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**SUBJECT II**  
**CLIMATE CHANGE-ITS IMPACT ON AGRICULTURE**  
**PRODUCTIVITY AND LIVELIHOOD: THE POLICY RESPONSE**

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**Climate Change Impact and Management Strategies for Sustainable Water-Energy-Agriculture Outcomes in Punjab**

**R.S. Sidhu, Kamal Vatta and Upmanu Lall\***

**I**

**INTRODUCTION**

Climate change poses a significant threat to agrarian societies in tropical regions. For South Asia and India, warmer temperatures, and increased variability in rainfall portend decreased yields, and corresponding impacts on rural livelihood and national food security. Since the 1960s, a number of factors, such as high-yielding varieties of wheat and rice, higher use of fertilisers, expansion in irrigation and increased cropping intensity, improved the resilience of India to the incidence of famine. The development of a national grain procurement, storage and distribution system contributed significantly towards food security of the nation.

The success of these programmes made it possible for a small state like Punjab, having just 1.52 per cent of the land area of India, to contribute around 50 per cent to the national pool of food grains. Such remarkable transition was facilitated initially by the construction of multi-purpose<sup>1</sup> Bhakhra dam and canal system on Beas and Sutlej rivers to tap Himalayan snowmelt and rainfall. Today, given the widespread rural electrification, the surface water (canal water) use is overshadowed by groundwater based irrigation.<sup>2</sup> Echoing a policy used in other states of the country, the Punjab government offers free electricity to agriculture, contributing to a dramatic rise in the number of tubewells<sup>3</sup> and to a faster depletion in the ground water, which has been termed as possibly the largest mining of water on earth based on the satellite images (Rodell *et al.*, 2009). The farmers who used to pump groundwater from just 5-10 ft below surface are currently drilling the tubewells upto 300 ft. The remarkable increase in water usage in agriculture has resulted from the transition of Punjab agriculture from traditional crops<sup>4</sup> to rice-wheat monoculture occupying almost 80 per cent of the cropped area, which ultimately leads to dramatic rise in the water usage in comparison of average annual water supply in the region.<sup>5</sup> Such change in

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the farmers' behaviour is the result of targeted procurement<sup>6</sup> of rice and wheat crops from this region by the Government of India at a guaranteed price, which is usually announced before the time of sowing of these crops.

Climate change is no longer a future phenomenon but has turned into a reality. A modest long-term rise in summer temperature and rainfall, relatively more pronounced increase in winter temperature and decline in winter precipitation was witnessed showing changing and variable climate in the north-region of the country.

The trends in the Punjab state are almost similar. The rise in minimum temperature is much sharper than the maximum temperature, which has serious implications for winter crops. The average precipitation has declined and mean temperature has risen. The practice of flood irrigation of rice being grown at more than 2.7 million ha area has contributed towards more humid conditions during the months of June to September. The increase in relative humidity has created favourable conditions for the increased incidence of diseases and pest attacks.

The recent trends, attributed to weaker winter precipitation and warmer temperatures, indicate towards declining wheat yields. An increase in variability of the summer monsoons, will accentuate the negative impacts on rice through excessive flooding, and will increase the need for higher irrigation due to longer dry spells. It will eventually increase the cost of production and will worsen the situation of the already dwindling groundwater resources in Punjab. Flood irrigation has not only led to increased water use, but has also led to changes in the regional microclimate. Increased incidence of insect-pest and diseases attacks, owing to rise in relative humidity, has favoured higher use of agro-chemicals and has led to degradation of ground water quality.

Farm level concerns on groundwater depletion and consequent water scarcity emerge from rising investments on deepening of tubewells, increasing cost of irrigation due to diesel usage and expected yield and income losses translating into food and livelihood insecurity. The other climate factors emerge at a lower level but are strongly associated with such concerns. Despite farmers' awareness on the contribution of climate and water factors to recent rise in agricultural and livelihood risk, clear relationships have not been documented or are less visible. Hence, this paper seeks to assess the impact of climate change and variability on sustainability of groundwater-energy-agriculture system in Punjab and has further suggested some useful management strategies for optimal outcomes from this system.

## II

### IMPACT OF CLIMATE CHANGE

*Impact on Water Resources:* Fall in precipitation is aggravating the already precarious and dwindling ground water resources of the region. Cultivation of rice crop, which uses 1800 mm of water, on an area of 2.7 million ha has caused severe drain on the groundwater resources, resulting into fall in groundwater table in central

Punjab where groundwater is fit for irrigation. While the water table depth was less than one metre in early 1970s, more than 90 per cent of area in this region is currently under more than 10 metres water table depth. The fall in water table is very high during low rainfall years. During 2009, when rainfall was almost 30 per cent deficit than normal during monsoons, water table declined by more than 90 cm as compared to the fall of only 61 cm in the year 2007-08 (Figure 1). The frequency of deficiency in rainfall has increased in recent years with less than normal rainfall in the state being recorded during the years 1999, 2002, 2006 and 2009, leading to greater fall in water table depth. The situation is further compounded by the energy subsidy given by the state government to the farm sector, the crop choices and inefficient irrigation strategies, causing a severe water supply-demand imbalance that leads to falling water tables.

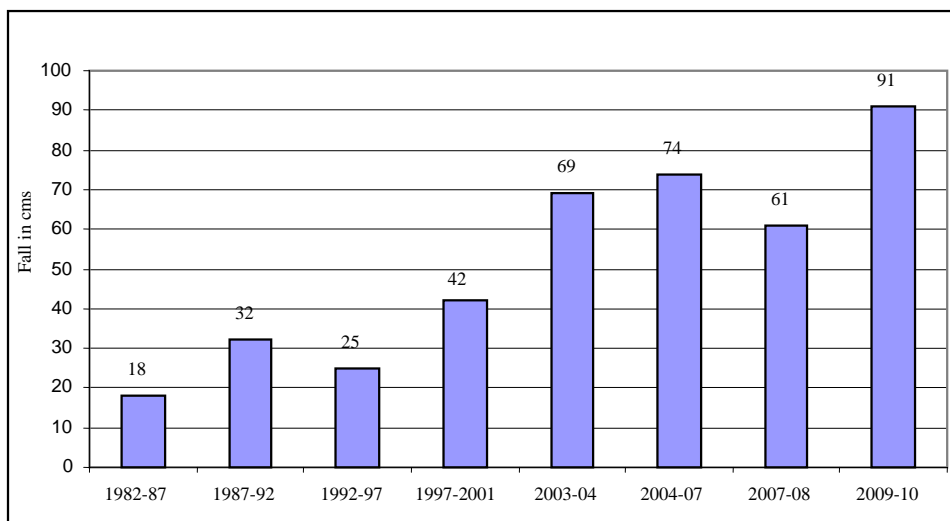


Figure 1. Trends in Average Annual Fall in Ground Water Table in Punjab

*Impact on Power Usage and Power Subsidies:* Punjab is a typical region where the impact of drought or lower rainfall is not translated into lower crop productivity and production, as witnessed in other parts of India during drought. It is due to the reason that more than 97 per cent cultivated area in Punjab is irrigated, out of which more than three-fourths of the irrigation is sourced through groundwater resources. Indiscriminate pumping of groundwater for irrigation during less rainfall years not only depletes the groundwater table but also results into increased use of energy in the farming sector.

The energy usage increases proportionally to drop in water level and quantity of pumped water. The increasing fiscal burden, due to burgeoning electricity subsidy for the farming sector, poses a perpetual budgetary challenge for the state government and adversely affects the budgetary allocations for other social security sectors such as education, health and other development programmes. During 2010-11, the electricity subsidy has been estimated to have reached Rs. 3100 crore in Punjab (Figure 2). Due to frequent deepening of borewells and shifting from centrifugal to submersible pump to draw water from deeper aquifers, the private investments on irrigation by farmers have increased. Irrigation expenditure (at constant prices of 2003-04) for rice jumped up by Rs. 1527/ha and that for wheat by Rs. 620/ha between 1993-94 and 2003-04 (Singh and Sidhu, 2006).

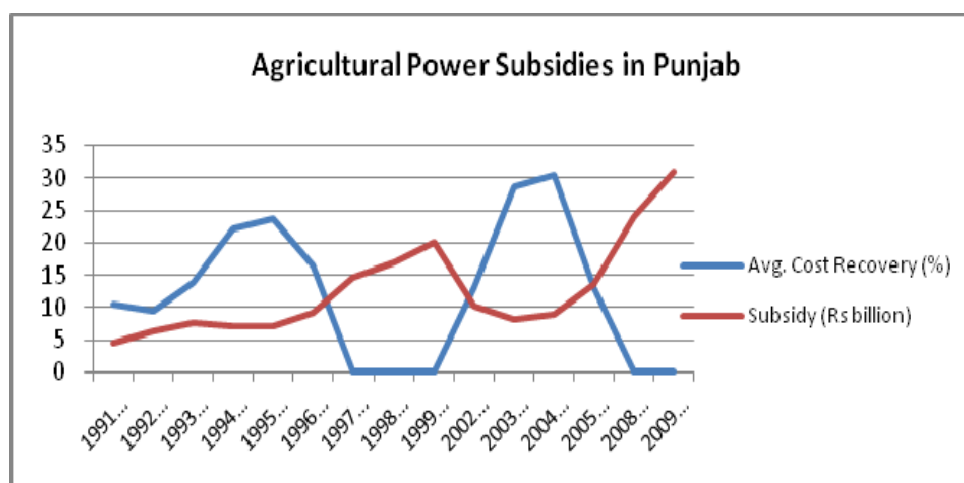


Figure 2. Historical Changes in Electricity Subsidy and Cost Recovery from Agriculture in Punjab

Concurrently, the deficient supply of electricity and its poor reliability negatively has an adverse impact on industrial development in the state. The household sector also faces frequent power cuts during summer months which range between 4-8 hours per day making life very difficult under more than 45° C temperature and more than 80 per cent relative humidity. The opportunity cost of power supplies to agriculture for pumping groundwater is likely to be immense, though there are no publicly available studies that have done a comprehensive and systematic analysis of these costs. The direct substitution by diesel generation triples the energy cost for users who are forced to resort to that option. In drought years, many farmers have to resort to this option since the overall generation capacity constraint limits on farm electricity supply and reliability. Thus climate variability emerges as a concern through its impact on energy supply (hydropower) and demand, even though the

region is “fully irrigated”, and hence considered immune to droughts. The social costs associated with industrial production costs and other disruptions are higher still. There are also increasing contributions to greenhouse gas emissions.

*Decline in Wheat Yields:* Wheat productivity was registering a steady growth since the introduction of high yielding dwarf varieties in the late 1960s due to continuous improvement in their genotypes as well as higher use of inputs like fertilisers and other plant protection technologies against rusts. Wheat is a winter crop and its yield is highly sensitive to temperature. Due to more pronounced change and variability in climate, especially rise in temperatures during winters, wheat yield has been impacted adversely. The yield declined from the peak of 4.7 tonnes/ha in 1999-2000 to 4.1 tonnes/ha in 2005-06. In the absence of any fall in the use of critical inputs like fertilisers, chemicals, irrigation, etc., the fall in wheat productivity may largely be attributed to the rise in temperature, especially during the critical periods of growth in the months of January, February and March.

TABLE 1. PATTERN OF PRODUCTIVITY AND USE OF IMPORTANT INPUTS IN WHEAT CROP IN PUNJAB

Year (1)	Yield (qtl/ha) (2)	Fertiliser use (kg/ha) (3)	Index of value of agro-chemical use (1995-96 prices) (4)	Irrigated area (per cent) (5)
1995-96	38.84	203.66	100.00	100.00
1996-97	42.34	220.17	118.91	100.00
1997-98	38.53	224.87	124.45	100.00
1998-99	43.32	212.26	170.03	100.00
1999-2000	46.96	217.00	175.50	100.00
2000-01	45.63	222.09	198.99	100.00
2001-02	45.32	225.35	249.18	100.00
2002-03	42.00	222.12	268.04	100.00
2003-04	42.07	223.80	254.55	100.00
2004-05	42.95	236.79	247.10	100.00
2005-06	41.79	231.82	222.86	100.00
2006-07	42.10	228.01	196.89	100.00

Source: Commission for Agricultural Costs and Prices, Government of India.

*Impact on Cost of Production and Income:* The frequent climate change and variability has started impacting cost and returns structure of the farming sector adversely. The fall and variability in precipitation during summer monsoons has resulted into an increase in the cost of production due to increased expenditure on diesel use for irrigating rice and has further increased the livelihood vulnerability of the small and marginal farmers. During 2009, a drought year, the expenditure on diesel use for irrigating rice increased by around Rs. 2780/ha with a simultaneous rise in the state power subsidy by Rs. 450 crore.<sup>7</sup> The increased costs of well deepening,

pump replacement and diesel use against stagnating/declining productivity are leading to increasing rural poverty rates in the state. Poverty in farming households is estimated to have risen from 8.7 per cent in 1995-96 to 11.4 per cent in 2005-06 (Joshi *et al.*, 2006).

The economic viability of small and marginal farmers is an important concern in the state due to low economic margins and increasing production risks to climate change, emerging water scarcity and increased incidence of diseases and pests. The productivity of cotton fell drastically due to the attack of American cotton bollworm during 1997-2002, completely derailing the economic sustenance of farmers. Similarly, fall in wheat productivity due to climate variability especially temperature, sunshine and relative humidity reduced wheat profitability during 2000-01 to 2004-05. The rice profits to farmers did not improve during 2001-02 to 2005-06 due to price and productivity stagnation and increase in cost of production. Yet, farmers continue to grow rice-wheat due to absence of any other economically sustainable alternative crop system.

Under the scenario of changing climate, the livelihood security of the farmers, especially small and marginal holders, is becoming increasingly precarious. Any adverse impact of the climate on water, energy and markets has the potential to severely jeopardise their food and income security. Small holders' market surpluses are generally low, and their access to groundwater is likely to fall due to capital constraints (needed for well deepening) in case groundwater further goes down under falling precipitation. In order to improve their food and livelihood security, strengthening their resilience to climate change and variability is very important, which is only possible if groundwater resources remain sustainable and crop productivity and income grows.

### III

#### STRATEGIES TO ADDRESS CLIMATE CHANGE IMPACTS

The Punjab example is poignant given its significant regional impact and also its national importance from contributions to national food security. The contribution of Punjab to national food stocks is even higher when precipitation falls in the country. In 2009, the production of rice fell by around 16 million tonnes due to poor precipitation while Punjab contributed 10 million tonnes of rice to national procurement for public distribution. But the water table in Punjab fell by more than 90 cm and state provided energy subsidy increased to Rs. 31 billion. It underscores the fact that while irrigated agriculture buffers the impacts of climate variability on food production, it shifts the vulnerability to (a) chronic impacts on water sustainability, (b) regional energy reliability and associated industrial development trajectories, and (c) a financial burden on the state and the increasing vulnerability of small holders in accessing groundwater from deeper layers. However, given the higher incomes, and use of technology that accompany irrigated agriculture in a state

such as Punjab, an opportunity for a more sophisticated and strategic intervention at field, market and policy levels to address these issues is necessary.

*Climate Forecasting:* Given the reliance on irrigation, farmers in the state typically follow a specified calendar, and very limited use is made of climate forecasts to adapt crops to emerging climate conditions. There is very limited capacity for climate forecasts or their application in the state. Evidence is thus needed to develop an integrated regional weather-climate forecast system covering precipitation, temperature and humidity over the year and its validation in the context of a specific decision time table to be used by farmers for irrigation, fertilizer and pesticide application scheduling as well as for pre-season crop choice.

The projected climate changes from the Intergovernmental Panel on Climate Change (IPCC) models for the region include changes in the average temperature (reliable), the average precipitation (uncertain), in the seasonality of temperature and precipitation (reliable) and in the frequency and duration of heat/cold/rainfall extremes (uncertain). Thus, changes in the planting calendars and crop choices may be necessary under a climate change scenario, as will be concerns as to the yields that may be achieved using traditional cropping choices and calendars. These concerns are already being voiced by the PAU scientists and by farmers, based on the static or declining wheat yields in 2000-07, when winters were anomalously warm. The cooler, wetter winter of 2010-11 has delivered record wheat production. Consequently, an analysis of the sensitivity of agricultural productivity to specific statistics of precipitation and temperature and their seasonal variation is a pre-requisite for any climate vulnerability analysis. An assessment of the short and long term predictability of the statistics thus identified from existing climate or empirical models would facilitate adaptation strategies.

*Formulation of Alternate Policies for Energy Subsidy and Water Saving:* The current electricity subsidy from the state government of Punjab provides electricity at a fixed cost (i.e., no charge per unit kwh consumed) to each agricultural well user. The subsidy contributes directly to the ongoing depletion of the groundwater table that has been recognised as a national issue from a long term food security and climate vulnerability perspective. Studies have shown that the well to do farmers typically derive the most benefit from the current subsidy system. At this time, there is considerable debate within the Punjab and across the Punjab and Central governments as to how the subsidy should be structured. The Planning Commission of India and the Central Government are advising the State Government to do away with the subsidy, while the Punjab Government wants the Centre to provide funds and subsidies for procuring crops other than rice and wheat from Punjab to change the current system.

It is thus clear that a reform in the electricity subsidy structure in Punjab that leads to metering and marginal cost pricing may be a useful mechanism for



improving water use efficiency. However, this is considered politically unfeasible given that there is an existing entitlement that provides essentially free electricity. A direct cash subsidy for electricity or across all subsidised farming inputs, coupled with metering for electricity use can prove as an effective alternative in the economic context. The alternatives include metered electricity provision and bundling the subsidy into the Government of India procurement process where the price paid to the farmer is pegged to the cost of cultivation plus a percentage. This would transfer the subsidy from the Punjab state to the Central government, which given that the rice-wheat rotation in Punjab is an outcome of the Central government's procurement strategy seems fair. However, the measure may not promote water or energy savings unless normative assessments of "fair" energy use were established, and the cost of cultivation pegged to that norm. If electricity use moved to unit pricing, then farmers may be motivated to find ways to save water, but particularly small farmers may not have the capital to implement alternative technologies or to change the cropping pattern to one (e.g., vegetables) that has higher market price risk. Consequently, a water or energy credit instrument may be considered that would allow a farmer to go for such alternatives. Any supply chain which provides either capital support or procurement support if water and energy savings were guaranteed, also gets credit for these savings either through the provision of guaranteed water or electricity or cash. Such an instrument could be designed such that it is revenue neutral for the state, and is financially attractive for those (farmers, supply chains) who earn the credits. The climate sensitivity analysis would inform the design of such an instrument, since the credits, the pricing structure and the subsidy entitlements could be pegged to the prevailing or forecast climate condition and the anticipated water and energy constraint.

*Water-Energy Saving Technological Choices:* This strategy rests on the physical and financial viability of technologies and practices that the farmers can pursue in each season and for each crop, with a view towards the diffusion and adoption of appropriate methods (including climate information) to save water/energy while improving crop yield and/or income and hence develop long term resilience to a variable climate. These technologies include tensiometer, laser leveling, intercropping, direct seeding of rice, drought resistant varieties and irrigation scheduling with or without guidance and should match farmer demographics, soil types and crop types. The use of tensiometers<sup>8</sup> in rice crops helped in optimal scheduling of irrigation and saved almost 22 per cent<sup>9</sup> of the water without any adverse impact on paddy yield in spite of the fact that the rains were more than normal during the last year. This technology has the greater potential in saving water and energy under low rainfall conditions by optimising the water usage to crop as per its requirement. Farmer interest in adoption is high. However, the results were quite variable depending on soil type. Soil heterogeneity is a well-known problem in designing irrigation application strategies and for assessing the soil moisture

variations. Soil scientists have developed sophisticated sensors for soil moisture measurement at a point and there is also some innovation in using fibre optics to develop spatial sensing of soil moisture. It is hypothesised that low cost technologies for soil moisture data collection integrated with a space and time modeling structure can be more informative and effective. The capital, maintenance and transaction cost associated with these technologies have to be considered for field success. How these vary relative to the small/poor and well-to-do farmers has to be considered while designing a recommendation of packages that a farmer could use as part of the pre-season investment decision and subsequent operation.

*Developing Agriculture Supply Chains:* In Punjab, the Central government conducts, in effect, the largest contract farming operation, with a guaranteed price procurement of rice and wheat, which in conjunction with the subsidised electricity provided by the state government map into the chronic groundwater depletion and climate induced energy crisis in years with droughts. For crops that are not procured, market prices fluctuate widely in a given season, or across markets in the same district. On the same day, the prices of fruits and vegetables can differ up to five times across different markets which may not be very far away. Consequently, the farmer faces considerable market price risk for potentially high value products such as vegetables and fruits, and items that are not procured by the government at guaranteed prices, which creates a disincentive to diversify crops beyond the high water using rice-wheat rotation.

Crop diversification away from only two crop (rice-wheat) based system is extremely important to counter risk emerging from climate change and variability. For crop diversification to occur, vertical integration of the supply/value chain involving small holders is necessary. For farmers, especially marginal and small holders, to be able to improve their resilience to climate and financial shocks, they need better access to markets and technology that a well designed agricultural supply chain could deliver. High value crops like vegetables and fruits give better returns but price risk force farmers especially small farmers not to go for these. If offered a price contract and assured lifting of produce through integrated supply chain management system, such labour intensive crops stand chance at small farms because labour is abundantly available on these farms. Crop diversification can improve their nutritional as well as livelihood security. But, climate information and its associated risk management is equally important. Lack of scientific information on production and market risks and their management strategies in the earlier attempts on crop diversification has failed both the supply chains and farmers in their efforts and rice-wheat system continues to drain the state's groundwater and financial resources. How best this supply chain can be designed to use climate and market information delivering equitable returns to farmers and corporations is a challenge. An examination of alternate crops, their potential yields and production and market risks under changing climate is an important aspect of this issue.

There have been nearly 20 years of effort to develop a contract farming model in Punjab to address this problem, through the Punjab Agro Industries Corporation and through private sector players such as Pepsico, Tata, ITC, Field Fresh, Reliance Retail and Nestle. These activities have had varied success in procurement and in influencing farmer practices. Farmer renegeing on contracts when market prices have been higher than contract and corporation renegeing when market prices have been lower has been a problem. Specialised or niche products such as specific potato varieties grown for McDonalds, or Baby Corn, that are not important for the primary retail market have fared well, as have export oriented contracts for flower seeds, potato or Basmati rice.

Agricultural supply chains in Punjab are still poorly developed. Some supply chains (corporations) are still interested and are keen to have access to large contiguous areas where farmers could grow products of high quality following modern, sustainable practices. The economic margin between farm and retail prices is large enough that if the middle men were removed, there is sufficient margin for capital and operational investment in better practices while improving product quality and mutual incomes. Through such aggregation a supply chain could reduce the financial burden associated with farm level insurance programmes, and with the procurement and deployment of technologies as well as implementation of better practices and higher yielding varieties. This is an opportunity, which can be developed, informed by pre-season and within season climate and market information, with the goal of developing sufficient penetration towards crop diversification such that there is a positive impact on the resilience of agriculture in the state.

For this to succeed, the assessment of the portfolio of crops that the supply chain would like to procure in the upcoming 1 to 3 years, and identify the potential for offering contracts with price and quantity indexed to average expected market prices for goods that have a current competitive market, and to “attractive” prices for niche products to stimulate farmer interest, is a pre-requisite. The indexed contract would allow the procurement price to fluctuate over a window indexed to average market prices over a specified time window in the season, and the width of the price window would be indexed to the price volatility over the time window. For instance, if the average price were Rs. 10/kg and the standard deviation over a 20 day harvesting window were Rs. 5, and the original contract were for Rs. 8/kg, it would be honoured at that price since it was well within the range of the volatility. However, if the price spread were only Rs. 0.5/kg then the situation is one in which the farmer has the incentive to renege. In this case, a prescription would be available such that the price could be re-set closer to Rs. 10/kg to prevent renegeing, accounting for transaction costs, and the value of longer term commitments, including incentives offered by the supply chain in terms of seeds, technologies and loans. If the average market price had gone upto Rs. 20/kg with a volatility of Rs. 0.5/kg, then it may be difficult for the supply chain/corporation to honour the contract. In this setting, an option for contract

insurance may be explored such that the extraordinary situation that results from climate (loss of production and hence a demand-supply imbalance) risk or other factors inducing market risk is covered and the contract can be honoured. Clearly, both extremes need to be covered by such a contract to address reneging by the farmer or the supply chain. One needs to work out the terms of such contracts such as the values associated with supply chain contributions towards farmer livelihood, better practices and resilience are recognised.

*Use of ICT Tools:* What is needed is a system to communicate weather, climate, market price forecast and guidance on scheduling irrigation, fertiliser application, pest control, contract farming and insurance options to the farmers to counter the adverse impacts of climate change and variability. Reducing irrigation water use and the ability to optimise crop choice/irrigation schedules to local rainfall patterns is an important element for both sustainability and adapting to climate change. The whole idea is to provide guidance on when and how to use different climate resilience technologies and practices. The spread of cell phone technology is extremely high among Punjab farmers and thus can be used very effectively for this purpose.

#### IV

#### CONCLUSIONS

Punjab is a semi-arid state, which through some of the highest grain yields in the country, contributes over half of India's annual food grain reserve through irrigated agriculture. While irrigation buffers rainfall variability, in Punjab it translates into one of the largest groundwater mining operations in the world. During dry years, 60 per cent of the total electricity consumption goes for agricultural pumping, impacting the reliability of the grid and industrial productivity. Climate in the state is undergoing change and experiencing greater variability in recent times. Climate change trends and projections suggest that regional agriculture, wheat yields, water levels and, energy use and consequently national food security and individual livelihood security are negatively impacted. Fall in precipitation has resulted into greater fall in groundwater resources and increased state subsidies on electricity. Similarly, increase in the temperature especially in winters has caused wheat productivity to decline. Before the introduction of Bt cotton, rise in relative humidity due to continuous ponding of rice fields over an area of 2.7 m ha led to higher incidence of pests attack especially cotton bollworm resulting into lower productivity. Consequently, increase in cost of production and fall in productivity have squeezed farm incomes. While Punjab rural incomes are some of the highest in the country, the rural poverty rate of small farmers are increasing and nutritional metrics worsening in recent years.

In this context, it becomes necessary to adapt crop choices, irrigation practices and technologies, and develop supply chains and other insurance options in a way to reduce the impacts of climate variability and change on water use and resource

depletion, and energy while maintaining productivity and rural income. Developing capacities in climate forecasts and decision tools has emerged as one of the important tool to guide irrigation scheduling, fertiliser application, and crop choice decisions. Promoting climate resilience through technologies such as tensiometers, laser leveling, and direct seeding of rice to improve irrigation water use efficiency and thus reduce the risk of water supply-demand imbalance and excessive energy use is equally important for long term sustainability of the agriculture system in the state. Developing agriculture supply chains to promote crop diversification and reduce risk through access to markets, technology, capital and insurance through corporate providers is another very important option to counter the adverse impacts of climate change on natural resources and the farming economy.

#### NOTES

1. Multi-purpose Bhkhra dam was built for irrigation, hydropower and flood control.
2. Almost 97 per cent of the cultivated area in Punjab is irrigated, out of which 75 per cent is irrigated through groundwater.
3. In 1960, there were only 1 lakh tubewells in India and today these are over 2 crore. The number in Punjab is 13.15 lakh, out of which 10.65 lakh are electricity operated (Government of Punjab, 2010).
4. The traditional crops were wheat, maize, pulses and vegetables.
5. The water supply in Punjab was assessed as that comprising accessible rainfall, canal water and groundwater recharge.
6. Punjab contributes 10 million tonnes of wheat and about 8-9 million tonnes of rice annually to the central pool.
7. These estimates were based on sample survey of 160 farmers with rice-wheat system, spread across different farm size categories in Punjab.
8. Tensiometer is a small device used to schedule irrigations in rice crop on the basis of soil moisture conditions. Without having any adverse impact on yield, the use of instrument is expected to bring water savings of 370 mm in rice (World Bank, 2010).
9. The joint project of Punjab Agricultural University (PAU) and Columbia Water Centre (CWC), Columbia University, New York, USA promoted the adoption of tensiometer on the rice fields of 525 farmers during 2010. The data on number of irrigations and hours of electricity motor usage were collected regularly from these farmers along with their motor horse powers. The results revealed 22 per cent savings in irrigation water in the tensiometer field in comparison to the fields of the same farmers where the tensiometer was not used.

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