the IPCC cites the early-warning system and heat preparedness plan of the city of Ahmedabad as an example of how community action and science-based prescriptive actions have been brought together to great effect (Carabine and Lemma 2014). According to the High Level Panel of Experts convened by FAO, there is no clear knowledge of how crop-livestock management practices are carried out locally while there is sufficient knowledge of emerging global scenarios in relation to climate change. According to this panel, “Gaining a better understanding of the differences in farm activities, and vulnerabilities to climate change is critical, both to finding ways to improve food security and to deal with the challenges which climate change poses to agricultural productivity and stability” (HLPE 2012). This is why developing an arrangement for two-way flow of data and information between the farmer and the expert is very important.

Sustaining and advancing gains from agronomic adaptation measures is dependent upon continued engagement with smallholder producers since they directly contribute to bulk of food production in the IGP. Global experience in managing risks from drought, a climate-induced phenomenon, shows that preparedness would be better than relief. This would imply development and management of viable channels of information flow between vulnerable communities and sources of expertise and policy making. Such an approach would be different from conventional approaches that emphasize top-down approaches, where information flows from sources of expertise to vulnerable communities. Fostering two-way flows is also important for experts and policy makers to gain intricate knowledge of differences of farm activities and vulnerabilities at a micro-level.

A survey of information channels available to smallholder farmers to access climate and weather-related information and advisory services was carried out in 2012 covering all four countries in the IGP. This survey covered conventional (face-to-face meetings, print medium and broadcasting) as well as digital channels (the Internet, text/voice messaging with mobile phones). A host of actors and stakeholders were covered (Government departments, allied agencies, university-based extension services as well non-government organisations). Results showed noticeable gaps between research systems (that generate and store such data and information) and the smallholder producers (Balaji and Craufurd 2011). In another survey, an assessment of farmers' information needs and sources of information (carried out in the IGP of India covering 20 districts in 5 states) showed that farmers are scouting multiple sources to obtain the information; no single source was found to be complete (Cramer 2012).

A recent sample survey using three sites in the IGP to assess the impact of climate change and adaptation mechanism adopted by the farmers was carried out in Nepal, India, and Bangladesh (Ojha et al. 2014) The three locations of the study provided rich diversity with respect to climatic and socioeconomic conditions, climate stresses (floods, rainfall patterns, droughts, warmer temperature, and declining groundwater), agro-ecological systems (coastal areas as well as inland), status of economic wellbeing (from high-poverty situation to relatively well-off communities), two scales of institutional settings related to climate change and agriculture, and agricultural innovation ecosystem (technology-driven agriculture in Punjab to more institutional innovations in the *Terai* region of Nepal). This survey also included gathering data at a household level covering aspects such as agricultural practices, perceptions on climate change and agricultural innovations. The farmers' perceptions on climate change are captured in the Box 1.

Results from this survey show that farmers indeed tend to take to adaptive practices in relation to climate change. For example, advice on timing of sowing and transplanting and irrigation/water management technologies was adapted by 65 % of respondents and technology in land/soil/pond preparation by 55 %. In the Punjab site, 92.9 % of farmers participated in some form of crop-varietal selection and 73 % in resource conservation, such as water management. Carefully designed and facilitated channels of information and knowledge flows will greatly increase the capacities of farmers in practising adaptation-oriented measures.

Technology-based approaches in this regard need to be scalable from macro to micro-levels. Solutions based on geographic information systems (GIS) have this advantage. MOOC also has such an advantage; it can be used in knowledge enrichment of tens of thousands of individuals, or it can be used to contact just a few. In the following, we will describe two case studies that demonstrate how these technologies can be applied in developing highly scalable solutions for sharing information with as well as for capacity building of small-holder farmers.

Improving micro-level drought preparedness using GIS and meteorology-based information and advisory services

Drought is a major driver of food insecurity. Experts are of the view that frequency and intensity of droughts will increase as climate changes set in, even

Box 1 Farmer perception of change on various climate change and related parameters

Summer has become hotter
Monsoon starts later
Drought has increased
Overall monsoon rainfall period decreased
Winter has become colder
Monsoon rainfall difficult to predict
Daily temperature range has increased

when mitigation measures are deployed. According to a report of NAAS-India, the entire country can be considered drought-prone, with about a third of the land surface prone to frequent drought (National Academy of Agricultural Sciences 2011). Considerable knowledge base exists in India in relation to drought management; however, adoption of suitable technologies by the small-holder farmers still remains limited, since the extant practices still focus on relief rather on providing early warning and fostering preparedness. Assessment of vulnerability to drought at a micro-level and promoting anticipatory and adaptive action at the level of villages can help alleviate the disastrous impacts of drought.

Normally, drought assessments are made using precipitation aberration and crop yield or area reduction (Pandey and Ramasastri 2001), neglecting the adaptive capacity of the regions (for example, food production can be supported using surface water or groundwater). There have been efforts to include information on soils, irrigation, farm holding sizes, rainfall, rainy days, and cropping pattern combining them with satellite-based information (Murthy et al. 2015) in assessing drought vulnerability in South Central Indian states Andhra Pradesh, Telangana and Karnataka. An integrated approach requires consideration of micro-level details on water demand and water availability along with the parameters above. In our study, a micro-level drought vulnerability assessment framework was developed. Field level investigations in a select area were conducted to assess the vulnerability of villages to drought to improve drought preparedness (Sreedhar et al. 2009, 2012). The area selected (Peddavagu river basin in the lower Krishna basin, now in Telengana state) is a highly drought-prone locality, where outmigration (especially of men) has been reported as a standard coping strategy (Mula et al. 2010). This is an example of autonomous adaptation at a local level.

We started in a micro-region covering 21 villages in Addakal *Mandal* which is located in Mahabubnagar district (now in Telangana state) in the lower Krishna basin. This locality receives a normal rainfall of 550 mm. Because it is in a rain shadow, this micro-region experiences fluctuating rainfall. An information hub for the locality has been operational in a community-based organization in Addakal with information centers in each village serving as outlets as well as gathering points (Sreedhar et al. 2009). Through this hub-and-spokes arrangement, information on crop cultivation and animal-rearing practices in the villages was gathered with the participation of farmers and landless workers. Drought vulnerability scenarios were developed based on the rainfall prediction from India Meteorological Department (IMD) for the growing season. A series of maps were prepared for the *kharif* seasons in 2009, 2010 and 2011 (Sreedhar et al. 2009, 2012). Each year during 2009–2011, color-coded maps of drought vulnerability for each village were prepared. These maps were based on parameters and methods described in (Sreedhar et al. 2009, 2012). Drought vulnerability variations were marked in color codes: red, indicating high vulnerability to drought, orange and yellow indicating lower vulnerability, while light green and green indicated low and very low vulnerability (Fig. 1). They were made available to farmers and their families using the rural information hub and the associated information centers equipped with PCs.

The assessment in 2011 *Kharif* season was that 18 out of 21 villages faced modest to severe vulnerability (significant surface water shortages, see Fig. 1). It emerged that all the 18 villages did indeed face serious scarcity of water for crop and livestock production. Rural families were able to state their usefulness or otherwise through a modified form of participatory rural communication appraisal (PRCA) technique (FAO 2004).

The maps were indeed found useful for the rural families in decision making in relation to drought. In 2011, a field assessment of impact was designed using a blend of ethnographic action research and PRCA. As stated earlier, our projection in 2011 was that 18 villages out of 21 villages faced moderate to severe vulnerability. In villages marked red, crop yield losses to an extent of 60 % were reported while the depletion of groundwater forced most pumps there to go dry. Specific advisories to shift to cultivation of dryland crops such as castor or pigeon pea or chickpea were not heeded generally because of the low prices such crops would fetch in the market. However, in some villages, farmers cultivated only 60 % of the cropping area, keeping in view the advisory and were able to avoid serious losses. Overall, the observation was that the advisories were helpful to farmers in making crucial decisions. They also contributed to improving farmers' understanding of micro-level drought preparedness. Several farmers made statements to this effect. An example is the statement of Balchander

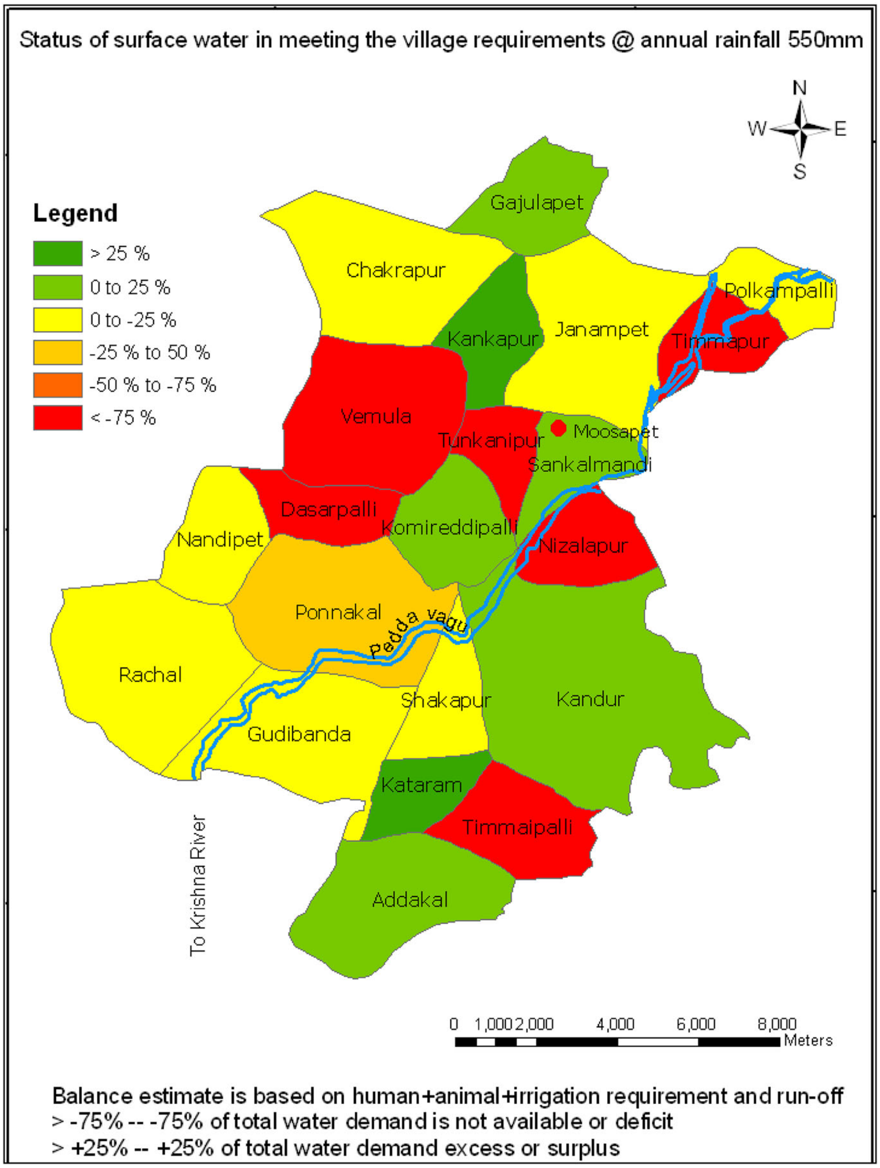

Fig. 1 Drought vulnerability map of Addakal Mandal based on 2011 long range predictions

Rakela in Rachala village (population 1800) (ICRISAT 2009). This village was forecast as a highly vulnerable location. Balchander stated that he was able to tide over the severity because he had a good idea of it beforehand. He says that "[the group] has provided color maps and gave advice on cultivation of dry crops like groundnut, millet, sunflower and maize. The color-coded maps … proved to be a serious aid." Over the three years, more farmers have started to adjust their production practices based on the most probable scenario projected for their villages.

This series of studies show that carefully planned and structured information sharing at a micro-level is important in fostering preparedness in relation to a climate-induced phenomenon such as drought. The approach here has been generalized and is now ready for trials on a much larger scale. The area selected is a much larger region in the Peddavagu river basin in the lower Krishna basin (also in Telangana state in South Central India). Vulnerability assessment using this set of information sharing and communication methods is now available for 594 villages (Fig. 2), scaling up from 21 earlier. The question now is more about how capacity building activities among vulnerable families can scale up in a similar way.

MOOC and mobiles in learning: new opportunities for capacity building of smallholder farmers at scale

The MOOC is a recent development in educational technology. Although identified more with leading research universities in the USA, MOOC as a concept and practice originated in Canada. A number of analyses of the profiles of learners and the faculty and their motivations have been published using learning analytic data from several hundred offerings. While few examples of application of MOOC in capacity building of farmers are known, we consider MOOC as a potential opportunity in this regard. Creative adaptations are necessary and use of basic cell phones rather than handheld computers should be considered.

The agropedia group of the Indian Institute of Technology-Kanpur (http://agropedia.iitk.ac.in), has built an advanced and highly scalable set of technologies for deploying mobile telephony technologies in support of expert-farmer knowledge sharing. This

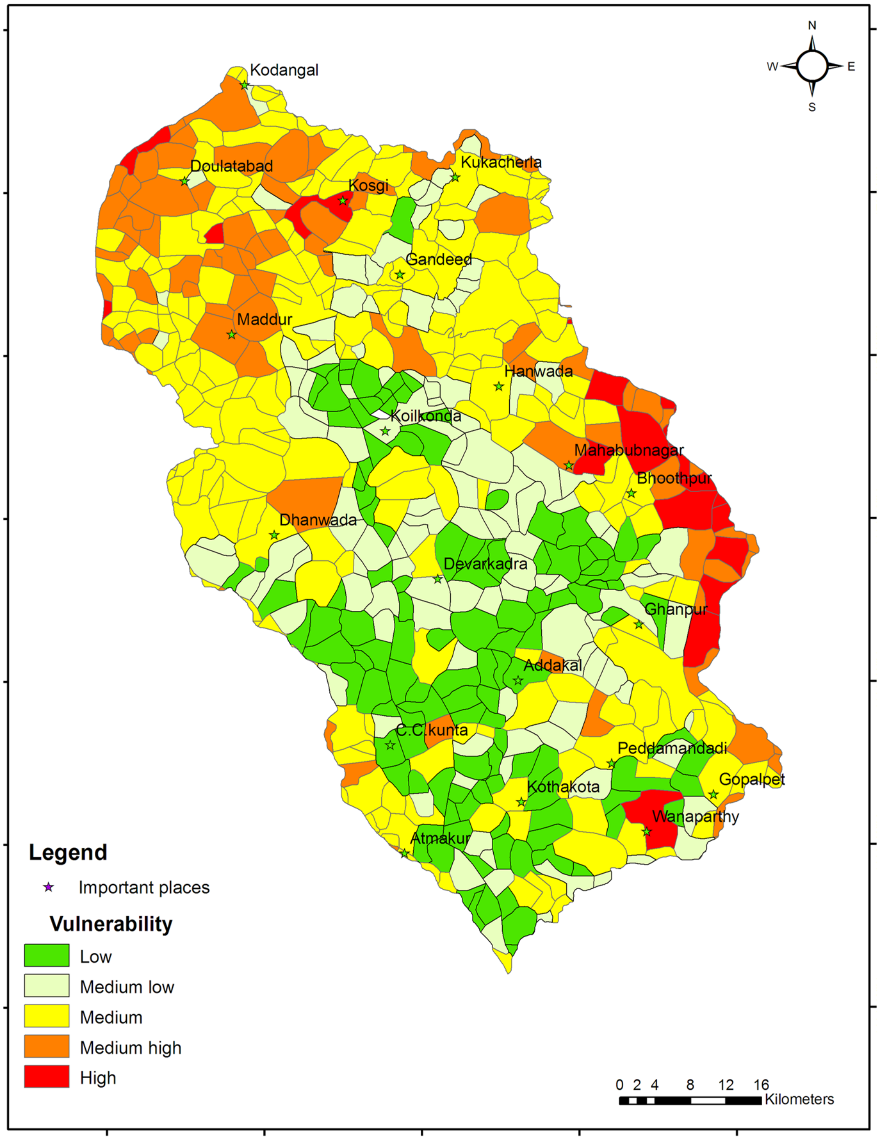

Fig. 2 Drought vulnerability map of Peddavagu river basin

technology suite, called vKVK by the team of developers, allows communication from the Web to the (basic) mobile phone and vice versa. Experts use the web interface to receive and transmit messages to hundreds of farmers, organized according to interest groups, while farmers use basic phones to leave queries in a voice-mail box. The arrangement is such that it is completely independent of particular telecom service providers. The vKVK has been made available as a regular service for over 3 years during 2011–2014 for about 30,000 farmers, mostly from the states of Uttara Khand (UK) and Uttar Pradesh (UP) in the IGP. Evaluation studies on this service indicate positive feedback about its effectiveness (Balaji and Prabhakar 2013). The unique aspect of vKVK effort is its interactive rather than broadcast character, which makes it more useful as a support in developing an online platform where thousands of learners can be brought.

MobiMOOC: bringing MOOC and mobiles together for farmers

The agropedia group was able to modify the vKVK suite of technologies to create a highly scalable learning services delivery platform. Central to this suite is the Interactive voice response technology which is widely used as a way to access a structured collection of audio files. Instructional material can be created and stored as audio files which a user can access through IVR. In the new arrangement, IVR was used along with content management systems that enable a user to be tracked precisely in terms of the files accessed and frequency of access. Tests and surveys can be administered using this arrangement. The agropedia group ran a few trials to assess the scalability of this suite of technologies and concluded that it was indeed capable of allowing simultaneous access by several hundred users (which in effect means that several thousand users in total can use this arrangement). The designers made use of open source technologies (such as freeswitch for telephony and Drupal for content management) which ensured that the total cost of operations would be lower. Using this technology, the agropedia group organized a MOOC for learners that had only a basic cell phone as an access device.

The agropedia team had identified gardeners (or, *malis*, as they are called in many parts of India) as a group of assetless or smallholder farmers who were in need of increased access to information on new practices and inputs. This group is relatively underserved by conventional extension services and broadcast media compared to farmers of cereal crops. Content was sourced from the most recent edition of the official handbook on packages of practices, published by the state of Uttar Pradesh. (This is because information in agricultural extension has a prescriptive character). It was rendered from text into audio format and grouped per crop for 22 select crops (identified by the team from local consultations). A number of lessons were associated with each crop as a topic, and were provided in the form of short audio files that had a duration ranging from 35–60 s. Total size of audio clips was about 120 min for all the crops, amounting to just under 300 s per crop. Quizzes were based on these learning materials. Trained artists were employed to voice these audio clips. A learner could join the MOOC by signing up with a mobile phone number directly by calling the course team or through contact sessions organized in five districts of Uttar Pradesh. Toll-free numbers were made available to the registered users. Following the vKVK practice, learners received a missed call to indicate that a lesson was waiting. They could use the toll-free number to call into listen to the lessons. At the end of a group of lessons, the learner could opt to do a quiz which required use of the number pad on the cell phone to select an option for an answer. With the mobile number provided by the learner as a unique ID, performance was tracked. A call center was operationalized for the duration of the course. Learners could contact this facility to get guidance; on occasions, team members called learners that were at risk of dropping out or when their performance was not at par.

This six-week course (Nov–Dec 2014) to smallholder farmers on science-based horticultural practices (http://mobimooc.in) attracted a total of 1055 individuals and just over 60 % were of the joiners were active. At the conclusion of the course, 296 participants stood eligible to receive certificates with eleven of them being rated as participants of distinction. Process documentation shows that the technology was stable and required no special skills on the part of learners and was not cumbersome to use. Learners gave high ratings to the audio quality as well as relevance of the content of the lessons. A noticeable proportion of smallholder farmers were able to apply some of the essential information almost immediately in daily work. The documentation also indicates that farmers preferred to act on advisories when they were part of learning opportunities and circumstances (Yadav, Kiran. MobiMOOC: an effectiveness study, Uttar Pradesh state, India. Commonwealth of Learning 2015). Work on an analysis of the process data is in progress.

We can thus infer that an advanced yet practical prototype for knowledge enrichment on a large scale is available for working with the farming community. Strengthened with evaluation and testing methods derived from non-formal learning and bolstered by locally accessible expert presence, this can become the core of a large scale capacity building process focused on farmers.

Conclusion

Impacts of climate change on food security will be noticed even if mitigation and adaptation activities are taking place. It is therefore essential that action commences at the micro- as well as at the regional and national levels simultaneously. While AFLOU activities add to GHG emissions, they can also act as carbon sinks offering major mitigation opportunities. We noted the expert view that the very rapid spread of new crop varieties and associated packages of practices during the early phase of green revolution was possible because of extensive communication with farmers and increase in their knowledge and capacities through field demonstrations. In the context of adaptation and mitigation activities, in a similar way, promotion of adaptation and mitigation action requires engagement with smallholder farmers on a large scale, involving exchange of information starting at the micro-level. At the core of micro-level activities lie early-warning systems and capacity building processes that foster preparedness.

In this paper, we have provided two case studies that show how interactive information channels can be used to communicate accurate data to smallholder farmers to help them adapt better to drought. When scientifically well-grounded information is conveyed with adequate reference to local data, the uptake of advisory is better. With the advent of network-connected rural information hubs, it has become easier and more viable to build such interactive information channels. Use of GIS products and methods allows for high levels of scalability while making advisories locally more accurate and relevant. Early-warning systems at micro-levels can thus be built and shared with smallholder farmers.

We also showed the operations of a viable prototype for large scale capacity development built in India recently. This prototype uses a recent advance such as the MOOC in a novel combination with mobile (voice) technologies. The MobiMOOC trial indicates that agronomic advisories have a better chance of uptake by smallholder farmers when they are part of a learning context. Sub regions such as the IGP require agronomic adaptation practices at scale which requires availability of effective channels of information sharing and capacity development, both of which have been prototyped and demonstrated at scale in this paper.

It can be said that the agricultural education and training sector has a strong preference for face-to-face methods because of historical successes (such as the green revolution) and has not made serious efforts to make use of other approaches including online methods. Given the urgency and scale of adaptation and mitigation action, new approaches need to be considered seriously. From this perspective, a recent policy brief from NAAS-India makes a departure by offering a set of recommendations about the importance and viability of deploying interactive online learning and capacity building arrangements involving MOOCs (National Academy of Agricultural Sciences 2014). A well-formulated blend of sound practices from the two case studies described here, and the policy recommendations of NAAS-India can substantially add to the platform of action toward developing food security-related responses to climate change in the IGP.

References

Anonymous Government makes 'neem coating' of 75% urea mandatory' The Economic Times. http://articles.economictimes.indiatimes.com/2015-03-30/news/60643886_1_domestic-urea-manufacturers-neem-coated-urea-neem-coated-urea

Balaji V, Prabhakar TV (2013) Changing the tunes from bollywood's to rural livelihoods—mobile telephone advisory services to small and marginal farmers in India: a case study. In: Ally M, Tsinakos A (eds) Increasing access through mobile learning. Commonwealth of Learning and

Athabasca University, Vancouver and Athabasca, pp 205–216
Balaji V, Craufurd P (2011) Using information and communication technologies to disseminate and exchange agriculture-related climate information in the Indo-Gangetic Plains Working Paper No. 20 CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark. Copenhagen. www.ccafs.cgiar.org. Accessed 10 Apr 2015
Carabine E, Lemma A (2014) The IPCC's fifth assessment Report: what is in it for South Asia? Overseas Development Institute and Climate Development and Knowledge Network, London
Carter MR, Lybbert TJ (2012) Consumption versus asset smoothing: testing the implications of poverty trap theory in Burkina Faso. J Dev Econ 99:255–264
Chike Anyaegbunam C, Paolo Mefalopulos, Titus Moetsabi (2004) Participatory rural communication appraisal: a handbook, Second Edition, Food and Agriculture Organization (FAO), Rome. http://www.fao.org/docrep/008/y5793e/y5793e00.HTM. Accessed 10 Apr 2015
Cruz RV, Harasawa H, Lal M,Wu S, Anokhin YB, Punsalmaa B, Honda Y, Jafari MC, Li C, Huu Ninh N (2007) Asia. Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change, Parry ML,Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds.), Cambridge University Press, Cambridge, UK, 469–506
Devakumar C (2005) Role of neem in crop protection and nitrogenous fertiliser management. Indian Farming 54:10–14
Erbs M, Manderscheid R, Jansen G, Seddig S, Pacholski A, Weigel H (2010) Effects of free-air CO2 enrichment and nitrogen supply on grain quality parameters and elemental composition of wheat and barley grown in a crop rotation. Agric Ecosyst Environ 136:59–68
High Level Panel of Experts on Food Security and Nutrition HLPE). Food security and climate change. HLPE, Rome. (2012) p. 33 http://www.fao.org/3/a-me421e.pdf%20 Accessed 10 Apr 2015
ICRISAT (2015) Interview with Balachander Rakela on drought preparedness. http://www.youtube.com/watch?v=gnQGyE5AWPA. Accessed 10 Apr 2015
Indian Network for Climate Change Assessment, India (2010): Greenhouse Gas Emissions—2007. The Ministry of Environment and Forests, Government of India, New Delhi, p 84
Lal R (2004) Soil carbon sequestration in India. Clim Change 65:277–296
Mula RP, Wani SP, Rai KN, Balaji V (2010) Lessons from women's participation in ICRISAT R4D projects: talking points for climate change initiatives. Clim Dev 2(4): 378–389
Murthy CS, Laxman B, Sai MS (2015) Geospatial analysis of agricultural drought vulnerability using a composite index based on exposure, sensitivity and adaptive capacity. Int J Disaster Risk Reduct. doi:10.1016/j.ijdrr.2015.01.004
National Academy of Agricultural Sciences (2011) Drought preparedness and mitigation. Policy Paper No. 50, National Academy of Agricultural Sciences, New Delhi, p 22
National Academy of Agricultural Sciences (2014) MOOC for capacity building in Indian agriculture: opportunities and challenges, Policy Paper No. 70, National Academy of Agricultural Sciences, New Delhi
Nelson GC, Valin H, Sands RD, Havlík P, Ahammad H, Deryng D, Elliott J, Fujimori S, Hasegawa T, Heyhoe E, Kyle P, Von Lampe M, Lotze-Campen H, Mason d'Croz D, van Meijl H, van der Mensbrugghe D, Müller C, Popp A, Robertson R, Robinson S, Schmid E, Schmitz C, Tabeau A, Willenbockel D (2013) Climate change effects on agriculture: economic responses to biophysical shocks. Proc Natl Acad Sci USA. doi:10.1073/pnas.1222465110
Ojha HR, Rasheed Sulaiman V, Sultana P, Dahal K, Thapa D, Mittal N, Thompson p, Bhatta GD, Ghimire L, Aggarwal P (2014) Is South Asian agriculture adapting to climate change? Evidence from the Indo-Gangetic Plains. Agroecol Sustain Food Syst. doi:10.1080/21683565.2013.841607
Pandey RP, Ramasastri KS (2001) Relationship between the common climatic parameters and average drought frequency. Hydrol Process 15(6):1019–1032
Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI (2014) Food security and food production systems. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, and White LL (eds). Climate Change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change . Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485–533
Prakash A (2011) Why volatility matters. In: Prakash A (ed) Safeguarding food security in volatile global markets. Food and Agriculture Organization of the United Nations (FAO), Rome, pp 3–26
Sreedhar G, Nagarajan R, Kumar VR, Lavanya N, Sylvester AG, Balaji V (2009). Disaster preparedness using IT tools: case studies on the use of ICT and GIS derived tools for micro-level drought preparedness. In: Proceedings of IEEE conference on humanitarian challenges, Bangalore, 28 Aug 2009. http://ewh.ieee.org/r10/gujarat/htccon/presentations/HTCCON_G%20Sreedhar_Disaster%20Preparedness%20using%20ICT%20Tools_280809.pdf. Accessed 28 April 2015
Sreedhar G, Mishra SS, Nagarjan R, Balaji V (2012) Micro-level drought vulnerability assessment in Peddavagu basin, a tributary of Krishna River, Andhra Pradesh, India. Earthzine IEEE Oceanic Engineering Society. http://earthzine.org/2012/01/18/micro-level-drought-vulnerability-assessment-in-peddavagu-basin-a-tributary-of-krishna-river-andhra-pradesh-india/. Accessed 10 Apr 2015
Thornton P, Cramer L (eds) (2012) Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR's mandate. CCAFS Working Paper 23. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen. www.ccafs.cgiar.org. Accessed 10 Apr 2015
Tubiello FN, SalvatoreM, Cóndor Golec RD, Ferrara A, Rossi S, Biancalani R, Federici S, Jacobs H, Flammini A (2014) Agriculture, forestry and other land use emissions by

sources and removals by rinks 1990–2011 analysis, ESS Working Paper No. 2, Food and Agriculture Organization, Rome.

United Nations Environment Programme (2012) Priority areas for capacity building for developing countries as listed in Decision 2/CP.7. United Nations Environment Programme (UNEP), Nairobi. http://unfccc.int/files/cooperation_and_support/capacity_building/application/pdf/cb_priority_areas.pdf. Accessed 10 Apr 2015

Venkateswarlu B, Singh AK (2012) Climate change adaptation and mitigation strategies in rainfed agriculture. In: Singh AK, Dagar JC, Arunachalam A, Gopichandran R, Shelat KN (eds) Climate change modelling, planning and policy for agriculture. springer, New Delhi. doi:10.1007/978-81-322-2157-9 **Springer eBook (2012)**

Yadav, Kiran (2015) MobiMOOC: an effectiveness study, Uttar Pradesh state, India. Commonwealth of Learning, HDL. http://hdl.handle.net/11599/574. Accessed 28 Apr 2015