EXPLORING THE WATER GOVERNANCE POLICY FRAMEWORK FOR IMPROVING PARTICIPATORY IRRIGATION MANAGEMENT REFORMS

Muhammad Arfan

(CGP #01-027)

RASTA CONFERENCE

Monday 28th & Tuesday 29th March 2022

PC Bhurban, Murree

RESEARCH FOR SOCIAL TRANSFORMATION & ADVANCEMENT

Pakistan Institute of Development Economics

Islamabad

ABSTRACT

Participatory Irrigation Management (PIM) reforms was introduced to mitigate the inept management of the traditional irrigation bureaucracy. It was hypothesized that these reforms would leave a positive impact on crop productivity and enhance the distributional equity of water among its users. The present study tried to compare the PIM and Non-PIM irrigation schemes under almostthe same cropping systems of Sindh and Punjab provinces of Pakistan—link it to farm sizes, irrigation management practices, institutional arrangements, and governance structures. Both qualitative andquantitative research methods were used for studying different aspects of irrigation management and reform process. It was concluded that canal water distributional inequity offspring economic inequity along the spatial position of the canal and tail user significantly under perform its actual potential. Reform unable to generate hydro-solidarity between head and tail sections of the canal and thus farmers managed institutions—FOs and AWBs, unable to check the rent-seeking behavior of irrigation bureaucracy. Level of participation in WUAs activities don't have a significant impact on the farm level productivity but the Institutional Performance of AWBs (IPAWB) have significant positive impact on the Composite Irrigation Management Performance (CIMP). Community cooperation and WUAs maturity have a significant positive impact on community participation in WUAs activities. Moreover, land asymmetry having significant negative relationship with land productivity, CIMP, IPAWB, and level of participation in WUAs activities. It has also been seen that irrigation bureaucracy only does an institutional mimicry under externally assisted push because there is substantial evidence that the PIM model was never adequately tested and implemented. Without active farmers' agency—small and landless peasants, these paper organizations are unable to create multi-level accountability in irrigation management.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

WUAs	Water Users Associations
WCAs	Water Course Associations
FOs	Farmers Organization
AWBs	Area Water Boards
PIDA	Punjab Irrigation and Drainage Authority
SIDA	Sindh Irrigation and Drainage Authority KP Khal Panchayat
PKPA	Punjab Khal Panchayat Authority
SWMO	Sindh Water Management Ordinance
PIM	Participatory Irrigation Management
IPD	Irrigation and Power Department
IBIS	Indus Basin Irrigation System

Unit of Conversion:

$ 1= 178.76 Pak Rupees

INTRODUCTION

After the downfall of the Union of Soviet Socialist Republics' (USSR), an era of Keynesian economic policy started fading during the 1980s (Townsend, 2004; Wolff & Resnick, 2012). The political economy of the world was dramatically transformed by neoliberal restructuring (Robinson, 2000), which redefined state responsibilities and economic processes (M. Wilder & Romero Lankao, 2006). This phenomenon is also termed Thatcherism (Hall & Jacques, 1983); with decentralization of state institutions as one of its salient features leading to strong localized municipalities, private corporations, and user associations (Ahlers, 2010; M. Wilder & Romero Lankao, 2006). The role of the state as sole driver of development and operations weakened (Azeem, 2020; M. Wilder & Romero Lankao, 2006).

During 1988, Pakistan's political regime change came with the idea of privatization and decentralization of state institutions (Ramanadham & Bokhari, 2019). The external push of funding institutions like the World Bank (WB) and Asian Development Bank (ADB) also influenced this restructuring (Kemal, 1995). Proponents of this idea advocated restructuring of state institutions as a noble rationale to improve the services, resource equity, stakeholder participation, empowerment of local communities, democratizing local peasantry, financial sustainability, and overall good governance (Larson, 2002).

After the Mexico water reform experience, the World Bank revised its previous strategy of “rehabilitate first, then transfer” to a new strategy of “transfer first, then rehabilitate” (M. Wilder & Romero Lankao, 2006). The irrigation bureaucracy of Pakistan saw it as an advantage to get the World Bank loan for introducing Participatory Irrigation Management (PIM) reforms in 1995 (Briscoe, Qamar, Contijoch, Amir, & Blackmore, 2005). This participatory reform package was introduced in the Indus Basin Irrigation System (IBIS) on selected canal command areas parallel with the traditional working of the provincial irrigation departments. Provincial Irrigation and Drainage Authorities (PIDAs) were established in 1997, and management of selected canal commands was transferred to newly established farmer organizations (FOs). It was argued that this reform package enables efficient services by localized self-management of farmer organizations (FOs) (Shah, Hussain, & Saeed-ur-Rehman, 2000). It was also assumed that localized self-management improves: distributional equity of water among its user, enable the collective action, enhance the trust and solidarity between head and tail reach, and financial self-sufficiency by reducing the financial burden—in the shape of a massive amount of subsidy to irrigation departments, and improve the overall livelihood of the community (Lin Crase, Vasant Gandhi, Bashir Ahmed, Bakhshal Lashari, Muhammad Ashfaq, 2020).

During the last two decades, since the reforms were introduced, Sindh province introduced two amendments: first amending Sindh Irrigation and Drainage Authority (SIDA) act 1997 to Sindh Water Management Ordinance (SWMO) 2002 and then Sindh Water Management (amendment) act 2005. However, Punjab province only tinkering with Punjab Irrigation and Drainage Authority (PIDA) act 1997 is to trim Participatory reform scope to a Punjab Khal Panchayat Act 2019 (Memon, Cooper, & Wheeler, 2019). Recently, Sindh province, after consultative engagement with a civil society organization, Strengthening Participatory Organization (SPO) and Collaboration with Commission on Status of Women in Sindh (CSWS) proposed a new amendment to ensure women participation at different tiers of nested governance structure (as shown in Fig 1).

The literature on participatory reform in Pakistan can be categorized into three strides: (1) reform outputs without the critical engagement with the local issues; (2) realizing the reform implementation challenges but only focusing on one reform player as a villain (i.e., irrigation bureaucracy or farmers agency); and (3) navigate between irrigation bureaucracy and development donor without engaging with policy problem critically. We attempted to critically engage with the reform process and look into the existing implementation challenges and how the issues associated with bureaucratic hurdles, community inefficacy, and donor participatory development approach reproduce each other in the reform process.

This working paper explores the participatory irrigation management reforms in Pakistan and answers the following research questions systematically:

1. How does the reform impact the distributional equity of the system as compared to the non-reform area?
2. Is reform able to enhance agricultural productivity as compared to the non-reform area?
3. If there is a difference between the agricultural productivity, is it associated with community and institutional characteristics?
4. What sort of resource user and resource characteristics play a role in the community collective action?
5. What are the challenges that PIM reform faced during the practice globally and locally?

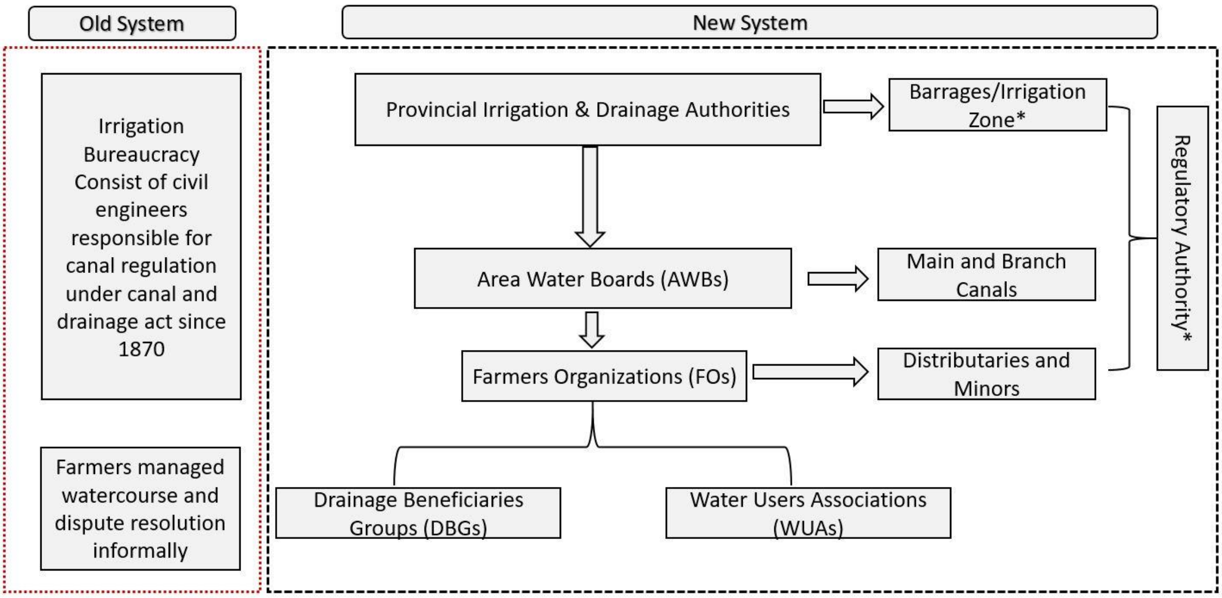
This paper has been organized into four sections. The introduction section presents the Pakistan irrigation sector and a critical discussion of the relevant literature on neoliberal assumptions and arguments underlying water reforms in the developing world; the main components of Pakistan's water reform program; and the influence of international organizations. The method section describes the study area descriptions and materials used in this study for each research question. The results section summarizes the key findings of each research question understudied. This section has discussed the outcomes of decentralization of the Pakistan water sector and explore the implications and conclusions of our research.

1.1 Irrigation Water Management and Governance in IBIS

During the colonial era, supply-side solutions were offered to address water scarcity, which included large dams, barrages/headwork, and canals (Yu et al., 2013). Irrigation bureaucracy and professionals were trained to manage this large-scale irrigation infrastructure. IBIS, one of the largest contagious irrigation systems is hence a supply-driven irrigation system that typically diverts water from barrage/headworks to main canals, and then main canals feed branch canals, and branch canal feed tertiary level irrigation system, termed as distributary/minor. Further distributary and minor diverted water to an outlet are applied predominantly through surface irrigation—flooding technique. This irrigation structure is governed through a nested framework and it is exclusively managed by the irrigation department up to the tertiary tier. Only below the tertiary tier, watercourses are managed by the community. Water is delivered through a unique system of *warabandi* in IBIS, which allocates water for a given time to each field of every watercourse on pro-rata with the area also termed as water allowance. Once water is drained from the outlet, it is distributed among fields sequentially according to the *warabandi* schedule (known as *Pacca Warabandi)*.

During the watercourse lining program, informal community organization was first organized into Water User Association/Water Course Associations to implement the watercourse lining program (managed under the agriculture department) (Byrnes, 1992). These WUA/WCA provided manual labor and a certain amount of financial share (which varied from time to time) to contribute financially to the community. After that experience, the World Bank further pushed the authorities to give these community organizations more organizational space up to the tertiary and secondary levels.

Figure 1. Comparison of Centralized Irrigation Department with Participatory Reform



1.2 International Context of the Reform

In a policy paper of the WB 1992, Bank describes three priority areas for future water management as main pillars: water as an economic good; improved institutional arrangement involving greater stakeholder participation, private sector, and NGO's; comprehensive management of water (Briscoe, Anguita, & Peña, 1998). International Conference on Water and Environment—held in 1992, a.k.a. Dublin Conference, concluded: "water has an economic value in all its competing uses and should be recognized as an economic good" (Lundquist, 1997). Following the Dublin principles, the United Nations Conference on Environment and Development (1992) also endorsed the idea—water as an economic good (Gleick, Wolff, Chalecki, & Reyes, 2002).

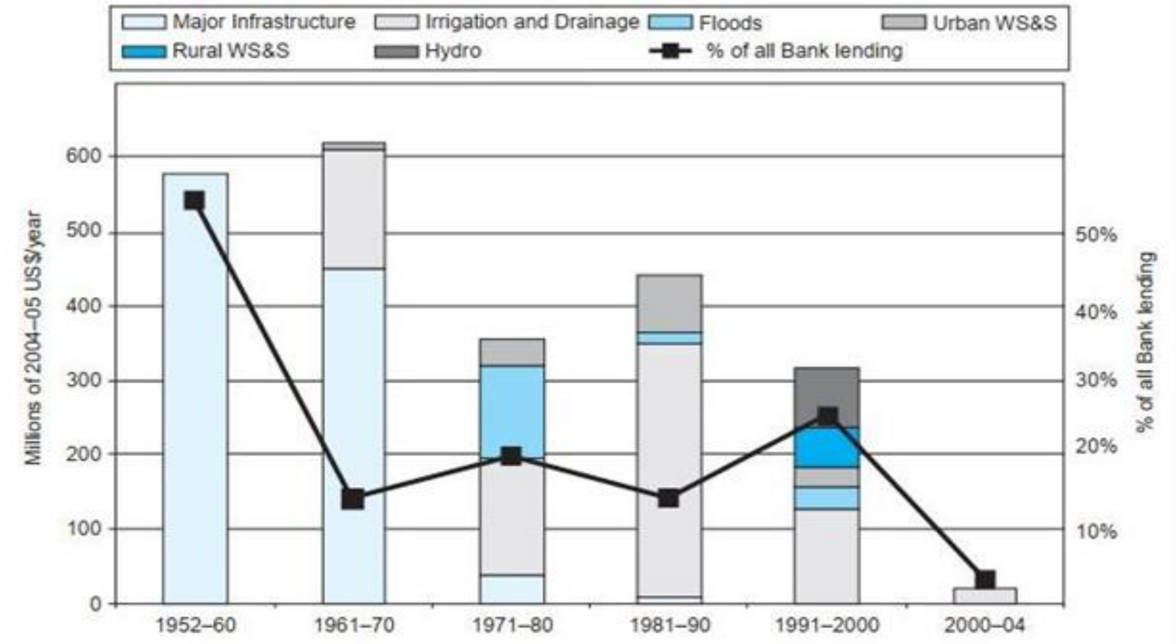
Therefore, the participatory introduction of the institutional reform in Pakistan is interlinked with the reform's international context and streamlined with the neoliberal economic agenda of water reforms and decentralized governance. Many developing countries adopted these reforms under the Bank's guidance and funding (Liebrand, 2019; Santiso, 2001; D. L. Vermillion, 1997). Third-world countries with economic dependence on the Bank's lending face severe financial indebtedness challenges (Santiso, 2001). The state's functioning and performance in service provision and developmental activities are significantly questionable. Under these circumstances, market forces and the private sector are portrayed as the “only” compelling alternative to government, and the state is claimed to be inefficient (Desmond McNeill, 1998) . The "only" option left behind includes the water user and other private sectors in water management as an integral part of an alternative form of participatory water governance movement (M. O. Wilder, 2002). This alternative decentralized governance is believed to improve "resource allocation, efficiency, accountability, and equity". Water pricing and participatory governance are considered as a means to achieve the goals mentioned above. After the widespread adoption, the "new" decentralized governance provides a tremendous body of literature highlighting its impacts outcomes and discussing different strategies of decentralization in different countries and contexts (Bandyopadhyay, Shyamsundar, & Xie, 2010; Ghumman, Ahmad, Hashmi, & Khan, 2014; Mukherji, Fuleki, Suhardiman, & Giordano, 2009; Parthasarathy, 2000; Raby, 2000; Reddy & Reddy, 2005; Senanayake, Mukherji, & Giordano, 2015; Sinclair, Kumnerdpet, & Moyer, 2013; Suhardiman, Giordano, Rap, & Wegerich, 2014; Uysal & Atiş, 2010; Douglas L Vermillion, Samad, Pusposutardjo, & Arif, 1999).

1.3 Political Economy Context of Reform

Pakistan’s water reform program is merged (both chronologically and ideologically) with a neoliberal economic transformation that began to take shape in the late 1980s, accompanied by a political opening that resulted in the election of Benazir Bhutto—leader of the leading opposition alliance called Movement for Restoration of Democracy (MRD), to the first women prime minister of Pakistan in December 1988. Bhutto's victory was widely celebrated and interpreted as a democratic transition after an 11-year rule of General Zia—a military coup in 1977. During the election campaign in 1988, Benazir Bhutto promised the industrial sector to end the nationalization path and carry out industrialization by means other than state intervention. A massive privatization plan was unveiled on 22 January 1991—Prime Minister Nawaz Sharif, inspired by the success of the privatization agenda introduced by British Prime Minister Margret Thatcher. Pakistan’s economic opening was also demonstrated by its 1995 participation in the General Agreement on Tariffs and Trade (GATT) (Noshab, 2000).

The World Bank has had a long history of lending in Pakistan water sectors since the Indus Water Treaty (1960). Figure 2 shows the Bank's lending in Pakistan's water sector. Initially, this lending focused on infrastructure development, and then in the 1980s, its focus shifted from infrastructure development to transforming the institution. In 1994, the Bank studied the water sector and prepared a report entitled "Pakistan—Irrigation, and Drainage: Issues and Options”. This report points out that In Pakistan, as in many other countries, the government treats irrigation water as a public good, whereas it is a private tradable good, for which markets can operate (Briscoe & Qamar, 2005).

Figure 2. World Bank lending to Pakistan for water-related sectors (1952–2004)



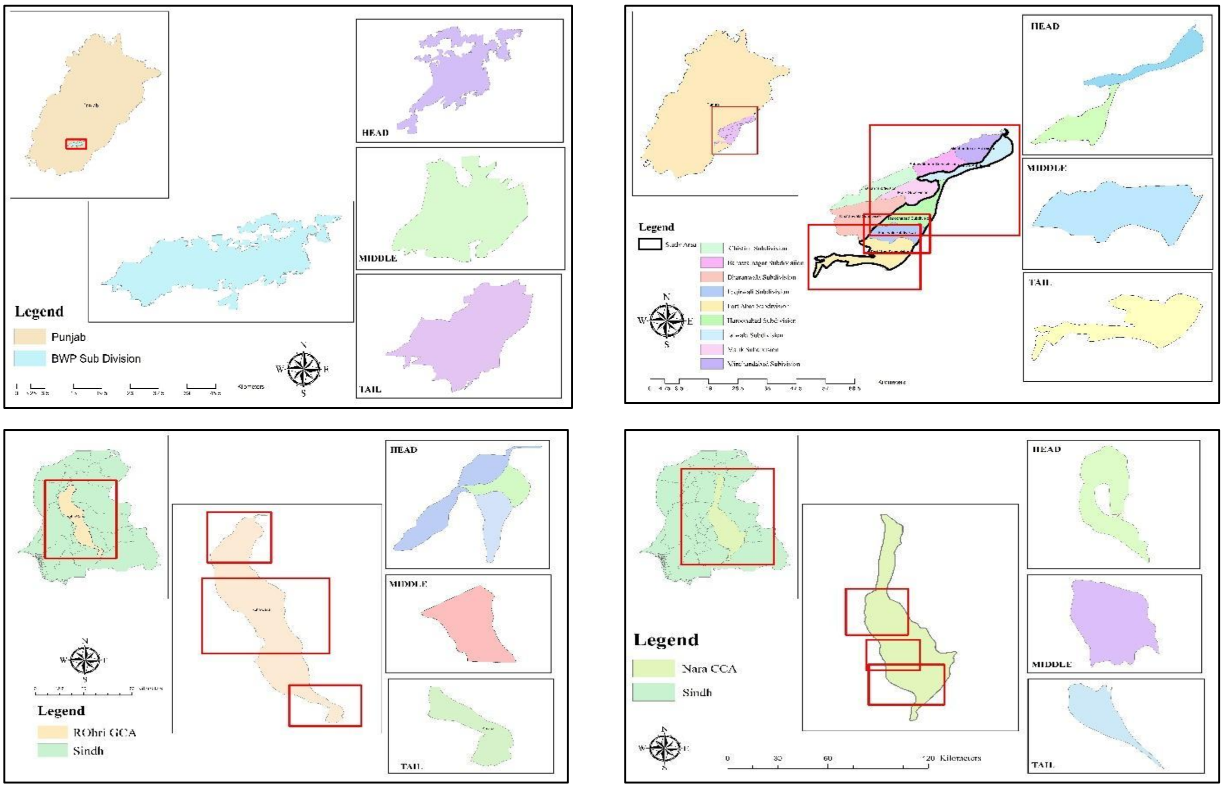
Source: The World Bank, 2004.

MATERIALS AND METHODS

2.1 Reform and Non-Reform Area Canals Description

Canal command areas of Punjab and Sindh were selected for this study. Two canals from each province were studied for comparative analysis of the reform; one was the area where the participatory governance regime is/was practiced, and one which where the provincial irrigation department solely manages. For this purpose, Bahawalpur and Bahawalnagar canal circles were selected in Punjab due to almost similar geophysical and climatic characteristics. Bahawalpur and Bahawalnagar lied in the princely state of Bahawalpur. Nawab of Bahawalpur designed the Sutlej Valley project with the help of British finance on the Sutlej River. Canals were selected in Sindh (Rohri and Nara) due to their geophysical and climatic characteristics. Both these canals are on the Left Bank of the Indus River. Rohri canal command has some comparative advantage due to its alignment with the Indus River floodplain areas in some sections. The dominant cropping pattern of these canals is wheat and cotton crops. Each main canal system was divided into three sections, i.e., head, middle, tail, to understand the irrigation system performance spatially, as shown in Fig 3.

Figure 3. Study Area Canal selected



The Punjab irrigation network has shown the head Suleimanki and Islam command area (Upper left and Right). Head Suleimanki command area, where the PIM reform was introduced, whereas head Islam command area under provincial irrigation department of Punjab. The Sindh irrigation network has shown the Nara and Rohri command area (Below Left and Right). Nara command area, where the PIM reform was introduced, whereas Rohri command area under the provincial irrigation department of Sindh.

2.2 Methodology for Each Research Question

Comparative Analysis of Irrigation Governance under PIM and Non-PIM Irrigation Schemes

Remote Sensing-based Irrigation Performance Indicators

Remote sensing data is widely used to assess the water use performance indicators globally, and this robust method assists resource managers to effectively decide the water allocation rules and decisions temporally and spatially. Remote sensing-based Normalized Difference Vegetation Index (NDVI), actual evapotranspiration, and evaporative fraction provide a better understanding of the real-time performance of different irrigation schemes and their water delivery system. In this study, we estimate the time series of cropping intensity, adequacy, reliability, and economic water productivity based on remote sensing time series data, in addition to the traditional survey-based estimates.

The single-source energy balance model named SEBAL was used to estimate the actual evapotranspiration. It is a well-tested and widely used method for the computation of actual ET (Allen et al., 2007; Wilhelmus Gerardus Maria Bastiaanssen, 1995; Wim G M Bastiaanssen, Menenti, Feddes, & Holtslag, 1998; Glenn et al., 2011; Jia, Wu, Tian, Zeng, & Li, 2011; Liou & Kar, 2014). SEBAL is a direct empirical method that incorporates the energy balance using some land surface properties like albedo, net radiation, canopy cover, surface temperature, and leaf area index. The surface energy balance equation gives the principle of ET estimation by remote sensing.

$$Rn = LE + H + G$$

Where,

Rn is the net radiation,

LE is the latent heat exchanges,

H is the sensible heat, and

G is the soil heat flux

The use of energy balance can help detect the reduction in ET caused by water shortage. Different models can improve the accuracy of the ET estimations from this method. However, these models are accurate if their interpolation and calibration are correctly done at the local level. For this study, the cloud-free scenes from MODIS were downloaded from USGS earth explorer from Jan 2015 to Dec 2021. The average seasonal actual ET was estimated for each Rabi and Kharif season during this period.

Land Use/Land Cover Classification Change

Eight LULC classes: Banana, Cotton, Rice, Sugarcane, Fallow land, Water Bodies, Built-up, and Mango were achieved after classification. The producers' and users' accuracy for different classes are shown in table 4.3. The overall accuracy for the Rohri and the Nara canal command 93% and 95%, respectively. The Kappa coefficient value is more than 90% for both the canal command, which is considered a good classification category. The built and water bodies have high separability. The mango and Banana fields are easier to categorize because they are large, frequent, and more separable from the other classes. The water bodies and rice cells are difficult to separate due to their low NDVI values. Same as fallow land and cotton fields are also having the same reflectance range.

Performance Indicators

Different performance indicators were used for the comparative analysis of the selected PIM and Non-PIM canal command areas. The purpose of using comparative indicators is to assess outputs and impacts of intervention in distinct systems, compare the performance of a system over time, and also allow comparison of systems in different areas and at the different systems at spatial scales (Molden, Sakthivadivel, Perry, De Fraiture, & Kloezen, 1998). Performance indicators help identify the differences in performance at the scheme level, seasons and irrigation sources (wim H. Kloezen, 1998). It also helps to find out the gaps in management policies. Contrary to process indicators, performance indicators are not data-intensive and cost-effective (wim H. Kloezen, 1998). Considering the complication of the process indicators and their estimation, we prefer to use comparative performance indicators proposed by IWMI (Molden et al., 1998). These performance indicators are best suited and applied at different scales cited in the literature (Cuamba, 2016; DEĞİRMENCİ, Büyükcangaz, & KUŞCU, 2003; Efriem & Mekonen, 2017; Hasan Merdun & ., 2004; Kloezen, Garcés-Restrepo, & Johnson III, 1997; Murray-Rust & Snellen, 1993; P. S. Rao & Rao, 1993; D. L. Vermillion, 1997). A basic illustration of the selected performance indicators is listed below.

Cropping Intensity (CI %) = Actual Cropped Area/Gross Command Area

Adequacy of Canal Water Supplies = Average Seasonal Evaporative Fraction

Reliability of Canal Water Supplies = Coefficient of Variation (CV) of Evaporative Fraction

Head to Tail Ratio CI = CI of Head Command Area/ CI of Tail Command Area

Water Productivity (Rs/m^3) = Gross Return/Actual Evapotranspiration (ET_{act})

Gini Coefficient of Agricultural land productivity

Output per Unit of Command Area (Rs/acre) = Net Return/Command Area Irrigated

Studying the Resource and Resource users' Characteristics

Mixed Methods Design

We used both quantitative and qualitative methodologies and primary and secondary data to generate a more holistic picture of the system, according to the complexity of the research issue and hypotheses. Structured watercourse (WC) interview surveys with representatives of farmers from Watercourse Associations (WCA/WUA) on canals where PIM reform was introduced and general farmers where the irrigation department managed the canal regulation. Semi-structured interviews with key informants from the Sindh Irrigation and Drainage Authority (SIDA) and Punjab Khal Panchayat Authority (previously worked as PIDA), the Irrigation Department (ID), farmer's organization chairman, and water experts currently affiliated with neither the SIDA nor the ID, and focus group discussions with sharecroppers, farmers from marginalized communities were among the "mixed methods" used. The purpose of key informant interviews and focus group discussions was to gain a better and holistic understanding of the underlying features of the irrigation system so that the survey findings could be better interpreted.

Sampling Design and Data Collection

Three distributaries were selected on each canal command area in Sindh and Punjab; hence, 12 distributaries were surveyed, four at the; head, middle, and tail reach. The sample size targeted 600, 300 in Sindh and 300 in Punjab. Total 8 FDG were conducted, one on each canal's distributary head and tail reach. Total 25 key informants selected.

Survey Tool Design

The survey instrument was developed using ideas and specific question examples from the literature on community cooperation and collective action, group dynamic effectiveness, technical rationality of irrigation infrastructure, irrigation management performance, community participation in participatory institutions, and the PIDA farmer's organization assessment evaluation scale. Furthermore, the principal investigator's theoretical and contextual understanding and his field experience as an enumerator aided in the refinement of several scale items.

Pretesting

The survey was pre-tested with many LBCAWB Farmers' Organization members who were not among the participants in the main survey poll. The survey instrument was further refined throughout the pre-testing phase to eliminate ambiguous questions, resolve conceptual ambiguity, enhance translations, convert certain open-ended questions to closed-ended questions, and reorganize question order to improve flow. A few more questions were added to the research study that was in keeping with the tone and goal. Members of the field crew were also able to evaluate time and give suggestions for making the survey more efficient during pre-testing. The survey tool used in the PIM and Non-PIM areas is slightly different due to the different governance regimes, and some scale and scale items were not relevant to their context, so this adjustment was made in the survey tool for data collection in the Non-PIM area. In Annex 2, you will find the final survey instrument in English.

Sampling Design

The sampling design was based on the subdivision selected for remote sensing analysis, and one distributary was selected in each head, middle, and tail of each main canals in the Punjab and Sindh. We targeted 50 respondents on each distributary at the head, middle, and tail; hence total sample size is 600. However, the targeted sample size achieved was 550 and after clearing the dust, the sample size used in the analysis is 457. The exact number of valid sample sizes for each canal was present in the annexure or table.

2.3 Data Analysis Framework

Hierarchical Regression

Hierarchical regression is an alternative approach to stepwise regression. It can be used to assess the contributions of variables other than those already known variables, as a statistical control method, and to investigate incremental validity. Hierarchical regression, like stepwise regression, is a sequential method that involves the progressive introduction of predictor variables into the analysis. In contrast to stepwise regression, the order in which variables were entered into the analysis was determined by theory(Lewis, 2007). Rather than allowing a computer software program to "select" the sequence to enter the variables, the researcher makes these decisions based on theoretical knowledge and already available evidence about the problem. While there is no "correct" method for choosing the order of variable entry in Stepwise versus Hierarchical Regression, (Kerlinger, 1966) noted that "no substitute for depth of knowledge of the research problem... the research problem and the theory behind the problem should determine the order of variable entry in multiple regression analysis" (p. 545). Mechanical model selection and modification processes... often cannot compensate for deficiencies in the data and are no replacement for judgment and intellect," (Fox, 2019) Simply put, "the data analyst understands more than the computer" (Henderson & Velleman, 1981, p.391).

When the variation on a criterion variable is explained by predictor variables associated with each other, hierarchical regression is an acceptable method for study (Pedhazur, 1997). Hierarchical regression is a good option because correlated variables are prominent in social science research. After adjusting for other factors, hierarchical regression is a popular approach for analyzing the influence of a predictor variable. This "control" is performed by measuring the change in adjusted R2 at each analysis stage, thereby accounting for the increase in variance after each set of variables is introduced into the regression model (Pedhazur, 1997).

PIM Agenda Implementation in Theory and Practice

For studying PIM agenda implementation in theory and practice, we studied the case studies of different continents and identified the key theme to review the global case studies and identify the key challenges PIM faced and compare those with our case study. We selected seven case studies across different continents, then we did an extensive literature review, and finally analyzed the published available evidence about the selected themes. The theme which we have selected for framework analysis covers the context of irrigation system, features of the hydraulic bureaucracy, an institutional feature of the reform model, external and internal drivers for reform, farmers politics for reform, consultation process, the role of the lending agency, how and what sort of rules and regulation devised for power shift from irrigation bureaucracy and to a community organization. Meanwhile, we used our insight from the field observation and key informant interviews with stakeholders involved in the reform process for our case study to understand the PIM reform implementation challenges in our context.

Focus Group Discussion

Members of vulnerable/disadvantaged groups – especially tenant farmers – participated in focus group talks to acquire a broader perspective on the issues of attaining water distribution equality. These conversations were exploratory in nature and intended to aid in interpreting evidence acquired through other means rather than directly informing the hypothesis.

Key Informant Interviews

Individuals with experience and knowledge about irrigation management in Sindh and Punjab were requested for interviews; a total of 25 key informant interviews were conducted. The goal of these interviews was to get a high-level understanding of the obstacles of implementing participatory irrigation management and get insights that would aid in interpreting survey data. All important informants were found through the personal network. Since these interviews were intended to be semi-structured, customized interview guidelines were created according to the context of each category of the key informant (see Annexure D.

Participants in the first category were (SIDA/PKPA (EX-PIDA) personnel were directly involved in the social mobilization and capacity development efforts of FOs. The second category consisted of existing Irrigation Department personnel, responsible for the distributary and subdivision level canal regulation and mandate to work in close coordination with FOs. Former and current FO's chairman for different distributaries made up the third category, and they asked to specifically speak about their experience in FO's activities and how different stakeholder expectations and responsibilities moderated being a FO's chairman. What sort of key challenges do they face during their tenure? The interviews were audiotaped with permission and specifically asked whether the information you provided was used as "on-record" or not.

RESULTS AND DISCUSSION

3.1 Comparative Analysis of Irrigation Governance under PIM and Non-PIM Irrigation Schemes

Comparative performance comparison of different canal irrigation schemes is a way to improve the canal or basin-scale water regulation. Since the 19th century, after the scaling up of irrigation schemes, a wide range of literature has been produced to measure these irrigation schemes, productivity, and efficiency in many ways. Hence, to assess the productivity and efficiency of these irrigation schemes, different indicators/indices were designed based on the nature of data availability. Initially, these performance indices methodologies relied on traditional survey approaches and canal level data measurement through rating scale. These data collection methods' accuracy was compromised under different conditions and contexts. Water resource specialists evolved different ways where this data scarcity and collection-related subjective biases could be minimized objectively.

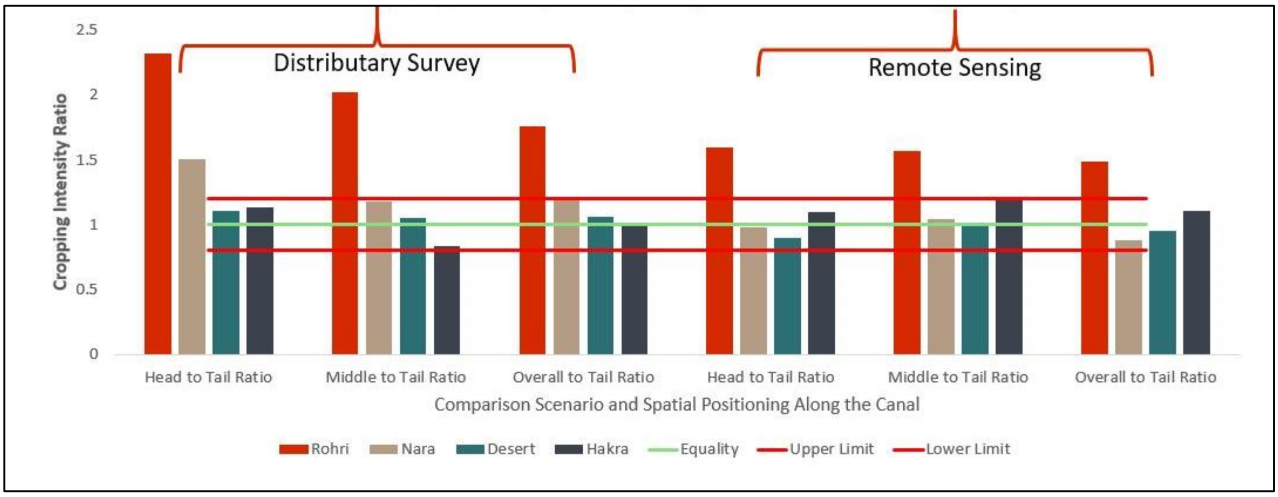
After an advancement in remote sensing techniques and free access to better temporal and spatial resolution scale remote sensing data, the use of these datasets became popular among the researchers, to better assist traditional data collection methods. Different irrigation schemes performance can be compared from different perspectives, like distributional equity, efficiency in resource use, and environmental sustainability. In this study, our focus remained on distributional equity, and its consequences resulted in agricultural economic return inequity. Fig A provides the methodological flowchart to visualize better how our data collection and argument navigate to answer this research question comprehensively. In the following section, we discussed section-wise results.

Cropping Intensity Comparison

Annual cropping intensity estimated through crop reported in a distributary level main survey and remote sensing approach—using NDVI as a proxy indicator to estimate the overall area under crop in each season. Remote sensing analysis was performed at the subdivision scale, whereas in the main survey, we selected the distributary in each subdivision. To compare the canal performance, we estimated the cropping intensity ratios at three scales— head to tail, middle to tail ratio, and overall to tail ratio, and compared the canals from the equality lens. Cropping intensity ratio indicator equal to one, means perfect equity, if value more than one, then it means the head section is a more cropped area as compared to the tail section, and if the value is less than one then tails section is a more cropped area as compared to head section. Head to tail inequality in canal system largely has two reasons: one is due to technical reasons as canal approaches towards tail its system losses increase which ultimately negatively impacted tail section, generally termed as inequality due to canal system, i.e., hardware problem, secondly, due to mismanaging the canal schedule to favor head/tail section or any targeted area, generally termed as software problem (Power Asymmetry) of the canal system. Keeping the above scenario, we used 20% plus and minus as uncertainty and denoted as a permissible limit.

Data analysis suggested that the Rohri canal has more inequity between head and tail reaches than the Nara Canal area in Sindh province. In Punjab, the difference in cropping intensity between head and tail remained largely within the permissible limits. The reason for this apparent equality relies on the conjunctive use of the saline and marginally fresh groundwater at the head, middle, and tail sections of the canal. We analyzed the estimated evaporative fraction data to validate these initial findings further.

Figure 4. Comparison of cropping intensity estimated at distributary and sub-division scale

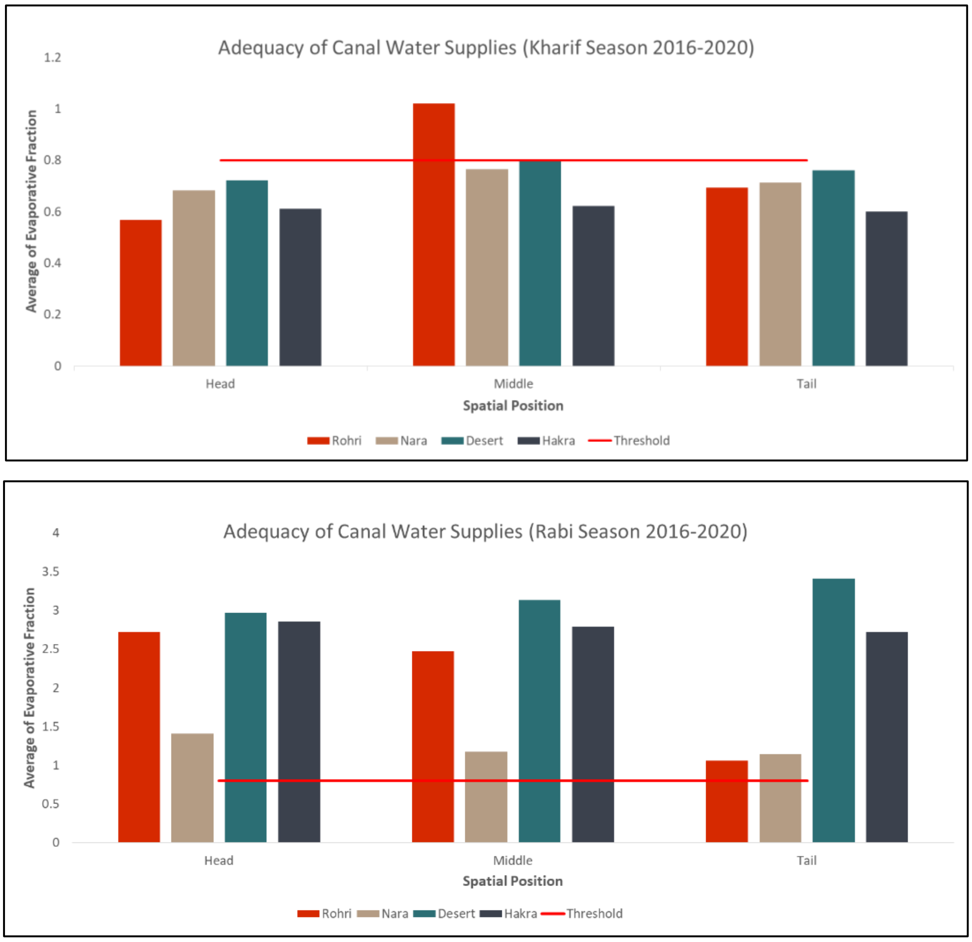


Adequacy and Reliability of Water Supplies

Figure 5 provides (see the table in annexure) the adequacy of the canal water supplies in the selected canal command area and the canal system's spatial position. Adequacy is defined in this study as the average seasonal evaporative fraction, and reliability is the temporal variability or the temporal coefficient of variation of the evaporative fraction across a season. Evaporative fraction levels of 0.8 or greater suggest little stress, whereas values below 0.8 indicate increased moisture scarcity due to insufficient water supply. Similarly, lower coefficients of variation indicate a more consistent water supply throughout the growing season (Ahmad, Turral, & Nazeer, 2009).

Comparison of the evaporative fraction for the selected canals showed the seasonal variation of the canal water supplies in each respective command area. During *rabi* season, over-allocated canal water from the wheat crop demand, and during the Kharif seasons, it marginally meets the crop water requirement of the cotton crop. The head, middle, and tail reach variation showed that canal regulation was inadequate and unreliable, and Kharif season water scarcity is easily managed through an existing available water resource with better canal regulation. In the Nara canal, *rabi* season, canal regulation seems much better than other canal commands, simply because the Nara canal has a Chotiari reservoir facility for managing the regulation in a better manner. The length of our canal system is exceptionally too lengthy that once the water diverts from the source to the canal, then there is no storage facility available in the canal system where the water can be stored if it is not needed at the field. During the field investigation, it was found that farmers reported this seasonal inadequacy of canal supplies as shown in Fig 6, and due to the over-irrigation in wheat crop, the wheat yield was hampered.

Figure 5. Adequacy of Canal Water Supply in Kharif and Rabi Season,



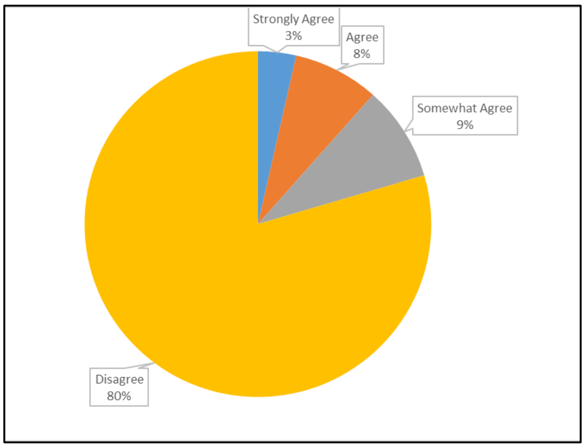


Figure 6a. Adequacy and Reliability in Kharif Season (Farmers Reported)

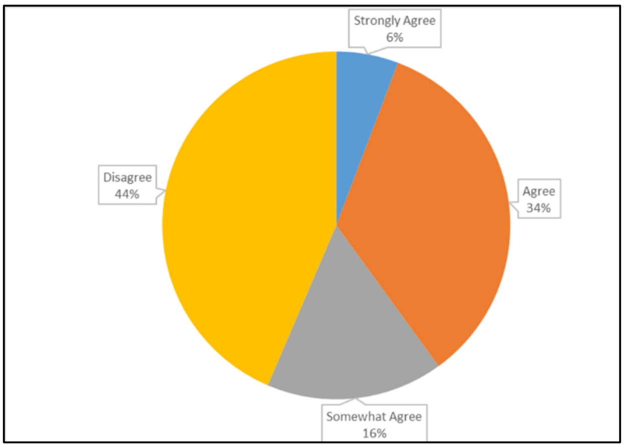


Figure 6b. Adequacy and Reliability in Rabi Season (Farmers Reported)

Farmers adapted to this inadequacy by changing the crop choices to annual crops like sugarcane and banana (in the case of Sindh), especially in the head and middle reaches. This shifting of crop choices in head and middle reaches due to enough availability of the canal supplies speculate huge crises for the tail area in the early Kharif season. Hence, the late sowing of cotton crops reduced their cotton crop yield. The difference in canal water adequacy and reliability between head, middle, and tail reaches was more significant in Sindh canals than Punjab canals, as shown in figure 5.

The foremost explanation for this phenomenon was simply the less variation in the high delta crops selection in Punjab canals. We observed that the adequacy and reliability difference between head and tail in Punjab is much better than that of Sindh. Can we conclude that canal water distribution in Punjab is equitable as there is less variation between the head and tail reaches of the canal? We hypothesized that apparent equity in cropping intensity and canal water adequacy/reliability between head to tail section primarily due to the groundwater use. However, this adaptation strategy does not provide an equal agricultural economic return. To validate the above stated hypothesis, we analyzed the land use and land cover classification, and the main distributary level survey reported agricultural return.

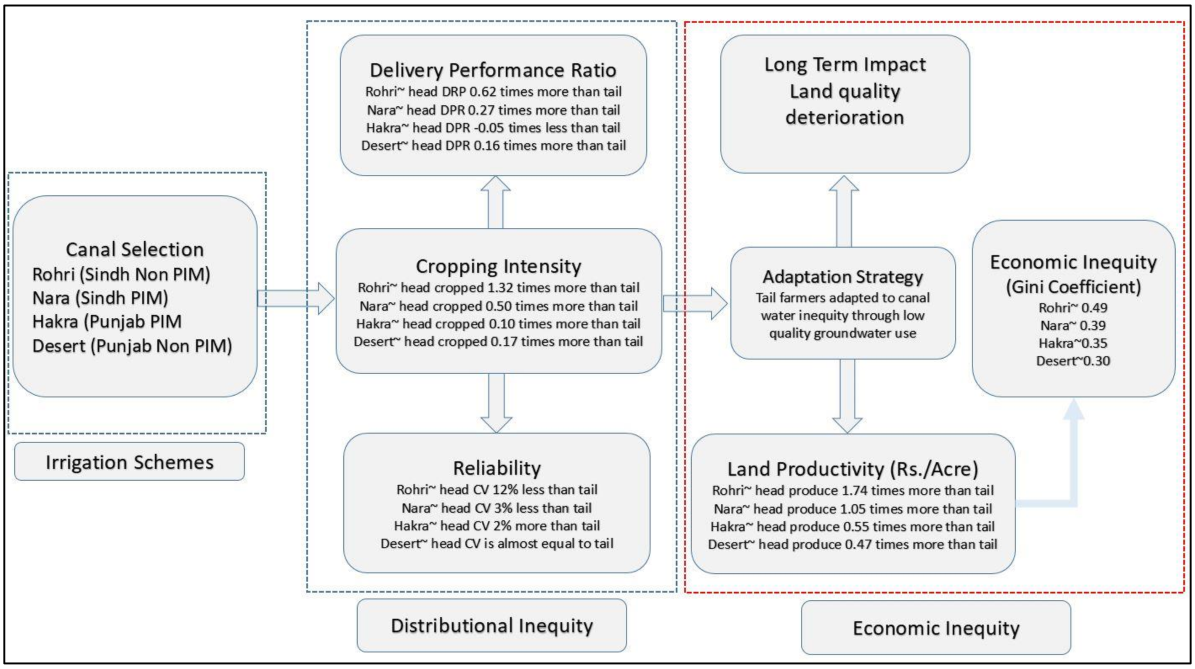
LULC classification reveals that overall area under cotton crop decreases in both canal command areas of Sindh, the rate of change in acreage in the cotton crop is 8.7% and 7.7% in Nara and Rohri canal command area, respectively. The high delta crop was more visible along with the head of the canal network, and as the spatial distance from the main or branch canal increased, the proportion of high delta crops decreased significantly. The variation in the crop choices for the head section ultimately influenced the low cropping intensity at the tail reaches of the canal system. This situation showed another form of inequity between the head and tail sections. This inequity led towards an economic inequity between the head and tail reaches of the canal system and was estimated as the Gini coefficient.

Water Inequity leads towards Economic Inequity

In the previous section, we employed different indicators to assess the distributional equity between head and tail sections in different canal systems. Fig 7 provided an overall summary of this section that shows how the land and water productivity estimates per unit acre and cubic meter of water used differently between the head and tail reaches.

We estimated the annual gross return and net return (Rs) from the crop production survey at the distributary level. The comparison of the gross and net return of land productivity (Rs/Acre) showed that the overall desert canal had the highest gross and net return compared to all other three canals. The head, middle, and tail reach canal comparison showed that the Rohri canal middle section had the highest gross return, and the desert canal had the highest net return at the head section. From an equity perspective, Rohri and Nara canal has more variation between head, middle, and tail reaches than the Desert and Hakra canal. Hakra canal has a better annual cropping intensity than Nara and Rohri, but this does not yield better gross and net return. The higher cropping intensity achieved through the conjunctive use of saline and marginally fresh groundwater compromised the per unit land yield for major cash crop—cotton, and compromised the land quality due to the continuous use of groundwater for cropping. In addition to yield compromise, groundwater use has an economic cost associated with its extraction, which further reduces the net return. Canal water scarcity pattern also confirmed, looking through Delivery Performance Ratio (DPR) data analysis.

Figure 7. Summary Results Showing how Distributional Inequity leads to Economic Inequity



Nara and Rohri have better DPR than Hakra canal and even in Desert canal case too, then why is the gross and net return of Rohri and Nara not exceptionally higher as one can expect?

This apparent anomaly partially explained from the fact that Nara and Rohri have low cropping intensity due to waterlogging and higher salinity menace. A low net return of Rohri and Nara canal provides another clue about the grim reality that both Rohri and Nara canal respondents reported in the survey that due to the poor state of irrigation infrastructure at the tertiary level canal system, the watercourse is unable to deliver the canal water under gravity flow condition. Hence, even head reaches farmers also need to lift canal water for irrigation, which has an economic cost, thus reducing the net return. Another sharp contrast between Sindh and Punjab canal systems was that the difference between the head and tail distributary land productivity in Punjab significantly less than in the Sindh. The partial explanation for this less inequity was explained through the percentage difference of higher cash crops at head reaches, and low cropping intensity at the tail reaches.

Economic Water Productivity (Rs/m3) [EWP] is an indicator of water use efficiency (WUE), widely used for efficiency comparison and also to assess the economic value of water at any desired scale. The World Bank recently estimated the EWP at the provincial level and reported Punjab having EWP 0.08 $/m3 and Sindh having 0.06 $/m3 (William J. Young, Arif Anwar, Tousif Bhatti, Edoardo Borgomeo, Stephen Davies, William R. Garthwaite III, E. Michael Gilmont, Christina Leb, Lucy Lytton, Ian Makin, 2019). Our estimate at canal level given in fig 8, showed that overall, Rohri, Nara, Desert, and Hakra canal had 0.08, 0.12, 0.07, and 0.06 EWP ($/m3), respectively. We estimated annual crop water use (m3) from actual evapotranspiration for the crop water year and used it as a denominator for gross per unit land productivity for the EWP estimate. The difference between our estimated results and World Bank is that they used the provincial level gross return estimates and provincial level crop water use. This comparison provides an interesting insight that in Punjab, Desert, and Hakra, being at the tail of the provincial canal network, perform near to the provincial average but in Sindh, Rohri, and Nara performing above the provincial average, which meant Sindh province remaining irrigation network performing much below the provincial average. Through this economic analysis at the canal level and at the provincial level, we were forced to conclude that inequity associated with the canal regulation is one of the sources for inequity related to agricultural returns, and this inequity up to certain extent managed through improved canal schedule.

Figure 8. Comparison of Water Productivity (Rs/m3) in Selected Canals at Spatial Position

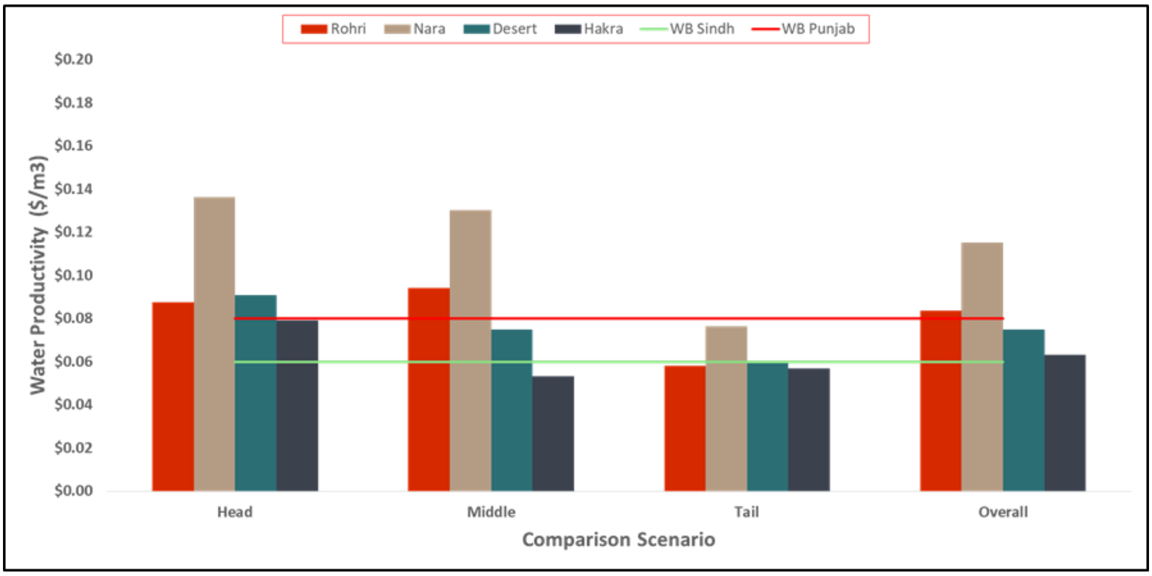
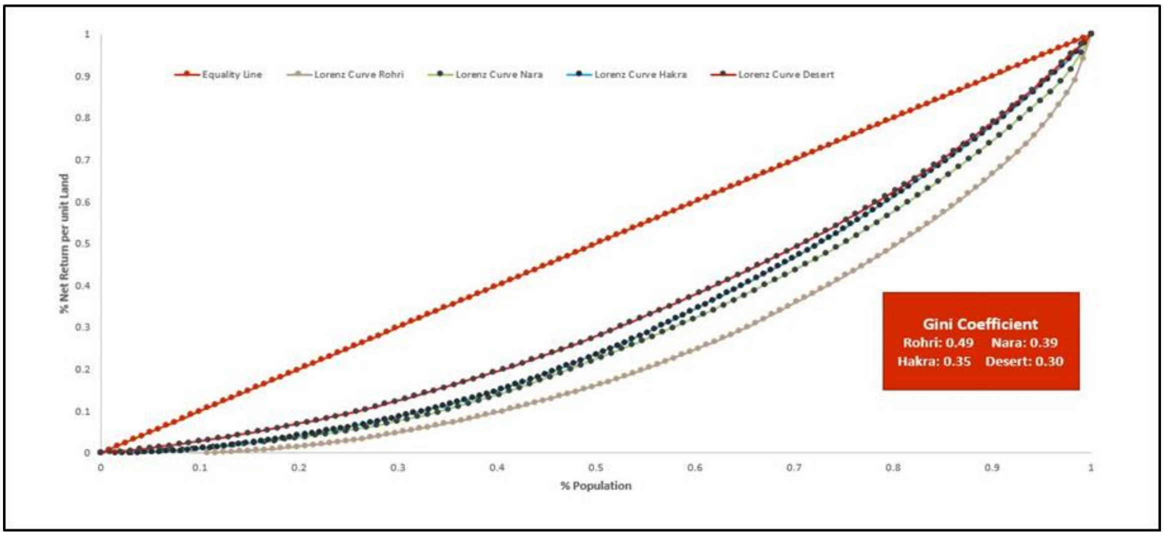


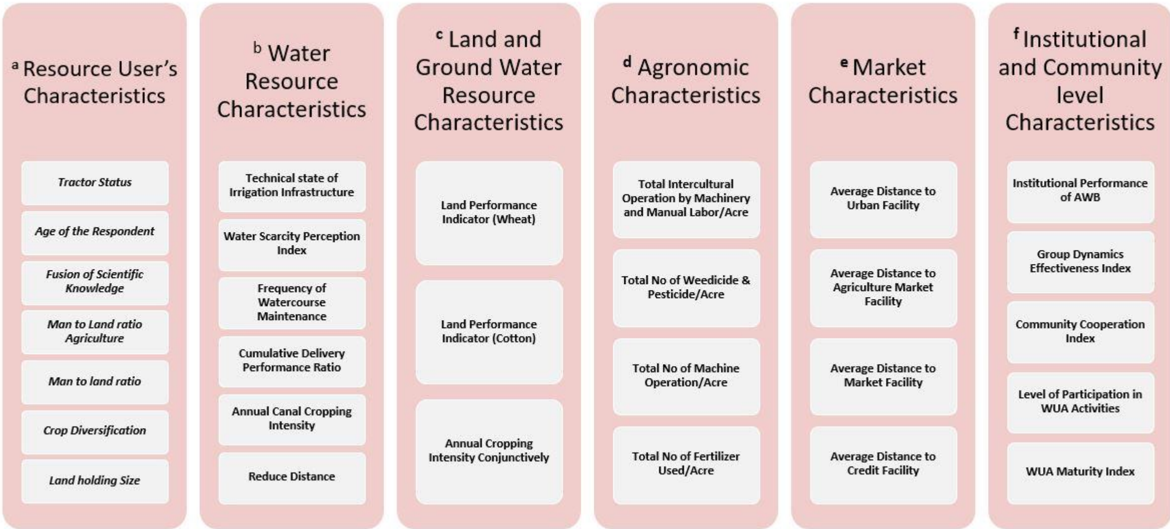
Figure 9. Gini Coefficient Comparison of the Different Canals



3.2 Studying the Resource and Resource users' Characteristics

What explains the economic divergence in agricultural land productivity (Rs/Acre) has remained a research focus of the researchers in different regions. Agricultural productivity is influenced through several exploratory predictors, and each of the predictors has a varying degree of influence over agricultural land productivity. We modeled agricultural land productivity (Rs/m^3) as Dependent Variable (DV) through a hierarchical regression framework. Figure 10. enlist the exploratory predictor and its hierarchical progression, which might influence our DV based on the literature evidence.

Figure 10. Hierarchical Regression Model Framework



We grouped all these exploratory variables into six categories and labeled them as resource user characteristics, water resource characteristics, land resource characteristics, agronomic characteristics, market characteristics, and institutional and community characteristics. Definition and construction methodology of these explanatory variables present in the annexure-A.

In this section, we analyzed how our exploratory factors defined above related to land, water, institutions, community traits and resource user's characteristics potentially contributed to the economic divergence in agricultural return? In the previous chapter we see how the changing pattern of canal regulation and water availability produces economic inequity in the existing agriculture-based water economy. Participatory irrigation management reform was introduced to improve this canal regulation inefficacy and irrigation infrastructure management quality by accommodating farmer's voice in the tertiary level irrigation infrastructure management in shape of—farmers' organization and WUA's, established at each scale of the irrigation infrastructure as shown in the figure 1. An interconnected series of research questions remained under scrutiny in this section.

Whether community participation in the WUA's/FO's activities and WUA's maturity significantly contributed in addition to other predictors of agricultural productivity?

To partial out the influence of variables already known as influencer of the agricultural productivity, hierarchical multiple regression was performed to examine the effectiveness of participatory institutions (level of participation in WUA activities/WUA maturity), to predict EWP (Rs/m3), after controlling for resource user's, water resource, land quality resource, markets proximity, and agronomic practices. For that purpose, we grouped the data of both canals where participatory reform was introduced and WUA's/WCA's still working—Nara and Hakra canal. Fig 11 provides the model summary of hierarchical regression results at each step of the model.

Figure 11. Summary of Model 1 Statistics

Model Summary										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.420[a]	.177	.150	34.19364	17.67%	6.561	7	214	.000	
2	.726[b]	.527	.495	26.35986	35.00%	21.871	7	207	.000	
3	.852[c]	.726	.703	20.19248	19.96%	49.586	3	204	.000	
4	.859[d]	.738	.710	19.95333	1.17%	2.230	4	200	.067	
5	.866[e]	.749	.718	19.70852	1.15%	2.250	4	196	.065	
6	.868[f]	.754	.716	19.77418	0.48%	.740	5	191	.594	1.626

Preliminary examination of model statistics like VIF, Tolerance, Durban Watson, Normality P-P plot, and residual plot for multiple regression assumption testing gives satisfactory results. All predictor variables were not statistically correlated with Economic Water Productivity (EWP).

In the first step of hierarchical regression, resource user characteristics were entered. This model was statistically significant and explained 17.67% of EWP variance. Out of seven factors, age, tractor status, land holding size, and man to land ratio made a significant unique contribution to the model (see Table 1 in annexure for standardized coefficient and nature of the relationship for each predictor). After adding the water resource characteristics block predictors at Step 2, the total variance explained by the model as a whole was 52%. The introduction of this block explained an additional 35% of the variance in EWP after controlling for the first block predictor, which was a significant contribution at a 99.9% confidence interval. During the 2nd stage, cumulative DPR, RD, ACCI, ACWU was a significant predictor. In the third step, after entering a land quality-related set of predictors, overall model predictor power reaches 72.6%, and this additional block contribution was 19.96% and statistically significant at a 99.9% confidence interval. In this block, land performance for cotton and wheat and the contribution of tube well in the cropping intensity were significant. At step fourth, after introducing agronomic practices related to block, only 1.17% additional variance in land productivity was explained, and this contribution was significant at a 90% confidence interval, as shown in Table 1. A fifth stage average distance to urban facility, agriculture markets, and credit facility the model explains additional 1.15% variance at 90% confidence interval. After entering the community cooperation, group dynamics, WUA maturity index, level of participation, and institutional performance of AWB at step 6, only contributed 0.48% additional contribution to the model, after controlling for all the previous five blocks of predictors, which is not statistically significant. At the final stage model predictive power is 75.4% and age (-.093,.023), tractor status (.112..012), landholding size (-.122, .021), man to land ratio (.108, .096), water scarcity perception index (-.101, .044), distance of land from the source of water (-.155, .003), annual canal crop intensity (.099, .050), annual crop use (-.473, 000), land performance for wheat (.205, 000) and cotton (.107, .008), groundwater contribution in cropping intensity (.478, 000), total intercultural operations (-.113, .033) and total number of fertilizer used (.204, .028) among the significant predictors.

In the next stage, we hypothesized that our desired independent variables could not capture the variance due to too many controlling predictors, probably due to the sample size limitation. So, in the next step, we use only those predictors that significantly influenced the EWP variance as control variables and check whether our desired predictors have any significant influence. This alteration in the model does not provide any evidence that these community characteristics block having any influence on the EWP. The model statistics for this alteration were presented in Fig 12.

Figure 12. Summary of Model 2 Statistics

Model Summary										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.321[a]	.103	.087	35.43835	10.326%	6.247	4	217	.000	
2	.699[b]	.488	.469	27.02830	38.473%	40.013	4	213	.000	
3	.847[c]	.718	.703	20.20718	22.985%	57.024	3	210	.000	
4	.850[d]	.723	.705	20.13498	0.468%	1.754	2	208	.176	
5	.854[f]	.730	.704	20.16189	0.698%	1.044	5	202	.393	1.558

EWP is an indicator related to water use efficiency that determines how much one cubic meter of water produces economic value in the system. As traditional estimation techniques to convert irrigation into the volume of water applied have limitations, we used the average actual evapotranspiration for each respondent's head, middle, and tail. This approach also has its limitations as it does not provide the variance within each distributary. In addition to that, there is no economic rationale to optimize the water use at the farm because water price is minimal. Our regression analysis also confirmed that annual crop water use (ACWU) negatively correlates with EWP because farmers do not have a strong rationale for optimizing it.

So to check our result's robustness, we run the same regression by changing EWP (Rs/m3) as the dependent variable to land productivity (Rs/Acre), a more direct estimate of physical land productivity. To optimize land productivity has a direct economic rationale. The results for this regression analysis have been provided in fig 13. In this model again controlling already known predictors that influence land productivity, it was again confirmed that level of participation, WUA's maturity, and community characteristics do not significantly influence the outcome.

Table 1. Statistical Standardized Coefficients in Different Regression Models

+,*, **, * shows the significance level at 90, 95, 99, and 99.9% respectively. Black bold showed the positive significant contribution and red bold showed negative. Model 1 includes all variables. Model 2 replace the non-significant contributor. Model 3 replace the dependent variable with land productivity**						
Variables Name	**Model 1**	**Model 2***	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Age	**-.093(.023)***	**-.112(.006)****	**-.12(.01)***			.027(.537)
Land holding Size	**-.122(.021)***	**-.086(.086)+**	**-.12(.04)***			**-.043(.402)**
Tractor status	**.112(.012)***	**.125(.004)****	**.09(.08)+**			
Crop Diversification index	.049(.314)					.039(.449)
Fusion of Scientific Knowledge	.016(.718)					.010(.841)
Man to Land Ratio Agri.	-.090(.144)					
Man to Land Ratio	**.108(.096)+**	.023(.625)	.02(.78)			
Reduce Distance	**-.155(.003)****	**-.106(.023)***	**-.16(.000)*****			**.102(.050)***
Water Scarcity Perception Index	**-.101(.044)***	**-.107(.017)***	-.07(.16)			**.128(.03)***
Technical State of Irrigation Infrastructure	.054(.244)					**.088(.080)+**
Cumulative Delivery Performance Ratio	-.022(.685)					
Annual Canal Cropping Intensity	**.099(.050)***	**.099(.038)***	.06(.24)			
Annual Crop Water Use	**-.473(000)*****	**-507(.000)*****	**-.31(.000)*****			
Land Performance Index Cotton	**.107(.008)****	**.105(.008)****	**.12(.01)***			
Land Performance Index Wheat	**.205(.000)*****	**.202(.000)*****	**.22(.000)*****			
Annual Cropping Intensity Conjunctively	**.478(000)*****	**.503(.000)*****	**.52(.000)*****			.023(.648)
Total Intercultural Operation (ML)	**-.113(.033)***	**-.103(.045)***	**-.12(.04)***			
Total No Weedicide & Pesticide	-.012(.882)					
Total No Fertilizer	**.204(.028)***	.084(.150)	.05(.46)			
Total Machine Operation	-.139(.171)					
Avg. Distance Urban Facility	.006(.887)					
Avg. Dist. Credit Facility	.081(.226)					
Avg. Dist. Agri. Market	.077(.207)					
Avg. Dist. Market Facility	-.068(.175)				**Urban Proximity**	.076(.100)
Community Cooperation Index	.085(.137)	**.094(.096)+**	-.04(.51)	.095(.295)	.365(.000)***	**.196(.003)****
Group Dynamics Effectiveness Index	-.025(.628)	-.043(.404)	-.01(.81)	-.049(.542)	.300(.000)***	.026(.644)
Institutional Performance AWB	-.074(.265)	-.075(.240)	-.07(.33)	**.227(.022)***		**.262(.000)*****
WUA Maturity Index	.012(.837)	-.001(.982)	.03(.62)	.013(.873)		**.411(.000)*****
Level of Participation in WUA	.042(.466)	.059(.307)	**.11(.09)+**	-.038(.702)	.263(.000)***	
R Square	**.754*****	**.730*****	**.64*****	**.064****	**.572*****	**.614*****
Dependent Variable	**Economic Water Productivity (Rs/m3)**	**Economic Water Productivity (Rs/m3)**	**Land Productivity (Rs/Acre)**	**Composite Irrigation Management Performance**	**Institutional Performance of AWB**	**Level of Participation in WUA**

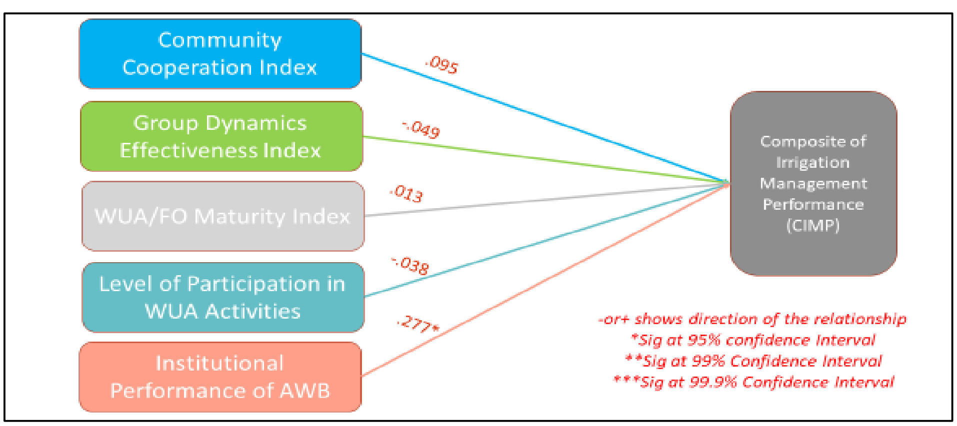
Figure 13. Summary of Model 3 Statistics

Model Summary										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.280[a]	0.08	0.06	40790.80	7.9%	4.62	4.00	217.00	0.00	
2	.581[b]	0.34	0.31	34914.22	25.9%	20.80	4.00	213.00	0.00	
3	.787[c]	0.62	0.60	26644.84	28.2%	51.91	3.00	210.00	0.00	
4	.791[d]	0.63	0.60	26527.61	0.7%	1.93	2.00	208.00	0.15	
5	.798[e]	0.64	0.60	26465.77	1.1%	1.19	5.00	203.00	0.31	1.60

Is community characteristics having a relationship with Irrigation Management Performance?

In this section, we examined community characteristics relationship with irrigation management performance and hypothesized that might be our desired predictors, influence the irrigation management performance directly, and then irrigation management performance, influence land, and economic productivity as shown in our previous analysis. We construct the Composite Irrigation Management Performance (CIMP) index to test this hypothesis. We defined the CIMP as a combination of agricultural land productivity, cropping intensity of canal and tube well use, technical state of irrigation infrastructure, cumulative delivery performance ratio. Since all these scale variables have different measurement units, to construct the composite index, we first standardized all individual items and then calculated the composite by assigning equal weight to each variable z scores. Use the CIMP as a dependent variable and LP, WUAMI, IPAWB, CCI, GDEI as predictors.

Figure 14. Summary of Model 4 Statistics

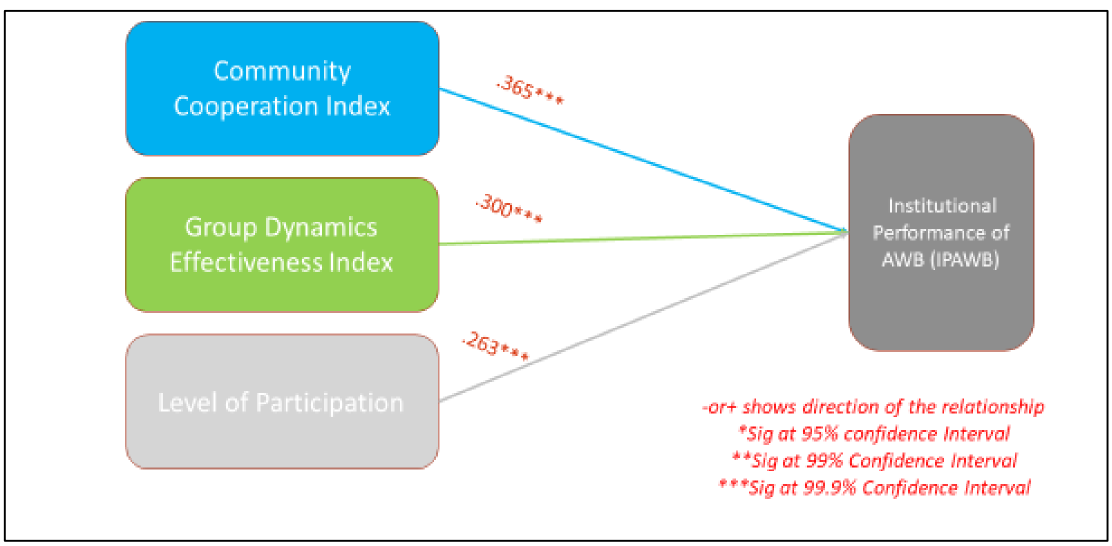


In the regression model, as shown in fig 14. IPAWB has a significant unique contribution to improving the CIMP index. The standardized Beta coefficient weights suggest that with every one unit increase in the institutional performance of the Area Water Board, irrigation management performance increased by 0.27%. Hence, at this step, we conclude if the AWB performed its duty better and managed the exchange of information related to irrigation decision making and controlled the rent-seeking behavior of irrigation officials more effectively, which resultantly improved irrigation management performance and provided the more equal agricultural economic returns among all farmers. This was an important result for understanding the role of collective action in improving irrigation management performance. This result gives us a strong reason to examine the causal pathways further.

What is the relationship of community characteristics with the Institutional performance of the Area Water Board?

The next level inquiry is how IPAWB could be improved and the relationship of community participation in WUA's activities, community cooperation index, and group dynamics effectiveness with IPAWB, and how they influence it. We put the IPAWB as dependent variables and use community cooperation index, group dynamics effectiveness, and level of participation in the WUA activities as predictors and run the regression. The model summary statistics given in fig 15, and we found that all these community characteristics have a positive and significant contribution to improving the institutional performance of AWB. The intention to introduce participatory irrigation reform uses this social capital as a resource for improving irrigation management but the factors that limit its effectiveness is our next level of inquiry in the following sections of the report.

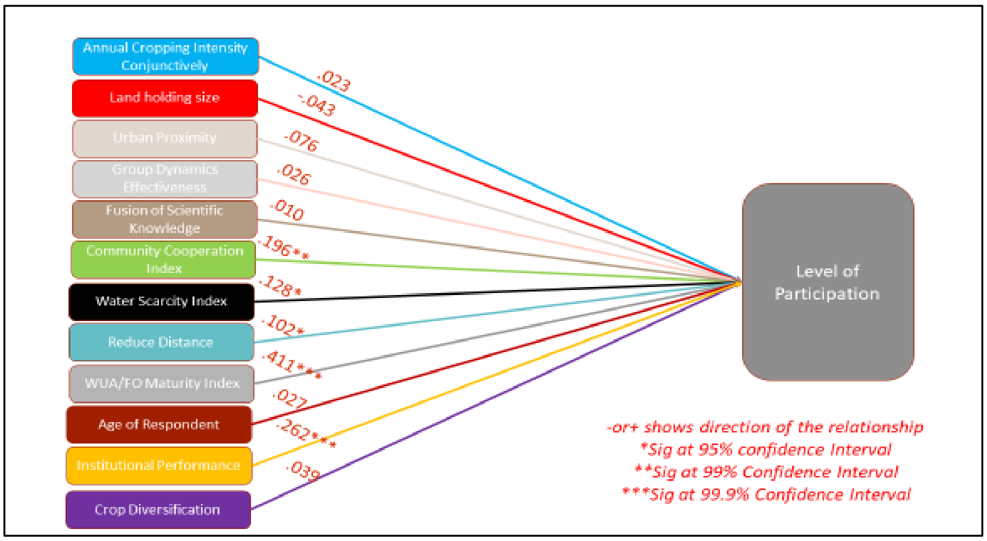
Figure 15. Summary of Model 5 Statistics



What Factors Explain the Community Participation in the Participatory Institutions?

In this section, we examined the factors which limit or enhance the community participation in the participatory institutions. This analysis helped devise the future course of action to enrich the participatory irrigation management reform more effectively. For this analysis, we used the level of participation of the community in the participatory institutions as dependent variables and community cooperation index, group dynamics effectiveness index, landholding size, the use of tube well (annual cropping intensity conjunctively), urban proximity indicator, reduced distance, water scarcity perception index, crop diversification, and fusion of scientific knowledge as an explanatory variable.

Figure 16. Summary of Model 6 Statistics



Regression results as shown in fig 16 suggest that the WUA maturity index, the institutional performance of AWB, water scarcity perception index, community cooperation index, and reduced distance have a unique positive contribution, whereas landholding size has a negative relationship but was not statistically significant. Overall these all predictors explain the 61% variance in participation at a 99.9% significance level. Based on the emic and etic perspective, land asymmetry influenced the working environment of the participatory institutions. We analyzed specific questions like “what do you think, do large farmers are dominant in the WUA/OF decision making” and "Being a member, I feel that large farmers are getting more water than me." Responses to the above questions showed that land asymmetry has a problematic relationship with the working environment of participatory institutions and maintaining the distributional equity of canal water as shown in fig 17 and 18. In the next chapter, we discuss specifically what went wrong with the reform process and how we can correct it. This chapter relies on the literature review of particular case studies and qualitative parts of the survey (Focus Group Discussion/Key Informant interview/ Content Analysis of SWMO) evidence.

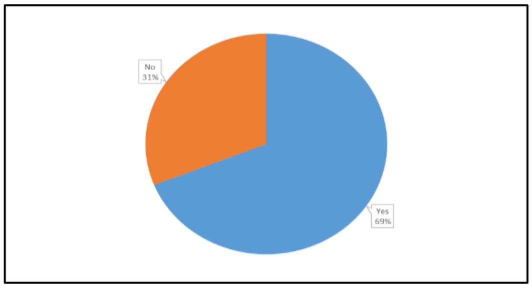


Figure 17. Large farmers getting more water as compared to me

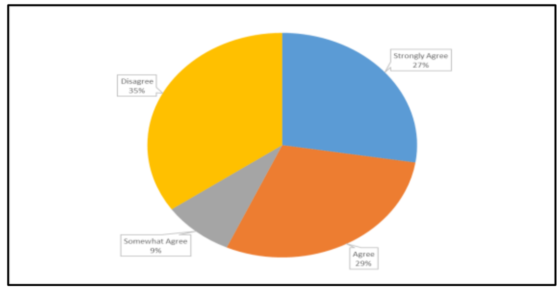


Figure 18. Large Farmers Dominant in WUA/FO Decision Making

3.3 PIM Agenda Implementation in Theory and Practice

What Explain Lackluster Success of PIM

There are three approaches currently in practice to manage the common pool resource: 1) strict state control, 2) user group collective action, 3) market forces or complete privatization of the resource. Pakistan adopts the second model with a limited role in the user group under the existing irrigation agencies (see the PIDA act 1997 and SWMO 2002). The delegation of power was limited and a more commanding role of the existing irrigation bureaucracy. Recent studies show that the performance of this limited delegation of power is not satisfactory (Ali, 2020). Here the question is, what factors explain this lower performance after almost two decades passed. There might be numerous explanations for this poor performance as promised at the time of reform. A few of these explanations are more related to discussing the neoliberal notion of restructuring and misreading the localized context in its implementation phase.

Politics of Reform and Resilient Irrigation Bureaucracy

The Irrigation Bureaucracy was interested in getting the WB loan for the irrigation system and drainage program. The Bank proposed the reform based on the Bank's experience with participatory ideas in Mexico, the Philippines, Indonesia, and etcetera. Bureaucracy was not interested in any attempt to curtail its role in decision-making and power she enjoyed in the status quo. Bureaucracy opposed the reform idea, but the Bank used the loan package as an arm-twisting tool to convince for reform ideas.

In this context, the Bank was willing to provide a loan of 28.5 million US $ for the National Drainage Programme (NDP), in 1997 (Briscoe & Qamar, 2005), with a promise of irrigation system reform. The core elements proposed in the reform package with NDP are (William J. Young, Arif Anwar, Tousif Bhatti, Edoardo Borgomeo, Stephen Davies, William R. Garthwaite III, E. Michael Gilmont, Christina Leb, Lucy Lytton, Ian Makin, 2019);

- Reorganize the provincial level irrigation departments into decentralized public utilities at the command level with full independence to collect and spend irrigation service fees and authority to gradually withdraw subsidies and privatize them.
- Provide full authority to farmer's organization at distributary level for the collection and expenditure decision about the irrigation service fee.
- Establish water markets for water trading and delink water rights from land ownership.

Irrigation bureaucracy amended the initial idea based on several reasons, which include;

- Renamed proposed decentralized public utilities as AWBs but the idea of privatization was neither implemented nor ruled out.
- Farmer-led management was implemented via FOs and WUAs/WCAs.
- Water markets were not established, and water rights were still associated with land rights.

These amendments were based on several technical reasons; the scale and complexity of technological poor and supply-driven features of the irrigation system. In contrast, other reasons to reframe the reform agenda are collusion of interest between irrigation bureaucracy, big landowners, and opinion leaders. For example, the idea of delinking water rights from the land right was considered equivalent to land reform, and privatization was considered a push for foreign control of Pakistan irrigation (Edward J. van der Velde, 2004). Pakistan Kissan Board, apparently a medium and small farmer body, opposed this reform based on the apprehension discussed above because this farmer body has a strong ideological inclination towards *Jamat Islami*, which historically remained an opponent towards land reform, attempted previously.

Water sector reforms were also introduced in the irrigation sector, and Provincial Irrigation and Drainage Authorities (PIDA's) were established in 1997. PIDA's act highlights its overarching goal in its preamble as "Whereas it is expedient to establish the Punjab Irrigation and Drainage Authority to implement the strategy of the Government of Punjab for streamlining the Irrigation and Drainage System; to replace the existing administrative setup and procedures with more responsive, efficient and transparent arrangements; to achieve economical and effective operation and maintenance of the irrigation, drainage and flood control system in the Province; to make the irrigation and drainage network sustainable on a long-term basis and introduce participation of beneficiaries in the operation and management."(PIDA Act, 2015)

There was an assumption that building the formal institutional structure would transform prior social relationships. However, the existing power structure proved resilient. Power to control irrigation water is not separable from power in other life domains; the old irrigation bureaucracy perhaps concealed this fact. The attempt to decentralize management exposed informal power structures that could not be easily changed by changing formal structures. Decentralization-based efficiency outcomes hold the assumption that specific paper regulations which allow collective action by default promote equity, efficiency, and financial self-sufficiency in irrigation management. After two decades of reforms, the experience proved this simplistic assumption wrong.

It is also assumed that institutional working effects forced institutions to become independent from the external or internal forces that constituted them once institutions formed. Under this assumption, the irrigation department's oversight role is defined in the reform package. However, unfortunately, in our situation, this assumption does not hold. In contrast, both institutions engaged in institutional infighting, as reported in many key informant interviews. Irrigation bureaucracy used its leverage to oversight the reform process as an instrument tool to arm the twisting of the new institutions. So, the idea of getting out from the influence those constituted never materialized. Why does it happen?

The cadre recruited the new institutions to mobilize the farming community limited in its knowledge of the technical aspects of irrigation infrastructure. So, the new institutions' dependency on irrigation bureaucracy provides them leverage in this nested governance equation. It is not authorized by the farmers' organization or AWB in the reform package that they hire technical staff independent from the irrigation bureaucracy. Old bureaucracy has a central role in this institutional power equation, so localized ownership of the resource does not exercise its paper power in reality.

Is Scaling-Up Possible with External Push

As pointed out by (Mansuri & Rao, 2004) that 'effective community-based initiatives require; slow, gradual, continuous learning by doing, with a project design that gradually adapts to local conditions by learning from the false starts and mistakes that are endemic to all complex interventions. They illustrate the community-based intervention required following conditions for the successful scaling up:

1. The scaling-up strategy starts with gradual "piloted scaling up" to "phased scaling up" and then "untested scaling up" at a national scale.
2. Scaling up required a strong work ethic, rigorous evaluations, and reliable monitoring systems to provide constant feedback.
3. Careful attention to the training of the core cadre of the social mobilization unit.
4. The country's strong political commitment to a cultural change in the institutional environment is to be more responsive, transparent, participatory, and downward accountable.

Mansuri and Rao (2004) studied community-based and driven development projects and summarized the evidence about the question that "is rapid replication of successful community initiatives possible through external interventions as the World Bank and other donors are attempting to do." They came up with an explanation that the successful replication of highly motivated groups, charismatic individuals, long term vision of structural transformation through—dedication, patience, and creativity, is problematic to scale up. Because when this daunting task is handed over to salaried professionals, whose only motivation is the wage, promotions and incentive lose the idea's actual cultural, social, and historic essence. Scaling-up of such ideas through external interventions mostly depends upon the social mobilizer or community trainer's capacity to seed the innovative idea in the community and mobilize it.

As pointed out by SIDA officials in response to a question "What do you see as the role of SIDA in the past and current?" in a key informant interview said

> "I don't see any big difference between past and current SIDA. I came here after the 2002 ordinance. Everybody here wants power but without knowledge. At this time, AWB does not have FOs, they want FOs as they want powers".

The discourse analysis of this quote unpacks the internal and external environment of the reform process. This quote also depicts no iterative learning process from the interventions and merely focused on the incentive and power capturing. In a key informant interview, when asked what types of challenges the SIDA social mobilization unit faced for effective social mobilization. Social mobilization team members responded.

> "According to my view, social mobilizers or social workers are neglected as compared to engineers. Engineers get everything i.e. proper offices, proper staff, AC cars but no-one wants to cooperate with us. We are not properly facilitated".

This quote validated the problem (as mentioned earlier) of salaried professionals for perks, drive, and competitive institutional environment, which is supposed to mobilize the community for effective participation and protect resource users' rights in a contested environment.

(Bruns & Atmanto, 1992) and (Suhardiman, 2008) studied the Indonesian context of irrigation policy reform and reported that the irrigation bureaucracy transformed the Irrigation Management Transfer (IMT) program into a construction program. They also noted that 'the capacity of bureaucrats to anticipate reform and take action, defend their interests, perspectives, and privileges and shape reform in a way that supports their institutional survival. (Suhardiman et al., 2014) studied the four case studies of irrigation management transfer of Indonesia, Mexico, Uzbekistan, and the Philippines and argued that irrigation (policy) reform could not be treated in isolation from the overall functioning of government bureaucracies and the broader political structure of the states. Understanding how and why irrigation bureaucracy shapes reform processes and outcomes indicate reforms' actual significance. This aspect is related to the fourth condition under which overall government support for the reform process is a precondition for scaling up the interventions. Bureaucratic reforms do not work in silos; it requires overall civil service reforms in every field of the political spectrum. It is widely perceived among the SIDA and PIDA officials that the irrigation bureaucracy does not want to see the irrigation reform succeed and replace their institutional powers.

Key informants of SIDA officials pointed out bureaucracy's role to impede the reform process and termed it an "outdated hierarchy."

> "Overall, if we look, the problem is in the outdated hierarchy, which is set in our institutions. We are from the development sector; our mindset has now changed. But now it's time to change the trends and mindsets of others".

> "Involvement of different agencies hinder the overall success of a FO."

> "Irrigation department staff don't like FO's. No one likes to distribute their powers".

What a Social Mobilization or Farmers' Engagement Process

Historically, the Irrigation and Power Department (IPD) enjoys extraordinary power in preparing water schedules, approving new water allocations, and revising existing allocation under the irrigation and drainage act. IPD operationalized its power through and for the benefits of the powerful landed elite (Kin Power and Landlord Class), and the voices of the small and tail-end farmers were not much appreciated. Sindh Water Management Ordinance (SWMO) tries to decentralize the powers by including the farmers in the decision-making. Thus SIDA established the "Social Mobilization" units to mobilize the farmers for active participation in the reform process and engage with previous power structures. However, farmers' engagement or participation was not achieved up to the initially perceived level. What went wrong? In this regard, looking into the topics of three types of training—basic training, specialized training, and refresher course, we found the training component was more skewed towards technical parts like explaining SWMO institutional features, organization management (housekeeping) of records, and financial management and procedures for *Abiana* assessment and collection, etc. In specialized training, technical management of irrigation water like flow measurement covered but neither general nor specialized training covered the aspect like; how the power from previous institutions shifted to the new farmers managed institution, how small farmers engage with formal and informal power structures, and established her rights, how and what sort of organizational measures improve the hydro solidarity, trust, and collective action and counter the kin-based and land-based power asymmetry. Unfortunately, training topics do not cover the political dimensions of irrigation management.

(Pettit, 2016) studied the Swedish Development Agency intervention for citizen engagement and critiqued the new liberal understanding of the 'citizen engagement' based on a rational choice to challenge the power—present in different forms (Mehta, 2016). He argued how a new liberal understanding of power ignores the 'civic habitus' and cannot create a more enactive and imaginative form of citizen agency, capable of challenging or transforming invisible power boundaries in society.

Extending the above argument, if we reflect upon the training material and training approach—in our case study of participatory irrigation reform, to engage farmers was insufficient to undo the power habitus of small farmers. The ways it delivered during the farmers' engagement at a farmers' organization formation stage could not deconstruct power boundaries historically associated with the irrigation bureaucracy and powerful kin & big landholding caste. Irrigation bureaucracy and local kin and land-based powerful elite having an invisible power in which only patrons and clients benefited. The fundamental assumptions in participatory irrigation are that irrigation bureaucracy and farmers are two distinct categories whose interests are opposite. However, in reality, this is not the case. The irrigation bureaucracy exercises power with the support of the big farmers.

Here one can argue that small farmers are more in numbers and also reform packages (SWMO 2001) ensure participation in a different tier of the nested governance structures (as shown in Fig 1 and annexure C) are in a better position to engage this nexus of the powerful elite and irrigation bureaucracy and more ideally can challenge too. It is pretty easy to imagine it but in reality, how the power dynamics work in society is to understand whether SWMO alone provides enough power to small farmers to engage meaningfully or challenge this nexus. In the presence of a highly kin-based and land-based asymmetric society, only SWMO some provisions were not sufficient to empower the powerless and challenge this power asymmetry.

Contrary to the development agency objectivist approach (Pettit, 2016) suggested a transformative approach to citizen engagement, which includes "action learning processes that focus not only on critical reason and awareness, but would complement this with more reflexivity, creative and embodied methods of learning and practice. These methods would draw on the imagination and envisioning of cultural change, and would use multidimensional methods of narrative, storytelling, visual and artistic expression, music, movement, and theater."

In our case study, we conclude that irrigation bureaucracy and powerful elite nexus cannot be challenged without critical small farmers' movement and meaningful moderation of the land asymmetry. This task is not part of the reform package and is not intended to be the current "status quo. If we further extend this argument and ask a question that to introduce a participatory reform and engage farmers for that purpose, whether implementing agency (SIDA) and development aid donors are interested in empowering the powerless and small farming community or only she (Implementing Agency) engages with the reform for international credibility as an isomorphic mimicry and taping the development budget.

Below, we present some empirical evidence that shows the reform process and training components cannot trigger the environment for collective action and cooperation for maintenance; hydro-solidarity between the head and tail reaches farmers and improves trust among the water users. The response regarding the questions does not somehow show satisfactory participation or engagement with the reform process. Overall, reform cannot generate the momentum of cooperation, hydro-solidarity, and interpersonal trust level among the organizational structure. If we look into the response of the question that "Most people who live on this [watercourse/distributary] can be trusted." We see that trust among the community at the WCA level is slightly better than the FO level (see fig 19). However, unfortunately, this community-level trust was not transcended into the WCAs and FO's institutions.

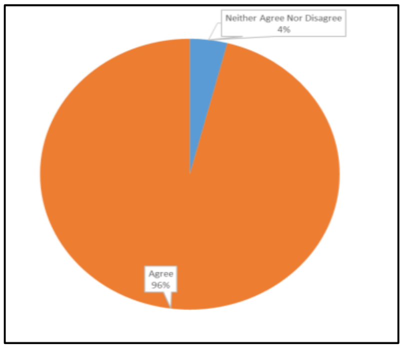


Figure 19a. Most people who live on this watercourse can be trusted

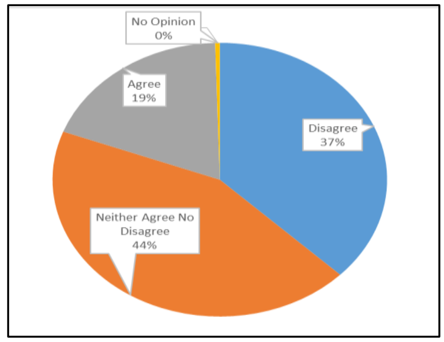


Figure 19b. Most people who live on this distributary can be trusted

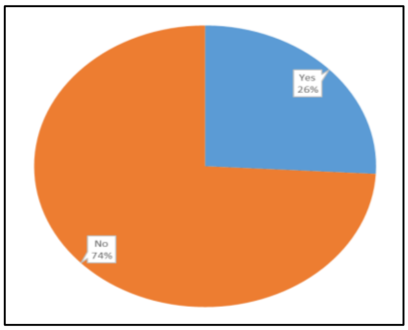


Figure 20. I have feeling WCA office bearers getting more water as compared to me

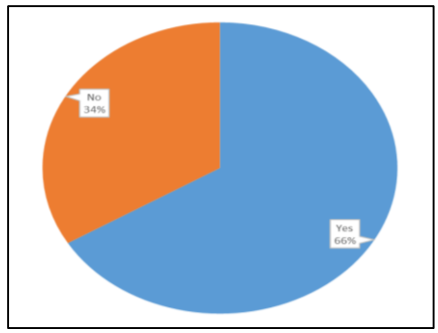


Figure 21. I have feeling FO office bearers getting more water as compared to me

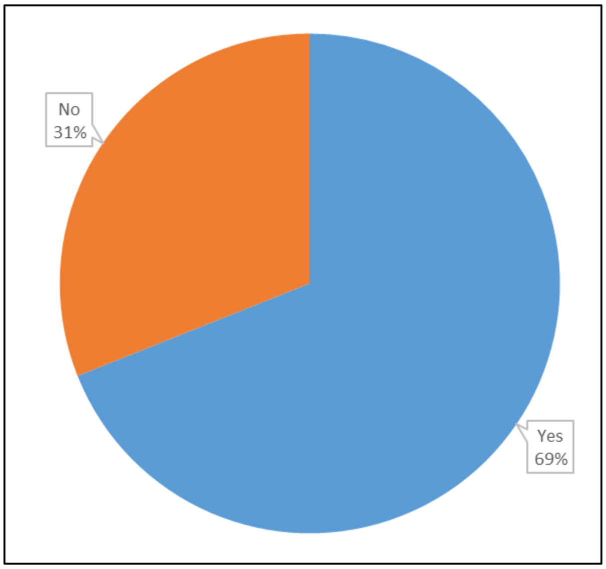


Figure 22. I have feeling Large Farmers getting more water as compared to me

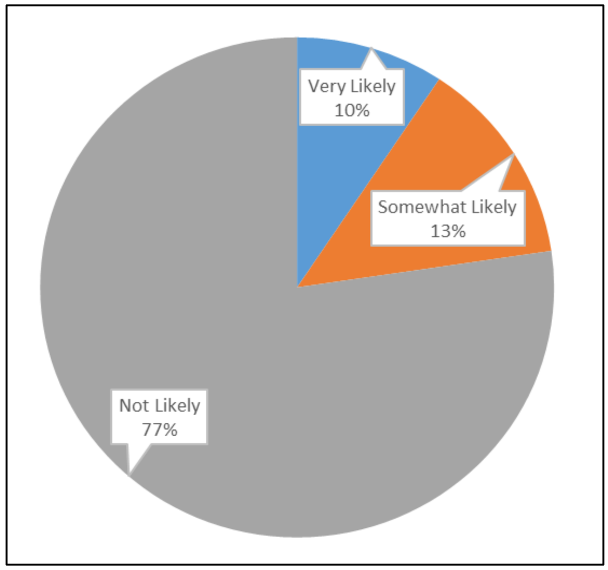
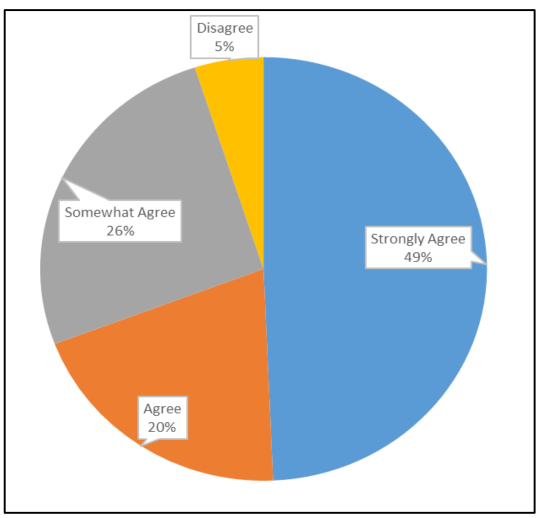


Figure 23. When some watercourses are not getting enough water, do the farmers of other watercourses show concern and empathy

Scanty Understanding of the Reform Bylaws

SIDA Act or Sindh Water Management Ordinance (SWMO) at the farmer level and how SIDA capacity building units cannot play their supposed role. The FO/WCA members' knowledge regarding the bylaws of the new participatory transition creates a sense of ownership. The members are generally aware of the reform process, but detailed study and understanding of the bylaws are scant.

Figure 24. Are you aware of the structure and functioning of Irrigation reforms laws



The possible reasons for this scant knowledge are less investment in rigorous training from the SIDA side, less enthusiasm from the farming community to involve in the reform process, low literacy rates because it limits detailed reading of the document and more reliance on oral communication. The essence of PIM is that it empowers the farmer organization to take ownership over management affairs of the irrigation system. Surprisingly, in this fieldwork with different project assignments, it has been observed that only a few WCA and FO committee members studied the bylaws in depth. In some cases, the FO chairmen had a very superficial knowledge of the reform process. The total knowledge stock is limited to the extent that the FO chairman has authority to collect the fee, and its 60% is submitted to SIDA, and 40% is used for FO O&M expanses.

One FO' chairman even pointed out that we only collect the Abiana to cover the SIDA share. In one FOs, we found out that the FO chairman pools the SIDA share from some influential landowner submits the SIDA share and compensates those influential through more inequitable water distribution. The tail farmers of this distributary reported inequity in water distribution too. This elite capture and misuse of power are also pointed out in a World Bank policy paper (Hanan G. Jacoby, Ghazala Mansuri, 2018) studied the discharge measurement taken in Punjab and reported that water theft increases on distributary managed by farmers' organization compared to the bureaucratically controlled irrigation system. This study also reveals that water theft is more along the channels where land inequity is more, and big landowners are situated at the channel's head.

CONCLUDING THOUGHTS

(Gibson, Andersson, Ostrom, Shivakumar, & others, 2005) and (Collier, 1997) studied aid as an instrument to reform policy and label the interrelated difficulties and problem as; when aid is linked with the reform package, then donor becomes the owner of the reform program which provide little incentive to the aid recipient countries to take responsibilities. Consequently, country leaders are unenthusiastic to plead the domestic consensus required for reform. (Collier, 1999) also notes that aid does not necessarily push the aid recipient's internal urge. In such a situation, aid is usually utilized to adjust other payment balances due to financial crises, and the reform agenda is fulfilled with specific mimicry actions. Another issue with the aid depended on the reform process that initially aid recipient countries show more enthusiasm for reform, and unrealistic reform implementation targets consume funds with more pace and little substantial impact.

Consequently, when funds squeeze, the enthusiastic activism is converted into passiveness. Finally, the donor interested in the funds' disbursement shows the project's success by showing the number of established organizations and covered spatial extent. This happened in Punjab, where the participatory reform process rolls back, and three-tier structures are contained to only a one-tier water user association.

Another possible explanation for this poor performance is that when the reforming process is designed, the focus of reform missionaries is to implant the successful model—ignoring the local context. (Meinzen-Dick, 2007) studied the canal irrigation reform in India and concluded that every institutional panacea does not work well in every condition, and attempts to implant structure/organization are more like paper tigers than real institutional change. She explains the donor behavior for such a successful model application because the donor is more "attracted in simplicity of an apparently successful model that offers a recipe for application elsewhere" (Meinzen-Dick, 2007; PETER P. MOLLINGA, 2004).

(Araral, 2005) studied the National Irrigation Agency (NIA) of the Philippines and explained NIA's inadequate performance through an analytical lens of the "moral hazard problem" and the fungibility of irrigation aid. Moral hazard is an economic concept that elaborates "a situation in which one party gets involved in a risky event knowing that it is protected against the risk and other party will incur the cost." The Bank's involvement and its interventionist role in the irrigation sector are more or less the same in developing countries. Bank's loan nourishes the irrigation bureaucracies with attractive perks, and irrigation bureaucracy provides a rationale for disbursement of Bank's loans. This historical relationship provides a possible explanation of the moral hazard problem, Pakistan's irrigation and agriculture sector going through chronic underinvestment since the 1980s from both aspects—as a percentage of GDP and public spending (Briscoe & Qamar, 2005). Banks provided loan for NDP during 1997 for institutional reform and irrigation bureaucracy dominantly used it to replace internal budget. However, irrigation bureaucracy introduced reform, but unfortunately, the emphasis was not per se the World Bank's strategy paper. However, Bank accepted the proposed model as an initial startup and assumed that deeper level reform discourse was implemented over time. After two decades, irrigation agencies step back from Punjab's reform path, and Sindh still struggles to comply with the reform promise with little hope.

Presently, there is a movement to end the PIM experiment in Pakistan and reinstate the old irrigation bureaucracy. This is based on assertions that PIM has failed to deliver on its promises. However, substantial evidence shows that the PIM model was never adequately tested and implemented. Specifically, PIM was introduced through an externally initiated process that treated PIM as a technocratic matter of decentralizing management authority to lower-level administrative units (i.e., Farmers Organizations and Watercourse Associations) rather than a political process requiring a shift of power from elites to non-elites. Shifting formal authority from one group to another is a necessary. Without this, the PIM model will struggle to succeed.

POLICY RECOMMENDATION

Based on the extensive literature review for global case studies and local level policy implementation, key issues were identified based on data evidence and key informant interviews with stakeholders. We are proposing a set of recommendations for each policy issue that need to be considered for improving the PIM.

Issue 1. Weak enforcement of the law, including the Sindh Water Management Ordinance (2002)

Participatory Irrigation Management (PIM) reform has not been fully implemented, and its full implementation requires some adjustment and innovation at the local level, which includes:

1-A. The Sindh Water Management Ordinance (SWMO 2002) has not been fully implemented. So we recommend the establishment of regulatory authority for dispute resolution and an oversight role on the working environment of SIDA

1-B. FO's need to be empowered to enforce the law against the free-rider and those who do not comply with the law.

1-C. Irrigation department personnel who come under the jurisdiction of FO's or cluster of the FO's need to be accountable to FO's chairman.

1-D. FOs or clusters of FOs should have the authority to hire their staff for canal monitoring and regulation.

1-E. There is a need to introduce some changes in the water rights regimes. The clustering of FO's/WCA's can establish the local water markets and share the water rights accordingly to improve the canal schedule.

1-F. SIDA rules are not in place yet; they need to be completed so that SIDA could recruit new staff on her terms and conditions.

1-G. AWB financial rules are not in place, AWB board is unable to spend the irrigation service collection for the operation and maintenance of irrigation infrastructure.

Issue 2. Institutional integration, pooling of resources, and revitalization of irrigation departments

It has been observed that the participatory institutions have a low staffing issue for the communication of information and maintaining the community organization/mobilization effectively.

2-A. Agriculture extension department has a union council level presence, and this staff is underutilized, and its scope of work is saturated. It needs to be revitalized as a "water and agriculture extension service" provider with an updated curriculum. It needs to couple with participatory institutions for a better outcome.

2-B. On-Farm Water Management (OFWM) and Provincial Irrigation Departments need to merge for effective water management and agricultural outcomes.

2-C. The existing functions of key departments, including PIDs, should be restructured and reformed via a transition from an engineering-only solution to water resources, engineering, and management approach through an induction of experts of diverse backgrounds and the development of cross-sectional/inter-organizational coordination. The monolithic structure of the human resources of these institutions limits their working efficacy; thus, these departments must be diverse professionally.

Issue 3. The maintenance of information management and sharing systems is an important pillar of PIM that appears to have been neglected.

Issue 3.1. Low irrigation service fee collection in farmers managed irrigation schemes

According to the SWMO 2005, the FOs management committee is responsible for the service fee collection, but farmers-managed irrigation schemes are facing serious challenges related to the irrigation service fee collection. Some innovations in SWMO might address this issue.

3.1-A. There is no coordination mechanism between WUA's and FOs for the irrigation service fee collection. It needs to be defined.

3.1-B. There is a need to introduce the behavioral nudges in SWMO 2005 for the better performance of FOs in irrigation service collection. Different slabs need to introduced on pilot-scale

3.1-C. FOs chairman needs to be empowered to take disciplinary measures against the free riders.

3.1-D. Last but not least, there is a need to establish a computerized fee voucher mechanism and online submission system like Easy paisa/Jazz Cash, etc.

Issue 3.2. There is no transparent mechanism for the maintenance of canal flow data and no practice for preparing the canal irrigation schedule

3.2-A. The digitization of the canal network need to augment with the real-time maintenance of canal flow data for transparent monitoring purpose

3.2-B. For preparing the localized canal water schedule FOs and Clusters of FOs need to involve in the decision making

3.2-C. As this decision-making might be difficult in a contested environment, irrigation officials' capacity building is required to encourage the FO’s inputs and collaboration with FOs.

3.2-D. Required and delivered water accounting budget for each season and year should be displayed on the AWB website and monitored to prepare next year's water schedule.

Issue 4. Problems with direct outlets, lift machines, changing cropping patterns, and distributional inequity

All these problems are interrelated and they ultimately affect the distributional inequity of the irrigation system. The following set of recommendations may help to resolve the problem:

4-A. The practice of direct outlets and lift machines is not allowed in any case, and existing facilitation needs to be incorporated within the irrigation network. These political bribes ultimately cost the poor and marginalized.

4-B. It was observed that changing cropping pattern towards high delta crops leads to distributional inequity between head and tail reaches of the main canal and even distributary. This distributional inequity aspect is easily managed by fixing the agro-ecological crop zoning in each region with stakeholders' consultation and its compliance through FOs.

Issue 5. Land asymmetry affects irrigation management performance and the institutional working environment of participatory institutions

4-A. There are historical and institutional reasons for this elite capturing phenomenon, which manifest mainly due to the passiveness of the small peasantry. To effectively handle this situation, there is a need to introduce a more politicized participatory model for community mobilization and participation, challenging the social and institutional hierarchy.

4-B. WUA's/WCA's need to provide more institutional support like community-owned agricultural implements cooperative, small storage house for harvested commodity handling, collective marketing of agricultural produce in the market, small loan schemes through WUA's/WCA's, and other community services to improve collective action and trust among different groups. These trust-building measures enhance community integration which ultimately improves the irrigation governance at a local level.

4-C. On a more radical note, targeted land reform (for optimal farm size) needs to be introduced to overcome the consequences of exceptionally large and small farm size negative impacts on-farm productivity.

REFERENCES

Ahlers, R. (2010). Fixing and nixing: The politics of water privatization. *Review of Radical Political Economics*, *42*(2), 213–230. https://doi.org/10.1177/0486613410368497

Ahmad, M.-D., Masih, I., & Turral, H. (2004). Diagnostic analysis of spatial and temporal variations in crop water productivity: A field scale analysis of the rice-wheat cropping system of Punjab. *Journal of Applied Irrigation Science*, *39*(1), 43–63.

Ahmad, M.-D., Turral, H., & Nazeer, A. (2009). Diagnosing irrigation performance and water productivity through satellite remote sensing and secondary data in a large irrigation system of Pakistan. *Agricultural Water Management*, *96*(4), 551–564.

Ali, S. A. M. (2020). Driving participatory reforms into the ground: The bureaucratic politics of irrigation management transfer in Pakistan. *World Development*, *135*, 105056. https://doi.org/10.1016/j.worlddev.2020.105056

Allen, R. G., Tasumi, M., Morse, A., Trezza, R., Wright, J. L., Bastiaanssen, W., … Robison, C. W. (2007). Satellite-based energy balance for mapping evapotranspiration with internalized calibration (METRIC)—Applications. *Journal of Irrigation and Drainage Engineering*, *133*(4), 395–406.

Araral, E. (2005). Bureaucratic incentives, path dependence, and foreign aid: An empirical institutional analysis of irrigation in the Philippines. *Policy Sciences*, *38*(2–3), 131–157. https://doi.org/10.1007/s11077-005-2309-2

Azeem, M. (2020). The state as a political practice: Pakistan's postcolonial state beyond dictatorship and Islam. *Third World Quarterly*, *41*(0), 1–17. https://doi.org/10.1080/01436597.2020.1780115

Bandyopadhyay, S., Shyamsundar, P., & Xie, M. (2010). Transferring irrigation management to farmer's associations: Evidence from the Philippines. *Water Policy*, *12*(3), 444–460. https://doi.org/10.2166/wp.2009.111

Bastiaanssen, Wilhelmus Gerardus Maria. (1995). *Regionalization of surface flux densities and moisture indicators in composite terrain: A remote sensing approach under clear skies in Mediterranean climates*. Wageningen University and Research.

Bastiaanssen, Wim G M, Menenti, M., Feddes, R. A., & Holtslag, A. A. M. (1998). A remote sensing surface energy balance algorithm for land (SEBAL). 1. Formulation. *Journal of Hydrology*, *212*, 198–212.

Briscoe, J., Anguita, P., & Peña, H. (1998). Managing Water as an Economic Resource : Reflections on the Chilean Experience FWLmE r Q DT Managing Water as an Economic Resource : Reflections on the. *World Bank, Enviromental Departament*, (April 1998).

Briscoe, J., & Qamar, U. (2005). *PAKISTAN ' S Water Economy Running Dry*. *Oxford University Press*.

Briscoe, J., Qamar, U., Contijoch, M., Amir, P., & Blackmore, D. (2005). *Pakistan 's Water Economy : Running Dry*.

Bruns, B., & Atmanto, S. D. (1992). *How to Turn Over Irrigation Systems to Farmers? Questions and Decisions in Indonesia*. Retrieved from http://hdl.handle.net/10535/4604

Byrnes, K. J. (1992). *Water users associations in World Bank-assisted irrigation projects in Pakistan*. *World Bank Technical Paper* (Vol. 173).

Collier, P. (1997). The Failure of Conditionality. In *Policy Essay-Overseas Development Council* (pp. 51–

77). Overseas Development Council.

Collier, P. (1999). Aid "Dependency": A Critique. *Journal of African Economies*, *8*(4), 528–545. Retrieved from http://jae.oxfordjournals.org/content/8/4/528.full.pdf

Cuamba, E. M. (2016). PERFORMANCE ASSESSMENT FOR SUSTAINABLE IRRIGATION WATER MANAGEMENT A case study of Lower Limpopo Irrigation System , Southern Mozambique PERFORMANCE ASSESSMENT FOR SUSTAINABLE IRRIGATION WATER MANAGEMENT A case study of Lower Limpopo Irrigation System , S, (August).

DEĞİRMENCİ, H., Büyükcangaz, H., & KUŞCU, H. (2003). Assessment of irrigation schemes with comparative indicators in the Southeastern Anatolia Project. *Turkish Journal of Agriculture and Forestry*, *27*(5), 293–303.

Desmond McNeill. (1998). Water as an economic good. *Natural Resource Forum*, *22*(4), 253–261. https://doi.org/10.2307/j.ctvbnm3xq.7

Edward J. van der Velde, J. T. (2004). Irrigation Policy Reforms in Pakistan: Who's Getting the Process Right? In *In Mollinga, P.P. and Bolding, A. (Eds),The Politics of Irrigation Reform. Contested Policy Formulation and Implementation in Asia, Africa and Latin America* (pp. 207–239). England: Ashgate. https://doi.org/10.1504/ijsd.2005.009654

Efriem, T. K., & Mekonen, A. (2017). Hydraulic performance assessment of Tahtay Tsalit small scale irrigation scheme, Tigray, Ethiopia. *International Journal of Water Resources and Environmental Engineering*, *9*(11), 254–263. https://doi.org/10.5897/IJWREE2017.0728

Fox, J. (2019). *Regression diagnostics: An introduction*. Sage publications.

Ghumman, A. R., Ahmad, S., Hashmi, H. N., & Khan, R. A. (2014). Comparative evaluation of implementing participatory irrigation management in Punjab, Pakistan. *Irrigation and Drainage*, *63*(3), 315–327. https://doi.org/10.1002/ird.1809

Gibson, C. C., Andersson, K., Ostrom, E., Shivakumar, S., & others. (2005). *The Samaritan's dilemma: the political economy of development aid*. Oxford University Press on Demand.

Gleick, P. H., Wolff, G., Chalecki, E. L., & Reyes, R. (2002). *The New Economy of Water*. *Benchmarking*.

Glenn, E. P., Doody, T. M., Guerschman, J. P., Huete, A. R., King, E. A., McVicar, T. R., … Zhang, Y. (2011). Actual evapotranspiration estimation by ground and remote sensing methods: the Australian experience. *Hydrological Processes*, *25*(26), 4103–4116.

Hall, E. S., & Jacques, M. (1983). Book Reviews "The Politics of Thatcherism. *Marxism Today*, (July), 43–44.

Hanan G. Jacoby, Ghazala Mansuri, F. F. (2018). *Decentralization and Redistribution Irrigation Reform in Pakistan ' s Indus Basin* (No. Policy Research Working Paper 8352).

Hasan Merdun, & . H. D. (2004). Topology of Performance Indicators of All Irrigation Schemes in Turkey. *Pakistan Journal of Biological Sciences*, *7*(2), 163–173. https://doi.org/10.3923/pjbs.2004.163.173

Henderson, H. V, & Velleman, P. F. (1981). Building multiple regression models interactively. *Biometrics*, 391–411.

Jia, K., Wu, B., Tian, Y., Zeng, Y., & Li, Q. (2011). Vegetation classification method with biochemical composition estimated from remote sensing data. *International Journal of Remote Sensing*, *32*(24), 9307–9325.

Kemal, A. R. (1995). *Retrenchment policies and labour shedding in Pakistan* (Vol. 40).

Kerlinger, F. N. (1966). Foundations of behavioral research.

Kloezen, W. H., Garcés-Restrepo, C., & Johnson III, S. H. (1997). *Impact assessment of irrigation management transfer in the Alto Rio Lerma Irrigation District, Mexico*. *IWMI Research Report 015 IIMI Research Report 015*. https://doi.org/http://dx.doi.org/10.3910/2009.001

Larson, A. M. (2002). Natural Resources and Decentralization in Nicaragua: Are Local Governments Up to the JLarson, A. M. (2002). Natural Resources and Decentralization in Nicaragua: Are Local Governments Up to the Job? World Development, 30(1), 17–31. https://doi.org/10.1016/. *World Development*, *30*(1), 17–31.

Lewis, M. (2007). Stepwise versus Hierarchical Regression: Pros and Cons. In *Paper presented at the annual meeting of the Southwest Educational Research Association, February 7, 2007, San Antonio.*

Liebrand, J. (2019). The politics of research on farmer-managed irrigation systems in Asia: Some reflections for Africa. *Water Alternatives*, *12*(1), 129–145.

Lin Crase, Vasant Gandhi, Bashir Ahmed, Bakhshal Lashari, Muhammad Ashfaq, J. A. M. (2020). *Efficient participatory irrigation and sustainable agriculture in south institutions to support productive Asia*. Canberra, Australia.

Liou, Y.-A., & Kar, S. K. (2014). Evapotranspiration estimation with remote sensing and various surface energy balance algorithms—A review. *Energies*, *7*(5), 2821–2849.

Lundquist, J. & K. S. (1997). Most worthwhile use of water : efficiency, equity and ecologically sound use : prerequisites for 21st century management. Retrieved from https://www.ircwash.org/resources/most-worthwhile-use-water-efficiency-equity-and-ecologically-sound-use-prerequisites-21st

Mansuri, G., & Rao, V. (2004). *Community-Based and -Driven Development: A Critical Review Ghazala*. *World Bank Policy Research Working Paper 3209*.

Mehta, L. (2016). Why Invisible Power and Structural Violence Persist in the Water Domain. In *in a, Power, Poverty and Inequality* (Vol. 47, pp. 31–42).

Meinzen-Dick, R. (2007). Beyond panaceas in water institutions. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(39), 15200–15205. https://doi.org/10.1073/pnas.0702296104

Memon, J. A., Cooper, B., & Wheeler, S. (2019). Mainstreaming gender into irrigation: Experiences from Pakistan. *Water (Switzerland)*, *11*(11). https://doi.org/10.3390/w11112408

Molden, D., Sakthivadivel, R., Perry, C. J., De Fraiture, C., & Kloezen, W. H. (1998). *Indicators for comparing performance of irrigated agricultural systems*. *IWMI Research Report 20*. https://doi.org/http://dx.doi.org/10.3910/2009.028

Mukherji, A., Fuleki, B., Suhardiman, D., & Giordano, M. (2009). Irrigation reforms in Asia : A review of 108 cases of irrigation management transfer Revitalising Irrigation. *Revitalising Asia's Irrigation: Options for the Future*, (October), 1–131.

Murray-Rust, D. H., & Snellen, W. B. (1993). *Irrigation System Performance Assessment and Diagnosis*.

Noshab, F. (2000). WORLD TRADE ORGANIZATION: CRITICAL ISSUES FOR PAKISTAN'S AGRICULTURE AND TEXTILE INDUSTRY. *Strategic Studies*, *20*(4), 30–56. Retrieved from http://www.jstor.org/stable/45182254

P. S. Rao, & Rao, P. S. (1993). Review of Selected Literature on Indicators of Irrigation Performance. *International Irrigation Management Institute*.

Parthasarathy, R. (2000). Participatory Irrigation Management Programme in Gujarat: Institutional and Financial Issues. *Economic and Political Weekly*, *35*(35/36), 3147–3154. Retrieved from http://www.jstor.org/stable/4409680

Pedhazur, E. J. (1997). Multiple regression in behavioral research, Orlando, FL: Harcourt Brace.

PETER P. MOLLINGA, A. B. (2004). *The Politics of Irrigation Reform Contested Policy Formulation and Implementation in Asia, Africa and Latin America*. *Ashgate Publisher*. England: Ashgate Publisher. https://doi.org/10.1504/ijsd.2005.009654

Pettit, J. (2016). Why Citizens Don't Engage-Power, Poverty and Civic Habitus. In *in a, Power, Poverty and Inequality* (Vol. 47, pp. 89–102).

Punjab, T. H. E., Authority, I., & Xi, A. (2015). the Punjab Irrigation and Drainage Authority Act 1997, *1997*(1), 1–6.

Raby, N. (2000). Participatory irrigation management in the Philippines: national irrigation systems. In D. Grownfeldt & M. Svendsen (Eds.), *Case studies in participatory irrigation management* (pp. 113–137). The World Bank.

Ramanadham, V. V., & Bokhari, R. (2019). Privatisation in Pakistan. *Privatisation in Developing Countries*, 145–177. https://doi.org/10.4324/9780429197932-7

Reddy, V. R., & Reddy, P. P. (2005). How Participatory Is Participatory Irrigation Management? Water Users' Associations in Andhra Pradesh. *Economic and Political Weekly*, *40*(53), 5587–5595. Retrieved from http://www.jstor.org/stable/4417612

Robinson, I. (2000). Neoliberal restructuring and U.S. unions: Toward social movement unionism? *Critical Sociology*, *26*(2), 109–138. https://doi.org/10.1177/08969205000260010701

Santiso, C. (2001). Good Governance and Aid Effectiveness : The World Bank and Conditionality. *The Georgetown Public Policy Review*, *7*(1), 1–22.

Senanayake, N., Mukherji, A., & Giordano, M. (2015). Re-visiting what we know about Irrigation Management Transfer: A review of the evidence. *Agricultural Water Management*. https://doi.org/10.1016/j.agwat.2014.11.004

Shah, T., Hussain, I., & Saeed-ur-Rehman. (2000). *Irrigation management in Pakistan and India: comparing notes on institutions and policies. IWMI Working Paper 4*. Retrieved from http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR4.pdf

Sinclair, A. J., Kumnerdpet, W., & Moyer, J. M. (2013). Learning sustainable water practices through participatory irrigation management in Thailand. *Natural Resources Forum*, *37*(1), 55–66. https://doi.org/10.1111/1477-8947.12012

Suhardiman, D. (2008). *Bureaucratic designs: The Paradox of Irrigation Management Transfer in Indonesia*. Wageningen University.

Suhardiman, D., Giordano, M., Rap, E., & Wegerich, K. (2014). Bureaucratic reform in irrigation: A review of four case studies. *Water Alternatives*, *7*(3), 442–463.

Townsend, P. (2004). From Universalism to Safety Nets: The Rise and Fall of Keynesian Influence on Social Development. In T. Mkandawire (Ed.), *Social Policy in a Development Context* (pp. 37–62). London: Palgrave Macmillan UK. https://doi.org/10.1057/9780230523975_2

Uysal, Ö. K., & Atiş, E. (2010). Assessing the performance of participatory irrigation management over time: A case study from Turkey. *Agricultural Water Management*, *97*(7), 1017–1025. https://doi.org/10.1016/j.agwat.2010.02.007

Vermillion, D. L. (1997). Impacts of irrigation management transfer: a review of the evidence. *IWMI Research Report 011 IIMI Research Report 011*, v, 35p. https://doi.org/http://dx.doi.org/10.3910/2009.018

Vermillion, Douglas L, Samad, M., Pusposutardjo, S., & Arif, S. S. (1999). *An assessment of the small-scale irrigation management turnover program in Indonesia*.

Wilder, M. O. (2002). In name only: Water policy, the state, and ejidatario producers in northern Mexico. The University of Arizona. Retrieved from http://hdl.handle.net/10150/280078

Wilder, M., & Romero Lankao, P. (2006). Paradoxes of Decentralization: Water Reform and Social Implications in Mexico. *World Development*, *34*(11), 1977–1995. https://doi.org/10.1016/j.worlddev.2005.11.026

William J. Young, Arif Anwar, Tousif Bhatti, Edoardo Borgomeo, Stephen Davies, William R. Garthwaite III, E. Michael Gilmont, Christina Leb, Lucy Lytton, Ian Makin, and B. S. (2019). *Pakistan Getting More Water*. WASHINGTON, D.C.

wim H. Kloezen, C. G.-R. (1998). *Assessing Irrigation Performance with Comparative Indicators: The case of the Alto Rio Lerma Irrigation District, Mexico*.

Wolff, R. D., & Resnick, S. A. (2012). *Contending Economic Theories Neoclassical, Keynesian and Marxian*. MIT Press.

Yu, W., Yang, Y.-C., Savitsky, A., Alford, D., Brown, C., Wescoat, J., … Robinson, S. (2013). *The Indus Basin of Pakistan*. *The Indus Basin of Pakistan*. https://doi.org/10.1596/978-0-8213-9874-6

ANNEXURE-A

Definition and Construction of Explanatory Variables

Resource user's Characteristics

Resource user's Characteristics block include binary variable;

- Tractor Status (TS) for 1 for having own tractor and 0 for hired tractor use
- Age of the respondents who cultivated the land in years
- Fusion of Scientific Knowledge (FSK) This composite score was measured through survey tool section 24 (see appendix for detailed)
- Man to Land Ratio Agriculture (MLRA) This ratio was measured as the number of household persons involved in agricultural activities
- Land Holding Size (LHS) This was a measure of the number of land units (acres) under cultivation
- Man to Land Ratio (MLR) This ratio was measured in another way than how many persons dependent (family size) on the land resource.
- Crop Diversification Index (CDI) this index was measured as the ratio of the number of crops cultivated reported in the main survey divided by the total number of crops, i.e., 12, can be grown.

This block of variables can be further divided into two like a physical resource— LHS, MLR, and variables related to the resource user's decision making and influenced under different social and behavioral caveats. The descriptive statistics of different variables in this block was present in table 3.1

Table 2: Descriptive statistics of Resource Users Characteristics

	Name of AWB/ Canal Division											
	Nara Canal			Rohri Canal			Hakra Canal			Desert Canal		
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Age (Years)	45	17		48	13		51	15		45	14	
LHS (Acres)	57	73		30	44		15	19		16	15	
CDI (0-1)	0.35	0.14		0.33	0.14		0.25	0.10		0.27	0.12	
FSK (1-10)	4.68	1.85		3.98	1.42		4.54	1.13		4.58	1.06	
MLR (%)	0.83	1.14		1.05	1.42		1.07	1.14		1.13	1.33	
MLRA (%)	0.13	0.18		0.17	0.25		0.20	0.21		0.25	0.28	
TS Yes			45			29			68			24
No			44			76			67			70

Water Resource Characteristics

Water resource characteristics block to combine the canal infrastructure and regulation related variables which include;

- Technical State of Irrigation Infrastructure (TSII) (see section 10.1 to 10.7 in survey tool)
- Water Scarcity Perception Index (WSPI) measured the adequacy and reliability of the water schedule and overall perception of the canal water scarcity for irrigation purposes (please see the survey question 19.1 to 19.5)
- Frequency of Watercourse Maintenance (FWCM) measured as a number in a year
- Cumulative Delivery Performance Ratio (CDPR) measured from section 12 of the survey tool. DPR was an estimated ratio of actual canal water supplies to the scheduled supplies. It was ideally estimated from the canal from deliveries data, but unfortunately, in our irrigation system, the management of canal data is not managed so precisely that it can be used with certain reliability. Different researchers reported how irrigation officials fudged these data sets easily because this was manually maintained in the register. So, we decided to use farmers' reported information of canal water turns required and received for different crops to estimate the annual CDPR.
- Annual Canal Cropping Intensity (ACCI) as the groundwater use is substantial in our canal command areas and varies in different canal reaches. So to control the influence of groundwater, we estimate the Annual Canal Cropping Intensity (ACCI) based on the information provided by the respondents.
- Reduce Distance (RD) was a proxy variable for the spatial positioning of the respondent land resource along the canal system. It was a distance measured from the source of water to land with the help of Google Earth.

Table 3: Descriptive Statistics of Water Resource Characteristics

	Name of AWB/ Canal Division							
	Nara Canal		Rohri Canal		Hakra Canal		Desert Canal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TSII (1-4)	2.12	1.08	1.77	0.96	1.73	0.71	2.21	0.56
WSPI(1.5-4.5)	3.11	1.11	3.07	1.37	3.83	0.66	2.97	0.69
ACCI (%)	110%	54%	105%	61%	80%	50%	163%	45%
ACWU (mm)	1547.43	45.09	2016.78	485.39	2345.78	38.06	2762.33	132.79
CDPR (0-1)	0.68	0.20	0.68	0.25	0.50	0.17	0.68	0.18
RD (Km)	141.57	61.75	77.06	52.33	150.48	26.02	141.76	19.94

Land and Ground Water Resource Characteristics

Land resource characteristics block to define the quality of land, and we measure land resource characteristics from a different proxy indicator, like Land Performance Indicator (LPIW) for wheat and LPIC for cotton crop. LPI is the ratio of the harvested yield of wheat and cotton to the potential yield that can be achieved for wheat and cotton. This ratio showed the current potential of the land. We use cotton and wheat because the selected canal command area was designated as the wheat and cotton zone of the country, and cotton and wheat still were the dominant crops in these canals. The gap in the yield was influenced mainly due to two reasons; one is related to the land quality (salinity and waterlogging), and the second is the groundwater availability for conjunctive use. We use cropping intensity as conjunctive use of the canal and groundwater to capture the effectiveness of groundwater.

Table 4: Descriptive Statistics of Land and Ground Water Resource Characteristics

	Name of AWB/ Canal Division							
	Nara Canal		Rohri Canal		Hakra Canal		Desert Canal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LPI Wheat (0-1)	0.70	0.23	0.66	0.22	0.77	0.13	0.76	0.14
LPI Cotton (0-1)	0.65	0.67	0.43	0.31	0.56	0.22	0.59	0.21
ACIC (%)	101%	43%	101%	56%	128%	53%	170%	43%

Agronomic Characteristics

Agronomic practices were another block of exploratory predictor which was related to resource user's characteristics, measured as;

- Total Intercultural Operation (TICOML) performed by machinery or manual labor per unit acre,
- Total Number of Weedicide and Pesticide (TNWP) used per unit acre,
- Total Number of Machine Operation (TNMO) per unit acre performed for the land preparation as primary or secondary tillage, and
- Total Number of Fertilizer (TNF) per unit acre applied as soil nutrient management.

This block of variables covers the majority of the aspect of production technology except for the seed rate, sowing, and harvesting dates of the crops. Since we used agricultural productivity in terms of economic value produced per unit acre, so seed rate and sowing and harvesting dates of the different crops varied and were difficult to combine into one variable; that's why we do not include those in our model.

Table 5: Descriptive Statistics of Agronomic Resource Characteristics

	Name of AWB/ Canal Division							
	Nara Canal		Rohri Canal		Hakra Canal		Desert Canal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TNMO (No/Acre)	1.05	1.18	1.76	3.48	1.19	1.15	1.12	1.10
TICOML (No/Acre)	.46	.56	.72	1.06	.35	.41	.22	.22
TNWP (No/Acre)	.58	.72	.80	1.18	.82	.87	.73	.69
TNF (No/Acre)	1.30	1.59	1.90	1.73	1.03	1.08	.89	.82

Market Characteristics

A wide range of literature evidence reported how the market distance to resource users had influenced farm-level productivity. Keeping in view the importance of the market dynamics influence as a techno-behavioral determinant of farm productivity, we estimate the variables from survey questions. In this block, we included the Average Distance to Urban Facility (ADUF) (like distance of village to health facilities, metaled road, distance to an agricultural workshop, and distance to the petrol pump and CNG stations), Average Distance Agricultural Market Facility (ADAMF) (which include distance to seed, fertilizer, pesticide, agriculture implement workshop, and local shopping market for household), Average Distance Market Facility (ADMF) (which include distance to livestock, grain, vegetable market, and Government procurement center), Average Distance Credit Facility (ADCF) (which include a distance of village to different types of credit facility, see section 20.3.1 to 20.3.8). A composite of equal-weights of all these variables was named as Urban Proximity Index (UPI). Basic descriptive statistics can be found in the table 3.5

Table 6: Descriptive Statistics of Market Resource Characteristics

	Name of AWB/ Canal Division							
	Nara Canal		Rohri Canal		Hakra Canal		Desert Canal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ADUF (Km)	8.40	5.38	8.41	4.89	8.91	5.08	9.56	8.20
ADCF (Km)	10.22	6.58	13.87	7.92	12.70	8.20	14.56	9.11
ADAMF (Km)	7.50	5.96	8.64	4.96	9.91	5.79	7.28	6.18
ADMF (Km)	8.57	5.81	10.18	5.45	12.70	6.07	16.69	9.32
UPI (Km)	8.55	5.12	10.03	4.64	10.20	5.76	10.84	6.48

Institutional and Community Characteristics

For institutional and community characteristics block, we included;

- Institutional Performance of Area Water Board (IPAWB) index was a composite scale variable that showed how the reform empowered WUA's and FO's to pursue irrigation-related affairs. We ask the respondents, especially how the reform empowered her to pursue irrigation-related affairs, access to information, decision making, and irrigation department personnel conduct related to rent-seeking (please see survey tool section 15.1 to 15.12 for details).
- Group Dynamics Effectiveness Index (GDEI) measures the group norms and how one individual can relate himself/herself in the group (please see section 16.1 to 16.10 for details).
- Community Cooperation Index (CCI) was a composite variable that talked about the measure of trust, cooperation between different WUA's/villages, trust, and empathy extended from head to tail reach farmers, and how they position themselves in such a situation. Level of solidarity/empathy of the watercourse community when some members do not get their due share of water (please see survey tool section 17.1 to 17.8 for detailed)
- Level of Participation (LPWUA) in WUA activities was measured from the responses of selected survey questions from sections 13.1 to 13.10.
- WUA Maturity Index (WUAMI) measured from selected questions of WUA/FO Maturity index section 14.1 to 14.18.

Table 7: Descriptive Statistics of Institutional and Community Characteristics

	Name of AWB/ Canal Division							
	Nara Canal		Rohri Canal		Hakra Canal		Desert Canal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CCI (1-3)	1.98	0.74	1.59	0.65	1.60	0.42	1.24	0.46
GDEI (0-1)	0.63	0.28	0.31	0.18	0.47	0.18	0.51	0.16
IPAWB (1-11)	5.03	3.92	2.23	2.15	2.24	1.98	1.70	1.52
LPWUA (5-25)	16.77	7.51			12.67	5.14		
WUAMI (15-47)	26.68	11.47			23.44	6.18		

Survey Tool Reliability

The Cronbach alpha, which is the most widely used method for analyzing data reliability, was utilized to examine the reliability of the scale employed in this study. It assesses the question's reliability by determining the mean correlation of the internal consistency as well as elements in the questionnaire. The Cronbach alpha coefficient is a number that ranges from 0 to 1. The measuring scale utilized is more trustworthy with higher alpha value. To ensure that the scale being used is credible, the value of scale items must not be less than 0.70, according to a rule of thumb. The table presented below provides a Cronbach alpha value for different scales used in the survey tool. All scale used in survey tools have a much higher value as compared to the standard one except GDEI which is on the margin.

Table 8: Reliability Statistics of the Survey tool scale

Scale Name	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
WSPI	.909	.911	5
CCI	.821	.815	10
GDEI	**.725**	**.721**	10
IP	.864	.888	11
TSII	.820	.855	7

APPENDIX B:

KEY FEATURES OF THE SINDH WATER MANAGEMENT ORDINANCE (2002)

For full text of the ordinance, see http://sida.org.pk/download/swmo_2002_English.pdf (retrieved 07/05/21)

Governance Level	Operations & Maintenance	Power and Authority	Additional Notable Features	Implementation Assessment
Regulatory Authority (RA)	N/A	- Enforce compliance with ordinance - Approve all regulations set by SIDA, AWBs, and FOs - Establish AWB performance standards - Establish Customer Service Committees for each AWB to investigate complaints related to FO distributor functions	- Although the RA is supposed to be established soon after the commencement of the ordinance, SIDA may function as the RA until the latter is established - Annual report on conduct of SIDA, AWBs, FOs, WCAs, and DBGs should be submitted to the government and a summary published in local newspapers in English, Urdu, and Sindhi as well as provide summaries to SIDA, AWBs, and FOs	- RA has authority to enforce SIDA to comply with ordinance. However, the RA has not been established as an independent body as per SWMO 2002. Rather, SIDA has been playing the role of RA. Thus, there is a significant conflict of interest that has persisted for nearly 20 years.
Sindh Irrigation and drainage Authority (SIDA)	- Operate and maintain aspects of irrigation and drainage system within its purview (i.e., barrages, outlets, spinal drains, inter-AEB drains)	- Establish Water Allocation Committee (WAC) at each barrage level to determine water shares (i.e., water rights), develop water schedules, ensure discharge measurements are taken correctly, compare planned	- Community Advisory Committee (CAC) may be established for the purpose of "smooth interaction" with communities. - Conduct research studies to appraise options and	- SIDA never took over control of the barrages. The Irrigation Department still maintains control. -Although SIDA has authority to operate and maintain irrigation

	- Implement flood protection - Receive irrigation water and deliver agreed quantities to AWBs, FOs, and other relevant parties	vs actual discharges, publish information publicly on regular basis, and receive complaints and negotiate priorities as needed - Levy and collect fees, rates, cess, and surcharges from areas outside the jurisdiction of AWBs and FOs - Investigate and solve problems referred by RA - Report non-compliance of AWBs to RA - Provide strategic advice to government	enhance environmental protection - Manage transition process and support development of AWBs and FOs	infrastructure, SIDA lacks relevant technical expertise/capacity to have legitimate authority and power to make these decisions. - WACs never fully operationalized: irregular meetings, no meeting minutes, and no publicly posted water schedules. Canal officers (ex-Irrigation Department officials) prepare water schedules rather than WACs. - CACs never established or not functional. - Staff transferred from Irrigation and Power Department work on the terms and conditions of SIDA but those terms and conditions shall not be less favorable than the terms and conditions admissible to them immediately before their transfer to SIDA.
Area Water Board (AWB)	- Operate, maintain, and improve aspects of irrigation and drainage system within its purview (e.g., main canals, branch canals,	- Establish WAC*, if AWB has branch canals such committees also established at branch level.	- AWBs have a duty not to extend the provision of water supply if doing so results in failure to meet pre-existing water supply obligations	- WAC Formation at AWB Level is absent. - Only Branch level WAC present whose working is not different from the SIDA level WAC.

	drainage tube-well drains with >15 cusecs) - Implement flood protection - Receive irrigation water from SIDA and deliver agreed quantities to FOs and other entitled parties (e.g., industries, wetlands, etc.) - Receive and convey drainage effluent - Monitor surface and groundwater quality - Monitor withdrawals of groundwater - Monitor toxic disposal of effluent - Maintain equipment	- Provide strategic advice to local and provincial government - Public disclosure of information, including publishing the planning of water distribution, the actual water distribution, and the comparison of the two - Charge fees for services and surcharges for late payments - Reduce irrigation water supplied to FOs for non-payment of water charges by its member(s) - Prevent unauthorized construction and encroachment - Notify RA of toxic effluent offenses	- Support development of FOs in its command area - CAC may be established for the purpose of "smooth interaction" with communities.	- Variation across AWBs in performance, but generally weak in terms of information management, analysis, and dissemination (e.g., no publication of planned vs actual water distribution; outdated FO records; fee collection data not readily available in disaggregated form to analyze compliance by FO; etc.) - Weak enforcement of rules - CAC never established
Farmers Organization (FO)	- Operate, maintain, and improve aspects of irrigation and drainage system within its purview - Implement flood protection - Receive irrigation water from SIDA or AWB	- Establish WAC* - Provide strategic advice to local councils - FO General Body can decide not to implement decision of WCA or DBG if doing so would have negative effect for FO or AWB levels	- Support development of WCAs and DBGs in its command area - Although FO has authority to decide not to comply with decision of WCA or DBG, the latter may appeal and seek arbitration by RA	- WAC never formed at FO level. - CAC never established

	and deliver agreed quantities to WCAs and other entitled parties, ensuring tail-enders and small farmers receive water and drinking water is available - Receive and convey drainage effluent	- Charge fees for services and surcharges for late payments - Reduce irrigation water supplied to WCAs for non-payment of water charges by its member(s) - Public disclosure of information	- WAC is supposed "to determine (initially on basis of design discharges, evolving over time to negotiated water rights incorporating the limitations posed by the infrastructural conditions, historic discharges, and market principles) the water share of the WCAs under "normal water availability" for a weekly interval." (SWMO 2002, p. 29) - CAC may be established for the purpose of "smooth interaction" with communities.	
Watercourse Association (WCA)	- Operate, maintain, improve, and rehabilitate watercourse, tube wells, lift pumps, field drains, and drainage infrastructure - Receive irrigation water from FO and distribute to members	- Organize labor for watercourse repairs - Ensure that WCA members contribute agreed share of labor or money to O&M - Establish water schedules and ensure all WCA members get due share of water - Assist in "determination and collection of general and special assessment" (SWMO 2002, p. 32)	- Ensuring all members contribute in the agreed manner for their share of labor or money - If WCA Board does not fulfill its water distribution duty, then 1/3 of WCA members may request a caretaker be made available by the FO until new elections can be held	- WCAs must do the manual labor of watercourse maintenance – and they are responsible for ensuring that all members comply – but they do not have authority or power explicitly mentioned in the ordinance to punish those who shirk their responsibilities.

Drainage Beneficiaries' Group (DBG)	- Operate, maintain, improve, and rehabilitate drainage structures	- Organize labor for repairs - Assist in "the determination and collection of general and special assessment" (SWMO 2002, p. 35) - Employ labor and obtain loans and grants	- If DBG Board does not fulfill its duty to collect and dispose of drainage water, then 1/3 of WCA members may request a caretaker be made available by the FO until new elections can be held	- DBGs never established. - Drainage issues (e.g., salinity and water logging) are major problems in Sindh (Sohaq, Mahessar, & Bohio, 2005).

ANNEXURE-C: SURVEY TOOL

Exploring the Water Governance Policy Framework for Improving Participatory Irrigation Management Reforms

Consent Statement

You are invited to participate in a research study "Exploring the Water Governance Policy Framework for Improving Participatory Irrigation Management Reforms" and share your information and experience regarding the irrigation management reforms introduced under the PIDA/SIDA Act 1997. The purpose of this research is to assess the performance of the different irrigation schemes and analyze how you experience the reform process. Your provided information only utilized for the research purpose and your identification remained confidential.

Name of Surveyor	Form Number	Date

Identification of Survey Location

Name of Village	**Taluka/District/Province**	**Name of AWB/ Canal Division**	**FO/Distributary Name**	**WCA/ Outlet Number**

Introductory Questions:

<table>
<tr><td>Name of Respondent</td><td colspan="2"></td></tr>
<tr><td>Sex: 1. Male 2. Female</td><td colspan="2">Age:</td></tr>
<tr><td>Education:</td><td colspan="2">1. No Education 2. Primary 3. Middle 4.High School
5. Intermediate 6. Graduation 7. Post-Graduation 8. Other…….</td></tr>
<tr><td>Religion:…………
Ethnic Group:
1. Sindhi 2. Baloch 3. Punjabi 4. Mahajir 5. Pashtun 6. Saraiki 7.Other……..
Caste: …………..</td><td>Did you come after 1947 in this area: 1. Yes 2. No</td><td>When did you settle in this area:</td></tr>
<tr><td>No. of Family members:</td><td colspan="2">Working members:'

Agriculture: ------------- 2. Non-Agriculture: -----------</td></tr>
</table>

Household occupations/income source	Main:	Other:
Relationship with the Organization	WUA's	FO
Relationship with FO/WCA		

Land holding:

Landholding (acres)	Total	Irrigated	Un-irrigated
Owned			
Leased-in			
Leased-out			
Total Operated			
Location of distributary at the main Canal	Head Reach:	Middle Reach:	Tail Reach:
Location of Water course at the distributary	Head Reach:	Middle Reach:	Tail Reach:
Location of land at the watercourse	Head Reach:	Middle Reach:	Tail Reach:

Land Quality Index

Do you think most of your land is in good condition? 1. Yes 2. No				
Type of Soil (i) Clay (ii) Loamy (iii) Sandy (iv) Other				
Extent of Soil Salinity and Water Logging	**N/A**	**High**	**Medium**	**Low**
Salinity (کلر)				
Water Logging (سیم)				

Water Table Depth (Approximate depth in meters or feet)

Season	This year	Last year	3 years ago	5 years ago	10 years ago	20 years ago
Rainy season						
Dry season						
How much area was Cultivated						

Village prone to drought/floods:

Your farm/village is affected by floods.

1. Agree 2. Somewhat Agree 3. Disagree

Your farm/village is affected by droughts.

1. Agree 2. Somewhat Agree 3. Disagree

Perceived Cropping Intensity:

Year	6.1 How much area did you cultivate during the Kharif and Rabi seasons through canal irrigation?	
	Kharif	Rabi
2021		NA
2020		
2019		
2018		

Do you use Tube -well irrigation for cultivating the crops?

1. No

2. Yes

Year	6.3 How much area did you cultivate during the Kharif and Rabi seasons through tube well irrigation?	
	Kharif	Rabi
2021		NA
2020		
2019		
2018		

Perceived Land Distribution on Water Course and Distributary:

4.1 According to your best estimate at this WC/Outlet how many farmers owned land proportionately in the following categories (acres)					
Less than 2 ( )	2-5 ( )	5-12 ( )	12-25 ( )	25-50 ( )	More than 50( )
4.2 According to your best estimate at this Distributory how many farmers owned land proportionately in the following categories (acres)					
Less than 2 ( )	2-5 ( )	5-12 ( )	12-25 ( )	25-50 ( )	More than 50 ( )

State of Irrigation Infrastructure:

How much do you contribute annually for the maintenance of distributary? ---------------- Rs

How frequent distributary desilting actions are performed (Number/year)? ----------------Years

How much do you contribute annually for the maintenance of Watercourse? ---------------- Rs

Frequency of watercourse maintenance (Number/year) ------------------------------------

You're Source of Irrigation? 1. Canal Water 2. Ground Water 3. Lift From Canal

How much irrigation expenses on average have you concurred annually on Maintenance?

1. Canal water ……… 2. Groundwater ……… 3. Lift Irrigation …….

Technical State of the Irrigation Infrastructure (4 = Strongly Agree, 3= Agree, 2= Somewhat Agree, 1= Disagree,

Questions	1	2	3	4
The location & placement of the irrigation structures is technically sound				
The structures & equipment are of good quality				
The structures & equipment are adequate				
The irrigation structures are regularly repaired and well maintained				
Government/ technically trained experts have been always involved				
The water release/distribution are technically well scheduled and managed				
Technical training and guidance are available & provided to all involved				
Do you think quality of irrigation infrastructure (O&M) under the supervision of FO/AWB is better as compared to irrigation bureaucracy?				

Agricultural Management Performance Assessment:

12.2 Based on your climate and land conditions what are your target and harvested yield of the following crops in the last 5 years? (Please recall your memories)							
Kharif Crops Name	Area Under Crop	Target Yield (Mound/Acre)	Harvested Yield (Mound/Acre)	Rabi Crops Name	Area Under Crop	Target Yield (Mound /Acre)	Harvested Yield (Mound/Acre)
1.Cotton				7.Wheat			
2.Rice				8.Sugarcane (Annual)			
3.Tomato				9.Banana (Annual)			
4.Chilli				10.Canola			
5.Onion				11.Maize			
6. Other				12.Other			

Perception Based Delivery Performance Ratio:

13.1 How many irrigations turn your crops need and received for the following?

Kharif Crops Name	Required Irrigation Turn	Received Irrigation Turn	Rabi Crops Name	Required Irrigation Turn	Received Irrigation Turn
1.Cotton			7.Wheat		
2.Rice			8.Sugarcane (Annual)		
3.Tomato			9.Banana (Annual)		
4.Chilli			10.Canola		
5.Onion			11.Maize		
6.			12.		

State of Participatory Irrigation Management and Farmer Organization

<table>
<tr><td>Questions</td><td colspan="2">WCA</td><td colspan="2">FO</td></tr>
<tr><td rowspan="2">WCA/WUA Does it exist?</td><td colspan="2">Yes

When was it formed?................</td><td colspan="2">Yes

When was it formed?...........</td></tr>
<tr><td colspan="2">No</td><td colspan="2">No</td></tr>
<tr><td>Are you a member? Yes/No</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td></tr>
<tr><td>Do you hold a position?</td><td>Yes

Position?..........</td><td>No</td><td>Yes

Position?.......</td><td>No</td></tr>
<tr><td>What is the selection method</td><td colspan="2">1.Selection by PIDA/SIDA
2.Nomination by few &powerful landholder
3.Consensus of all share holder,
4.Election</td><td colspan="2">1.Selection by PIDA/SIDA
2.Nomination by few &powerful landholder
3.Consensus of all share holder,
4.Election</td></tr>
<tr><td>What is the frequency of the election?</td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

Did you participate in the election?	Yes	No	Yes	No
Is there any rotation in leadership?	Yes	No	Yes	No
Frequency of meetings	1. Once in a month 2. Quarterly 3.Bi-Annualy 4.Annual 5.On Demand		1. Once in a month 2. Quarterly 3.Bi-Annualy 4.Annual 5.On Demand	
When was the last meeting held?				
Did you attend?	Yes	No	Yes	No

WUA/ FO Maturity Index:

In general, do you agree or disagree with the following statements? **(1 = Strongly Agree, 2= Agree, 3= Somewhat Agree, 4= Disagree, N/A applies for No opinion)**	1.	2.	3.	4.	N/A
General body members actively participate in the meeting	1.	2.	3.	4.	N/A
Office bearers actively involved and encouraged the member to participate in the meetings	1.	2.	3.	4.	N/A
What do you think office-bearers educated and lead the group actively?	1.	2.	3.	4.	N/A
What do you think when elections occur did all shareholders participate actively?	1.	2.	3.	4.	N/A
What do you think, do the office holders actively pursue the Abiana collection?	1.	2.	3.	4.	N/A
Does any water dispute occur on the WC?	1. Yes			2. No	
What type of dispute generally happens at the WC/Distributary?					
How actively WCA/FO leadership involve in decision making?	1.	2.	3.	4.	N/A
Do you play an active role in the WCA?	1.	2.	3.	4.	N/A

Do you play an active role in the FO?	1.	2.	3.	4.	N/A
Are you aware of the structure & functioning of FO/WCA?	1.	2.	3.	4.	N/A
Can you recall how many disputes have been resolved yet through WCA/FO leadership?					
Can you recall FO/WCA ever decide or modify the watercourse irrigation turns?	Yes			No	
Can you recall FO to decide any new entitlement on your watercourse?	1. Yes			2. No	
If Yes, how many decisions are undertaken recently					
What do you think, do large farmers are dominant in the WCA/FO decision making?	1.	2.	3.	4.	N/A
How many WCA management committee members having land holding more than 25 acres?					
How many FO management committee members having land holding more than 25 acres?					

Institutional Performance of AWB:

Do you think after reform is it easy to pursue irrigation related provision?	**Yes**	**No**
Reform impacted the distributional equity of water among head and tails.	**Yes**	**No**
Do you feel empowered after the reform taking place?	**Yes**	**No**
Do you think after the reform operation and maintenance of irrigation infrastructure taking place comparatively better from the previous system?	**Yes**	**No**
How many times you experience to meet irrigation or SIDA/PIDA officials for canal and irrigation related matters?	**Yes**	**No**
Do you experience that irrigation official demand bribes for irrigation related matters?	**Yes**	**No**
You know someone directly or indirectly who experience this situation in irrigation department?	**Yes**	**No**
What is your general perception that after the reform frequency of such instances reduced?	**Yes**	**No**
Did you experience any change in the official conduct of the irrigation personal?	**Yes**	**No**
Do you feel you have better access to information after the reform?	**Yes**	**No**

Do you feel accountability of the irrigation staff employees for their performance, after reform?	**Yes**	**No**
Do you think after the reform Irrigation staff is more accountable to FO's?	**Yes**	**No**
Do the farmers' groups/organizations generally approach for the distributary maintenance or lining?	**Yes**	**No**
If Yes, then what is the mechanism for lobbying Political lobbying 2. Administrative lobbying 3. Others --------------------		

Group Dynamics of WUA/FO:

Questions	**Yes**	**N0**
Being a member of WCA, I feel a sense of equality in this association and other members of this group treated me as equal?		
After revealing that someone is involved in the non-compliance (like non-payment of irrigation fee, free riding of water turn/ theft/not participating in the O&M activities), He /she was still accepted by the group?		
Being a member, I have feeling that we all have the same type of problems		
Being a member, I have feeling that large farmers are not getting more benefits from water as compared to me		
Being a member, I have feeling that head farmers are not getting more benefits from water as compared to me		
Being a member, I have feeling that officer bearers of this WCA are not getting more benefits due to their position		
Being a member, I have feeling that officer bearers of this FO are not getting more benefits due to their position		
Being a head farmer, I am feeling bad when tail farmers not getting water on the water course or distributary		
Do you think member of this WCA/FO considered helping others without discrimination of caste/ religion		
Do you think members of this WCA/FO was forgetting self-interest and always eager to help others		

Community Cooperation Index:

In general, do you agree or disagree with the following statements?	**[Use the following code] 1=No/Disagree 2=Neither Agree nor disagree 3=Yes/Agree**					
	WATERCOURSE			**DISTRIBUTARY**		
Most people who live on this [watercourse/distributary] can be trusted.	3	2	1	3	2	1

In general, do you agree or disagree with the following statements?	**[Use the following code] 1=No/Disagree 2=Neither Agree nor disagree 3=Yes/Agree**		
Do the different villages of this distributary work together to solve common problems?	1	2	3
Do the different biraderis of this distributary work together to solve common problems?	1	2	3
Do the different WCA of this Farmers' Organization work together to solve common problems?	1	2	3
When some watercourses do not get enough water, do the farmers of other watercourses show concern and empathy?	1	2	3
Are people of this watercourse willing to exchange obligations and favors with people of other watercourses?	1	2	3
Are people from other watercourses willing to exchange obligations and favors with people of this watercourse?	1	2	3
Are the leaders of this Farmers' Organization very concerned when some members are not getting their due share of water?	1	2	3
Do the official of the irrigation department show concern, when members do not get their due share of water?	1	2	3

Hydro-Solidarity:

If there is a shortage at the tail-end of the distributary, how likely is it that farmers at the head-end will cooperate to help tail-enders get water?	
Very likely	☐
Somewhat likely	☐
Not likely	☐

Water Scarcity Perception Index: (1 = Strongly Agree, 2= Agree, 3= Somewhat Agree, 4= Disagree, N/A applies for No opinion)

In general, do you agree or disagree with the following statements?	1	2	3	4	N/A
You face water scarcity on your farm	1	2	3	4	N/A

Farmers on your watercourse suffer crop loss due to insufficient water?	1	2	3	4	N/A
Farmers on your watercourse are receiving "the right amount of water at the right time in the right place" in the Kharif season?	1	2	3	4	N/A
Farmers on your watercourse are receiving "the right amount of water at the right time in the right place" in the Rabi season?	1	2	3	4	N/A
Farmers on your watercourse get enough canal water for irrigation	1	2	3	4	N/A

Market Dynamics/ Integration/Incorporation:

What is the average distance of wholesale markets from your village (Km)?		
Name of the Village	Type of Facility	Average Distance
	Livestock Market	
	Grains Market	
	Fruits/Vegetable Market	
	Govt. Procurement Center	
Distance of village from the retail market (bazar) and sources of agricultural inputs supplies		
Name of the Village	Type of Facility	Average Distance
	Seeds Shop	
	Fertilizers shop	
	Pesticides shop	
	Bazar*	
Distance of Mouzas from credit facility and its different type		
Name of Village	Type of Facility	Average Distance
	1.ZTBL	
	2.Cooperative Bank	
	3.Commercial Bank	
	4.Commercial Bank (Online Banking Facility)	
	5.Micro Finance Bank	
	6.NGO	
	7.Government	
	8.Aarthi/Commission Agent	
	9.Distance of Mouzas from health facilities	

	10.Distance of Mouzas from the facilities of diesel/petrol pump and depot/agency as well as CNG/LPG				
	11.Distance of Mouzas from the facility of metaled road and transport				
	12.Village to the nearest agricultural workshop to implement maintenance and repairs				
Impact of Agricultural Extension Services on agricultural Performance					
Village Name	Type of Facility		Average distance		
	Village to nearest agriculture extension or research office				
20.5 How often agriculture extension officers visit your village?	1. Monthly	2.Quarterly	3.Bi-Annually	4.Annually	5. Never
20.6 Has agricultural extension ever organized any farmer field school in your village?	Yes		No		
20.7 Has agricultural extension ever planted any demonstration plot in your village for the promotion of new technology?	Yes		No		
20.8 Do you think agricultural extension services help to access the latest production technology and information related to crop?	Yes		No		

Fusion of Scientific Knowledge into Traditional Knowledge:

Which Primary and Secondary tillage instrument you used for the crops.

Tillage Practice	Yes	No
Laser leveling		
Wooden or Indigenous Plough		
Rotary Plough		
Mouldboard Plough		

Disc Plough		
Chisel Plough		
Disc Harrow		
Rotavator		
Bed Shaper		
Drill sowing		

Cost of Land Preparation per Acre

Tractor (i) Owned (ii) Hired Tractor HP________________

Activity	WHEAT		COTTON		SUGARCANE		RICE		MAIZE	
	No	Per Unit Cost	No	Per Unit Cost	No	Per Unit Cost	No	Per Unit Cost	No	Per Unit Cost
Deep Ploughing										
Ploughing										
Planking										
Laser Leveling										
Disc Harrow										
Rotavator										
Ridger/Bed										
Sowing Cost										
Sowing Time Month / Week										
Seed Rate (Kg per Acre)										
Seed Price (Rs per kg)										

Cost of Irrigation per Acre

Activity	WHEAT			COTTON			SUGARCANE			RICE			MAIZE		
	No	Per Unit Cost	Applicat ion Cost	No	Per Unit Cost	Application Cost	No	Per Unit Cost	Applicati on Cost	No	Per Unit Cost	Applicati on Cost	No	Per Unit Cost	Applicat ion Cost
Canal Irrigation (Abiana Rs/Season)															
Tube well Irrigation															

Fertilizer, FYM, Pesticide and weedicide Application per Acre

Activity	WHEAT			COTTON			SUGARCANE			RICE			MAIZE		
	No	Per Unit Cost	Application Cost	No	Per Unit Cost	Application Cost	No	Per Unit Cost	Application Cost	No	Per Unit Cost	Application Cost	No	Per Unit Cost	Application Cost
DAP															
UREA															
SSP															
Nitrophos (NP)															
Potash															
Others															
Farm Yard Manure															
Micronutrient															
Weedicide															
Pesticide															
Intercultural Opr. by Machinery															
Intercultural Opr. Labor															

Harvesting and Threshing Cost per Acre

	WHEAT	COTTON	SUGARCANE	RICE	MAIZE
Harvesting/Picking Cost (Rs)					
Threshing Cost (Rs)					
Transportation if any (Rs)					
Average Yield (Monds)					
Price per Mond (Rs)					
Price of By-Product (Rs/Acre)					

ANNEXURE- D: KEY INFORMANT GUIDELINE

FO's Chairman/SIDA Mobilization/ Irrigation official Key Informant Interview Guideline

1. What is your opinion about initial period of reforms?
2. What differences have you noticed in community behavior about reforms in initial and current periods?
3. If it was better in initial period, then what was the reason behind their good response earlier?
4. If it is better in current period, then what is the reason behind their good response now?
5. What is the status of water distribution after reforms? What do you think about the impacts of reforms on water distribution?
6. Which major interventions have been introduced by SIDA since its formation and what were the results?
7. What have been your mobilization strategies and techniques? Kindly discuss in detail.
8. What is the status of water distribution after reforms? What do you think about the impacts of reforms on water distribution?
9. Which major interventions have been introduced by SIDA since its formation and what were the results?
10. How do you see the interest and response of community towards reforms and interventions?
11. Have you remained successful in controlling the water theft? If YES what were you strategies? If NO what were the key reasons of failure?
12. How do you see the relationship between SIDA and Irrigation department?
13. In your opinion, what are the major reasons behind failed FOs?
14. In your opinion, what are the major reasons behind successful FOs?
15. In your opinion, what are the major influential factor involve in working mechanism of FOs?
16. What is the election process? How do you elect the members and office bearers?
17. Did the farmers try to bring the power to the grass root level?
18. Are influential people equally accountable for their wrongdoings?
19. What do you think about the impacts of reforms on crop production? Kindly discuss with the reasons.
20. Have you ever tried to convince farmers about cultivation of more profitable crops? If No, why? If yes what was their response?
21. What do you think about the behavior of irrigation officials towards social parity between deprived and privileged castes?

22. What do you think about the behavior of irrigation officials towards social parity between small and large farmers?

23. How do you see the cooperation/helpfulness of irrigation staff? Has it improved after reforms?

24. What is your opinion about SIDA act 2002? Does it need certain revisions? If yes then kindly define.

25. Does SIDA Act 2002 provide enough powers to FOs to control irrigation system? If No kindly discuss where it lacks?

26. What is the major difference between the distributaries/Canals controlled by SIDA and Irrigation department?

ANNEXURE-E VARIATION IN THE CULTURABLE COMMAND AREAS

Sub Div. Name	Areas GCA (Acres)	Rohri Canal Circle (2014-15)		Rohri Canal Circle (2016-17)		Rohri Canal Circle (2017-18)		Rohri Canal Circle (2017-18)		Rohri Canal Circle (2018-19)		Rohri Canal Circle (2020-21)		Rohri Canal Circle (2021-22)
		Kharif 2015	Rabi (15-16)	Kharif 2016	Rabi (16-17)	Kharif 2017	Rabi (17-18)	Kharif 2018	Rabi (18-19)	Kharif 2019	Rabi (19-20)	Kharif 2020	Rabi (20-21)	Kharif 2021
Head	286587.8	233209.5	259719.3	256537.3	260942.9	259783.5	261961.9	244122.3	256230.7	184194.5	246234.0	204072.7	246647.7	156697.7
Middle	761038.9	651018.0	683012.5	623120.5	692301.0	671073.5	673885.9	562953.5	659181.5	567444.9	646389.8	515360.3	645165.9	527617.2
Tail	169963.7	100569.4	127047.6	93621.2	75123.4	65092.3	89362.9	65092.3	89362.9	54649.4	115557.3	84632.4	119568.2	57877.0

Sub Div. Name	Areas GCA (Acres)	Nara Canal Circle (2014-15)		Nara Canal Circle (2016-17)		Nara Canal Circle (2017-18)		Nara Canal Circle (2017-18)		Nara Canal Circle (2018-19)		Nara Canal Circle (2020-21)		Nara Canal Circle (2021-22)
		Kharif 2015	Rabi (15-16)	Kharif 2016	Rabi (16-17)	Kharif 2017	Rabi (17-18)	Kharif 2018	Rabi (18-19)	Kharif 2019	Rabi (19-20)	Kharif (20)	Rabi (20-21)	Kharif (2021)
Head	248578.6	172271.1	167645.2	167667.9	35141.0	167159.2	141697.2	139805.3	153129.6	133192.3	160292.0	140343.5	162586.7	148194.1
Middle	264278.1	198776.9	196723.0	148980.9	56970.2	199053.0	134199.0	175942.0	178739.3	156288.0	182517.0	157789.9	178085.4	179303.3
Tail	218400	135147.7	165526.4	129683.8	169479.3	109935.3	107940.1	102622.8	130551.7	102074.6	149809.3	115317.7	141269.1	117170.6

Sub Div. Name	Areas GCA (Acres)	Desert Canal Circle (2014-15)		Desert Canal Circle (2016-17)		Desert Canal Circle (2017-18)		Desert Canal Circle (2017-18)		Desert Canal Circle (2018-19)		Desert Canal Circle (2020-21)		Desert Canal Circle (2021-22)
		Kharif 2015	Rabi (15-16)	Kharif 2016	Rabi (16-17)	Kharif 2017	Rabi (17-18)	Kharif 2018	Rabi (18-19)	Kharif 2019	Rabi (19-20)	Kharif (20)	Rabi (20-21)	Kharif (2021)
Head	114272.4	70301.0	95075.5	95300.5	95815.7	99405.6	100904.6	89513.4	94240.5	80205.5	97087.2	79137.4	95753.8	74429.2
Mid	80436.98	65628.3	67859.7	75245.5	70689.2	76662.4	73629.7	71004.3	71706.9	64176.4	72636.3	64380.1	72414.5	59073.1
Tail	88894.77	74564.6	77598.6	78787.3	81946.6	84149.9	83148.3	77456.8	82468.1	71448.0	82800.8	71066.6	82734.8	67239.9

Sub Div. Name	Areas GCA (acres)	Hakra Canal Circle (2014-15)		Hakra Canal Circle (2016-17)		Hakra Canal Circle (2017-18)		Hakra Canal Circle (2017-18)		Hakra Canal Circle (2018-19)		Hakra Canal Circle (2020-21)		Hakra Canal Circle (2021-22)
		Kharif 2015	Rabi (15-16)	Kharif 2016	Rabi (16-17)	Kharif 2017	Rabi (17-18)	Kharif 2018	Rabi (18-19)	Kharif 2019	Rabi (19-20)	Kharif(20)	Rabi(20-21)	Kharif(21)
Head	394624	148718.58	321397.12	266912.37	337592.07	276563.4	311267.1	243131.22	297610.26	174645.9	340430.71	195745.85	333206.1	221871.26
Middle	160920	81044.56	121183.21	118372.3	134408.75	121442.6	128801.51	116435.59	125321.26	93394.12	130832.03	92401.8	131604.2	109072.89
Tail	308192	114752.07	209754.28	176139.35	216874.49	189618.8	211473.92	178526.69	205996.74	138274.6	212679.07	137059.24	215976.6	173515.004

ANNEXURE- E ADEQUACY AND RELIABILITY CALACULATION

Bahawalnagar Hakra Command Area Actual Evapotranspiration

Seasonal Average Actual ET (mm)											
CCA	Kharif 2015	Rabi (15-16)	Kharif 2016	Rabi (16-17)	Kharif 2017	Rabi (17-18)	Kharif 2018	Rabi (18-19)	Kharif 2019	Rabi (19-20)	Kharif (2020)
Head	844.30	1564.29	562.15	1480.97	1257.60	1450.72	542.56	1535.51	663.00	2001.80	867.69
Middle	854.47	1608.85	631.08	1359.89	1288.60	1516.00	493.31	1438.51	659.81	1923.17	898.12
Tail	818.74	1455.86	582.43	1440.76	1285.19	1508.31	504.18	1420.70	632.80	1825.77	827.00
ETrF											
Head	0.65	2.78	0.44	2.64	0.97	2.58	0.42	2.73	0.51	3.56	0.67
Middle	0.66	2.86	0.49	2.42	1.00	2.70	0.38	2.56	0.51	3.42	0.70
Tail	0.63	2.59	0.45	2.56	1.00	2.68	0.39	2.53	0.49	3.25	0.64

Yearly Average Actual ET (mm)						
CCA	2016	2017	2018	2019	2020	Avg
Head	2126.44	2738.57	1993.28	2198.52	2869.49	2385.26
Middle	2239.93	2648.49	2009.31	2098.31	2821.29	2363.47
Tail	2038.29	2725.95	2012.49	2053.50	2652.77	2296.60

ETrF Statistics			
Standard Deviation		Coefficient of Variation	
(Rabi)	(Kharif)	(Rabi)	(Kharif)
0.40	0.21	0.14	0.34
0.39	0.22	0.14	0.35
0.30	0.22	0.11	0.36

Crop Water Use (2020-21) [mm]					
Sub Div. Name	Cotton	Sugarcane	Rice	Wheat	Mango
Head	685.109	2506.3387	705.448	1509.321	2609.5926
Middle	567.8414	2340.153	560.65	1314.384	2675.4354
Tail	528.944	2342.145	549.285	1179.801	2604.516

Bahawalpur Desert Command Area Evapotranspiration

Seasonal Average Actual ET (mm)											
CCA	Kharif 2015	Rabi (15-16)	Kharif 2016	Rabi (16-17)	Kharif 2017	Rabi (17-18)	Kharif 2018	Rabi (18-19)	Kharif 2019	Rabi (19-20)	Kharif(20)
Head	905.202	1543.29	856.461	1580.55	1336.48	1579.9894	735.474	1643.26	878.1269	1994.551	1140.514
Middle	782.146	1535.4	641.553	1645.16	1437.12	1652.3092	534.608	1680.48	797.7567	1944.979	1029.092
Tail	397.762	1111.27	309.181	1183.81	1070.86	1224.4488	224.593	1190.22	420.7349	1430.301	599.3102
ETrF											
Head	0.62	2.36	0.59	2.42	0.92	2.42	0.50	2.52	0.60	3.05	0.78
Middle	0.54	2.35	0.44	2.52	0.99	2.53	0.37	2.57	0.55	2.98	0.71
Tail	0.27	1.70	0.21	1.81	0.73	1.88	0.15	1.82	0.29	2.19	0.41

Yearly Average Actual ET (mm)						
CCA	2016	2017	2018	2019	2020	Avg
Head	2399.75	2917.04	2315.46	2521.39	3135.06	2657.74
Middle	2176.95	3082.28	2186.92	2478.24	2974.07	2579.69
Tail	1420.45	2254.67	1449.04	1610.95	2029.61	1752.95

ETrF Statistics			
Standard Deviation		Coefficient of Variation	
(Rabi)	(Kharif)	(Rabi)	(Kharif)
0.28	0.15	0.11	0.23
0.23	0.22	0.09	0.37
0.18	0.21	0.10	0.61

Crop Water Use (2020-21) [mm]					
Sub Div. Name	Cotton	Sugarcane	Rice	Wheat	Mango
Head	674.755	2650.3761	838.642	1313.127	2747.9051
Middle	588.215	2813.8677	736.92	1150.593	2855.069
Tail	218.1977	2188.851	484.884	631.7314	1806.75

Rohri Command Area Actual Evapotranspiration

Seasonal Average Actual ET (mm)											
CCA	Kharif 2015	Rabi (15-16)	Kharif 2016	Rabi (16-17)	Kharif 2017	Rabi (17-18)	Kharif 2018	Rabi (18-19)	Kharif 2019	Rabi (19-20)	Kharif (2020)
Head	573.965	1335.02	452.687	1202.34	1124.26	1335.0497	311.256	1595.45	842.6365	1817.578	846.38
Middle	1194.56	1332.75	1254.5	1106.03	917.509	1189.8241	1023.74	1365.57	1645.466	1616.127	1429.353
Tail	853.689	670.019	1069.72	515.561	292.195	508.4325	666.806	350.397	1007.418	787.9776	1184.09
ETrF											
Head	0.43	2.00	0.34	1.80	0.84	2.00	0.23	2.39	0.63	2.73	0.63
Middle	0.89	2.00	0.94	1.66	0.69	1.78	0.77	2.05	1.23	2.42	1.07
Tail	0.64	1.00	0.80	0.77	0.22	0.76	0.50	0.53	0.75	1.18	0.89

Yearly Average Actual ET (mm)						
CCA	2016	2017	2018	2019	2020	Avg
Head	1787.71	2326.60	1646.31	2438.09	2663.96	2172.53
Middle	2587.25	2023.54	2213.57	3011.03	3045.48	2576.17
Tail	1739.74	807.76	1175.24	1357.81	1972.07	1410.52

ETrF Statistics

Crop Water Use (2020-21) [mm]

Standard Deviation		Coefficient of Variation	
(Rabi)	(Kharif)	(Rabi)	(Kharif)
0.37	0.22	0.17	0.43
0.29	0.20	0.15	0.21
0.25	0.24	0.30	0.38

Sub Div. Name	Cotton	Sugarcane	Rice	Wheat	Banana
Head	476.265	2013.94	411.787	1244.41	2022.304
Middle	1068.028	2536.954	1167.747	1407.572	2542.668
Tail	437.746	1301.695	587.884	883.464	1387.1293

Nara Command Area Actual Evapotranspiration

Seasonal Average Actual ET (mm)											
CCA	Kharif 2015	Rabi (15-16)	Kharif 2016	Rabi (16-17)	Kharif 2017	Rabi (17-18)	Kharif 2018	Rabi (18-19)	Kharif 2019	Rabi (19-20)	Kharif (2020)
Head	771.597	768.834	821.913	630.63	479.976	648.43922	666.634	731.828	1133.468	988.6579	1115.029
Middle	923.915	698.8	1090.77	520.018	340.876	542.11942	789.049	555.563	1229.972	824.8819	1214.666
Tail	852.173	722.418	1089.84	551.619	329.906	556.20294	693.334	422.89	1098.732	811.8229	1150.832
ETrF											
Head	0.59	1.12	0.63	0.92	0.37	0.94	0.51	1.07	0.87	1.44	0.85
Middle	0.71	1.02	0.83	0.76	0.26	0.79	0.60	0.81	0.94	1.20	0.93
Tail	0.65	1.05	0.83	0.80	0.25	0.81	0.53	0.62	0.84	1.18	0.88

Yearly Average Actual ET (mm)						
CCA	2016	2017	2018	2019	2020	Avg
Head	1590.75	1110.61	1315.07	1865.30	2103.69	1597.08
Middle	1789.57	860.89	1331.17	1785.53	2039.55	1561.34
Tail	1812.26	881.52	1249.54	1521.62	1962.65	1485.52

ETrF Statistics	
Standard Deviation	Coefficient of Variation

Crop Water Use (2020-21) [mm]						
Sub Div. Name	Cotton	Sugarcane	Rice	Wheat	Banana	Mango

(Rabi)	(Kharif)	(Rabi)	(Kharif)
0.21	0.20	0.19	0.31
0.19	0.26	0.21	0.36
0.22	0.24	0.25	0.36

Head	848.698	1694.396	862.991	1027.184	1766.9	1990.794
Middle	908.127	1466.767	960.146	919.59	1513.323	1619.13
Tail	649.603	1327.639	718.376	785.789	1239.18	1352.336