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SUBJECTS

(1) Disadvantaged Regions and People: Is There a Way Forward?

(2) Role of Technology, Institutions and Irrigation in Agricultural Development.

(3) Economic Contribution of Women in Agriculture.

RAPPORTEURS' REPORTS

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Rapporteur's Report on Role of Technology, Institutions and Irrigation in Agricultural Development

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The Subject II deals with three sub-themes Role of Technology, Institutions and Irrigation in Agricultural Development and hence it is crucial to consider the research contributions in the three distinct fields. Considering the first sub-theme, the role of technology, articles were expected to focus on sub-optimal performance of technologies; economic reasons and implications of slow/sluggish performance of agricultural technologies, plateauing of productivities; reasons and solutions for declining contribution of research, extension, irrigation to total factor productivity (TFP) over time in different agro-climatic regions, economic implications on livelihood and economic security; innovative approaches for quantification of technological contributions in NARS incorporating depreciation of technology, probability of performance and rate of adoption of technology in the field. In all, 31 papers were received covering the three sub theses in Subject II, of which six papers are accepted for full presentation and 18 papers are accepted in summary form.

A. Role of Technology

In this subtheme, the articles by Baljinder Kaur Sidana *et al.* entitled "Optimizing irrigation water use in Punjab agriculture: Role of crop diversification and technology" and by A. Narayanamoorthy *et al.* entitled "Is the Role of Irrigation in Agricultural Output Declining in India?: A District-Wise Study of Six Time Points" are discussed. The article by Baljinder Kaur Sidana *et al.* analyse the role of crop diversification and technology in optimising irrigation water use in Punjab agriculture. Punjab has an amazing growth trajectory in farming, with 98 per cent of the net area sown being irrigated, perhaps the highest in any part of the world, has a cropping intensity of 186 per cent, with net area irrigated by tubewells forming 72.5 per cent followed by canals 26.2 per cent, supporting[1] large farmers (above 2 ha) accounting for 64.6 per cent, small farmers 16.7 per cent and marginal farmers 18.7 per cent. The number of tubewells with electrical IP sets has increased at a compound growth rate of 6.23 per cent between 1970 and 2013. Punjab is contributing 35-40 per

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cent of rice and 40 to 75 per cent of wheat to the central pool,[2] and this social benefit is at the colossal social cost of unsustainable water use for irrigation. According to Sushil Gupta, Regional Director of Central Groundwater Board,[3] Punjab has a net dynamic ground water resource of 21.443 MCM, with the net draft of 31.162 MCM, registering an overdraft of 9.719 MCM with a draft – recharge of 145 per cent. Thus, Punjab is "over- exploited" and hence has already reached unsustainable levels in groundwater use. Thus, the assumption made by the study, that water draft = water recharge in estimating the optimum crop planning, is untenable. Instead, for sustainable water use, the assumption should have been that water draft = 0.55 * recharge, since the level of overexploitation is already 145 per cent which has to be brought down to zero level, by equating water draft to recharge. The area under rice which is not a staple food crop of Punjab increased from 6.87 per cent of the total cropped area in 1970 to 35.85 per cent in 2010, while the area under wheat, a staple crop has been consistently around 40 to 44 per cent. It is startling to note that between 1960 and 2013, area under rice increased by 1126 per cent (0.23 ml ha to 2.82 ml ha), while that under wheat increased by 153 percent (1.39 ml ha to 3.52 ml ha). The total area under food grains formed 69 per cent of the total in 1970 and increased to 83 per cent in 2010. Thus, agriculture (crops) is contributing to 64 per cent of the primary sector income, followed by livestock 31 per cent at constant prices. This study has not included the contribution of livestock (cows, she buffaloes, small ruminants) in the optimum crop planning exercise.

The productivity of rice in Punjab, can certainly be more impressive (than 3.83 tonnes/ha), as the source of irrigation is the economically scarce groundwater irrigation, as compared with Karnataka, where the productivity ranges from 1.98 tonnes per ha in rainfed hilly zone to 2.6 tonnes per ha in canal irrigation in Mandya district. Farmers using economically scarce resource can be relatively more efficient than farmers using the relatively economical surface water. This paper has no explicit mention of how volumetric measurement of groundwater has been arrived at using the data from CCS / primary data. Examining all the relevant RT form numbers pertaining to irrigation such as No. 210 on land inventory, 211 on changes in land, 410 on building inventory, 411 on building changes, 440 in irrigation structure, 441 on irrigation structure changes, 710 on crop operation hours, 711 on crop operation payments, 730 on special activity operations hours, 740 on machine upkeep operation hours, 741 on machine power provided outside farm, it is clear that in none of the forms, there is any information on the water yield of the well/s at the time of drilling or at any other time. Without this crucial information on groundwater used on the farm, any other estimation made on the volumetric measurement of groundwater is only an approximation. In the article, the author/s mention that cropwise water has been is calculated by the number of hours of irrigation times the volume of water pumped per hour. They also mention that farmers possess irrigation pumpsets with different capacities and are standardised on the basis of discharge rate in LPS (litres/second). However, as none of the RT forms carry information on discharge rate per well, CCS data cannot provide information on volumetric use of water for irrigation. Also, the cost of pumping groundwater ought to vary from well to well, due to variation in the depth of pump placement, HP of the pump and yield of the well. Thus, the CCS data does not incorporate information on volumetric measurement of water. Thus, the article hides more than what it reveals, when it pertains to how irrigation water has been volumetrically measured and incorporated in the Linear Programming model. It is likely that the authors have measured the yield of the well through primary data and then used along with information from RT 710 regarding crop operation hours to obtain the volumetric water applied.

Quoting from studies the authors indicate that out of 1600 mm of water for paddy, 1100 mm is pumped from groundwater. With this estimation of 1.1 meter of water for 1 ha (or 10,000 sq meters), the total groundwater applied would work out to 11000 M^3 (or 107 ha cms) per ha. Even at a conservative estimate of the cost of groundwater at Rs. 100 per ha cm, the water cost works to Rs. 10700 per ha of paddy.

The authors indicate that in addition to paddy-wheat cropping system, it is also the urbanisation which is resulting in overdrafting of groundwater. However, this needs to be checked since, the demand for urban and domestic use forms not only around 10 percent of total water utilised, but also, this water is non-consumptive use, since it can be recovered. What is crucial is to note that the area under canal irrigation in Punjab is fast reducing from 1286000 ha in 1970 to 1133000 ha in 2012, a reduction by 11.89 per cent or 0.28 per cent per year. However, the reasons for reduction in canal area are not provided.

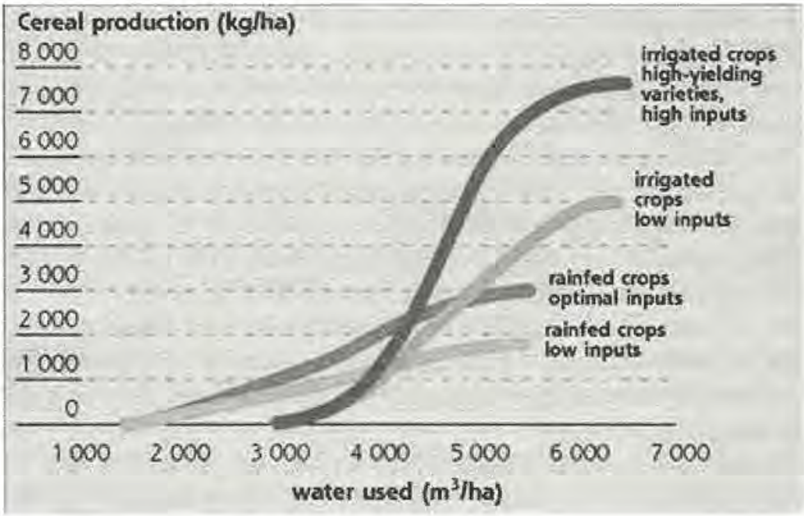
The results indicated that paddy which occupied around 71 per cent of the total area, is now reduced to around 60 percent of the area in Optimal Plans I and II. However, in Optimal plan I, there may not be substantial water saving since only conventional paddy cultivation is recommended to be followed for both paddy and Basmati. But in Optimal plan II, the conventional paddy is recommended to be 32 per cent of the area, followed by water saving paddy through Direct Seeded Rice of around 17 per cent and tensiometer lead paddy cultivation of 10 per ent, can save water. Even then, there has been no substantial savings in water which is to the tune of 8 to 17 per cent. Also, even though the authors have introduced maize, green gram, pigeon pea, lady's finger and brinjal, the optimal plan again focuses on different types of paddy. In fact the optimal plan has removed lady's finger, cauliflower, green gram and barley in both the plans proposed!

It is paradoxical to note that, Delhi being the closest Metropolitan to Punjab, which has potential to absorb substantial quantities of fruits and vegetables which can be economically cultivated in Punjab, has failed to offer backward linkages, similar to the demand from Bangalore Metropolitan to farmers of Kolar and Chikkaballapur districts who are benefited by the impact of the diversity of demands for different types of crops from Metropolitan. The water saving in Punjab, needs to be achieved by a thorough and phase wise shift in crop pattern towards low water consuming, high value, non-paddy and non-sugarcane crops. A linear programming formulation, vastly reducing area under any kind of paddy, but shifting to possibilities of a plethora of non-paddy alternative crops which are not only low water consuming, but also high on net returns per unit volume of water, such as horticulture vegetables and fruits, should have been demonstrated to farmers. These crops are not utopian, since. This requires honest and committed efforts on the part of agricultural extension and irrigation extension impacting maximising on 'net return per rupee of groundwater irrigation' rather than 'more crop per drop'. This study also needs to provide the initial tableaux which specifies the input-output coefficients for all the constraints and especially for water constraint. The authors demonstrate the role of technology in water saving such as use of DSR and Basmati rice, which has only resulted in a modest saving of water from 8 to 16 percent when compared with the conventional crop pattern.

A. Narayanamoorthy *et al.* in their paper focus on technology in agricultural development and have attempted to quantify the contribution of irrigation to agricultural output using time series data across districts in India. The article has passive conclusion: "Although both univariate and multivariate regression results show a declining trend of irrigation coefficient over time, one may not be able to firmly say that the role of irrigation in determining the value of agricultural output has reduced over time, as this could have happened due to acceleration in the productivity of crops cultivated in the rainfed/less irrigated districts.". The authors provide a review of studies which are skeptical regarding the contribution of irrigation (Fan and Hazell, 1999; Thorat and Fan, 2007). According to (Fan *et al.*, 2000: 1050), referred by the author/s, investment on irrigation has a modest impact on growth in productivity and reduction of rural poverty. Further, the study by Vaidyanathan *et al.*, (1994) using data for 1962-65, 1970-73 and 1980-83, which includes the green revolution period, found no consistent relationship between irrigation and agricultural output.

Thus, studies largely based on secondary data in Armchair researching portray modest or poor performance of field irrigation in productivity. It is crucial to look at the some of the common sense indicators of contribution of irrigation. First the share of private in total investment in agriculture has increased from 53.9 percent in 1980 to 82.4 per cent in 2008. Second, the rate of growth of private investment in agriculture was positive, 2.5 per cent during 1981-90, 4.11 per cent from 1991-2000 and 5.15 per cent from 2001 to 2009, while the rate of growth in public investment was largely negative (-3.8 per cent for 1981-90; -0.22 per cent for 1991-2000 and +15.74 per cent for 2001-2009). A major part of the private investment in agriculture has been on irrigation. If private investment (by farmers) is increasing in agriculture, then it cannot happen unless farmers are realising economic profits. Third, with India's production of food crops, horticulture crops and dairy ranking top first or second in the world, next to China, this should be possible with irrigation, and the role of groundwater irrigation has increased, since 70 percent of irrigation is now provided by groundwater.

This paper provides the *prima facie* evidence of inability of researchers in using the right data set and methodology for addressing the researchable issue. In this case, the author/s mention, "….. the specific objectives of the study are: (a) to measure the independent relationship between irrigation and agricultural output (measured in terms of Rs./hectare), and (b) to analyse the contribution of irrigation and other factors to agricultural output over time". First, the major objective states, "to understand the role of irrigation on agricultural output" than 'analysing' the role of irrigation. Even a novice can experience that in a tropical country such as India, with average daily temperatures running as high as 40 degrees to 45 degrees Celsius, due to irrigation water, productivity increases by at least 100 percent as also taught in Agronomy courses. And in the case of drip irrigated crops, there will be dual benefit of increased productivity coupled with water thrift. Second, the first specific objective statement in itself assumes 'independent relationship' between irrigation and value of agricultural output. Instead, it should have been stated to measure the relationship between irrigation and value of agricultural output, and later interpret depending upon the significance of the magnitude and direction of regression coefficient. A recent study[4] on the impact of irrigation on agricultural productivity in India, using descriptive and econometric approaches conclude that "irrigation has a strong impact on land productivity". It is crucial to note that irrigation no longer means surface irrigation. Since 70 percent of irrigation in India is now contributed by groundwater, irrigation should be classified as (i) surface irrigation, (ii) groundwater irrigation, and further as (iii) sprinkler or (iv) drip or (v) subsurface drip irrigation. Therefore mere use of the word 'irrigation' is generic and needs to be specified to mean specifically which type, in order to measure its contribution. In addition, irrigation can also mean (1) irrigation infrastructure, or (2) irrigation water (3) interaction effect of both infrastructure and water. If the researcher is intending to find the impact of irrigation infrastructure such as canals, reservoirs, then secondary data may be appropriate and may like to use TFP. If the researcher wants to quantify the contribution of irrigation water in agriculture, then primary data from farmers is relevant for a production function approach to quantify singular and interaction effects of water and on farm infrastructure (using intercept and slope dummy variables). The impact of irrigation is neatly depicted by FAO as under:



Source: http://www.fao.org/docrep/005/y3918e/y3918e10.htm

Figure. Impact of irrigation

Therefore using secondary data and drawing major conclusions on economic contribution of irrigation is defective as there are serious limitations in the model formulation as also in the secondary data which does not portray the contribution of irrigation. The authors indicate that effect of irrigation on agricultural output can be examined by covering different time points. One can only understand whether the effect of irrigation development on agricultural output is increasing or decreasing over time by covering different time points. Further the authors indicate that time lag needs to be provided for irrigation variable to enable to measure the impact.

This is not tenable because, crop economics and productivity responds immediately to irrigation water. One need not wait for more than a crop season of three or four months to measure the contribution of irrigation. Perhaps what the author/s meant may be irrigation infrastructure, and not irrigation water. The role of Irrigation infrastructure can be captured by the concept of TFP and construction of canals, their maintenance, is over a time period.

In this study, percentage of irrigated area to cropped area is the key variable used as (1) IRRI: the continuous variable of the ratio of irrigated area to cropped area and (2) IrD: the dummy variable to represent irrigation. In the description column of the variable, it is stated as ratio, but in the unit of measurement, it is stated as percentage. Even in the description column, it should have been stated as percentage. It is not clear whether irrigated area refers to net or gross irrigated area and correspondingly cropped area is net cropped or gross cropped area. This variable underestimates irrigation since, among the 35 crops considered in this study, it is unclear whether perennial crops have been considered and if so, whether area irrigated is taken as one ha or more than one ha is not clear, since perennial crops are irrigated for more than two seasons. Second, it is incorrect to convert a continuous variable to a discrete variable: if the IRRI is < 30 per cent, 0 is assigned and if IRRI is > 30 per cent, then 1 is assigned. As the data on area irrigated itself, a continuous variable is available, there is no need to convert the continuous variable to a discrete variable as in this study. Further, there is no basis for indicating that the minimum level of irrigation coverage should be 30 per cent. Treating irrigation as proportion of cropped area irrigated also has an aggregation error, since response to irrigation is specific to crops, seasons, agroclimatic regions, soils, management efforts, but are assumed as *ceteris paribus* for all the 235 districts of India from 1970 to 2008!

The value of agricultural output VAO variable, includes value of 35 crops of India, which are cultivated under both irrigated and rainfed conditions. Hence VAO is an over estimated variable since it should have only included the value of irrigated agricultural output of (35) crops.

Further the data is limited to 13 states (for example excludes Haryana) and a few districts within each of the 13 states (for example for Karnataka only 18 districts are considered out of 30). Thus, these further limit the quantification of irrigation. The authors indicate that (ROAD, ELEC, LITE) are <u>infrastructure variables,</u> and IRRI, IrD (irrigation dummy), FERT, CI and VAO are <u>growth related</u> variables. However, as OLS used makes no distinction between the two types of variables. Infrastructure is also a growth related variable. This study uses IRRI (the ratio of irrigated area to cropped area) and CI (Cropping Intensity) as exogenous variables influencing VAO. Obviously IRRI and CI move together. Accordingly the model (5) suffers from (severe) multicollinearity. The authors state that in (5) irrigation as 'normal' variable (percentage of irrigated area), instead, should have stated as 'continuous' variable since in (6) IRRI is treated as a categorical variable. There is no classification of variable as 'normal' or 'non normal' variable.

The study states that VAO depends upon "the quality of irrigation (source of water) available to farmers" hinting that quality of irrigation refers to source of water. The quality of irrigation means (1) timely availability (2) adequate volume (3) management of irrigation leading to proper distribution of water in all reaches. The source of water means, whether surface water or groundwater. The authors need to note these differences. Further, classification of districts into low (<30 per cent), medium (30-50 per cent) and high (> 50 per cent) level irrigation, is incorrect as mentioned earlier, since the continuous variable (IRRI) should not be treated as 'ordinal' variable – low, medium, high, since continuous variable needs to be treated as a continuous variable, and there is no need to convert a continuous variable to an ordinal variable. The authors state their aim is to study VAO by level of irrigation. However the ratio or irrigated area to cropped area, is too much of a simplification of the measurement of irrigation to mean the 'level of irrigation', a vague terminology. Irrigation intensity (gross irrigated area ÷ net irrigated area) could represent 'level of irrigation', to some extent, but the proportion of area irrigated is a weak representation of the 'level of irrigation'. Accordingly the results of VAO according to level of irrigation (Table 2) shows modest ratios hovering around 1.5, rarely touching 2.0. The authors have further simplified the VAO to reflect 'high and low irrigated districts'. As mentioned earlier, proportion of irrigated area is a weaker representation of level of irrigation when compared with irrigation intensity, which would have projected higher ratios in Table 2.

The univariate linear regressions unlagged (Model 1) and lagged (Model 3) present insipid results. What is crucial is to note all the intercept and slope coefficients (perhaps including the R^2) are highly significant. Even then, the contribution of exogenous variables other than IRRI to VAO are highly significant as indicated by the large highly significant intercept coefficients for all the years. For instance, for 1970, the intercept forms 58 per cent; for 1980, 55 per cent; for 1990, 49 per cent; for 2003, 60 per cent; and for 2005, 58 per cent of VAO. This in itself is the *prima facie* indicator, that the contribution of factors other than Irrigation (as considered in this study) are 50 per cent to 60 per cent since 1970, the years of green revolution as well as post green revolution. In addition, the interpretation of slope coefficient has to be made with respect to a percentage variable (percentage of irrigated area divided by cropped area). If the percentage of irrigated area out of cropped area increases by one percent, then the VAO increases by Rs. 46.43 in 1972, by Rs. 70.07 in 1970, by Rs. 77.09 in 1980, by Rs. 95.95 in 1990, by Rs. 70.15 in 2003 and by Rs. 70.36 in 2005. Considering the regression for the latest year 2005, even with 100 per cent irrigation facility, according to the authors, a farmer realises an average value of agricultural output of Rs. 11,788 per ha in India, and this is neither economically substantial nor a realistic figure.

Further, there is also no substantial difference between results of Model 1 and Model 2, which is a prima facie indicator of the choice of improper variables and mis specification of model to measure the contribution of irrigation to VAO. The authors further indicate that "The results of univariate regression estimated treating irrigation as a normal continuous variable show that IRRI impact on agricultural output appears to be inverted 'U' shape curve over the years (see, Table 3)". It is puzzling to note, by estimating a straight line - linear relationship, how any body can view a U shaped relationship! After specifying the model, as long as the R^2 is statistically significant (as indicated by the F value), the size of R^2 has no relevance. The authors (mis) interpret that the level of variation in VAO has reduced over the years, which is of no significance for interpretation.

Similarly the results in Table 4 with lagged impact of irrigation are also of no theoretical or empirical significance, since as stated earlier, Irrigation measured as proportion of cropped area irrigated out of the total cropped area is treated as a categorical variable. The results here further underestimate the role of irrigation. For instance, for 2005, the average value of agricultural output for India is further underestimated to be Rs. 8991 per ha compared with results in Table 3. In Table 5, the authors present results of multiple linear regression model 5. For the latest year 2005, by substituting the coefficients from Table 5 and multiplying with the average values of explanatory variables such as fertiliser, electricity, irrigation, road, cropping intensity, rural literacy from Table 1, the Value of Agricultural output (VAO) works to hardly 8165 per ha for India, which is the reflection of a very unrealistic and insipid contribution of the crucial inputs. According to the Model 5, a farmer realises the value of agricultural output of Rs. 8165 per ha of irrigated land. This is not a realistic figure. This further shows the model mis-specification and inadequacy. For instance, one of the mistakes, is the use of both IRRI and CI variables, which are highly correlated as it results in multicollinearity. Therefore, even though the R^2 has been significant for both univariate and multivariate regressions used in this study, they are not providing realistic results.

Similarly in Table 6, the authors present results of multiple linear regression model 6, where irrigation is represented by a dummy variable. For the latest year 2005, the value of Agricultural Output works to Rs. 8461 per ha for an average farmer in India with irrigation facility. Thus, a farmer realises only Rs. 8461 per ha with irrigation as well as with contributions of electricity, road, fertilisers, cropping intensity, literacy, which is a gross underestimation of the economic contribution of irrigation in India. In conclusion, the authors indicate "Although both univariate and multivariate regression results show declining coefficient of irrigation over time, one may not be able to firmly say that the role of irrigation in determining the value of agricultural output has reduced. This could have happened due to acceleration in the productivity of crops cultivated in the rainfed districts". This is a surprising interpretation, since the productivity of crops in rainfed districts is certainly lower than that in irrigated districts. Thus, with weak construction of variables to represent the critical and vital variable like irrigation, and with model misspecification which includes choice of weak (linear) model, the authors arrive at a gross under estimation of the value of agricultural output from irrigation in India. The results showing that the value of agricultural output in India is around Rs. 8000 to Rs. 11000 per ha, is a gross underestimation, since even on rainfed lands, the gross output is around this figure, even from a single food grain crop. In India, at present 70 percent of irrigation is from groundwater irrigation where the crop and enterprise diversification is higher than that from canal irrigation. Considering these developments, the results of the study need to be reworked by improvising the model specification – using quadratic or transcendental function and improvising the choice of variables to truly represent irrigation, by using primary data, since irrigation, especially groundwater irrigation has enlarged agribiodiversity.

B. Role of Institutions

In the second sub-theme, the role of institutions, the following two papers are discussed:

In the article on death of Kuhl irrigation system, Ashwani Kumar Sharma *et al.* have highlighted institutional failure in virtually killing the institution of Kuhl irrigation system in Kangra valley of Himachal Pradesh. What role institutions can play in upholding and preserving a system of irrigation and how institutional failure can result in devastation of the well preserved irrigation system, is amply explained by the authors. The *kuhl* irrigation was initiated in 1850, as a community managed gravity flow irrigation system in Kangra Valley of Himachal Pradesh comprising 715 large and 2500 small *kuhls* and the system worked sustainably till 1980s. Khuls are narrow canals carrying water through gravity flow with varying capacities due to gradient of the area cultivated, productivity, water holding capacity of soil, alternate post monsoon sources of water, extent of socio-economic (in) equity, scale of coordination for management of kuhls. In a matter of last 24 years, there has been failure of institutions in Kuhl system, where, the area under paddy for water right holders in kharif reason reduced by more than 80 percent. There has been passive participation of right holders in Kuhl management due to economic opportunities created in non farm employment diluting their interest in the institution of kuhl water managements,

The sub-section 5, offers an interesting explanation where the entry of State Agricultural University – the Himachal Pradesh Krishi Vishvavidyalaya (HPKVV, Palampur) has been responsible for drawing water from Khuls which are located in the vicinity of 3 to 8 kms from the University, due to an agreement made with Kuhl management especially pantul and daei, where the agreement was pro - SAU, detrimental to the interest of the Kuhl institution. I quote the authors "As per agreement, SAU agreed to guard the water in upstream areas and use water at will. After the agreement, the volume of water as well as its frequency of running was reduced considerably. The establishment of SAU in the uncultivated area through which the pantul and daei *kuhl* passes, has emerged as an artificial and unbearable upper cluster to the network. Other factors responsible for institutional failure of Kuhl system are 1. Migrant population 2. small tractors (power tillers?) resulting in wheat cultivation wiping out rearing of bullocks thus, reducing area under paddy resulting in *kharif* fallow (for fodder/grazing) followed by rabi wheat, reducing drudgery to farmers and 3. improvement in milch animals, replacing paddy cultivation. Currently the *Daei* and *bharul kuhl* networks are taken over by the Government and investments have been made in civil structure (concrete?), resulting in lack of water in Kuhls since last 2 years. The authors conclude Kuhl system can be revived with an in-depth understanding of relations between villages, within villages and between networks promoting people participation.

In the article on role of institutions Kiran Kumar Patil analyses sharing of water as groundwater institution in reducing negative externality due to intense well drilling, thereby enhancing economic efficiency and welfare in hard rock area. The article explains the role of groundwater sharing among siblings in farm families, responsible for reduction in drilling irrigation wells and thereby reduce the negative externality due to violation of isolation distance and cone of depression in hard rock areas. The institution of 'sharing' groundwater for irrigation is portrayed as collective action within farm families as informal rule addressing the demand side of groundwater. The basis of the study hypothesis that sharing well water reduces reciprocal negative externality is not mentioned by the authors and is a drawback of the study.

Kiran Kumar Patil points out that the parents/elders of the farm family exercise the line of control in deciding on water sharing as well as cropping pattern to be followed, sharing investment on drilling wells and O and M expenditure including the period of rotation for irrigation water. The authors report that, one borewell water was being shared by two to seven heirs, the mode being three heirs. Therefore, where, water is shared among two heirs, each heir will get irrigation, every alternative day. In the case of three heirs, each heir gets water twice a week to irrigate their farm. This also has been a function of yield of borewell, the number of heirs among whom shared and the acceptable cropping pattern. As the number of heirs increased, farmers cultivated the less water intensive - high value crops such as flowers. The shared well farmers had higher proportion of area under flowers compared with control farmers. This reflects the role of water institution in augmenting economic efficiency in water use.

The profile of irrigation wells, amply indicates that water institution such as sharing of water, enhances not only the proportion of functioning wells, but also the age of wells, both of which add to sustainable use of water as also reducing the reciprocal negative externality, rampant in hard rock areas. For shared well farmers, cost of groundwater reduced by 78 percent (Rs. 415 per ha cm on control farms vis-à-vis Rs. 199 per ha cm on shared well farms) and the net return per rupee of groundwater increased by 50 percent over control farmers. The study has pointed out that the marginal product of groundwater is Rs. 5,705 per acre inch for 88th acre inch of water used on the shared irrigation well farms. There is a mistake in interpretation. Since linear function has been used, this MP is Rs. 5705 irrespective of the level of use of water, and not specific to the 88th acre inch or ha cm. What is crucial to note is the quantification of the water institution – that the gross returns are shifted up by Rs. 2,11,782 by sharing of irrigation well water among siblings, resulting in a total returns of Rs. 4.47 lakhs per farm (Table 5). This certainly is an impressive performance of water institution. The authors could have also tried using a slope dummy variable, which would have shown the rate of increase in gross returns on water sharing farms compared with control farmers.

Further, using the Pontryagin's maximum principle – optimal control theory, the author has demonstrated that by honoring the institution of sharing well water for irrigation, the life of irrigation wells will be around 45 years, when compared with farmers who are not sharing water, in which case the life of irrigation well is just 8 years. The discounted net benefit per shared well farmers was Rs. 78,349, while it was a mammoth Rs. 317891 for control farm situation (Table 6) and this amply reflects that sustainability implies sacrifice on the part of farmers in terms of returns, but can reap sustainable net returns every year for 45 years, while control farmers will have to drill another (uncertain) well, to continue their farming. The results from the use of intercept dummy variable to reflect the contribution of the institution of sharing (Rs. 2.12 lakhs per farm) is not reflected in the discounted net benefit from the application of optimal control theory trajectory. This needs to be reexamined.

C. Role of Irrigation

In the third sub theme, the following two papers are discussed:

In the article by Shivendra Srivastava *et al.*, the authors focus on unsustainable groundwater use in Punjab agriculture drawing insights from the Cost of Cultivation survey (from cost of cultivation scheme data). Rohith *et al*, discuss why and how cost of irrigation is not accounted in computing the cost of cultivation and thereby the DES/CACP methodology underestimates the cost of cultivation of crops and obviously overestimates net returns.

Srivastava *et al.*, evaluate whether groundwater use in Punjab in crop production is optimal, indicating reasons for its over use. The estimate of volume of groundwater extraction for paddy, wheat, cotton, sugarcane and maize, the major crops in Punjab in terms of cubic meters per hour is drawn from CCS data. However, as mentioned earlier, in none of the RT forms of CCS, such data are recorded. The authors indicate that the irrigation hours (hours per ha) for each crop and plot are obtained from CCS data. Without any information on the yield of groundwater per hour from borewell, recorded in any of the Record Type (RT) forms of CCS, it is unclear how the authors obtained or estimated the information on plotwise water applied. Using the information from RT 710 on crop operation hours, it is possible to obtain the number of hours irrigated for each crop in each plot. However, there is no information on water yield of the well. The following formula used by the authors

$$\text{Groundwater draft (lit/sec)} = \frac{\text{Hp} \times 75 \times \text{Pump efficiency}}{\text{Total head (m)}}$$

and the total head cannot be the same for all borewells, as the head varies from well to well, and this information on total head is not available in RT forms of CCS. The information on yield of borewell is also not available in RT forms of CCS. Thus, such information needs to be obtained and the RT forms need to be revised to include information on all aspects of irrigation, precision farming and so on. This paper has incorporated volumetric measurement of groundwater in production of paddy and wheat which is the special feature of this paper though the authors have averaged the groundwater data for tehshil level.

The authors have estimated the Cobb-Douglas (CD) production function for paddy and wheat and the estimated coefficients are reported in Table 5. An important property of the Cobb Douglas production function is that it can accommodate economic optimal input leading to economic optimal output, provided that all the coefficients are in the second region of the production function (with the elasticity of production coefficients ranging between 0 and 1 (not including 0 and 1, since it does not accommodate the point of MP=AP as well as MP=0, due to the very property of the CD production function. However, in this study the elasticity of production of all the inputs meet the requirements of the CD function except the Labor input (hrs/ha) in both paddy and wheat crops. In the case of wheat, the cost of seed has the negative elasticity of production of -0.017. However since it is statistically not significant, it can be considered as equal to zero. But the labor hours has coefficient of -0.142 in paddy production and -0.023 in wheat production, and both these coefficients are statistically significant at 1 percent level. Hence the estimated model as well as the interpretations suffer from this violation of assumption of CD function. Accordingly it has to be reestimated either by dropping labor and/or other inputs in such a way that all the inputs will realise coefficients (elasticity of production) meeting the property of CD function. It is incorrect to ignore the negative coefficient of CD function and interpret the other coefficients.

The article has indicated that for paddy the MR/MC ratio is 0.48 indicating over use and for wheat the ratio is 2.47 indicating underuse (Table 6). In the estimated production function the coefficients estimated are interdependent on other coefficients, and accordingly the elasticity of production with respect to water which is estimated to be 0.036 in paddy and 0.062 in wheat, reflects that the factor share (= expenditure on water out of the total revenue in each crop). Groundwater being a crucial economically scarce input, the factor share is a modest figure ranging between 3 and 6 percent for the two crops, in itself is also suggestive of reestimating the production function, meeting the properties of the CD model. The cost of groundwater is estimated as Rs. 4182 per ha meter which works to Rs. 41.82 per ha cm. This cost also needs to be reexamined considering the groundwater depletion taking place in Punjab as also properly accounting for the cost of groundwater in the cost of cultivation of crops. The methodology of costing groundwater also needs to be reexamined in thus paper, since the cost of Rs. 41.82 per ha cm is too low and is not reflecting the type of groundwater over exploitation / depletion as reported in the very title of this paper "Unsustainable groundwater use in Punjab Agriculture…".

Agricultural economists and water resource specialists are yet to treat the scarce irrigation water as in economic input in the cost of cultivation of crops. G.V. Rohith *et al*, attempted to incorporate the cost of irrigation water in cost of cultivation of crops in Karnataka for the years 2008-10 using the CCS data. The authors indicate that "In India irrigation water cost is not properly accounted by the CACP/FMS. It is crucial to revise the methodology followed by CACP by properly accounting for cost of groundwater".[5] The authors indicate that due to high probability of well failure in hard roc areas, farmers are forced to frequently invest on borewells / tubewells / wells as the life and age of wells is falling with the result that wells yield water for around 1 or 3 years or even lower, which used to serve for 20 or 30 years before. Thus, the investment on wells need to consider the variable cost and fixed cost. The present methodology of DES/CACP considers investment on wells as a fixed cost accounting for depreciation. This ignores the failed wells and the associated investments. Thus, the authors indicate that the existing method under estimates cost of groundwater assuming that wells serve along with irrigation pumpsets. However, life of pumpset differs from the life of irrigation well/s.

Hence depreciation of irrigation equipment representing the fixed cost of water, underestimates the real cost of water, Hence the irrigation water also has the variable cost component which helps in decision making. The authors explain all the Record Types (RT) of CCS field forms dealing with irrigation (Table 1). Here the type of data collected for all the crops pertaining to irrigation and the modifications necessary in the RT forms by including data such as yield of the irrigation well, whether the well is functioning or not, volumetric measurement of water pumped, are suggested. In Table 3, the Costs and Net Returns from Borewell irrigated crops (Rs. /ha) for 2008-10 for Karnataka are highlighted. It is interesting to note that the cost of groundwater irrigation (canal irrigation) forms 19.22 (6) percent of the cost of cultivation of ragi, forms 35.48 (13.01) percent of the cost of cultivation of sugarcane, forms 40.5 (7.44) percent of the cost of cultivation of paddy, and 43.86 (5.50) percent of the cost of cultivation of Maize. This shows how expensive is groundwater in relation to surface water, which is also heavily subsidised. If the cost of groundwater is not properly accounted, the net returns from these crops also are also overestimated.

In addition to computation of net returns at market prices where subsidies are subsumed, the net returns are computed at economic prices, where subsidies are treated as cost. The net returns are computed at natural resource values incorporating the benefits from nitrogen fixation in leguminous crops and the costs due to GHG emissions. Lastly the net returns are computed by including the cost of groundwater irrigation which worked to around Rs. 200 per ha cm for the years 2008-10. The authors highlight that the extent of under estimation of cost of cultivation varies from 16 per cent to 49 per cent of the cost of cultivation in the case of groundwater irrigated crops and 4 per cent to 14 per cent in the case of canal irrigated crops. Therefore at present, the MSP which is also based on the CCS data, does not include and property account for the cost of irrigation water in the cost of cultivation of the principle crops cultivated. The authors conclude that the extent of under estimation of cost of cultivation varies from 35 per cent in sugarcane to 40 per cent in paddy. In canal irrigation, MSP offered does not cover the costs incurred on water in paddy, ragi, jowar, bajra, cotton, sugarcane, though the estimated cost of canal irrigation formed 4 percent to 14 percent of the cost of cultivation. This article has reiterated the need to revisit and revise the methodology of cost of cultivation and MSP offered, by properly accounting for the crucial input in agriculture, being the cost of water for irrigation.

Considering the research articles accepted as summaries, two articles discuss the role of technology, nine discuss the role of institutions and six discuss the role of irrigation.

R.N. Barman discusses the extent of gaps in adoption of technologies in rice wheat, rapeseed, mustard, jute and sugarcane in Assam. Non-availability of quality seeds and planting materials are reported to be constraining production of rice. The optimal plan using linear programming does not incorporate risk involved, water used for irrigation. Incorporating results of Cobb Douglas production function regressing crop output on area, in optimal crop plan may also improve the results of the study, is used in the optimal crop plan could not be known. Sukhpal Singh *et al.* in their article highlight the dynamics of land use in Punjab from 1970 to 2011 and crop pattern from 1980 to 2011. They highlight that the extent of diversification of agriculture ranges from 1 to 2 percent as the State has specialised in rice and wheat cultivation. Using DEA, the authors report impressive technical efficiency in all crops except rice (0.4). However in basmati rice (0.82), wheat (0.71), sugarcane (0.99) and cotton (0.92) the technical efficiency was impressive. The authors report that despite poor technical efficiency in rice, the reason for increase in rice area is due to MSP and assured procurement. The article makes mention of the agroecological problems due continuous rice-wheat cropping system. Considering the significant improvement in agriculture in West Bengal, Anjan Chakrabarti gives credence to the role of green revolution technology as well as functioning of panchayats in augmenting production and productivity. The author concludes that economic reforms had positive relationship on agricultural productivity. The level of adoption of recommended doses of fertilisers by farmers of Gujarat is analysed by Mrutyunjay Swain *et al.* who found that the level of adoption of recommended doses of fertiliser based on soil test was low even though it benefitted the farmers in realising higher productivity and income. The quality of program implementation was not adequate which would have helped farmers to increase their adoption levels.

The role of micro finance in Srikakulam, Andhra Pradesh is examined by Tata Rao Dummu using limited dependent variable models. The transaction cost of borrowing was higher from formal sources of finance than from informal sources and reduced considerably in group lending. Highlighting the scarcity of groundwater and coping mechanisms, N. Nagaraj *et al.* share their experience from the VDSA villages of Karnataka. They recommend incentivisation of farmers to promote efficient use of ground water resources in addition to improvements in irrigation systems, water transfer between basins, water harvesting techniques, and efficient agricultural water management. In addition, the authors recommend precision irrigation technology, outreach for promoting water saving technologies as also water recharge technologies. Similarly D. Suresh Kumar shares the watershed development experience from Tamil Nadu analysing the contribution of women participation in SHGs resulting in welfare of household as reflected in quality and quantity of food consumed, health of family and improvement in children education. Mary Prathyusha Gondi, and S.M. Feroze, analyse the role of agribased SHGs in Meghalaya and reported their positive role in improvement in livelihood of SHG members. Vinod Kumar highlights the role of Water Users Associations in equal distribution of water resulting in reduced water disputes, augmented crop productivity, improved cropping intensity, shift towards high value crops, reduced distress migration, and improved self employment opportunities in Rajasthan. The role of irrigation in reducing the inequality in addition to land distribution in Kalahandi district is analysed by Ramya Ranjan Patel.

Ram Singh *et al.* highlighted the role of mobile based agroadvisory services in remote village of Meghalaya, benefitting ginger crop, artificial insemination and vaccination in pig. However, the paper does not also emphasise on the role of human touch which is crucial for farmers despite the role of ICTs. Similarly the role of Roads and market infrastructure in agricultural development of Punjab is highlighted by M.K. Sekhon and Amarpreet Kaur. They found that that the road length significantly impacted the value of agricultural output improving connectivity with urban markets.

Sunil Bhaskar Rao Nahatkar and Parvez Rajan computed correlation between percentage area irrigated and wheat productivity and report impressive correlation coefficients for two periods (1990-91 to 2001-02) and (2002-03 to 2013-14). As correlation does not indicate causation, it is difficult to conclude the causal factor/s. For Bundelkhand region of Uttar Pradesh, Babu Singh *et al.* report that assured irrigation facilities resulted in expansion in cultivated area, increase in livestock and improvement in crop productivity. Similarly for Madhya Pradesh, Kamlesh Kumar Shrivastava and Sunil Sharma have documented the role of irrigation in agricultural development. The impact of different sources of irrigation in Rajasthan is analysed by O.P. Singh *et al.* and their results have shown that farmers realised highest net income per ha under conjunctive irrigation followed by surface irrigation. Biplab Sarkar documented that farmers in Amarsinghi village of West Bengal benefited from electricity run state owned deep tubewell in comparison with diesel pump run tubewell. Analysing the expansion of drip irrigation in Rajasthan, Anisha Modi reports that drip irrigation is influenced by subsidy scheme and is not independent of the subsidy component and suggests to remove the bottlenecks involved in subsidy scheme for its expansion.

NOTES

1. http://www.aercpau.com/docs/Punjab per cent20Profile.pdf browsed on 17th oct 2015, 9 am.

2. http://www.aercpau.com/docs/Punjab per cent20Profile.pdf browsed on 17th Oct 2015, 9.45 am

3. http://cgwb.gov.in/documents/papers/incidpapers/Paper per cent2011- per cent20sushil per cent20gupta.pdf browsed on 16th Oct 2015, 7.45 pm.

4. S. Jin, W.Yu, HGP. Jansen, R. Muraoka, 2012, The impact of Irrigation on Agricultural Productivity: Evidence from India, International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012. http://ageconsearch.umn.edu/bitstream/126868/2/The_impact_of_Irrigation_on_Agricultural_Productivity_Evidence_from_India.pdf browsed on 18th Oct 2015, 7.45 AM.

5. Summary recommendation of Inter Conference in Indian Journal of Agricultural Economics, 2014, Vol 69, No.4, p. 503.