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Socio-Economic Analysis of Groundwater Resource Management for Balochistan, Pakistan

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Institute for Land, Water and Society

Socio-Economic Analysis of Groundwater Resource Management for Balochistan, Pakistan

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Photo Reference

- Pishin Sub basin, Huramzai site area (cover page) Photo courtesy Dr S.M.Khair
- Group Interview Meeting at Zarghoon (back cover page) Photo courtesy Dr S.M.Khair

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1 Executive Summary

- Pakistan is heavily reliant on its agriculture-based economy. Agriculture accounts for around 95% of the country's water consumption and more than 50% of this water is groundwater. In parts of the Balochistan Province, the dependence on groundwater for irrigated agriculture is up to 100%. Available groundwater is not sufficient to meet growing demands and there is immense pressure from over-extraction. Consequently, groundwater levels are declining. It is estimated that the groundwater decline in Balochistan, has reached several hundred metres. This makes pumping more expensive and undermines farming livelihoods, especially for poor smallholder farming families.
- This study, which formed part of a larger project focused on improving groundwater management to enhance agriculture and farming livelihoods in Pakistan, aimed to gain an understanding of the current agricultural and irrigation practices and sources of livelihood of farming families in the Balochistan Province and to provide recommendations for improved water use and agronomic practices.
- Interviews were conducted with 104 farmers from the Kuchlak and Pishin sub-basins of Pishin Lora Basin in Balochistan to gain an understanding of the socio-economic and demographic characteristics of farming households and the current irrigation and cropping practices of farmers.
- Analysis was also undertaken to determine: (1) the relative cost of different production inputs for different crops; (2) the efficiency of water, seed and fertilizer use; (3) the technical, allocative and economic efficiency of different crops; and (4) the degree to which over-watering of crops occurs.
- In both areas, the average age of the farmers was 38 years and they had an average of 17 years farming experience. This indicates that experienced persons are heading the households. However, very few farmers had received any training from agricultural extension officers or from NGOs. The average family size was quite large, around 23 persons, and this was due to joint family system (rather than nuclear or extended family) prevailing in the area in which people prefer to live together for many socio-cultural reasons
- Income is generated from both cropping and livestock (e.g. sheep, goats, cattle and buffalo). The income generated from livestock can be particularly important in the off-season. Livestock are mainly used for milk and meat production. Animals are sold in the markets to earn income. Milk is also sold in the markets, but some is consumed at home. Over 90% of what is produced from crops is sold at the markets indicating commercial farming.
- The majority of farmers (> 80%) acquire their crop inputs (seed, fertilizer, pesticide and diesel fuel) through credit from non-institutional sources such as inputs dealers, *arthis*¹, and friends/relatives due to difficulties in accessing institutional credit. In addition to the need for credit to purchase crop inputs, unavailability of inputs on time, high prices of inputs and lack of awareness regarding the quality of inputs lead to difficulty in attaining crop inputs.
- For cropping, traditional irrigation practices are used and much of the area is irrigated using the traditional flood irrigation method. However, water shortages do occur and 53% of farmers reported that water shortages were most common in the Kharif (summer/monsoon) season while 16 % reported it in Rabi (winter) season. The majority of farmers (96%) use their own tube-wells, while the remaining (4%) were using Karez/spring as source of irrigation. The tube-wells are reliant on the national grid for

¹ Is a marketing functionary also called Commission agent who charge a certain rate of commission for selling the produce through auction process

electricity supply which is rationed and supplied for six hours a day, so during periods of water shortage, some farmers rent electric generators.

- The gross margin analysis showed that the largest cost incurred cost was associated with irrigation which ranged from 45% to 70% of variable costs for different crops and fruits. The cost associated with renting electric generators during times of water shortage (such as the drought in 2018) further increases the cost of irrigation.
- The average water use efficiency was 76% in the Pishin sub-basin whereas it was 70 % in the Kuchlak sub-basin. This indicates that water use efficiency can be improved in both areas. Among the crops grown, wheat crop production was more water use efficient while tomato, apple and apricot were less efficient with significant scope for improvement.
- In line with the water use efficiency results, the analysis of technical, allocative and economic efficiency showed that there was room for improvement for all of the crops (apple, apricot, tomato and wheat). In addition to inefficiency in relation water, there are some inefficiencies in fertilizer and seed use. For example, the average fertilizer use efficiency was 70 % in the Kuchlak sub-basin whereas it was 81 % in the Pishin sub-basin.
- The water productivity analysis showed that under the current irrigation system (mainly flooding) farmers are using 50% more water than the actual crop water requirement. The tomato growers in the Kuchlak sub-basin achieved the highest productivity (2.59 kg/m³ of water). However, the comparison of results of this study with those of other studies undertaken nationally and internationally shows that water productivity in Balochistan is below the national and international levels.
- The results from this study indicate that there is a need for farmers to be educated and trained and for irrigation practices to be changed so that irrigation water is used more water efficiently and wasteful use of water is reduced. The installation of high-efficiency irrigation systems would increase crop yields and help minimize groundwater stress in the basin.

2 Introduction

Pakistan is among the most groundwater dependent nations in the world and currently, is the third largest consumer of groundwater, accounting for about 9% of global groundwater withdrawals (Fiene and Arshad, 2016). Approximately 1.4 million tube-wells have been set up throughout the country (Watto and Muger, 2014) and this has resulted in massive pumping of groundwater and an associated rapid decline of water tables. The continuous decline of groundwater levels which has been observed not only in Pakistan but throughout the Indus Basin more broadly, points to an imbalance between the groundwater extraction and its recharge (Watto and Muger, 2016).

Balochistan is the largest of the four provinces in Pakistan. Groundwater is a major source of water for irrigation in the Province. Groundwater pumping commenced after the 'Green Revolution' in the 1960s and with electrification of the rural areas it grew exponentially. Groundwater extraction has been important for the agricultural sector as farmers with access to groundwater have 50-100% higher crop yields than those applying surface water only (Qureshi et al., 2010). Today around 50% of overall irrigation requirements are fulfilled via groundwater extraction in Balochistan as well as in Pakistan more broadly (Watto and Muger, 2016; Khair et al., 2019).

The massive dependence on groundwater has been associated with a behavioural norm among agricultural families, to overuse groundwater and in the main, this has been due to subsidized electricity. The relatively low cost of extracting water has resulted in the extraction of groundwater far exceeding its replenishment, and this has caused resource depletion in many basins in Balochistan (Khair et al., 2015). The high dependency of farming communities on groundwater has resulted in some 73% of households surveyed in the area experiencing income decline owing to groundwater depletion with a similar effect on livelihoods (Nasrullah et al., 2011). With diminishing water reserves and low agricultural water productivity, it is important to improve water use efficiency and to make efficient use of available water reserves (Watto and Muger, 2014).

There is significant potential to improve groundwater practices through improved water use efficiency or, more importantly, improvements in water productivity to enhance crop yield and improve farming livelihoods (Molden et al., 2010; Sharma et al., 2015). However, innovative management techniques are needed to enhance groundwater supply and to manage its demand more effectively. Even a modest rise in groundwater productivity would have significant benefit given that over 50% of Pakistan's irrigation requirements are met through groundwater (Qureshi et al., 2010).

Irrigation water use efficiency can be defined as the amount of water actually utilized by the crop compared to the amount of water supplied to that crop (Watto and Muger, 2016; Susanne et al., 2018). In a broad sense, water use efficiency relates to the net socio-economic and environmental benefits achieved through the use of water in agriculture. Water productivity relates to the amount of production per unit of water. Increasing water productivity is particularly important where water is scarce compared with other resources involved in production (Sharma et al., 2015). When water is a scarce resource, it is important to maximise production by considering other production inputs, namely fertilizers, high-quality seeds, tillage and land formation, labor, electricity and the use of machinery. A good understanding of the measurement and improvement of water productivity can thus constitute a strategic response to growing water scarcity (water demand) and optimization of other production inputs to enhance farm incomes and livelihoods (Sharma et al., 2015).

The study reported here is part of the the Australian Centre for International Agricultural Research (ACIAR) project LWR-036, that is focused on improving groundwater management to enhance agriculture and farming livelihoods in Pakistan. This integrating project is bringing together a range of organisations, and combines biophysical, social and economic inquiry.

This study aimed to gain an understanding of the current socio-economic characteristics of farming households in two sub-basins (Pishin and Kuchlak) of the Pishin Lora Basin (PLB). The majority of fruits, vegetables, and crops in Balochistan are produced in the PLB. As such, a significant proportion of people in the PLB are dependent on the agriculture sector for their

livelihood. The two focal sub-basins (Pishin and Kuchlak) are case study areas for the larger LWR-036 project. In both sub-basins, water, seed and fertilizer use efficiencies were determined using a non-parametric model to determine how efficiently the farm families are at using these crop inputs. This study will guide improved groundwater use and farm livelihoods in these areas of Balochistan.

Objectives:

The objectives of the study were to:

1. Describe the socio-economic and demographic characteristics of farming households in selected areas of the Pishin Lora Basin
2. Highlight the current irrigation and cropping practices of farmers
3. Estimate the farm level technical, economic and water use efficiencies of key crops including tomato, grapes, wheat and apple
4. Highlight the problems faced by farmers; and
5. Suggest measures for improved water use and agronomic practice

3 Methodology

3.1 Study area

The study was conducted in two sub-basins of the Pishin Lora Basin (PLB) namely the Kuchlack sub-basin (KSB) and the Pishin sub-basin (PSB). The PLB is one of the major river basins in the Balochistan Province (Figure 1.1 and 1.2). The drainage direction of the major streams in the PBL is from north to south in the northern parts and from south to north in southern parts. The streams tend to flow towards the west after meeting the principal stream (Pishin Lora). The main streams are Shore Rud, Bostan-Lora and Pishin-Lora. The Shore Rud drains the southern part of the basin (Kalat, Mastung, and Shirinab), the Bostan-Lora drains the south eastern part (Kolpur, Quetta and Kuchlak) (Halcrow, 2008). The PLB receives low rain fall and experiences high rates of evaporation and temperature. The average monthly rainfall is around 217.67 mm.

Traditionally agriculture used the ancient and community-managed karez systems, where groundwater is tunnelled from higher underground storages for use by communities below (Khan and Nawa, 1995). Aquifer storages in Balochistan have localised spatial limits, which have allowed local management of karezes to work well over many generations of use, but have enabled localised aquifer depletion from mass installation of tube-wells.

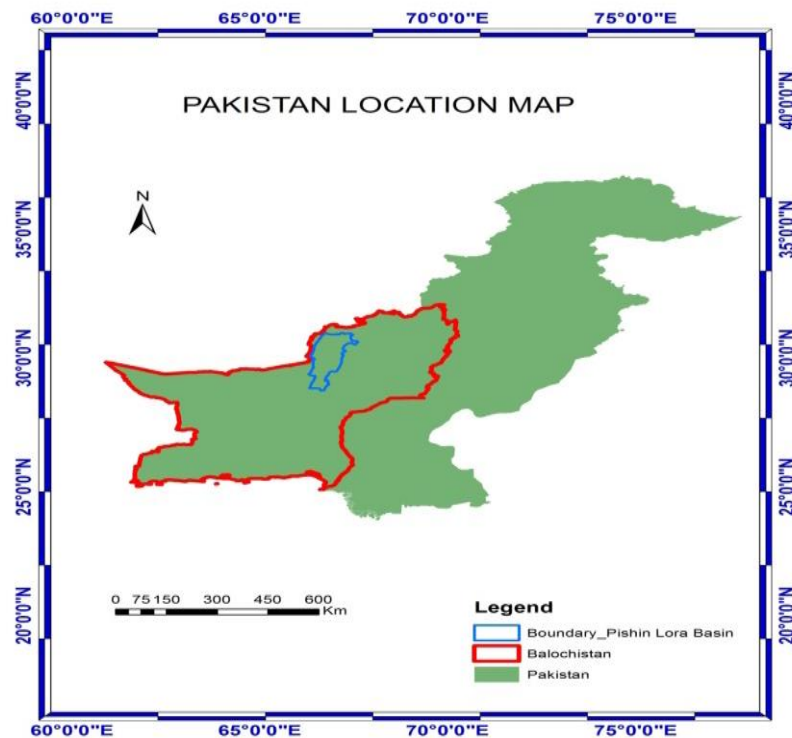


Figure 3.1: Location of Pishin Lora Basin in the Balochistan Province, Pakistan

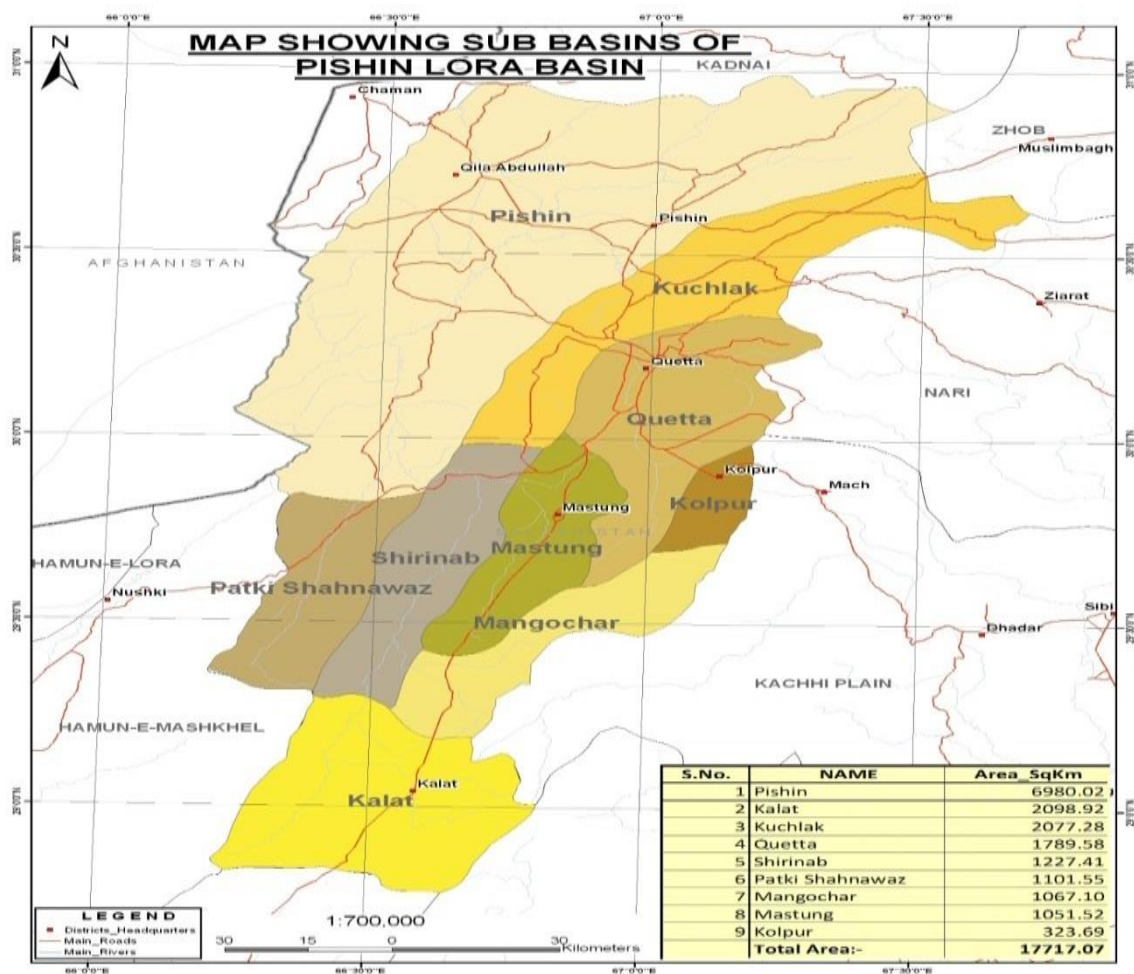


Figure 3.2 Location of Pishin and Kuchlak sub-basins of Pishin Lora Basin

3.2 Sampling strategy and sample size

Due to resources and time constraints, it was not possible to survey all the farmers from the study area, hence a sample of 104 farmers including some 47 (45%) respondents from Kuchlak sub basin and 57 (55%) from Pishin sub basin were purposively selected and interviewed. These farmers included cropping, vegetable and fruits growing farmers. They were interviewed during November to December 2018. The respondents were interviewed at their own farm premises. Information on socio-economic characteristics, production of major crops, agriculture inputs and practices, energy supply, groundwater quality and *Karez* water supply system was collected.

3.3 Data collection

Socio-economic characteristics of all case study farming communities was collected using a survey instrument (questionnaire) that built on the history of similar surveys, along with information from the PRAs and gender co-inquiry. Questions that provided information on four key areas were included in the survey design: Net water availability; agricultural practices, with a focus on crops, vegetables and fruits; water productivity and water use efficiency; and the impacts on farmer's income, equity and environment.

The data was collected on CommCare a mobile app with the assistance of ACIAR project partners. However, due to poor network and signals arising in the field, some data was also collected separately on paper questionnaires. Enumerators were hired locally for assistance in the data collection. Before conducting interviews, the enumerators were given essential training

to ensure they understood what was required when collecting the data. In addition, group meetings were conducted at different locations with farming groups to provide detailed information about the research survey and its purpose.

Secondary data were collected from relevant government departments, local NGOs, national and international agencies.

3.3.1 Data envelopment analysis and efficiency measurements

Technical, economic and water use efficiency of apple, apricot, grape, wheat and tomato crops were calculated using Data Envelopment Analysis (DEA) and efficiency measurement system (EMS). DEA is a non-parametric approach and the relationship between inputs and outputs is defined by making a linear piecewise frontier (Kuosmanen and Johnson, 2010). In the analysis, input-oriented DEA was used following Watto (2013) and Manjunatha et al. (2011), assuming variable returns to scale (VRS) to estimate the technical, economic and water use efficiencies of apple, apricot, grapes, wheat and tomato crops for both Kuchlak sub basin and Pishin sub basin. A multi-crops and multi-inputs model were developed to measure the technical and economic efficiencies of the farms.

Technical efficiency was defined as farm productivity or average production per cubic meter of water. Economic efficiency was defined as the ratio of the value of the output to the cost of the inputs. Water use efficiency was defined as farm productivity with respect to water use by keeping other inputs constant. The efficiency of a specific input in non-parametric research is measured by two approaches: the DEA sub-vector efficiency model and slack-based DEA method (Watto and Muger, 2014; Imran et al., 2019).

3.3.2 Estimation of gross margins and net returns from different crops

Gross margins of farm enterprises provide a simple method for comparing the performance of different enterprises that have similar requirements for labour and capital. The gross margin of an enterprise refers to the total income less the variable costs incurred in the enterprise during the cropping season. Gross margins and net returns from different crops (tomato, apricot, apple, grapes and wheat) were calculated. The estimation of gross margins (GM) was done using the following formula:

$$\text{Gross margin (GM)} = \text{Total Revenue (TR)} - \text{Total Variable Costs (TVC)}$$

Where;

$$TR = (P_a \times Y) + (P_b \times Z) \quad .I$$

P_a = price of main product;

Y = quantity of output;

P_b = price of by-product;

Z = by-product quantity.

And

$$TVC = \sum_{i=1}^n P_{xi} \times X_i \quad .II$$

X_i = quantity of input X_i for $i=1, \dots, n$

P_{xi} = price of input x_i for $i=1, \dots, n$.

3.3.3 Water productivity (WP)

Economic water productivity is defined as the value derived per unit of water used, and thus has also been used to relate water use in agriculture to nutrition, jobs, welfare and the environment (Sharma et al., 2015). Water productivity/Water use efficiency (WUE) is generally defined as marketable yield/evapotranspiration, but economists and farmers are most concerned about the yield per unit of irrigation water applied. Thus, the WUE is calculated as yield (kg/ha) divided by irrigation water (m³/ha). Thus, water productivity = Agricultural benefits/Water use (Cook et al., 2006). The economic measure of productivity at field scale can be measured by Gross Margin for a single product during a single phase of the crop rotation (Sharma et al., 2015).

3.3.4 Shortcomings and limitations of the study

There were three key short-comings or limitations to how the data was collected:

- The survey data are based on farmers' recalls and estimates, as written records were not maintained by majority of the farmers.
- Because general contact lists or directories are unavailable, sampling occurred from within existing contact groups. As such, a non-random sampling technique was used for the selection of respondents.
- Sample size was restricted due to the sparsely distributed population and a shortage of time and resources.

4 Results and discussion

4.1 Socio-economic and Demographic Characteristics of Respondents

The averages and standard deviation of the seven socio-economic variables that were measured is presented in table 4.1. The standard deviations show the variation of the sampled averages from the mean which are seemingly in acceptable range. The average age was 38 years with very small difference between the two sub-basins which shows that experienced people are heading the households in both areas. The average family size was 23 people, 22 in Kuchlak and 24 in Pishin. The reason for the large family size was the joint family system that is prevalent in the area in which people prefer to live together for many socio-cultural reasons. The households are evenly distributed into adults, youth and children for both sub-basins showing good prospects in terms of the availability of the working family labour. The average education level was 8.25 years among the sampled households, 9.40 years in Kuchlak and 7.30 years in Pishin. This shows that levels of formal education in the study sites is quite low. The average farming experience was around 17 years with negligible difference between the two sites, showing that households are quite experienced.

Table 4.1: Socio-economic and demographic characteristics of respondents. Figures in parenthesis are the standard deviations.

Socio-economic characteristics	Pishin Lora Basin		Total
	KSB	PSB	
Age (years)	38.11 (12.336)	38.32 (12.576)	38.22 (12.40)
Family size (Number)	22.17 (16.563)	24.17 (13.423)	23.277 (14.88)
Adults (Number)	7.02 (5.799)	7.88 (6.361)	7.49 (6.09)
Youth (Number)	6.68 (6.705)	7.50 (5.127)	7.13 (5.87)
Children (Number)	8.34 (6.696)	8.44 (5.97)	8.39 (6.29)
Formal education (years)	9.40 (4.251)	7.30 (5.285)	8.25 (4.93)
Farming experience (years)	16.34 (11.089)	17.43 (11.179)	16.94 (11.09)

4.2 Gender roles

Women were not interviewed as part of this study because the women in these areas are not directly involved in water management related activities. However, separate sessions were held with them by a gender specialist to understand their role at the household level to support their families. Moreover, keeping in view the importance of improved water management and the requisite role of women and youth, they are being involved in other project activities through training and awareness programs.

4.3 Marital status of respondents

Figure 4.1 shows the marital status of sampled respondents. The majority of respondents (86%) were married and only 14% were unmarried. This shows that most of the respondents have family responsibilities.

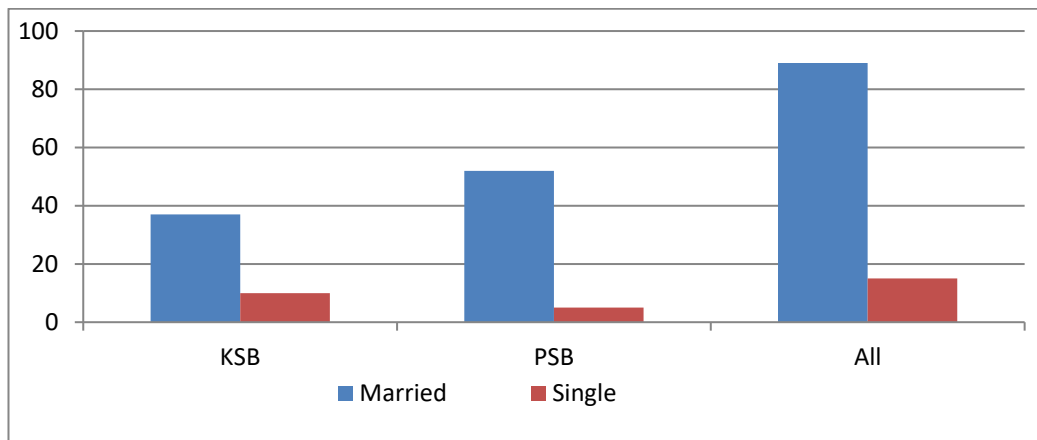


Figure 4.1: Marital Status of respondents

4.4 Family structure

Figure 4.2 shows that majority of families in both areas were joint families followed by nuclear and extended families. Extended family consists of cousins, uncles, aunts, in-laws who do not stay together but are related by birth or marriage. Joint is a family structure where people stay together under one roof and share the house as well as the financial and other available resources. Joint family system is an extended family system and include more family members like parents and siblings of husband. In joint families more than one generation live together. They may include children living with parents and grandparents. Nuclear is a family structure where a couple and their dependent children, regarded as a basic social unit. This suggests that the overwhelming majority of people prefer to live in a joint family and this is probably one of the main reasons for the large family size in both areas.

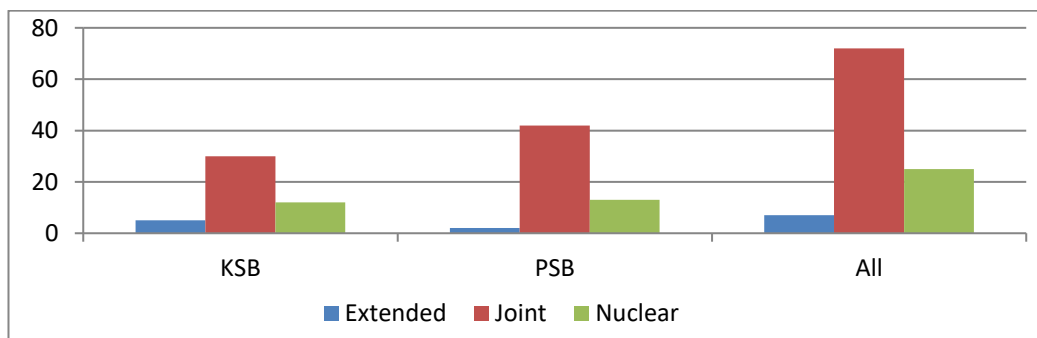


Figure 4.2: Family Structure of the sampled households.

4.5 Time devoted to farm activities by the family members

The information given in Table 4.2 shows the average number of hours that different family members (adults and young) spend working on the farm. The standard deviations are larger than means showing that the data set is very widely distributed indicating that there is huge variation among families. This is probably due to the trend of tenancy or share farming where the tenant undertakes the bulk of farm production activities and the landowner just supervises them. The information also shows that the household head gets good support from the other family members.

Table 4.2: Average number of hours worked on the farm by different household members (average number of days per annum). Figures in parenthesis are standard deviations.

Household workers on farm	Pishin Lora Basin		Total working days (days/acre)
	Kuchlak sub-basin	Pishin sub-basin	
Household Head	53.61 (93.92)	59.15 (104.05)	56.652 (99.16)
Adult	60.26 (82.17)	52.00 (79.36)	55.73 (80.36)
Young	34.97 (68.06)	12.29 (19.12)	22.54 (48.95)

4.6 Accessibility

Figure 4.3 shows the distance of the respondents to nearby towns, main roads and other markets. It shows the area is well-connected to the rest of the country by metaled (sealed) roads and to markets in the big cities of the country.

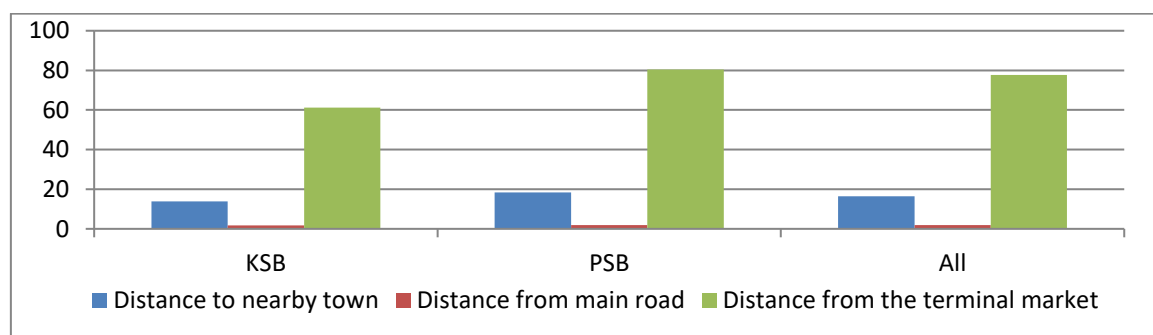


Figure 4.3: Distance to nearest main road, nearby town and markets in large cities (in Km)

4.7 Farm Characteristics

The information given in Figure 4.4 shows that traditional irrigation practices are used on the study sites. Much of the area is irrigated by traditional flood irrigation method. The use of water saving technology was also not reported in either area. The use of water saving technology such as modern irrigation practices, modern irrigation techniques (such as sprinkler, drip, bubbler irrigation system) and laser levelers were not observed in the area.

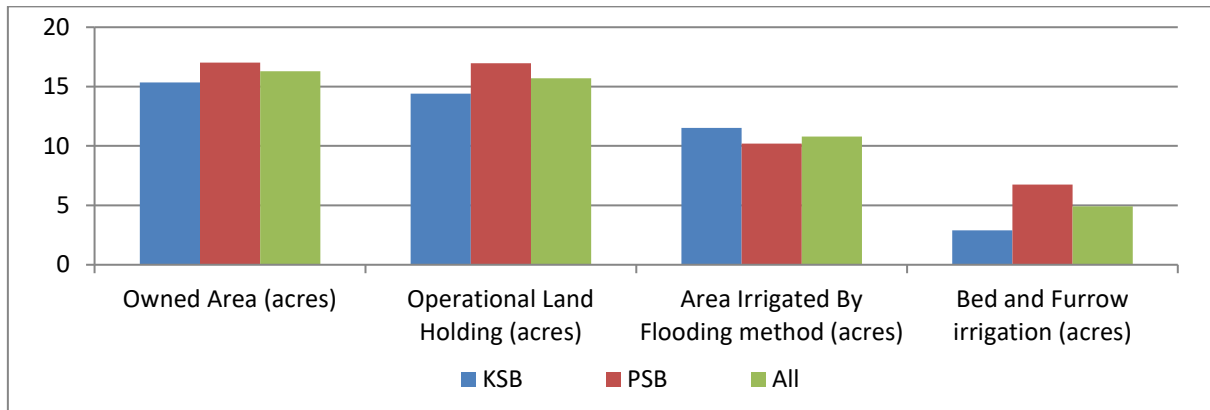


Figure 4.4: Farm characteristics of respondents

4.8 Livestock owned by sampled households

The information given in Figure 4.5 shows the different types of livestock owned by sampled households. The livestock are mainly used for milk and meat production. Milk is usually consumed at home while the animals kept for meat are sold in the markets and good income is earned from animals selling as shown by Figure 3.7. Livestock rearing is also an important source of livelihood, but due to drought over many years and the devastation of rangelands, sheep and goat rearing is on the decline in the area however, large animals such as cattle and buffalo are kept at homes. The average milk production was 5.66 and 7.21 liter per day in KSB and PSB respectively. The milk production was quite low because majority of farmers (> 50%) had small milking animals (sheep and goats) in their herd of animals.

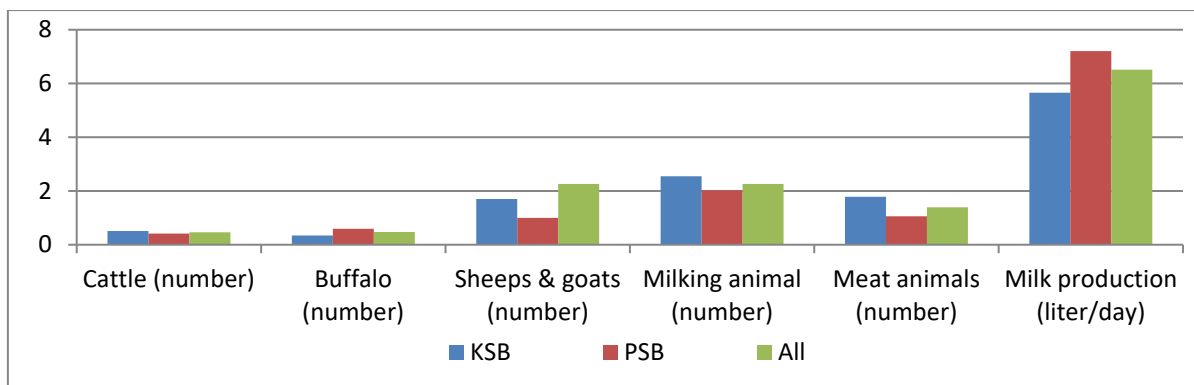


Figure 4.5: Livestock ownership and milk production

Figure 4.6 show that farmers are also getting income from selling milk or animals (cattle, buffalo, sheep and goats). The income from this source serves as supplementary source to their incomes from agriculture, which also serves as a source of liquidity in the off season.

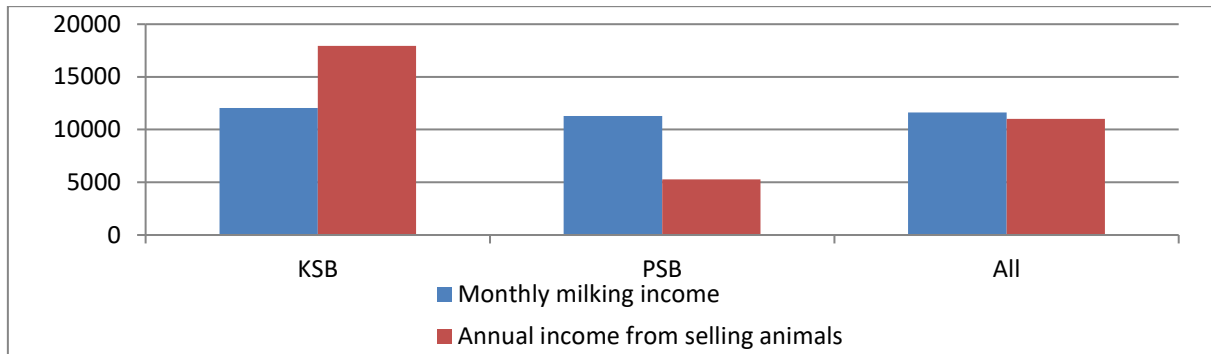


Figure 4.6: Income from selling milk (in Rs).

4.9 Usage of crops

The information in Figure 4.7 shows how agriculture crops produced at the farm are used. It shows that a meager amount is kept for home consumption and more than 90% is sold in the markets showing that commercial farming is common in the area.

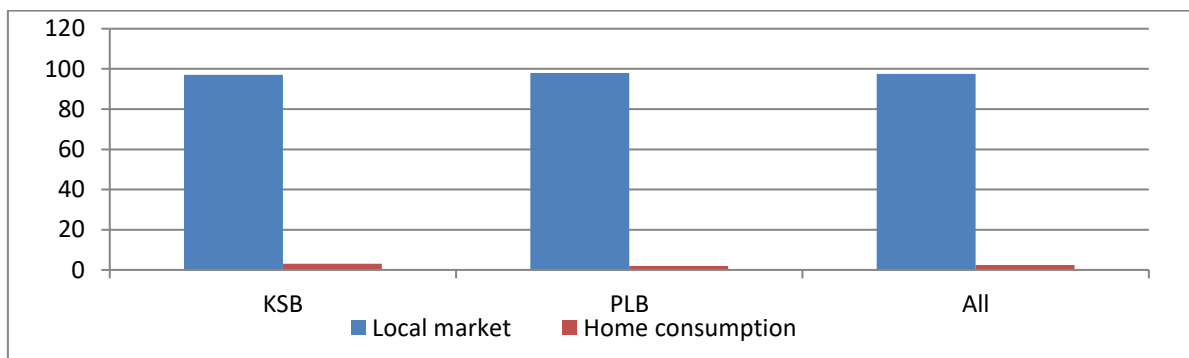


Figure 4.7: Usage of crops (average %)

4.10 Provision of training to the farming communities by NGOs and agriculture extension department

The majority of respondents from both the study areas replied that no training had been offered by NGOs or agriculture extension workers as shown by the results given in Table 4.3. A small number of respondents however, respond positively that they received some training on water management or agriculture during the past.

Table 4-3: Training by NGOs and extension workers across study area.

Training by NGOs	Pishin Lora Basin		Total
	KSB	PSB	
No	43	54	97
Yes	4	3	7
Total	47	57	104

Training by extension department	Pishin Lora Basin		Total
	KSB	PSB	
No	44	53	96
Yes	4	4	8
Total	47	57	104

4.11 Farm cultivation methods and tractor ownership

Farmers responded that they use tractor only for farm activities and no one reported using bullocks in the study area. Regarding the ownership of tractors it was found through the information that most of the farmers use rented tractors for farm operations such as ploughing, land leveling, ridges making etc. (Figure 4.8).

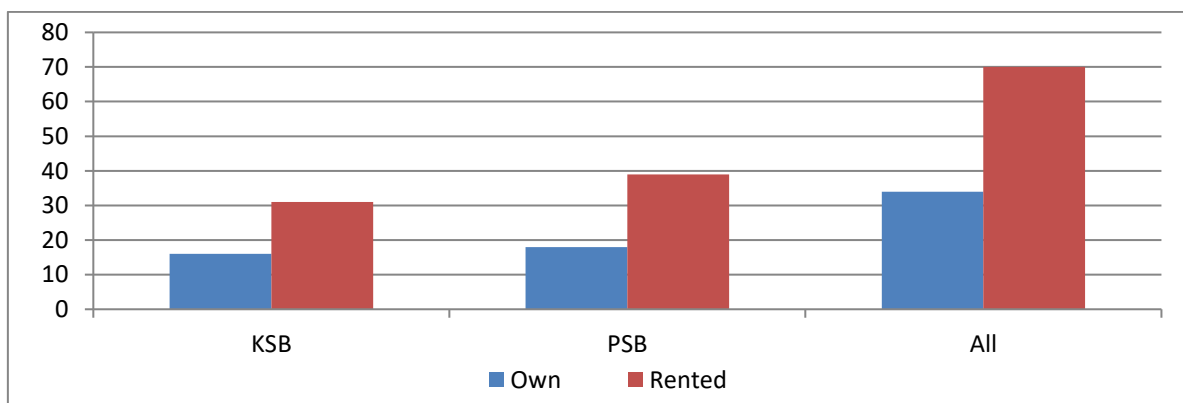


Figure 4.8: Tractor ownership (%) by respondents

4.12 Soil types

The results of data analysis show that majority of farms have clay soil (67%), followed by sandy loam soil (30%) and silt loam (3%) as shown by Figure 4.9.

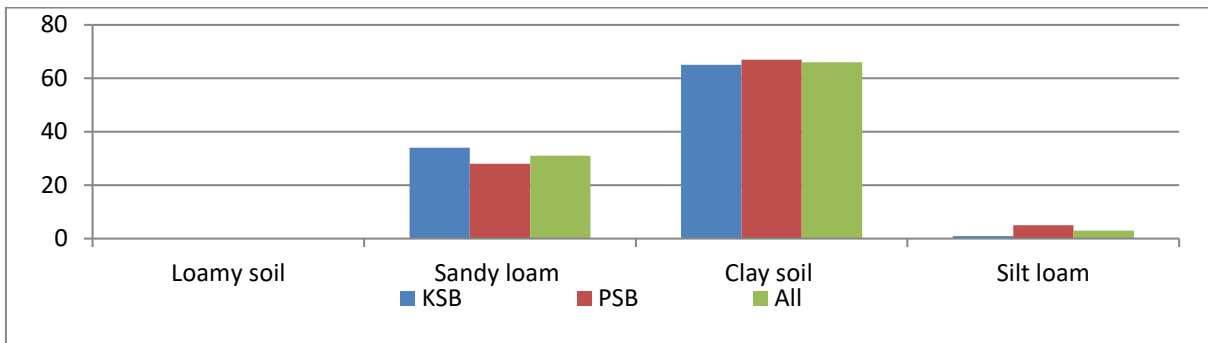


Figure 4.9: Soil types found on the respondents' farms

4.13 Water shortage season

Some 53% respondents reported that the irrigation water shortage occurs in the Kharif (monsoon) season while 16% reported it in Rabi (winter) season. The remaining 32% were of the view that there was water shortage year-round (Figure 4.10). The reasons for water shortage during the Kharif season was peak water demand during hot summer days. Moreover, the tube-wells depend on national grid for electricity supply which is rationed and supplied for six hours a day and that creates a water shortage. Some farmers reported using electricity generators and solar pumps to cater for the acute water shortage.

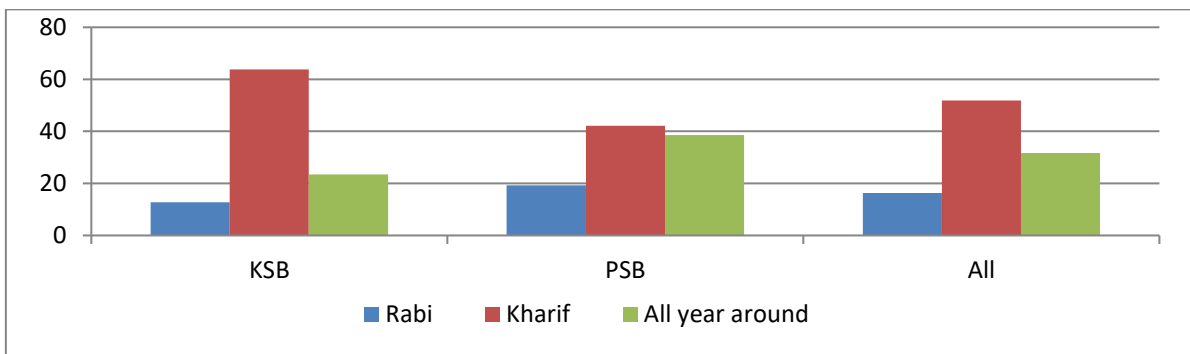


Figure 4.10: Reported season of water shortage.

4.14 Mode of purchase of crop inputs

The results shown in Table 4.4 shows that majority of farmers (> 80%) acquire their inputs (seed, fertilizer, pesticide and diesel fuel) for the crops through credit. A small percentage of farmers (12.5%) reported that they acquire these inputs using cash. While 7 to 8% responded that they use both cash and credit as mode of acquiring their inputs (Table 4.4).

Table 4.4: Mode of purchase of inputs. Figures in parenthesis are percentages.

Mode of purchase for crop inputs	Pishin Lora Basin		Total
	KSB	PSB	
Seed			
Cash	4 (8.51)	3 (5.26)	7 (6.73)
Credit	36 (76.60)	48 (82.21)	84 (80.77)
Both	7 (14.89)	6 (10.53)	13 (12.50)
Total	47	57	104
Fertiliser			
Cash	3 (6.38)	3 (5.26)	6 (5.77)
Credit	36 (76.59)	48 (82.21)	84 (80.77)
Both	8 (12.02)	6 (10.53)	14 (13.46)
Total	47	57	104
Pesticide			
Cash	3 (6.38)	3 (5.26)	6 (5.77)
Credit	37 (76.60)	48 (66.67)	85 (81.73)
Both	7 (14.90)	6 (10.53)	13 (12.5)
Total	47	57	104
Diesel			
Cash	3 (6.38)	3 (5.263)	6 (5.70)
Credit	37 (76.60)	48 (66.67)	85 (81.73)
Both	7 (14.89)	6 (10.53)	13 (12.50)
Total	47	57	104

4.15 Source(s) of credit

Table 4.5 shows the responses on the sources of credit. No respondent reported using an institutional credit source. Non-institutional sources of credit were used by the majority of farmers. Some 61% reported taking credit from arthis (commissioning agents) to either buy production inputs for crops and/or marketing purpose. The remaining 24% reported getting credit from friends/relatives. The reason for not using institutional credit was cited as difficulties in accessing it (see section 4.16 below).

Table 4.5: Sources of credit used by respondents (Multiple Response). Figures in parenthesis are percentages. ZTBL is the Zarai Taraqiati Bank Limited, an agricultural development bank.

Source of credit	Pishin Lora Basin		Total
	KSB	PSB	
Commercial banks			
No	47	57	104 (100)
Yes	0	0	0
Total	47	57	104
Neighbors			
No	45	54	99 (95)
Yes	2	3	5 (5)
Total	47	57	104
ZTBL			
No	47	57	104 (100)
Yes	0	0	0
Total	47	57	104
Friend/relatives			
No	38	41	79 (76)
Yes	9	16	25 (24)
Total	47	57	104
Shopkeeper/arthis			
No	20	21	41 (39)
Yes	27	36	63 (61)
Total	47	57	104

4.16 Access to credit

The respondents reported that institutional credit accessibility was very difficult (41%), difficult (30%), and moderately difficult (12%) (Figure 4.11). Only 11% reported that it was easy to access. The difficulties in accessing credit reported by respondents were due to procedural formalities, collateral requirements, and high interest rate charged.

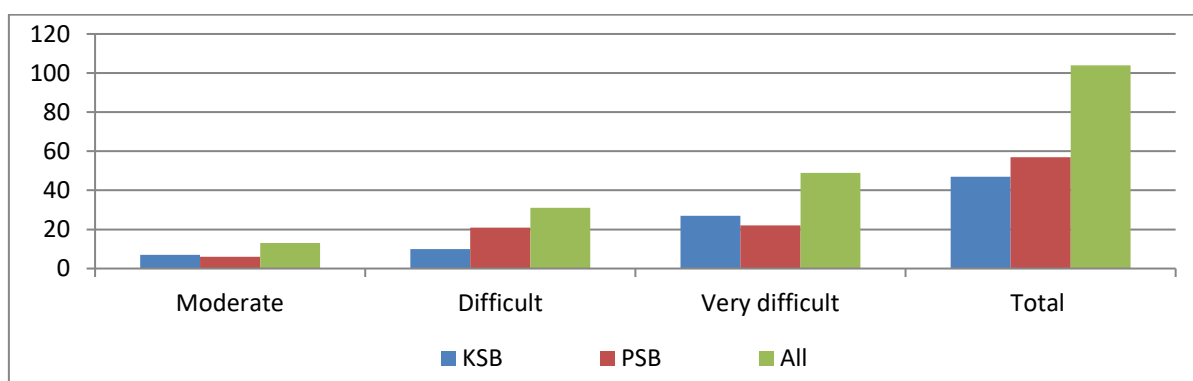


Figure 4.11: Reported degree of difficulty in accessing institutional credit by respondents.

4.17 Problems in attaining farm inputs

Table 4.6 shows the problems faced by farmers in attaining crop inputs. Lack of cash was ranked first by farmers as hindrance in getting farm inputs. Unavailability of inputs on time and high prices of inputs were ranked second by the farmers of Kuchlak and Pishin respectively. Lack of interest free finance and lack of awareness regarding the sources of quality inputs were ranked third by respondents.

Table 4.6: Major problems in attaining farm inputs as reported by respondents.

Problems	KSB		PSB	
	N	Rank	N	Rank
Lack of cash	20	I	19	I
Not timely available	16	II	12	III
Lack of interest free finance	10	III	12	III
Lack of awareness	10	III	12	III
Expensive/black marketing	9	IV	13	II
Transportation	3	V	4	IV

4.18 Irrigation sources

The majority of farmers (96%) use their own tube-wells as the source of irrigation water (Figure 4.12). The remaining (4%) use Karez/spring as the source of irrigation. Purchased water for cash was used by one of the farmers in the Pishin sub-basin suggesting that no excess water is left after meeting own needs to sell for cash. However, for crops share, water selling was reported on majority of farms. Three farmers from Kuchlak reported using leased tube-wells (Rs. 100,000/- paid for one year for water extraction) to supply water to their fields through pipelines. Water marketing was also reported in area though at small scale for cash due to the volatile electricity supply that makes it difficult to pump water in excess of own need of the farmers.

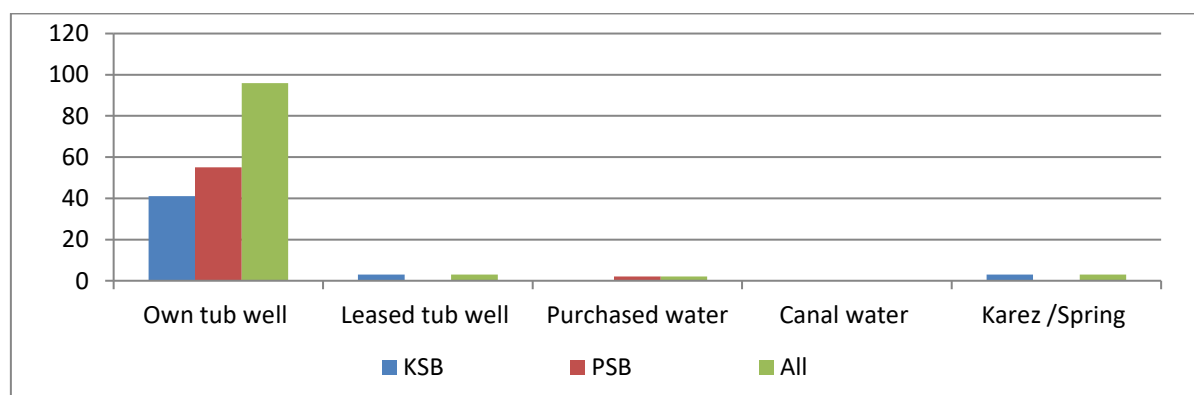


Figure 4.12: Reported sources of irrigation water (%) for respondents.

4.19 Tube-well characteristics

According to respondents the average diameter of pipes that are used to pump water from tube-wells is 3 inches. 40 horsepower electric motors are most commonly used to extract water from the depth of 400 to 600 feet at KSB and PSB (Table 4.7).

Table 4.7: Tube-well characteristics. Figures in parenthesis are standard deviations.

Tube-well characteristics		Pishin Lora Basin		Total
		KSB	PSB	Mean
Diameter of pipe (Inches)	Inches	3.02 (0.14)	2.93 (0.42)	2.97 (0.32)
Tube-well horsepower (Hp)	Hp	35.36 (8.76)	39.21(6.73)	37.55 (7.89)
Bore depth (Feet)	Feet	548.36 (148.83)	646.43 (175.04)	579.40 (161.94)

The above sections 4.1 through to 4.19 address the first two objectives for this study: (1) to describe the socio-economic and demographic characteristics of farming households in the Pishin District and (2) to highlight the current irrigation and cropping practices of farmers

The following section presents the gross margin analysis, water use efficiency analysis and water productivity analysis. These will help understand how much economic, technical and allocative efficiencies exist in terms of using different inputs on growing different crops.

4.20 Gross margin analysis for major crops during 2018

A gross margin is the difference between the gross income or total revenue and the direct costs (or variable cost of inputs) required for production. Gross Margin analysis is a very important tool in determining the level of farm profitability. It also provides information regarding the percentage of various costs items in the direct costs. Table 4.8 shows the gross margins from different crop enterprises such as apple, apricot, wheat and tomato that are grown by farmers. The highest gross margin or profit earning crop is apple, followed by tomato, apricot and wheat (Table 4.8).

Table 4.8: Gross margins from different crops in 2018 (Rupees per acre).

Costs items	Apricot		Apple		Grape		Tomato		Wheat	
	KSB	PSB	KSB	PSB	KSB	PSB	KSB	PSB	KSB	PSB
Seed	n/a	n/a	n/a	n/a	18436	19884	2093	2576		
Fertilizer and FYM	4210	11519	3373	29718	10113	8602	8045	8806		
Pesticides	7967	18979	21138	5055	1704	3280	1750	2417		
Labor	12500	15163	13524	14565	12564	12941	5778	8786		
Irrigation	62500	66500	50000	45410	30800	35200	13975	15200		
Variable Costs (VC)	87177	112161	88035	94748	55181	60023	29548	35209		
Income	218538	363984	341922	279720	125692	140011	53039	53905		
Yield/acre (kg)	3834	8987.25	9304	4144	6898.6	6222.73	1253	1231		
Market price (PKR/Kg)	57	40.5	36.75	67.5	18.22	22.5	42.33	43.79		
Gross Margins (GM)	131361	251823	253887	184972	70511	79988	23491	18696		
GM % of income	60	69	74	66	56	57	44	35		

The irrigation cost was the major cost item among the other cost items and constitutes about 40 to 70% of the variable costs for different enterprises (Figure 4.13). One of the reasons for the high cost of irrigation was the use of electricity generator to run tube-wells all year around. The electricity supply of 6 hours per day could not fulfill the water needs of the farmers. As a result, the farmers rent electric generators that cost around Rs. 1500 per hour. This implies that currently farmers are using flooding method of irrigation and most of the crops are over irrigated by around 50 percent of their water requirement, which is also causing more expenses on irrigation. This high cost is despite the 50-70% subsidized electricity that is currently being provided to farmers. It suggests that if the subsidy on electricity was withdrawn by the government, it is likely that farming would no longer be economically viable.

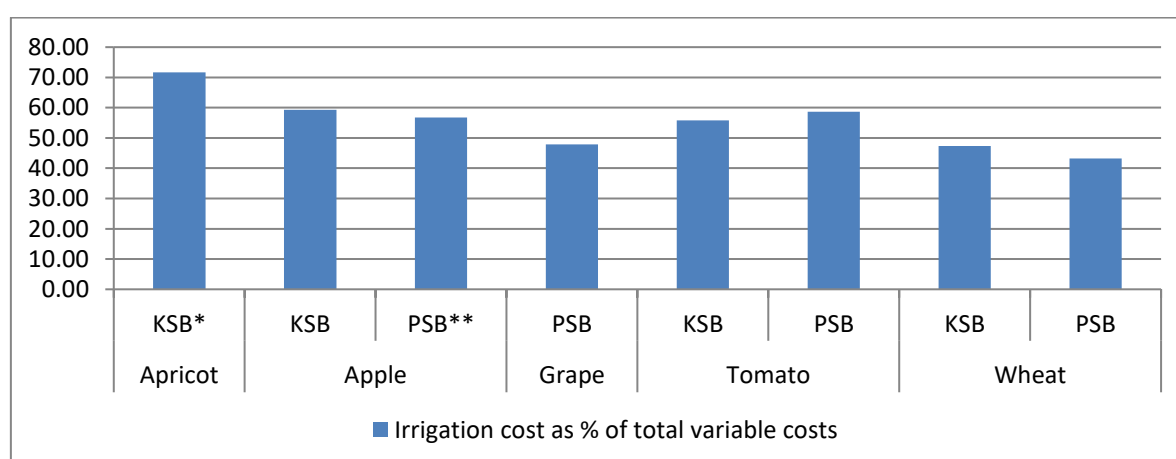


Figure 4.13: Irrigation costs as percent total variable cost

Gross margin may also be expressed in terms of the most limiting resource in the enterprise, such as water use, acres of land or working capital (Government of Victoria, 2009). Table 4.9

shows the gross margins (PKR) per cubic meter water applied to each crop during the entire season. The amount of water in cubic meters per acre was calculated with the help of equation III given below. The highest amount of irrigation water was consumed by apple crops, followed by apricot, grapes, tomato and wheat in PLB. The results show that KSB farmers earn more gross margins per cubic meter water. While farmers in PSB were earning more than KSB on tomato and grapes as shown by gross margins. It also depends upon yield and market value of the crop. The highest yield was observed in apple, followed by tomato in both sub basins. While, grape farmers in PSB received higher gross margins than apricot producers in KSB.

Table 4.9: Estimates of gross margins per unit of water used in PLB Balochistan

	Apricot	Apple		Grape	Tomato		Wheat	
	KSB*	KSB	PSB	PSB	KSB	PSB	KSB	PSB
Gross Margin (PKR/acre)	43107	122632	120412	81191	57503	69527	20007	12611
Volume (m ³ /acre)	5406	6758	6823	4659	3244	3119	1506	1560
Irrigation water applied (mm)	1336	1670	1686	1151	802	771	372	385
PKR per m ³	7.97	18.15	17.65	17.43	9.28	15.26	13.28	8.09

4.21 Efficiency analysis

This section describes different type of efficiencies for selected crops in PLB in Balochistan. Application of essential inputs such as irrigation water, fertilizer, seed and pesticide were calculated to understand their level of efficiency. Moreover, technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE) were also derived to know farmers skill, cost combination of inputs and level of resource allocation.

4.21.1 Water use efficiency (WUE)

The results show that the average water use efficiency was 76% in PSB whereas it was 70% in KSB, implying that there is room to improve WUE at PSB and KSB respectively (Table 4.10). More specifically, in PSB about 50% of tomato growers had water use efficiency below 70% while it was 71% at KSB which implies that there is a room for improvement in WUE in tomato production at both the locations. Application of right amount of irrigation water at the right time to maintain optimal soil water conditions for maximum yield and fruit quality production) is critical. Determining "when" to irrigate and "how much" to irrigate is one of the most common problems with irrigation systems. Growers evaluate the crop response visually to determine when to irrigate, which in most of the cases comes too late and water stress had already adversely affected tree growth and/or production (Fares and Alva, 2000).

Table 4.10: Water use efficiency. Figures in parenthesis are percentages.

Efficiency Level	Apricot	Apple		Grape		Wheat		Tomato	
	KSB	KSB	PSB	PSB	KSB	PSB	KSB	PSB	
< 50 %	5 (36)	4 (14)	2 (8)	19 (54)	0 (0)	0 (0)	18 (72)	4 (36)	
50-70 %	1 (7)	16 (55)	15 (63)	6 (17)	0 (0)	0 (0)	3 (12)	2 (18)	
> 70 %	8 (57)	9 (31)	7 (29)	10 (28)	1(7)	1 (25)	4 (16)	5 (45)	
MEAN	14 (65)	29 (66)	24 (68)	35 (55)	13 (93)	7 (85)	25 (45)	11 (68)	

The information in Table 4.10 shows that the average water use efficiency for apricot was 65% in KSB, suggesting that there is room to improve. Moreover, water use efficiency for apples in PSB that are widely irrigated by flood and furrow basin irrigation systems, is around 68% and is the major livelihood of the farmers. There is 33% inefficiency estimated in apple production and an introduction of high efficiency irrigation system may increase crop yield and will reduce groundwater stress in the basin. Literature indicates that flood irrigation system is the least efficient manner of irrigation (InTeGrate,2018). Therefore, adoption of improved irrigation methods is needed to enhance water use efficiency and reduce groundwater exploitation.

Inefficient irrigation techniques were also noted in the production of tomato and grapes. Approximately, 45% inefficiency was found for PSB farmers growing grapes in trenches and 55% for tomato by KSB farmers. The KSB farmers were frequently irrigating tomato in deep ridges, where huge application losses were noted during the survey period. There was a severe attack of the parasitic weed (*Orobancha*) on tomato crops and farmer behavior was to frequently irrigate the crops with the application of fertilizer so that crops would survive with the herbaceous weed. No such control was recommended to farmers by agriculture department or pesticides companies.

The average water use efficiency for wheat crops was 85% in PSB and 93% in KSB, showing that compared to other crops wheat growers are quite water use efficient (Table 4.10). The reasons for wheat growers' water use efficiency may be that because wheat is a winter season crop there is less need for irrigation as compared to other crops. Moreover, due to winter rains, they need small number of irrigations. While, the average water use efficiency for apple was 68% in PSB whereas it was 66% in KSB, implying that there is room to improve WUE for apple at both the sites.

4.21.2 Seed use efficiency (SUE)

The information in Table 4.11 shows the average seed use efficiency calculated for different crops for the two areas. For tomato crops, the SUE was 78% for KSB and it was 84% for PSB, implying that the tomato growers were more efficient probably due to the use of hybrid imported seeds, compared to wheat growers, though the hybrid seed is highly expensive. The information reveals that there is still scope for improvement in the seed use efficiency especially for wheat.

Table 4.11: Seed use efficiency for tomato and wheat crops

Efficiency level	Tomato		Wheat	
	KSB	PSB	KSB	PSB
<50%	1(4)	1 (10)	21(87)	0 (0)
50-70%	6 (24)	1 (10)	0 (0)	0 (0)
>70%	18 (74)	9 (80)	3 (13)	8 (100)
MEAN	25 (78)	11 (84)	24 (15)	-

4.21.3 Fertilizer use efficiency (FUE)

Fertilizer use efficiency is a measure of how well plants use the available nutrients. It can be defined as the yield per unit input or the ratio of nutrients to biomass lost in litter fall (Fixen et al., 2014). The information in Table 4.12 shows that the average fertilizer efficiency at KSB and PSB for the different crops. The data shows that there is room for improvement in FUE for all the crops at both locations, except for the wheat in PSB where the FUE is 96%.

Table 4.12: Fertilizer use efficiency (FUE). Figures in parenthesis are percentages.

Efficiency Level	Apricot	Apple		Grapes		Tomato		Wheat	
	KSB	KSB	PSB	PSB	KSB	PSB	KSB	PSB	
<50%	10 (71)	23 (79)	20 (83)	24 (69)	18 (36)	3 (27)	0 (0)	0 (0)	
50-70%	0 (0)	2 (7)	0 (0)	0 (0)	5 (20)	3 (27)	17 (71)	0 (0)	
>70%	4 (29)	4 (14)	4 (17)	11 (31)	2 (8)	5 (45)	7 (29)	8 (96)	
MEAN	14 (29.2)	29 (32)	24 (25)	35 (33)	25 (54)	11 (72)	24 (70)	8 (96)	

The information in Table 4.12 also reveals that the average fertilizer use efficiency for apricots was very low (29 %) in KSB, indicating that fertilizer use could be reduced to produce a given output of apricot. It means that the inefficiency in fertilizer application needs to be improved in the best productive way in KSB

The FUE for grapes was estimated to be 33% in PSB, suggesting that farmers need to practice efficient fertilizer application methods to increase efficiency. For apples the average fertilizer use efficiency was 32 % in KSB and 25 % in PSB, indicating that there is room to improve FUE both at KSB and PSB by 68% and 75% respectively. More specifically, at KSB about 79% apple producer had fertilizer efficiency below 50% while at PSB it was 83 %, this implies that there is huge room for improvement in FUE in apple production.

These results indicate that there is a lot of potential to increase efficiency and as such, we argue that that farmers should prioritize the adoption of such agronomic practices that increase yields, productivity, and agricultural input use efficiency.

4.21.4 Tomato crop's technical, allocative and economic efficiency

Estimates of different efficiency parameters associated with tomato, apricot, wheat and apple production in KSB and PSB are shown in Figure 4.14. For tomatoes, the majority of the farmers from PSB had a technical efficiency that is greater than 86% and for farmers from KSB it was 62%. The mean economic efficiency in PSB and KSB was estimated at 64% and 61% respectively. Allocative inefficiency results indicate that tomato farmers can save on costs by the efficient allocation of inputs because only two farmers of PSB and two farmers from KSB were allocatively efficient and the mean allocative efficiency was 86% and 77% respectively indicating that there is 14% and 23% of scope for farmers to save cost by using inputs more efficiently.

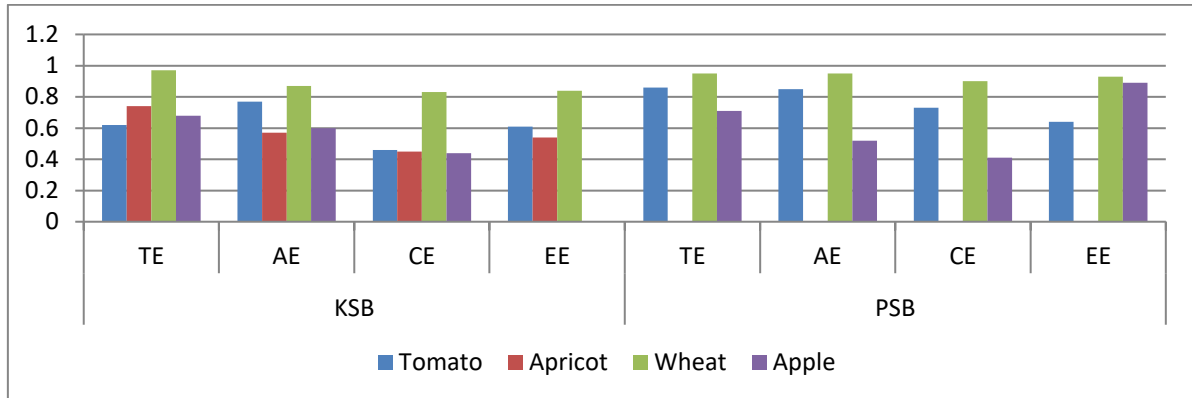


Figure 4.14: Technical, Allocative, cost and economic efficiency analysis. TE is technical efficiency, AE is allocative efficiency, EE is economic efficiency, CE is scale efficiency

Apricot producers in KSB had an average technical efficiency of 74% (Figure 4.15). The mean economic efficiency for apricot producers in KSB was 54% indicating that farmers in KSB can reduce cost of production by 46% without compromising their productivity.

The information given in Figure 4.15 shows that the average technical efficiency of wheat crops in KSB and PSB was 94% and 96% respectively due to higher productivity. The reasons for comparatively higher productivity of wheat was due to the fact that wheat is a winter season crop that enjoys the abundant availability of irrigation water as the fruits plants don't need water at that time. Moreover, wheat is a comparatively easy crop in terms of production practices undertaken; therefore, the technical efficiency was greater. The mean scale efficiency for KSB and PSB was estimated 85% and 93% respectively. The mean allocative efficiency was 86% and 94% respectively, indicating that there is some scope for the farmers of KSB to save 14% of cost by using inputs efficiently.

The estimated mean economic efficiency for wheat was 84% and 93%, respectively, in KSB and PSB indicating that wheat growers in PSB are somewhat economically more efficient than in KSB (Figure 4.14). Farmers in KSB and PSB can reduce the cost of production by 16% and 7%, respectively without declining productivity.

The technical efficiency of apple production in KSB and PSB was 68% and 71% respectively (Figure 4.14). The mean allocative efficiency of was 51% and 60% respectively at PSB and KSB, implying that there is significant scope for the farmers of PSB and KSB to save 49% and 40% of production costs by using inputs more efficiently. The results also showed that allocation of inputs was a greater issue than amount of inputs used because mean allocative efficiency is less than the mean technical efficiency.

4.21.5 Crop water requirements and the extent of over irrigation by farmers

The groundwater extraction volume (in litres) was calculated using a pre-tested model of estimation by Eyhom et al., (2005) followed by Srivastava et al., (2009). Watto and Mugeru (2015) also used same methodology for an approximate estimation of the total amount of water (in liters) to a crop. The same procedure was adopted with the help of equation (III) to estimate irrigation water applied to specific crop during the entire season.

$$Q = \frac{t \times 129574.1 \times BHP}{d + [(255.5998 \times BHP^2)/(d^2 \times D^4)]} \text{ --- (III)}$$

where Q denotes the total volume of water applied (in litres), t is the total irrigation time (in hours) applied to each farm during the whole cropping season, d is the depth (in meters) of bore, D is the diameter (in inches) of the suction pipe, and BHP is the power (in horsepower) of the motor pump. Water quantity in liters was estimated and then converted into cubic meter (m³).

Given the low rainfall in this arid area, and the high rates of evapotranspiration by plants, the amount of irrigation water extracted is very high. The International Union for Conservation of Nature (IUCN) (2006) estimated the irrigation requirements for crops grown in PLB based on Quetta metrological station's climate data. This is presented in Figure 4.15 below alongside the total volume of water applied. The difference between the two values represents the degree of over irrigation. The flooding of orchards with valuable irrigation water combined with unlevelled fields reduces the water use efficiency.

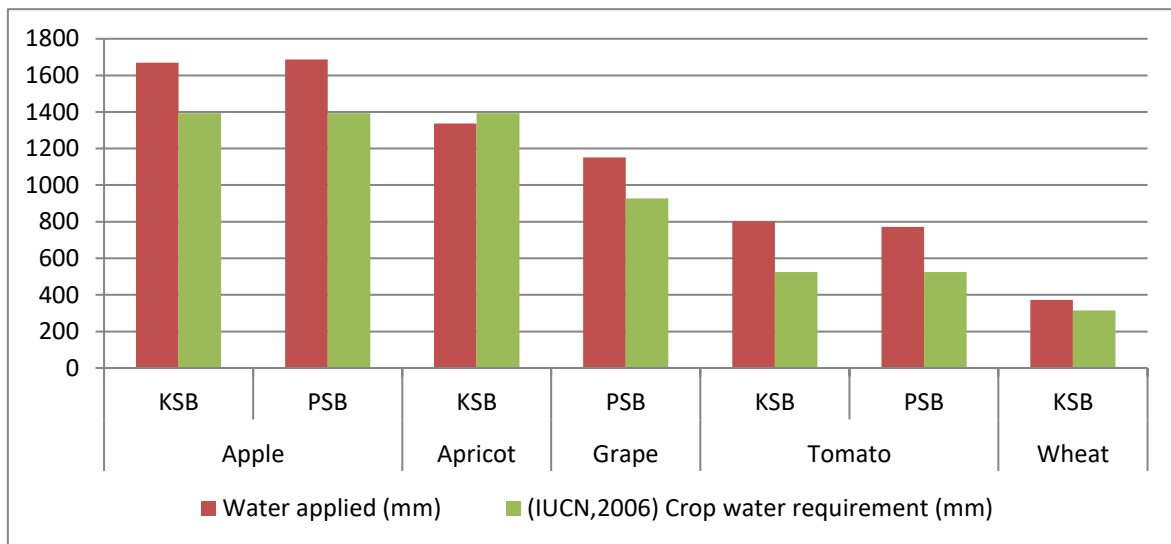


Figure 4.15: The total volume of water applied and the estimated water requirements for the different crops in KSB and PSB.

4.21.6 Water use efficiency (WUE)

Water use efficiency is generally defined as marketable yield/ET, but economists and farmers are most concerned about the yield per unit of irrigation water applied. Thus, the WUE is calculated as yield (kg/acre) divided by irrigation water (m³/acre). Thus, water productivity = Agricultural benefits/Water use. The economic measure of productivity at the field scale is measured as Gross Margin for a single crop during a single phase of the crop rotation (Sharma et al., 2015). Water productivity can be enhanced either by increasing crop yield or by reducing water consumption and maintaining yield.

In the present study, only applied groundwater irrigation was considered to estimate water use efficiency, since rainfall was presumed to be distributed uniformly across all farms and there was no surface irrigation on the sample farms.

Productivity of irrigation water was greatest for tomato crops, followed by apple, grapes, wheat and apricot (Table 4.13). More specifically, the tomato growers in KSB achieved the highest productivity (2.59 kg/m³ of water). The comparison of the results with those of other studies undertaken nationally and internationally shows that water productivity in Balochistan is markedly below the national and international levels. For example, Molden et al., (2010) reported that the water productivity of wheat, tomato and apple in South Asian and Sub-Saharan African countries was 0.2, 0.15, and 0.8. The yield kg per cubic meter for wheat was in the range of (0.2-1.2), for tomato (5-20kg) and for apple (1-5kg). While the \$/cubic meter of water used were (0.04-0.30 for wheat), (0.75 to 3 for tomato), and (0.80 to 4 for apple).

Table 4.13: Water use efficiency of major crops grown in the study area

	Apricot	Apple		Grape	Tomato		Wheat	
	KSB*	KSB	PSB	PSB	KSB	PSB	KSB	PSB
Yield/acre (kg)	3834	8987	9304	4144	8403	7197	1253	1231
Volume (m ³ /acre)	5406	6758	6823	4659	3244	3119	1506	1560
Water productivity (Kg/m ³)	0.71	1.33	1.36	0.89	2.59	2.31	0.83	0.79

This result has also been found in other studies. For example, in the article '*Per unit productivity of water in agriculture very low in Pakistan*' (2019), it is reported that the per unit productivity of water in agriculture is very low in Pakistan compared to other countries. Cereal was grown on 0.13 kg/m³ of water in Pakistan, while in USA, China and India it was grown on 1.56 kg/m³, 0.82 kg/m³, and 0.39 kg/m³. Similarly, Water Watch, (2002), reported that in an average rainfall year, the water productivity for wheat in Pakistan was 0.76 kg/m³ of water which was 24% less than the global average of around 1 kg/m³ and, therefore, can be classified as moderately acceptable.

In terms of measures for improvement of water productivity, Molden et al. (2010) report that South Asia and sub-Saharan Africa have the highest potential to gain from increase in water productivity due to very low crop yields. Moreover, there is scope for improvement in productivity as their current levels of water productivity shows a large variation by commodity. By adopting proven agronomic and water management practices, many farmers could raise water productivity.

The steps to increase water productivity could help reduce poverty as these are also areas of extreme poverty, with the largest concentration of poor people with a high dependence on agriculture. This is an important conclusion because a focus on these areas can both reduce the

amount of additional water needed for agriculture globally and help to reduce poverty. Water Watch (2002) suggested that in Pakistan increased water productivity can only be achieved by increased crop yields as shown by an experiment by the Pakistan Agricultural Research Council (PARC) that showed that the overall yield of wheat can be increased by 54%, provided that inputs are used in an optimal manner. These include improved management of water quality and evacuation of drainage water. Moreover, seed quality, fertilizers, and pesticide control should also be improved.

5 Conclusions and recommendations

5.1 Conclusions

This study was conducted in Kuchlak sub basin (KSB) and Pishin sub basin (PSB) of Pishin Lora basin (PLB) to assess the socio-economic and demographic characteristics of farming families. It also aimed to gain knowledge regarding the current agricultural and irrigation practices and sources of livelihood of farm families.

It was noted that farmers are using traditional irrigation methods that are not water efficient and they grow water intensive crops. Moreover, there is lack of general awareness about the water resources and their availability. There is a need to introduce high efficiency irrigation techniques and low delta crops, and to provide training to farmers and general population on water conservation and its judicious use. In addition to this, an extensive campaign is needed to educate farmers about improved water management practices.

Among the different crops that are grown, wheat crops were water use efficient while tomato, apple and apricot and grapes were less efficient with significant scope for improvement. Ultimately, farmers practice poor conventional irrigation methods combined with unlevelled fields that reduce water output.

In terms of seed and fertilizer use, the majority of farmers were inefficient on technical, allocative and economic efficiency criteria. This was caused by overuse of water. Training regarding good agricultural practices (GAP) are needed to equip farmers with the necessary skills to enhance their skills on proper inputs use.

The gross margin analysis shows that largest cost was incurred on irrigation. This cost ranged from 45 to 70% of the variable costs for different crops and fruits. Due to drought like conditions in 2018, and the fragile electricity supply from the national grid to the tube-wells, farmers frequently irrigated crops by running their tube-wells through rented electric generators that increased the cost of irrigation. Moreover, according to the results, farmers apply more irrigation water to their crops than by more than their water requirement.

It is important to apply the right amount of irrigation water at the right time to maintain optimal soil water conditions for maximum yield and quality. The fruits, vegetables and other crops are estimated to be inefficient in terms of water and other inputs use. The installation of high-efficiency irrigation system will increase crop yields and help minimize groundwater stress in the basin. Moreover, it is also needed to implement improved irrigation methods to increase efficiency in water use and to reduce groundwater depletion.

Water productivity analysis shows that under the current irrigation system (mainly flooding) farmers are using more water than the actual crop water requirement, suggesting that farmers need to be educated and trained and irrigation practices be changed to use irrigation water efficiently and avoid wasteful use of water.

The comparison of these study results on water productivity with those of other studies undertaken nationally and internationally shows that water productivity per cubic meter of water in Balochistan was well below the national and international levels.

5.2 Recommendations

On the basis of the findings from this study, the following recommendations are presented to help ensure a sustainable economic future for the livelihoods of the inhabitants of water deficit PLB, Balochistan:

- There is need to introduce high efficiency irrigation techniques and low delta crops and to train farmers and educate general masses on water conservation and its judicious use. In addition to this, extensive campaign is needed to educate farmers about improved water management practices.
- The Provincial Water Management Department needs to improve on farm irrigation and agricultural practices to enhance water productivity and promote water conservation.
- In both study areas, fruits, vegetables and crops are irrigated through traditional flooding methods in which farmers apply more water than crop water requirement. It is recommended that bed and furrow cropping methods, that uses less water than the existing methods, be introduced to increase the water use efficiency.
- The introduction of drip irrigation and micro sprinklers can increase efficiency from less than 60% to more than 95% (Kulkarni, 2011). Literature indicates that drip irrigation can reduce water requirements by 35% to 40%, though it is expensive. Therefore, a subsidy may need to be provided to small farmers.
- Good agricultural practice (GAP) training is needed to equip farmers with necessary skills to enhance their skills on proper inputs use and minimize waste of irrigation water.

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Figure 6.1 Community meeting at the Zarghoon site in Balochistan in 2016



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