INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

IFPRI

RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security

CGIAR CCAFS

IFPRI Discussion Paper 01337

April 2014

Farmers' Preferences for Climate-Smart Agriculture

An Assessment in the Indo-Gangetic Plain

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ABSTRACT

This study was undertaken to assess farmers' preferences and willingness to pay (WTP) for various climate-smart interventions in the Indo-Gangetic Plain. The research outputs will be helpful in integrating farmers' choices with government programs in the selected regions. The Indo-Gangetic Plain (IGP) was selected because it is highly vulnerable to climate change, which may adversely affect the sustainability of the rice-wheat production system and the food security of the region. Climate-smart agriculture (CSA) can mitigate the negative impacts of climate change and improve the efficiency of the rice-wheat-based production system. CSA requires a complete package of practices to achieve the desired objectives, but adoption is largely dependent on farmers' preferences and their capacity and WTP.

To assess farmers' choices and their WTP for the potential climate-smart technologies and other interventions, we used scoring and bidding protocols implemented through focus group meetings in two distinct regions of Eastern and Western IGP. We find that laser land leveling (LLL), crop insurance, and weather advisory services were the preferred interventions in Eastern IGP. Farmers preferred LLL, direct seeding, zero tillage, irrigation scheduling, and crop insurance in Western IGP. Through the bidding approach, farmers implicitly express their WTP for new technologies that could transform current agricultural practices into relatively low-carbon and more productive farming methods. But actual large-scale adoption of the preferred climate-smart technologies and other interventions would require access to funding as well as capacity building among technology promoters and users.

Keywords: willingness to pay, climate-smart agriculture, Indo-gangetic plain, scoring method, bidding method

ACKNOWLEDGMENTS

This report was prepared as a contribution to the project "Prioritizing Interventions for Reducing Impact of Climate Change and Increasing Incomes of Smallholders in Indo-Gangetic Plain," with generous support from Climate Change Agriculture and Food Security (CCAFS). The authors thank Dr. B. R. Kamboj and Dr. Anil Kumar of the Cereal System Initiative in South Asia, Karnal, Haryana; Dr. R. K. P. Singh of the ICAR Research Complex for Eastern Region, Patna, Bihar; and Mr. Devender Prasad Singh and Mr. Sanjeev Singh, farmers from Vaishali District in Bihar, for helping organize focus group discussions with farmers.

ABRREVIATIONS AND ACRONYMS

AIBP	Accelerated Irrigation Benefit Programme
CCAFS	climate change, agriculture and food security
CSA	climate-smart agriculture
Eastern IGP	Eastern Indo-Gangetic Plain
FAO	food and agricultural organization
IADP	Intensive Agricultural Development Programme
IGP	Indo-Gangetic Plain
IPCC	Intergovernmental Panel on Climate Change
LLL	laser land leveling
NAPCC	National Action Plan on Climate Change
NFSM	National Food Security Mission
NPPBUF	National Project on Promotion of Balanced Use of Fertilizers
NPOF	National Project on Organic Farming
SRI	system rice intensification
Western IGP	Western Indo-Gangetic Plain
WTP	willingness to pay

1. INTRODUCTION

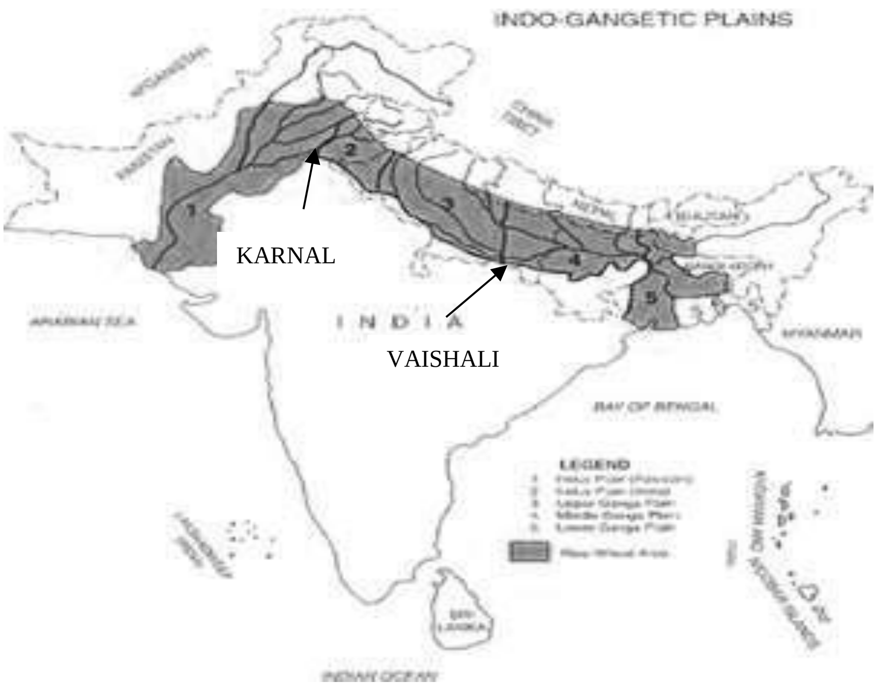
The impact of climate change on agriculture and food security is a major issue of global concern. Climate change exacerbates existing pressures on natural resources such as land and water. Extreme weather events in the form of heat, droughts, floods, and variable rainfall patterns will have a significant negative impact on agriculture production. According to one assessment, by the 2080s world agricultural productivity will decline by 3–16 percent (FAO 2010). Agriculture, which accounts for nearly 14 percent of greenhouse gas emissions, also contributes to climate change (IPCC 2007). The good news is that agriculture can be integrated into the solution to reduce the pace of climate change by sequestering carbon in the soil instead of emitting it into the atmosphere. It is possible to achieve what the World Bank (2010) terms “climate-smart agriculture” or “triple wins”: attaining higher yields, placing more carbon in the soil, and achieving greater resilience to heat and drought. Climate-smart agriculture (CSA) is a bundle of interventions that help in realizing the triple wins. A set of climate-smart interventions is location specific, and its large-scale adoption must be compatible with users’ skills and their willingness to pay (WTP). This study examines the suites of climate-smart interventions for two well-known rice-wheat cropping zones in the important Indian regions of Eastern IGP and Western IGP. It assesses farmers’ preferences and their WTP for the climate-smart interventions.

The report is organized as follows. Section 2 introduces the climate, land, and water resources and the agricultural production systems in the two distinct zones, Western and Eastern IGP, and defines the objectives of the study. Section 3 discusses the methodology used to determine WTP and provides a review of relevant studies on farmers’ WTP. The approach, the specifics of the study area, and issues relating to data are addressed in Section 4. CSA comprises several groups of technologies focusing on water, planting methods, nutrients, and energy, among other factors, and institutional interventions such as agricultural insurance, weather advisory services, and so on. The technologies identified for preference assessment are discussed in Section 5. Results of the assessment of farmers’ preferences, the conditions favoring the adoption of these technologies, and CSA-aligned programs are addressed in Sections 6 and 7. The paper concludes with a set of technology and policy recommendations, which are presented in Sections 8 and 9.

2. THE INDO-GANGETIC PLAIN

The IGP is a vast area of fertile land spread over 255 million hectares (ha), across four major countries: India, Pakistan, Nepal, and Bangladesh (Figure 2.1). With a population of about 800 million, it has been a food bowl for centuries. Based on climatic, hydrologic, and physiographic variations, the IGP consists of five homogeneous regions: (1) Trans-Gangetic plain in Pakistan; (2) Trans-Gangetic plain in India; (3) Upper-Gangetic plain; (4) Middle-Gangetic plain; and (5) Lower-Gangetic plain (Gupta et al. 2001). But from the point of biophysical and socio-economic development, the Indian IGP can be divided into two broad categories: Western IGP, comprising regions 2 and 3, and Eastern IGP, in region 4.

Figure 2.1 Locations of study areas in the Indo-Gangetic Plain



Source: Gupta et al (2001).

Climate

The climate is monsoonal and is characterized by two distinct seasons, summer and winter, which define the cropping seasons. Climate change is expected to significantly modify weather patterns. Climate change projections indicate major variations in temperature, rainfall intensity, number of rainy days, and extreme weather events (Box 2.1). The temperature rise may exceed 4°C in parts of northwest India and Bihar. The number of rainy days could decrease by about 15 days in Western IGP and between 5 and 10 days in Eastern IGP. In increase in rainfall intensity by 1–4 millimeters per (mm/) day in Eastern IGP and increased frequency of storms would result in flood-drought syndrome. Wheat, a major crop of the IGP, is expected to face a significant risk of reduced productivity due to a rise in winter-season temperatures. Climate change, under the present circumstances, will hinder the realization of food production targets and threaten the food security of the country.

Box 2.1 Climate projections for the IGP at a glance

Maximum temperature: Increase by 2–4°C during 2050s in regions above 25°N.

Minimum temperature: Increase by up to 4°C in most parts of the country. May exceed 4°C over the southern peninsula; northeast India; and some parts of Punjab, Haryana, and Bihar.

Monsoon rainfall: Marginal changes in the monsoon months (June, July, August, and September). Large changes during non-monsoon months.

Number of rainy days: Decrease in the number of rainy days per year over a major part of the country, especially in the western and central parts (by more than 15 days). Closer to the foothills of the Himalayas (Uttaranchal) and in northeast India the number of rainy days may increase by 5–10 days.

Extreme rainfall events: Overall increase in the intensity of rain is expected, by 1–4 millimeters per (mm/) day, except for small pockets in northwest India where the rainfall intensities will decrease by 1 mm/day.

Cyclonic storms: Increase in frequency and intensity is expected.

Source: IWMI (2009).

The State of Agricultural Production Systems

There are significant differences in these regions in terms of natural resource endowment, demography, and agricultural productivity. Western IGP has benefitted from Green Revolution technologies and has supported very intensive agriculture, characterized by high inputs of capital, labor, water, and fertilizers, resulting in huge productivity gains for rice and wheat. The surplus food production in Western IGP provided regional food security, generated employment, and attracted seasonal in-migration from Eastern IGP. However, the increased agricultural productivity in the region was achieved at the cost of a decline in soil health and exploitation of aquifers and the disturbance of river ecosystems. These negative externalities, particularly a secular decline in the groundwater table and soil salinity, have resulted in desertification. It is estimated that more than 30 percent of the production in the region was based on mined groundwater. And, of the 1,068 blocks (groundwater development units) in the three states (Punjab, Haryana, and Uttar Pradesh), 214 were characterized as dark or gray (groundwater extraction exceeds the annual recharge) in the context of groundwater depletion (Kamra 2007). Water balance analysis showed that the available water supply from all sources was inadequate to support the present water-intensive cropping system, and the region faces a serious to alarming physical water scarcity. The occurrence of nutrient deficiency and imbalance has led to reduced total factor productivity and consequently increased costs of production and lowered incomes from farming activity.

In contrast to Western IGP, Eastern IGP is better endowed in terms natural resources, particularly land and water. Eastern IGP is regularly hit by floods from rivers and has relatively less-exploited groundwater resources due to high energy costs. Agriculture here is more dependent on the monsoon rains. Droughts and floods frequently affect agricultural production. Over the years, their extent and intensity have increased and are making agriculture riskier. Poor management of water resources, a low level of infrastructure development, the absence of proper land records and ownership, and a highly prevalent high tenure system have resulted in low penetration of improved agricultural technologies and consequently low agricultural productivity. For example, the productivity of the dominant cropping system of rice-wheat in Western IGP is more than 10 tons /ha, compared to only 6.2 tons/ha in Eastern IGP (Yadav, Yadav, and Singh 2008). Despite its superior resource endowments, Eastern IGP is a food-deficit region with meager employment opportunities. Though lying in the same basin, Western IGP and

Eastern IGP have contrasting characteristics (Table 2.1) with respect to resource management and policy support.

Table 2.1 Comparative characteristics of agricultural production systems in Western and Eastern IGP

Factors	Western IGP	Eastern IGP
Agroeconomic development	High agricultural productivity, food surplus	Low agricultural productivity, food deficit
	High agro-input use, including seeds, fertilizer, and chemicals	Low agro-input use, including seeds, fertilizer, and chemicals
	Medium penetration level of water management and other agro-technologies	Low penetration level of water management and other agrotechnologies
	Good infrastructure	Poor infrastructure
	High employment opportunities in agriculture, labor in-migration	Low employment opportunities in agriculture, labor out-migration
Natural resource endowment	Groundwater overexploited, continued decline in water table, high pumping costs	Moderate groundwater development, considerable scope for future development
	Physical water scarcity	Economic water scarcity
	Soil salinity and poor groundwater in some areas	High arsenic concentration in groundwater in some areas
	Decreasing soil fertility, low factor productivity	Floods more common, occasional droughts
	Occasional droughts but reasonable drought-proofing due to irrigation	
Issues arising from climate change	How will climate variability affect food production systems with respect to water demand, groundwater, greenhouse gases, livelihoods?	Will climate variability further aggravate vulnerability to floods in resource-poor regions?
	To what extent can climate-smart agrotechnologies/policies reduce production variability and remove stagnation in the productivity of the rice-wheat system?	Can crop diversification / fisheries improve farm incomes and rural livelihoods and minimize large-scale migration of people?
		How can infrastructure and markets be strengthened to take advantage of the typical surface- and groundwater regime?

Source: Authors.
Note: IGP = Indo-Gangetic Plain.

Western IGP, a region with a better economic resource base, has experimented with some climate-smart interventions thanks to public-sector funding. Eastern IGP, in contrast, has a relatively poor economic resource base. It is now at the threshold of the Green Revolution with great potential for further development. The IGP food production system provides a unique opportunity to test farmers' preferences and WTP for climate-smart intervention on a large scale.

Objectives of the Study

The IGP has been identified as a region where climate change is expected to make a significant difference in agricultural productivity. To escape the negative effects of climate change, there is considerable scope for exploring a variety of location-specific technologies and policy interventions. Agriculture is dominated by a large number of marginal farmers and smallholders with varying levels of knowledge, skills, capital, and resource bases. It is hypothesized that farmers' choices and WTP for climate-smart technologies and interventions is differentiated by the attributes (explanatory attributes) of the technologies themselves, by agroclimatic conditions, and by the backgrounds of the farmers.

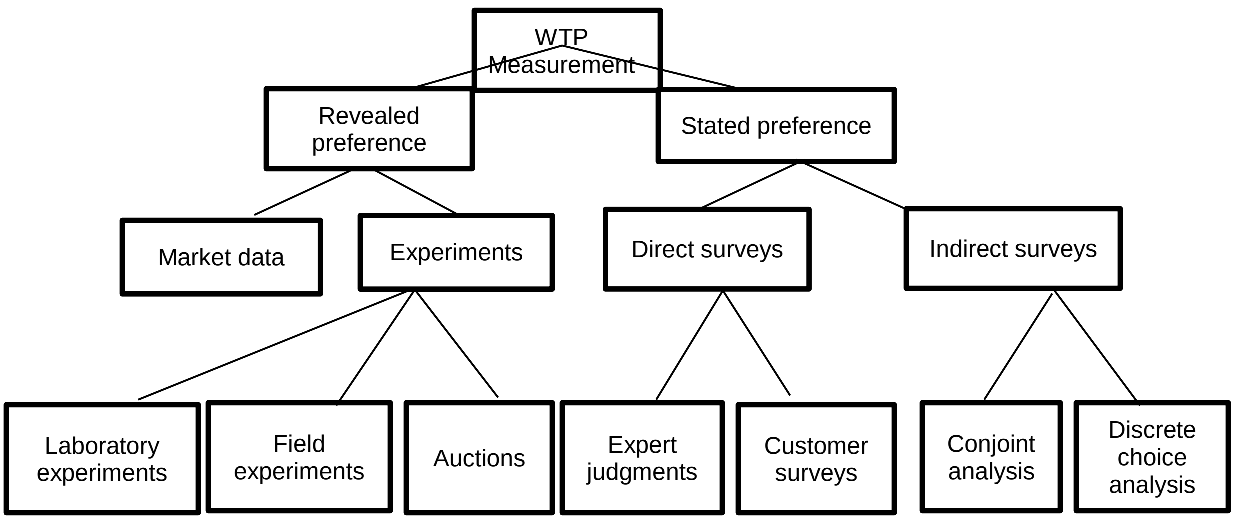
In this study, the issues for investigation are therefore as follows:

1. Which potential technological options for the dominant rice-wheat cropping system of IGP would help farmers adapt and/or reduce the risk of climate change?
2. What are the preferred technologies and/or interventions for the two distinct regions of the IGP, which are differentiated in terms of their natural resource bases and socio-economic conditions?
3. How willing are farmers to pay for the available technological options?
4. What are the necessary conditions for success in large-scale adoption of farmers' choices? How can farmers' choices and WTP be aligned with government policies and institutional arrangements to promote large-scale adoption?

3. METHODOLOGY FOR ASSESSMENT OF WILLINGNESS TO PAY

There are a number of competing approaches and corresponding analytical techniques to measure WTP (Figure 3.1), with differential conceptual foundations and methodological implications (Breidert, Hahsler, and Reutterer 2006). But two methods are used widely: (1) the revealed preference method and (2) the stated preference method (contingent valuation or choice experiment). In the revealed preference method, there is an assumption of a relationship of substitutability between a market good and the nonmarket good of interest. While in stated preference methods (contingent valuation or choice experiment), respondents are asked about their preferences. Surveys can be direct, in which respondents are asked to state how much they would be willing to pay for a product or service, or indirect, in which some sort of rating or ranking procedure for different products is applied to develop a preference structure from which WTP can be derived (Marbeau 1987).

Figure 3.1 Classification framework for methods to measure willingness to pay (WTP)



Source: Breidert, Hahsler, and Reutterer 2006.

Contingent Valuation for Assessing WTP

Contingent valuation is one the methodologies often used for assessing users' preferences for goods and services that do not have a well-defined market price. The technique derives its name from the fact that the value estimates are contingent on a hypothetical scenario that is presented to the respondents for valuing. The contingent valuation method is also known as the *stated preference method* or the *direct approach* because people are directly asked to state or reveal their preferences (Mitchell and Carson 1989). The techniques rely on stated preferences in surveys that are specially designed for assessing preferences and WTP. In the application of contingent valuation it is important that biases of different kinds (hypothetical/scenario misspecification, strategic bias) are eliminated as far as possible. It should be understood that assessment of the true WTP depends upon how the questions are framed and the level of awareness among the survey population. Otherwise, there could be large differences between stated and actual WTP (Cohen and Zilberman 1997). The current trend is to include expertise from other disciplines such as market research, survey research, social psychology, and cognitive psychology in designing contingent valuation surveys.

An understanding of key stakeholders' WTP is important for developing business strategy and evolving policy direction. In the context of agriculture, it is important to understand and measure farmers' WTP for the products and services on offer before deciding their final prices. Evidence-based and empirical information on WTP not only benefits the industry and service providers but also helps the government shape its policies and programs. The contingent valuation techniques for assessing WTP have largely been applied in the context of natural resources, and in developing countries water supply has been the most researched using this technique (see Ahmed et al. [2002] for arsenic in Bangladesh and Altaf et al. [1992] for rural Punjab). Some relevant studies are reviewed below.

Determinants of WTP

Studies on WTP can be justified only if the findings help in designing private-sector business strategies or in refining government policies and programs to promote and extend the use of desired technologies and/or interventions. A necessary condition to achieve this objective is to find out what makes farmers willing to allocate resources and invest in a particular technology. So it is no surprise that, in addition to assessing the level of WTP for particular technologies and services, most studies have been designed to establish the relationship between WTP and the attributes of the technology and the socio-economic background of the target population (Mwangi 1998).

It is generally believed that degree of knowledge influences the choices made by a consumer or farmer. But in a well-conducted choice experiment on WTP to fight climate change, de Chaisemartin and Mahe (2009) found that a subject's level of knowledge did not influence a subject's WTP. This corroborates Haba's (2004) research study on Rwanda in which farmers' duration of association with a coffee cooperative or their education level, which might have provided an opportunity to gain knowledge about the product on offer, had little influence on their WTP. It was further discovered that the phrasing of the question had a big significant influence on the responses.

To assess Ugandan farmers' WTP for agriculture services including soil fertility management, crop protection, varieties, marketing, and disease control, Ulimwengu and Sanyal (2011) used a multivariate probit model to establish the influence of the key determinants. Based on their analysis, they made the very significant observation that WTP for one service was not independent of WTP for the other services required in agricultural production; the attitudes were highly and positively correlated. Therefore, required services would need to be provided for the entire production system. Another important conclusion was that prior access to extension services decreased farmers' WTP. Land ownership and farm income were positively correlated with WTP, while lack of either had a negative impact.

In a study on WTP for extension advisory services in coffee plantations in Rwanda, Haba (2004) found a strong correlation between farmers' WTP for agricultural information delivery technologies and some of their demographic characteristics (age, gender, marital status, level of education, number of dependents, length of time spent as a cooperative member, income derived from agribusiness, and yearly expenditures on basic necessities). Age and gender were found to have a stronger correlation with WTP, with younger male farmers being more willing to pay. Coffee planters in Rwanda were also of the opinion (48 percent) that providing agricultural technology information was the government's responsibility.

Mirroring these findings in Africa, developing countries in Southeast Asia also showed that providing agricultural extension services to the farmers is considered the government's responsibility, though the service is often far from satisfactory. A study on farmers' WTP for private agronomic advisory services for various crops grown in Pakistan-Punjab, it was discovered that farmers were crop selective in extending support to private extension (Ali et al. 2008). Results of the analysis showed that farmers were willing to pay for disease-control advisory services relating to cotton, rice, and wheat on a limited scale. The survey did not mention any specific charges for the service, and it was concluded that there were only limited opportunities for a fee-based private extension system in Pakistan.

Improved seed varieties are an important component of Green Revolution technology and are readily accepted. Using contingent methods, Horna, Smale, and von Oppen (2005) examined the preferences for seeds of new rice varieties and the WTP for seed-related information in villages in Nigeria and Benin. The researchers used an ordered probit regression to estimate the indirect utility function. Farmers were asked to rank a sample of rice varieties with and without seed-related information. Explanatory factors included variety attributes, farmers' characteristics, and extension variables in addition to a price. Overall, the findings on WTP for seed-related information among participants supported the hypothesis that extension activity had potentially positive marginal benefits. However, the level of marginal benefits may still be too low to encourage private extension services.

Risk Hedging through Weather-Risk Insurance

Farmers face considerable weather-induced risks in the form of droughts, floods, and outbreaks of pests and diseases, which reduce their income stability. Weather-risk insurance for crops provides a means for farmers to minimize their loss at a cost. Though well suited to calamities and extreme weather events such as high floods and typhoons, insurance does not work well with the uncertainties present in normal weather. The worldwide development of a new financial tool called weather derivatives has added a new and useful method to hedge climatic risk. These derivatives have emerged as an insurance offshoot that is expensive and requires a demonstration of loss (of assets or of profits). Many researchers have studies the role of weather insurance in risk management for agriculture in developing countries (Mishra 2006; Sharma and Vashistha 2007; Singh 2010), but weather-risk crop insurance is a new intervention in India, and there are few structured studies on WTP for this instrument.

Seth, Ansari, and Datta (2009) conducted a seminal study assessing the WTP for risk hedging among farmers of Rajasthan. They carried out a survey of more than 500 farmers in six villages in Rajasthan and performed a contingent valuation. The survey included questions on factors that could have a bearing on the farmers' WTP and a bidding game in which responses were solicited to premiums in a hypothetical market. Probit and logit models were used to determine the WTP probabilities of "Yes" responses to various bids and the mean WTP. The researchers found that the farmers' mean WTP was around 8.8 percent of the maximum possible payout of a weather derivative contract.

In conclusion, the experiences with contingent valuation are quite varied and have been found to capture the interactions of product attributes, ability to pay, and the policy environment.

4. RESEARCH METHODOLOGY

Approach

The approach used to assess farmers' preferred technologies and their WTP for those technologies is the stated preference technique (Merino-Castelló 2003). A number of procedures can be used to elicit stated preference from subject groups. The present study is based on a contingent rating in which respondents are presented with a number of scenarios, one at a time, and are asked to rate each one individually on a numeric scale.

Rating and Ranking of Technologies by Scoring Method

The technologies, including their advantages and disadvantages, were explained to farmers through various techniques, and the farmers were then asked to score these technologies on a scale of 0 to 3. In this scoring method a score of 0 indicated no preference, 1 low preference, 2 medium preference, and 3 high preference. Only those technologies that received a score of 3 at least once remained for further assessment, and these were later classified into four groups according to their percentage of level-3 ratings (Table 4.1).

Table 4.1 Rating and ranking criteria for evaluation of farmers' preferences by scoring method

Rating scale	Level of preference	Ranking scale (of level-3 scores) (percent)	Class / assigned value
0	Zero	0–25	Poor (1)
1	Low	25–50	Low (2)
2	Medium	50–75	Medium (3)
3	High	75–100	High (4)

Source: Authors.

Determining Technology Preferences through the Bidding Process

The bidding process was organized with pseudo currency. The farmers groups, who had participated in the scoring process, were asked to bid for only those technologies for which they had given a score of 3, irrespective of the frequency, which determined their rank. A two-parameter criterion-weight assigned to a given technology and the bid frequency was used to determine the level of preference.

$$\text{Technology weight in the bidding game } (W_t) = \left(\frac{\text{Amount of bid by a group on a technology}}{\text{Cumulative amount of bids for all the technologies with a score of 3 in scoring game}} \right) \text{X } 100 \qquad (1)$$

$$\text{Average weight of technology } (W_{tav}) = \left(\frac{\text{Sum of weights assigned by the groups}}{\text{Number of groups participating in bidding}} \right) \qquad (2)$$

A scale ranging from 0 to 100 was chosen to classify technologies into two groups on the following basis:

- If all the technologies had the same weight, then on a scale of 0–100 the mean weight would be W_{tm} = (100 / number of technologies).
- If for a technology $W_{tav} \geq W_{tm}$, it is rated as a high-weight technology.
- If for a technology $W_{tav} \leq W_{tm}$, it is rated as a low-weight technology.

The technologies were further weighed on the basis of the frequency of their distribution on a 0–100 scale and were finally arranged into four groups, similar to the scoring process (Table 4.2).

Table 4.2 Level and value of technology preferences by bidding method

$W_{tav} \geq W_{tm}$ Frequency ≥ 50 percent **(4)**	$W_{tav} \leq W_{tm}$ Frequency ≥ 50 percent **(3)**
$W_{tav} \geq W_{tm}$ Frequency ≤ 50 percent **(2)**	$W_{tav} \leq W_{tm}$ Frequency ≤ 50 percent **(1)**

Source: Authors' calculations based on focus group surveys.
Note: Numbers within parentheses are the values assigned to degree of preferences. (1) = poor, (2) = low, (3) = medium, (4) = high.

Study Area

The Indian IGP traverses the states of Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal. Haryana, which represents the agroclimatic conditions of Western IGP, and Bihar, of Eastern IGP, were the two states selected for the study. Two districts, Karnal in Haryana and Vaishali in Bihar, were selected from these regions. These are the key sites of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) (Figure 2.1). Karnal has been a district under the Intensive Agricultural Development Programme (IADP), during the Fourth Five Year Plan, in which different kinds of pilot programs were initiated by the government and research institutes located there. It is an intensively cultivated semiarid (rainfall 700 mm/year) irrigated region with irrigation intensity exceeding 175 percent. It has benefitted from the Green Revolution, and the penetration of new technology among farmers here is overwhelmingly high. The key problems that farmers in this district face are soil salinity, the declining groundwater table, occasional droughts, and stagnating crop yields. In contrast, Vaishali district in Bihar, in Eastern IGP, is located in a water-rich zone with high rainfall (1,168 mm per year) and has good potential for groundwater development, which at present is about 65 percent. However, despite high rainfall, droughts are quite common. The acute shortage of energy is a major constraint on groundwater development in the district. The CCAFS program is active in a number of villages in two districts. Two villages from each district, Pakhana and Sandir in Karnal (Haryana) and Rajapakar and Mukundpur in Vaishali (Bihar), were randomly chosen for the assessment of farmers' preferences and conducting their WTP.

Data

The data for ascertaining farmers' preferences for climate-smart technologies were obtained via survey by the CCAFS research team during 2011 (Aggarwal et al. 2012). A participatory rapid rural appraisal was conducted in the selected villages, and basic information on aspects such as landholdings, crops and cropping practices, and exposure to new technologies was obtained. The dominance of the rice-wheat cropping system is the common feature in the selected locations, but the study sites differ with regard to size of landholdings, exposure to technology, and economic conditions. The average size of landholdings in Karnal in Haryana is much higher (5.5 ha) than the average in the study sites in Vaishali in Bihar (0.7 ha). Farmers in the selected study sites had some exposure to zero tillage, laser land leveling (LLL), direct-seeded rice, leaf color charts, drought-tolerant seed varieties, and composting.

The study team randomly selected 25–30 farmers at each site (50–60 farmers for each district) and familiarized them with selected climate-smart technologies through exhibitions. These farmers were then divided into six focus groups of five or six persons each to elicit their technology preferences. A questionnaire was developed to elicit responses during interviews. After ascertaining the farmers' technology preferences on a 0–3 scale, the study team conducted bidding for only those technologies that secured a rating of level 3 in the scoring exercise. The outcome of these scoring and bidding processes is given in Tables A.1 to A.9 in the appendix.

5. CLIMATE-SMART TECHNOLOGIES FOR ASSESSING WILLINGNESS TO PAY

CSA includes a number of technological, policy, and institutional interventions (Aggarwal et al. 2004) revolving around seed, water, energy, and nutrients and some risk-averting and risk-insuring instruments that increase the resilience and stability of agriculture and thus help farmers adapt to and reduce the risk of climate change. The selection of climate-smart technologies for the present study (Table 5.1) was based on the principle of triple wins, as discussed above. This approach took the form of biointensive agriculture and sought to increase production per unit of land/water/nutrients. The end result is a reduction in the emission of greenhouse gases per ton of farm produce; sequestration of carbon dioxide in the soil; and increased crop resilience to heat, droughts, and floods.

For the sake of clarity and better communication, we classify the various technologies and interventions into five groups: water-smart, energy-smart, nutrient-smart, crop-smart, and weather-smart interventions. The specifications of the technology basket are provided in Table 5.1.

Table 5.1 Selected technology options for choice experiment

Type of technology	Definition
1. Water-smart technologies	**Interventions that reduce water requirements to produce the same or a higher level of yield.**
• Rainwater management	In situ rainwater storage in rice paddies with 20–25 centimeters (cm) bunds. This technique is for rice only.
• Laser land leveling	Leveling of land with a laser leveler.
• System of rice intensification	7- to 10-day-old seedlings are transplanted at 20 cm spacing with 1–2 seedlings per hill.
• Furrow-irrigated raised bed	Growing crops on ridges or beds. Irrigation is applied through furrows separating the beds.
2. Energy-smart technologies	**Technologies that help reduce energy consumption during land preparation without affecting yield levels. These also help reduce water requirements for crops.**
• Direct-seeded rice	Dry seeds are sown either by broadcasting or drilling in line.
• Zero tillage / minimum tillage	The crop is seeded through a seeder in an untilled field, and the crop residue is incorporated into the soil. At present, this technique is limited to wheat only.
3. Nutrient-smart technologies	**Technologies that save/supplement/avoid chemical fertilizer use for crops and enrich carbon in the soil.**
• Green manure	Cultivation of legumes in a cropping system. This practice improves nitrogen economy and soil health/quality.
• Integrated nutrient management	Integrated use of organic and chemical fertilizers to partially (25 percent to 50 percent) reduce NPK (nitrogen, phosphorus, and potassium) requirements without affecting productivity and improve soil health.
• Leaf color chart	Standardized color charts are used to identify nutrient deficiency to estimate fertilizer doses in different field locations.
4. Weather-smart instruments	**Interventions that provide services related to financial security and weather advisories to farmers.**
• Crop insurance	Crop-specific insurance to compensate income loss due vagaries of weather.
• Weather advisories	Information and communication technology–based forecasting about the weather.
5. Introduction of stress tolerant crops and diversification	**Tolerant crops withstand biotic and abiotic stresses and crop diversification reduces water demands and helps in harnessing nutrients from different soil layers.**
• Drought-tolerant variety	Seed variety that is tolerant to drought or relatively dry weather conditions.
• Crop diversification (maize-wheat cropping)	Rice is replaced by maize on part of the land to economize on water use.

Source: Authors.

Water-Smart Technologies

A major impact of climate change on agriculture will be experienced in the form of water stress. Therefore, land development, water conservation and harvesting measures in both rainfed and irrigated agriculture, crop planting, and irrigating techniques, among others, could form a package of practices to help overcome the climate-imposed stress (Sharma et al. 2006; Tyagi 2009). Specific technologies in this group include LLL, in situ rainwater management for rice (with 20–25 cm high bunds) and system rice intensification (SRI). The water-economizing and yield-maximizing potential of these technologies has been adequately established through experimental studies and on-farm trials in a number of locations in the IGP (Tyagi 2009), and farmers have acquired some familiarity with these technologies.

Energy-Smart Technologies

Energy is the most important component for present-day agriculture. Although energy contributes to greenhouse gas emissions, the lack of it is a major barrier to agricultural development. Conservation agriculture is an energy-smart emerging intervention for sustainability (Lumpkin and Sayre 2009). The recent stagnation in productivity growth in the irrigated areas of the IGP has led to the development and refinement of resource-conserving technologies that save water and energy, improve soil health, and increase productivity. Practices to overcome energy constraints are zero tillage and direct seeding. Although these technologies focus on reducing energy use and the cost of production, the measures simultaneously save irrigation water by improving the soil moisture provided by rainwater, decreasing soil moisture evaporation, and decreasing pre-sowing irrigation. Each of these technologies has the potential to reduce water demand between 10 and 20 percent and boost crop yields by a similar level. Incidentally, zero tillage, SRI and LLL were developed not only to save water but also to increase mechanization to cope with the growing demand for labor in agriculture.

Nutrient-Smart Technologies

Agricultural practices that ensure soil and nutrient management and carbon management along with nitrogen management can contribute to the conservation of resources, sequestration of carbon, and safeguarding of future food security (Lal et al. 2011). There are a wide range of practices associated with this group of technologies, including green manure to supplement the applied chemicals and improve the physical condition of the soil, integrated nutrient management, and organic manure (farmyard manure and/or vermicompost) in a certain ratio (ICAR 2009). Some of these practices reduce emissions of greenhouse gasses and build organic carbon into the soil. The site-specific application of nutrients based on plant indicators such as leaf color is a technology that has been standardized for various crops. Leaf color charts are commercially available to help farmers monitor plant nutrient status and apply nutrients according to the plants' needs at different locations.

Stress Tolerant Seeds and Crop Mix -Smart Technologies

Water- and nutrient-input-responsive cultivars were a major factor in triggering the Green Revolution in India, as they were the least expensive and highest yielding option. Sustained efforts in recent years have led to the development of crop varieties that are resistant to biotic (pests and disease) and abiotic (flood and drought, salinity and heat) stresses for irrigated and rainfed conditions (ICAR 2009). Drought is a major climatic aberration that is experienced in both the states and therefore a technology representing drought-tolerant crop varieties was included in the assessment. Further, it has been established that the current large-scale rice-wheat cropping system is creating long-term groundwater imbalances, requiring a switch to less water-dependent crops (Tyagi et al. 2004; Ambast, Tyagi, and Raul 2006; Amarasinghe, Shah, and Singh 2007).

Diversification of crops, cropping systems, and farming systems could be a potential response to overcome water scarcity and also to act as a mechanism to minimize weather-induced losses and stabilize incomes. Maize, with its high yield potential and low irrigation requirements, is considered a good option and has been included as a crop diversification measure.

Weather-Smart Instruments

The vagaries of weather events such as floods and drought are a major reason for fluctuating productivity and farm incomes. These events are more frequently experienced in Eastern IGPthan in Western IGP. This situation is expected to worsen under the current climate-change scenario. Risk management through the dissemination of weather advisories and climate information, together with weather-based insurance, is a nonstructural intervention to reduce production losses and stabilize farmers’ income. Weather forecasting and advisory services and their dissemination through information and communication technology have made it possible to offset farming losses. Therefore, weather advisories and crop insurance have also been included as possible instruments to stabilize incomes and improve farmers’ capacity to adopt other productivity-enhancing technologies.

6. RESULTS AND DISCUSSION

The study on technology preferences and WTP included some crop-specific technologies (for example, SRI and direct-seeded rice were exclusively used for rice, and zero tillage was exclusively used for wheat) and some technologies that were common to both crops. The technology basket offered for scoring preference was the same across the states/districts/villages. Therefore, the analysis of results obtained is organized keeping the crop in the focus. We present the outputs of the stated preferences and WTP for both the regions for rice, followed by wheat. We identify the preferred technology package for each location and discuss marked intra- and inter-district and state variations with a view to understand the influence of some explanatory variables.

Assessment of Preferences for Technologies for Rice Cultivation

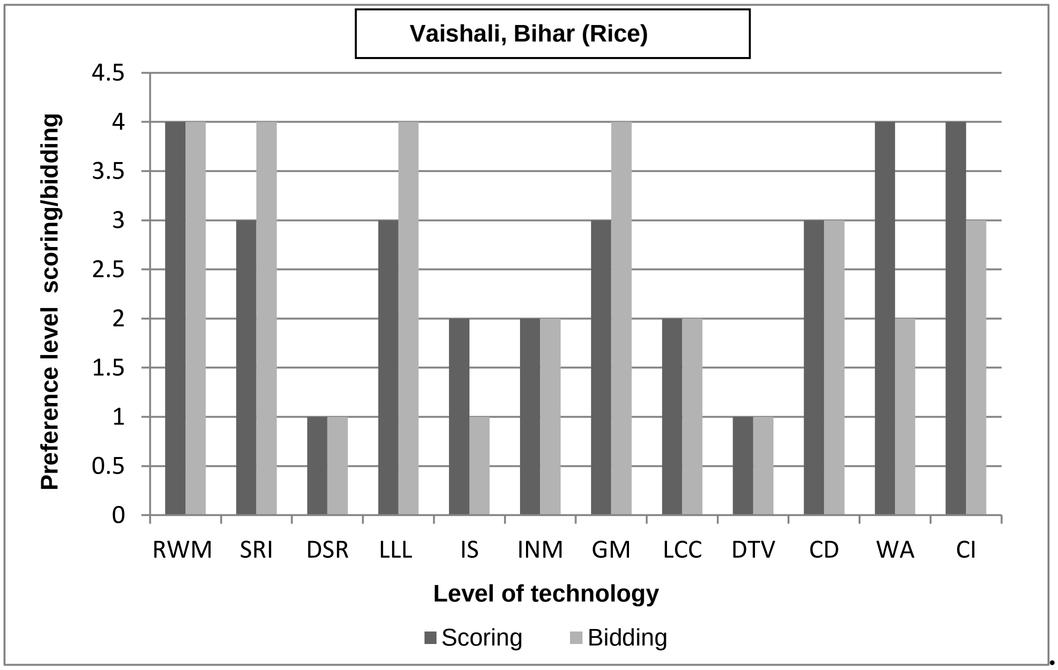
We employed two distinct methods, scoring and bidding (which we refer as WTP), in assessing farmers' preferences.

The technology preference scores in Eastern and Western IGP (more specifically, districts of Vaishali in Bihar, and Karnal in Haryana), as obtained by implementing the criteria for scoring (Table 4.1), are presented in Figures 6.1 and 6.2. Farmers expressed high (75 percent) to medium (50–75 percent) preferences for some of the technologies, such as LLL and green manure, in both regions. Similarly, technologies such as drought-tolerant varieties and irrigation scheduling found low preference across the locations. However, technologies such as SRI, direct-seeded rice, and in situ rainwater storage in rice paddies are marked by state-selective high preferences. For example, SRI had zero preference in Western IGP, but it secured medium (>50 percent) preference in Eastern IGP. Rainwater management through in situ storage of rainwater in rice paddies is an existing practice in water-deficient Western IGP sites, but the farmers there gave a lower score to this technology than did those in Eastern IGP, where its preference was high (>75 percent). Site-specific fertilizer application was a technology with high preference in Western IGP but lower preference in Eastern IGP. Farmers in Western IGP showed very little preference for crop diversification, where it is most needed.

Before assessing the possible determinants for the choices made, we first examined whether the method of eliciting preference had an effect on the order of preference. Adopting the procedure explained in Section 4, the degree of preference, based on classes distinguished by percentages, was reduced to numbers on a scale ranging from 1 to 4. The lowest preference class (<50 percent frequency and bid value $W_t \leq W_{tm}$) was given a value of 1, and the highest score was kept at 4 (frequency ≥50 percent and $W_t \geq W_{tm}$). The levels of preference thus obtained by the bidding process are shown in Figures 6.1 and 6.2).

In Eastern IGP, the level of preference for rainwater management, direct seeding, leaf color charts, drought-tolerant varieties, and crop diversification remained unchanged between the bidding and scoring processes. In the bidding method, LLL, SRI, green manure, and rainwater management were the top preferences, with first three technologies improving their positions from level 3 to 4 (Figure 6.1). The scores of the other three technologies, irrigation scheduling, weather advisories, and crop insurance, which were in contention in the scoring method, were reduced significantly in the bidding method.

Figure 6.1 Levels of preference by scoring and bidding (WTP) for rice-growing technologies in Vaishali, Bihar, Eastern IGP



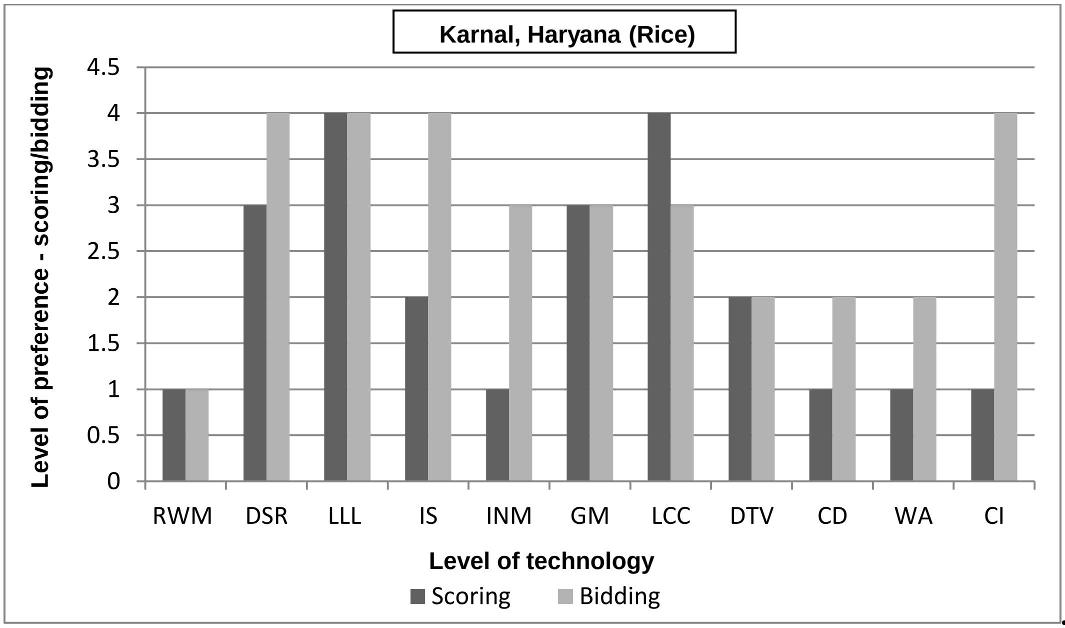
Source: Authors.

Note: IGP = Indo-Gangetic Plain; WTP = willingness to pay; RWM = rainwater management; SRI = system of rice intensification; DSR = direct seeding; LLL = laser leveling; IS = irrigation scheduling; INM = integrated nutrient management; GM = green manure; LCC = leaf color chart; DTV = drought-tolerant variety; CD = crop diversification; WA = weather advisories; CI = crop insurance.

In Western IGP, direct seeding, LLL, irrigation scheduling, and crop insurance received the top rank of level 4 in the bidding process (Figure 6.2). There was a significant departure in the technology preferences expressed through the bidding method in the case of low-cost technologies such as irrigation scheduling, direct seeding, and rainwater management, for which the degree of preference moved up from low to high levels (Figure 6.2). A dramatic change occurred in the case of irrigation scheduling, which moved up from poor in the scoring method to the most preferred group of technologies in the bidding method. Farmers in Eastern IGP showed greater consistency in expressing their preferences, as there were only marginal changes in their level of preference between the two methods as compared to Western IGP.

The reason for these marginal changes in the two approaches is that in the bidding approach, farmers were assigned a specific budget and asked to invest in their preferred technology. Assigning a budget to the farmers helped them prioritize the technologies based on their costs, benefits, and resource savings. In the case of Western IGP, technologies such as irrigation scheduling, direct-seeded rice, and rainwater management moved up. This is because according to the farmers, these technologies save water or reduce the number of irrigations, which brings down the cost of irrigation and improves their incomes.

Figure 6.2 Farmers' preferences and WTP for rice-growing technologies in Karnal, Haryana, Western IGP



Source: Authors.
Note: IGP = Indo-Gangetic Plain; WTP = willingness to pay; RWM = rainwater management; SRI = system of rice intensification; DSR = direct seeding; LLL = laser leveling; IS = irrigation scheduling; INM = integrated nutrient management; GM = green manure; LCC = leaf color chart; DTV = drought-tolerant variety; CD = crop diversification; WA = weather advisories; CI = crop insurance.

High-Preference Group of Rice Technologies in Bihar and Haryana

Crop production is not a single technology-driven enterprise but a package of practices that contribute to the various operations, from sowing to harvest. Based on the analysis of farmers' preferences elicited by two different methods and an examination of the degree of preference, technologies obtaining level 3 and 4 preference by both methods were classified as high-preference technologies and those at levels 1 and 2 as less preferred technologies. Based on the above criterion, the high-preference technologies for the two regions were identified (Table 6.1).

Table 6.1 Selected technology options by the farmers based on their willingness to pay

	Eastern IGP		Western IGP
1	Laser land leveling (4)	1	Laser land leveling (4)
2	Rainwater management (in rice paddies through dykes) (4)	2	Direct-seeded rice (4)
3	System of rice intensification (4)	3	Irrigation scheduling (4)
4	Green manure (4)	4	Crop insurance (4)
5	Crop diversification (3)	5	Leaf color chart (3)
6	Crop insurance (3)	6	Integrated nutrient management (3)
		7	Green manure (3)
		8	Weather advisories (3)

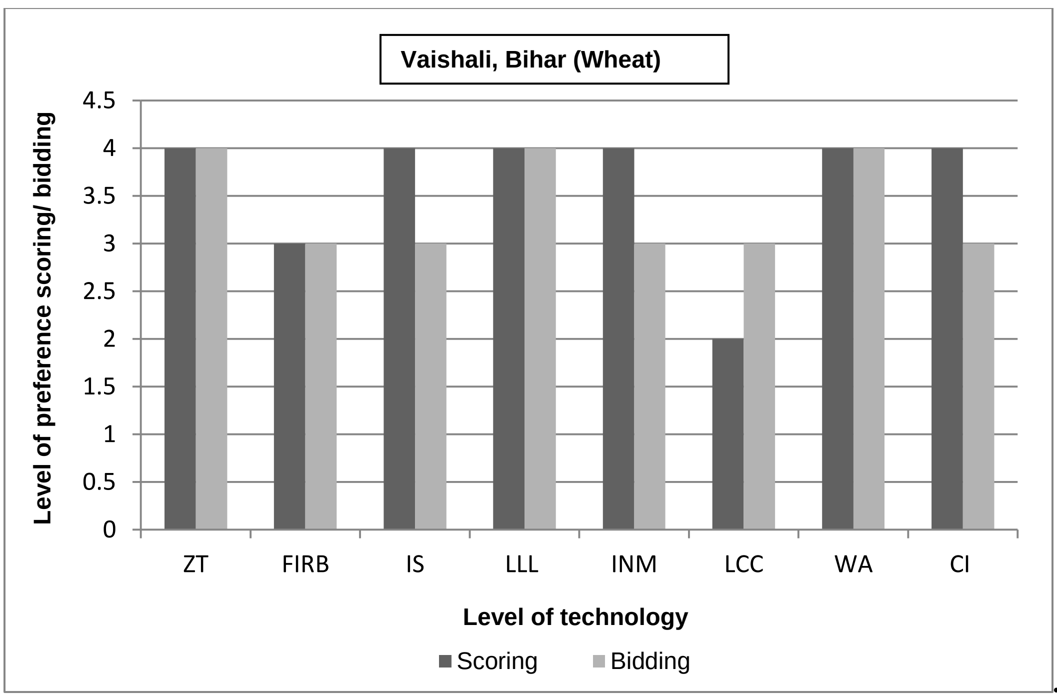
Source: Authors.
Note: Indo-Gangetic Plain. Numbers within parentheses are the level of preference. (1) = poor, (2) = low, (3) = medium, (4) = high.

Farmers in each region gave four technologies the top ranking of level 4. Except for LLL, which received top ranking in both regions, the choice of top-ranked technologies differed. This issue of commonalities and differences in choices was examined in some detail. Farmers put rainwater management, green manure, and SRI in the level-4 preference category in Eastern IGP, whereas direct seeding, irrigation scheduling, and crop insurance are the level-4 technologies in Western IGP. LLL is the preferred technology irrespective of the region. LLL is essentially a non-crop-specific technology and offers multiple advantages in terms of uniform irrigation, reduced irrigation time, and higher yields, among others (Tyagi 1984), and has generated keen interest among farmers following field demonstrations by the Rice-Wheat Consortium (Mehla et al. 2000). The striking difference in preferences relates to rice planting technology. SRI is a labor-intensive technology that is preferred in Eastern IGP, a labor-surplus region, whereas direct-seeding technology, a labor-saving technology, has more takers in Western IGP. In Western IGP, with groundwater levels declining sharply every year, farmers in the region gave high ratings to technologies that save water.

Technology Preference by Scoring Method

The dominance of wheat is more pronounced in Western IGP than in Eastern IGP, where some diversification in terms of horticultural crops already exists.

Figure 6.3 Level of preference by scoring and bidding (WTP) for wheat-growing technologies in Vaishali, Bihar, Eastern IGP

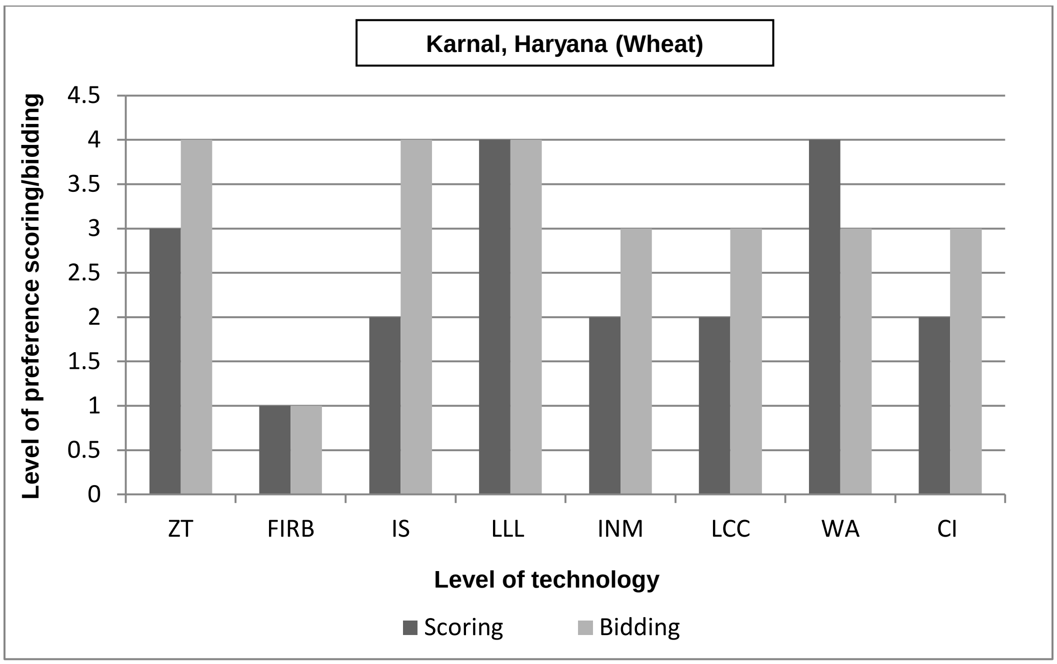


Source: Authors.

Note: IGP = Indo-Gangetic Plain; WTP = willingness to pay; ZT = zero tillage; FIRB = furrow-irrigated raised bed; IS = irrigation scheduling; LLL = laser leveling; INM = integrated nutrient management; LCC = leaf color chart; WA = weather advisories; CI = crop insurance.

LLL remained the preferred technology in both regions (Figures 6.2 and 6.3). Zero tillage, a relatively new technology that plays a role in conservation agriculture, and ICT-based weather advisories were the two other technologies that commanded higher preferences in both regions. In Eastern IGP, except for leaf color chart–based technology for site-specific nutrient application and furrow-irrigated raised bed planting, for which the preference was at a medium level, all the other technologies in the scoring method were in the high weight and frequency class. It seems that farmers in Eastern IGP, where yield levels of the rice-wheat system are only 60 percent of those in Western IGP, were more keen to improve increase their yield levels through improved farming practices.

Figure 6.4 Level of preference by scoring and bidding for wheat-growing technologies in Karnal, Haryana, Western Indo-Gangetic Plain



Source: Authors.
Note: WTP = willingness to pay; ZT = zero tillage; FIRB = furrow-irrigated raised bed; IS = irrigation scheduling; LLL = laser leveling; INM = integrated nutrient management; LCC = leaf color chart; WA = weather advisories; CI = crop insurance.

Technology Preferences for Wheat Production by Bidding (WTP) Method

The technology preferences expressed through the bidding method in Eastern IGP trace the same path that was followed in the scoring method (Figure 6.3). The technologies that rated high (level 4) were zero tillage, LLL, and weather advisory services. There were only minor differences in the degree of preference between the scoring and bidding methods in the case of irrigation scheduling, integrated nutrient management, and crop insurance, whose degree of preference decreased by one step, and of the leaf color chart, which moved up one level. There were, however, very significant changes in the technology preferences elicited by the two methods in the case of Western IGP. The degree of preference in terms of WTP improved for all the technologies that attained a low level of preference in the scoring method.

Highly Rated Technologies for Wheat Production in Eastern and Western IGP

The preferred technologies for wheat cultivation in the two regions were LLL and zero tillage, followed by irrigation scheduling in Western IGP and weather advisory services in Eastern IGP. Note that the impact of irrigation scheduling based on weather data is more pronounced for wheat than for rice, where fields are mostly kept under shallow soil submergence, or the alternate wetting and drying practice is followed. Furrow-irrigated raised bed planting has not been used for wheat crops in Western IGP, and its application has so far been limited to some demonstrations by research and development agencies. There have been some problems related to uniform seeding with the planting machines that are used to sow wheat on raised beds. Weather-induced uncertainties are greater in Eastern IGP than, Western IGP, and this is reflected in a higher level of preference for weather advisories in Bihar.

Table 6.2 Group of high-preference technologies for wheat cultivation in Eastern and Western IGP

	Eastern IGP		Western IGP
1	Laser land leveling (4)	1	Laser land leveling (4)
2	Zero tillage (4)	2	Zero tillage (4)
3	Weather advisories (4)	3	Irrigation scheduling (4)
4	Irrigation scheduling (3)	4	Leaf color chart (3)
5	Furrow-irrigated raised bed (3)	5	Integrated nutrient management (3)
6	Integrated nutrient management (3)	6	Weather advisories (3)
7	Leaf color chart (3)	7	Crop insurance (3)
8	Crop insurance (3)		

Source: Authors.

Note: IGP = Indo-Gangetic Plain. Numbers within parentheses are the level of preference. (1) = poor, (2) = low, (3) = medium, (4) = high.

7. LINKAGES BETWEEN FARMERS' CHOICES AND GOVERNMENT PROGRAMS

India is one of the few developing countries that has launched a very strong program for combating the challenges of climate change. In 2008, the country launched a National Action Plan on Climate Change (NAPCC) with eight National Missions, with a focus on promoting understanding of climate change, adaptation and mitigation, energy efficiency, and natural resource conservation (PMCCC 2008). The National Missions on Sustainable Agriculture and Water focus on rainwater harvesting, improving methods to conserve soil and water, efficient irrigation systems, drought- and pest-resistant crop varieties, dissemination of agroclimatic information, financial support to enable farmers to adopt relevant technologies to overcome climatic stress, and the strengthening of agricultural and weather insurance programs. Some of the public-sector initiatives that have a direct link to the choices made by farmers in Western and Eastern IGP are discussed below.

CSA-Aligned Programs

To achieve the objectives of climate-resilient agriculture, the action programs have been incorporated into development plans, and a number of schemes that support climate-smart technology adoption by farmers have been initiated. The important schemes include the National Project on Organic Farming (NPOF), which promotes development of organic agriculture in the country by augmenting the production of organic nutrients such as biofertilizers, organic manures, and compost; the National Project on Promotion of Balanced Use of Fertilizers (NPPBUF) to promote judicious soil-test-based application of fertilizers; the National Food Security Mission (NFSM), which envisages increased production and productivity of wheat, rice, and pulses on a sustainable basis and is focused on the IGP; and the Accelerated Irrigation Benefit Programme (AIBP), which provides financial support to farmers for adoption of efficient irrigation technology—a new initiative launched during the Eleventh Five Year Plan (Planning Commission 2011).

Crop insurance has been a major initiative to help farmers deal with the vagaries of weather. Two schemes, the Weather Based Crop Insurance Scheme and the National Agricultural Insurance Scheme, are in operation. The first scheme compensates farmers for financial losses attributable to incidences of adverse weather conditions such as rainfall, temperature, frost, and humidity. The National Agricultural Insurance Scheme provides financial support to farmers in the event of crop failure due to natural calamities, pests, or diseases. The insurance premium is 10 percent of the insured amount. The scheme also promotes adoption of advanced technology in agriculture.

In conclusion, the government has implemented a number of policy initiatives to support CSA, and the present study to assess farmers' technology preferences is aligned with the development programs initiated in recent years.

8. CONDITIONS FOR ADOPTION OF CLIMATE-SMART TECHNOLOGIES: THE POLICY PATHWAYS

The assessment of farmers' preferences indicates that they are keen to adopt new technologies and interventions that would transform agriculture into a relatively more productive, higher-income, and lower-carbon activity. But the availability of new technologies alone is not a sufficient condition to bring about the change. Effective institutions and sustained policy support to bring the technologies within the reach of farmers are equally important for technology adoption on a large scale.

Incentives for Technology Adoption through Institutional Arrangements

Earlier studies have shown that the capital cost of the technology has a great bearing on technology adoption (Garido 2005). Thus, if the cost of adoption is totally private, the technology will be implemented if the private returns from investment are more than the private costs. If this is not the case, the adoption of technologies may be deferred until the benefits exceed the cost. Under such circumstances, it is important to know whether some of the benefits are social, such as resource conservation and carbon sequestration, and contribute to environmental services. Such initiatives may be included in ongoing government programs, allowing some of the private cost to be shared by the government. For example, micro-irrigation is part of the AIBP. LLL and zero tillage provide similar benefits and should become part of AIBP.

Other financial instruments, such as low-interest loans for specific technology components, subsidized insurance premiums, and minimum-income guarantees, can also be provided by the government. Some of the climate-smart practices involve new equipment and services, which may require additional capital, and most of the small and marginal farmers may not have access to the formal credit system. Studies have established that increased access to credit helps farmers overcome short-term liquidity constraints and increase technology adoption (FAO 2010). Some of the programs, such as crop insurance, are already in operation. The need is to rationalize and intensify them to achieve greater coverage. To expand access to finance, the government has initiated several schemes, such as Kissan Credit Cards that help farmers obtain credit from nationalized banks. Microfinance facilities are also useful for small landholders. But it is often observed that the major beneficiaries of government schemes are large farmers who find it easier to approach and access these institutions. There appears to be a lack of awareness among smallholders or a hesitation to approach public-sector institutions, and this need to be addressed.

Design financial instruments that reduce adoption costs and facilitate easy credit as part of the development programs.

Minimizing Risk and Uncertainty

Most farmers, particularly small and marginal farmers, not only have low risk-bearing capacity but are also psychologically averse to risk and uncertainty. Therefore, in the transition phase from traditional to CSA, misconceptions as well as uncertainties surrounding the performance of available technologies must be addressed. Ways to achieve faster rates of adoption include encouraging adaptation of the technologies to local conditions by local entrepreneurs and ensuring certain minimum returns through risk-hedging insurance policies. While well suited to calamities and extreme weather events such as high floods and typhoons, insurance does not work well with the uncertainties of normal weather (Seth, Ansari, and Datta 2009). New financial tools called weather derivatives may be a more useful method to hedge climatic risk.

Provide insurance cover to climate-induced risks and uncertainties.

Strengthened Institutional Capacity for Dissemination of Technology

Access to information is a key element in the adoption of new technologies, and thus both the credibility of the source and the quality of the information are important. Climate-related information is at present being disseminated by a number of agencies, including Krishi Vigyan Kendras, Agromet Advisory, television, and numerous nongovernmental organizations. There is need to improve the density of the information networks with increasing use of satellite and smartphones over large areas and large numbers of farmers, and to establish coordination among the various agencies so that only authentic and well-tested information and delivery systems that do not confuse farmers are disseminated. This will require capacity building at various levels, including among technology generators, disseminators, and users.

Create institutions to build capacity among technology developers, disseminators, and farmers.

Providing Accurate Information on Costs and Benefits

To a farmer, agriculture is a means of earning a livelihood, and he or she is likely to adopt a new technology if it maximizes income and improves food security. Minimizing the adverse impacts of climate change is only a secondary objective for farmers. For example, in agriculturally advanced Western IGP, technologies such as LLL and zero tillage found some acceptance only when groundwater availability declined and pumping costs increased significantly. Farmers will be more interested in adopting a new technology if they have clear knowledge of not only the costs and benefits but also the trade-offs between adoption and nonadoption or partial adoption. Considerable effort will be needed not only to generate the required information but also to communicate it in an effective way so that it is understood by farmers.

Custom Hiring Services

Because machinery for climate-smart technologies, such as laser land levelers, zero-till drills, and seed planters, is costly and the requirements are seasonal, these technologies will not be affordable to individual smallholder farmers. The spread of these technologies will depend on reliable custom hiring services and local repair and maintenance facilities. The recent spread of these technologies has been possible largely due to custom hiring facilities and strong extension support provided by the Rice-Wheat Consortium, especially in Western IGP.

Markets

New technologies require greater access to markets, not only for buying technology-associated inputs such as seed, fertilizer, pesticides, and equipment at frequent intervals but for marketing surplus produce. Market access also influences the price realized by the farmers, as middleman commissions are reduced and, consequently, both ability and WTP improves.

Develop markets for access to inputs and disposal of farm produce.

Payment to Farmers for Providing Environmental Services

The introduction of CSA requires significant funds, which are difficult to spare in a developing economy. But because CSA not only contributes to food security but also reduces emissions, this can help make up for the costs invested. CSA is also in some ways a clean development mechanism, though it is not recognized as such at present. In recognition of the role of CSA as an engine of green growth, a mechanism should be established to assess the value of these services and the benefits to the environment and compensate farmers for the additional costs involved in practicing CSA.

Recognize CSA as an engine of green growth and a provider of environmental services and pay farmers for these services.

9. SUMMARY AND CONCLUSIONS

The Eastern and Western IGP, country's food grain basket, are highly vulnerable to climate change, which has significant implications for food security. This region, which is the focus area of the CGIAR Research Program on CCAFS, has been the country's field research laboratory where various agrotechnologies have been developed, tested, refined, and disseminated. CSA requires a complete package of practices to achieve the desired objectives, but adoption is largely dependent on farmers' preferences and their capacity and WTP. The present contingent valuation–based study on technology preferences provides insight into how farmers view climate change and their response to this challenge. Although this focus group–based exercise does not lend itself to the rigor of a statistical analysis, it does highlight some interesting revelations. Farmers' choices of technologies and interventions elicited by the scoring and bidding techniques show only minor variations in terms of level of preference, indicating farmers' consistent judgment of the usefulness of the technologies to meet their objectives. The assessment of farmers' preferences in both Eastern and Western IGP indicates that farmers have some knowledge of the potency of new technologies to help them achieve higher productivity and incomes. The fact that the adoption of these technologies could help counteract the impact of climate change is secondary to them, as is shown by their low levels of preference for stress-tolerant varieties, integrated nutrient management, and crop diversification. Based on this study, the important inferences with respect to climate-smart technologies and enabling policies in the IGP are as follows.

Technology

Eastern IGP

Rice: LLL and crop insurance, followed by weather advisory services, are the three preferred non-crop-specific interventions. Among the crop-specific technologies, rainwater conservation and management, SRI, and green manure are the high-preference technologies. Only minor differences in choices are elicited by the scoring and bidding techniques.

Wheat: In addition to LLL, crop insurance, and weather advisory services, the emerging technology of choice is zero tillage. This technology needs to become part of a full-fledged conservation farming package including furrow-irrigated raised bed planting and mulching to reap the full benefits. Irrigation scheduling, a nonstructural water-saving intervention that is preferred by many farmers, should be promoted.

Western IGP

Rice: The preferred technologies are LLL, direct seeding, irrigation scheduling, and weather-risk insurance for crops.

Wheat: LLL, zero tillage, and irrigation scheduling are farmers' preferred technologies.

This assessment of technology preferences reflects only the current level of understanding among farmers about the potential benefits of CSA, and the choices made do not reflect the level of understanding of the complete package. Earlier studies on WTP indicate that the choices of technologies are not independent of each other, but the choice of one technology is related to the choice of another technology (Ulimwengu and Sanyal 2011). Crop diversification and stress-tolerant crops, which show poor to low levels of preference, are logically very relevant and important interventions for both Eastern and Western IGP. Some added efforts would need to be made to bring them to the attention of the farming community.

Policy

Overcoming climate-imposed constraints to socio-economic development through the promotion of CSA is the well-defined goal of the government, as expressed by the establishment of a separate mission program for agriculture. A broad framework of policies in support of CSA, such as AIBP, weather insurance for crops, and nutrient-based subsidies for fertilizers, are in place. There is, however, a need to modify these policies and increase the basket of technologies for which benefits are provided, in view of the experience gained. Further, there is a need to introduce some innovative policies that would benefit farmers and increase their capacity to practice CSA.

Support for Location-Based Technology Packages

The climate-smart technology package is location specific, but the programs receiving support are regional or national in nature.

Redesign of Crop Insurance Policies

The crop insurance policy should be redesigned as a no-claim bonus scheme similar to the policy prevalent in the automobile industry. This would improve the spread of crop insurance and increase the stability of farmers' incomes and their ability to pay for CSA technology. Financial tools such as weather derivatives may be a more useful method to hedge climatic risk.

Payment to Farmers for Environmental Services

At present, agriculture is not considered a clean development mechanism, which attracts payment for carbon credits. The policy should be revised to include CSA so that payments can be made to farmers for environmental services.

Financing Technology Hubs

The technology generated at research centers must be adapted to suit local conditions. This particularly applies to technologies such as zero-till tillers, seed planters, weeders, and so on that are mechanical in nature. A network of agrotechnology hubs should be established with liberal financial support.

Institutions for Capacity Building

Despite the efforts of the past few years, capacity for generation, dissemination, and adoption continues to be weak. Diffused efforts have limited impact. The density of the institutions providing these services must be increased to provide effective support to CSA.

Large-scale adoption of climate-smart technologies and other interventions requires capacity building among technology promoters and users. The fact is that smallholder farmers are typically risk-averse, and low capacity to accept risk was identified as an additional barrier to the adoption of climate-smart interventions. However, under favorable and more assured environments, it is possible to overcome these constraints. This would require designing policies that encourage the private sector to promote technologies, facilitate financing innovations, and expand the availability of custom-hire facilities. Creating incentives to adopt climate-smart interventions may initially appear to require larger financial commitments, but the socio-economic and environmental benefits would exceed these costs in terms of higher incomes, resource savings, and improved environmental services, such as carbon sequestration. Success will rely on developing appropriate capacity-building mechanisms, smallholder-friendly institutional arrangements, and effective policy support that links farmers' preferences with regional and national goals.

APPENDIX: SUPPLEMENTARY TABLES

Table A.1 Frequency distribution of scores for wheat-growing technologies in Vaishali, Bihar, Eastern Indo-Gangetic Plain

Technology	Number of groups* giving a score of 3** on a scale of 0–3	Frequency (percent)
Rainwater management (20–25 centimeter dike formation)	10	83.3
System of rice intensification	6	50.0
Irrigation scheduling	5	41.7
Laser land leveling	8	66.7
Direct-seeded rice	2	16.7
Green manure	7	58.3
Leaf color chart	4	33.3
Weather advisories	9	75.0
Crop (rainfall/temperature) insurance	9	75.0

Source: Authors.

Note: *Total groups = 12. **3 = high preference.

Table A.2 Determination of technology preferences by bidding method for rice in Vaishali, Bihar, Eastern Indo-Gangetic Plain

Technology	Bid for each technology	Weight of bid (percent)*	Number of groups bidding for the technology**	Frequency (percent)	Degree of willingness to pay on a scale of 1–4***
Rainwater management (dike formation)	195,000	10.5	10	83.3	4
System of rice intensification	210,000	11.2	7	58.3	4
Irrigation scheduling	128,000	6.8	5	41.6	1
Laser land leveling	505,000	26.8	8	66.7	4
Direct-seeded rice	30,000	1.6	2	16.7	1
Green manure	173,000	9.2	7	58.3	4
Leaf color chart	77,000	4.1	4	33.3	1
Weather advisories	135,000	7.2	9	75.0	2
Crop (rainfall/temperature) insurance	152,000	8.1	9	75.0	3
Drought-tolerant variety	41,000	2.2	3	25.0	1
Integrated nutrient management	95,000	5.1	5	41.6	1
Crop diversification	138,000	7.3	6	50.0	3
Total	1,879,000	100			

Source: Authors.

Note: * Bid for each technology; total bids for all technologies = 100. ** Total groups = 12. Mean weight (100/No. of tech.) = 8.33 percent (100/12). ***1 represents poorly preferred, 2 represents low preferred, 3 represents medium preferred, 4 represents highly preferred.

Table A.3 Frequency distribution of scores and level of preference for wheat-growing technologies in Vaishali, Bihar, Eastern Indo-Gangetic Plain

Technology	Number of groups with a score of 3* on a scale of 0–3	Frequency (percent)	Level of preference on a scale of 1–4**
Furrow-irrigated raised bed	8	66.7	3
Irrigation scheduling	10	83.3	3
Laser land leveling	11	91.6	1
Zero tillage	10	83.3	1
Leaf color chart	5	41.6	2
Weather advisories	10	83.3	4
Mean weight=8.33 percent(100/12)			
Crop (rainfall/temperature) insurance	10	83.3	4
Integrated nutrient management	9	75	4

Source: Authors.
Note: *3 = high preference.**1 represents poorly preferred, 2 represents low preferred, 3 represents medium preferred, 4 represents highly preferred.

Table A.4 Willingness to pay for technologies used for growing wheat in Vaishali, Bihar, Eastern Indo-Gangetic Plain

Technology	Total bid	Weight of bid (percent)*	Number of groups bidding for the technology**	Frequency (percent)	Degree of willingness to pay on a scale of 1–4***
Furrow-irrigated raised bed	205,000	9.5	8	66.7	3
Irrigation scheduling	240,000	11.1	10	83.3	3
Laser land leveling	572,000	26.4	11	91.7	4
Zero tillage	285,000	13.2	10	83.3	4
Leaf color chart	93,000	4.3	10	83.3	3
Weather advisories	290,000	13.4	10	83.3	4
Crop (rainfall/temperature) insurance	260,000	12.0	9	75.0	3
Integrated nutrient management	220,000	10.2	9	75.0	3
Total	2,165,000	100.0			

Source: Authors.
Note: * Bid for each technology; total bids for all technologies = 100. ** Total groups = 12. Mean weight (100/No. of tech.) = 12.5 percent. .***1 represents poorly preferred, 2 represents low preferred, 3 represents medium preferred, 4 represents highly preferred.

Table A.5 Willingness to pay for technologies used for growing rice in Karnal, Haryana, Western Indo-Gangetic Plain

Technology	Bid for each technology	Weight of bid (percent)*	Number of groups bidding for the technology**	Frequency (percent)	Degree of willingness to pay on a scale of 1–4***
Rainwater management (dike formation)	41,333	2.7	4	36.4	1
Irrigation scheduling	163,667	10.9	8	72.7	4
Laser land leveling	512,667	34.1	10	90.9	4
Direct-seeded rice	229,667	15.3	9	81.8	4
Green manure	134,100	8.9	8	72.7	3
Leaf color chart	129,667	8.6	9	81.8	3
Weather advisories	43,000	2.9	7	63.6	3
Crop (rainfall/temperature) insurance	155,250	10.3	7	63.6	4
Drought-tolerant variety	24,500	1.6	6	54.5	2
Integrated nutrient management	19,567	1.3	6	54.5	3
Crop diversification	50,333	3.3	5	45.5	2
Total	1,503,751	100.0			

Source: Authors.
Note: *****Bid for each technology; total bids for all technologies = 100. **Total groups = 12. Mean weight (100/No. of tech.) = (100/11) = 9.1 percent. *** 1 represents poorly preferred, 2 represents low preferred, 3 represents medium preferred, 4 represents highly preferred.

Table A.6 Frequency distribution of scores and level of preference for wheat-growing technologies in Karnal, Haryana, Western Indo-Gangetic Plain

Technology	No. of groups* with score of 3** (on a scale of 0–3)	Frequency (percent)	Level of preference on a scale of 1–4***
Furrow-irrigated raised bed	2	18.2	1
Irrigation scheduling	5	45.5	2
Laser land leveling	10	90.9	4
Zero tillage	8	72.7	3
Leaf color chart	5	45.5	2
Weather advisories	2	18.2	1
Crop (rainfall/temperature) insurance	5	45.5	2
Integrated nutrient management	5	45.5	2

Source: Authors.
Note: *Number of groups = 11. ** 3 = high preference. *** 1 represents poorly preferred, 2 represents low preferred, 3 represents medium preferred, 4 represents highly preferred.

Table A.7 Willingness to pay for technologies used for growing wheat in Karnal, Haryana, Western Indo-Gangetic Plain

Technology	Bid amount	Weight of bid (percent)*	Number of groups bidding for the technology**	Frequency (percent)	Degree of willingness to pay on a scale of 1–4***
Furrow-irrigated raised bed	48,667	3.4	5	45.5	1
Irrigation scheduling	160,333	11.2	9	81.8	4
Laser land leveling	462,667	32.3	10	90.9	4
Zero tillage	441,667	30.9	10	90.9	4
Leaf color chart	120,667	8.4	9	81.8	3
Weather advisories	45,333	3.2	7	63.6	3
Crop (rainfall/temperature) insurance	89,000	6.2	7	63.6	3
Integrated nutrient management	62,333	4.4	7	63.6	3
Total	1,430,667	100.0			

Source: Authors.
Note: * Bid for each technology; total bids for all technologies = 100. **Total groups = 11. Mean weight (100/No. of tech.) = 9.1. *** 1 represents poorly preferred, 2 represents low preferred, 3 represents medium preferred, 4 represents highly preferred.

Table A.8 Farmers' technology preferences by scoring and bidding process for rice cultivation in Bihar (Eastern IGP) and Haryana (Western IGP)

Technology	Level of preference			
	Eastern IGP, Vaishali, Bihar		Western IGP, Karnal, Haryana	
	Scoring	Bidding	Scoring	Bidding
Rainwater management	A (4)	A (4)	D (1)	D (1)
System of rice intensification	B (3)	A (4)	-	-
Direct-seeded rice	D (1)	D (1)	B (3)	A (4)
Laser land leveling	B (3)	A (4)	A (4)	A (4)
Irrigation scheduling	C (2)	C (2)	C (2)	A (4)
Integrated nutrient management	C (2)	C (2)	D (1)	B (3)
Green manure	B (3)	A (4)	B (3)	B (3)
Leaf color chart	C (2)	C (2)	A (4)	B (3)
Drought-tolerant variety	D (1)	D (1)	C (2)	C (2)
Crop diversification	B (3)	B (3)	D (1)	C (2)
Weather advisories	A (4)	C (2)	D (1)	C (2)
Crop insurance	A (4)	B (3)	D (1)	A (4)

Source: Authors.
Note: IGP = Indo-Gangetic Plain. "A" represents highly preferred, "B" represents medium preference, "C" represents low preference. "D" represents not preferred. (1) represents poorly preferred, (2) represents low preferred, (3) represents medium preferred, (4) represents highly preferred.

Table A.9 Farmers' technology preferences by scoring and bidding process for wheat cultivation in Bihar (Eastern IGP) and Haryana (Western IGP)

Technology	Level of preference			
	Vaishali-Bihar (Eastern IGP)		Karnal-Haryana (Western IGP)	
	Scoring	**Bidding**	**Scoring**	**Bidding**
Zero tillage	A (4)	A (4)	B (3)	A (4)
Furrow-irrigated raised bed	B (3)	B (3)	D (1)	D (1)
Irrigation scheduling	A (4)	B (3)	C (2)	A (4)
Laser land leveling	A (4)	A (4)	A (4)	A (4)
Integrated nutrient management	A (4)	B (3)	C (2)	B (3)
Leaf color chart	C (2)	B (3)	C (2)	B (3)
Weather advisory	A (4)	A (4)	A (4)	B (3)
Crop insurance	A (4)	B (3)	C (2)	B (3)

Source: Authors.

Note: IGP = Indo-Gangetic Plain. "A" represents highly preferred, "B" represents medium preference, "C" represents low preference. "D" represents not preferred. (1) represents poorly preferred, (2) represents low preferred, (3) represents medium preferred, (4) represents highly preferred.

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