Improved Land and Water Conservation Practices to Enhance Wasteland Productivity in Thal Desert

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1 Introduction

1.1 Background

Drylands cover about 80% of the world's agricultural land¸ home to more than two billion people and contribute to at least two-third of the global food production. Moreover, dryland ecosystems play a major role in the global biophysical processes and provide much of the world's grain and livestock, forming the habitat that supports many vegetable species, fruit trees and microorganisms. The highly variable rainfalls, both on quantity and intensities, are salient characteristics of dryland regions, as are the occurrence of prolonged periods of drought.

In Pakistan, drylands cover about 12 million hectares (Mha) which is about 40% of the total culturable land. These lands are defined either based on the length of growing period in a certain region or a ratio of annual precipitation to potential evapotranspiration. These encompass grasslands, agricultural lands, forests and urban areas. In these areas poorest of the poor live as livelihood options outside agriculture are limited.

Nevertheless, these areas have high potential to contribute to livelihood and food security of the poorest due to: (i) wide gap between current level of agricultural productivity and its potential, (ii) largely belong to poor communities, and (iii) large area available for out-scaling of promising interventions. Therefore, these lands need to be exploited to meet the ever increasing food and fiber demands. Better crop selection, management of soils, rainwater, soil moisture, and supplemental irrigation are the key factors to improve land and water productivity and livelihood of these areas.

The water availability is a serious issue in such areas as much of rainwater either leaves the areas as a surface runoff or is evaporated due to inappropriate/ inadequate rainwater capturing arrangements. Other alternate is groundwater which is either not available or if available is of poor quality. However, the relatively limited recharge of groundwater resources is dependent largely on the amount, intensity and duration of the rainfall and soil properties. Surface runoff events, soil-moisture storage, and groundwater recharge in dryland regions are therefore, more variable and less reliable than in more humid regions. As a result, agricultural productivity is much low due to numerous land and water management issues.

Unsustainable crop yields, soil erosion, deforestation, loss of biodiversity, and climate change have further aggravated the situation. Setting research management strategies and priorities in drylands are therefore, need of the time to deal with different aspects of land and water resources planning, development, management, and service delivery.

PCRWR has been extending its research endeavors on augmenting water resources in deserts, using site specific technologies like; rainwater harvesting, developing and disseminating conjunctive use of saline groundwater for economic utilization of deserts waste lands. The mounting pressure on our economy to feed more people has increased the importance of utilizing the potential rain fed regions to improve food security (Mahmood et al.,1991). The research conducted by PCRWR (2014) in Thal Doab reveals that about (67%) of the Doab is underlain by good quality groundwater (PCRWR, 2014). The simulation for 2015 and 2025 predicted that this aquifer can attain 20 MAF recharge from rivers and irrigation networks, without causing adverse effect on groundwater aquifer. This huge groundwater resource has a potential for irrigating around 0.81 Mha (2 million acres) for agriculture production.

This project therefore, aims to introduce knowledge and best practices to deal with the emerging challenges for productive agriculture and improved livelihood especially under growing threats of climate change and food insecurity through benefitting from regional as well as international experiences. The project aimed to introduce sustainable water management technologies, to utilize this precious water, through participatory pilot sites in Thal Doab and to put the desertified waste lands to production. There was need of a coherent approach like; disseminating the shelter belt technology for sand-dunes fixation and developing arid horticulture on scientific grounds. This is directly related to vision 2025 (GoP) wherein great stress has been laid on the economic utilization of available water resource to achieve production potential of waste lands which would help in attaining goals 9 and 16 of the Pakistan Vision 2025. The project was in line with the sectoral objectives of the five-year plan 2018-23, National Water Policy stressing the conservation of the dwindling water resources and the SDGs 1, 6, 7, 13 and 15.

Thus, the project intended to undertake activities for the identification of water resources development and management problems in the desert areas, and develop an integrated plan for the implementation and dissemination of advanced techniques and activities for the conservation of water resources both quantitatively and qualitatively for sustainable agriculture development and management. The research results would provide a guideline for the policy makers and development agencies involved in the region to initiate sustainable and integrated water resources management and development activities leading to agricultural and socio-economic uplift of the area as well as the country.

1.2 Objectives of the project

The main objective of this project was to identify the problems related to water resources management in Thal desert, develop and implement water conservation plan to increase per unit productivity of water. The specific objectives however, were:

i. To identify the water and agriculture related issues and problems in Thal Doab and develop management strategy to enhance land and water productivity;

ii. To implement improved measures for; controlling wind erosion and developing groundwater using improved techniques on farmers' fields; and

iii. To demonstrate and disseminate improved technologies to stake holders for their wide-scale adoption.

2 Profile of the Project Area

The project was implemented in three districts of Punjab which are Mianwali, Bhakkar and Khushab. These three districts fall under the Thal Doab.

2.1 Area profile

Thal desert is situated in Punjab, Pakistan. The vast expanse is located between the Jhelum and Sindh rivers near the Pothowar Plateau. The total length from north to south is 308 km with and a maximum breadth of 113 km and minimum breadth of 32 km. The desert covers districts of Bhakkar, Khushab, Mianwali, Layyah, Muzaffargarh as well as Jhang, from the left bank of the river Jhelum. However, the project was implemented as pilot in the three districts of Thal Doab namely, Mianwali, Khushab and Bhakkar.

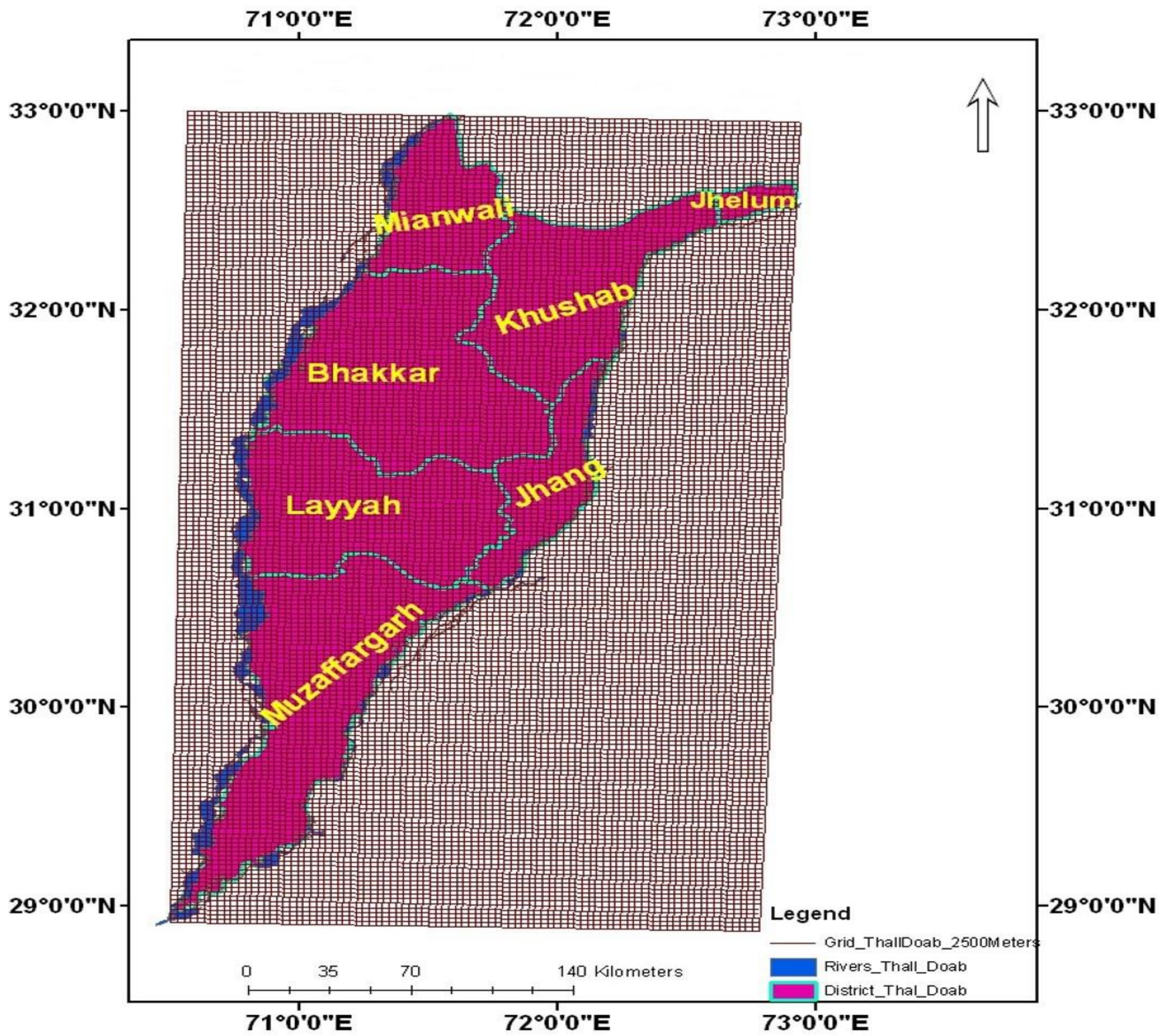

Figure 1: Location Map of Thal Doab

2.2 Geographic profile

Thal desert of Pakistan lies at altitudes above mean sea level of approximately 200 m in the north which gradually decrease to around 120 m in the south. It falls under the agro-ecological zone-III and is a sandy, arid to semi-arid region. The desert is divided into the districts of Bhakkar, Khushab, Mianwali, Jhang, Layyah and Muzzafargarh, all of whom display very similar geographical features.

The main towns of the region, which see the greatest human activity, include Roda Thal, Mankera, Hayderabad Thal, Dullewala, Piplan, Kundiyan, Kot Aazam, Saraye Muhajir, Mehmood Shaheed Thal, Rang Pur, Jandan Wala, Mari Shah Sakhira, Noor Pur Thal, and Muzafargarh.

The desert largely constitutes of ridges of sand dunes and rolling sand plains which alternate with narrow valleys of flatter, more cultivable land. These sand dunes are a prominent feature of the zone and consist of sediment reworked by wind and brought in by the Indus river, which lays upstream of the orogenic front. They commonly reach heights of around 175 m and cover 50-60% of the Thal desert (Mahboob et al., 2013).

The area is also underlain by Quaternary fluvial and Eolian deposits over 350 m thick in southern areas, and even thicker in the central region of the desert. This underlying alluvium consists largely of laterally continuous bodies of fine to coarse sand, with minor gravel and isolated mud lenses. Coarser deposits occur in the north closer to the Salt Range, but otherwise the distribution of grain sizes is irregular (Garzanti et al., 2020)

The currently active Indus river flood plain stretches more than 20 km in width at the southern edges of the desert and the abandoned flood plain reaches even wider, covering areas of higher ground. These uplands are actively eroded by the Jhelum river and form up to scarps which face the floodplain (Greeman et al.,1967)

As compared to the Upper Indus sand, the sand dunes of the Thal are poorer in quartz and sedimentary to low-rank meta-sedimentary rock fragments. However, they are higher in feldspars, volcanic, meta-volcanic and meta-basite rock fragments and heavy minerals. The dune sand is thought to be derived from the Trans-Himalayan arcs (40–45%, predominantly from the Kohistan arc), the Karakorum-Hindukush Ranges (40–50%, of which a third is via the Kabul river), the Nanga Parbat massif (< 10%), and the Himalayan belt (< 10%, inclusive of detritus recycled by the Soan river) (Rehman et al.,1997)

2.3 Climate

Thal desert is a subtropical sandy region with severe climactic conditions that are prone to temperature extremes. Approximately 50% of the region sees hyper-arid climactic conditions (annual rainfall less than 200 mm) and the remaining half sees semi-arid climactic conditions (annual rainfall between 200 mm and 500 mm). The desert is also characterized by strong winds that blow year-round and can cause serious wind erosion that leads to local crop damage (Dasti and Agnew, 1994; Shaheen et al., 2020).

2.4 Temperature

Summers in the area see temperatures generally range from 32ºC - 40ºC and average around 35ºC between June to July. However, southern borne hot winds blowing with high velocity can see these temperatures rise to over 45ºC. Dust storms, resulting from unsteady thermal conditions, are also common in the summer months. This has made crop cultivation challenging as the soil becomes difficult to bind, leading to extensive erosion and losses for the farming community. In winters, temperature vary between 3ºC and 8ºC and is accompanied by cold, dry winds from the north. In January, temperatures can reach near freezing point (Haroon et al., 2017; Lok Sanjh Foundation, 2013).

2.5 Precipitation

Thal desert's rainfall patterns are low and erratic with mean annual values ranging between 150-350 mm. The majority of precipitation occurs between the months of June and August however, there is high variability across seasons and even years. Total annual rainfall has been seen to progressively decrease from the northern end of the desert to the south. It also displays cyclic fluctuations, where two to three years of continued decreased rainfall is followed up by several years of higher precipitation levels (Faraz et al., 2020).

The climatic conditions in Thal Doab are tropical with sporadic annual rainfall of 250 mm. summer temperature reaches up to 50°C which results in high evaporation rate. About half of Thal falls in arid zone (rainfall less than 200 mm) and the remaining half is semi-arid climatic zone (200 –500 mm). About third of the semi-arid part receives over 300 mm (ADB, 2020).

The climatic uncertainty due to erratic rainfall, with high spatial and temporal variations, is the main reason for low crop production under rain fed conditions. Only one moderate crop can be obtained in a favorable year from dry farmed area, where two good crops can be obtained from flood plains with improved management practices. Farmers only cultivate their lands during the rainfall season and leave their lands fallow for the rest of the year (Mirza et al., 2013)

There is high potential for development and managed use of groundwater resources, which is available in the form of alluvium of rivers; Indus, Jhelum and Chenab, applying appropriate technologies and adopting scientific land management practices to enhance agricultural production of the region.

Hailstorms, generated by air turbulence owing to the high temperature difference between the warm surface and the cold upper atmosphere, are also common between March and April and can cause severe damage to the crops and buildings.

2.6 Vegetation and flora

The vegetation of Thal desert consists predominantly of grasses and sedges which are most commonly used as fodder by the local population. Thorny and prickly shrubs as well as perennial herbs capable of enduring droughts, are also present. A floristic checklist of Thal desert observed that Poaceae was the main family with 52 species. Most of the flora is of herbaceous nature, followed by grasses, trees, shrubs, sedges and climbers in decreasing abundance (Shaheen et al., 2017).

The trees which grow in the desert include the Khagal (Tamarix aphylla), Shareen (Albizia lebbeck), Kikar (Acacia), Beri (Ziziphus Jajoba) and Karir (Capparis decidua). Ephemeral herbs also appear seasonally and shed their seeds before the arrival of summer when climatic conditions become more unfavorable throughout the desert (Shaheen, 2015).

Medicinal purposes also account for another major usage of the plants; for example, Harmal (Peganum harmala) is used for indigestion and Kartuma (Citrullus colocynthis*)* is used to treat wounds. Other uses including thatching huts, building livestock shelters and creating household items such as baskets and dyes. The most commonly used species is the Saccharum with its various uses in sheltering, fodder and making objects (Shaheen et al., 2014).

Most sub-regions of the desert are dominated by one species of plant, which is a notable feature of such deserts. The vegetation is also highly dependent on the seasonal rainfall patterns which determine the ability of species to re-establish in the next sufficiently wet monsoon (Abbas et al., 2010). Most plants grown are for the sole purpose of soil binding as this helps to bind the sandy soil and fertilize it for future generations. Gram (chickpea) is the most successfully cultivated crop in the region's arid conditions and the desert accounts for the bulk of chickpea production in Pakistan (Shah et al., 2007).

Thal desert has also seen severe erosion to its natural vegetation as a result of anthropogenic activities, such as human settlement and land cultivation, which led to desertification. Much of the natural vegetation has been replaced by perennial grasses, which may be a response to the anthropogenic pressure on the flora by human as well as animals (Shaheen et al., 2014).

2.7 Fauna

Livestock plays an important role towards the livelihood of the people in the region, serving as a relatively secure source of income as compared to unpredictable crop yields.

The average herd size is 17 standard units and typically consist of goats, sheep, cattle, buffaloes, camels, donkeys, and mules (Lok Sanjh Foundation, 2013).

The desert's natural wildlife, inclusive of deer, jackals, parrots and wood-peckers, has seen drastic decline since the 1970's with current numbers nearing extinction. The common (desert) red fox, Kuhl's pipistrelle, Indian desert cat, Chinkara, Indian hare, and Indian hairy-footed gerbil habitats are also present but in very small numbers as result of direct reductions and habitat changes over the last century (Taber et al., 1967).

The desert is home to both resident and migratory species. Thal Game Reserve is estimated to host over 2.5 million birds from 55 different species. Bird populations peak around December–January, due to an increase in the population of migratory and winter visitor species. After midwinter, overall population begins to decline and reaches its minimum between May–June. Migratory birds include the Peregrine Falcon, Common quail, Sky Lark, Rosy Starling, Yellow Wagtail and the Desert Warbler (Mahboob et al., 2013).

These species breed in western Siberia and migrate to Pakistan during winter. The overall density of resident bird species is higher with the most abundant species being Turdoides squamiceps (Arabian babbler) and Lanius excubitor (Great grey shrike) (Wardman and Warrington, 1997). The birds feed on the large variety of insects found in the desert. These include the Cattle egret, Little green bee-eater, Persian bee-eater, Indian roller and Golden backed woodpecker.

Cultivated crops such as chickpeas, wheat, maize and rice are also an important food source to the granivorous birds. Larger species such as the Laggar and Peregrine falcons also prey on rodents, lizards and small birds found in the area (Mahboob et al., 2013).

2.8 Land characteristics

The districts of Mianwali, Bhakkar and Khushab consist of agricultural waste lands forming ridges of sands including longitudinal, transverse sand sheets with silty and clayey deposits that occur in narrow strips. The sand ridges are 5 to 15 m high. Between the sand ridges, there are hollows where runoff water is collected after the rain (Rahim et al., 2010). Most of the area is barren wasteland with scanty drought resistant trees, shrubs and grasses.

The development of irrigation activity in Thal Doab was made by Rangpur, Thal and Muzaffargarh canals where native vegetation is of arid type. Thereafter, efforts have been made through construction of the greater Thal Canal and tube wells installations to bring desert areas under cultivation. Chickpea, a drought tolerant cash crop, is widely grown in Thal. However, the yield can be increased many folds by addressing various constraints such as water availability.

2.9 Land utilization statistics

Land utilization status in six districts of Thal desert is depicted in Table 1. It is obvious that a significant area in district Khushab goes without cultivation due to being under desert conditions. The southern part of Lower Thal is under extensive agriculture where different crops and orchards are grown.

Table 1: Land Utilization Status in Thal (2013-2014)

(000) ha

District	Reported area	Cultivated Area			Uncultivated Area				Crop Area		sown more than once
		Total	Net sown	Current fallow	Total	Cultural waste	Forest	Not available for cultivation	Kharif	Rabi	
Layyah	628	474	369	105	154	98	11	45	162	341	134
Muzaffargarh	831	427	350	77	404	267	35	102	309	363	322
Bhakkar	813	741	660	81	72	14	26	32	196	589	125
Khushab	654	468	373	95	186	108	41	37	88	341	55
Jhang	617	484	417	67	133	71	5	57	252	425	261
Mianwali	577	428	308	120	149	3	10	136	142	216	50

Source: Punjab Development Statistics 2016, Bureau of Statistics, Govt. of Punjab, Lahore: 40-41

The area under tube well irrigation in districts; Muzaffargarh, Jhang, Layyah and Bhakkar varies for 22 to 72% (Table-2; Table-3) where groundwater is used for supplement irrigation. About 4% desert area is available for grazing throughout the year wherein sheep, goats and cattle are the dominant livestock of the area. Also, more than 60 % area of district Bhakkar and Layyah (forming middle of Thal) is prone to meteorological and agricultural drought conditions; soils are non-saline, non-sodic in nature and a complex of mainly poor sandy grazing land to poor sandy irrigated crop land. The prevailing landscape could be altered by implying wind breakers, developing shelterbelts (Shaheen et al., 2020).

Table 2: Area Sown, Irrigated and un-irrigated by Mode of Irrigation (2004-05)

(000) ha

District	Total area sown	Un-irrigated area	Irrigated				
			Total	Canals	Wells	Tube wells	Others
Layyah	467	77	390	35	6	348	1
Muzaffargarh	671	22	650	74	9	566	1
Jhang	940	71	869	89	32	747	1
Bhakar	770	403	419	138	52	229	-
Khushab	433	306	127	89	7	29	2
Mianwali	316	96	220	99	4	116	1

Source: - Punjab Development Statistics 2007, Bureau of Statistics, Govt. of Punjab, Lahore: 67

Table 3: Area Sown, Irrigated and un-irrigated by Mode of Irrigation (2014-15)

(000) ha

District	Total area sown	Un-irrigated area	Irrigated				
			Total	Canals	Wells	Tube wells	Others
Layyah	543	98	445	3	12	430	0
Muzaffargarh	671	33	626	120	12	503	3
Jhang	633	45	559	17	29	539	3
Bhakar	847	419	428	121	10	297	0
Khushab	440	290	150	92	18	38	2
Mianwali	363	79	284	127	46	104	7

Source: - Punjab Development Statistics 2016, Bureau of Statistics, Govt. of Punjab, Lahore: 75

2.10 Population

The population census 2017 indicates a 53 % average increase in population in Thal Doab. The total population is over 13 million, however, the, majority is still dependent on rainfalls for the irrigation of their crops.

Table 4: Population Statistics of Pakistan

District	Division	Population 2017	Population 1998	Percentage Increase
Mianwali	Sargodha	1,546,094	1,056,620	46.32
Khushab	Sargodha	1,281,299	905,711	41.47
Bhakkar	Sargodha	1,650,518	1,051,456	56.97
Jhang	Faisalabad	2,743,416	1,869,421	46.75
Muzaffarhgarh	D.G.Khan	4,322,009	2,635,903	63.97
Layyah	D.G.Khan	1,824,230	1,120,951	62.74
Total		13,367,566	8,640,062	64.64

Source: - Population Census (2017): Pakistan Bureau of Statistics, Islamabad

3 Methodology and Implementation

A comprehensive methodology to achieve project objectives was defined in the PC-I of the project and the same was adopted for implementation of the project activities. However, details of objective wise methodology is as under;

3.1 Objective 1: To identify the water and agriculture related issues and problems in Thal Doab and develop management strategy to enhance land and water productivity;

One of the major components of the project was to identify prevailing water and agriculture related issues in the project area and accordingly devise a management strategy to implement project activities to enhance land and water productivity. For this purpose, the project team relied on the available secondary data at first. This first hand data was useful to layout project area's demographic, geographic, topographic and climatic profiling. Furthermore, an inception meeting of the project was also conducted in the beginning of the project. Detail is given below;

3.1.1 Project inception workshop

An inception meeting was held at Mianwali on 25th October, 2017. District Officers from On-Farm Water Management and Agriculture Extension Department, District Mianwali, Khushab, Jhang, Muzaffargarh, Layyah and Bhakkar attended the meeting. Progressive farmers of the project area also attended the event. A list of the workshop participants is annexed (Annexure-II). Project Director gave a detailed presentation on aims and objectives of the project and informed the participants about groundwater investigations and mapping carried out by PCRWR, during last decade in Thal Doab. He also elaborated the implementation methodology and site selection criteria for provision of water management packages for Thal desert under the project. In the inception meeting all the participants were asked about success and failure of the existing irrigation, water and soil conservation practices in the area. They were further asked to suggest measures and ways for improvement of agricultural productivity through soil and water conservation techniques. The participants were asked to identify; the problems and works/activities already carried out by relevant line departments in Thal Doab; the gaps in work already been done; and the potential partners and beneficiaries.

Whereas, for the identification of project specific issues a reconnaissance survey in the project area was conducted by PCRWR team. This survey aimed to collect preliminary information of agricultural, irrigation, economic and cultural practices of the project area. The data collected through the reconnaissance survey was analyzed and a questionnaire was developed for an extensive baseline survey.

3.1.2 Questionnaire development

On the basis of information obtained during reconnaissance survey, a questionnaire was developed and piloted to understand the socio economic aspects of farmers and to identify water and soil related issues in the project area. The main features of the questionnaire included information about existing irrigation and cultural practices, cropping pattern and production, extent of land and water problems (salinity & sodicity, waterlogging, infertility, erosion, etc.), water availability and irrigation systems and methods. Farmers' attitude towards improvement and acceptance of the latest water related technologies were also taken into account.

3.1.3 Baseline field survey

After successful pretesting of the developed questionnaire an extensive baseline survey of the project area was conducted by the project team. Total 135 farmers were interviewed during the baseline survey in three project districts (Table 5). The information related to water and soil management issues was collected through the questionnaires. Moreover, data on social and economic conditions was documented.

Table 5: List of No. of UCs Surveyed, Farmers Interviewed and Sites Identified for Project Interventions

Sr. No	Surveyed District	Surveyed Tehsil	Union Councils	Farmers Interviewed	Sites Identified
1	Khushab	Noorpur Thal	12	42	07
2	Bhakkar	Mankera	09	30	10
		Darya Khan	08	25	07
3	Mianwali	Piplan	12	38	12
Total			41	135	36

3.1.3.1 Sampling technique

The project area spans over 20,504 Km^2 consisting of 10 tehsils. The tehsils in each district are characterized with different geological, morphological and topographic characteristics. Although all the three districts lie in Thal desert, however, these tehsils don't possess the same characteristics. Therefore, it was a major challenge to identify a representative sample from the entire population. However, the project team opted cluster sampling method for this purpose. Cluster sampling is a method of probability sampling that is often used to study large populations, particularly those that are widely dispersed geographically.

In this project, the project team used Union Councils of the eligible tehsils as units of the cluster. In each cluster a list of farmers/ landowners was developed by the help of local administration to screen out eligible landowners/ farmer for the purpose of data collection. One of the major criteria to identify the eligibility of the farmer/ landowner was ownership of at least 10 acres of land will to adopt new irrigation technologies. After screening process, a list of farmers was finalized and eligible farmers/ landowners were randomly selected for the baseline survey. Table 5 describes the cluster wise sampling of tehsils, union councils and total No. of respondents in each cluster.

3.1.3.2 Data analysis of baseline survey

All the collected data through baseline survey was edited on paper at first to cross check the errors and omission and validate the values. Then the data was entered into excel spreadsheet. Meanwhile, all the variables to be analyzed were defined on Statistical Package for Social Sciences Software (SPSS 24). The spreadsheet data was exported to SPSS and was analyzed according to objectives of the study.

A total of 135 farmers were interviewed during the baseline survey. The survey aimed to assess the prevailing water related and socio-economic issues faced by the local farmers. A comparative analysis of all four tehsils was carried out to identify the correlation between different dependent and independent variables and to obtain a clear picture of the study area. Figure. 1 shows the minimum, maximum and average area of farms in all four tehsils of the study area. It depicts that largest farms existed in Mankera and Noorpur Thal tehsils with average farm size of above 30 acres and 15 acres respectively. However, the maximum area for a farm in tehsil Piplan was noted as 50 acres. Figure below shows that average farm size in respect with area in the tehsil were above 15 acres. Figure 1. clearly indicates that tehsil Darya Khan had least cultivable land as it was found that average farm size in the tehsil was below 15 acres.

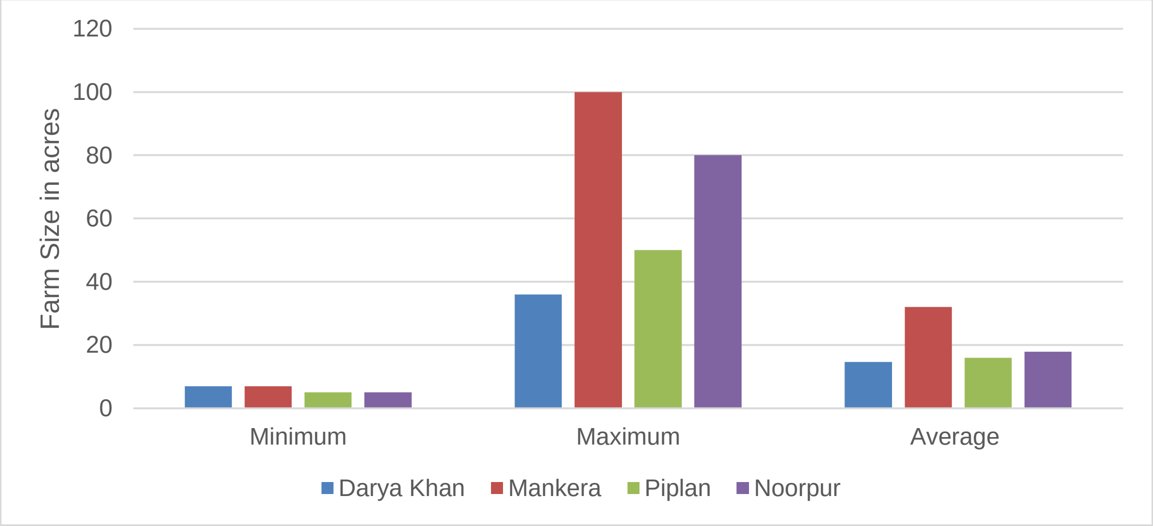

Figure 2: Distribution of Farm sizes in respect to minimum, maximum and average area

Figure 2 shows the annual per acre expenditure in four tehsils in term of maximum, minimum and average. It was found that annual maximum expenditure per acre in tehsil Darya Khan came out to be Rs. 70,000 which had the least average farm size. However, annual per acre expenditures in tehsil Mankera and tehsil Piplan were found to be higher. The average for Mankera and Piplan was Rs. 20,000 and Rs. 17,000 respectively compared to the other two tehsils. These two tehsils with higher average annual expenditures had been found with higher average areas of farms. It is found that there is a strong correlation between farm size and annual per acre expenditure.

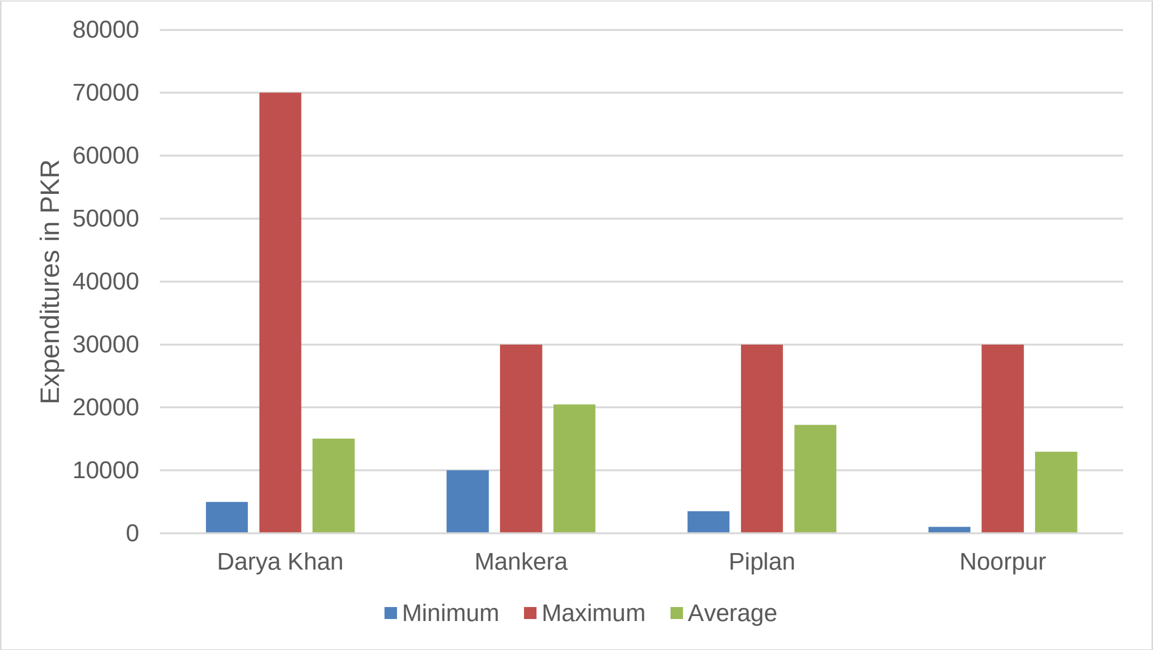

Figure 3: Minimum, maximum and average annual per acre expenditures

Figure 3 shows the maximum, minimum and average per acre annual income in the study area. It was found that there was a strong correlation between cultivable land, expenditure and income and is significant at 0.9 level. Figure 3 depicts that maximum annual income per acre was in tehsil Darya Khan however, annual per acre income on average was found higher in tehsil Mankera and tehsil Piplan with an average of Rs.40,000 and Rs.35,000 respectively. The average, maximum and minimum annual per acre income in tehsil Noorpur Thal was noted significantly low as compared to other tehsils. Whereas, annually expenditure of Noorpur Thal was found to be closer to other tehsil.

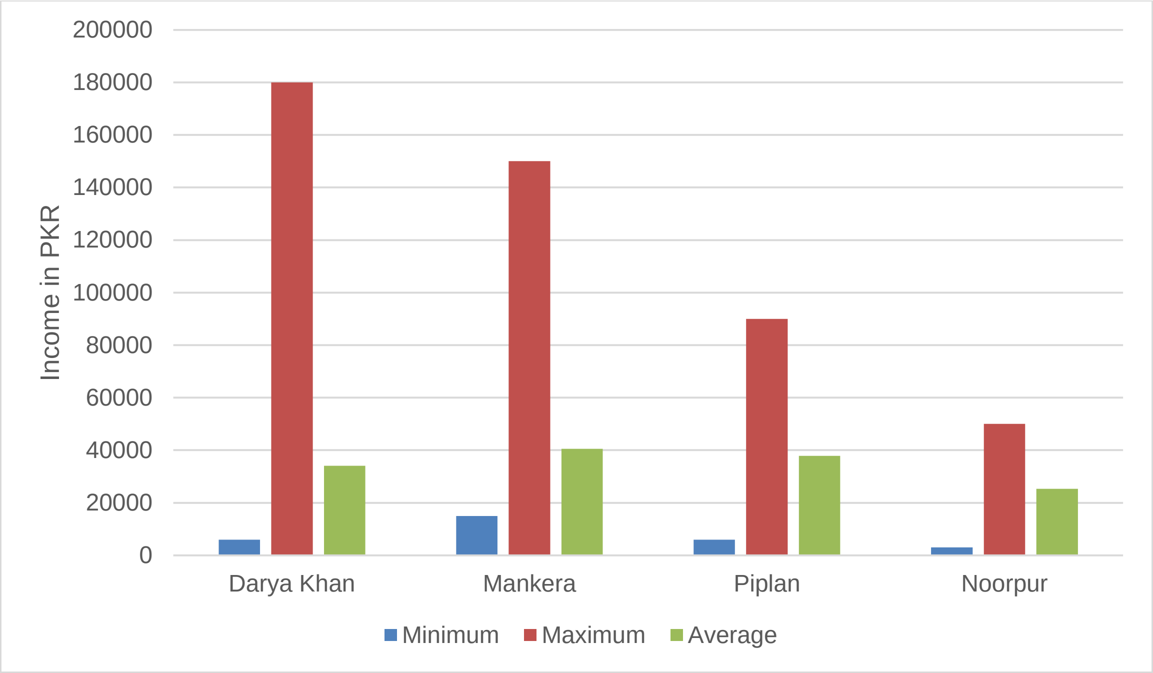

Figure 4: Minimum, maximum and average annual per acre income

Figure 4 shows the basic farm machinery owned by the farmers at their farms in the four tehsils. It clearly indicates that percentage of owned farm machinery in tehsil Mankera and Piplan is higher than Darya Khan and Noorpur Thal. It shows that more than 70 % farmers in the two tehsils own basic farm machinery including tractor, cultivator and drill. It was also found that despite low average annual income in tehsil Darya Khan and Noorpur Thal compared to Mankera and Piplan, more than 50% farmers own basic farm machinery.

It indicates that there is strong relationship between owned farm machinery, farm size and income. The tehsils with higher area of farms had higher income and more percentage of owned farm machinery i.e. average farm size in tehsil Mankera was found 32 acres, average annual expenditure was Rs.20,483 and average annual income was Rs.40,483 which indicates about 50% annual profit to farmers and therefore, high number of farmers own farm machinery. Whereas in tehsil Noorpur Thal average farm size is lowest and respectively the expenditures and income is also low, therefore, less number of farmers own farm machinery.

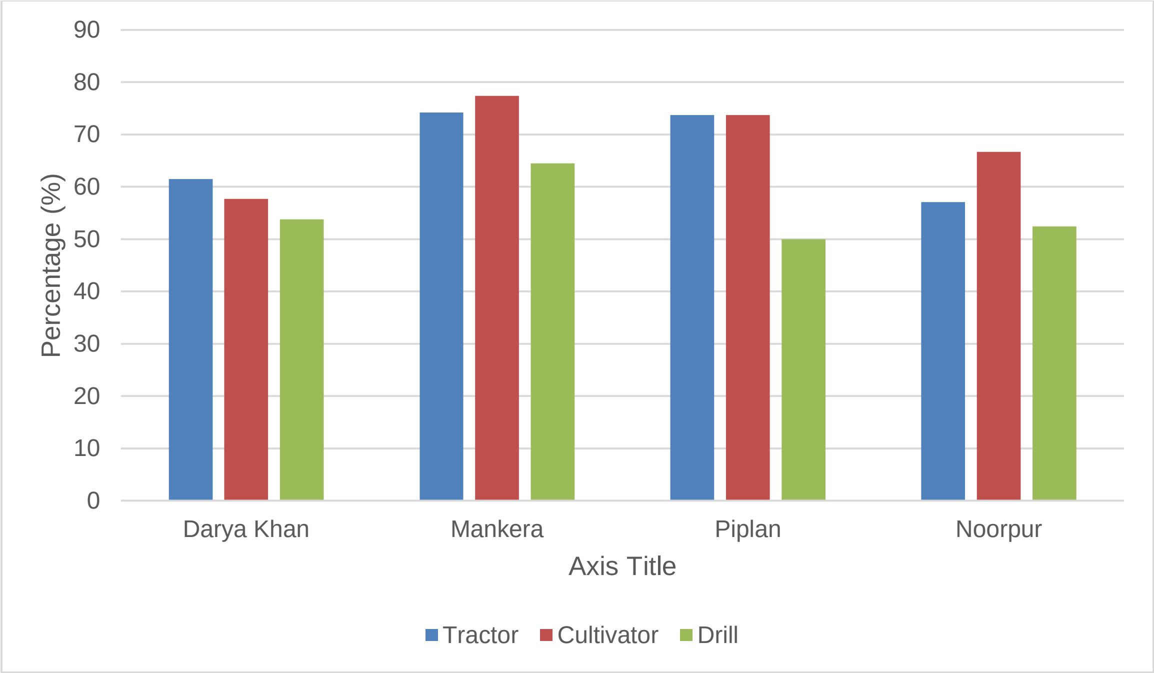

Figure 5: Percentage of farmer owning basic farm machinery

Figure 5 shows percentage of farmers in the study area who avail canal irrigation facility to irrigate their lands. It is evident that more than 50 % farmers in tehsil Piplan had access to canal irrigation facility whereas, irrigation facility availed by the farmers in all remaining three tehsils was found to be less than 33 %. It depicts that a major proportion of farmers in the study area either had no access to canal irrigation system or were not availing the canal irrigation facility.

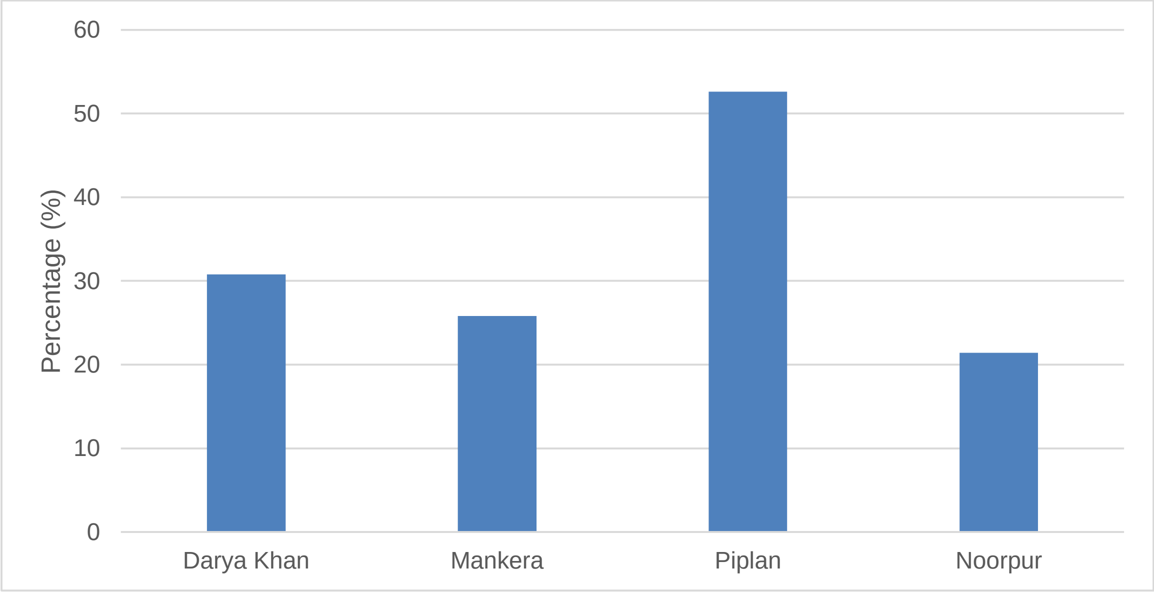

Figure 6: Percentage of farmers availing canal irrigation facility

Figure 6 shows the percentage of land owner who own the tubewells to irrigate their lands in the study area. It shows that farmers in those tehsil with least access to irrigations facility owned more number of tubewells than those who had access canal irrigation system. Figure 6 also shows that about 90 % farmers in tehsil Mankera and about 70 % farmers in tehsil Noorpur Thal owned tubewells. However, the percentage of farmers availing tubewells for irrigation in Darya Khan was a meagre 50 %.

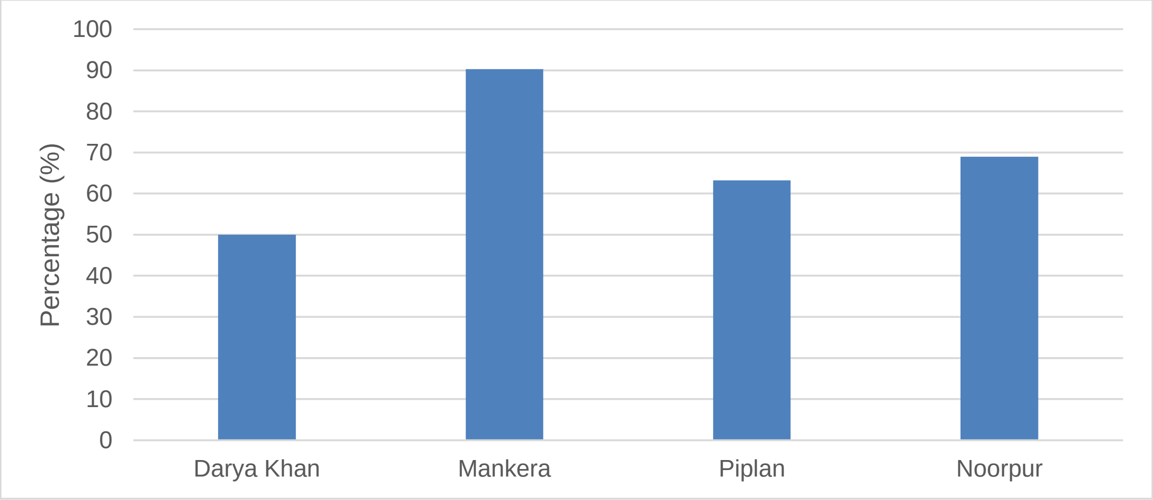

Figure 7: Percentage of farmers availing tubewell facility

Figure 7 shows last ten years' production in respect to very good, average and very poor in the four tehsils. The results show a strong relationship between irrigation facility and production in last ten years. It could be concluded that farmers in tehsils Mankera and Piplan had the best average for the last ten years whereas, Darya Khan had the worst average production, indicating a strong correlation between canal irrigation facility and average production.

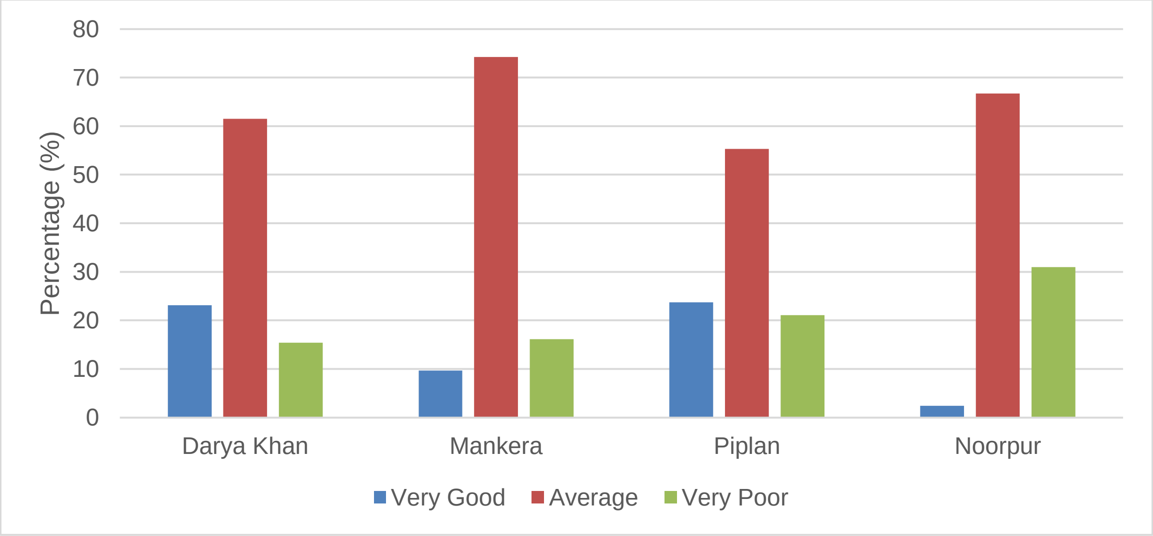

Figure 8: Tehsil wise farmers according their perception of last ten years' production

Figure 8 shows overall percentage of farmers in respect to their perception about last ten years' production. It shows that about 65 % farmers had the view that their production had been on average, more than 20 % said that the production had been very poor and more than 10 % said their product during the last ten year's had been very good. So, it is evident that a major proportion of farmers in the study area were either not very satisfied with the production or were disappointed.

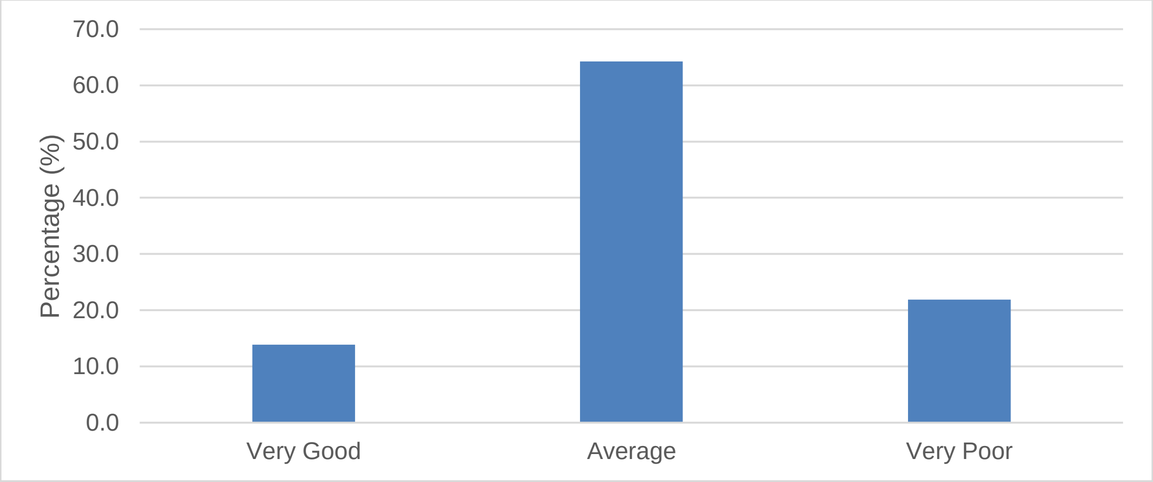

Figure 9: Perception of farmers for last ten years' production in study area

Figure 9 shows the distribution of cropping pattern in four tehsils. It shows that major crop of the study area was wheat which was being sown by the more than 40 percent farmers in each tehsil of the study area. The second major crop was pulses as the area and land is most suitable for cultivation of pulses. It was found that more than 30 percent farmers in each tehsil grow pulses as major crop. Whereas, it was also found that a small proportion of farmers were also growing Sugarcane as major crop. However, this was restricted to the areas with available canal irrigation.

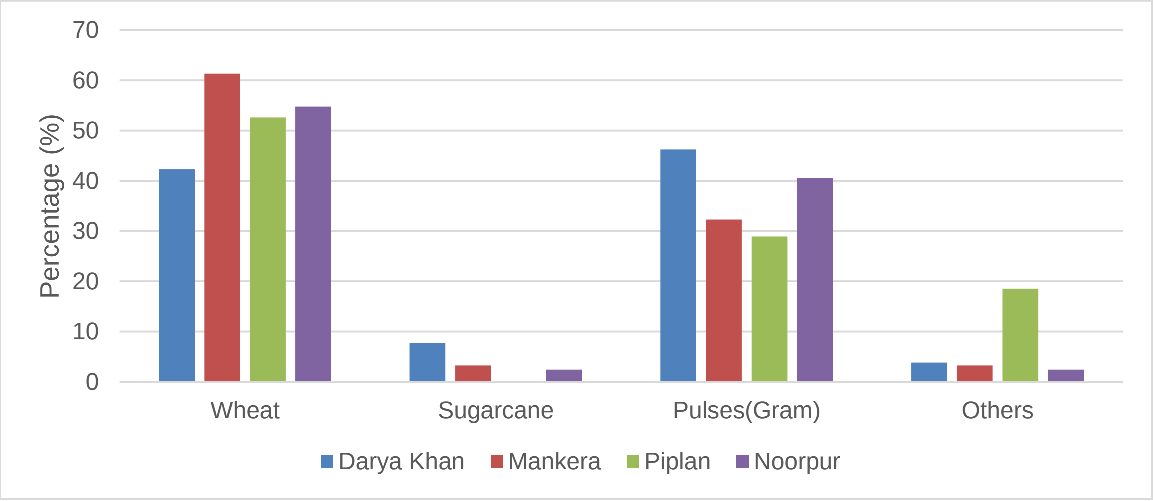

Figure 10: Tehsil wise distribution of major crops

Figure 10 shows the overall cropping pattern in the whole study area. It could be noticed that wheat was found major crop of area covering more than 50 % of total cultivated land followed by Pulses which covers about 36 % of the total area. Other crops grown at a very low percentage were found to be sugarcane, cotton, millet and oil seeds covering about 8 percent of total area.

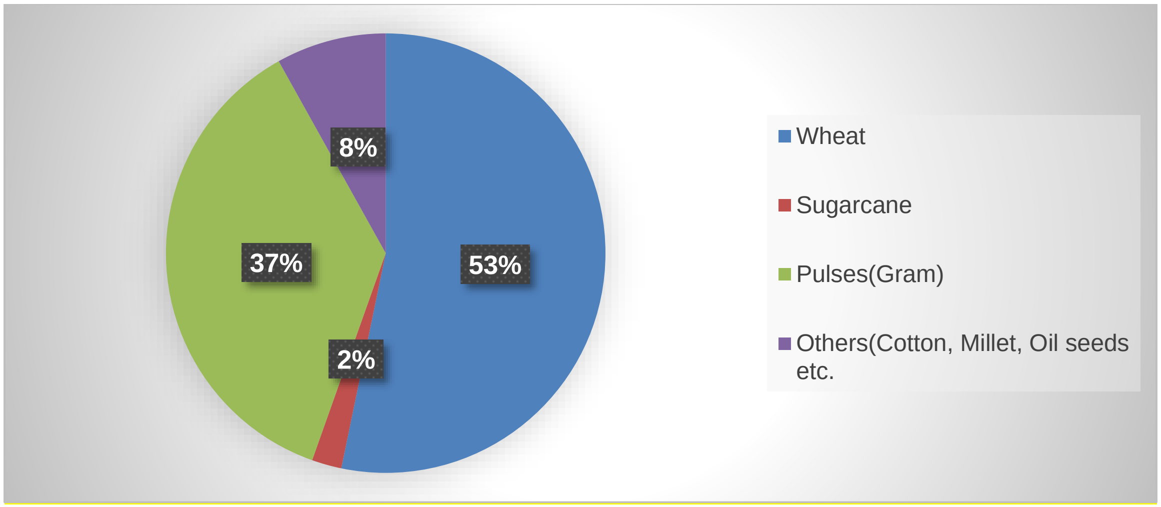

Figure 11: Area under cultivation of major crops in study area

Figure 11 shows land levelling status in the study area. It shows that tehsil Noorpur Thal and Piplan had the maximum area levelled at about 70 % and more than 60 % respectively. Whereas, in tehsil Noorpur Thal only 2.4 % area was not levelled. Land levelling status in tehsil Darya Khan shows almost equal proportion for levelled, partially levelled and not levelled. Whereas, it was found that a large area about 80 % in tehsil Mankera was partially levelled, only about 12 percent was fully levelled and about 6 percent was not levelled yet.

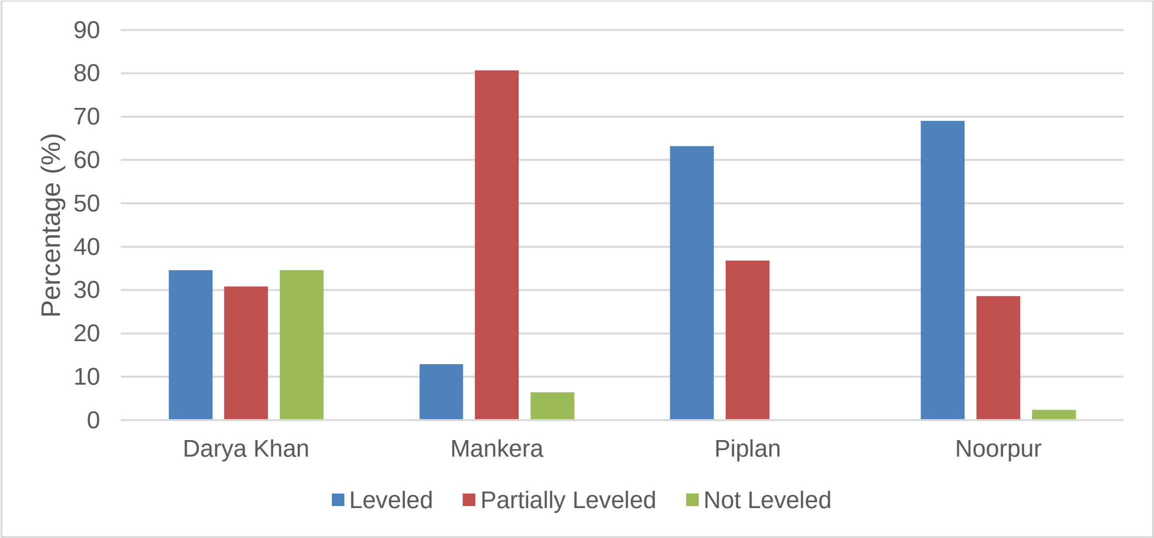

Figure 12: Tehsil wise land levelling status

Figure 12 shows the distribution of land according to their levelling status in the study area. It was found that about 48 percent area was levelled, 43 percent was partially levelled whereas only about 9 percent area was not levelled.

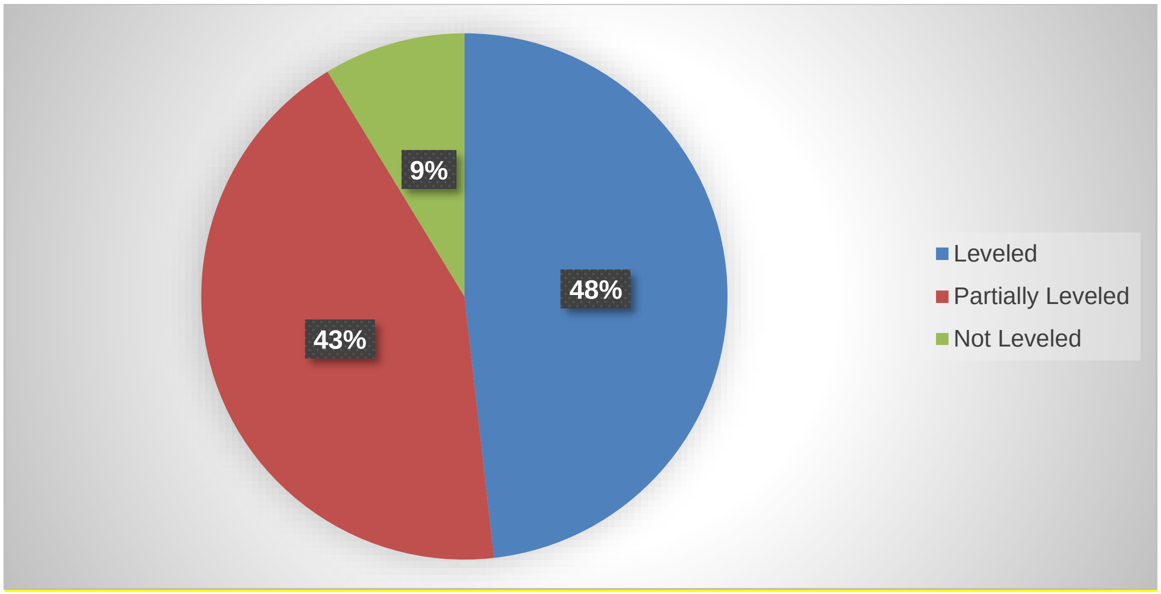

Figure 13: Overall land levelling status of study area

Figure 13 shows the availability of groundwater in four tehsils. It was found that more than 80 % farmers had normal groundwater availability at their lands. Only very few in three tehsils; Darya Khan, Piplan and Noorpur Thal were of the view that groundwater was scarce in their lands. However, a larger number of farmers had normal groundwater available at their lands.

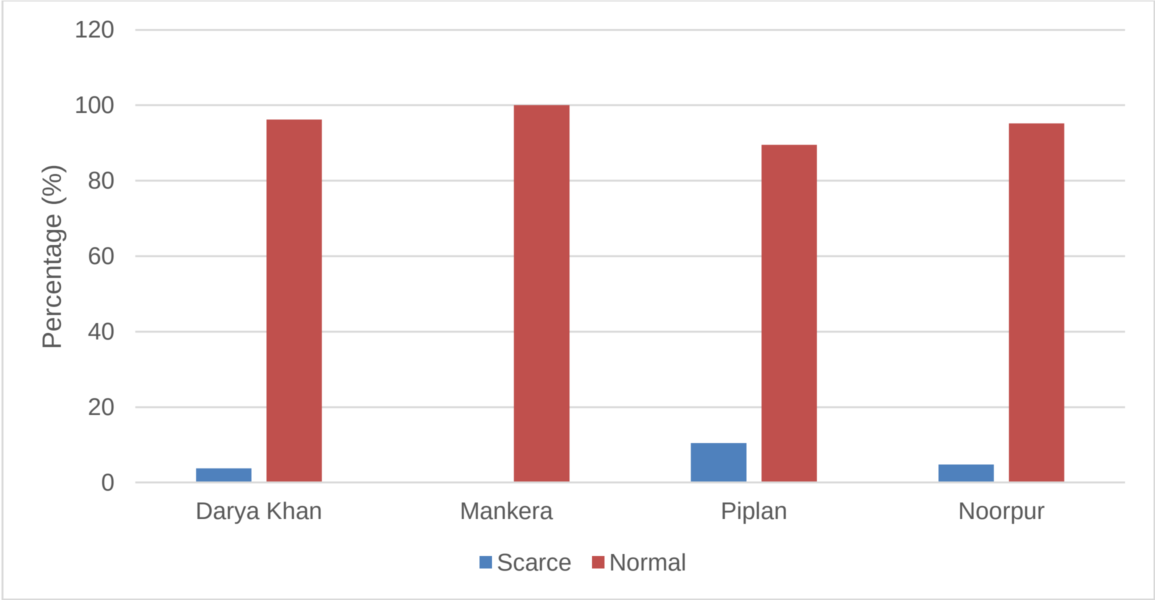

Figure 14: Tehsil wise availability of groundwater

Figure 14 shows that a major proportion of the farmers were found to be satisfied with the traditional methods of irrigation. The most number of farmers who were found to be satisfied with the traditional methods were those in tehsil Mankera. This satisfaction was for areas with canal irrigation, however, areas that were rain fed showed dis-satisfaction.

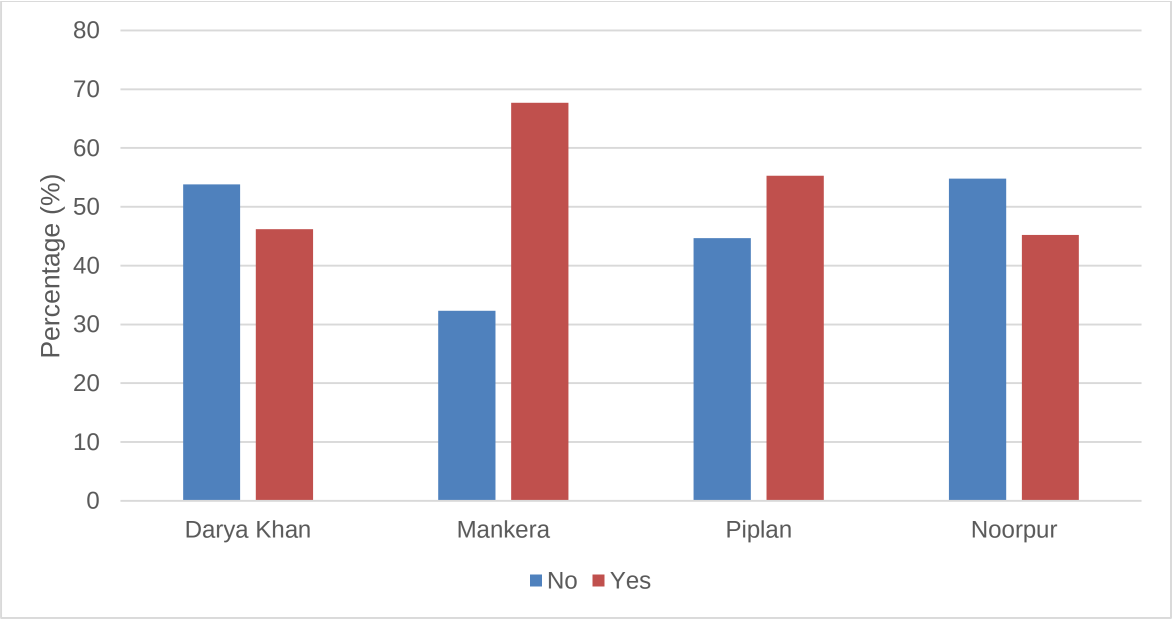

Figure 15: Tehsil wise percentage of farmers according satisfaction with traditional irrigation

Figure 15 shows the overall level of satisfaction among the farmers for traditional irrigation methods. It shows that more than half of the farmers were satisfied with traditional method of irrigation.

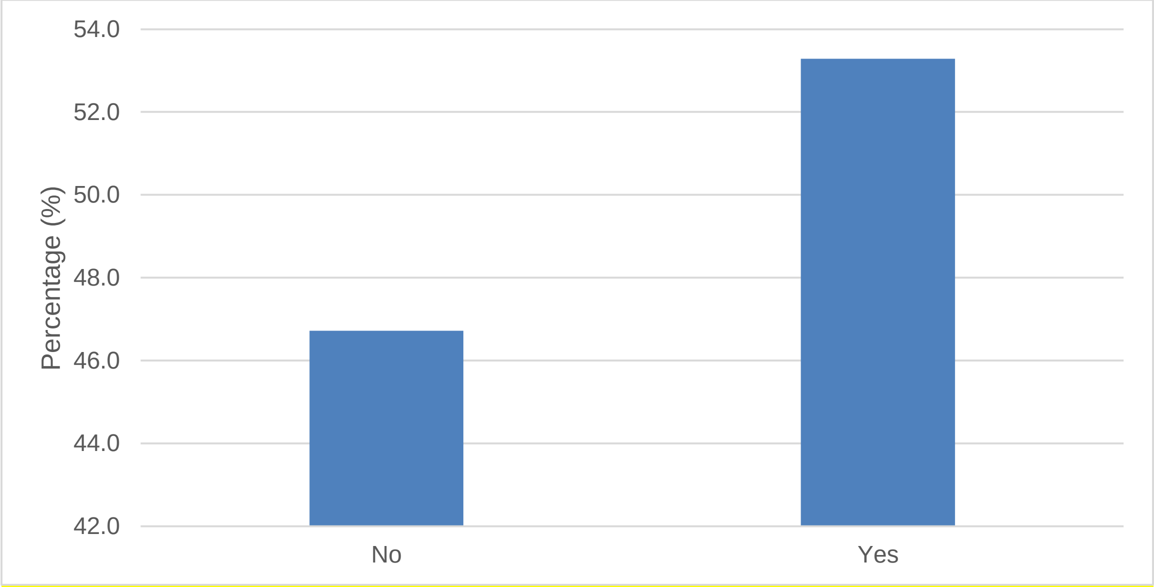

Figure 16: Over-all satisfaction of farmers with traditional methods of irrigation

Figure 16 shows the percentage of farmers having knowledge of high efficiency irrigation methods. It was found that more than 70 % farmers in tehsil Mankera and Noorpur Thal were aware of High Efficiency Irrigation system (HIES) and more than 50 % of the farmers in Darya Khan had its knowledge. Whereas, it was found that slightly 44% farmers had knowledge of HEIS in tehsil Piplan.

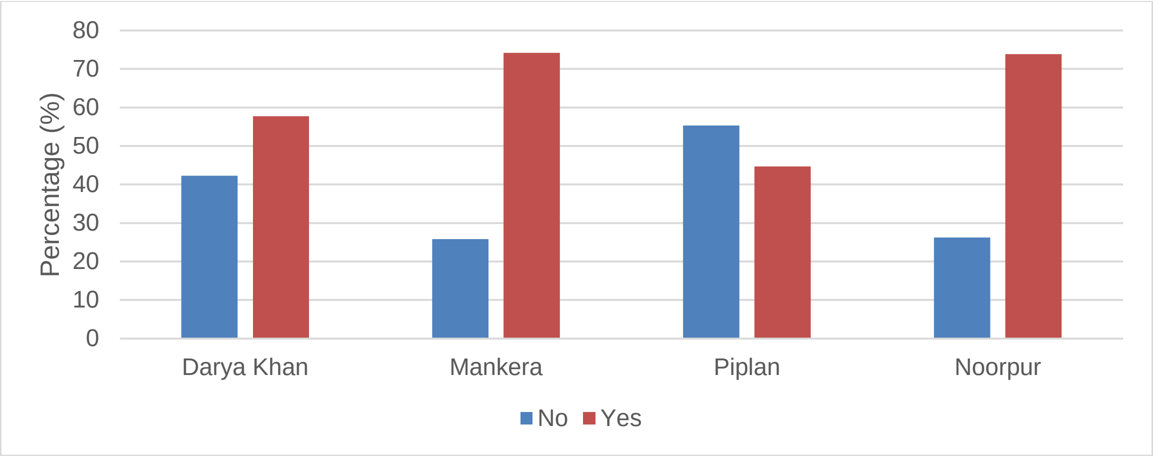

Figure 17: Tehsil wise percentage of farmer aware of high efficiency irrigation methods

Figure 17 shows the percentage of farmers willing to install solar powered pumping system at their farms. It was found that almost all the farmers in three tehsils; Darya Khan, Mankera and Noorpur Thal wanted to install solar powered pumping system to irrigate their lands. However, 10 % farmers in tehsil Piplan refused to install solar powered pumping system at their lands. It could be concluded that those who refused to install solar systems were unaware or had no knowledge of high efficiency irrigation methods. It is also evident that more than half of the farmers in tehsil Piplan had no knowledge of high efficiency irrigation methods. It is also evident that a large number of farmers were willing to install solar tubewells at their lands to enhance crop and food productivity.

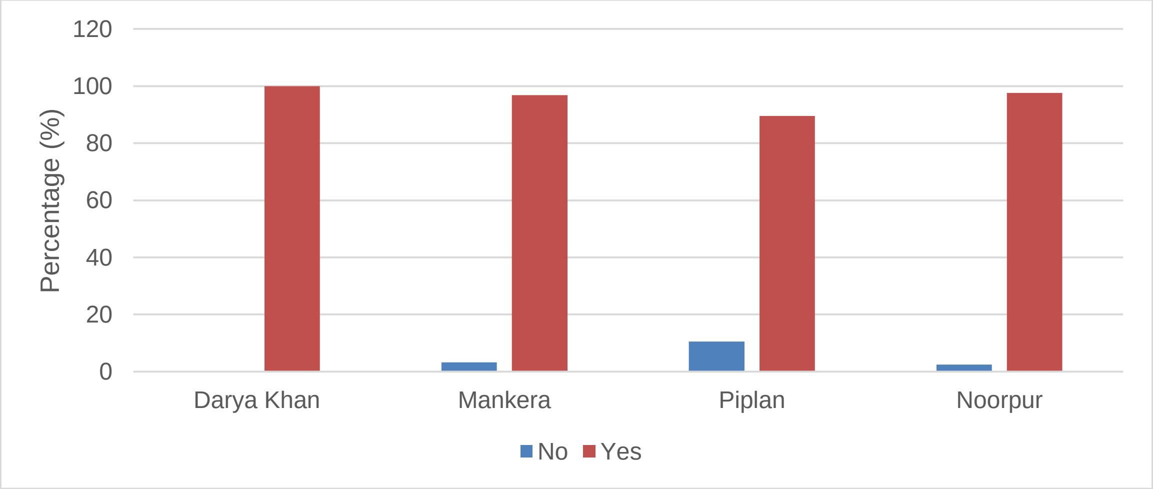

Figure 18: Percentage of farmers according to will to install solar pumping system

3.1.4 Management strategy

A detailed baseline survey was conducted in the project area to identify the issues of the area. On the basis of the survey, problems were identified and consequently a mitigation/management strategy was devised which was sustainable, cost efficient and would maximize the productivity which in turn would be beneficial for the improvement of livelihood of the community as described below.

3.1.4.1 Solar-powered pumping system

The area is underlain by huge reservoir of water (20 MAF) in the form of groundwater aquifer as identified in PCRWR's study. However, the primary issue identified during the baseline survey was the unavailability of water to the farmers for irrigation purpose. This was due to lack of resources and facilities to pump groundwater which was available at shallow depths both due to financial constraints at the end of farmer and constant supply of electricity. To mitigate these issues, a sustainable and cost efficient system in the shape of solar powered pumping system was selected. This system in particular is ideal for the project area due to constant and round the year availability of solar energy. In addition, it was also observed during the survey that average farm size of the area was 10-20 acres, for which solar powered pumping through submersible pumps was best suited, which could be easily coupled with High Efficiency Irrigation Systems.

3.1.4.2 High efficiency irrigation system

Another issue identified during the survey was lower yield of crops due to sole reliance on rain and unsuitable strata for traditional agriculture practices. The soil strata of the area is sandy and traditional practices are not suited in the area. To utilize the potential of the area to the fullest and maximize the income of the farmer, High Efficiency Irrigation System (Drip and Sprinkler) coupled with the solar powered pumping system was introduced under this project. Based on the land and topography of the individual farm, the land was divided in two areas. One for fruit orchard on drip irrigation and the other for crops on sprinkler irrigation system. Consequently, layout plans for the same were developed for proper implementation (Attached at Annexure-I).

3.1.4.3 Vegetative cover for controlling wind erosion

Thal doab is primarily a desert area which is prone to high level of erosion due to winds. This causes immense problems to the already suffering farmers of the area. The crops sown are frequently uprooted due to erosion. To counter this problem, each model site was given a shelter belt/vegetative cover of fast and locally grown hard species of Tamarixaphylla (Khagal). In addition, this vegetative belt was provided with irrigation through the drip system keeping in view the aspect of sustainable management. This belt/cover provides two advantages to the farmers, one is that the issue of land erosion and subsequent damage to the crops is curbed and the other is that the trees once grown can be cut and sold to generate income without disturbing the protection of vegetative cover.

3.2 Objective 2: To implement improved measures for; controlling wind erosion and developing groundwater using improved techniques on farmers' fields

During the baseline survey all the respondents were explored for their willingness to adopt water conservation technologies and smart irrigation techniques. A list of those farmers who were agreed to adopt the improved irrigation technologies for better land productivity was prepared. The next step was to identify an appropriate site selection for implementation of project. Following process was adopted for the purpose.

3.2.1 Site selection criteria for water conservation technologies

The PC-I of the project clearly mentions the criteria for the selection of sites for provision of water conservation technologies. During the implementation phase, the same criteria was followed to identify and select the sites. The criteria is as;

i. The project sites are to be selected based upon their ease of access and development prospects like availability of harness-able water, vegetation cover, reasonable land use and cropping intensity, etc.

ii. The site selection mainly encompasses progressiveness, receptiveness and motivation level of the farmers.

iii. Farmer has agreed to the technology provisions and cost sharing arrangements in terms of unskilled labor, land leveling etc. and full responsibility of operation and maintenance of the system.

3.2.2 Final site selection

Final site selection was carried out according to the above mentioned criteria through the list of potential progressive farmers/landowner willing to adopt the water conservation technologies and contribute their share. Total thirty-six potential farmers were identified based upon the farm's ease of access and development prospects like availability of harness-able water, vegetation cover, reasonable land use and cropping intensity, etc. Out of these potential farmers eight were finalized for the installation of the water management package keeping in view the progressiveness, receptiveness and motivation level of the farmers, readiness to bear their share of the capital cost in the form of unskilled labor for bed and furrows, land leveling etc. and full responsibility of operation and maintenance of the system. A total 08 such sites were identified. The selected sites were strictly screened for the parameters identified in the PC-I. The final site selection is also dependent on the farmers agreeing to the cost sharing arrangements in terms of unskilled labor, land leveling etc. and full responsibility of operation and maintenance of the system. The details of the selected sites are as follows: -

Table 6: Detail of Selected Sites for Project Interventions

No.	Famer Name	Tehsil	District
1	Farooq Shah	Piplan,	Mianwali
2	Mian Nasrullah	Dullewala,	Bhakkar
3	Mian Rehmat-Ullah	Dullewala	
4	Muhammad Amer	Dullewala	
5	Mian Anjum Saeed	Mankera	
6	Afzaal Nadeem	Noorpur Thal	Khushab
7	Aziz ullah Budhana	Noorpur Thal	
8	Sultan Ahmad	Noorpur Thal	

3.2.3 Signing of deed

After successful selection of the sites, an agreement defining the roles and responsibilities of the two parties was signed between PCRWR and the selected beneficiary farmers to execute the project activities. The beneficiaries of the package were required make commitment to adopt soil and water conservation measures suggested by PCRWR. Specimen of the deed agreement is given at Annexure-III.

3.2.4 Topographic survey

After the agreement signed between farmers and PCRWR, the field team along with farmer conducted the site survey to carry out investigations required for the efficient design of the water conservation technologies. The data on site layout, soil type, topography, water source, power source, etc., was collected during the survey.

3.2.5 Design of water conservation technologies

On the basis of the topographic survey conducted at farmer's sites, design of water conservation practices, drip irrigation and sprinkler systems were made, including solar pumping system to make technology implementation sustainable. Details of each site for project interventions is as below in the table: -

Table 7: Detail of Project Interventions at Each Site

No.	Famer Name	Solar Panels (Nos.)	7.5 HP Submersible pump (Nos.)	Drip System (Acres)	Sprinkler System (Acres)	Shelter Belt Khagal Plants (No)
1.	Farooq Shah	34	01	5	4	2,480
2.	Mian Nasrullah	34	01	5	5	2,200
3.	Muhammad Amer	34	01	5	4	3,100
4.	Mian Anjum Saeed	34	01	6	4	1,200
5.	Mian Rehmat-Ullah	26	01	10	2	4,300
6.	Afzaal Nadeem	26	01	6	4	2,325
7.	Aziz ullah Budhana	34	01	5	4	2,480
8.	Sultan Ahmad	34	01	6	4	2,500

Layout designs of the project interventions for each site were developed and annexed (Annexure I).

3.2.6 Lift irrigation system

Solar powered pumping has been used in Thal desert for the project keeping in mind the financial constraints and the availability of energy resources in the area. The system consists of 34 solar panels with moveable frame/tracker. Submersible pump of 7.5 hp has been provided to the identified farmers for irrigation of 9-10 acres. This system is designed for 20 acres and the farmer in future can extend the system at their own cost.

3.2.7 High efficiency irrigation system

Considering the potential of high value orchards and the topography of the project area, drip irrigation system was selected for irrigating orchards. Two types of drip were used. One for the orchards and one for the vegetables to be grown between the rows of orchard. The latter done through integrated pipes with emitter spacing of 50 cm and row to row distance of 3 ft. This practice would enable the farmers to utilize the land to the maximum and for their social uplift.

The drip and sprinkler system was designed keeping in mind the future prospects of expansion. The solar powered pumping along with the drip and sprinkler system was installed on 10 Acres but could be expanded to 20 Acres if the farmer desires to. Submersible pump of 7.5 HP was selected for the purpose and accordingly the solar panels were selected. Two systems of drip were installed at the site. One was to grow orchard of famer's choice with 15 ft distance from plant to plant and row to row. While, the other was integrated drip system to grow vegetables between the rows of plants to maximize the land utilization maintaining a distance of 3 ft between the rows of integrated drip lines. To maintain the pressure throughout the farm, various zones were created using valves. Similarly, hydrants were installed at a distance of 198 ft from each other to cover 4 acres with sprinkler irrigation system. The farmer was also provided with a portable sprinkler gun to cater for the irrigation needs as deemed appropriate.

3.2.8 Vegetative shelter belt

The project area is prone to high intensity winds and rainstorms, thus, causing extensive wind erosion. This is worrisome as it causes damage to the orchard as well as the installed system and the fertile layer of the soil. To counter this problem a vegetative shelter belt of indigenous Khagal (Tamarix aphylla) plants has been provided around the periphery of the farms in such a way that it acts as a wind breaker and protects the farm from adverse effects of intensive winds Another advantage of khagal is that the tree once fully grown can be cut and sold to the market earning livelihood for the farmers. The tree re-grows, hence there would be no need to replant the tree.

3.3 Objective 3: To demonstrate and disseminate improved technologies to stake holders for their wide-scale adoption.

The pre-project information on survey, design and implementation activities were documented after conducting through surveys based on cluster survey approach. An inception workshop was also organized to identify major issues of the area by interacting with the stakeholders. This helped developing a systematic approach to introduce of improved techniques to Thal Doab. Moreover, water management and conservation technologies like; solar powered pumping, drip and sprinkler irrigation for converting desert waste land into green areas were installed at farmer’s lands to act as models sites for dissemination purpose. In order to enhance wide scale adoptability of the installed technologies, various famer field days were conducted. These field days helped to promote the installed technologies by demonstrating the efficacy of the systems. The famers participated and witnessed the changes that took place through improved technologies and ultimate socio-economic uplift of the farmers. Moreover, the field days were also helpful in eliminating the misconceptions of the farmers about the high efficiency irrigation systems through practical knowledge and advocacy of their fellow farmers who have adopted the high efficiency irrigation system.

4 Impacts of the Project

4.1 Post project impact assessment

The project team carried out a post project assessment by visiting the sites and interviewing the farmers after a year of completion of project activities. Though it was very difficult to assess the full impacts of the project in such short duration, however, some of the effects of the projects were evident from the interviews of the farmers and observations during the post project assessment. The project team explored the impacts of four main dependent variables i.e. socio-economic conditions, environment impacts, transfer of knowledge through technology interventions and awareness raising.

4.1.1 Socio-economic impacts

The project team during the interviews with the farmers explored that how much these inventions had contributed in their socio-economic condition. It was found that the solar powered technology and efficient irrigation techniques helped the farmers in not only saving operational costs for but also increased the income substantially. The cropping pattern has seen a shift from one crop per year to at least two crops per year. The income from the cultivated crops on the sites of intervention is elaborated in the following table based on the post intervention survey:

Table 8: Comparison Between Barrani Irrigation and Sprinkler Irrigation System

(Rs.)

Method of Irrigation	Detail (Per acre)		Crop:1 (Chickpeas)	Crop: 2
Barani Irrigation (pre Intervention)	Expenditure	Land Preparation	7200	
		Seeds	3000	
		Sowing (labor)	2500	
		Irrigation	0	
		Fertilizers	0	
		Pesticide/ Herbicides	0	
		Harvesting	2500	
		Total	15200	
	Gross Income		24000	
	Net Income		8800	
	% Net Income Profit		57.9%	
Method of Irrigation	Detail (Per acre)		Crop:1 (chickpeas)	Crop: 2 (Sorghum)
	Expenditure	Land Preparation	7200	7200
		Seeds	3000	2500

Method of Irrigation	Detail (Per acre)		Crop:1 (Chickpeas)	Crop: 2
Sprinkler Irrigation System (Post Intervention)		Sowing (labor)	2500	2500
		Irrigation	2500	2500
		Fertilizers	0	0
		Pesticide/Herbicides	0	0
		Harvesting	2500	2000
		Total	17700	16700
	Gross Income		32000	40000
	Net Income		14300	23300
	% Net Income Profit		80.8%	139.5%

The table depicts the intensity of crops, expenditure, gross and net income per acre of land on barani irrigation and after installation of High Efficiency Irrigation System (HEIS). It shows that the farmers were bound to cultivate only one crop (chickpeas) annually on their land because they were solely dependent on rainwater to irrigate their lands, that too had very less yield. Whereas, now with the installation of HEIS and availability of water round the year, farmers have multiple choices to cultivate variety of crops. A comparative analysis of expenditure and income was also carried out and it reveals that the average expenditure for cultivation of chickpeas remained the same on barani and HEIS systems except operational and maintenance charges of HEIS. Whereas the net income (around 22%) of the farmers after installation of HEIS was increased due to increase in average yield resulted by the availability of water whenever it was needed. It is also worth noting that the income recorded for pre intervention scenario was for the years with ample rainfall in the area, which was not more than 2 years during the last decade. The rest of the period was drought ridden and the production for the same period was almost negligible causing heavy losses to the farmers.

It was observed that mostly farmers in the project area cultivated Sorghum as second crop and the estimated net income profit for the Sorghum crop in the project area was 139%. Thus, it was calculated that the net income of the farmers has increased about 110% annually on average from the cultivation of crops.

Besides the cultivation of crops on sprinkler irrigation system, orchards and vegetables were being grown on drip irrigation system. Though, the orchards had not starting producing fruits, but the farmers had cultivated two to three vegetables during the year on the intercropping drip lines. A comparative analysis of the traditionally grown chickpeas with the vegetables and fruits grown through drip irrigation system on the same land is given in the table below;

Table 9: Comparison Between Barani Irrigation and Drip Irrigation System

(Rs.)

Detail (Per acre)		Traditionally grown Chickpeas	Onions	Watermelon
Expenditure	Land Preparation	7200	2400	2400
	Seeds	3000	5000	1200
	Sowing (labor)	2500	3500	3500
	Irrigation	0	0	0
	Fertilizers/manure	0	3000	10000
	Pesticide/ Herbicides	0	2000	1000
	Harvesting	2500	4000	5000
	Total	15200	19900	23100
Gross Income		24000	163500	280000
Net Income		8800	143600	256900
% Net Income Profit		57.90%	721.60 %	1112.12%

The table clearly depicts that the availability of water through HEIS has enabled farmers to grow vegetables and fruits on their lands increasing the profit manifolds. It is estimated that net profit 57.90% has increased to 585% per acre annually by the introduction of drip irrigation system. And if we calculate cumulative income from both crops and vegetables being grown by the farmers, an increase of about 700 % per acre on average is recorded in the first year of the intervention.

From the aforementioned preliminary results, it can be deduced that the average annual income of the farmers has seen rapid and exponential increase contributing towards the improvement in the livelihood and socio-economic conditions.

4.1.2 Environmental impacts

The project team during the post project assessment carried out an "effect based" assessment of environment. As it is evident that high efficiency irrigation system has many environmental benefits over conventional methods of irrigation, the environmental benefits of project interventions were assessed and explored at farm based micro level. First and utmost impact of the project intervention on the environment was converting barren lands into green productive lands. The lands which were once deserted and were producing only one crop per year which was also highly dependent on rainfall, had now been capable to produce at least two crops a year. It is evident that environment and agriculture are interrelated processes, both of which take place on a worldwide scale. Agriculture has been shown to produce significant effects on environment, primarily through the production and release of greenhouse gases such as carbon dioxide, methane and nitrous oxide. In addition, agriculture that practices tillage, fertilization, and pesticide application also releases ammonia, nitrate, phosphorus, and many other pesticides that affect air, water, and soil quality, as well as biodiversity.

However, agriculture also alters the Earth's land cover, which can change its ability to absorb or reflect heat and light, thus contributing to radiative forcing. Change in land use could be beneficial to control factors that impact climate change such as deforestation and desertification. A component of the project activity was also to grow native Khagal plants on the project sites. After a year of plantation, the Khagal plants had grown exponentially (Growth shown below). Though, this land cover change has minimal environmental impacts but it was clearly visible and reported by the farmers.

4.1.2.1 Biodiversity

It was found that chickpeas was the major crop of the project area during the preliminary survey of the project. This was mostly grown on rain fed areas and was highly dependent over the rainfall. However, the introduction of irrigation through solar powered pumping system provided farmers an opportunity to irrigate their crops whenever it was required. The farmers now got the choice to cultivate other cash crops at low cost and availability of water. The introduction of drip irrigation system by the project in the area and growing of orchards on the drip irrigation system had changed the biodiversity of the lands of local famers as the land once were considered to grow only rain fed wheat and pulses were now producing fruits, vegetables and other crops. The table below reflects the change in cropping pattern due to introduction High Efficiency Irrigation System;

Table 10: Comparison of Conventional and High Efficiency Irrigation System

Conventional Agriculture		High Efficiency Irrigation	
Crops	Fruits/ Vegetables	Crops	Fruits/ Vegetables
Chickpeas	None	Chickpeas	Onion
Wheat		Wheat	Garlic
		Sorghum	Watermelon
		Cotton	Pumpkin
			Citrus
			Orange

Moreover, some of the farmers had adopted intercropping at the project sites. The farmers told that they had grown onions, watermelons and garlic in the orchard fields during the last season and cultivated a reasonable yield. They told that it all had become possible due to consistent source of irrigation water at almost negligible operating cost (in the shape of repair and maintenance of drip lines etc.).

4.1.3 Transfer of technology and awareness raising

It is evident that this system has several advantages over conventional irrigation systems such as water saving, higher yields, reduced weed growth, and improved germination. Despite all these benefits and increasing global use of HEIS, these technologies are still not popular in Pakistan and the main obstacles toward their adoption include the heavy initial capital investment, lack of awareness and training. Therefore, one of the objectives of project was the introduction of High Efficiency Irrigation technology and to raise awareness among the farmers for better utilization of land for uplifting their socio-economic conditions and to contribute in national food economy. During the post assessment survey, interviews from the farmers who were the main beneficiary of the project and the neighboring farmers were interviewed to assess that to which extent project had been successful to introduce HEIS and raising awareness.

The farmers who were the beneficiaries were very happy with the system and grown expertise over a year with the system. They were well aware that due to installation of HEIS they had become able to grow multi crops and vegetables on their lands with very low cost and high profits. Most of the farmers were willing to upgrade their systems and were planning to do so. They also told that farmers from surrounding area often visit their sites and obtain information to answer their queries. They told that when they tell other farmers that they were growing more than one crop, this interests mostly farmers and they urge to know more about the HEIS. They told most of the farmers believe in seeing and visit the sites to see the actual conditions. The beneficiary farmers believed that the project sites had become model sites for the surrounding farmers and almost everybody in the project areas had now become well aware of it.

On the other hand, the neighboring farmers were also interviewed and were asked about their knowledge of HEIS. It was found that almost all the farmers in close vicinity of the intervention sites were well aware of HEIS and its potential benefits. However, on the question that why did they not installed HEIS at their lands, they told that there were several reasons for not installing HEIS at their own. One of the main reason was its installation cost as it costs minimum of around 2 lacs per acre to install solar powered HEIS, which for small to medium level farmers is almost impossible to generate considering that the worth of their land is also equivalent to this amount. Another reason for not installing HEIS was the misconceptions, myths and unverified failure stories of the HEIS. They told that they were observing the HEIS installed under the project that whether they were successful or not. It was also observed that many of the large land owners had already adopted the technology after success of HEIS by the project. However, most of the land owners in the project area were small to medium farmers and despite knowing the benefits, potential and success of HEIS, they were unable to purchase and install it due to high cost of the system. Whereas, very few farmers had adopted local made small prototype HEIS which costs around 0.3 million rupees and were successfully operating it.

Site 1: Farooq Shah, Piplan, Mianwali

Before Intervention

Fruit orchard after intervention

Site 2: Mian Nasrullah, Dullewala, Darya Khan, Bhakkar.

Before Intervention

Fruit orchard after intervention

Site 3: Aziz Ullah Budhana, Adhi Sargal, Noorpur Thal, Khushab.


Before Intervention


Fruit orchard after intervention

Site 4: Sultan Ahmad, Peelowains, Noorpur Thal,


Before Intervention


Fruit orchard after intervention

Site 5: Muhammad Ameer, Dullewala, Darya Khan, Bhakkar


Before Intervention


After intervention

Site 6: Mian Anjum Saeed, Mankera, Bhakkar.


Before Intervention


Fruit orchard after intervention

Site 7: Afzaal Nadeem, Burhan, Noorpur Thal, Khushab

Before Intervention

After intervention

Site 8: Mian Rehmat-Ullah, Dullewala, Darya Khan, Bhakkar.

Before Intervention

Drip laterals after intervention

Glimpses of Growth of Vegetative Cover on Drip Irrigation System

4.2 Recommendations

It was concluded that the objectives of the project to introduce HEI technology and raise awareness among farmers have successfully been achieved. As almost all the farmers who were interviewed were aware of the technology and its benefits and were willing to install the system. But due to certain constraints and conditions they had not installed the system. However, it could be safely concluded that the concept of HEI technology has widely been adopted and accepted by the farmers in the project area, whereas, the adoption of the technology itself is still scanty owing to its high initial installation cost. However, specific recommendations based on the pre and post intervention survey are as follows: -

i. The solar powered high efficiency irrigation system is not being adopted due to its high initial installation cost. The procedure for its installation should be made farmer friendly by introducing interest free loans or subsidized schemes.

ii. Another issue was spread of myths and misconceptions about the operation being extremely technical and therefore, failure of the system in lesser span of time. This can be easily countered through creating awareness about the system by organizing field visits of model sites and sharing the success stories at broader scale.

iii. It was also noted that the systems are mostly installed by experts which are not available at rural areas and are based out of big cities. Similarly, the parts in case of damage, are not available at local level to these farmers and they have to be managed from bigger cities causing both financial and time hazards.

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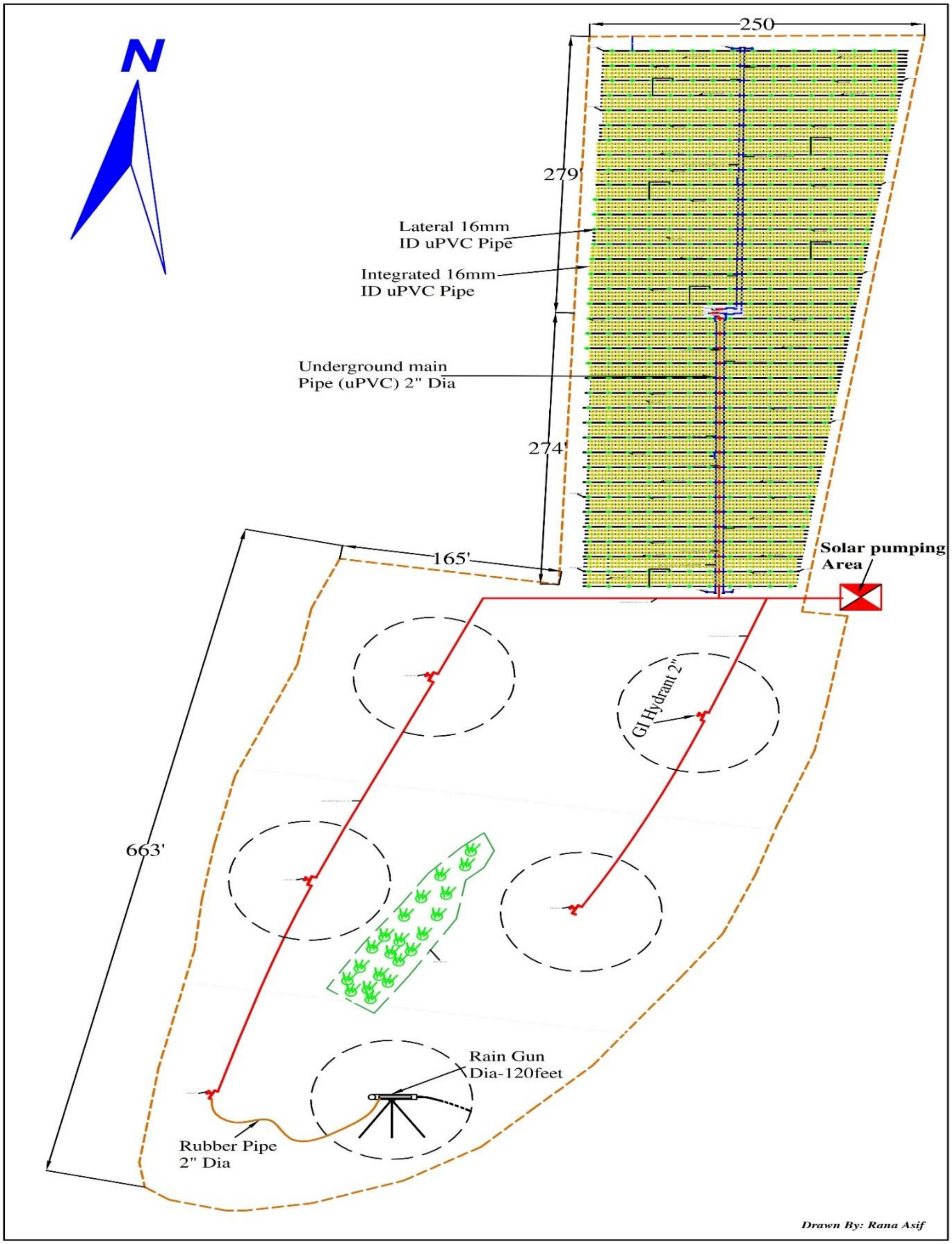
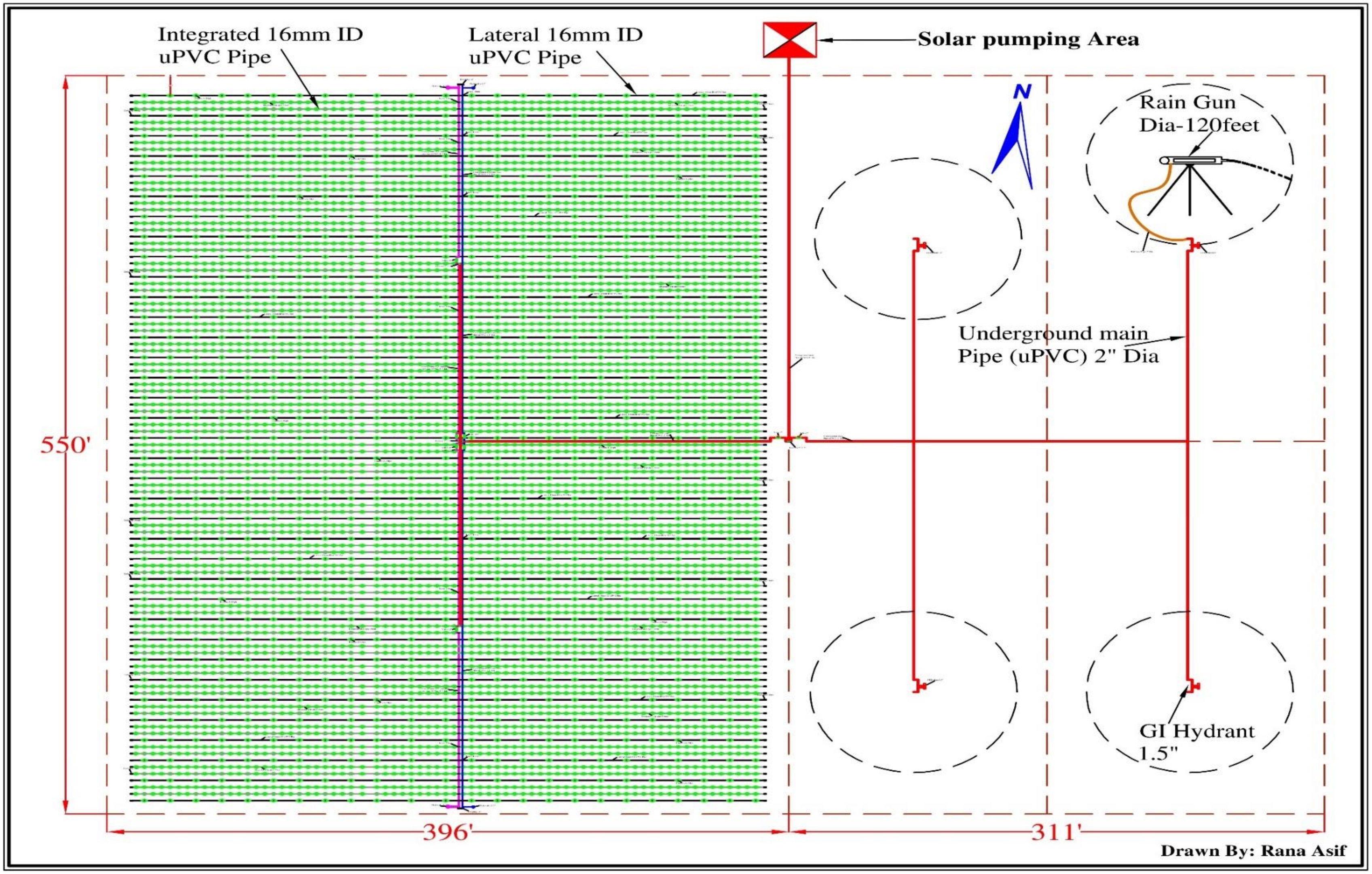
Annexure-I

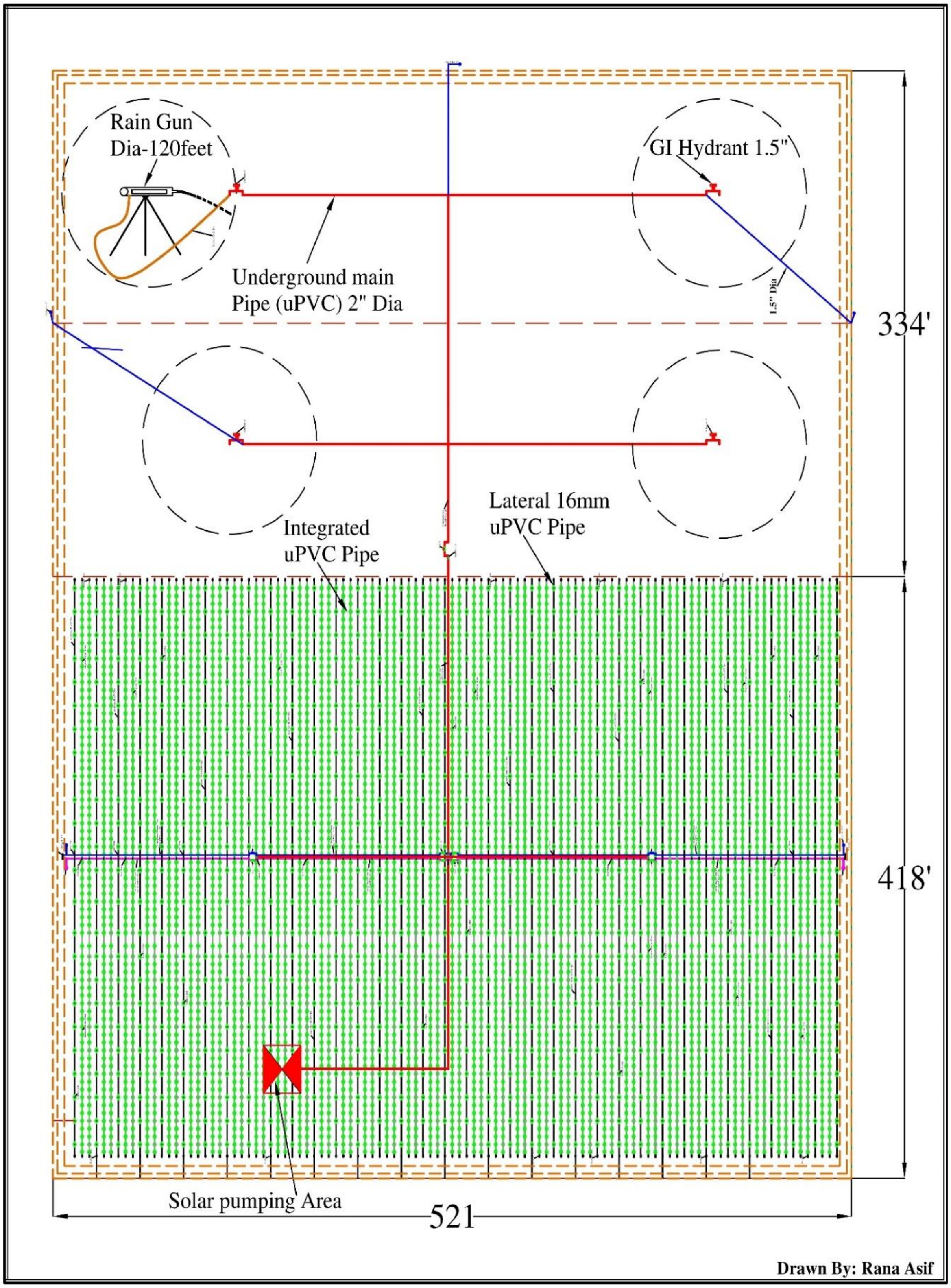
Design Layout of Drip and Sprinkler Irrigation System at Dolaywala, Darya khan Bhakkar



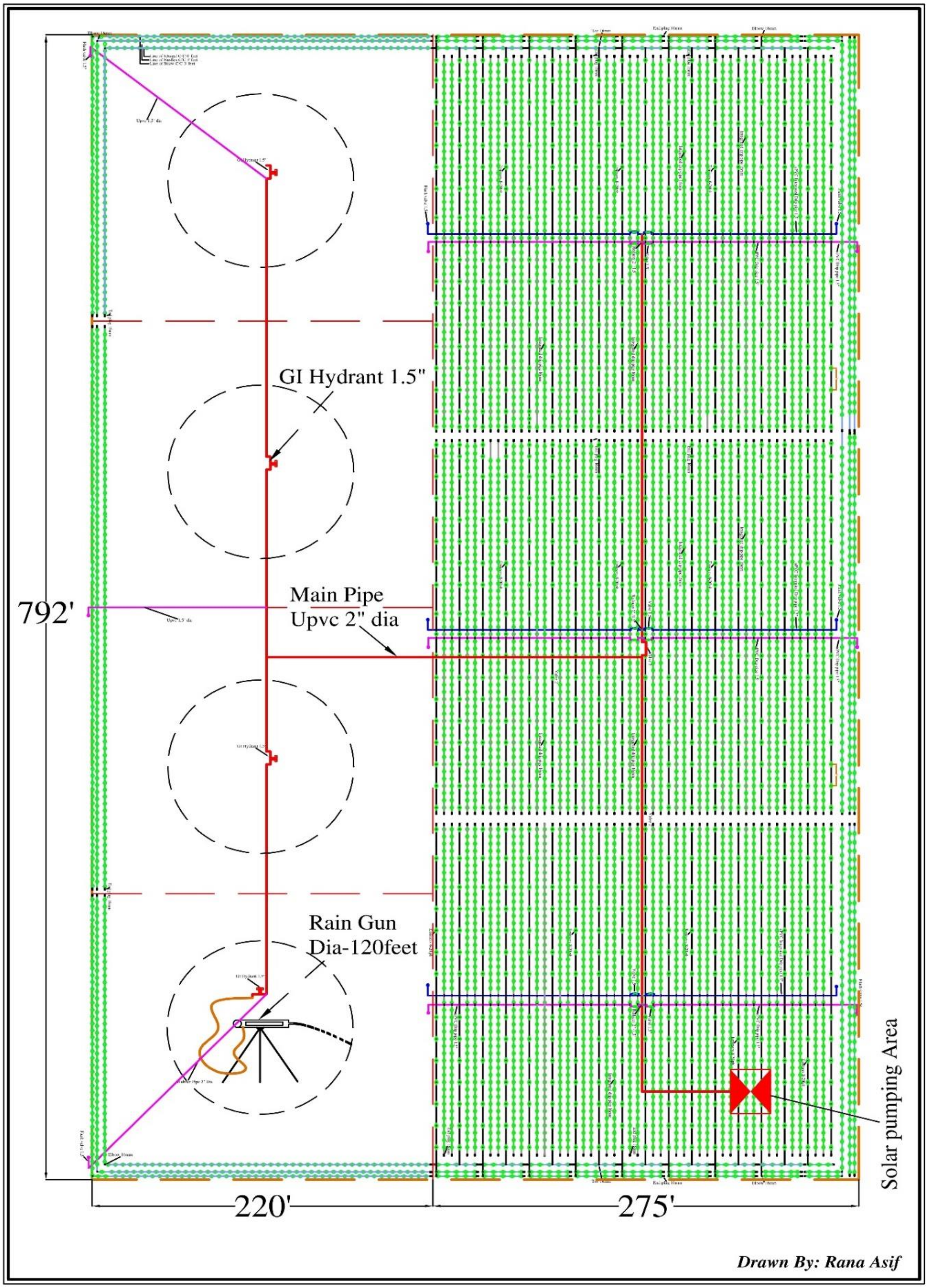
Design Layout of Drip and Sprinkler Irrigation System at Chak Mureedabad, Adhi Sargal, Tehsil Noorpur Thal, District Khushab



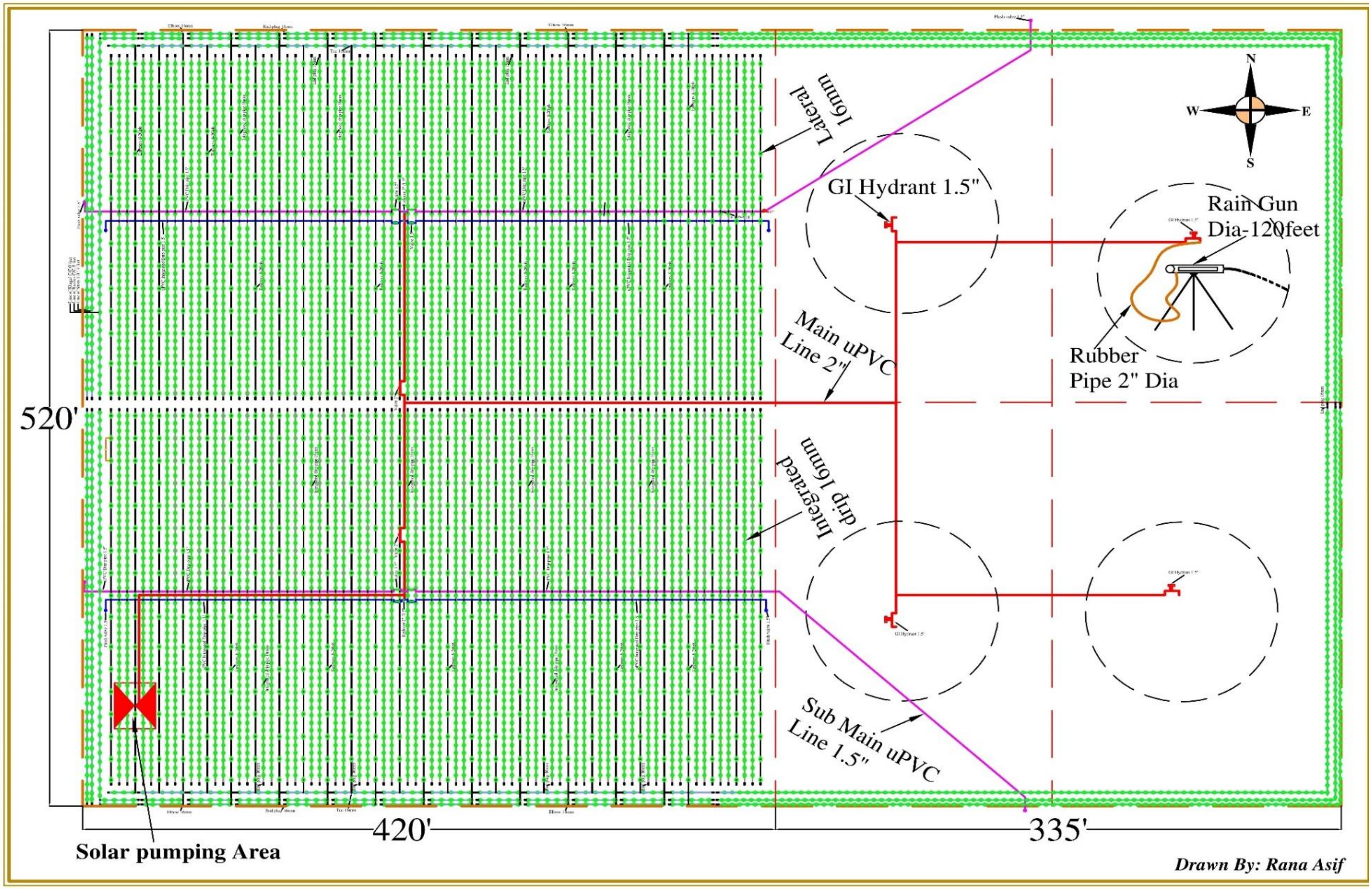
Design Layout of Drip and Sprinkler Irrigation SystemWith Vegetative Cover at Dolaywala, Tehsil Darya Khan, District Bhakkar.



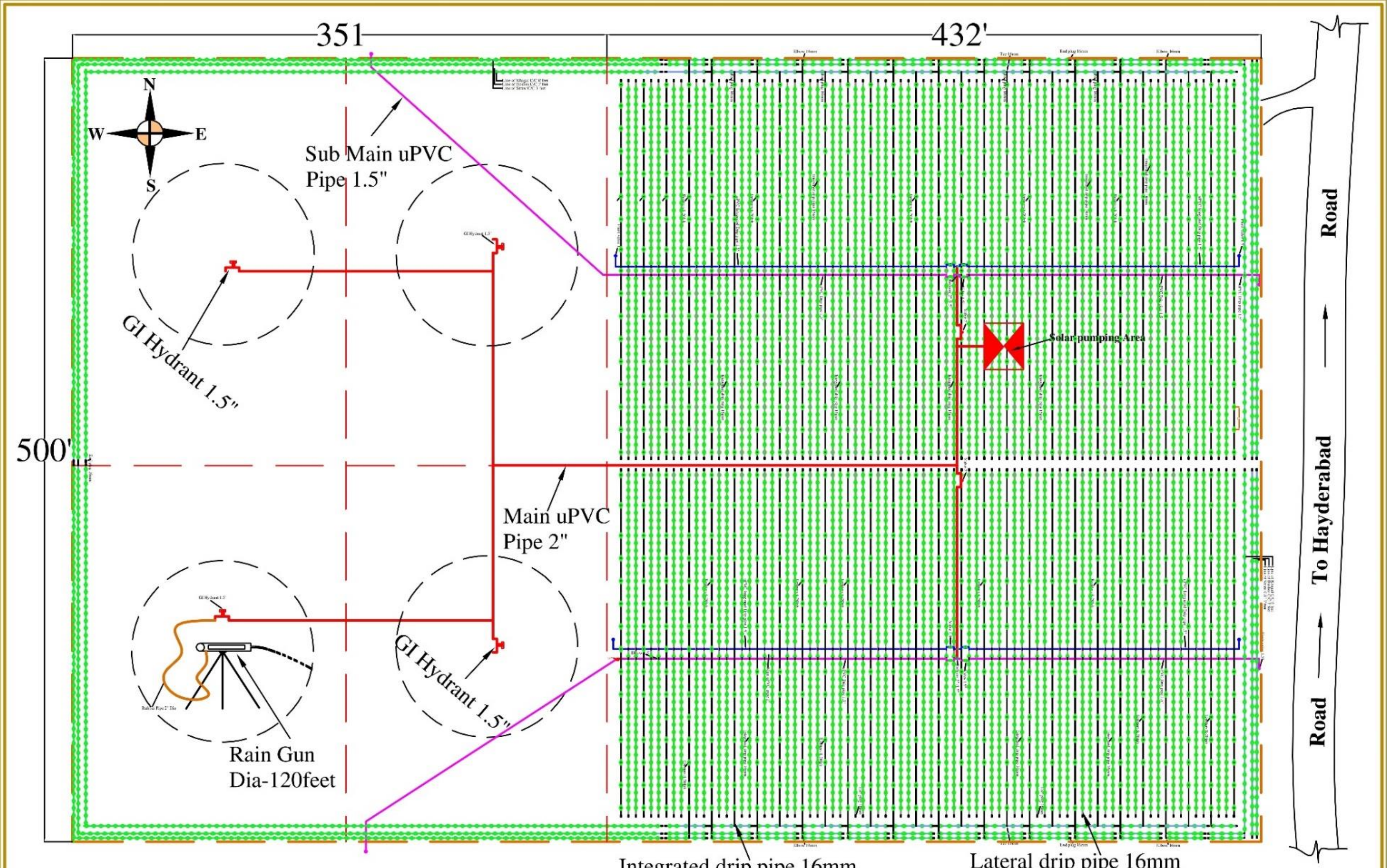
Design Layout of Drip and Sprinkler Irrigation System With Vegetative Cover at Burhan, Tehsil Noorpur Thal, District Khushab.



Design Layout of Drip and Sprinkler Irrigation SystemWith Vegetative Cover at (Gadai) Dolaywala, Tehsil Darya Khan, District Bhakkar.

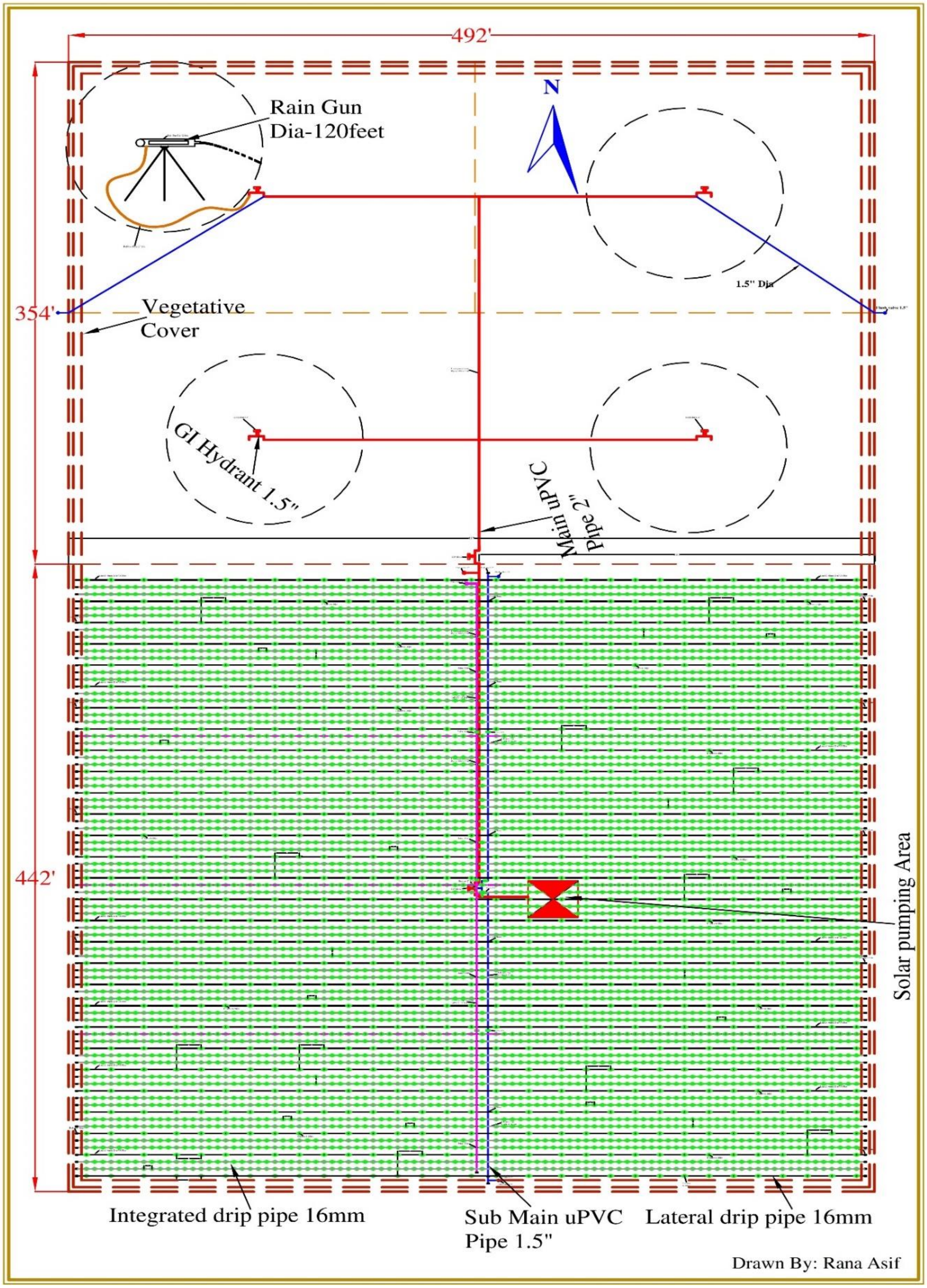


Design Layout of Drip and Sprinkler Irrigation System With Vegetative Cover at Hyderabad Thal, Tehsil Mankera, District Bhakkar.

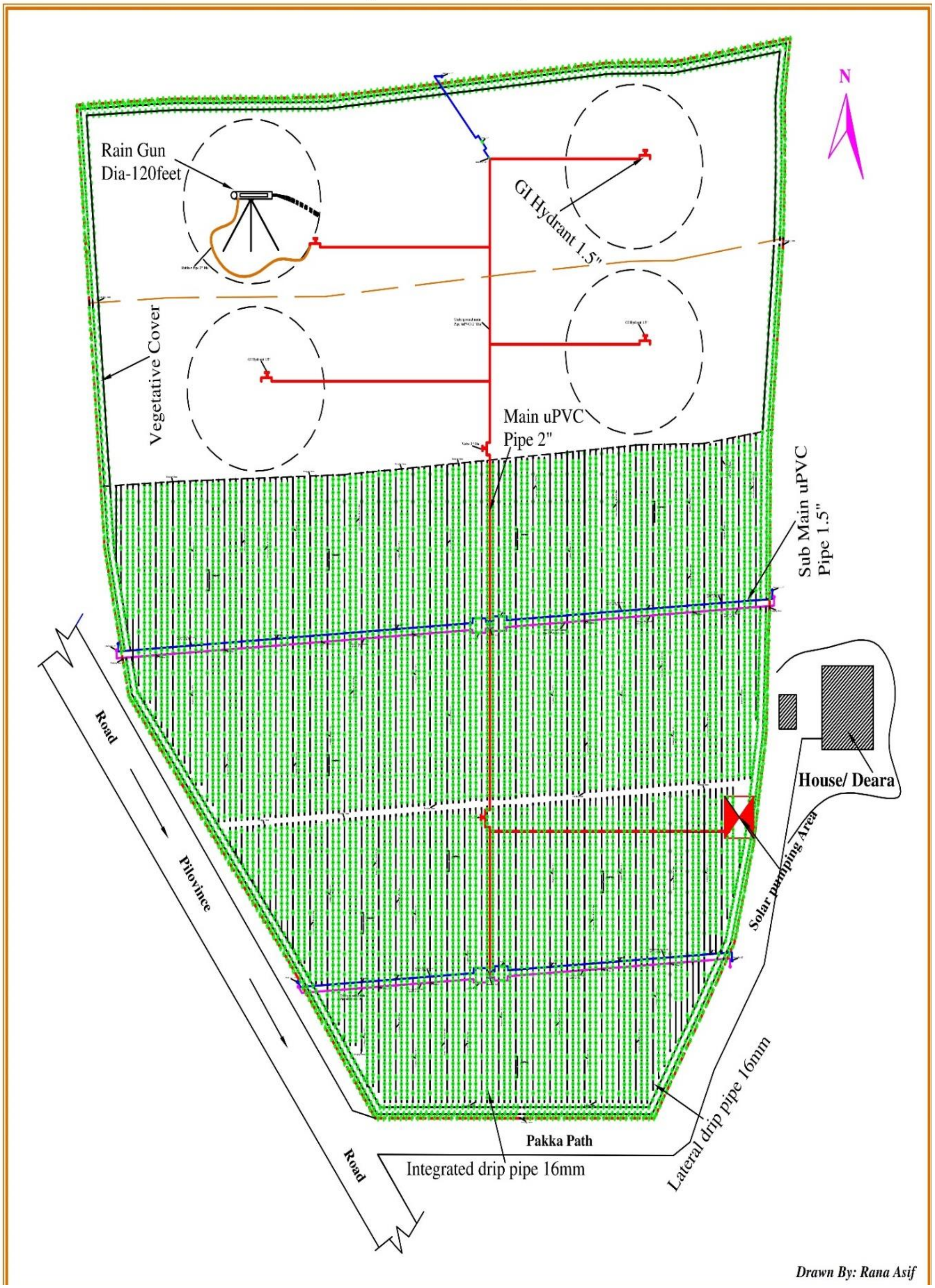


Drawn By: Rana Asif

Design Layout of Drip and Sprinkler Irrigation System With Vegetative Cover at Chak# 7 DB ,Piplan, Mianwali



Design Layout of Drip and Sprinkler Irrigation System With Vegetative Cover at Moza Peelowains, Tehsil Noorpur Thal, District Khushab



Annexure-II

List of Stakeholders

Sr. No.	Name/Designation	Mobile No.
1.	Dr. Shafeeq, DO, Mianwali	0333-6841492
2.	Engr. M. Akram Khan, DD Agriculture (WM). **Bhakkar**	0300-6099619 akramniazi99@gmail.com
3.	Mr. Muhammad Ashraf, District Officer, **Bhakkar**	0453-9200144 doaextbkr@yahoo.com
4.	Dr. Ameer Hussain, AD Agriculture (Ext), **Bhakkar**	03336-842620 amirdr205@gmail.com
5.	Dr Sajjad Hussain, DD (Agriculture), **Bhakkar.**	0343-6472235
6.	Mr. Abdul Hameed, Agri Officer, Dollewala, **Bhakkar**	0345-7640599
7.	Mr. Mian Nisar Ullah (Farmar), **Dollewala**	0344-6892001 0302-7952001
8.	Mr. Zahid Khan Chuhan, DO (WM),Khushab	0300-4188411 engrzahid1122@gmail.com
9.	Mr Khan Bahadur, DD (Agriculture), **Khushab**	0300-7674848 0454-920958
10.	Mr. Maqbool Ahmad, AD (OFWM), Nurpur Thal	0300-6603057

11.	Mr. Muhammad Yasir Iqbal, AD Agri (EXT), **Nurpur Thal**	03017953993 ddoaextnpt@gmail.com
12.	Mr. Zafar Iqbal, (Farmer).	0300-6555029
13.	Mr. Haji M. Sher, (Farmer Peelovance).	0301-5605187
14.	Mr. Umar Farooq, (Farmer).	0300-6603602
15.	Mr. Abdul Qayoom (Farmer)	0302-5317400
16.	Mr. Qasir Akram, DO Mianwali	0337-7622817
17.	Dr Muhammad Tariq (Director) Bari **Chakwal**	0321-5365576 0543-594499 barichakwal@yahoo.com
18.	Mr. Arshad, Field Assistant BARI Field Office, Piplan, **Mianwali**	0345-5805342
19.	Mr. Rashid Ahmed Changwani, DO (WM), **Layyah**	0337-1403030
20.	Mr. Mian Qurban, Agri. Engr Sargodha Division	(048)3702450
21.	Mr. Mirza Iftikhar Chughtai, Director (WM), **Sargodha**	0345-6537507 048-3712057
22.	Mr. Muhammad Ramzan Khan Niazi, Director Agri. (Ext) **Sargodha**	0300-6067670 048-9230526

23.	Malik Fateh Khan Chief Executive, NRSP, **Islamabad**	
24.	Engr. Zamir A. Soomro Regional Director PCRWR, Lahore	
25.	Ms. Farhana WMO, **Jhang**	0305-5314270
26.	Rana Munir DO (WM), **Bhakkar**	0300-9607484
27.	Mr. Elahi Bux DO (WM), Muzaffargarh	0307-4792979 0333-4792979
28.	NGO Mianwali	
29.	Mr. Engr Hammad khan	0334-8992887
30.	Mr. Ijaz D.D Agriculture	0333-5269487
31.	District Officer, **Mianwali**	0459-920218

معاہدہ برائے تنصیب قطراتی نظام آبپاشی بمعہ شمسی توانائی پمپنگ سسٹم / اسپرنکلر نظام آبپاشی

یہ معاہدہ مورخہ ________ کو فریق اول (کاشتکار) ____________ ولد ____________ قوم ________ گاؤں / چک نمبر ____________
یونین کونسل ________ تحصیل ____________ ضلع ____________ اور فریق دوئم پاکستان کونسل برائے تحقیقاتِ آبی وسائل (پی سی آر ڈبلیو آر)
خیابانِ جوہر H-8/1 اسلام آباد کے درمیان ہوا ہے۔

فریق اوّل کے ذمہ مندرجہ ذیل امور ہونگے:

(1) کاشتکار ________ ایکڑ رقبہ چک نمبر / گاؤں ____________ میں سسٹم کی تنصیب کے لیے فراہم کرنا۔

(2) اگر کنٹریکٹر / کمپنی کی طرف سے سامان کی ترسیل کیلئے فراہم کی گئی ٹرانسپورٹ براہِ راست مقرر مقام پر نہ پہنچ سکے تو کاشتکار کے کھیت یا فارم تک سامان پہنچانا۔

(3) کھیت یا فارم پر سامان کی حفاظت یا سکیورٹی کی ضمانت دینا۔

(4) سسٹم کی تنصیب کے دوران کھدائی و بھرائی اور وٹ بندی وغیرہ بنانا اور اس سلسہ میں غیر ہنرمند مزدور مہیا کرنا۔

(5) پکی سڑک یا زیرِ زمین گیس لائن، ٹیلیفون کیبل یا نکاسی آب کے پائپ کو پار کرانا۔

(6) بجلی کی فراہمی جیسے جنریٹر، تار، سٹارٹر، فیوز اور تمام ضروری آلات فراہم کرنا۔

(7) پھلدار پودوں کی نرسری فراہم کرنا۔

(8) کام والی جگہ کا شہر سے دور (۲۰ کلومیٹر سے زائد) پہنچ مشکل ہونیکی صورت میں سٹاف کی رہائش کا بندوبست کرنا۔

(9) کاشتکار کو سسٹم کی جان کاری حاصل کرنے اور تنصیب کے بعد سسٹم کے لیئے مطلوبہ اہلیت کا آدمی فراہم کرنا۔

(10) متفقہ تفصیلات کے مطابق تیار کردہ ڈیزائن کے علاوہ مطلوبہ تبدیلی یا سسٹم کی بنیادی ترتیب میں تبدیلی جو کہ سروے کے وقت نامعلوم وجوہات کی وجہ سے ناگزیر ہو یا کاشتکار کے ذہن میں موجود ہو جسکے نتیجہ میں زائد سامان درکار ہو اس کی قیمت کا فرق کاشتکار براہ راست کنٹریکٹر / کمپنی کو ادا کرنے کا پابند ہوگا۔

(11) کاشتکار کی غیر ضروری مداخلت کی وجہ سے کام میں تاخیر کی صورت میں پی سی آر ڈبلیو آر کو معاہدہ کی منسوخی کا اختیار ہے اور کاشتکار کنٹریکٹر / کمپنی کو سامان کی ٹوٹ پھوٹ، سامان کی سرکاری قیمت، استعمال شدہ سامان اور بقایا سامان کی کنٹریکٹر / کمپنی کو ترسیل کا خرچ ادا کرنے کا پابند ہوگا۔

(12) سسٹم کی تنصیب کے بعد باغ، پودوں اور فصلوں کی کاشت اور کھاد، بیج، سپرے وغیرہ کی ذمہ داری کاشتکار پر ہوگی۔ اس سلسلہ میں ادارہ پی سی آر ڈبلیو آر ذمہ دار نہ ہو گا۔

(13) سسٹم کی تنصیب کے بعد سسٹم کی دیکھ بھال اور ہر قسم کی توڑ پھوڑ کی مرمت کرنا۔

(14) سسٹم کی تنصیب کے بعد پی سی آر ڈبلیو آر کا عملہ کسی بھی وقت سسٹم کے معائنہ اور ڈیٹا کلیکشن کا حق محفوظ رکھتا ہے اور اس صورت میں کاشتکار پی سی آر ڈبلیو آر کے عملہ سے ہر طرح کا تعاون کرنے کا پابند ہوگا۔

فریق دوئم کے ذمہ مندرجہ ذیل امور ہونگے:

(1) متفقہ تفصیلات کے مطابق تیار کردہ ڈیزائن کے سسٹم کا سامان بذریعہ کمپنی / کنٹریکٹر، کاشتکار کو فراہم کرنا۔

(2) منصوبے کے تکمیل کے بعد سسٹم کی ملکیت کاشتکار کو منتقل کرنا۔

ناگزیر وجوہات کی وجہ سے سسٹم کی تنصیب میں تاخیر کی صورت میں فریق دوئم (پی سی آر ڈبلیو آر) ذمہ دار نہ ہوگا۔

____
دستخط / نشان انگوٹھا کاشتکار

گواہ نمبر ۱: ____________
شناختی کارڈ نمبر ____________

____
دستخط مجاز آفیسر (پی سی آر ڈبلیو آر)

گواہ نمبر ۲: ____________
شناختی کارڈ نمبر ____________