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Traditional persian wheel irrigation and sustainable adaptation of agro-pastoralist community on the North-Western Side of Indus River in District Swabi, Pakistan

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Abstract

Irrigation is the primary contributor of agriculture in arid climate. The traditional Persian Wheel irrigation is one of the oldest methods of irrigation in the study area. The use of modern technologies and mechanization in the agriculture sector pressurized the traditional practices methods of agriculture and irrigation. On the one hand, the tube well and private diesel engine water pump irrigation systems pressurized the usage of traditional Persian Wheel irrigation system while on the other hand, the land defragmentation, high cost associated with modern technologies, multi uses of draught animals and inherited traditions of the agro-pastoralist community encourage their uses. The present study explores the relationship between the use of traditional Persian Wheel irrigation and subsistence agricultural system. The existence of these traditional methods is the product of sustainable adaptation of agro-pastoralist community for low cost, subsistence economy, traditions and sustainable water utilization.

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Introduction

The climate of Pakistan is hot arid. The similar climate is prevailing in the Peshawar vale in general and in the study area, specifically (Pakistan Meterology Department [PMD], 2007; Khan F. K., 2016). From centuries, different irrigation systems are used to combat this aridity. The irrigation systems and their patterns are varied from region to region due to geographical, social, economic, and political factors (Abrahão, *et al.*, 2015; Siebert, *et al.*, 2015). The irrigation pattern in the study area was *barani,* canal, Persian Wheel, electricity & solar tube wells and private diesel engine water pumps (PDEWPs) irrigated areas. Due to scanty rainfall, irrigation plays a vital role in agriculture of the study area. The canals and Persian Wheel are traditional methods of irrigation (Hasan & Ali, 2007; Laufer, 1933; Kar, 2014). The mechanization in agriculture brought major changes in the subsistence agriculture systems. However, in the areas of small landownership, mechanization least affected the subsistence agriculture systems. Similarly, the modern and innovative technologies in the irrigation systems affected the traditional techniques of irrigation (Singh I. J., 1971; Singh C. , 1985). With the passage of time, the agro-pastoralist community adapted with these changes (Wichelnsa & Qadir, 2015). The persistence use of traditional Persian wheel irrigation is the part of this adaptation. The major limitations associated with the usage of Persian Wheels are: high cost of construction and maintenance; low water supply capacity; time consuming; and dependency on draught animal (Dangi & Hitoshi, 2016; Farshad & Zinck, 1998; Wakeyo & Gardebroek, 2017). The perseverance use of Persian Wheels was due to pre-constructed Persian Wheels, high of cost of fuel, problems with technological transformation, and inherited traditions of the agro-pastoralist community (festivals, draught animals as symbol of pride, competition of animals etc.). Recently, its use is the form of sustainability rather than perseverance (Gilmartin, 2003; Singh C. , 1985; Khair, Mushtaq, & Smith, 2014). The use of Persian Wheel for irrigation was practised from seventh century (A. D.) in district Swabi.

In 1898 Dane reported 5864 Persian Wheel unit in this area. Majority of these were located along the Indus river bank area where water table was higher than remaining areas (Dani, 1995; Dane, 1898). After Indus Water Treaty Accord the canal irrigation was developed in this area which brought vital changes in agriculture production. The right bank canal from Tarbela Dam was constructed in mid 1960s from which *Kotha* left tributary canal started irrigation in the study area (Gilmartin, 2003). The tube well irrigation was introduced during Mardan SCARP project in limited areas particularly where water logging and salinity problems were existed (WAPDA, 1984). The few private tube wells irrigation schemes were started in 1980s when government gave subsidy on electricity to the farmer for limited time (GOP, 2005a; GOP, 2005b). The Persian Wheel has a limited capacity for lifting the water from well. The work progress was slow and cost of the maintenance of Persian Wheel increased with the passage of time. Similarly, the time specification, limited quantity of water and small area covered by canal irrigation were those limitations which encouraged farmers to take initiatives for other source of water. The change in this traditional irrigation pattern started in 1990s when high power diesel engine water pumps were introduced for lifting the water from existing Persian Wheels. Later on, these diesel engine water pumps started lifting water for irrigation from other sources like canals, nullahs, and tube wells also (Gilmartin, 2003; Dangi & Hitoshi, 2016; Khair, Mushtaq, & Smith, 2014; Schilfgaarde, 1994).

After 1990, the construction of new Persian Wheels was almost abandoned due to high cost of construction, induction of tube well drilling technology, electricity water pumps, private diesel engine water pumps, and very recently solar-electricity water pumps. With the passage of time, some serious problems were surfaced with the use of modern irrigation system: the temporary depletion of water table due to rapid water pumping, high cost of fuel, watering time for cash crops, singular use of tube wells, land defragmentation and use of right for irrigation etc.

The private tube wells and diesel engine water pump are almost abandoned due to high cost of fuel. The farmer community in general and the agro-pastoralist community in specific are directly dependent on the production of cash crops. The major cash crops in the study area are: tobacco, field vegetables and fruits. Most of these cash crops need water on proper time. In new scenario, the adaptation of Persian Wheel irrigation system almost solves these problems particularly associated with cash crops. The command land of Persian Wheel irrigation is ideal for cash crops. Now a day, modified types of land tenancy are practiced to overcome these problems e.g. full rent; half cost & production share and full cost with one fourth production share. The use of Persian Wheel irrigation has the capacity to least affect the water table, provide opportunity for multi-users at one time, least and/or no fuel charges, draught animal husbandry, continuation of inherited traditions. Consequently, the agro-pastoralist community has achieved the sustainable adaptation with the use of traditional Persian Wheel irrigation system.

Sustainability in subsistence agriculture practices are rear phenomena without the help of modern technologies (Blanco-Gutiérrez, Varela-Ortega, & Purkey, 2013; Meinzen-Dick, 2014). The aim of the study to analyse the root causes that provide sustainability to the use of traditional irrigation system i.e. Persian Wheel in the study area. It is pertinent to note that other modern irrigation methods like canal, electricity & solar tube wells and PDEWPs are present in the study area. However, Persian Wheel irrigation system was not only old & traditional system of irrigation but also widely practised system of irrigation for production of cash crops i.e. tobacco, sugarcane, field vegetables and fruits etc. For this purpose, land use & irrigation pattern are studied and corelated with tenancy & cash crops. The cash crop production system is the best indicator for the analysis of sustainability of traditional Persian Wheel because this cash crop system is the product of agriculture practices and socioeconomic conditions of the framers. Likewise, any sustainable system, the present cash crops production system has also threats and opportunities in form of technologies, environmental and social conditions (Wezel, *et al.,* 2014). The framer choice of this traditional system of irrigation has directly link with the subsistence agriculture system in the current socioeconomic conditions of the farmers. Certainly, the farmers choose this system only because it is the most suitable system (socially and economically) for agriculture production. The outcome of this study has greater implications for the studies of sustainability in subsistence agriculture systems. The sustainability is the product of traditional irrigation system and farmers' tenancy system with solutions related to agriculture problems of social, economic and environmental in the cash crops production system.

Materials and methods

Study Area

The study is carried out in the union council Thand Koi which is a *Patwar* Circle, situated on main Zaida – Topi road, District Swabi, Pakistan. It is historical Topi – Hund – Jehangira alignment and possesses a rich cultural and archaeological heritage, beginning with the fifth century BC when Greek historian Herodotus mentioned Caspapyros in this region (Ali, 2003) (Dane, 1898). The study area is inhabited by Mir Ahmad Khel, a sub tribe of Yousufzai (Khan R. K., 1985; Rittenberg, 1988). The Indus river flows along the southern boundary of the district Swabi, at a distance of six kilometres to south of the study area. The village is located 34^{o} $02^{/}$ $02^{//}$ to 34^{o} $04^{/}$ $45^{//}$ North Latitude and 72^{o} $29^{/}$ $30^{//}$ to 72^{o} $31^{/}$ $20^{//}$ East Longitude (Fig. 1). It has an area of 2190 acre (Government of Pakistan [GOP], 1999). According to population census of 2017, the population is 18,094 persons, 2374 households with 3.6% annual growth rate (GOP, 2018). The soil is fertile due to alluvium. The plain is dissected by drainage nullahs, flowing toward Indus river. The climate of the study area is arid subtropical with hot summer and cool winter. The summer season is extremely hot. A steep rise of temperature is observed from May to June. A rapid fall of temperature is recorded from October onwards. Towards the end of the cold weather, there are occasional thunderstorms and hail storms.

The rainfall from monsoon and western depressions is inconsistent and uneven (annual average of 60 cm), which does not fulfil the needs of agriculture (PMD, 2007; Khan F.K., 2016). The land holdings are small (less than 0.2 acre per person on average) and cultivated by tenants and landowners. The land is cultivated with traditional and modern techniques (Hasan & Ali, 2007).

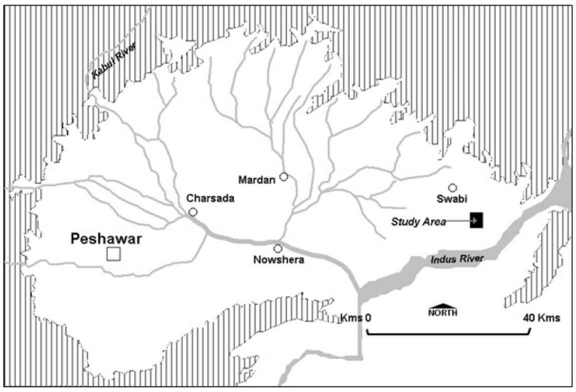

Fig. 1. Location Map of the Study Area

The irrigation land use pattern was studied through change detection from 1996 to 2016. Revenue record (*Lal Kitab*) of the UC Thand Koi was collected from Revenue and Estate Collector Office Swabi which was mosaiced in GIS (Geographic Information System). The Google Earth historical imageries were used to record the 1996 and 2016 land uses (Fig. 3 & 4). After field survey, the recorded land use pattern of irrigation was transformed to GIS. Using GIS platform, the land use data of irrigation pattern of 1996 and 2016 were tabulated. The comparative study of maps and data shows the change in land use of irrigation pattern in the study area.

The irrigation pattern, tenancy of land and cropping pattern were studied through questionnaires, field observation and field inquiry methods. On the basis of irrigation system, the farmers were asked about tenancy of land and their cropping pattern. The irrigation pattern and cropping pattern was studied through cartographic analysis. A base map of irrigation pattern – 2016 was used for recording of cropping pattern through field observations and field inquiry methods. The recorded data was tallied and then visual correlation of irrigation with cropping pattern was established on a map.

*Inter-relationship of Tenancy & Cash Crops and Subsistence Agriculture System*A purposive survey about pattern of tenancy, irrigation system and cropping pattern was carried out from the farmers. A stratified random sample size of 100 farmers was selected with sub categories of canal (30), Persian Wheel (30), PDEWPs (30), and solar & electric tube wells (10). Being a nominal nature of the respondents' data, the association and inter-relationship of pattern of tenancy, irrigation system and cropping pattern was studied through phi coefficient (φr) and Cramér's V (φc) (Eq. 1 & 2)

$$\varphi r = \frac{x^2}{n} \text{ (Eq. 1)}$$

$$x^2 = \sum_{i.j} \frac{\left(nij - {ni.nj}/{n}\right)2}{{ni.nj}/{n}}$$

Cramér's V is computed as

$$\varphi c = \sqrt{\frac{\varphi^2}{\min\ (k-1, r-1)}} \text{ .. (Eq. 2).}$$

Whereas,

φ is the phi coefficient

x^2 is derived from Pearson's chi-squared test

n is the grand total of observations

k being the number of columns

r and being the number of rows

The values of ranges between 0.00 to 1.00 (no relationship to perfect relationship)

On the basis of these relationships, the cash crops production system is thoroughly studied. The farmer social, economic and technological dependencies for the cash crops production were studied to understand the subsistence agricultural system in the study area. The relationship of subsistence agricultural system with irrigation system was analysed.

Sustainability Analysis

After analysing the relationship between Persian Wheel irrigation and subsistence agriculture system, the sustainability of the use of Persian Wheel was studied. The matrix properties of the agriculture development i.e. irrigation system, production, cost, time, economics, social welfare, conflicts, and environmental problems etc. were studied for sustainability analysis.

The matrix properties were normalized in the range of "-4 to +4" (Equation 3). These properties were crosstab and plotted on scattered diagram, which provide matrix view of all properties. The irrigation system was plotted on x-axes and the rest of all properties on y-axes.

$$X_{New} = \frac{x - \mu}{\sigma} \quad \text{.. (Eq. 3)}$$

Or $$X_{New} = \frac{x - x_{Min.}}{x_{Max.} - x_{Min.}}$$

Whereas μ represents the mean value of the variable, σ is the standard deviation between different values of the variable, $x_{Min.}$ is the minimum value of the variable and $x_{Max.}$ is the maximum recorded value of the variable.

$$r_{ij} = a + \frac{X_{ij} - \min\{X_{ij}\}}{Max\{X_{ij}\} - Min\{X_{ij}\}}(b - a) \quad \text{(Eq. 3a)}$$

$$r_{ij} = a + \frac{\max\{X_{ij}\} - X_{ij}}{Max\{X_{ij}\} - Min\{X_{ij}\}}(b - a) \quad \text{(Eq. 3b)}$$

For indirect functional relationship among the variables (negative domain), equation "3a" was used, while for variables having direct functional relationship (positive domain), equation "3b" was used.

Result and discussion

Land uses and Irrigation Pattern in the Study Area

The base map for land uses was prepared from cadastral map and Revenue Record *(Lal Kitab)*. The cadastral maps were scanned then corrected and mosaicked in GIS. The geo-referencing was made with help of Topographic Map and Google Earth data. The land use data of 1996 and 2006 were collected from Revenue and Estate Collector Office Swabi, Agriculture Census, and field observations. The major land uses in the study area were built up areas, cultivated areas, cultivable waste (*banjar*) areas, graveyard, playground, roads, streets, and water bodies. The agriculture area of cultivated and cultivable waste (*banjar*) areas were further studied for irrigation pattern analysis. The irrigation pattern consisted of different methods of irrigation like canal, Persian wheel, electricity tube-well, solar-electricity water pumps, *barani* (Rainfall), and PDEWPs irrigation systems.

The solar-electricity and private diesel engine water pump were operated on canal, Persian wheel, tube-well, and drainage nullahs.

Systematic pattern was observed in land use changes as the built-up area was increased, agriculture was decreased and the area of road, streets, nullahs, and other small drains was almost remained constant. The category of cultivable waste (*banjar*) land as well as graveyard and playground were the common property of the village. The graveyard and playground have no change in their land use area. However, the cultivable waste (*banjar*) was sharply decreased due public buildings and illegal occupancy. The increase was observed in built-up area due to construction of new houses and public buildings. The percentage share of built-up area was increased from 7.91% in 1996 to 11.63% in 2016 of the total. The percentage share of the total of agriculture land use was decreased from 89.11% to 85.66%. Although, the agriculture land use gain 0.1 acre from *Banjar* land with 0.04 acre in 2006 and 0.06 acre in 2016. The agriculture land use included cultivated and cultivable waste irrespective of their present use. The last category of land use which was labelled as 'others' consisted of road, streets, nullahs, and other small drains. It has small gain of 0.1 acre due to new roads and street construction from 33.04 to 33.14 acres (Table 01 and Fig. 02, 03, & 04).

Table 1. Land Use Pattern in UC Thand Koi (Acre).

Year	Built-up	*Banjar*	Graveyard & Playground	Agriculture	Others	G. Total
1996	173.28	8.42	23.83	1,951.43	33.04	2,190.00
2006	213.63	5.06	23.83	1,914.40	33.08	2,190.00
2016	254.69	2.32	23.83	1,876.02	33.14	2,190.00

Source: Revenue and Estate Collector Office Swabi and Field Survey, 2016.

The irrigation pattern was compound and complex. The types of irrigation system practised in the study area were canals, Persian Wheels, *Barani,* PDEWPs, electricity and solar tube wells systems.

The traditional irrigation system was consisted of canals, Persian Wheels, and *Barani*. In 1996, most of the area was irrigated through traditional irrigation system and very limited area by electricity tube wells system. The canals and Persian Wheels irrigation command area has 50 and 28 percentage share of the total agriculture area which small proportion was decreased with the passage of time due to built-up area development. The major change was observed in 2006 after the intervention of PDEWPs irrigation system. The PDEWPs irrigation system not only converted *Barani* area into irrigated but also supported the traditional irrigation system which played a vital role in cash crop production. The share of PDEWPs irrigation system was 12.6% in 2006 and 13.23% in 2016. The rising cost of electricity almost abandoned the electricity tube wells systems for irrigation purposes. However, the physical infrastructure of these electricity tube wells was almost replaced by solar tube wells systems which has least but certainly encouraging share in present irrigation system (Table 02).

Table 2. Irrigation Pattern in UC Thand Koi (Acre).

Year	Canals	Persian Wheels	*Barani*	Electricity Tube Wells	PDEWPs	Solar Tube Wells	Total
1996	971.80	562.34	417.19	0.10	0.00	0.00	1,951.43
2006	971.79	532.09	161.92	1.98	246.62	0.00	1,914.40
2016	969.65	512.86	132.43	0.00	258.23	2.85	1,876.02

Source: Revenue and Estate Collector Office Swabi and Field Survey, 2016.

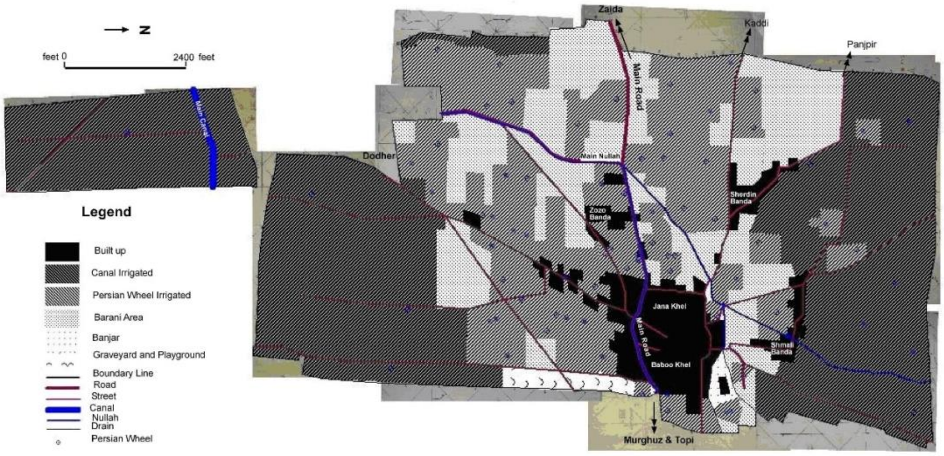

Fig. 2. Irrigation Patten and Agriculture Land Use in the Study Area – 1996
Source: Revenue and Estate Collector Office Swabi and Field Survey, 2016.

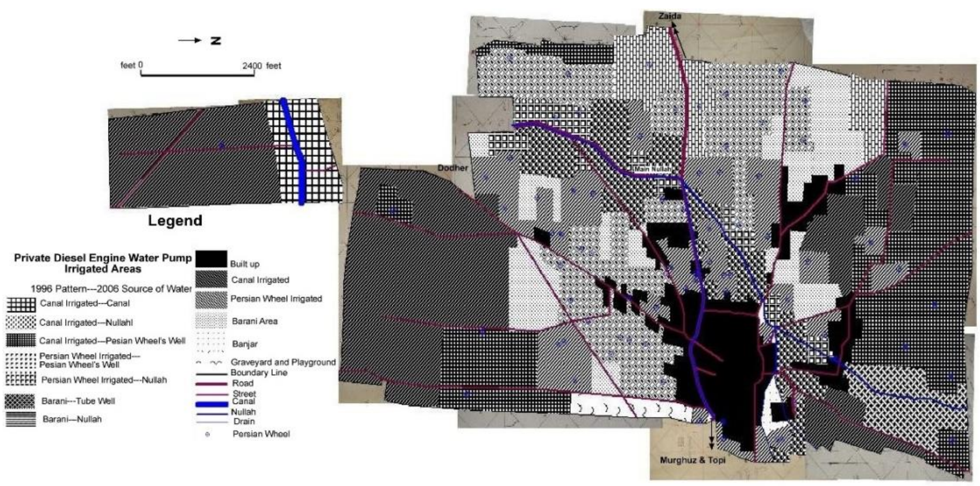

Fig. 3. Irrigation patten and agriculture land use in the study area – 2006
Source: Revenue and Estate Collector Office Swabi and Field Survey, 2016.

Irrigation, Land Tenancy and Cash Crop Pattern

Tobacco, sugarcane, field vegetables and fruits are the major cash crops in the study area. Tobacco, vegetables and fruits need more water and labour on proper time. This extra demand of labour and watering had changed and reshape the tenancy, irrigation and cropping pattern in the study area. The limited quantity of water and fixed timing were major limitation of canal irrigation in the study area. Similarly, the Persian Wheels has limited capacity of watering which delimited the small command area. The PDEWPs supported the traditional irrigation system for cash crop production.

It provided water from water from different sources i.e. canals, wells, and nullahs. The water supply from canal was purely illegal and practised only on major canal banks in southern part of the study area. The second supported source of water was Persian Wheel wells. However, it was only used for tobacco crop as field vegetables and fruits needed more water on specific time which caused water table depletion in Persian Wheel wells. The major change occurred in *Barani* areas alongside of drainage nullahs, which were solely depended on rainfall water converted into cash crops production areas (Table 03 and Fig. 3a & b).

Table 3. Supported Irrigation Pattern in UC Thand Koi (Acre).

Year/ Irrigation	Pattern	Traditional	PDEWPs	Electricity Tube Wells	Solar Tube Wells	Total
1996	Canals	970.60	0.00	1.20	0.00	971.80
	Persian wheel	562.10	0.00	0.24	0.00	562.34
2006	Canals	455.61	514.88	1.30	0.00	971.79
	Persian wheel	170.54	361.31	0.24	0.00	532.09
2016	Canals	449.00	516.20	0.00	4.45	969.65
	Persian wheel	148.92	360.14	0.00	3.80	512.86

Source: Revenue and Estate Collector Office Swabi and Field Survey, 2016.

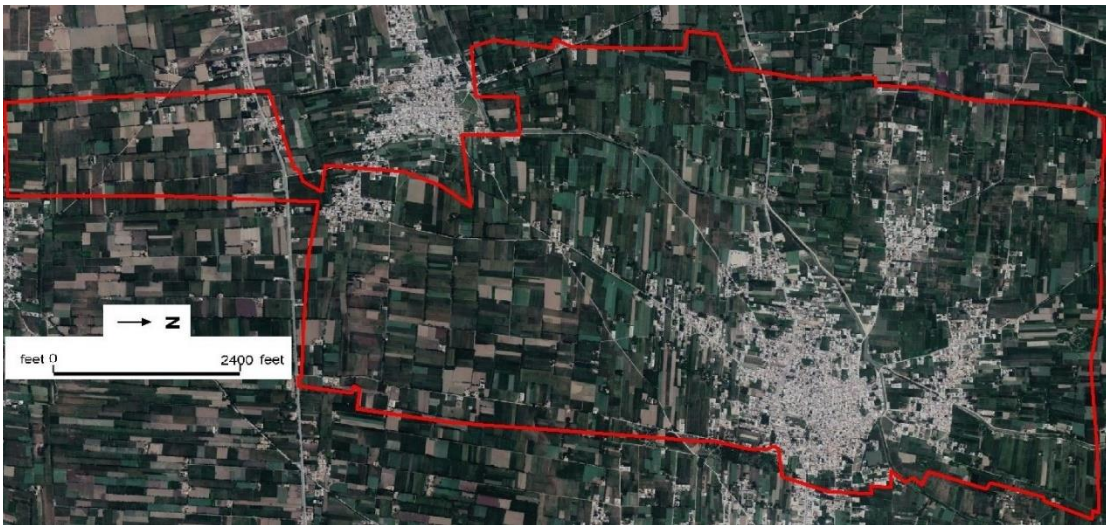

Fig. 4. Agriculture Land Uses in the Study Area – 2018
Source: Google Earth, 2018.

The availability of skilled persons for the labour of cash crops was directly controlled by tenancy system in the study area. Consequently, the cropping pattern particularly of cash crops was reshaped by water availability and tenancy system in the study area. The water was available for cash crops in Persian Wheel, PDEWPs, electricity and solar tube wells command area of irrigation. The inter-relationship of these irrigation system with tenancy for cash crops production was controlled by landownership, land defragmentation, cost, and traditions. According to Revenue and Estate Collector Office Swabi (2016), there was no single person with more than 10 Acres landownership.

Similarly, no single *Khasra Number* (Plot) with more than 05 Acres area. Most of the large area *Khasra Numbers* were owned by families rather than individuals. This land defragmentation situation directly supported the *Ajra* (full rent and/or lease) tenancy system which was widely practiced system in the study area. The electricity and solar tube wells command area were mostly cultivated by landowners. The half cost & production share was very popular tenancy system among large landholding families. However, this system was mostly practiced for sugarcane production and in very few cases for tobacco, also. The type of tenancy of one fourth production share was only practiced in tobacco production in which skilled labour only work for their limited share of production. The production of field vegetables and fruits were mostly related with self-employed tenancy system in Persian Wheel and PDEWPs command irrigation areas. The values of phi coefficient and Cramér's V for association and their inter-relationship of pattern of tenancy, irrigation system and cropping pattern showed strong binary relationship (Table 04).

Table 4. Association of Irrigation's Method and Tenancy with Cash Crop Production.

	Irrigation System				
Cash Crops	Canal	Persian Wheel	PDEWPs	Solar tube wells	Total
Wheat, Maize etc.	16	3	20	8	47
Sugarcane etc.	9	0	2	0	11
Tobacco	4	13	4	2	23
Vegetables & Fruits	1	14	4	0	19
Total	30	30	30	10	100
Phi 0.74 & Cramer's V 0.427					
Tenancy					
Cash Crop Production	Landowner	Full Rent/Lease	1/2 Cost, Labour and Production	Labour and 1/4th Production	Total
Wheat, Maize etc.	32	8	7	0	47
Sugarcane & etc.	5	6	0	0	11
Tobacco	5	8	5	5	23
Vegetables & Fruits	6	12	1	0	19
Total	48	34	13	5	100

Phi 0.624 & Cramer's V 0.36.

Source: Field Data, 2016.

Persian Wheel Irrigation and Subsistence Agriculture System

The agro-pastoralists community of the study area were practicing different cash crops farming activities for their livelihoods. Out of 100, 53 farmers were engaged in cash crops production. In tenancy, the low-income groups i.e. 1/2 cost, labour & production and full labour and 1/4th production were directly dependent on cash crops production for their livelihoods. This portion consist of highly skilled personals with social and economic attachment with agriculture. In high income class, the full rent and/or lease system having very high dependency on cash crops production. Most of the respondents were engaged due to their social and economic attachment with agriculture. It was the class which really enjoy the complexity of tenancy and modernization of agriculture.

The landowners, has mix response for their livelihoods dependency. Most of them were fully engaged in cash crops production. However, due to large family size and/or presence of remittance their dependency of livelihood was compound rather than single agriculture activity. The livelihoods dependency syndrome was more visible in Persian Wheel irrigation system than any other of irrigation system. Most of the respondents had very high dependency level due to social and economic affiliation. Rest of the categories had also high dependency of livelihoods on agriculture as only skilled personals were attached with cash crops production (Table 05).

Persian Wheel irrigation and agriculture system were traditionally very high symbol of social status and signature in our landlord society.

With passage of time, the landlord social system was disintegrated. However, Persian Wheel irrigation and agriculture system still maintain its stature of social status among rural community. The impacts of agriculture modernization in form of induction of PDEWPs or Tube wells always support the traditional Persian Wheel irrigation and agriculture system. The response of the framers regarding supported irrigation system revealed that the Persian Wheel irrigation and agriculture system were central point of all modernization and mechanization. Most of the framers attached with Persian Wheel irrigation and agriculture system had very high compassion with the said agriculture system. The locally arranged seasonal competition (*Jilsa*) of Persian Wheel and draught animals were the social festival that were attendant by huge general masses. The exhibition and participation of these festival revealed the importance of agriculture and social attachment with Persian Wheel irrigation system (Table 06). Overall, the analysis shows that cash crops production prevails subsistence agriculture system most particularly in Persian Wheel irrigation system. The Persian Wheel irrigation and agriculture system was inherited tradition of subsistence agriculture system.

Table 5. Livelihoods Dependency; Tenancy and Irrigation System.

Livelihoods Dependency	Full	Very High	High	Half	Very Low	Negligible	Total
Tenancy System							
Landowner	3	3	1	5	2	2	16
Full Rent/Lease	14	7	2	1	1	1	26
1/2 Cost, Labour and Prod.	1	5	0	0	0	0	6
Labour and 1/4th Prod.	2	3	0	0	0	0	5
Total	20	18	3	6	3	3	53
Irrigation System							
Canal	1	6	2	3	1	1	14
Persian Wheel	17	5	0	3	1	1	27
PDEWPs	2	6	1	0	0	1	10
Tube well	0	1	0	0	1	0	2
Total	20	18	3	6	3	3	53

Source: Field Data, 2016.

Table 6. Social Status and Irrigation System.

Irrigation System	Canal	Persian Wheel	PDEWPs	Tube Wells	Total
Social Status					
Pride	2	18	1	0	21
Entertainment	0	3	0	0	3
Economics	6	3	6	2	17
No Feeling	6	1	3	0	10
Humility	0	2	0	0	2
Total	14	27	10	2	53
Supported Method of Irrigation					
PDEWPs	8	12	0	2	22
Persian Wheel	2	0	0	0	2
Tube Wells	0	1	1	0	2
Nil	4	14	9	0	27
Total	14	27	10	2	53

Source: Field Data, 2016.

Persian Wheel Irrigation and Sustainability

The performance of Persian Wheel irrigation was tested against present all other modernized and mechanized irrigation system. Certainly, the cash crops production was the prime indicator of all agriculture development. All farmers, work hard for their cash crops production based on their knowledge, social & cultural perception, and available resources. Based on focus group discussion with farmers, the important indicators for sustainability of cash crops production were enlisted: cost of unit production; time consumption; cost efficient; social welfare; associated conflicts; and environmental problems.

The production of cash crops was considered on current market value of their type, mass (Kg) per area, seasonal time etc. The vegetable and fruits were high production value than tobacco, sugarcane and sunflower, respectively. The Persian Wheel has higher production value as most of the vegetable and fruit production was directly or indirectly (with supported method of irrigation) associated with this type of irrigation system. The sustainability of the irrigation systems was analyzed as matrix property of development and associated problems. The best expression of this association was reflected in the production of cash crops. Depending on the method of irrigation, the indicators of sustainability on the one hand boosted the production while on the other hand it restricted the production of cash crops. Consequently, the cash crop production was considered as dependent variable and rest of indicators as independent variables. The combined effect of all six independent variables was measured as development in specific irrigation method.

The cost of unit production included the total cost of irrigation, fertilizer, seeds, labour, mechanization, insecticides etc. However, the framers were asked in nominal value rather than scaler to avoid any complication for mathematics. Canal irrigation system has least cost of production followed by Persian Wheel and PDEWPs irrigation systems. The time consumption associated with irrigation, labour and time period for a final production was the second indicator of sustainability analysis. PDEWPs irrigation systems has unmatchable performance regarding time consumption indicator. Canal and solar/electric tube wells had very poor response as on time availability for cash crops was major constrain in these irrigation types. Cost efficient indicator was combination of available resources like skill, equipment, capital, customs & social tradition of farming, and availability of water with relation to cash crops production. The subsistence agriculture system along with inherited traditions of farming provide high scoring opportunity for Persian Wheel irrigation system in this category. The social welfare associated with irrigation system responses indicated that most of the farmers were well aware of the fact that the usage of PDEWPs on canals were serious crime and nullahs as community resources exploitation. On the other side, the Persian Wheel irrigation system was based on sharing of resources and community self-help based system. The usage of PDEWPs on canals and nullahs always created conflicts among farmers due to water resources exploitation for cash crops production. The water table depletion was a serious environmental problem associated with the usage of PDEWPs. This issue was more serious in summer season and bone of contention among framers. For better understanding, the responses of the respondents regarding sustainability indicators were recorded in nominal data form. The responses were converted to whole number range of scale data form. Based on the data collection mode, the indicators of sustainability of cost of unit production; time sustainability analysis in which the dependent indicator of "production" was plotted on x axis and rest of independent indicators on y axis. The scattered diagram revealed the performance of all irrigation system in detail (Fig. 05 & 06). In a nutshell, the practice of Persian Wheel irrigation system in the study area was sustainable adaptation of the agro-pastoralists community which was based on their socioeconomic condition of subsistence agriculture system.

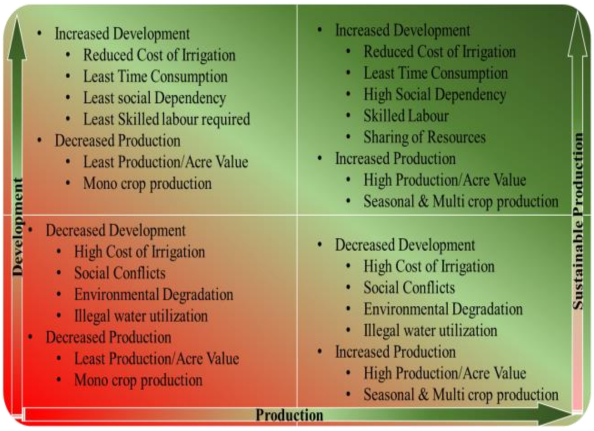

Fig. 05. Matrix Diagram of Sustainable Production System.

Source: Field Data, 2016.

Table 7. Normalized Values of Sustainability Indicators.

Type of Irrigation	Canal	Persian Wheel	PDEWPs	Solar/Electric Tube Wells
Production	2.8	3.6	3.4	2.4
Cost of Unit Production	3.6	3.0	2.0	2.0
Time Consumption	1.1	2.0	3.9	1.6
Cost Efficient	3.0	3.4	2.4	2.4
Social Welfare	-3.4	3.9	2.0	3.0
Associated Conflicts	-3.2	3.6	-3.0	3.6
Environmental Problems	-2.0	3.5	0.0	3.7
Average (Excluding Production)	-0.2	3.2	1.2	2.7

Source: Field Data, 2016.

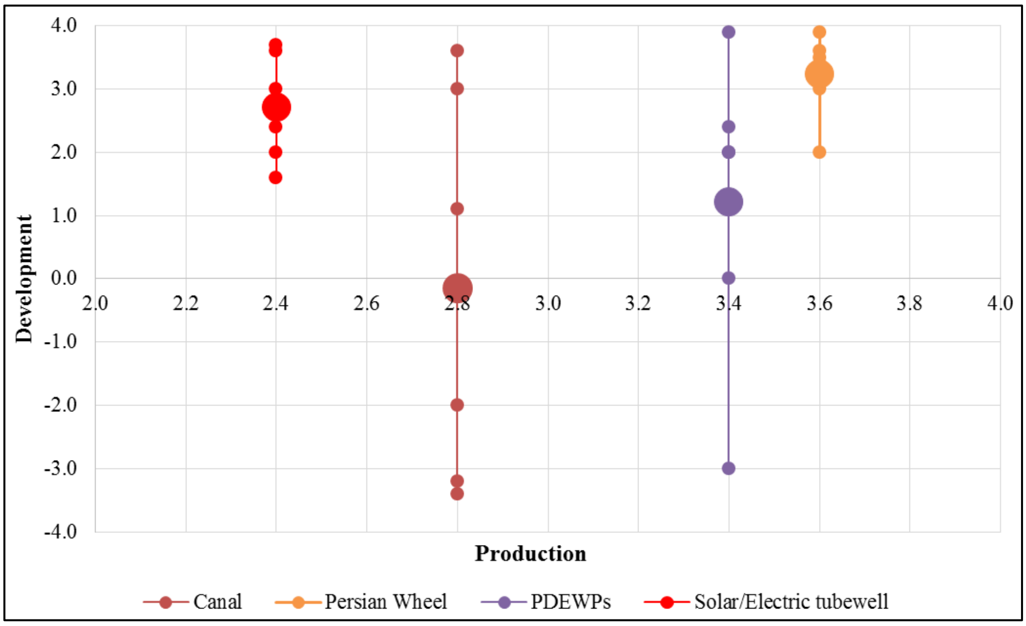

Fig. 6. Performance of Irrigation System against selected Indicators of Sustainability.

Source: Field Data, 2016.

Conclusions

Indus river is one of the most important river in Peshawar vale. It has enriched history of different civilizations. Persian Wheel irrigation system was part of this cultural traditions. In this era of modernization, the command area of Persian Wheel irrigation (locally called '*Arat*') was still considered as a high social stature. People living in this area proudly enjoyed the festivals associated with the Persian Wheel irrigation. Certainly, its presence in modern time of mechanization in agriculture was considered as perseverance of old technology. However, the present study explored that the existence of Persian Wheel irrigation was sustainable adaptation of the Agro-Pastrolist community against land defragmentation, complex tenancy system, high fuel cost, skilled labour, and modern irrigation methods.

The land use and irrigation pattern revealed that the Persian Wheel irrigation has a lion share of 27% in agriculture land uses. This share was major contributor of cash crops production. Cash crops harvested in canal commanded area was mainly mono crop production. Highly value cash crops were harvested in Persian Wheel and PDEWPs irrigated areas. In depth study of agriculture system revealed that subsistence agriculture system was involved in the cash crops production. In this subsistence agriculture system, the production cost was reduced by skills, labour, sharing, social welfare and inherited traditions. The Persian Wheel irrigation system provided an ideal environment for this subsistence agriculture system to cope with modernization, land defragmentation, social conflicts, and environmental problems. The value of cash crops productions was higher than any other irrigation system.

The sustainable cash crops production analysis disclosed that the Persian Wheel irrigation system has more sustainable cash crops production system than any other competitor. At the summation, the modernization, land defragmentation, mechanization etc. directly affected the marginalized rural Agro-Pastrolist community which pushes the agriculture system to more complex production environment. In this complex production environment, the Persian Wheel irrigation system not only survive but also achieved a sustainable production system.

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