Groundwater Irrigation-Electricity-Crop Diversification Nexus in Punjab

Trends, Turning Points, and Policy Initiatives

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The present wheat-rice cropping pattern, groundwater irrigation, procurement policy, and electricity policy have bound farmers in Punjab into a convenient yet vicious relationship that is economically and ecologically unsustainable. The state government provides free electricity for agriculture and a high minimum support price and yet recommends a shift away from rice to curb groundwater depletion. This paper analyses the trends and turning points in irrigation development in the state, its shifts in cropping pattern, and trends in electricity consumption. It further examines the real-world feasibility of the long-pending recommendation to shift the cropping pattern from water-intensive rice and wheat to less water-intensive maize and wheat.

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1 Introduction

With an aim of achieving self-sufficiency in foodgrain production, India's agricultural policy in the 1960s initiated a major government-supported technological revolution in agriculture, which began in the north-western part of the country. To build up a buffer stock and a public distribution system, the government procured foodgrains from farmers. With this initial advantage, Punjab successfully implemented the "grain revolution" through subsidised use of high-yielding variety (HYV) seeds, fertilisers, and irrigation. With the adoption of HYV technology, irrigation was no longer considered a risk-reducing technology, but a complimentary input to augmenting production. Gradually the nation, and more particularly Punjab, experienced a major shift from canal irrigation to tube well irrigation as it was a more reliable and flexible source of water, assuring a greater increase in yield. With groundwater as the major source of irrigation, the semi-arid state of Punjab shifted from the traditional wheat-maize cropping pattern to the water-intensive wheat-rice cropping pattern. In 20 years, Punjab began experiencing alarming signs of over-exploitation of groundwater as electrification of pump sets and free electricity in agriculture resulted in over-pumping and also unprecedented electricity consumption. A nexus of the wheat-rice cropping pattern, groundwater irrigation, food procurement policy, and electricity policy has bound farmers in Punjab into a convenient yet vicious relationship, which though economically and ecologically unsustainable, seems to offer no way out.

Crop diversification had been one of the suggestions to bring about positive changes in Punjab's agriculture since 1986. Two Johl Committee reports (1986 and 2002) recommended a shift away from the wheat-rice cropping pattern to a wheat-maize one. A draft document submitted by the Government of Punjab to the Committee for Formulation of Agriculture Policy for Punjab State (Government of Punjab 2013) reiterates the same solution. It is an irony that although Punjab has been harping on shifting from rice cultivation to maize cultivation in the kharif (monsoon) season to curb groundwater depletion, the major cropping pattern still remains wheat-rice. While recommending crop diversification, Punjab has followed a very lenient policy on payments for using electricity for agricultural purposes, which has turned into a regime of free electricity from a flat price one. In May 2013, the Punjab government approved a new agriculture power tube well policy under which it was to grant 25,000 tube well connections to farmers during 2013-14 (North Gazette 2013).

Against this background, this paper studies the cropping pattern-groundwater-energy nexus in Punjab. It analyses the trends and turning points in irrigation development, shifts in cropping pattern, and trends in electricity consumption in the state through the lens of its changing agricultural and electricity policies since the early 1970s. It further elucidates on the real-world feasibility of the long-pending recommendation to shift the cropping pattern from water-intensive rice-wheat to less water-intensive and less electricity-consuming maize-wheat. The paper is divided into six sections. The introduction is followed by a brief discussion on the study area and an overview of the changing electricity policy on agriculture in Punjab, followed by the methodology and database. Section 3 is on temporal and spatial trends and the turning point in irrigation development while shifts occurred in both the cropping pattern and the policy on agriculture. Section 4 brings out the relationship between three of the most important and interconnected components of agricultural development in the state – cropping pattern, tube well irrigation, and electricity consumption – and the minimum support price (MSP). Section 5 is on the feasibility of an alternative cropping pattern of wheat and maize and the economic viability of shifting back to maize without compromising on farmers' incomes. The last section discusses emerging concerns and makes policy recommendations.

Table 1: Socio-economic and Agricultural Profile of Punjab and India

Indicators	Punjab	India
Total population (million; 2011 Census)	27.70	1,2101.93
Population density (persons/km^2; 2011 Census)	550	382
Population below poverty line (based on Tendulkar Methodology 2011-12)	8.26%	21.92%
Gross state domestic product (GSDP) (Rs in crore at current prices for 2010-11)	2,268,67.02	49,33,183
Share of agricultural sector in GSDP (2010-11)	19.54%	14.2%
Growth rate of GSDP (2007-08 to 2010-11)	6.53%	9.32%
Growth rate of agricultural sector (2008-09)	1.67%	7.53%
Number of irrigation pump sets, tube wells energised	1.18 million	16.03 million
Percentage of electrified villages	100%	94.6%
Average size of landholding (ha)	4.11	1.32
Per capita income (Rs) (2007-08) (at 2004-05 prices)	44,783	36,342
Indebtedness of farmers (%)	25.7	29
Indebtedness of farmers (Rs per household)	16,502	7,539

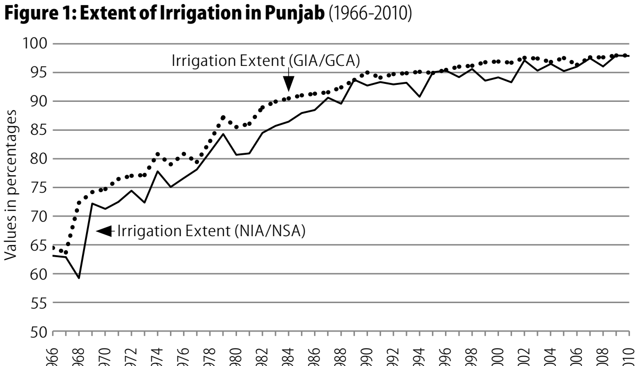
Sources: *Economic Survey 2009-10*; *Statistical Abstract of Punjab*, various years.

Table 2: Shifts in Cropping Pattern in Punjab (1975-2010)

Years	Percentage of Area under Crops: Rice	Wheat	Coarse Cereals	Pulses	Groundnut	Oilseeds	Cotton	Fruits and Vegetables
1975	10.56	44.70	15.82	8.06	3.11	5.80	10.61	1.34
1980	19.90	47.51	8.84	5.76	1.45	4.01	10.98	1.54
1985	27.06	49.47	5.39	3.57	0.73	3.29	8.87	1.61
1990	30.28	49.12	3.54	2.15	0.17	1.54	11.35	1.86
1995	32.07	48.13	3.19	0.47	0.12	3.97	9.76	2.28
2000	37.44	48.10	2.47	0.46	0.02	0.60	9.04	1.87
2005	37.67	48.53	2.59	0.29	0.08	0.78	7.81	2.25
2010	38.74	48.69	2.34	0.28	0.03	0.83	7.06	2.03

Source: Computed from *Statistical Abstract of Punjab* (various issues).

Figure 1: Extent of Irrigation in Punjab (1966-2010)

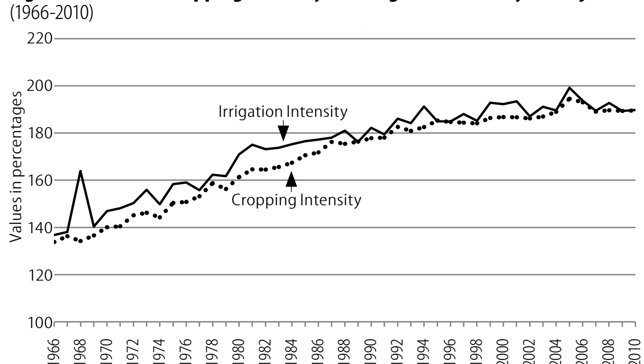


Source: *Statistical Abstract of Punjab* (various issues).

2 Study Area

Among Indian states, Punjab holds pride of place for agriculture and rural development (Table 1). It covers only 1.5% of India's geographical area, but produces 18.91% of the country's wheat and 12.6% of its rice. The state receives an annual average rainfall of 780 mm. The rain-fed area in the state accounts for only 88,000 hectares, which is less than 2% of its cultivated area. The state has the highest percentage of net irrigated area at 98% and the highest irrigation intensity at 190% (*Statistical Abstract of Punjab 2013*).

Figure 2: Trends in Cropping Intensity and Irrigation Intensity in Punjab (1966-2010)



Agricultural Electricity Policy-Crop Diversification Nexus

The provision of electricity for groundwater irrigation has always been an important policy in Punjab. Electric pump sets were metered when they were first introduced in support of the green revolution and farmers were charged a consumption-based electricity tariff. The newly introduced biochemical farm technology helped cushion the additional expenditure by volumetric pricing of groundwater. Moreover, institutional finance for farm equipment on liberal terms encouraged the adoption of new water-extraction pumps, encouraging tube well irrigation in the canal-irrigated regions of north-western India (Dhawan 1975).

In the second half of the 1970s, the net return on wheat production in Punjab declined considerably, stimulating the emergence of a powerful farmers' movement, the Bharatiya Kisan Union (BKU). One of the major demands of the BKU in the early 1980s was lowering the prices of inputs, including fertilisers, diesel, and electricity. The BKU demanded that the newly increased electricity rates be withdrawn and encouraged farmers to not pay their electricity bills. In 1984, the government announced a considerable reduction in connection and line service charges and committed itself to clearing pending electricity connections in three months. The recovery of electricity bills for tube wells was postponed (Birner et al 2007).

Table 3: District-Wise Crop Combinations in Punjab (1970-2010)

Districts	1970	1980	1990	2000	2010
Gurdaspur	WRMSuSBeRpCBjL	WR	WR	WRSu	WR
Amritsar	WRMRpCSuBjSBeL	WR	WR	WR	WR
Kapurthala	WRMGr	WR	WR	WR	RW
Jalandhar	WMRGrSuCRpBeSL	WRM	WR	WR	WR
Hoshiarpur	WMR	WMTR	WMR	WMRSu	WRM
Rupnagar	WMSuGrRRpCSBSo	WMRSuGTGrMaBC	WRMSuMoCABRP	WRM	RM
Ludhiana	WMGrCRBeSuRpBj	WRMGrCSuBMoPG	WR	WR	WR
Ferozpur	WCRRpBjMBeSuSoGr	WRCGRBMBjMoMas	WRC	WRC	WR
Faridkot	(Part of Ferozpur)	WCRGRBBjMMoSu	WCR	WRC	WR
Bhatinda	WCBjRpMSuBeRGrSo	WCG	WC	CR	WCR
Sangrur	CMSRpWBeGrLBjCs	WCRMGBjGrB	WR	WR	WR
Patiala	CWMSBeGrRpLRSa	WR	WR	WR	RW

Where the crop combinations are more than 10, only the names of the first 10 are mentioned;
W-wheat, R- rice, M-maize, T-tobacco, Su-sugar cane, Rp-rapeseed and mustard, G-gram, Gr-groundnut, Ma-mash, Be-barley, C-cotton, Mo-moong, P-potato, Bj-bajra, A-arhar, Mas-masar, S-sesamum, L-linseed, So-shorgham, Cs-castor, Sa-safflower.
Source: Author's calculation.

From mid-1980 to mid-1990, the sustainability of Punjab's agricultural development pattern became a main concern (Prihar et al 1990; Johl 1996; Sidhu and Dhillon 1997; Chand 1999; Sarkar et al 2009). In 1985, the state government appointed a commission led by S S Johl. The commission argued for crop diversification and recommended a reduction of at least 20% of the area under rice and wheat. On electricity, the committee acknowledged the need for subsidised power, but emphasised that the cost should at least partly reflect the scarcity value of the resource so that there were incentives for its economic use (Johl 1986).

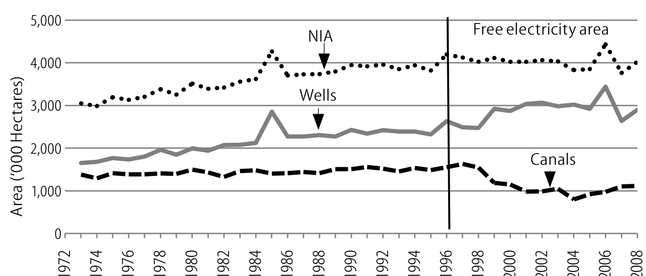
Neither the recommendations on electricity nor on crop diversification were implemented. A committee report found that explicit subsidies doubled between 1994-95 and 1996-97 (Kumar 1999). Free electricity for agriculture, together with free canal water, was introduced in 1997 when the financial situation was precarious. As a consequence, the World Bank stopped funding projects in the state (Birner et al 2007). Between 1997 and 2002, the area irrigated by canals decreased by 40%, adding 10,000 hectares to the area under groundwater irrigation (*Statistical Abstract of Punjab 1997, 2002*).

The Punjab State Electricity Regulatory Commission (PSERC) was set up in 2000. Since then, the electricity subsidy to agriculture has explicitly been stated in the state budget, and compensation is paid to the Punjab State Electricity Board (PSEB). Although unbundling was not undertaken at this time, the government appointed an expert committee led by Gajendra Haldea to promote power sector reforms. The recommendations of the committee included open access; reducing power theft based on specific legislation; increasing tariffs for all categories of consumers; metering the power supplied to agriculture; reducing the staffing levels of the PSEB; and restructuring its debts. In spite of strong resistance from employees, the state government signed a memorandum of understanding with the Government of India to implement power sector reforms. In April 2010, unbundling of the electricity board was initiated amid protests. There is a high proportion of unmetered agricultural connections in Punjab, which makes it difficult to measure the actual power consumption by agricultural consumers that has to be subsidised. Some SEBs classify higher than actual unmetered power consumption in the agricultural category to earn higher state subsidies and report better performance. Besides, unmetered connections present serious limitations to establishing the baseline data required for tariff determination, and to fix targets for aggregate technical and commercial loss reduction. The Punjab State Power Corporation Limited (PSPCL) decided in 2013 to install electricity meters on new connections following directions from the PSERC, but faced strong protests from farmers (Pal Sharma 2013). It was amid this that the new agriculture power tube well policy was approved by the state government.[1]

Methodology

The paper examines trends and turning points in irrigation over the period 1971-2012. The major variables of interest in the trend analysis are net sown area (NSA), net and gross irrigated area (NIA), and cropping patterns. The cropping pattern analysis includes 19 major crops – rice, maize, wheat, millet, and other coarse cereals; gram, tur/arahar and other pulses; groundnut, sesamum, sunflower, and other oilseeds; sugar cane, fruits, and vegetables; cotton, tobacco, and fodder crops.

Figure 3: Irrigated Area and Net Sown Area by Source of Water in Punjab



Source: *Statistical Abstract of Punjab* (various issues).

We use J C Weaver's method (1954) of crop combination index (σ) to derive the crop combination regions. The formula used is

$$\sigma^2 = \frac{\Sigma (x_i - X)^2}{N}$$

where X is the theoretical percentage, x_i is actual percentage, and N is the number of crops.

Crop specialisation has been measured by the entropy index (EI). The formula used is

$$EI = \sum_{i=1}^{N} P_i \log P_i$$

where *EI* is the entropy index, *N* is total number of crops, and P_i is the acreage proportion of the ith crop in the total cropped area. The increase in the value of the entropy index indicates a decrease in specialisation.

Data

Details of land use, and data on crop production were collected from various sources for the period 1971 to 2008. The data between 1971 and 1998 are from the International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) database, and between 1999 and 2009 from the Ministry of Agriculture, and Statistical Abstract of Punjab (various years).

3 Trends and Turning Points

In the last five decades, along with the shift to groundwater irrigation from canal irrigation, Punjab has experienced an enormous expansion of the area under water-intensive wheat and rice. There was a quantum jump in the area under groundwater irrigation from 1.7 million hectares in 1966 to 3 million hectares in 2012, changing the structure of irrigation in the state. While the area under foodgrains increased from 64% in 1966 to 82% in 2012, the area under rice increased from 5.2 million hectares to 23.39 million hectares, and that under wheat from 28 million hectares to 35.2 million hectares. In 2013-14, Punjab contributed 10.8 million tonnes to the central pool, and government agencies are expected to purchase 11 million tonnes for 2014-15 (Das 2014).

There is not an iota of doubt that Punjab's agricultural growth has been made possible by augmenting the irrigated area. Irrigation was the prerequisite, it led to the introduction and rapid spread of HYV seeds and increasing use of chemical fertilisers to boost yield. Punjab has achieved irrigation coverage of 98% of its NSA, which is highest in the country (Figure 1, p 65).

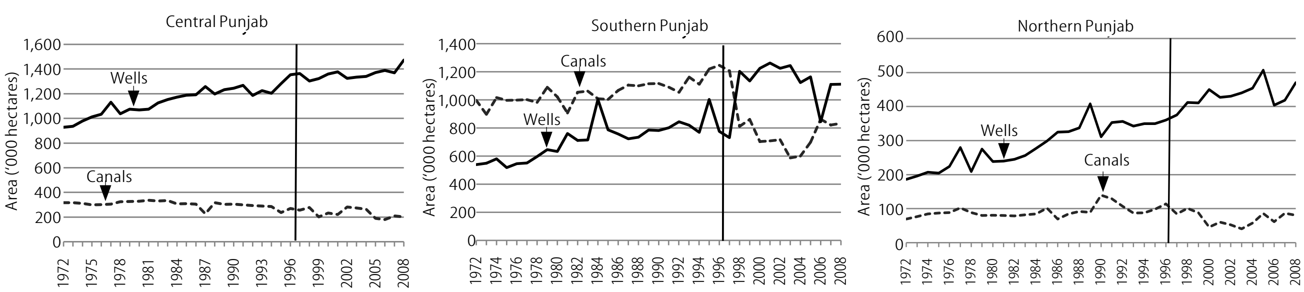
Since irrigation is a land-augmenting technology, along with increase in irrigation extent, irrigation intensity leads to increase in cropping intensity. This is very evident in Punjab (Figure 2, p 65). Cropping intensity and irrigation intensity are the highest in the central part of the state, followed by the southern and northern zones. There is a lot of fluctuation in irrigation intensity and cropping intensity in the hilly tracts of the north as a higher proportion of the area there is rain-fed.

There are only two major irrigation sources in Punjab, tube wells and canals, which together provide 99.75% of the irrigation in the state. While canal irrigation has declined over the years, tube well irrigation has been on the rise (Figure 3, p 66 and Figure 4). It is worth mentioning that the rise in tube well-irrigated area and the decline in canal-irrigated area jumped after 1997 when electricity was made free for agriculture. In the last 25 years, all the 12 districts have recorded a decline in the growth of canal irrigation. Nine of them even show a negative growth in the net area under canal irrigation, indicating a decline in the absolute area under it. The major drawback of the canal irrigation system is that it is supply-driven rather than demand-driven, which makes it less efficient than tube well irrigation. Being a perennial source, tube wells encourage crop activity throughout the year. Its dependability in drought permits crop intensification of a high level as the farmer is insulated substantially against production risks (Dhawan 1982). A couple of studies pointed out that tube well irrigation systems were best in terms of efficiency and productivity. They were thought to be a precursor to enhancing productivity and managing water resources efficiently (Kaul et al 1991; Siddhu 1999).

Over the years, with more demand for productive groundwater irrigation, lack of maintenance of the canal irrigation system has led to many canal networks drying up in Punjab. Moreover, data for conjunctive irrigation is not given in secondary statistics and field enumerators often use their judgment to decide whether something counts as a well-irrigation system or canal-irrigation system (Dhawan 1982). So anomalies can be found and farmers irrigate their fields with either tube wells or canals, or both. During field visits (Sarkar 2010), it was also noticed that canals existed in some places but there were no water in them, and farmers therefore resorted to groundwater irrigation.

Groundwater is the major source of irrigation in central Punjab, which has been a dominant tube well irrigated zone since the 1970s. In southern Punjab, until the mid-1990s, farmers depended mostly on canal irrigation to grow cotton and wheat. With the announcement of free electricity in 1997, this region underwent a shift from cotton to rice cultivation and a significant increase in deep tube well irrigation, reducing canal irrigation to 45% (Figure 5, p 68). This was inevitable as free electricity gave a major incentive to farmers to shift to tube well irrigation. Northern Punjab saw the emergence of

Figure 4: Irrigated Area by Source of Water in Different Regions of Punjab



1997 was a benchmark year with agricultural electricity being made free.
Source: *Statistical Abstract of Punjab* (various issues).

tube well irrigation in the early 1980s, and free electricity gave a boost to its expansion. The tube well-irrigated area has more than doubled in the last 40 years.

Shifts in Cropping Pattern

There have been significant shifts in cropping patterns in the state (Table 2, p 65). It is worth noting that the area under wheat increased from 29.59% in 1966-67 to 49% in 2010-11. Similarly, the area under rice increased from 4.8% to 47.6% in the same period. Punjab was not a traditionally rice-growing state in the pre-green revolution period. With controlled irrigation and HYV seeds, the productivity of these two crops in Punjab ranks highest in the country. The major area under foodgrain is the tube well-irrigated central zone where rice and wheat account for more than 96% of the gross cropped area. Rice and wheat have replaced the area under coarse cereals, pulses, and oilseeds. The area under cotton has fluctuated in the last two decades because of the American bollworm, and farmers have shifted to rice to get a stable yield and an assured income (Rangi and Sidhu 2004). Cotton is grown only in the south and there too it faces major competition from rice.

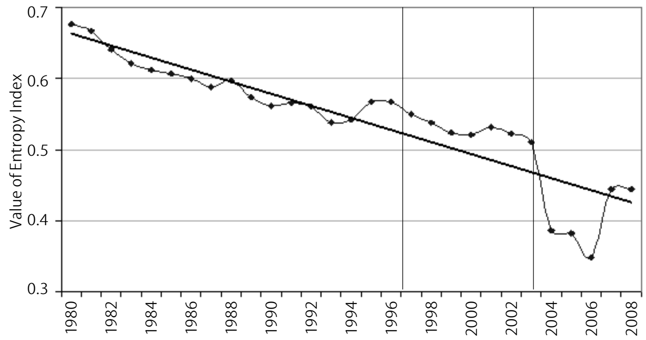
Crop specialisation is evident in all the districts of Punjab as the crop combination analysis shows (Table 3, p 66). Barring Hoshiarpur and Bhatinda, all the districts became wheat-rice crop regions by 2010.

Declining values of the entropy index indicate a trend towards crop specialisation in the state (Figure 5). It is interesting to note that the area under rice in the state determines its crop specialisation (Figures 6 and 7). Being the most economically remunerative crop (Kaur et al 2010) with an assured market price, farmers prefer to grow rice over other crops. Nevertheless, rice cultivation in semi-arid Punjab is wholly dependent on groundwater irrigation, making water availability the major determinant of rice cultivation. Since tube wells are run on power, electric or diesel, their prices determine rice acreage and crop specialisation. In 1994-95, there was a steep hike in the price of electricity (Singh and Singh 1998), which resulted in the area under rice cultivation declining, and an increase in crop diversification. After free agricultural electricity in 1997, groundwater could be used at zero marginal cost, and it gave a boost to rice cultivation, further strengthening crop specialisation.

4 Cropping Pattern, Groundwater Development, Energy and Support Price Nexus

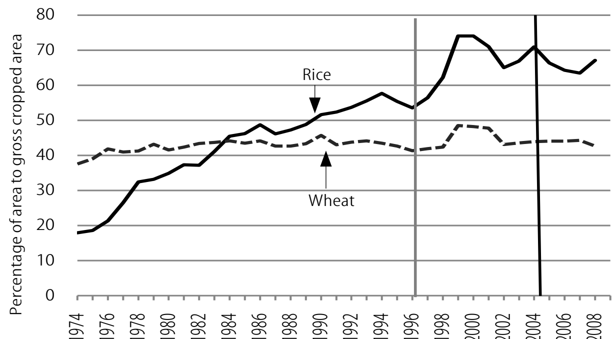
With the spread of tube well irrigation, most of the shallow wells dried up in the first phase of the green revolution. To maintain the volume of the water draft, centrifugal pumps were introduced. But these pumps were suitable for lifting water only up to a depth of 30 feet.[2] To extract water from deeper water tables, these pumps were replaced by submersible pumps. Shortage of power and frequent cuts in its supply brought in diesel-operated pump sets. Electric tube wells along with diesel pump sets provided more flexibility and reliability to the irrigation system in Punjab (Kaul et al 1991). However, the increasing price of diesel meant the cost of irrigation went up, lowering the profits from diesel-operated tube well irrigation. The rising price of diesel coupled with free agricultural electricity led to the fast energisation of tube well technology in Punjab (Figure 8, p 69).

Figure 5: Trends in Crop Specialisation in Punjab (1980-2008)



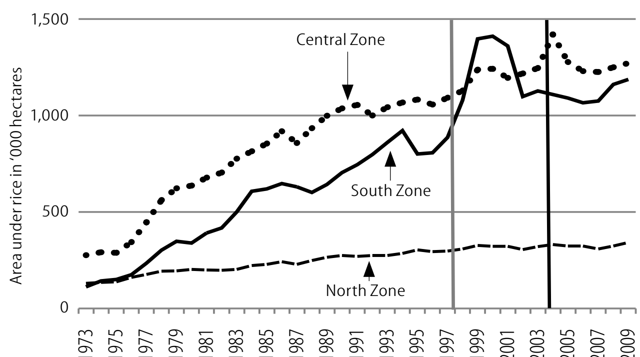
Source: Computed from *Statistical Abstract of Punjab* (various issues).

Figure 6: Area under Rice and Wheat in Punjab (1974-2008)



Source: Computed from *Statistical Abstract of Punjab* (various issues).

Figure 7: Area under Rice in Regions of Punjab (1973-2009)



Source: Computed from *Statistical Abstract of Punjab* (various issues).

Groundwater irrigation has been continuously on the rise in the last 40 years. A major turning point was the near simultaneous adoption of submersible pump sets after the mid-1990s and the government's decision to provide electricity free of tariff in 1997. Submersible pumps consume around three to four litres of diesel an hour, which works out to a running cost of approximately Rs 165 to Rs 220 an hour. With free electricity, the adoption of submersibles became comparatively more cost effective as farmers had to pay only a one-time cost of around Rs 1,80,000. So after the free electricity regime began, groundwater irrigation not only replaced surface water irrigation, but also brought more area under assured irrigation, all through the spread of tube well technology (Figure 11, p 69).

Figure 8: Trends in Diesel and Electric-operated Tube Wells in Punjab (1970-2009)

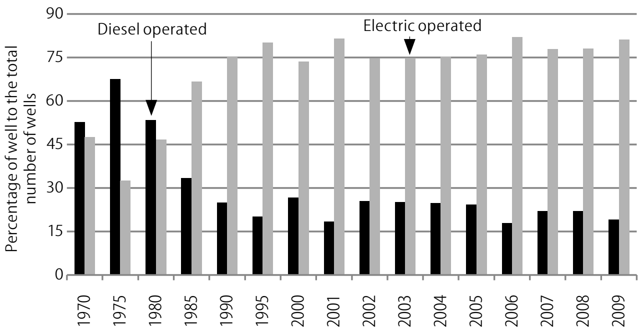
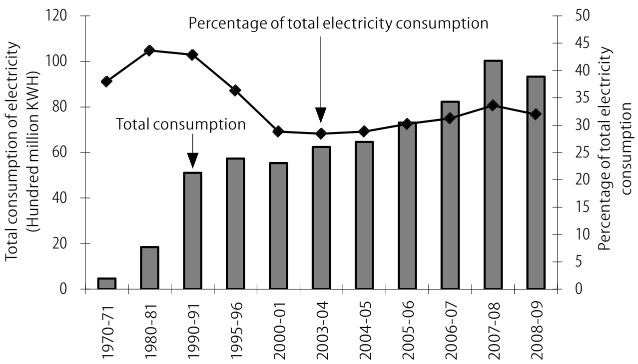
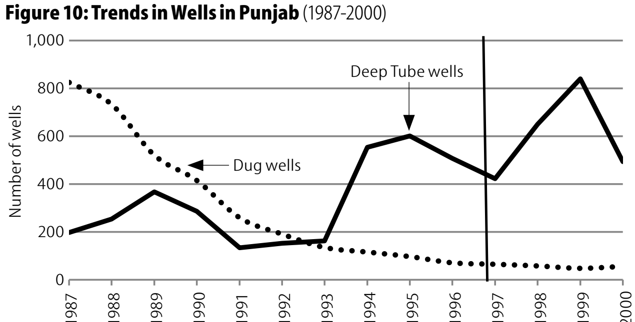


Figure 9: Consumption of Electricity in Agriculture in Punjab (1970-2008)



Source: www.indiastat.com

Figure 10: Trends in Wells in Punjab (1987-2000)



Source: Computed from *Statistical Abstract of Punjab* (various issues).

The analysis of groundwater development and agricultural growth in Punjab point to two things. One, the growth in irrigation extent and irrigation intensity was largely contributed to by the expansion of groundwater irrigation, which, in turn, increased cropping intensity in the state. Two, with groundwater development, the state moved to crop specialisation or a bi-crop rotation of rice-wheat, which further increased the demand of groundwater. Since the increase in groundwater irrigation was made possible with tube well energisation, Punjab's agriculture is highly dependent on the supply of electricity (Figure 9).

With expansion of rural electrification after the 1970s, the growth of electric pumps recorded a steep rise. Diesel-operated pumps have been gradually replaced by electric pumps (Figure 12, p 70) over the last 40 years. In 1994-95, there was a steep hike in the price of electricity, but electricity for agriculture was made free in 1997-98. With a decline in the water table, a number of dug wells dried up and the number of deep tube wells increased (Figure 10), especially after 1997. Most of these deep tube wells were fitted with submersible pumps, but with diesel prices rising, farmers preferred electricity over diesel. But by the first decade of this century, when electricity rationing became a norm, farmers began irrigating with diesel when the power supply was erratic during the peak rice-sowing seasons (Field visits 2013).

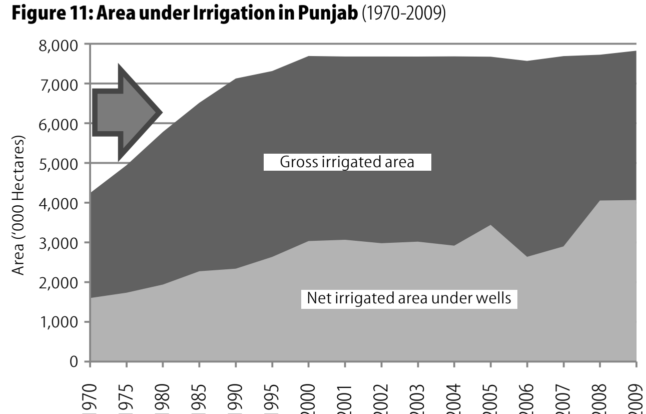
The increase in the number of deep tube wells and pump energisation were largely responsible for the increase in gross irrigated area in Punjab. Corresponding with the increase in electric-operated pumps, groundwater irrigation increased manifold, augmenting the gross irrigated area in equal proportion (Figure 11 and Figure 12, p 70).

Rice is always grown in irrigated conditions in Punjab. The correspondence of the extent under rice cultivation and the extent of groundwater irrigation with electricity consumption is an interesting point (Figures 13 and 14, p 70). The extent of tube well irrigation highly corresponds to the extent of area under rice and energy consumption. Rice cultivation has tremendous significance as far as electricity consumption in Punjab is concerned, especially in this era of electric submersible pumps.

One can argue that the electricity subsidy to farmers is a public policy choice that the government has made to increase agricultural growth and rural incomes. The biggest change that was brought about by this subsidy was the shift to paddy cultivation. Whether this is a positive change for agricultural development in the state is very debatable because though it has led to assured incomes, it has also led to groundwater depletion, income inequality, and unsustainable agriculture (Sarkar 2011, 2012).

Converting the metered tariff to a flat rate and then free has not had any desirable outcome on the efficiency of electricity consumption. Electricity consumption per hectare of agricultural land has increased over time whereas agricultural production per unit of electricity consumption has not increased with free power supply, rather it has been falling over time (Figure 16, p 71). This indicates serious inefficiency in the consumption of electricity in Punjab's agriculture sector, and steps need to be taken to curtail this. Further, since electricity is not metered, transmission and distribution losses and other unaccounted electricity consumption is officially shown as electricity consumed by the agriculture sector. From field

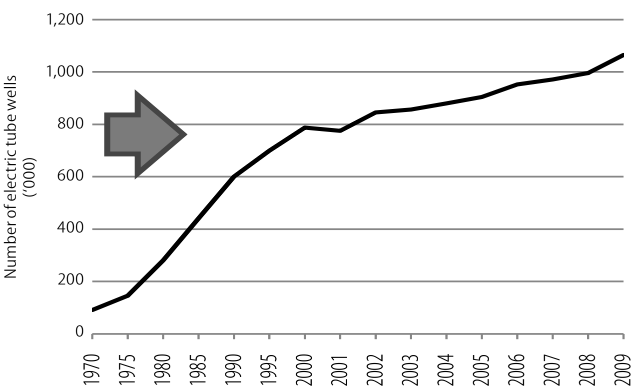
Figure 11: Area under Irrigation in Punjab (1970-2009)



Source: Computed from *Statistical Abstract of Punjab* (various issues).

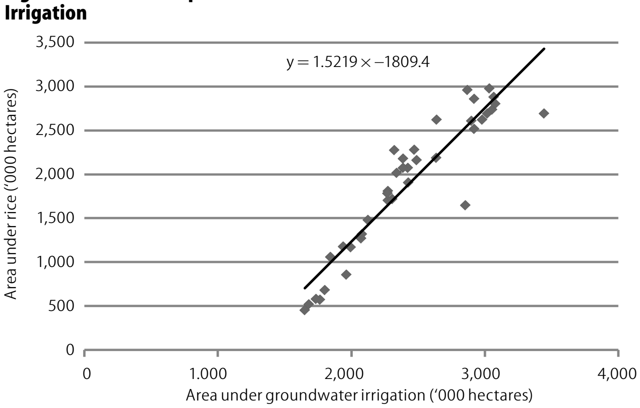
observations, it was clear that though electricity is free, villages are given power between eight and four hours during the peak irrigation period. For better management of the agriculture-energy nexus, alternative policies are needed for desirable outcomes in agricultural development in the state (Kaur and Sharma 2012).

Figure 12: Number of Electric Tube Wells in Punjab (1970-2009)



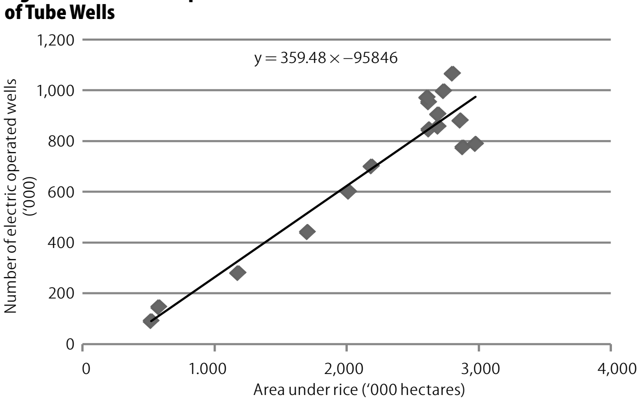
Source: Computed from *Statistical Abstract of Punjab* (various issues).

Figure 13: Relationship between Rice Cultivation and Groundwater Irrigation



Source: Computed from *Statistical Abstract of Punjab* (various issues).

Figure 14: Relationship between Area under Rice Cultivation and Number of Tube Wells



Source: Computed from *Statistical Abstract of Punjab* (various issues).

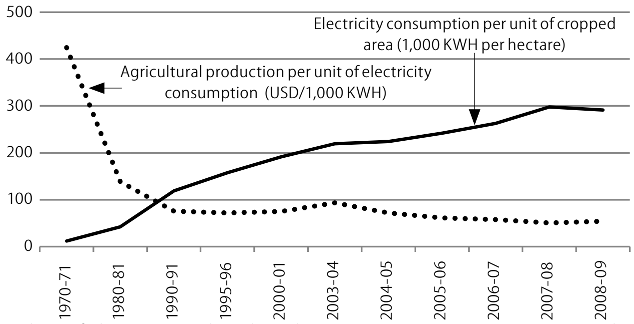
Another aspect of free electricity consumption and declining agricultural production per unit of cropped area is the rationing of electricity, which became common after 2000. From eight to 10 hours of supply a day during the peak rice cultivation season, it came down to six to eight hours. This point is reiterated in Figure 16, which shows the relationship between the number of wells and the net irrigated area under tube wells. It depicts that tube well productivity declines over time and an increase in the number of tube wells does not simultaneously increase the net irrigated area. The explanation for this trend may be, one, an increase in groundwater depletion and falling water tables, along with rising instances of tube well interference.[3] Two, it strongly indicates that the productivity of tube wells has declined over the years with rationing of electricity. With submersible pumps where electricity is the only energy source, less supply eventually leads to less pumping of groundwater. This is also supported by the fact that farmers have begun using laser levellers to level their fields so that water can be evenly spread out across them (Humphreys et al 2010).

Thus even with free electricity, farmers were not able to run their pumps to full capacity. So in peak seasons many farmers were compelled to use diesel to pump water in times of acute shortage leading to an increase in the cost of cultivation and decreasing the profitability of rice. It is pertinent to understand the importance of the MSP given to the farmers as more than 80% of the rice produced in Punjab is procured by the government for the public distribution system (PDS). Figure 17 shows that after mid-2005, there was a very steep hike in the MSP of both rice and wheat. The cropping decisions of a majority of farmers in Punjab are based on the declared MSP (Sarkar 2010). So taking into consideration the rise in the assured market price, even with low-quality electricity supply, farmers invested in diesel to grow rice as its selling price (MSP) did not give them any market signal of the depleted resource. It can also be argued that if an electricity subsidy is given directly to farmers, it is doubtful whether they will go in for less irrigation by growing water-saving crops and shift from rice as the returns from rice and wheat are determined by MSP and not by electricity pricing. In that situation, the money given to farmers as direct subsidy for electricity saving should be more than the profit from rice cultivation. In other words, only if farmers get a higher incentive value for saving electricity (and hence groundwater) than the profit they get from growing rice will they pump less water and shift to a less water-intensive crop. On the other hand, if the MSP is set high, farmers will not only use up the electricity subsidy given to them, but also irrigate through diesel pumps. So it is uncertain if farmers who are already using all the electricity they get and diesel in times of power cuts will go for electricity saving if the present cropping pattern is supported by a high MSP.

5 Feasibility of an Alternative Cropping Pattern of Wheat and Maize

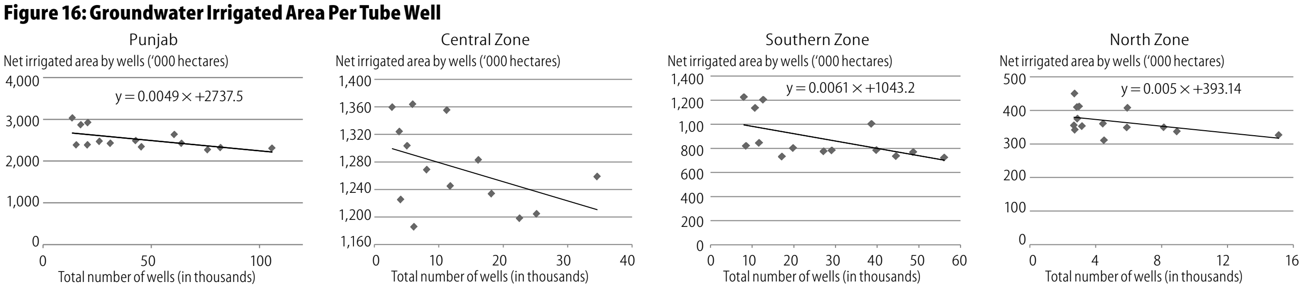
To empirically examine this phenomenon, we assume that the cashback for energy savings should be such that it should make other crops preferable over rice. Water requirements of various crops are different. Since no volumetric pricing of water exists, farmers do not choose crops on the basis of water requirements, rather they choose crops based on water availability and estimated net returns. If there is direct delivery of a subsidy to farmers, they would shift the crop if the value of money they get from saving electricity compensates for the

Figure 15: Energy Efficiency and Agricultural Growth (1970-2009)

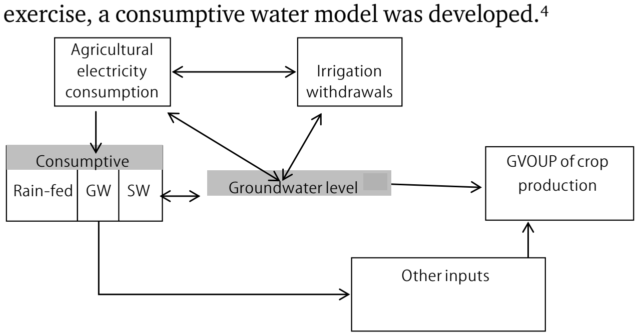


value of the return they lose by not growing rice. For example, if a farmer shifts from paddy to arhar in the kharif season, he loses a return of Rs 16,088 per hectare but at the same time saves 8,911 m^3 of water per hectare. Considering that 78% of the irrigation is from tube wells, a farmer can save 6,950.58 m^3

Figure 16: Groundwater Irrigated Area Per Tube Well



of groundwater and an equivalent of electric energy if he uses only electricity to pump water. If farmers are given a greater incentive to save electricity, the rational ones among them would choose the optimum combination of crops that brings maximum returns (Figure 15). As a result, with less amount of water being withdrawn, electricity will be saved and groundwater draft can be minimised. To carry out this hypothetical exercise, a consumptive water model was developed.[4]



$$\ln Y_1 = \alpha_1 + \alpha_2 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \text{NSA} + u_i \quad ...(1)$$
$$\ln X_1 = \alpha_1 + \alpha_2 \ln X_4 + \alpha_2 \ln X_5 + \alpha_3 X_7 + u_i \quad ...(2)$$
$$\ln X_4 = b_1 + b_2 \ln X_5 + b_3 \ln X_6 + u_i \quad ...(3)$$

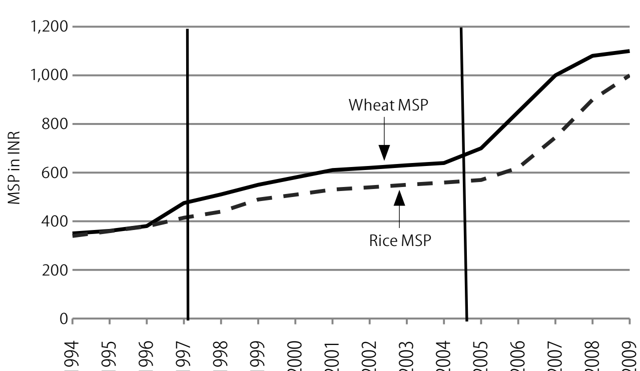
Where,

Y_1 = Gross Value of Output (GVOUP) (thousand rupees)
X_1 = Consumptive Water Use (MCM)
X_2 = Area under surface water irrigation (hectares)
X_3 = Fertiliser use (thousand tonnes)
X_4 = Electricity consumption in agriculture (million KWH)
X_5 = Percentage of rice crop area in total cropping area (%)
X_6 = Depth of water table (metres)
X_7 = Rainfall (mm)

If Punjab shifts 25% of the area under paddy cultivation to maize cultivation, the immediate loss in gross value of output (GVOUP) will be Rs 5,287.02 crore, which will directly affect farmers' annual income (Table 4, p 72). Of this, some is recovered from the cultivation of maize, and from the subsidy for saving electricity used for irrigation, which would amount to Rs 2,114.81 crore. Given this calculation, the crop shift is worth Rs 2,668.85 crore, which is almost half the revenue loss. To expect any market mechanism to work, an additional Rs 2,500 crore is required (even we assume no transaction cost and leakage). The Punjab government has to arrange this for farmers willing to shift from paddy to maize. Or else, these farmers will shift back to paddy after experiencing a monetary loss with maize. In other words, saving electricity through changing the cropping pattern is not economically feasible in Punjab, given the existing yield and pricing mechanism.

To make our claim more robust, we can investigate if such a cropping pattern change (Table 5, p 72) can be self-sustainable after 10 years assuming a business as usual (BAU) situation. If we consider a BAU situation that considers an extreme case of degradation there will be a 5-metre decline (Krishan Gopal et al 2014) in the groundwater level in the next 10 years (at the current rate of depletion).[5] By assuming the pricing situation to be constant, we can make this analysis dynamic over time by varying the water level. In such a case, the current electricity supply would lead to significant decline in the availability

Figure 17: Trends in Minimum Support Prices for Rice and Wheat in Punjab (1994-2009)



of consumptive water (approximately 8,741.0 MCM), which will lead to a fall of the gross value of agricultural output. To maintain a similar level of crop moisture availability, an additional 3,022.06 million Kw of electricity will be required, which will require an additional power subsidy of Rs 1,511.03 crore. This will take the total direct economic benefit of cropping pattern

Table 4: Situation Where 25% of Paddy Cultivation Is Replaced by Maize Cultivation

	Rice GVOUP (Rs Crore)	Loss in Rice GVOUP (Rs Crore)	Rice CWU (MCM)	MCW saved if Converted to Maize (MCM)	Saving in Electricity (Million Kwh)	Saving in Subsidy @ 5 (Rs crore)	Revenue through Maize (Rs crore)
Amritsar	1,939.83	484.96	1,548.45	193.56	196.40	98.20	193.98
Bhatinda	895.59	223.90	567.54	70.94	18.84	9.42	89.56
Faridkot	778.94	194.74	551.24	68.91	26.36	13.18	77.89
Fatehgarh	735.67	183.92	347.81	43.48	23.92	11.96	73.57
Ferozpur	1,813.77	453.44	1536.88	192.11	21.78	10.89	181.38
Gurdaspur	1,204.16	301.04	582.61	72.83	61.53	30.76	120.42
Hoshiarpur	466.61	116.65	170.64	21.33	20.82	10.41	46.66
Jalandhar	1,196.63	299.16	611.26	76.41	79.17	39.59	119.66
Kapurthala	850.44	212.61	480.36	60.04	45.96	22.98	85.04
Ludhiana	2,257.80	564.45	1,051.67	131.46	100.22	50.11	225.78
Mansha	609.61	152.40	415.03	51.88	11.67	5.84	60.96
Moga	1,527.78	381.94	1,003.06	125.38	95.95	47.97	152.78
Muktsar	728.14	182.04	552.43	69.05	11.81	5.91	72.81
Nawan Shehar	436.51	109.13	203.37	25.42	23.23	11.62	43.65
Patiala	1,881.50	470.38	955.88	119.49	124.07	62.04	188.15
Rupnagar	438.39	109.60	255.44	31.93	30.85	15.42	43.84
Sangrur	3,386.70	846.68	1,895.68	236.96	215.50	107.75	338.67
Total	21,148.06	5,287.02	12,729.34	1,591.17	1,108.09	554.04	2,114.81

Source: Author's own calculation.

Table 5: Situation If There Is a 5-Metre Decline in Water Table

District	Ground Water Depth (m)	Loss in CWU If Same Electricity Is Supplied	Increased Electricity Demand	Increased Subsidy Burden	Increased Power Subsidy Burden	Saving of Consumptive Water Due to cropping Pattern Change
Amritsar	14.83	483.04	386.85	123.79	193.425	193.56
Bhatinda	12.06	601.27	126.01	40.32	63.005	70.94
Faridkot	7.53	404.73	122.22	39.11	61.11	68.91
Fatehgarh	16.9	103.63	45	14.4	22.5	43.48
Ferozpur	5.33	1,953.92	174.83	55.95	87.415	192.11
Gurdaspur	7.48	439.73	293.23	93.83	146.615	72.83
Hoshiarpur	11.29	164.16	126.45	40.47	63.225	21.33
Jalandhar	18.88	172.54	141.11	45.16	70.555	76.41
Kapurthala	12.62	179.3	108.31	34.66	54.155	60.04
Ludhiana	18.09	281.36	169.3	54.17	84.65	131.46
Mansha	10.01	472.34	83.87	26.84	41.935	51.88
Moga	17.34	262.81	158.73	50.79	79.365	125.38
Muktsar	2.58	2,182.86	294.77	94.33	147.385	69.05
Nawan Shehar	22.52	57.37	41.38	13.24	20.69	25.42
Patiala	14.15	341.64	280	89.6	140	119.49
Rupnagar	6.95	232.62	177.36	56.75	88.68	31.93
Sangrur	23.37	407.7	292.64	93.65	146.32	236.96
Total		8,741.01	3,022.06	967.06	1,511.03	1,591.17

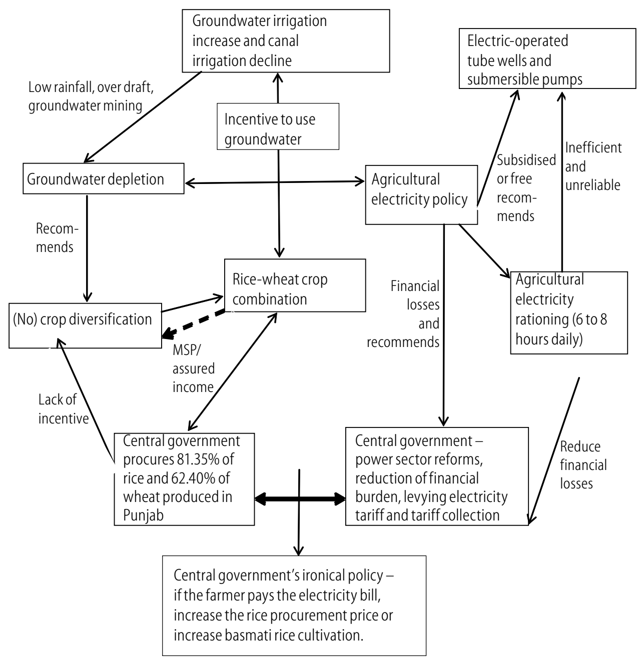
This could well happen in 10 years.
Source: Authors' calculation.

to Rs 3,625.84 crore, which is still much less than the revenue earned by paddy if the current MSP policy continues. Thus the amount of subsidy required to support this crop diversification will be much higher than the electricity subsidy saved even in the next 10 years, alongside a continuous depletion of groundwater. In other words, the model indicates that in the current pricing situation, shifting from paddy to maize cultivation is impossible without proper incentives from the state.

6 Conclusion and Policy Implication

Punjab's groundwater-energy nexus is unique as there is a third component to it – the procurement policy (Figure 17, p 71). Even with a policy of free power and an assured income through the MSP, Punjab sees crop diversification as a solution to the groundwater-energy problem. Though the state consecutively failed to implement diversification as recommended by Johl in his reports in 1986 and in 2002-07, again in March 2013, the Committee for Formulation of Agriculture Policy for Punjab submitted a draft report seeking crop diversification as a solution. The central government stepped in with additional funds of Rs 224.5 crore as part of its Rs 500 crore crop diversification plan in the original green revolution states (Punjab, Haryana and west Uttar Pradesh) under the Rashtriya Krishi Vikas Yojana (RKVY) during 2013-14. Interestingly, the report

Figure 18: Groundwater Irrigation-Electricity-Procurement Policy Nexus in Punjab



talks of the need and plan for diversification but does not explain how it will be implemented. The last attempt at diversification during 2002-07 could not go beyond 0.25 million hectares under paddy against a target of one million hectares despite all kinds of incentives and schemes. It proposed that maize be increased four times without any assessment of the demand for it and procurement mechanisms (Singh 2013). Encouraging farmers to take up crop diversification to progressively wean areas away from paddy and wheat is a key water management strategy. It looks like an easy solution to a very complex problem. But our study clearly shows that under the prevailing conditions of electricity pricing and MSP, rice will remain the most remunerative crop and farmers will not move towards maize cultivation.

Although the literature on the water and energy nexus in Punjab highlights concerns over the sustainability of the state electricity board and the agricultural base in the state, there is no denying that groundwater irrigation contributes towards the higher yield of HYV of rice and wheat in the state (Figure 18). On the groundwater front, Punjab introduced a law banning paddy transplantation before 14 June and this has reportedly had the effect of reducing groundwater withdrawals by up to 9% (Singh 2011). On the agricultural front, initiatives including attempts to lure farmers away from water-intensive paddy through efforts aimed at diversification, better on-farm water management practices, such as mulching and laser levelling, are being tried (Humphreys et al 2010). However, our contention is that Punjab is a unique state where farmers mine groundwater to grow rice, an agro-ecologically misfit crop, to contribute to the central pool. In other words, while not compromising on the assured incomes of farmers, the centre procures groundwater from the state with a double subsidy for procurement and electricity. In the absence of a linkage between the procurement policy and the energy policy that will incentivise farmers to use groundwater efficiently, none of the measures to achieve crop diversification are likely to be successful.

NOTES

1 In an interview to *Hindustan Times*, Johl said, "As the government is giving free power to farmers, the Commission for Agriculture Cost and Prices, while calculating the MSP on foodgrains, does not take the expenditure on running agriculture tube wells into consideration. This benefit is passed on to the consumers of 20 million tonnes of foodgrains produced, who live outside Punjab. I am not against subsidy to the farm sector, but it should be passed on in cash. I have tried to make the Punjab government understand, but they continue with this political stunt (January 2014).

2 The efficiency of centrifugal pumps starts declining with an increase in the depth of the water table after 25 feet or so.

3 With rising density of tube wells, the area of interference of one well overlaps with others, decreasing the water yield from them.

4 The major assumptions of the model framework are:

• The cropping and land use pattern are the major drivers of water demand, CWU.

• In Punjab, 98% of the land is under irrigation.

• Irrigation from groundwater is the major source of irrigation and in areas under surface water irrigation, ground water irrigation is also used to supplement surface water irrigation.

• It is assumed in the model that all irrigated land is irrigated under groundwater irrigation.

• Groundwater irrigation is done through energised pump sets.

• Electricity consumption is dependent on groundwater depth.

The calculation of revenue and expenditure is based on current pricing conditions.

5 The groundwater level analysis in the current pattern of irrigation structure and irrigation draft for the present cropping pattern is taken to estimate water draft. Considering the balance in the groundwater recharge and draft, Krishan Gopal et al (2014) estimates a groundwater depletion of five metres in the next 10 years. Their estimation of groundwater depletion is used in our study to understand the feasibility of shifting the cropping pattern to maize, considering the existing electricity pricing and MSP policies in the state.

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