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Farmers' prioritization of climate-smart agriculture (CSA) technologies

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ABSTRACT

Addressing climate change impacts on agriculture is special challenge. There are number of factors that influence the extent to which farmers in a particular location adopt CSA technologies. This study applied a participatory assessment method to assess farmers' preferences and willingness-to-pay for selected CSA practices and technologies in diverse rainfall zones. The study found that farmers' preferences for CSA technologies are marked by some commonalities as well as differences according to their socio-economic characteristics and rainfall zones. The most preferred technologies by local farmers were crop insurance, weather-based crop agro-advisories, rainwater harvesting, site-specific integrated nutrient management, contingent crop planning and laser land levelling. The results also indicate that farmers' preferences and willingness-to-pay are influenced by technologies and their cost of implementation. This study shows the potential for using a participatory CSA prioritization approach to provide information on climate change adaptation planning at local level.

1. Introduction

Climate change is emerging as a major threat on agriculture, food security and livelihood of millions of people in many places of the world (IPCC, 2014). Several studies indicate that agriculture production could be significantly impacted due to increase in temperature (Lobell et al., 2012; Aggarwal et al., 2009), changes in rainfall patterns (Prasanna, 2014; Mall et al., 2006) and variations in frequency and intensity of extreme climatic events such as floods and droughts (Brida and Owiyo, 2013; Singh et al., 2013). The estimated impacts of both historical and future climate change on cereal crop yields in different regions indicate that the yield loss can be up to −35% for rice, −20% for wheat, −50% for sorghum, −13% for barley, and −60% for maize depending on the location, future climate scenarios and projected year (Porter et al., 2014). Changes in crop cultivation suitability and associated agriculture biodiversity, decrease in input use efficiency, and prevalence of pests and diseases are some of the major causes of climate change impacts on agriculture (Zabel et al., 2014; Norton, 2014). Agriculture production systems require adaptation to these changes in order to ensure the food and livelihood security of farming communities.

There are several potential adaptation options to reduce moderate to severe climatic risks in agriculture. Adaptation options that sustainably increase *productivity*, enhance *resilience* to climatic stresses, and reduce *greenhouse gas emissions* are known as climate-smart agricultural (CSA) technologies, practices and services (FAO, 2010). Broadly, CSA focuses on developing resilient food production systems that lead to food and income security under progressive climate change and variability (Vermeulen et al., 2012; Lipper et al., 2014). Many agricultural practices and technologies such as minimum tillage, different methods of crop establishment, nutrient and irrigation management and residue incorporation can improve crop yields, water and nutrient use efficiency and reduce Greenhouse Gas (GHG) emissions from agricultural activities (Branca et al., 2011; Jat et al., 2014; Sapkota et al., 2015). Similarly, rainwater harvesting, use of improved seeds, ICT based agro-advisories and crop/livestock insurances can also help farmers to reduce the impact of climate change and variability (Mittal, 2012; Altieri and Nicholls, 2013). In general, the CSA options integrate traditional and innovative practices, technologies and services that are relevant for particular location to adopt climate change and variability (CIAT, 2014). In this study, we consider a technology or practice as climate smart if it can help to achieve at least one pillar of CSA (either increases *productivity* or increases *resilience* or reduces *GHG emission*). For all adaptation options, farmers need to make ex-ante decisions under climatic risk, while making short and long-run investments depending on the extent of current climate variability and expected climate change in the future (Callaway, 2004).

The implementation of CSA technologies (hereafter CSA technologies indicate technologies, practices and services together) individually or in combination have substantial potential to reduce climate change impacts on agriculture. For example, Finger and Schmid (2007) projected that simple adaptation measures such as changes in crop

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sowing dates and adoption of irrigation technologies can result in higher yields with less variations than without adaptation. A meta-analysis of crop simulation under several climate scenarios found that farm level adaptations can increase crop yields by an average of 7–15% when compared to without adaptation (Challinor et al., 2014). Various studies show that benefits of adaptation vary with crop and with temperature and rainfall changes (Easterling et al., 2007). Similarly, several farm level studies also suggest that adoption of CSA technologies can improve crop yields, increase input use efficiency, increase net income and reduce GHG emissions (Khatri-Chhetri et al., 2016; Sapkota et al., 2014; Gathala et al., 2011).

Despite the various benefits of CSA technologies, the current rate of adoption by farmers is fairly low (Palanisami et al., 2015). There are many factors that influence extent of adoption of CSA technologies such as socio-economic characteristics of farmers, bio-physical environment of a particular location, and the attributes of new technologies (Campbell et al., 2012; Below et al., 2012; Deressa et al., 2011). The identification, prioritization and promotion of available CSA technologies considering local climatic risks and demand for technology are major challenges for scaling out CSA in diverse agro-ecological zones.

Basically, the identification and prioritization of CSA technologies support climate change adaptation planning in agriculture by designing an investment portfolio across various agro-ecological zones. When designing CSA implementation strategies at the farm level, one must consider adaptation options that are well evaluated and prioritized by local farmers in relation to prominent climatic risks in that location (FAO, 2012). Despite the importance of prioritization of CSA technologies at farm level, existing climate change adaptation programmes lack such information for better adaptation planning. Evidences on farmers' prioritization can support key stakeholders make informed decisions that are in line with government policies and institutional arrangements.

There are several prioritization approaches such as the use of simulation models, expert judgement, household and key informant surveys, participatory appraisal and hybrid methods (Mwongera et al., 2014; Taneja et al., 2014; Claessens et al., 2012). This paper describes and applies a participatory assessment method of farmers' preferences and willingness-to-pay for CSA technologies. This methodology was applied in a state of Rajasthan in India which is the most vulnerable state to climate change in the country. This state has the highest level of rural households (78.4%) dependent on agriculture (GoI, 2014). The agriculture sector contributes about 20% of total Gross Domestic Product in Rajasthan (UNDP, 2011). Frequent drought, extremely low and erratic rainfalls and very limited availability of surface water resources are major issues for climate change adaptation in Rajasthan (TERI, 2010). The state has the maximum probability of occurrence of drought in India with a 2–3 years return period (Pathak, 2011). This study uses socio-economic data and climate information of the study areas to assess farmers' preferences for CSA technologies in diverse rainfall zones and that are highly vulnerable to climate change and variability. This study area represents many similar climate change vulnerable locations in the region.

2. Sites, data and methods

2.1. Sites and data

This study was conducted in 16 villages in four diverse rainfall zones (ranging from 200 mm to 1000 mm rainfall per year) of Rajasthan in India (Fig. 1). The moderate drought probability in the selected districts (Bhilwara, Jhalawar, Jodhapur and Rajsamand) ranges from 19% to 27% and severe drought probability is above 5% (Gore et al., 2010). Rainfed agriculture is very common in the study areas which is ranges from 44% to 85% (Table 1). The major crops in Kharif (rainy season) include maize, soybean, bajra, Jawar, groundnut and sesamum. The crops grown in Rabi (winter season) include wheat, gram, mustard, lentil and barley. Maize-Wheat, Soybean-Wheat, Maize-Pulses and Pearlmillet-Wheat/Pearlmillet-Mustard are the major cropping systems.

This study has assessed a distribution of mean annual rainfall for last 30 years in the study areas. Average rainfall over last 30 years in Bhilwara district is 582 mm/year with 31–40% coefficient of variation (CV), Jhalawar 916 mm/year with 21–30% CV, Jodhapur 371 mm/year with 41–50% CV and Rajsamand 512 mm/year with 21–30% CV. This CV represents inter-annual variation in rainfall; the higher the CV, the more variable is the year-to-year rainfall.

Four villages in each district were selected to assess farmers' preferences and willingness to pay for climate-smart technologies after extensive discussion with government officials, community service organizations (CSOs) and key informants of the communities. These villages were selected by considering different rainfall zoness, high dependency on rainfed agriculture and high probability of drought prevalence. A climate change and agricultural vulnerability assessment report (Rao et al., 2013) also indicates that the agriculture in all selected districts is highly vulnerable to climate change and variability.

Data for this study was obtained through survey and group discussions with randomly selected group of 25–30 farmers in each village. The research team had interacted with the selected farmers to assess their understanding of climate change and variability, past climatic threats and their impacts on agriculture, and what adaptation options were available to them. A list of CSA technologies was developed based on a review of past studies conducted in similar study areas (Khatri-Chhetri 2016; Sapkota et al., 2015, Aryal et al., 2015; Jat et al., 2014; Sapkota et al., 2014) and in consultation with researchers in the region. We consider that any practice or technology that supports at least one of the three pillars: *productivity*, *resilience* and *mitigation* in agriculture under climate change and variability can be a CSA technology. During the discussion, detail information about existing CSA technologies suitable for local conditions were provided to all farmers (Table 2). This discussion helped to identify the most suitable CSA technologies which can minimize the climatic risks in each village. In-person interviews were also conducted with farmers to collect their basic socio-economic information.

This study used a stated preference method to analyse farmers' choice of CSA technologies in diverse rainfall zones. In the stated preference method, respondents are asked about their preferences in a list of technologies. Whereas in the revealed preference method, actual adoption of technology or related technology reveals farmers' preferences and the market value is available for that technology. The revealed preference methods can be an appropriate tool to assess farmer's preferences, but it is difficult to obtain sufficient variation in the preference data to examine all variables of interest (Kroes and Sheldon, 1988). Therefore, many studies on valuation of environmental services and consumers' preferences ranking use stated preference method. In this study, farmers' preferences for climate-smart technologies were obtained in two steps. In first step, farmers' were organized into a group of 5–6 for discussion on CSA technologies and then asked to score each technology from 0 to 3 scale (0 = no preferences, 1 = low preference, 2 = medium preference, and 3 = high preference). These values were converted to percentiles and categorized into four classes (Table 3).

In the second step, the study team conducted a bidding exercise using pseudo money for only those technologies that were highly preferred by the farmers in the scoring exercise. All selected technologies were further weighted ranging between a 0 to 100 scale based on payment schedule in terms of bidding amounts and categorized into four preference classes (poor, low, medium and high). The weight for each technology from bidding exercise was estimated based on following formula:

$$W_t = \frac{\text{Amount of bid on a technology}}{\text{Cumulative amount of bids for all the technologies}} \times 100$$

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