ECONOMIC VALUE OF WATER IN AGRICULTURE: COMPARATIVE ANALYSIS OF A WATER-SCARCE AND A WATER-RICH REGION IN INDIA

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Abstract

If the balance between availability and requirement drives the value, then the economic value of water in agriculture should be remarkably higher in water-scarce regions when compared to water-rich regions. Similarly, in water-abundant regions, if the land is scarce, then the incremental return per unit of land should be higher than that in land-rich region that are water-scarce. These hypotheses are tested by comparing the situation in western Punjab, which is land-rich and naturally water scarce and eastern Uttar Pradesh which is land-scarce and water-rich. The methodology used for assessing the economic value of water considered estimating the incremental value of output for a composite farming system from a unit of irrigation water used. The incremental value of farm output was estimated on the basis of the volume-based weighted average of the water productivity values (Rs./m^3) in various agricultural crops and milk production. The total effective volume of water used for various crops and milk production were estimated using physical productivity of water in various crops and milk production (kg/m^3), and the weight of outputs in the respective crops and milk.

The regression analysis shows that every extra unit of water diverted for agriculture generates more economic surplus in western Punjab. Regression of land against economic surplus shows that every extra unit of land put under cultivation generates more economic surplus in eastern Uttar Pradesh when compared to western Punjab. The total economic value of agricultural output generated from a unit of water in western Punjab (Rs.14.85/m^3) is higher than that of eastern Uttar Pradesh (Rs.11/m^3). The farmers in western Punjab allocate a larger share of their water for growing crops and dairying activities that have high water-productivity thereby maximizing the return per unit of water, whereas in eastern Uttar Pradesh, land productivity is an important consideration in deciding the cropping patterns. The livelihood impact of irrigated agriculture in western Punjab, with a livelihood index of 0.928 is higher than that of eastern Uttar Pradesh with a livelihood index of 0.87, meaning greater dependence of Punjab farmers on agriculture for livelihoods. Hence, transfer of water from a water-rich, land scarce region to a water-scarce, land rich region for agriculture might result in realization of higher economic value.

1. INTRODUCTION

In recent years, global discussions on water scarcity have been dominated by considerable amount of debate on the true value of water (Turner et al., 2004). The price that users are willing to pay for use of the resource reflects its marginal value (Young, 1996). Since markets often do not exist for many uses of water and even when exist are often imperfect, estimating the total as well as marginal value of water is difficult. This problem in valuation is true for India also. In India, groundwater lies in the open access regime with the absence of well-defined property rights (Singh, 1995). Though it is traded extensively for agricultural purpose, no tax is to be paid by users for groundwater. More over, agricultural users are not confronted with full marginal cost of abstraction due to heavily subsidized electricity in the farm sector (Kumar et al., 2005a). In the case of public canals for irrigation, there are no entitlements for the water supplied. Irrigation charges are highly-subsidized, and are not based on volumetric allocation (Brewer et al., 1999). In such situations, the incremental economic output that could be realized from its use per unit volume can be treated as its total economic value (Young, 1996).

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Agriculture is the principal 'user' of raw water globally accounting for nearly 70% of the water withdrawn and 93% of water consumed annually (FAO, 2004). In developing countries that are facing water scarcity, as water demand for urban domestic and industrial uses is likely to double from 1995 to 2025 (Rosegrant et al., 2002), irrigation water supplies are likely to be threatened, given the fact that it is the most inefficient and largest user of supplied water in economic terms (Turner et al., 2004). Agriculture accounts for a major share of the total consumptive use of the diverted water in India (GoI, 1999). But, with many regions in the country running short of water and with increasing competition from other high priority sectors, there is a need to raise the incremental value product or the economic surplus of water in agriculture. Enhancing productivity of water is the key to raising the economic surplus from its use in agriculture, thereby it value.

Both the marginal and the total value of irrigation water is determined by the water deficit experienced by the crops at any point of time, which is a function of the agro climate, and the type of crop grown. Hence, the total and marginal value of water in irrigation can be enhanced through efficient use of water and other inputs, or through adoption of more water-efficient crops with intensive cropping. Therefore, when demand for irrigation water exceeds its supplies, farmers should divert it for high valued uses, or use it more efficiently in the field through on-farm water management, farm management and better crop technologies.

But, in India, due to the inefficient pricing of canal water and electricity, the influence of market forces in ensuring transfer of water to high valued uses is almost absent. These low water charges can have adverse impact on the effectiveness of irrigation systems, and efficiency of water use at the farm level (De Moor and Calamai, 1997). Much socio-economic improvement through water use can also be secured through water transfer from surplus to deficit regions (Molden et al., 2001) and using water in regions where its economic value is high. But, water being a "bulky" resource, its economic value (total) tends to be relatively low. Therefore its conveyance over long distances will be economically viable, only if high incremental value is realized by water transfers (Young, 1996).

Going by Malin Falkenmark's physical water scarcity indicator, which is based on per capita total renewable water resources of a region, western Punjab is "water scare". Though the region's ecology is fragile and not favourable for irrigated agriculture, it practices intensive farming with green revolution technologies, with the limited supplies of canal water. Nevertheless, the farmers here are increasingly allocating the water for more economically efficient crops, thereby raising the total value of water.

On the other hand, eastern Uttar Pradesh is relatively water-abundant with rich alluvial aquifers and abundant rainfall in the plains of alluvial Gangetic belt (Shah, 2001). The access to arable land is limited. The farmers of the region, by and large, enjoy sufficient access to water for irrigation in both physical and economic terms due to free boring schemes, subsidized pump sets and groundwater markets (Pant, 2004). The region grows low risk crops such as paddy, wheat and maize, and some high valued vegetables. The cost per unit volume of canal water is low for highly water-intensive crops such as paddy. Water from public tube wells is also highly subsidized. The farmers take three crops, thereby raising the value of land (Pant, 2004).

Punjab's agricultural sector has been under attack for the intensive external-input based rice-wheat farming system costing heavily to its resource and economy in the form of groundwater depletion, and free electricity for farm sector (Singh and Kalra, 2002). But, what is less appreciated is the high productivity potential of irrigation water in this arid region and the value realized from use of imported water. Also, its unique positioning in terms of access to large arable land and arid to semi-arid climate increases the marginal as well as total value of water. India as a whole is characterized by significant mismatch between distribution of water resources and the requirement for water, major share of which comes from agriculture (Kumar et al., 2006). The intensity of use of water for agriculture is high in semi-arid and arid regions, which have poor water endowments. They produce surplus food for water-rich regions that face food deficits (Amarasinghe et al., 2005).

2. RESEARCH OBJECTIVES, HYPOTHESIS

2.1 The Objectives

Though water management involves many trade offs, much socio-economic improvement can be secured without the imposition of excessive costs or loss of environment integrity, through transfer of water to alternative crops and uses; water transfer from surplus to water-deficit regions; and use of water in regions where its economic value is high. The ultimate objective of this paper is to examine whether it makes economic sense to transfer water from water-rich region to water-scarce region, as a strategy to manage growing water demands. It is realized through a comparative analysis of the total use value of irrigation water in agriculture in regions with differential water endowments. While doing that, it does not try to address the complex political and hydrological issues inherent in water transfer project.

The specific objectives of the study are: to carry out a comparative analysis of economic value of water in agriculture in water-scarce western Punjab and water-rich eastern Uttar Pradesh (U.P.); to analyze the response of economic surplus generated from water use in agriculture to change in irrigation water use in the two regions; to analyze the response of economic surplus generated from water use in agriculture to change in land use in these regions; and to examine how livelihood impact of irrigated agriculture in an average farm household differs between the two regions?

2.2 Hypotheses and Assumptions

In line with the main objective, the main hypothesis postulated in this paper is that in water scarce regions, higher economic value is realized from use of water in agriculture as compared to water rich regions. The economic value of water is assessed in terms of surplus value product from a unit volume of water used in irrigation. The hypothesis is further divided into the following three sub-hypotheses. 1. The economic surplus generated from marginal increase in the use of water in agriculture is higher in water scarce regions as compared to water rich regions as farmers in these regions put water to comparatively more productive uses. 2. The economic surplus from marginal increase in land use in agriculture is higher in water-rich regions as compared to water scarce regions as farmers in these regions use their scarce land resources more intensively. They also use it more productively, selecting crops that give high returns, without much consideration to water needs. 3. The livelihood impact of irrigated agriculture in an average farm household is higher in water scarce region as compared to water rich region.

But these hypotheses are based on some assumptions. First, the "user cost" of water is higher in water scarce region as compared to a water-rich region because of higher direct cost of water abstraction or higher "opportunity costs". Such high direct cost can be due to higher cost of pumping groundwater, owing to higher depth to water table. High opportunity cost can come from either increased irrigation water requirement per unit of land owing to low precipitation and high evapo-transpiration, or poor availability of good quality groundwater for irrigation, or relatively restricted allocation of canal water for irrigation when compared to the amount of land available for cultivation, or a combination of all or some of them. Hence, farmers would allocate water to crops and farming systems that give higher income return per cubic metre of water and that are low water intensive, but involve high risks.

Second, the water-rich regions generally have limited arable land. This is applicable to regions such as eastern Uttar Pradesh, most parts of Bihar and most parts of Kerala. This makes water a "surplus commodity" with negligible user cost. This means, they would have the comparative advantage of selecting crops that are highly water intensive, but give potentially high income per unit of land cultivated. Third, at the regional level, dairy farmers have to depend heavily on endogenous resources to be used as inputs such as fodder, though at the micro level some might be able to depend on markets to access dry and green fodder. This is because, if every farmer starts depending on imported fodder, then the price of fodder itself can shoot up in the market, thereby reducing the net return from dairy farming.

3. METHODOLOGY

3.1 Study Areas, Types and Sources of Data

Two regions viz., Bathinda district of South-Western Punjab and Varanasi district of Eastern Uttar Pradesh were selected for the study. The first is water-scarce and the other is water rich. Two villages from each region were selected for primary data collection. Data pertaining to a normal agricultural year (2003-04) were collected for the two selected regions with the help of a structured questionnaire, using a recall survey. A well structured and a pre-tested questionnaire was used for the interviews. The types of primary data included crop inputs and outputs viz., cropped area, irrigated area, crop-wise labour inputs, irrigation, fertilizer and pesticide use, yield of main crop and byproducts; dairy inputs such as feed and fodder, drinking water, average daily milk production in different seasons, market value of crop produce and milk, and household income from sources other than cropping and dairying. A sample of 160 farmers (40 from each village) belonging to different holding sizes was covered and it included well owners, water buyers and water sellers.

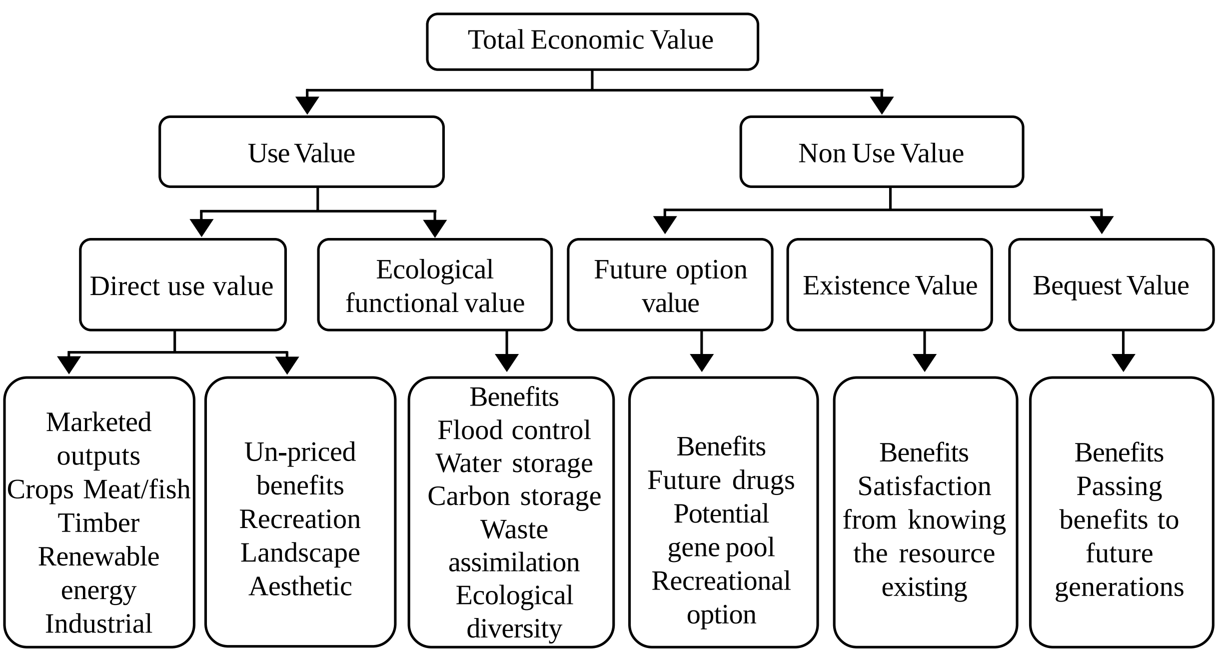
3.2 Estimation Procedure

The methodology used for assessing the value of water involved estimation of the incremental value of output for a composite farming system for a unit volume of water. The incremental value of farm output was estimated on the basis of the volume-based weighted average of the water productivity (Rupees per cubic metre of water) of applied water in various crops and milk production. The economic surplus from irrigated agriculture was estimated for individual farmers by taking into account the net income from crops and dairying. The livelihood impact of irrigation was estimated for individual farmers as the ratio of net annual income from crops and dairying and sale of irrigation water and the total income of the farmers' family from all sources including petty trade and employment.

3.2.1 Economic Value of Water in Agriculture

From an economist's point of view there are two important scientific approaches in valuing all natural resources including water. The first asks individuals, what they would be willing to pay for a given amount of

Figure 1: Total Economic Value



Source: Hodge and Dunn (1992)

resource. The second approach, estimates value by identifying the amount an individual is willing to pay for goods and services that use that resource. The marginal value refers to the price of the resource or good generated from the resource use for meeting a certain level of demand, where as the total value refers to the total price against the total use. Determining the value of water using the second approach is extremely difficult unless we understand the different values individuals attach to water. The classification of different values begins with the concept of Total Economic Value (TEV) of water (see Figure 1 based from Hodge and Dunn, 1992).

Identifying different uses of water is necessary to assess its value. Out of the many values of water, the present study considers the direct use value, i.e., the value of the marketed output (goods) produced with irrigation water, after deducting the production costs. This is same as the incremental value of the outputs generated from its use, which according to Young (1996) can be treated as the value of the resource, provided the market price of the produce reflects its true value that also takes into account the cost of production. Also, estimating the value of water realistically through such methods in non-market situation demands that the actual contribution of irrigation water supplies to generating farm surplus is segregated. Here, the total volume of water used by a farmer for producing all farm outputs and the net value of the product were estimated, and therefore, the value of water, being referred to, is the total value of water

$$\text{Economic value of water in agriculture} = \left[\sum (IWP_i * V_i) + \sum (IWP_j * V_j) \right] / \left[\sum V_i + \sum V_j \right]$$

Here, IWP_i is the net value product per unit of irrigation water used in crops “i” or the combined physical and economic productivity of irrigation water in crop production. IWP_j is the irrigation water productivity of milk production from cattle “j”. V_i is the volume of water used to produce main product of crop “i” and V_j is the volume of water used for producing milk from cattle type “j” in the study location.

3.2.2 Physical Productivity of Water in Crop and Milk Production

The physical productivity (Kg/m^3) of the main product of crop “i” was estimated by taking the ratio of the yield (Kg/ha) of the crop grain (main product) of crop “i” and the volume of water allocated (m^3/ha) to the crop grain (vi), and that of the crop by-product (Kg/m^3) was estimated by taking the ratio of the yield (Kg/ha) of the byproduct of crop ‘i’ and the volume of water (m^3/ha.) allocated to the byproduct. The physical productivity of water in milk production (l/m^3) was estimated as the ratio of the daily average of the quantity of milk produced (litres) by a cow or buffalo in its entire life cycle (Pd) and the daily average of the volume of water (m^3) used by a cow or buffalo over its entire life cycle, both as direct consumption (drinking water) as well as embedded water in all cattle inputs produced using the region’s local water resources. The volume of water embedded in cattle input (V_d) was estimated using the formula

$$V_d = \{(W_{df} / AE_{df}) + (W_{gf} / AE_{gf}) + (W_{cf} / AE_{cf}) + V_{dw}\}$$

W_{df}, W_{gf}, W_{cf} *and* V_{dw} are the daily average weight of the cattle inputs such as dry fodder, green fodder, cattle feed and drinking water, respectively. AE is the physical productivity of water and the subscripts df, gf and cf stand for dry fodder, green fodder and cattle feed.

3.2.3 Combined Physical and Economic Productivity of Water in Crop and Milk Production

The combined physical and economic productivity of water in crop and milk production were estimated using the same procedure as that employed for estimating physical productivity of water, but instead of the yield figures, the figures of net returns are used.

4. RESULTS AND DISCUSSIONS

4.1 Characteristic Features of the Study Areas

Various agro-ecological parameters of the study areas are presented in the Table 1. The major determining factors of agriculture like soil, temperature, rainfall, and relative humidity and irrigation facilities show a great deal of variation. In western Punjab the soil is saline with higher daily average temperature as comparison to eastern U.P. Again, the region has lower rainfall and relative humidity as compared to eastern U.P.

Western Punjab faces problems of inferior quality groundwater as compared to eastern U.P. But in eastern U.P., farmers are having more assured irrigation facility. These factors, in turn, influence the cropping pattern and the cropping intensity of the areas. Comparison of some of the socio-economic parameters of the study area clearly shows that the population pressure on land is higher in eastern U.P. (614 person/ sq. Km) as compared to western Punjab (350 persons/sq. Km).

The per capita holding size is lower in eastern U.P. (0.45 ha against 1.70 ha in western Punjab), meaning low investment capacity. The credit deposit ratio and the number of commercial banks per one lac population are higher in western Punjab (55) than that in eastern U.P. (22). Western Punjab faces labour shortage along with higher incidence of in-migration. Higher number of marketing co-operative societies in case of western Punjab (0.54 against 0.11 for lac population) facilitates better marketing of the produce and provides remunerative price to the farmers as compared to eastern U.P. Besides the above factors, the land consolidation and tractorisation helped in modernization and commercialization of agriculture in western Punjab (source: statistical abstract of Punjab and U.P.; Hira and Khera, 2000).

4.2 Cropping Pattern

In western Punjab, the cropping pattern is mainly determined by access to well water, as there are no major reliable sources of surface irrigation. Eastern U.P. experiences a warm and moist climate with adequate amount of water round the year, and has a good network of canals supported by various ground water-based lift irrigation schemes.

In western Punjab farmers mostly grow Kharif and Rabi crops. In water-rich eastern U.P., farmers take three crops in a year namely Kharif, Rabi and Zaid (summer). The major Kharif crops of western Punjab are cotton (54%), paddy (43%) and bajra, where as in U.P. the major Kharif crops are paddy (87%), brinjal (10%) and bajra (3%). In Rabi wheat accounts for 77.6%; grams 15.4% and jowar 3.7% of the cropped area in western Punjab, whereas in eastern U.P., wheat occupies 87%; cauliflower occupies 7.8% and potato occupies 5% of the area. During Zaid most the land in western Punjab remains fallow due to non-availability of water, where as in eastern U.P. farmers grow maize (33.6%); bitter gourd (17.4%) and okra-a vegetable crop (15.3%). There are major differences in crop yield as well owing to agro ecological factors and socioeconomic conditions such as availability of water and crop technologies and inputs. Paddy yields are far higher in western Punjab villages (18.6 quintal/acre) against eastern U.P. villages (13.18 quintal/acre). Most of the farmers in western Punjab keep some part of their land for producing fodder. In U.P., it was found that crops such as bajra and jowar are grown for dual purposes of fodder and grain production.

4.3 Irrigation Scenario

The percentage of irrigated land in the villages surveyed in western Punjab and eastern U.P. are 95% and 83% respectively. Farmers depend on both tube wells and canals for irrigation in both the areas. The share of other sources of irrigation like tank is very negligible.

In Bathinda district of western Punjab, the ground water and soils are alkaline in nature. But the depth to water table is only 45-50 ft. In the study villages, farmers use ground water and canal water in conjunction for applying to crops. Sometimes, they are blended before applying to the crops. Around 28% of the sample farmers solely depended on tube well for irrigation, where as 72% of the farmers depend both on tube well and canal for irrigation.

In eastern U.P. villages, both ground water and soils are free from salinity. The depth to water table is only 15-20 ft. But, due to poor financial conditions, instead of investing in wells, farmers rely on canal water. But the state government has undertaken several lift irrigation schemes which lift water either from canals or tube well. Around 41% of the sample farmers depended solely on tube well water and 59% depend on both tube-wells and canals. But, in eastern U.P., the canal network is more developed as compared to western Punjab.

While most of the farmers have their own irrigation sources (tube wells), some well-owning farmers also purchase water for some parcels of land. Out of the total number of farmers surveyed in the villages of Bathinda district (western Punjab) 47% irrigate their field with their own tube wells. The percentage of farmers who use only their own wells for irrigation is only 11.25 in the villages of Varanasi district. On the other hand, 11.25% and 75% of the farmers in western Punjab and eastern U.P., respectively, purchase water. The extent of water purchase is high in U.P. Because of the state-owned tube wells and low affordability of the farmers, one reason for this being the low average land holding size (three acres against 9.4 acres in western Punjab).

There are two different type of access to well water. Accordingly, the cost of irrigation water can be worked out. The first is for well owners, based on the costs actually incurred for irrigation. The second is for water buyers, based on the purchase price of water. Private cost has been calculated by taking all the fixed and variable costs involved.[2] Considering the life of the tube well as 20 years, the depreciation cost was worked out and added to the variable cost to derive the hourly cost of the irrigation.

For estimating the private costs, all costs were considered at the current market rate, including that for family labour. Table 2 presents the private costs and selling rate of water for both electric and diesel tube wells. The little variation in private cost of water between the study regions is due to the difference in cost of labour and pumping depths. Again the price of water (selling rate), which includes a profit margin for the water seller, is determined by the balance between demand for irrigation water in that market, and access to supplies. In U.P, government charges a flat rate of Rs. 20 per hour for irrigation services provided by the state-run tube well schemes, for all crops, which seem to be subsidized.

4.4 Livestock Rearing

Livestock rearing is common in both the regions because of its complementarity with farming. In western Punjab farmers keep cattle mostly to meet their domestic needs, where as in eastern U.P. cattle rearing has been taken by some farmers as an alternative source of income due to lack of adequate land resources. The sample livestock population of the study area is divided into three categories, viz., buffalo, indigenous cow and crossbred cow. In western Punjab the type of buffalo breed found was Murrah where as in U.P., Murrah as well as Bhadawari type of buffalo are reared. Generally Sahiwal, Red Sindhi and Jersey are the common crossbred cows found in both the regions. Comparison of livestock composition in the two locations shows that buffaloes account for 84% of the livestock holding in western Punjab, against 52.5% in eastern U.P. But, the percentage of crossbred cow to total cattle population was higher in eastern UP than western Punjab.

4.5 Cost of Cultivation and Returns from Different Crops

Table 3 and Table 4 provide weighted average of various costs incurred in crop production in western Punjab and eastern U.P. villages, respectively. The costs include: cost of irrigation; and cost of various other inputs such as seed, fertilizers, organic manure, pesticides and labour. The tables also show the output (main and byproducts) and the net economic return from crop production. The cost of inputs including irrigation varies across the two regions. The differences in crop yields observed between the regions, is due to a number of factors such as climate, levels of inputs, and selected crop technologies. Cotton is the most profitable crop (Rs. 15,630/acre) in western Punjab where as vegetables such as cauliflower (Rs. 13271/acre), potato (Rs.18186/

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[2] Fixed costs included cost of land, cost of installation, cost of the motor, cost of digging the well or drilling the bore well, cost of pipe and digging of field channels. Variable cost included labour, electricity/diesel charges and other maintenance costs.

acre), brinjal (Rs. 13823/acre), okra (Rs. 8448/acre) and bitter gourd (Rs. 16099/acre) are the profitable crops in case of eastern U.P.

4.6 Cost and Returns of Livestock Rearing

The private returns from dairying in both the districts were estimated using estimates of average cost of cattle inputs and income gained from milk output per cattle unit. For estimation for input costs and outputs, the entire animal life cycle and different seasons was considered with four stages, viz., calving stage, pregnancy stage, lactating stage and dry stage. To get data on quantum of inputs, season-wise data on feed and fodder use of livestock were collected for different stages of animal life cycle. The estimated values of daily average feed and fodder consumption for milch animal are presented in Table 5. It shows that in eastern U.P. the amount of feed and fodder consumption level is generally higher than that in western Punjab. The reason is that the small and marginal farmers undertake dairy as an alternative source of livelihood in eastern U.P., owing to limited land resources. Based on the data collected on daily milk yields of animals and its variations with age, the average daily milk production was worked out for different livestock types. The estimated average daily milk production for the entire animal life cycle for western Punjab and eastern U.P. are 3.25 litres and 3.95 litres for buffaloes; 2.98 and 3.45 litres for indigenous cows, and 4.46 litres and 4.69 litres for cross bred cows, respectively. The costs of all inputs such as green fodder, dry fodder and concentrate were estimated on the basis of the actual cost of production or market price whichever is applicable. Table 6 presents the cost, revenue and the net return per day per animal.

4.7 Water Productivity in Crop and Milk Production

Water productivity in crop production (Rs./m^3) was estimated for all the crops grown in both the regions and the mean values are presented in Table 7. In western Punjab, cotton has highest water productivity (Rs. 40.4/m^3), whereas in eastern U.P., brinjal has highest water productivity. The figures also show that many crops grown in eastern U.P. (brinjal, vegetables such as potato, bitter gourd, okhra and cauliflower), have higher water productivity as compared to the crops grown in western Punjab such as jowar and gram grown in western Punjab. Wheat in eastern U.P. has slightly higher water productivity than that for the same crop in Punjab. But, paddy in western Punjab has higher water productivity as compared to that in eastern U.P. Over and above, cotton, which has high water productivity, is not grown in eastern U.P.

Nevertheless, the overall net water productivity depends on how much area is dedicated to each crop and the water productivity of that particular crop. As a matter of fact, farmers in western Punjab allocate a significantly large share of their land to Kharif cotton, whereas farmers in eastern UP allocate a small percentage of their land under crops that are highly water efficient, mostly in this case, vegetables.

In the case of milk production, water productivity figures are extremely higher in case of western Punjab (see Table 8). In case of buffaloes, water productivity in milk production was Rs.7.06/m^3 in western Punjab against Rs. 2.62/m^3 in eastern U.P. In the case of indigenous cows, water productivity was Rs. 16.41/m^3 for western Punjab against Rs. 2.5/m^3 for eastern U.P. The higher water productivity was due to higher values of physical productivity for green and dry fodder, and the much smaller quantum of green and dry fodder used for feeding the livestock, which reduces the value of denominator, i.e., the volume of water used for producing the milk (by reducing the water equivalent of all the green and dry fodder used for feeding the cattle) in the estimation of water productivity, though the net return from milk production are higher for all the livestock types in eastern U.P. As a matter of fact, physical productivity of water in dry fodder in western Punjab is 70.48 Kg/m^3 against 29.32 Kg/m^3 to 46.75 kg/m^3 in eastern U.P. Similar trend was found for green fodder.

4.8 Economic Surplus from Irrigated Agriculture

Based on the values of total economic surplus generated from agriculture available for individual farmers, an attempt was made to know the response of the economic surplus to the volume of water used and the acreage of land under cultivation in both the water scarce and water surplus areas. For this different regression models such as linear, quadratic, exponential, logarithmic and power functions were run. Among these six models the best fit model was selected on the basis of higher R^2 value and was used for the further estimation of economic surplus.

4.8.1 How the economic surplus from agriculture changes with volume of water diverted?

For this, regressions were run taking economic surplus for individual farmers from each location as the dependent variable and volume of water diverted by the farmers as the independent variable.

Six regression models were run for establishing the relationship between "economic surplus" and "volumetric water application", and a linear function having an R^2 value of 0.582 was chosen for further study ($Y = 61790.6 + 12.59\ X$). Hence, linear function is the best fit line describing the response of economic surplus to volume of water used in western Punjab. While general economic theory suggests diminishing marginal returns with increasing level of use of a resource (here water), we must keep in mind that the increasing volumetric use of water occurs with proportional increase in the use of land and therefore what appears as marginal surplus here is not actually marginal for a unit of land, but increase in total farm surplus with some changes in farm size, and consequent change in water use. Further, the relatively scarcity of water for large farm holders is more than that of small holders, again forcing the farmers to increase the productivity of their water.

Similar regression results were obtained in case of eastern U.P. Among them, a linear regression model having an R^2 value of 0.794 was found to be the best fit ($Y = 22875.1 + 8.8620X$). Figure 2 and Figure 3 show how the economic surplus generated from agriculture vary with changing water diversion for agriculture among the sample farmers in western Punjab and eastern U.P., respectively.

To compare and contrast the trend in economic surplus generated from every unit of water diverted for irrigation between the two regions, the values of economic surpluses were estimated for each farmer by imputing values for "volume of irrigation water diverted" in the best fit regression model. The trend lines obtained for both the regions are presented in Figure 5. From Figure 4, it is clear that the slope of the trend line for western Punjab is steeper than that of eastern U.P. The estimated value of average increment in economic surplus per cubic metre of water used are Rs 12.59 and Rs 8.86 for western Punjab (water scarce) and eastern U.P. (water surplus) respectively, indicating that in western Punjab, water is used more efficiently for crop production in rupee terms, owing to allocation of larger share of land under low water-intensive and high-valued crops such as cotton and gram. It further implies that in western Punjab the criticality of applied irrigation water in generating economic surplus from agriculture is more as compared to the eastern U.P.

4.8.2 How Economic Surplus from Agriculture Responds to Increasing Land Use?

For this, regression was run taking economic surplus as the dependent variable, and acreage of land used in agriculture as the independent variable. From the six regression models run, power function having an R square value of 0.651 for western Punjab ($Y = 32846.8\ X^{0.6806}$), and R^2 value of 0.519 for eastern U.P ($Y = 33128^*\ X^{0.7092}$), were selected as the best fit models. The reason for choosing this function is that ideally, the net economic surplus from agriculture production should become zero when the land availability becomes zero, and that happens only in the case of the power functions. Figure 5 and Figure 6 show trends in the economic surplus generated from agriculture vary with changing levels of land use among the sample farmers in western Punjab and eastern U.P., respectively.

But, it can be seen that with increase in area under cultivation, the increase in economic surplus with a marginal increase in land size is smaller at higher holding sizes. This could be explained by the lower intensity of use of land by large farmers, due to several constraints, such as labour, water (at least in western Punjab), and farm inputs which require capital.

To examine the differences in the trend in economic surplus generated from every acre of land used in agriculture, estimated values of economic surpluses were obtained for the power function. The trend lines obtained for both the regions are presented in the Figure 7. From Figure 6, it is clear that the slope of the line for eastern U.P. is steeper than that of western Punjab. The estimated values of average increment in economic surplus per acre of land used are Rs. 10774 and Rs. 9528 for eastern U.P. and western Punjab, respectively.

This means every additional area of land put to cultivation gives higher returns in eastern U.P. as compared to western Punjab, perhaps due to the fact that farmers allocate more area under high-valued crops (in terms of returns per unit of land) in eastern U.P. This implies that the criticality land in generating economic surplus is more in eastern U.P. as compared to western Punjab.

4.9 Economic Value of Water in Agriculture

The estimation of economic value of water use in agriculture considers the average incremental value of the economic output generated with every unit volume (m^3) of water diverted/used in agriculture. It is important to remember here that the volume of water diverted at the level of individual farmer is not the same as the amount of water directly used by the farmer for irrigating the crops and feeding the livestock. It includes all the water embedded in the feed and fodder used for livestock, which might be available from the farmers' own farm or through purchase, but excludes the water embedded in the fodder etc. not used by the farmer. The economic value of water from agriculture is higher in western Punjab (Rs.14.852 per m^3 of water) as compared to eastern U.P. (Rs.11 per m^3 of water). This means that a unit volume of water used in agriculture generates more economic value in western Punjab than in eastern U.P.

4.10 Livelihood Impact of Irrigated Agriculture

Analyzing livelihood impacts of irrigation is important because many believe that sustaining irrigated agriculture is not a wise decision for naturally water-scarce regions from the point of view of ecological sustainability. Their point of contention is that such regions had evolved livelihood systems that are less dependent on human-managed water, and need for water transfers is not very compelling.

In Punjab, farmers have access to water from canals. Reliability of canal water is high. The power supply is good and comes with heavy subsidy. The diverted water is used to maximize area under irrigated production with more area under wealth-creating water efficient crops. Larger size of holding and land consolidation makes mechanized farming operations easy. The dry fodder in the form of byproducts of cropping are fed to a high cattle population instead of producing fodder in the farms. Thus, farmers resort to comparatively low input-based, but efficient production methods. Larger quantities of biomass and mechanization of farming allows farmers to keep good number of livestock for dairying.

On the contrary, water-richness enables farmers to keep the land use intensity at high levels in the land-scarce eastern U.P. with cultivation of water-intensive vegetable and paddy. Availability of green and dry fodder throughout the year from irrigated crops such as paddy, wheat bajra and maize enable them take up input-intensive dairy farming. But since farmers are engaged in crop cultivation in all seasons, the cattle-holding is kept low as livestock keeping is labour intensive. The landless get to work in farms throughout the year for key agricultural operations as wage labourers. It is to be noted here that the level of mechanization of farming is low due to lack of land consolidation, which inhibits the use of tractors.

In western Punjab, higher per capita land under irrigated crops and livestock holding demands more labour throughout the year. Labour has to be brought in from Bihar in view of the large labour shortage within the region. Though the labour absorption in main agricultural crops had declined over the past decade due to over-mechanization in Punjab with extensive use of combine harvesters for harvesting and threshing, and weedicides (Sidhu and Singh, 2004: pp2), mechanization generates its own micro economies in rural areas with creation of new employment opportunities for operation of farm equipments and their maintenance. Analysis shows that the livelihood index based on irrigated agriculture in western Punjab (0.928) is higher than eastern U.P. (0.878). This implies that irrigation plays a greater role in the earnings as well as day to day life of the people of western Punjab as compared to eastern U.P. (Table 9).

Table 9 also shows that the average household earnings from crop production and dairying are much higher in western Punjab when compared to eastern U.P. Also other sources of earnings directly or indirectly dependent on irrigation are higher in western Punjab. The major reason of larger impact of irrigation in western Punjab is the greater availability of land resources for cultivation, while farmers manage their cropping with less water intensive and highly water efficient crops such as gram and cotton. It is important to remember that though average increase in farm surplus from every additional acre of land used is lower in western Punjab as compared to eastern U.P., the average net returns are higher there due to larger land area under cultivation. On the other hand, in eastern U.P., due to low per capita arable land, the surplus water resources could not be put to beneficial use. This forces the farmers to take to non-farm enterprises/activities. Also irrigated agriculture supports livestock rearing by supplying adequate amount of feed and fodder. This not only reduces the risk and uncertainty in farming but also improves the disposable income of the farmers.

5. MAJOR FINDINGS

The findings emerging from the analyses can be summarized into those pertaining to: water productivity in crop and dairy production; incremental economic surplus with a unit increase in land and water use; the economic value of water in farming; and the livelihood impact of irrigation. As regards water productivity, many vegetables grown in eastern U.P. namely okhra, potato, bitter gourd and brinjal have higher water productivity, where as only two of the crops grown in western Punjab, namely, cotton and gram have high water productivity. However, Punjab farmers allocate a significantly large portion of their land to cotton and gram unlike farmers in eastern U.P. who allocate a small portion of their land for vegetable growing. As regards dairying, farmers in western Punjab get higher water productivity compared to eastern U.P. Also, 63% of the farmers surveyed in western Punjab were found to be keeping buffaloes against 36% in eastern U.P.

In terms of economic surplus generated against the volume of water used in irrigated agriculture, water-scare and water-rich regions show different trajectories. The estimated value of average marginal increase in economic surplus per metre cube of water used are Rs. 12.59 and Rs.8.86 for western Punjab and eastern U.P., respectively. This implies that in western Punjab the criticality of irrigation water in generating farm surplus is more as compared to the eastern U.P.

The marginal increment in the economic surplus generated per acre of land use is higher in eastern U.P. as compared to western Punjab, though, as the model suggests, the incremental return would decline at higher levels of land use in both the regions. This implies that in eastern U.P., farmers make efforts to maximize the return from every unit of land, and highest consideration is given to the productivity of crops chosen per unit of land.

The economic value of water in agriculture is higher in water-scarce western Punjab as compared to water-rich eastern U.P. owing to judicious allocation of water. Though certain crops grown in eastern U.P. give very high returns per unit of water used, a larger share of the land is allocated to crops such as paddy and wheat which have low water productivity. Over and above, farmers in western Punjab secures higher water productivity in dairying as compared to their counterparts, and they do it much more intensively, and this component of farming has slightly higher water productivity as compared to paddy and wheat if we consider different types of livestock. Hence, the incremental value realized from every unit of water in western Punjab over eastern U.P. is Rs. 3.65/m^3.

The livelihood impact of irrigated agriculture assessed in terms of a livelihood index based on irrigated agriculture in higher in western Punjab (0.928) than eastern U.P. (0.878). This implies that irrigation plays a greater role in income earnings as well as day to day life of the people of western Punjab as compared to eastern U.P. The major reason of larger impact of irrigation in western Punjab is the greater availability of land resources, which enable them to put all the available water resources to productive use, and keep larger number of livestock. On the other hand, in eastern U.P. given the constraint of limited arable land, surplus water resources cannot be put to economically beneficial uses. This forces the people to take other sources of non-farm enterprises/activities as their mainstay of life.

The findings discussed above provide strong empirical support for the economic and social argument behind transferring water from water surplus regions to water-deficit regions. As seen from the analyses, water transfer would not only increase the effective utilization of water with the removal of land constraint in expanding crop production, but would also boost the economic surplus from agriculture, raise the overall productivity and value of water and create better impact on the livelihoods of farmers. The higher economic value of water realized in deficit regions would demand more than the real "volumetric surplus" available within the water-rich region to many water-scarce region that exist in the country, that are also agriculturally prosperous, if cost of transfer of water is less than the incremental economic value realized and mechanisms exist for compensating for the economic and livelihood losses suffered by the water-rich region.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

The most important findings from the key analysis presented in the paper support the hypotheses set out in the beginning that the impact of irrigation water on generation of economic surplus is much higher in a water-scarce region, when compared to a water-rich region; and impact of land in generating economic surplus in "water-surplus, land-scarce" region is more when compared to a "water-scarce, land-rich" region; higher economic value is realized in the use of irrigation water in a water-scarce region as compared to a water-rich region; and it creates greater impacts on livelihoods in water-scarce regions as compared to water-rich regions. That said, the following points also deserve merit. For estimating the economic value of water, the productivity of applied water was considered for different crops and dairying. The actual water depleted by the crop including fodder could be much higher than the applied water, given the fact that there could be significant amount of soil moisture depletion during the cropping seasons of kharif and winter. But the soil moisture component in the total water used by the crops in a unit of crop land would be higher in a rainfall rich region like eastern U.P., than a scanty rainfall area like western Punjab. Hence, the over-estimation possible due to the use of "applied water" instead of evapo-transpirative use as the denominator in estimating crop water productivity function would be of a much higher order in eastern U.P. than in western Punjab. Hence, it could be argued that the incremental value of water in a water-scarce region would be much higher than what is estimated using the current methodology.

The contribution of modern agricultural technologies alone would be less effective in generating economic surplus in areas facing water scarcity. Higher economic surplus would be generated in those areas with the allocation of more water for agriculture than through any other measure. This is because, in water-scarce areas farmers are already growing crops that are inherently highly water-efficient, choosing right crop technologies, and economizing on the use of all other inputs. This is in spite of the fact that the scarcity value of the resource is not reflected in the prices farmers pay for canal water or the prices electricity they use for pumping groundwater. Higher economic surplus can also be generated in land-scarce regions by putting every unit of land under cultivation into crops that are "high-valued", adopting modern crop technologies, and increasing the intensity of cropping.

Hence, in the ultimate analysis, it appears that the water-scarce regions would be able to boost agricultural production only with increased allocation of water for irrigation. But, this can cause many negative environmental effects if such regions start using its own internal water resources for boosting agricultural production. There are increasing evidences to suggest that these regions have already used up more than what is ecologically sustainable. Many agriculturally prosperous regions in India, especially in the Peninsular and western parts, that are naturally water scarce, are hit by groundwater depletion due to over-draft for irrigation. This has put a break on the agricultural growth in these regions. A recent study by Aggarwal and others (2005) showed that water availability is a major constraint in ensuring agricultural growth and sustained food production even in the relatively water rich Haryana (Aggarwal et al., 2001).

As analysis presented in this paper suggests, there is incremental economic value realized from the use of every cubic metre of water in water-scarce and land-rich region as compared to the use of the same quantum of water in a water-rich, but land-scarce region. This has major policy implications for the allocation and use of water in agriculture across regions that are characterized by mismatch endowment of land and water resources. Many water-rich regions, be it eastern UP or Bihar are at a natural disadvantage of being land-poor. In Bihar, the per capita cultivable land is less than 0.092 ha (Kumar, 2003), while cropping intensities are already high (GoI, 1999). The total factor productivity growth in this region, which falls partly in hot subtropical climate, and partly in tropical cool winter climate, has been on the decline over three decades from 1958-1987

(Evenson et al., 1999: Table 22) in spite of reasonably high irrigation intensities. At the same time, the TFP growth in Punjab, Haryana and western UP falling in "subtropical monsoon" climate was on the rise (Evenson et al., 1999: Table 22).

As has already been noted in the case of Varanasi, farmers take three crops, viz., rain-fed Kharif, and irrigated winter and summer crops. Thus the ability of these regions to enhance crop yields or agricultural productivity per unit of arable land through increased allocation of water is extremely limited. This combined with low TFP growth keeps the value of irrigation water low. While transfer of surplus water from water-rich regions to water scarce regions does not need a better economic rationale than increasing the productive use of the un-utilized water, the notable fact is that such transfers for agriculture lead to realization of greater economic value. The fact that there is a significant incremental value realized from water transfer might demand reallocation of more than the real "volumetric surplus" available within the water surplus region to a water-scarce region. But such transfers have to satisfy two conditions. First: the incremental value realized exceeds the cost of such transfer. Second: mechanisms exist for compensating for the economic and livelihood losses suffered by the water-rich region.

Finally, there are complex ecological, hydrological and engineering considerations involved in water transfer projects other than those which are economic. In the Indian context, regional water transfer is also a major political issue. The proposals for water transfer are under severe scrutiny not only on political grounds (Goel, 2005), but also on economic (Bandyopadhyay and Perveen, 2003; Goel, 2005), ecological (Bandyopadhyay and Perveen, 2003; Khalequzzaman et al., undated), environmental (Vaidyanathan, 2003a), hydrologic (Khalequzzaman et al., undated), financial (Rath, 2003), and scientific grounds. Often, the very methodology for assessing "water surplus" and "water-deficit" nature of some basins has been contested by scholars (Vaidyanathan, 2003b). But healthy debates of such issues are often plagued by lack of sufficient empirical, scientific data on many of these dimensions of water transfers, including those on economics. This is a major hindrance to the process of facilitating informed and scientific debate on regional water transfers, often leading to situations where political interests over-ride other regional interests. So from that perspective, the present analysis would be useful for academicians, policy makers and practitioners to have an informed debate.

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Table 1: Agro-ecological Parameters of the Study Areas

Sr. No.	Parameters	Punjab (Bathinda)	Uttar Pradesh (Varanasi)
1.	Climate	Hot and semi arid	Dry sub-humid to moist sub-humid
2.	Soil	Black soil with alkalinity	Alluvial soil with free from salts
3.	Temperature	Max: 42-45^{0}C Min: 2-6 ^{0}C	Max. 38-40 ^{0}C Min. 4-6 ^{0}C
4.	Rainfall	360mm	1025 mm
5.	Humidity	80%	90-95%
6.	Major crops grown*	Rice, Wheat, Cotton, Pulses and Fodder	Rice, Wheat, Vegetables and Pulses
7.	Cropping intensity*	200%	250%-300%
8.	Sources of irrigation	Tube well (59.7%), canal (40.1%)	Tube well (85%), canal (12.5%)
9.	Percentage of irrigated land	95	83

Sources: Statistical abstracts of Punjab and Uttar Pradesh
* Indicates the primary data.

Table 2: Private Cost and Actual Selling Price for Well Irrigation in Sample Villages

District	Private Tube well with				Government Tube well with Electric Pump
	Electric Pump		Diesel Pump		
	Private Cost/hour	Selling Rate/hour	Private Cost/hour	Selling Rate/hour	
Bathinda	18.51	40	43.6	70	-
Varanasi	15.5	20	40.5	60	20

Source: Authors' own estimates based on analysis of sample survey data

Table 3: Cost of Cultivation and Net Economic Return per acre from different crops of Villages Kotsameer and Tungwala of Bhatinda District of Western Punjab

Season	Crops (Rs)	Irrigation cost (Rs)	Total cost (Rs)	OUTPUT				Gross output (Rs)	Net Economic Surplus (Rs/Acre)
				Main product		By product			
				Q	R	Q	R		
Kharif	Cotton	1150	10678	13.3	1833	17.5	100	26241	15630
	Rice	1280	7645	18.6	596	12.5	100	11720	4075
	Fodder Bajra	300	1883	41.3	50	4.8	400	3985	2102
Rabi	Wheat	750	6158	12.3	717	11	50	9429	3271
	Fodder Jowar	250	1539	50	50	5.4	362	4829	2907
	Gram	80	1488	1.9	2753	-	-	5251	3764

Q=Quantity in quintal per acre, R=Rate in Rupees per quintal and V=Value in rupees

Table 4: Cost of Cultivation and Net Returns per acre from different Crops of Bachhao & Dindaspur villages of Varanasi district of Eastern Uttar Pradesh

Season	Crops (Rs)	Irrigation cost (Rs)	Total cost (Rs)	OUTPUT				Gross output (Rs)	Net Economic Surplus (Rs/Acre)
				Main product		By product			
				Q	R	Q	R		
Kharif	Paddy	450	5483	13.2	567	12.2	50	8088	3164
	Fodder Bajra	350	1680	67	50	4.4	250	4450	2894
	Brinjal	803	6407	40.3	502	-	-	20230	13823
Rabi	Wheat	514	4700	12.4	658	17	100	9445	4921
	Potato	981	10714	64.8	446	-	-	28900	18186
	Cauliflower	1035	14180	60.2	456	-	-	27451	13271
	Bitter Gourd	948	7621	40	593	-	-	23720	16099
Zaid	Okra	827	6638	38	397	-	-	15086	8448
	Maize	286	3566	46.7	510	4.1	60	7294	3728

Q=Quantity in quintal per acre R=Rate in Rupees per quintal

Table 5: Daily Average Feed & Fodder Consumption per Milch Animal

Feed/Fodder	Animal Type	Bathinda	Varanasi
Green Fodder(Kg/day)	Buffalo	19.46	23.2
	Indigenous Cow	12.92	16.35
	Crossbred Cow	14.41	24.37
Dry Fodder(Kg/day)	Buffalo	7.94	6.68
	Indigenous Cow	5.07	3.82
	Crossbred Cow	4.33	4.62
Concentrate(Kg/day)	Buffalo	2.28	3.2
	Indigenous Cow	1.2	2
	Crossbred Cow	1.4	2.75
Drinking Water(Litres/day)	Buffalo	55.8	62.5
	Indigenous Cow	52.6	61.8
	Crossbred Cow	60.2	66.4

*Green fodder, Dry Fodder & Concentrates are in Kg/day/animal. Water is in litres

Table 6: Net Return from Livestock (per Milch Animal per Day)

Study Areas	Gross Income (Rs)			Expenses (Rs)			Net Return (Rs)		
	B	C	CB	B	C	CB	B	C	CB
Bathinda	38.94	33.4	48.5	26.4	16.5	27.3	12.5	16.9	21.2
Varanasi	45.8	38.4	56.2	30.1	20.2	32.3	15.8	18.2	24.5

* B: Buffalo; C: Indigenous Cow; CB: Cross bred Cow

Table 7: Water Productivity of Different Crops in Western Punjab and Eastern Uttar Pradesh

Name of Season	Name of Crop	Water Productivity (Rs/m^3)	
		Wastern Punjab	Eastern Uttar Pradesh
Kharif	Cotton	40.40	
	Kharif Paddy	7.75	4.51
	Fodder Bajra	2.93	4.78
	Brinjal		45.58
Rabi	Wheat	8.05	9.11
	Fodder Jowar	6.32	
	Gram	24.48	
	Potato		33.02
	Cauliflower		28.97
Zaid	Bitter Gourd		30.14
	Okra		30.11
	Maize		8.91

Source: Sample Survey
* Figures in the bracket indicate the % of the total cultivated area

Table 8: Water Productivity in Milk Production for Different Types of Livestock in Western Punjab and Eastern Uttar Pradesh

	Name of Livestock	Water Productivity in Milk Production (Rs/m^3)	
		Western Punjab	Eastern Uttar Pradesh
1	Buffalo	7.06 (50)	2.62 (29)
2	Cross breed Cow	17.44 (5)	1.28 (3)
3	Indigenous Cow	16.41 (13)	2.52 (17)

Note: the figures in parenthesis shows the number of farmers who rear the livestock

Table 9: Livelihood Index of Irrigated Agriculture in the two Regions

Study areas	Annual household income from various sources (Rs)								Livelihood Index (LI)
	Agriculture	Dairy	Selling Water	Working in others farm	NFWL (Non Farm Wage Labour)	Services	Petty trade	Any other	
Bathinda	257845	15364	3566	1450	826	12907	4721	3560	0.92
Varanasi	100242	53514	5038	1000	1858.7	17940	6673	4893	0.87

* Figures in the table are in Rs; LI is the livelihood index.

Figure 2: Response of Economic Surplus to Irrigation Water in Western Punjab

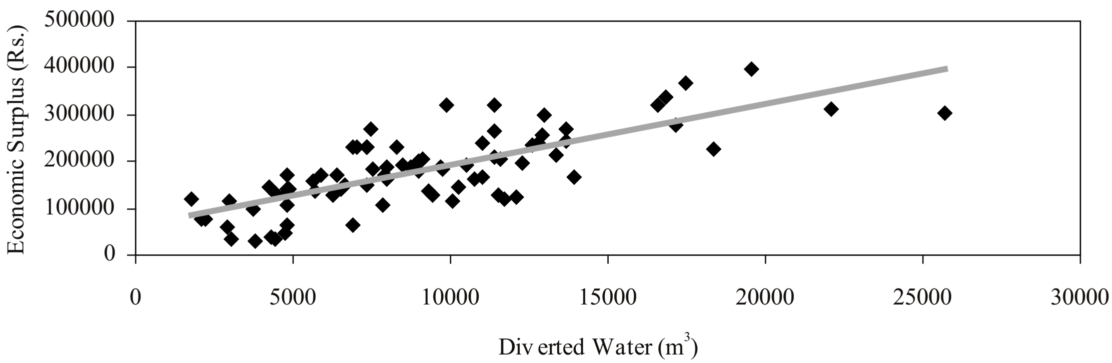

Figure 3: Diverted Water Vs. Economic Surplus in Estern Uttar Pradesh

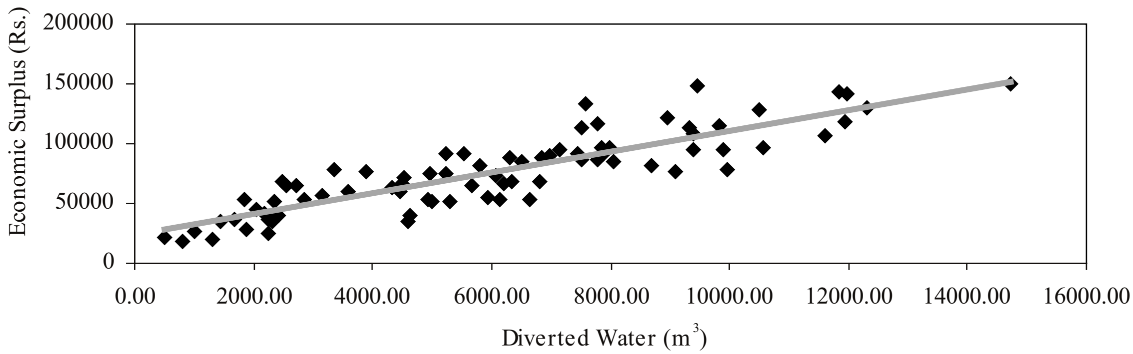

Figure 4: Estimated Values of Economic Surplus for Different Levels of Irrigation in the Two Regions

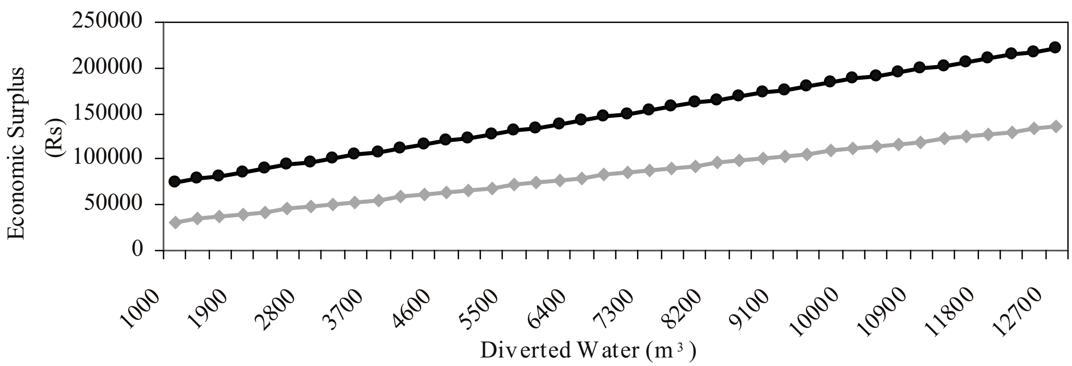

Figure 5: Land use vs Economic Surplus in Western Punjab

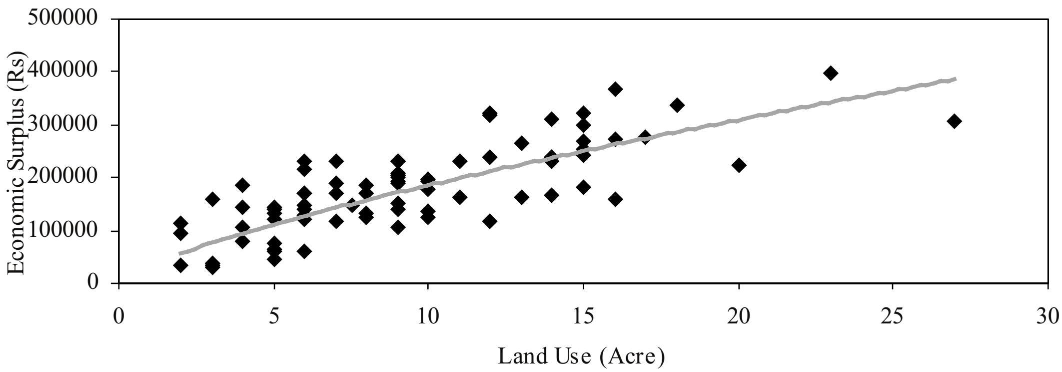

Figure 6: Land use vs Economic Surplus in Estern Uttar Pradesh

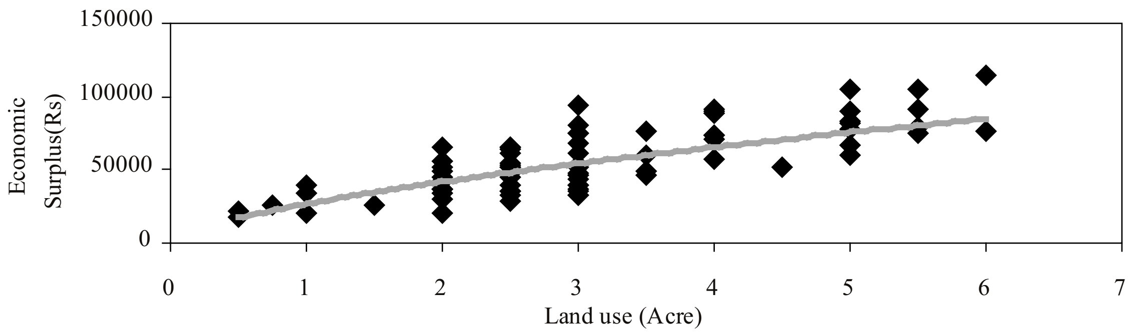

Figure 7: Estimated Values of Economic Surplus for Different Levels of Land use in the Two Regions