Adaptation of farming community to climatic risk: does adaptation cost for sustaining agricultural profitability?

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Adaptation strategies that can minimize the negative effects of climatic risk were implemented in over 2000 farms in 12 villages of Mewat district in Haryana, India. Detailed household (HH) level data from 120 farm families for two periods (prior to intervention and end of project period) indicated: (i) agricultural profit of adapted farmers was more than that of non-adapted farmers in all strata according to the difference in difference model; (ii) non-adapted farmers in <4 acre groups have to either alter the existing agricultural practices to reduce management cost and increase profit or incur additional cost for adaptation; (iii) large farmers may have to rationalize their management investments for gaining more profits; (iv) the profit is not directly proportional to the cost of adaptation, if any, among different strata of farmers; (v) agricultural income alone cannot sustain small and marginal farm (<4 acre) families, however with adaptation a self-sustaining agriculture could be achieved; (vi) suitable adaptation can reduce the cost of farm operations, and increase agricultural profits as well as adaptive capacity to climatic risks; (vii) additional cost is not always required for adaptation, and rationalizing agricultural expenditure is essential to adapt to climatic risks. At community level differential costs of adaptation and profits are likely. Policies for incentivizing these 'responsive adaptation' costs for small and marginal farmers would be required. However, investments may be required for establishing permanent agricultural-infrastructure for managing water and agricultural produce in order to sustain agricultural profitability.

Keywords: Adaptation cost, agricultural profit, climate change, farm family, land holding.

Introduction

OVER–exploitation of fossil fuels, deforestation and less eco-friendly technologies have led to rapid accumulation of greenhouse gases (GHGs) in the atmosphere. CO_2 concentration has increased from a pre-industrial value of about 280 to 400 ppm in 2014. Similarly, the global atmospheric concentration of methane and nitrous oxides and other important GHGs has also increased considerably. These are projected to cause an increase in temperatures up to 4.8°C by the end of the century. Further, the IPCC AR5 report[1] on climate change has projected an increase in the frequency of droughts, floods, and extreme events of temperature and rainfall. Since climate is the most influencing factor for monsoon-dependent Indian agriculture, climate-related aberrations have been significantly affecting crop productivity in India. Abnormal monsoons have been affecting the productivity of *Kharif* season (monsoon) crops. Heat stress (both terminal and early) are lowering wheat yield while extreme weather events are affecting almost all crops. For instance, heavy rainfall during the 2013 monsoon season in Madhya Pradesh coinciding with pod maturation affected soybean yield. In 2014, the hailstorm during March in Maharashtra affected many horticultural crops while in 2015, hail storm and heavy rainfall during March and April affected many winter season crops across the country.

Simulation studies have projected that climate change will affect the productivity of several crops. On an all-India basis, the impacts of climate change on yields in 2030s will range from –2.5% to –12% for crops such as rice[2], wheat[3], maize[4], sorghum[5] and mustard[6]. On the other hand, yields of some crops such as potato[7] (in northwest India), soybean[8] and coconut[9] are projected to gain due to climate change. Studies further indicate that adaptation is essential, not only to minimize the negative impacts but also to harness the positive effects of climate change in some regions. These studies have estimated an increase in yield by 11% for wheat[3], 17–20% for rice[2], 21% for maize[8], 8% each for potato[7] and sorghum[8], 12% for soybean[8], 25% for mustard[6] and 33% for coconut[9]. Simulation analysis indicated that agricultural regions and crops in changing climate will have three types of effects: (i) negative impacts on regions/crops that can be offset by adaptation; adaptation in these regions/crops

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may not only overcome the negative impacts but can also improve the yields significantly; (ii) climate change may benefit regions/crops due to shift in current sub-optimal temperatures and rainfall regimes shifting to optimal range. Improved management can increase these benefits; (iii) regions which are projected to be negatively affected will remain vulnerable despite adaptation and more innovative adaptation strategies (genotypic as well as agronomic) need to be developed for such regions[2–9]. Adaptation in agriculture is especially important as it influences the livelihood of over 60% of population and hence the gross domestic product. Therefore, it is necessary to develop the climate-smart agricultural systems.

The concept of climate-smart agricultural system, as given by FAO[10], includes the system which contributes to achieving sustainable developmental goals. It integrates the three dimensions of sustainable development (viz., economic, social and environmental) by jointly addressing food security and climate challenges. It consists of three main components: (1) Sustainably increasing agricultural productivity and incomes; (2) Adapting and building resilience to climate change; and (3) Reducing and/or removing GHG emissions, wherever possible. Though climate change is a global phenomenon, its impacts are location- and situation-specific. So are the adaptation options and resultant gains. Hence it is important to contextualize the adaptation strategies. The efforts to implement location-specific climate-smart technologies are going on worldwide[11,12] as well as in India with varying degrees of successes[11–14]. Most of the efforts are related to crop and/or water-based interventions. Apprehension about additional costs of adaptation technologies by the farming communities is the major bottle-neck. Lack of comprehensive adaptation strategies is another reason. Since the livelihood security in climatic risk situation is linked to not only farm income but also to the total family income, there is a need for understanding the farm family income dynamics from the adaptation perspective. In the World Bank-GEF NAIP funded project, multi-pronged adaptation strategies were implemented in Mewat, a drought-prone district of Haryana, India in an action research mode.

Mewat has the normal mean annual maximum and minimum temperatures of 31.7/17.3°C. During the year, normal maximum temperatures fall in the range of 21–41°C and minimum temperatures in the range of 5–27°C, with warm and dry summers and very cool winters. It receives an annual rainfall of ~583 mm mainly during last week of June to mid-September. Climate change is projected to increase the climatic stresses in this drought-prone district making agriculture more vulnerable. The main cropping systems of Mewat include pearl millet/fodder sorghum-wheat/mustard, fallow–mustard and vegetables–wheat/mustard. The region has a lot of livestock such as buffalo, cow and goat. Most families are dependent on agriculture for livelihood. In the current study, adaptation interventions varied from farm, off-farm as well as non-farm activities and implemented for four years. These included introduction of improved varieties of wheat, mustard, pearl millet, fodder sorghum, pigeon pea and vegetables such as brinjal, bottle gourd, okra and tomato; crop diversification (e.g. introduction of maize); improvements in crop management (timely sowing, appropriate seed rate, spacing and sowing method, timely irrigation and proper dose of fertilizers, pheromone traps for pest management) water management (reduction in water conveyance loss by laying pipelines, laser levelling, drip irrigation, sprinkler irrigation, soil water conservation, etc.); value addition (pickle making, goose berry powder, etc.); livestock management (immunization, nutrient supplementation); secondary skill development for income augmentation (tailoring); and enabling farmers with information (mobile based two-way communication system). All these were targeted to reduce the crop and income loss due to climatic stresses (Table 1) so as to increase the farm and farm family resilience to climatic stresses.

In this paper, we present the analysis based on questions such as: (i) are the adaptation gains same across farmers with different land holding size?, (ii) does the adaptation cost? (iii) if they do, how does that vary across the farm size strata? In any conflict between long-term sustainability and immediate profitability, it is always the latter that gets precedence. As a proxy variable for sustainability, we use the cost of adaptation. Two models have been built to check this, the first focuses on the change in agricultural profitability as a result of adaptation, whereas the second focuses on the costs of adaptation. To test this, we used two hypotheses. In the first null hypothesis, agricultural profit of the adapted farmers would be the same as that of non-adapted farmers. The alternate hypothesis is that the profit of an adapted farmer would not be equal to that of a non-adapted one. In the second null hypothesis, the cost of adaptation was the same as that of cost of business as usual scenario. The alternate hypothesis stated that the cost of adaptation was not equal to that of business as usual scenario. Then the family income surplus was deduced taking farm and non-farm income into consideration to delineate the adaptive capacity to climatic risks.

Data and methods

The household level data on over 1200 parameters were collected from 120 households belonging to 13 villages, out of which 9 villages were under the NAIP–WB–GEF project intervention for adaptation to climate change during 2009–2013 (Figure 1). All these households had adopted at least some of the interventions. The remaining four villages were from the non-intervention area but with similar agricultural characteristics. Data were

Table 1. Indicative interventions for minimizing climatic risks and enhancing livelihood security

Intervention	Description	Relevance to climatic stress and livelihood security
Crop varieties	Wheat–WR544 (short duration, late sown variety); heat and drought tolerant varieties and short duration varieties of pearl millet, pigeon pea, etc.	To overcome/avoid terminal heat stress in wheat, drought/ heat stress in monsoon crops
	Multi-cut fodder sorghum variety	Heat and drought tolerant varieties; increased fodder for livestock
Crop diversification	Maize in place of pigeon pea, or in fallow land	Being a C4 crop can withstand higher temperatures; increased income
	Short duration vegetable crops	To fit in cropping sequence window; increased income
Cropping pattern	Fallow-early mustard–wheat/vegetables	To minimize loss due to crop failure during uneven and delayed monsoon
Water saving technologies	Laser levelling	
	Sprinkler	Reduced water loss; increased water use efficiency by over 50%; 450–650 m^3 water saved; 20% additional area under irrigation with same amount of water; reduced emission of 65–120 kg CO_2/ha.
	Rain gun	
	Drip irrigation	
	Underground pipeline for water conveyance	
	Soil moisture conservation (mulching) in vegetable crops	
Crop management	Improved seeds, timely sowing	Reduced in-breeding loss Avoid terminal heat stress in wheat; avoid water stress in monsoon crops
	Recommended seed rate	Avoid inter-plant competition and lodging due to heavy winds
	Timely and recommended irrigation	Improve water use efficiency and reduce diesel/electricity for pumping water; reduce GHG emissions
	Recommended fertilizers	Avoid excess fertilizer application; reduce GHG emissions
	Pest management	Pheromone traps – eco-friendly; reduce pesticide load and GHG emission
	Shade nets	Disease free nursery of horticultural crops for main- and off-season; improved income
Horticultural and fruit plants	Back-yard horticultural and fruit plants such as guava, sapota, pomegranate, papaya, etc.	Carbon sequestration; nutritional security
Livestock	Increased availability of fodder and feed	Improved fodder led to increase in milk yield (1.5–2 l/animal/day)
	Regular health checkup; immunization; mineral nutrient mix supplement	Reduced calf mortality from 70% to 20%; improved the health of livestock; increased climatic risk coping ability due to availability of more number of male calves for distress or other-wise selling, improved income insurance in stress conditions
Value addition	Wheat flour making Grading of tomato Pickle making Dhal-dhalia making	Improved income for farm produce
Secondary skill development	Tailoring, mushroom culture, poultry, etc.	Income augmentation
Information and weather-forewarning	Pusa-m-Krishi mobile based information system on weather, crop management, market and training	Weather-based crop management; information on markets, training, etc.; enabled farmers with information on climatic risk management.

collected using the stratified sampling method in a two-step process. First, entire households were categorized into three strata: intervention farmers (henceforth called as adapted farmers), non-adapted farmers in same village (these farmers were out of project purview) and non-adapted farmers from other villages (outside project area). Subsequently, each of the three groups were sub-divided on the basis of land-holding size i.e., <2 acres, 2–<4 acres, 4–<6 acres and ⩾6 acres. Out of 120 households (HH), 81 HHs represented adapted farmers. Another 19 HHs represented non-adapted farmers from same village. The remaining 20 HHs represented non-adapted farmers from other villages outside project. An extensive questionnaire was used for capturing the HH information. The total number of variables exceeded 1200 which covered socio-economic details, farm characteristics, farm (crop and livestock) management details, expenditure and income from farm, household secondary income and expenses, assets and liabilities, etc. Out of these, 1030 variables were used to capture the expenses and incomes from important activities (Table 2).

The focus was on agricultural profit (profit from all crops taken together) and the cost of adaptation which includes expenses on agriculture and depreciation on agricultural equipment. To facilitate comparison, data were standardized by dividing with the land-holding size. Crop-wise profit values were calculated from respective expenditure and income[15]. The opportunity cost of farm family labour based on ongoing wage rate, ongoing rate for self-use of grain or fodder and ongoing rental value of land was also considered wherever applicable. Depreciation on machinery and farm equipment was calculated at 30% on written down value method (Since agricultural income is not taxable, official depreciation rates are not available; the equivalent rates for industry have been used. Depreciation rates have been provided at 30% on written down value method as per IT Dept of India.). To eliminate the difference due to inflation, data for the base period were adjusted with 1986–87 consumer price index inflation for rural workers[16]. The data were then adjusted for 2013–14 prices. Two hypotheses were tested using econometric models

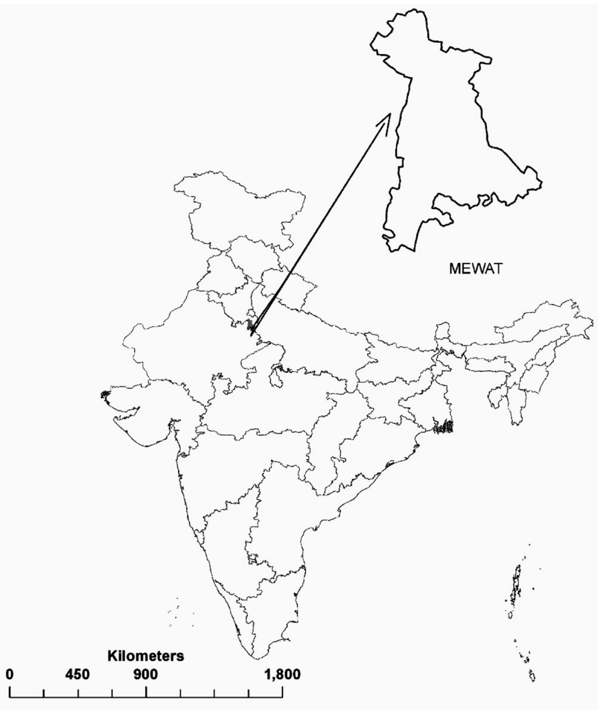

Figure 1. India map showing the Mewat district, the project area.

Table 2. Details of number of variables used for the analysis under each category

Variable group	Expense variable	Income variable	Profit variable
Before intervention			
Crops	32	16	16
Other income	0	104	0
Other expenses	130	0	0
After intervention			
Crops	297	99	22
Livestock	10	30	10
Other income	0	104	0
Other expenses	130	0	–0
Assets			
Land	12	0	0
Agricultural equipment	12	0	0
Other implements/transport vehicles	6	0	0

Hypothesis on agricultural profit:

H_0: $\text{profit}_0 = \text{profit}_A$,

H_1: $\text{profit}_0 \neq \text{profit}_A$,

where profit_0 is for the initial period (baseline 2009–10) and profit_A is for post-project period (2013–14).

Hypothesis for cost of adaptation:

H_0: $\text{COA}_0 = \text{COA}_A$,

H_1: $\text{COA}_0 \neq \text{COA}_A$,

where COA_0 is the cost of adaptation for the initial period (baseline 2009–10) and COA_A is the cost of adaptation for the final year of the project (2013–14).

Difference in difference model description

To demonstrate the difference due to the interventions made, the difference in difference (DD) model[17,18] was used (Figure 2). This model is a basic two-way fixed effects model with cross-section and time fixed effects. Time series of a non-adapted group was used to establish what would have occurred in the absence of intervention. Two such models were used. The first one compared cost of adaptation and profitability of adapted groups and control (non-adapted groups in the same village) over time for all four strata. The second model compared the cost of adaptation and profitability of adapted groups and control (non-adapted groups in other villages) over time for all four strata. The second model has been taken to eliminate spillover effects, if any. Control group identifies the time path of outcomes that would have happened in the absence of treatment. Here, profit (Y) changes by $Y_{c2} - Y_{c1}$

even without the intervention. So the treatment effect is given by the equation $(Y_{t2} - Y_{t1}) - (Y_{c2} - Y_{c1})$ instead of just $Y_{t2} - Y_{t1}$. This was done after calculating the agricultural profits as well as costs of adaptation for all 3 groups (adapted, non-adapted same village and non-adapted other village) for all 4 strata (<2 acres, 2–< 4 acres, 4–<6 acres and ⩾6 acres).

After deriving the cost of adaptation, the household surplus was calculated based on (i) agricultural income and (ii) after considering all the sources of HH income as well as the expenses. The surplus per capita is expressed based on the agricultural income alone and also based on total HH income.

Results and discussion

Climatic risks in the study area

Mewat is a climatically sensitive area since the region is drought-prone. An analysis of the past weather data indicated that during last 100 years, Mewat experienced 18 moderate droughts and 8 severe droughts. This region receives an annual rainfall of about 589 mm out of which about 500 mm occur during the monsoon season. However, a lot of variation was noted in total rainfall received during monsoon. On an average in a decade, 4 years received less than 80% of normal rainfall in all four blocks while one year had just about 80% of normal rainfall. Only three years had more than normal rainfall while the remaining two years received less than normal but above 80% of normal rainfall. Climate change is projected to increase the monsoon season mean maximum temperatures by 1.2 to 1.9°C in 2030 (2020–2050) period in A1b scenario in Haryana[19]. The A1b scenario assumes a balanced mix of technologies and supply sources, with technology improvements and resource assumptions such that no single source of energy is overly dominant. The *Kharif* seasonal mean minimum temperatures are projected to increase between 1.6°C and 1.9°C. Rainfall during monsoon is projected to increase from 5–20% over the values presented for baseline. On the other hand, the winter season mean maximum temperatures are projected to increase by 0.5–1.4°C in the 2030 period. The mean minimum temperatures are projected to increase between 1.9°C and 2.3°C. Rainfall during winter is projected to change between –5% and +35% over the baseline values of 40–70 mm. Since the projected climate change and variability would increase the climatic stresses on crops and agricultural income and therefore threatening the livelihood security, adaptation interventions were implemented.

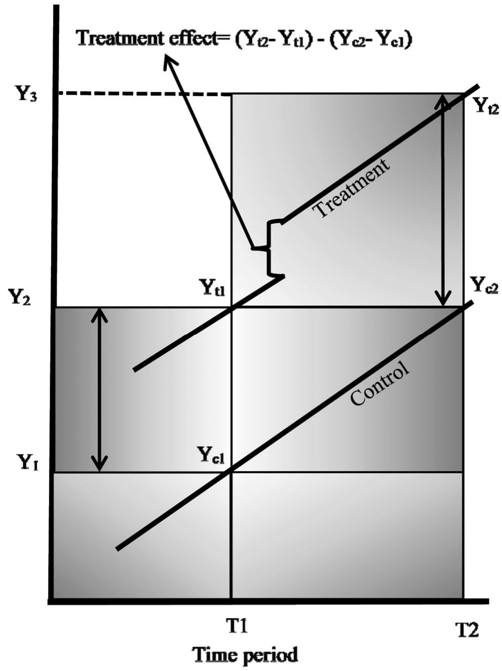

Figure 2. The difference in difference model components. T1, Project initial time; T2, Project conclusion time; Y1, Y2, Y3, Profits; Yc1, Profit of the control farmers at the beginning of the project; Yt1, Profit of the adapted farmers at the beginning of the project; Yc2, Profit of the control farmers at project conclusion time; Yt2, Profit of the adapted farmers at project conclusion time.

Agricultural profit and expense per acre from crops

The adaptation technologies including improved crop varieties and crop management as well as water management led to yield increase in the range of 8–33% for crops such as wheat, mustard, fodder sorghum, tomato, brinjal etc. Analysis indicates that the agricultural expense increased over time, more so for the adapted farmers followed by the non-adapted ones from same village (Figure 3). The agricultural expenditure per acre was more in small landholdings of less than four acres. For >=6 acre strata, it is marginally greater for non-adapted farmers from other villages. Data indicates that adaptation leads to more expenses for small and marginal farmers. Laser levelling of land, use of improved seed, pheromone traps, and laying of new water conveyance systems, sprinklers and rainguns led to higher investment. However, most of these are capital expenses. The agricultural profit rose over time for all types of farmers sampled from the project intervention area. However, the magnitude of profit varied across the three farmer categories (viz. adapted, non-adapted from same village and non-adapted from other village). While the profitability decreased with increase in land holding size in the sample HHs, adaptation to climatic risks led to an increase in agricultural profit.

Agricultural profit from livestock

Poor health conditions of livestock led to calf mortality of up to 50% in the region. Basic reasons were found to be

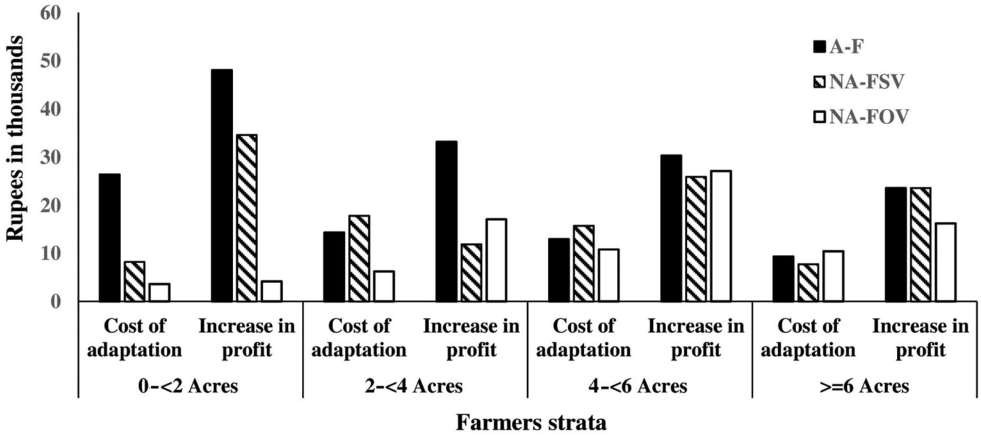

Figure 3. Landholding based cost of adaptation and change in profit in agriculture in adapted farmers (A-F), and non-adapted farmers from same (NA-FSV) and other (non-project) village (NA-FOV).

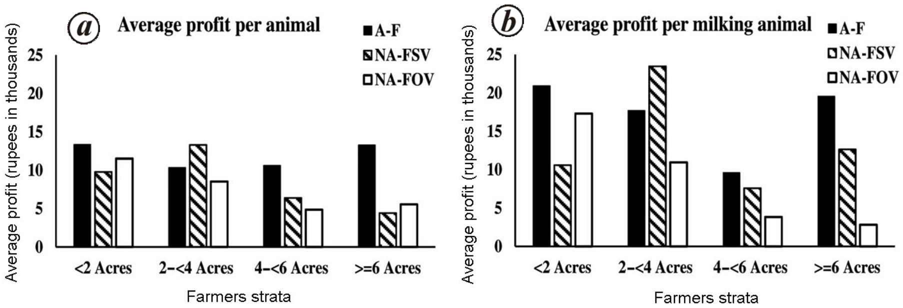

Figure 4. The profit from (***a***) livestock and from (***b***) milking animal to the farmers under different groups. A-F, Adapted farmers; NA-FSV, Non-adapted farmers from same village; NA-FOV, Non-adapted farmers from other village.

infections, poor management and non-availability of adequate fodder and feed. Interventions such as immunization, nutrient supplements, deworming, and availability of additional fodder and feed have been very helpful in increasing the profitability in the intervention group of farmers. The milk yield increased at the rate of 1.5 to 2.5 l/animal/day over an average yield of 8 l/animal/day. The annual expenditure on cows varied from Rs 30,000 to 32,500 while expenditure on buffaloes ranged from Rs 40,000 to 45,000. This included cost of nutrient supplements (around Rs 75/kg used for 20 days/animal), deworming, fodder and feed. These costs did not vary across size of land holding. Since milking animals are inherently more profitable than non-milking ones, the average depicted (Figure 4 *a*) might not be a true representation of the livestock productivity. So the profitability of milking–animals is also worked out (Figure 4 *b*). The number of animals increased as the land-holding size increased (data not included).

Cost of adaptation and profit from a farm

Difference in difference model was used to analyse the profit and cost of adaptation for all agricultural activities at the farm level (Table 3). These estimates for profit were positive for adapted farmers with respect to the non-adapted farmers of the same (project) village as well as from the other (non-project) villages. This implies that the per acre profit earned by the adapted farmer is more than per acre profit earned by non-adapted farmers, even after factoring for trend and base line profits. The estimate for cost of adaptation implies the difference in the change of per acre expenses and depreciation of farm equipment over time between adapted and non-adapted farmers. It is mostly negative for non-adapted farmers in the same village and mostly positive for non-adapted farmers in other villages. Analysis indicates that the non-adapted farmers in less than four acre groups, particularly those in 2–<4 acre group, have to alter the existing agricultural practices so that their management cost reduces, and the profit due to technological benefit increases. The spillover effect of adaptation strategy seems to be more among farmers with land holding of 4 acres and above in same village as well as in the other villages. However, farmers with land holding of >=6 acres seem to be spending more for crop management as compared to project intervention farmers of the same strata. In less than two acre strata, farmers have to either adjust their crop

Table 3. Difference in difference (DD) estimate for profit and cost of adaptation in different strata of farmers belonging to adapted and non-adapted group

	DD estimate (per acre/year)			
Group	Profit (Rs)	Level of significance	Cost of adaptation (Rs)	Level of significance
Change for adapted farmers – change for non-adapted (same village)				
<2 acres	12,668	0.66	–776	0.95
2–<4 acres	20,174	0.07	–5,857	0.19
4–<6 acres	2,683	0.77	2,782	0.73
⩾6 acres	8,485	0.44	–1,532	0.79
Change for adapted farmers – change for non-adapted (other village)				
<2 acres	46,009	0.09	14,470	0.21
2–<4 acres	4,839	0.65	5,717	0.13
4–<6 acres	2,538	0.82	1,881	0.85
⩾6 acres	8,341	0.21	–1,658	0.61

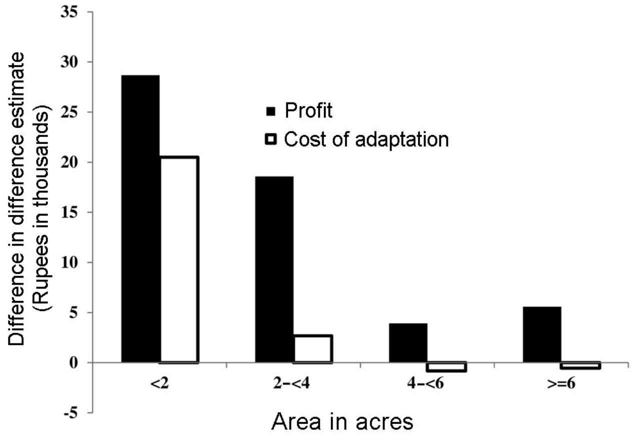

Figure 5. Difference in difference estimates for profit and adaptation cost for different strata of farmers

management without additional cost or incur additional cost for adaptation. By doing so, they can achieve significant improvement in profit (Figure 5). In 2–4 acres strata, almost similar trends are found but the profit may not increase proportionately. The analysis also indicates that the profit is not directly proportional to the cost of adaptation, if any, among different strata of farmers. Variation in estimates for non-adapted farmers from the same villages and those from other village may be due to time lag in spillover effect.

Project was operational for 4 years, which gave ample opportunity to non-intervention farmers to adopt improved technologies. Similarly, adaptation cost was not the same across the strata. In general, small farmers had more adaptation costs than the large farmers. However, the small farmers realized higher profit/unit area. These farmers generally have the cereal–vegetable cropping system. Large holding farmers generally grow cereal based cropping systems and thus, the profits are less. Large farmers may have to rationalize their management investments for gaining more profits, whereas small farmers may have to face additional costs for adaptation to climate change.

Analysis on household surplus income

The average surplus income available from total household income (Figure 6 *b*) or agricultural income (Figure 6 *a*) has varied across the strata. Total household income includes agricultural income as well as income from other sources. Average surplus income per person per acre in a year showed a declining trend as the land holding size increased. The adapted farmers of less than two acre land holding could improve income due to the adaptation. The agricultural profit of non-adaptors could not sustain the family expenses, and they had to depend on non-farm income for sustenance. The income contribution from non-agricultural activities seem to be very less in households with land holding of 4 acre and above. However, these results are specific to the sample HHs. Further, size of the farm families increased as the size of land holding increased. One reason could be than the joint families living together have bigger farms as compared to nuclear families. In addition they have abundant farm labour at home to manage bigger farms.

When surplus is expressed on landholding basis (Figure 6), it is clear that farmers with small land holdings cannot support themselves with agricultural income alone, without changing their crop management. However, with adaptation, as in the case of intervention farmers, a self-sustaining agricultural system could be achieved. The non-intervention farmers in this strata sustained their family through income from other sources than from agriculture alone. Except for the farmers in >=6 acres strata, adapted farmers exhibit higher surplus in all strata. The per acre surplus increased with the size of land holding.

Crop diversification, improved varieties and growing of horticultural crops are found to be the major reasons for increased profit from agriculture. Findings indicate

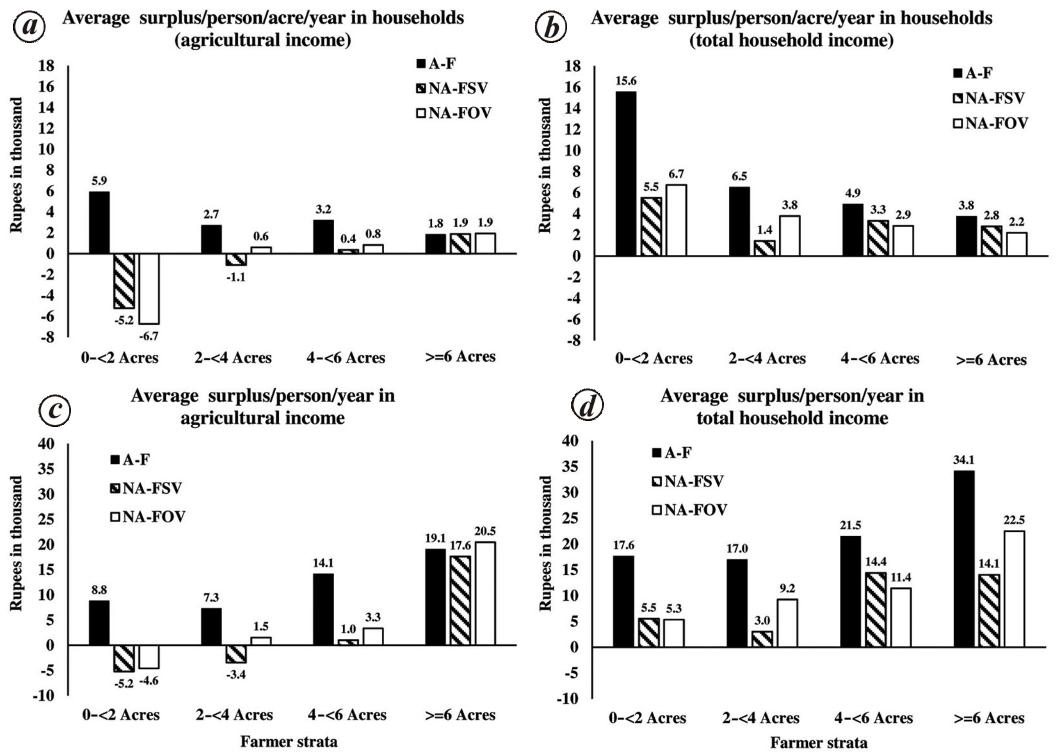

Figure 6. Variation in average surplus per person per acre in a year in different groups of households based on (***a***) agricultural income and (***b***) total household income. Lower graphs indicate variation in average surplus per person in a year in different groups of households based on (***c***) agricultural income and (***d***) total household income. The values are for the after intervention period (2013–14). The numbers above the columns represent the average number of family members in all groups and in their different strata. A-F, Adapted farmers; NA-FSV, Non-adapted farmers from same village; NA-FOV, Non-adapted farmers from other village.

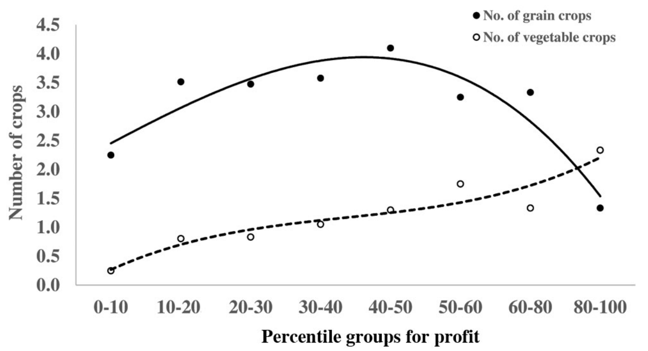

Figure 7. Change in profits from agriculture due to cultivation of crops and vegetables in various combinations. The *Y*-axis indicates number of crops and *X*-axis represents percentile groups for profit with 80–100 indicating top percentile for profit.

that growing one grain crop and two vegetable crops during a year can be highly profitable (Figure 7). The farmers in the lowest ten percentile of income mostly grew grain crops and a few vegetables, while the farmers in the top twenty percentile grew mostly vegetables and only few grain crops. However, those growing 3–4 grain crops could increase profits by replacing at least one grain crop with vegetable cultivation.

Conclusions and policy options

From the study it can be concluded that adaptation increases agricultural profit. Adopting proper varieties, crop and livestock management strategies and technical know-how can reduce the cost of farm operations, increase agricultural profits as well as the capacity to adapt to climatic risks. Additional cost is not always required for adaptation, and rationalizing agricultural expenditure through scientific crop management is essential for adapting to climatic risks. Diversification of farm income is needed for improving the adaptive capacity as well as livelihood security. Small and marginal farm (<4 acre) families cannot support themselves with agricultural income alone, however with adaptation, a self-sustaining agriculture could be achieved. In general, large farmers may have to rationalize their management investments for increasing their profits, while small farmers may have to face additional cost for adaptation to climate change. Small farms can get more profit/unit area/unit cost of adaptation. Therefore at the community level, which comprises a mixture of different sizes of landholding, differential costs of adaptation and profits are likely.

Policies for incentivizing these responsive adaptation costs for small and marginal farmers would be required.

Further, improved input delivery services and development of knowledge based agriculture needs policy support. On the other hand, large investments may be required for implementing planned adaptation strategies such as establishing permanent agricultural-infrastructure for managing water, agricultural produce, etc. in order to sustain agricultural profitability. There is a need to develop farm income-based insurance products since the primary objective of climate change adaptation in farming communities is to achieve livelihood security. Currently, the Government of India has a National Action Plan on Climate Change (NAPCC) with eight National Missions and with at least two of them directly related to adaptation in agriculture. The National Mission for Sustainable Agriculture aims to support adaptation in agriculture through the development of climate–resilient crops, expansion of weather insurance mechanisms, and agricultural practices. Further, the National Water Mission aims at a 20% improvement in water use efficiency through pricing and other measures. Other three Missions viz., National Mission for Sustaining the Himalayan Ecosystem, National Mission for a 'Green India' and National Mission on Strategic Knowledge for Climate Change also directly or indirectly deal with agricultural adaptation. Apart from these, most of the States have State Action Plans on Climate Change by integrating climate change concerns into policies, plans and programmes in line with the objectives of the NAPCC. They also help to build adaptive capacities at the local level. However, the current study indicates the complexities of adaptation gains in different strata of farmers and thus the suggested policy options may be streamlines for inclusive growth.

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