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Irrigation and Food Security: A Quest for Distribution, Ranking and Relationships in the districts of the Punjab Province, Pakistan

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Abstract

It is stylized fact that irrigation plays pivotal rolein crop husbandry, enhances many folds yields per acreand this may, consequently, have augmented food security. This study was devised to observe the irrigation distribution / inequalities in the districts of the Punjab province of Pakistan. These districts were ranked as per irrigation distribution / inequalities, ratios of water availability through various modes of irrigation including canal, Tubewell, canal plus Tubewell and overall irrigated area to total cultivated area. Moreover,impacts of target variables were quantified onfood insecure population (%). In this regard, cros-sectional data were collected form Punjab Agriculture Census Report 2010 (Government of Pakistan 2012) and food insecurity in Pakistan 2009 (SDPI, SDC, WFP 2009). Irrigation distributions / inequalities were estimated by using Gini Coefficient while ascending and descending orders were used for ranking of the districts for the target variables as per nature of the values of the indicators had been determined by using different tools. Moreover, econometric modeling was done using Multiple Linear Regression by taking food insecure population (%) as an endogenous while Gini values of irrigation distribution /inequalities, ratios of water availability for crop rearing per cultivated area including some control variables like Gini of operational farm holdings, farmers' literacy rates, farms using chemicals (%) and livestock population per acre in the districts. Results were found as expected that food insecurity increases with rise in Gini of irrigation distribution and vice ver. Moreover, food security increases with rise in water availability through various modes of irrigation.

Keywords: district ranking, Irrigation inequality, Canal irrigation, tubewell irrigation, canal plus tubewell irrigation,water distribution, food security, food insecurity, Punjab, Pakistan

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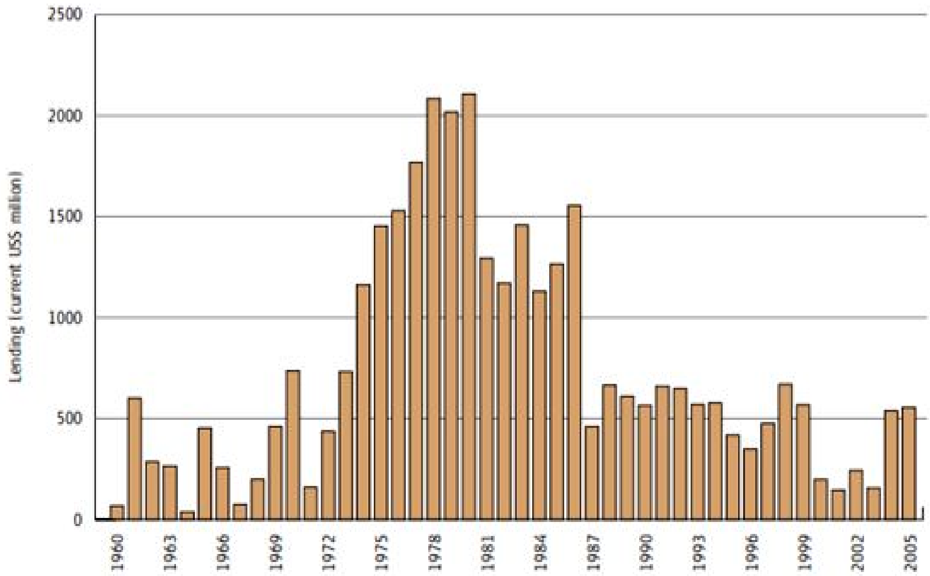
1. Introduciton

Food Security for all means that people at all times will have economic and physical access to adequate level of nutritious, safe and culturally appropriate food and energy (The World Food Summit, 1996). According to Dietary Energy Supply (DES), there should be 2800 kcal/person/day available as national threshold in order to avoid countries to suffer from severe chronic under nutrition (United Nations, 2006).Having the paramount importance, malnutrition and hunger have been top ranked in the MDGs of the United Nations.Despite the sincere efforts by the public and private sector organizations there were still 847 million undernourished in 2010-2012 as compared to 979 million in 1990-1992 people, living over the globe(ADB, 2013). Moreover, a meager amount of hungry population reduced from 325 to 299 million in South Asian region in the same period (Ibid).The scenario is not different in case of Pakistan where 66% of the rural populationhas failed to fulfill the needs of the rest of population of the country (Government of Pakistan 2012-13).According toFood Insecurity Report Pakistan (SDPI, WFP and SDC 2009),61% districts (i.e. 80 out of 131) of the country were below the critical levels of food security. Moreover, the report exclaimed that amongst the 48.6% food insecure population 22.4% wereextremely food insecure. As per National Nutritional Surveyof Pakistan (UNICEF, 2011), 58% of the households are food insecure in the countrywhile the hungry population increased from 35 million to 45 million in past few years consumingless than 1700 calories per day. These grave food security issues can be only resolved by taking serious measures to facilitate food production.

Food is produced in rural areas employing various factors of productions like land, water, labor, seed fertilizers, pesticides, machinery etc. though all the factor of production are extremely significant but water is no doubt the vital factor for the sustainable food production (Munir, et.al. 2010). Agriculture uses 70% of the fresh water available for human use, making them largest user of water (United Nations, 2006).This water resource not only maintains the crop production level but also helps in poverty alleviation of crop and non-crop producing farmers'.

Historically, it is the proven fact that the lands with easy access to water produce more than double as compared to rainfed farming systems(WDR, 2008).

However out of total available crop lands (i.e. 13 billion hectares)only 18% is well irrigated(United Nations, 2006). There exists only 4 percents of irrigated agriculture in Sub-Sahara Africa as compared to 39 percents in South Asia and 29 percents in East Asia, having strong implications for food security / food insecurityin the concerned regions. Due to the significance of irrigated agriculture International institutions like World Bank played a pivotal role in development of irrigation infrastructurein the continents of the world. In this regard, a number of studies concluded that investment(Figure 1) on irrigationinfrastructure would make only a moderate contribution to agricultural production and agricultural GDP (Fan et al. 2000, Fan and Chan-Kang 2004),while a large number of studies claimed that this investment has large economic gains (Huang et. al. 2005, Barker et al. 2004, Hussain and Hanjra 2004, Rosegrant et al. 1998, Datt and Ravallion 1997).



Source: United Nations, 2006

2. Review of Literature

This part of the paper would precisely enlighten the benefits of irrigation in agricultural production, poverty alleviation etc. cited in previous empirical and review studies.

A study conducted in Khyber Pakhtun Khaw Province, Pakistan, concluded that easy availability of water improved the cropping pattern and land use intensity in the study area (Pervaiz, et al. 2010).However, Jin et. al. (2012) observed similar trends like improvements in cropping intensity due to irrigation in their study.

Hussain *et al*. (2004) stated that rise in water availability makes crops less prone to arid and semi arid climates. Moreover, Swati *et al*. (1985) observed that any increase in the number of irrigations were equally associated with an increase in yield and yield components. However, similar results were also delineated by Kuixianget. al. (1994) on observing increase in wheat grain yields with the increase in water from 0 to 1200 to 2400 m^3.

According to review of World Bankfunded (IEG 2006) and International Water Management Institute assisted projects (ADB/IWMI 2005) irrigation has significant role in poverty alleviation and increasing economic growth. There are direct and indirect ways affecting poverty via irrigation. As far as the direct effects are concerned that availability of irrigation enhance crop intensity and diversification, augment yields per hectare and in turn increases yields, income, employment and consumption of the households. However, it indirectly increases the employment of landless farmers as well as their wages. Moreover, rise in production due to better irrigation availability reduce food prices and, consequently, make easy food access to the poor. This is also confirmed by many other studies that crop yields is higher in irrigated areas as compared to rainfed ones in all of the developing countries of the world (Lipton et al. 2005, Hussain and Hanjra 2004, Ringler et. al. 2000 Rosegrant and Perez 1997).

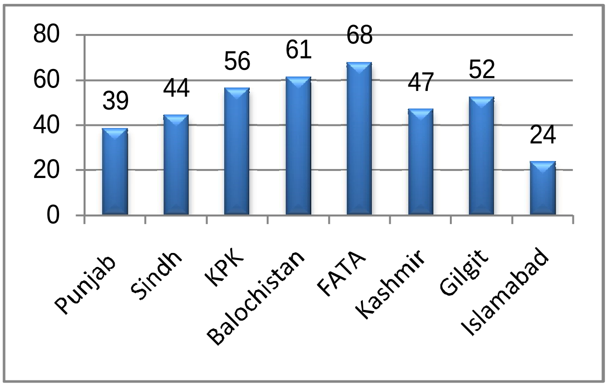
As far as reliability of water availability through different modes of irrigation are concerned, Munir et al. (2002) studied wheat farms in Pakistan and found that canal irrigation is the least reliable source of irrigation while they found combination of tubewell and canal as most reliable and categorized tubewell irrigation in the middle of both aforesaid sources. They also concluded that the reliability of the water source also affects the crop productivity and, consequently, bring higher yields as compared to non-irrigated farms. Moreover, about similar observations were corroborated by Meinzen-Dick and Sullins (1994), they also found lesser yield impacts of canal irrigation as compared to tubewell.

Hussain and Wijerathna (2004) concluded that areas with irrigated lands have 20-30 percents less poverty as compared to non-irrigated ones.

However, they opined thatthis effect is also different for different types of cropping systems withdifferent water quality. Moreover, Van den Berg and Ruben (2006)conducted a study in rural Ethiopia and observed that irrigation is highly beneficial for the farmers directly involved in crop production. They also concluded that farmers having irrigated lands are less poor as compared to the farmers with non-irrigated lands.

As this study was rendered in Pakistan and, therefore, it would be appropriate to highlight water resources situation in Pakistan. Pakistan's agriculture uses 95% of its total water resources (Government of Pakistan 2002).The composition of water supply accounts for 15% from rainfall, 60% from Indus River System i.e. canal irrigation and remaining 25% is extracted from groundwater resources (United Nations 2000).The total irrigated area (18.67 million Ha) in Pakistan is supported by canal irrigation (6.40 Million Ha), canal plus tube well irrigation (7.60 million Ha), tubewell irrigation (3.92 million Ha) and with some other minor sources (Government of Pakistan 2011-12).The irrigation system of the country is the largest contiguous system of the world which supports 80% cropping intensity per annum while 50% duingKharif and 30% during Rabi seasons (Starkloff and Zaman 1999).

Figure.2: Territorial distribution of Food Insecure Population in Pakistan (%)



Source: Food Insecurity Report Pakistan (WFP, SDC and SDPI 2009)

As food security situation is not much encouraging in Pakistan (Figure 2) and water availability direly needed for better crop husbandry to address this grave issue.

Therefore this study was devised to explore the water distribution in the districts of the Punjab, the largest province of the country in terms of population, water use and agriculture production. Moreover, ranking of the districts of the province has been rendered on the basis of water inequality with respect to farm size and ratios of water availability through various modes of irrigation to total cultivated area. Furthermore, impact of water distribution, ratios of water availability through various modes of irrigation to total cultivated area on food security trends were also gauged in the province under study.

3. Methodology

This part of the paper exhibits the brief description of the target study area, data, data sources and analytical tools rendered to achieve the objectives of the study.

3.1. Study Area and Data Description

Punjab is the largest province of Pakistan. It shares 55 % population, contributes 57 % of the cultivated area and caters 69 % of cropped area for crop production as well animal husbandry (Government of Punjab, 2013). Moreover, Punjab produces lions' share of staple food and cash crops like wheat (76%), rice (70%), sugarcane (68%) and cotton (69%), respectively, of the total production of the country (Ibid). Therefore, population of the country, mainly, depends upon Punjab for its food needs. The province has been stratified into 35 administrative units called districts. As per best of our knowledge, distribution of resources like water/irrigation amongst the districts has yet not been empirically explored. In this regard, crossectional data was attained from various secondary data sources i.e. Punjab Agricultural Census Report 2010 (Government of Pakistan 2012) and Food Insecurity in Pakistan 2009 (World Food Program, SDC and SDPI, 2009).

As far as the descriptions of variables are concerned, food insecure population was used in the form of percentages as per availability from the data source. Moreover,ratios of overall irrigated area, canal irrigated area, tubewell irrigated area and canal plus tubewell irrigated area to total cultivated area of all of the districts of the Punjab province were used to achieve the objectives of the study. Furthermore, distribution of overall irrigated area with reference to their farm size categories (i.e. less than 1, 1 to less than 2.5, 2.5 to less than 5, 5 to less than 7.5, 7.5 to less than 12.5, 12.5 to less than 25, 25 to less than 50, 50 to less 100, 100 to less 150 and, 150 and above) were quantified by using Gini Coefficients.

4. Data Analysis

Before using any kind of statistical data analysis tool, variables of interest were converted into desired format e.g. Gini Coefficients of overall irrigated area was estimated while rest of the variables regarding irrigated area were converted into their ratios with their total cultivated area available in the districts.However, following methods of data analysis were employed to achieve the objectives of the study.

4.1. Gini Coefficient (GC)

GC is a World Bank recommended and globally acknowledge tool to determine resources/wealth inequality. Its numeric values (i.e. 0 to 1) delineate perfect equality and perfect inequality, respectively. Prior to rank the overall irrigated areas in the districts reference to their farm size categories was converted into their GC byusing following mathematical expressions i.e.

$$GC = \sum_{i=1}^{n} \frac{(\mathbf{X_{i+1}})\ (\mathbf{Y_i})}{(\mathbf{X_i})\ (\mathbf{Y_{i+1}})}$$

Where,

i and n means number of observations from 1 to n while X_i means cumulative percentage of frequency with respect to number of farms corresponding to the size of class (X_i =1,2,3…..n). Moreover, Y_i means cumulative percentage of frequency with respect to farm area corresponding to the size of class (Y_i =1,2,3…..n) while $\sum$ is sign of summation.

$\mathbf{X_{i+1}}$and $\mathbf{Y_{i+1}}$= Preceding observation of X_i and Y_i

4.2. Districts Rankings

On the basis of available data in hands after their conversion into GC and Ratios were ranked to know the positions of the districts in the concerning irrigation inequality. Raking of the districts on the basis of GC of overall irrigated areas were undertaken in ascending order while the rest were ranked in descending order.

4.3. Econometric Models

Multiples linear regression modeling were rendered to observe relationships of Gini of overall irrigated area, ratios of canal, Tubewells, canal plus Tubewells irrigated area to total cultivated area with food insecure population (%). OLS (i.e. Ordinary Least Square) method of estimation was employed to determine the relationships between endogenous and exogenous variables under study. Moreover, enter method of regression was rendered to model the available variables and quantify the relationships by using SPSS 20 (i.e. Statistical Package for Social Scientists). Nevertheless following econometric models was selected to explain the results of the study.

$$FIP = \beta_0 + \beta_1 GIA + \beta_2 RCTI + \beta_3 RTI + \beta_4 RCI + \beta_5 GOPFH + \beta_6 LSPPA + \beta_7 CHEM + \beta_8 FLR + \mu$$

Where,

FIP means % food insecure population in the districts of Punjab while GIA, RCTI, RTI, RCI, LSPPA, CHEM and FLR stand for Gini of irrigated area, ratio of canal plus Tubewell irrigated area to total cultivated area, ratio of Tubewell irrigated area to total cultivated area, ratio of Canal irrigated area to total cultivated area, Gini of Operational farm Holdings, Livestock population per acre, percents of farms with chemicals (Pesticides+ herbicides+ fungicides) and Farmers' literacy rate in all of the districts of the Punjab province. Besides the irrigation variables, the rest indicators have been used as control to get the econometric model fit and significant.

5. Results and Discussion

The result and discussion part of the paper have been arranged in a sequential manner to describe ranking and then relationships between endogenous and exogenous variables. Table 1 shows the ranking of the districts on the basis of Gini Coefficients of the overall irrigated area with reference to their farm size categories in all of the districts of the Punjab. It is evident from the table that Rawalpindi, Gujrat and Sialkot are top ranked with least irrigation inequalities in the province while Attock, Layyah, Bhakker, Mianwali and Sargodha are found in the end of the table with highest irrigation inequality in these districts. However, Sahiwal, Sheikhupura and Kasur lie in the middle of the table.

Having a keen look on the values of Gini Coefficients of the top and bottom ranked districts in table 1, it can be concluded that water distribution in all of the districts is highly skewed because it starts with 0.646 in Rawalpindi District and ends with 0.869 in Attock district.

Table.1: District Ranking of Gini Coefficient of overall Irrigated Area

Rank	District	IA	Rank	District	IA	Rank	District	IA
1	Rawalpindi	0.646	13	Rajanpur	0.735	25	Lahore	0.753
2	Gujrat	0.707	15	D G Khan	0.738	26	Hafizabad	0.762
3	Sialkot	0.710	15	Khanewal	0.738	27	Khushab	0.765
4	Jehlum	0.714	15	Sahiwal	0.738	28	MandiBahauddin	0.768
5	Muzaffargarh	0.717	17	Vehari	0.739	29	Bahawalnagar	0.772
6	Multan	0.722	18	Sheikhpura	0.744	30	Okara	0.775
7	Lodhran	0.723	19	Kasur	0.745	31	Sargodha	0.776
9	Balawalpur	0.725	20	Pakpattan	0.747	32	Mianwali	0.779
9	Nankana Sahib	0.725	22	Faisalabad	0.748	33	Bhakhar	0.804
11	Chakwal	0.727	22	Gujranwala	0.748	34	Layyah	0.820
11	R Y Khan	0.727	23	T T Singh	0.749	35	Attock	0.869
12	Jhang	0.729	24	Narrowal	0.752			

Source: Author Estiamtion from Punjab Agricultural Census Report 2010 (2012)

The following tables (2,3,4 and 5) delineates ratios of areas covered by different major modes of irrigation (Canal, Canal plus Tubewell and Tubewell) and overall irrigated area to total cultivated area in the their respective districts. Mix results has been found in all of the districts regarding the target indicators here. As far as ranking of districts regarding ratios of overall irrigated area to total cultivated area (Table 2) is concerned, it is evident from the table that districts from central, south and upper Punjab territories are not fixed with in top or bottom position in the table. Those are scattered around top bottom and central ranks of the table 2. Same is the case with table 2,3, 4 and 5. However, in most of the cases (i.e. table 2,3 and 5) districts belonging to Barani region of the province are found in bottom 6 districts of the tables. However, table 3 shows that Jehlum district is ranked 5^{th} in case of Tubewell irrigated area and it is the only district of the Barani region having such a high rank in any of the mod of irrigation in the province. This is first district of Barani region on the border of the central Punjab after district Gujrat. As canal irrigation is not available here, therefore, farmers are constrained to use tubewells for rearing their crops. Moreover, his might also be due to particular topographic patterns.

Having a look on table 3, it can easily be understood that due to less coverage (i.e. 42 % of cultivated area of top ranked district) of canal irrigation farmers has to lift ground waters with the help of tubewells to enhance their production and for risk aversion.

Table.2:District Ranking of Ratio of Overall Irrigated Area to Total Cultivated Area

Rank	District	IA/TCA	Rank	District	IA/TCA	Rank	District	IA/TCA
1	Lahore	99.84	13	Lodhran	98.96	25	Bahawalnagar	94.54
2	Okara	99.56	14	Sheikhpura	98.94	26	Jhang	91.21
3	Gujranwala	99.55	15	Sahiwal	98.90	27	Mianwali	69.72
4	Pakpattan	99.54	16	Rajanpur	98.87	28	Gujrat	66.61
5	Muzaffargarh	99.49	17	TTSingh	98.86	29	Layyah	50.08
6	Multan	99.46	18	Faisalabad	98.83	30	Jehlum	48.27
7	Vehari	99.28	19	Balawalpur	98.79	31	Bhakhar	45.96
8	Sargodha	99.26	20	Hafizabad	98.69	32	Khushab	36.86
9	MandiBahauddin	99.12	21	Khanewal	98.68	33	Attock	10.99
10	Kasur	99.04	22	Sialkot	98.53	34	Rawalpindi	4.27
11	R Y Khan	99.02	23	D G Khan	96.34	35	Chakwal	4.21
12	Nankana Sahib	98.98	24	Narowal	94.65			

Source: Author Estiamtion from Punjab Agricultural Census Report 2010 (2012)

Table.3:Disrict Ranking of Ratio of Canal Irrigated Area to Total Cultivated Area

Rank	District	CI/TCA	Rank	District	CI/TCA	Rank	District	CI/TCA
1	Kasur	42.12	13	Rajanpur	14.55	25	Sheikhpura	4.34
2	Lahore	40.29	14	Sahiwal	11.93	26	Lodhran	4.13
3	Sargodha	32.80	15	MandiBahauddin	11.76	27	Vehari	4.08
4	Faisalabad	32.56	16	Khanewal	11.71	28	Hafizabad	1.65
5	D G Khan	32.21	17	Okara	11.60	29	Pakpattan	1.23
6	NankanaSahib	27.68	18	Muzaffargarh	11.25	30	Attock	1.13
7	Bahawalnagar	27.25	19	Multan	8.64	31	Sialkot	0.96
8	Mianwali	27.04	20	Bhakhar	7.82	32	Narowal	0.58
9	Balawalpur	25.70	21	Layyah	6.03	33	Rawalpindi	0.25
10	T T Singh	24.20	22	Gujranwala	4.96	34	Jehlum	0.24
11	R Y Khan	22.22	23	Gujrat	4.81	35	Chakwal	0.03
12	Khushab	18.36	24	Jhang	4.44			

Source: Author Estiamtion from Punjab Agricultural Census Report 2010 (2012)

Table.4:District Ranking of Ratio of Tubewell Irrigation Area to Total Cultivated Area

Rank	District	TI/TCA	Rank	District	TI/TCA	Rank	District	TI/TCA
1	Narowal	86.33	13	MandiBahauddin	20.33	25	Pakpattan	8.94
2	Sialkot	84.59	14	Layyah	19.53	26	Okara	7.60
3	Gujrat	51.69	15	Toba Tek Singh	15.09	27	Lodhran	7.43
4	Hafizabad	43.67	16	Kasur	14.52	28	Bahawalnagar	6.82
5	Jehlum	43.39	17	Khushab	13.75	29	Sahiwal	6.45
6	Gujranwala	40.83	18	Nankana Sahib	13.72	30	Attock	6.15
7	Jhang	34.64	19	Multan	13.40	31	R Y Khan	5.75
8	Rajanpur	33.02	20	Sargodha	12.92	32	Vehari	4.64
9	Mianwali	32.12	21	Bhakhar	12.48	33	Chakwal	3.70
10	Sheikhpura	22.27	22	D G Khan	11.91	34	Faisalabad	3.28
11	Lahore	21.96	23	Balawalpur	9.69	35	Rawalpindi	1.82
12	Muzaffargarh	20.57	24	Khanewal	9.30			

Source: Author Estiamtion from Punjab Agricultural Census Report 2010 (2012)

Table.5: District Ranking of Ratio of Canal &Tubewell Irrigation Area to Total Cultivated Area

Rank	District	CI/TCA	Rank	District	CI/TCA	Rank	District	CI/TCA
1	Vehari	90.50	13	Faisalabad	62.97	25	Bhakhar	25.32
2	Pakpattan	89.36	14	Bahawalnagar	59.87	26	Layyah	24.46
3	Lodhran	87.38	15	T T Singh	59.55	27	Sialkot	12.84
4	Okara	80.32	16	NankanaSahib	57.55	28	Gujrat	9.56
5	Sahiwal	80.20	17	Gujranwala	53.68	29	Mianwali	8.27
6	Multan	77.28	18	Sargodha	53.50	30	Attock	6.15
7	Khanewal	76.56	19	Hafizabad	53.02	31	Narowal	5.56
8	Sheikhpura	72.21	20	Jhang	52.09	32	Khushab	3.63
9	R Y Khan	71.02	21	Rajanpur	48.68	33	Jehlum	2.04
10	Muzaffargarh	66.97	22	D G Khan	44.48	34	Rawalpindi	0.48
11	MandiBahauddin	65.85	23	Kasur	42.18	35	Chakwal	0.26
12	Balawalpur	63.30	24	Lahore	37.55			

Source: Author Estiamtion from Punjab Agricultural Census Report 2010 (2012)

Regression results of econometric model shows positive relationship between Gini of irrigated area .i.e. unequal water distribution with reference to their farm sizes and percent food insecure population residing in the districts of the Punjab province. Table 6 exclaims that 1unit rise in water inequality would increase about 14 unitsof food insecure population (%). Moreover, if it is taken in vice versa scenario in case of food security then rise in Gini of irrigation distribution would increase food secure population (%) in the study area. Although this relationship was expected but it had not been proven statistically significant.

Therefore, we cannot express these results asdefinite view point. Furthermore, the insignificant results might be due to small number of observations i.e. only 34. However, the relationships between ratios of irrigated areas to cultivated areas in all of the districts has been found negative with food insecure population as corroborated in table 6. Ina Pearson Correlation analysis(i.e. a pre-requisite of Multiple Linear Regression to check multicolinearity among exogenous variable) the relationship between ratios of canal irrigated to cultivated areas and food insecure population (%)were found positive which became

Table.6: Regression Results

Dependent Variable= FIP			**Collinearity Statistics**	
Variables	**Beta**	**p-value**	**VIF**	**Tolerance**
(Constant)	75.670	0.072		
GIA	13.744	0.775	1.59	0.629
RCI	-0.049	0.685	1.16	0.856
RTI	-0.036	0.683	1.61	0.618
RCTI	-0.120	0.073	1.82	0.549
OPFH	-50.118	0.382	1.91	0.521
LP	3.244	0.334	1.33	0.748
CHEM	5.050	0.036	1.33	0.747
FLR	-0.272	0.054	1.52	0.657
R^2	0.425			
F Stat	2.4			
P-Value of Mo(	0.04			

negative by controlling with farmers' literacy rates as given in the table 6. Unfortunately, most of the target exogenous variables like canal and Tubewell irrigation were found statistically insignificant including water distribution but canal plus tubwell mod of irrigation had been observed as statistically significant in the Econometric model. As no such work has been witnessed, yet, therefore it would be favorable to relate these relationships with farm production and poverty with water availability in the literature as given in the introductory part of this paper. Table 6 delineates the strongest relationship between canal plus tubewell irrigated area and food security confirming the similar findings between canal plus tubewell and farm productivity cited in literature (Munir et al. 2002)

6. Conclusions

The study was devised to observe the water distribution scenario and Ranking and relationships of other target indicators like ratios of overall, canal, Tubewell and, Tubewell plus canal irrigated area to total cultivated area with food security in the districts of the Punjabprovince, Pakistan. It was found that water distribution is extremely skewed in about all of the districts on the basisof available data. However, canal plus Tubewell irrigation with respect to total cultivated was found amply high in the entire districts of the province with the exception of few districts of Barani and thal region. On the basisof results of the study, it is recommended that policy makersmust work on better water distribution for greater farm productivity and in turn to increase food security in the province.

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