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Evaluating the Impact of Water User Associations on Irrigation and Agricultural Productivity in Assam: A Case Study of Nalbari District

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Abstract: Transforming institution-building for the attainment of irrigation is crucial to the economy's balanced development of agriculture. Over the years, agriculture's performance in the irrigation sector has sunk due to inadequate management and poor farmer participation, affecting the economy's balanced development. Therefore, Govt of Assam has been pushing to form a Water user association (WUA) under the Irrigation Water User Act, of 2004. Participatory management, involving farmers as users, is widely used in water distribution, overseeing operation and maintenance. The PIM approach proposes the equitable and economic distribution of water for irrigation, with local participation. It results in a spike in productivity in agriculture. The study explores water usage among WUA members in Assam, focusing on irrigation schemes and their socio-economic benefits for local farmers. The study reveals that due to effective coordination between regional irrigation departments and WUAs, farmers are better informed about PIM and canal construction, thereby enhancing production, but still requires rural areas in Assam to be connected with PIM for adequate capacity. The study recommends that continuous policy reforms are needed to improve community participation in Assam, tackle the current challenges in PIM, and enhance the effectiveness of WUAs.

Keywords: Agriculture, Irrigation, Farmers'participation, wateruser association, PIM.

1. Introduction

Water is a key natural resource for all sectors and it is becoming more stingy with growing environmental

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degradation. In the context of the economy of India, the industry and services sectors, which constitute more than 80 percent of the GVA in the country, employ 54.5 percent of the workforce, and, agriculture, which includes one-fifth of the total economy (GVA) of the country in 2020-21, retains 46.5 percent workforce. (Chand & Singh,2022). The development of the agriculture sector is essential for achieving sustainable development of the Indian economy (Sivramkrishna &Jyotishi, 2009). Gunnar Myrdal, an economist, asserts that the long-term economic development of the Indian economy will primarily depend on the contribution of the agriculture sector.

The National Sample Research Organization (NSSO) 2019 research, Economic Analysis on Rural Communities along with Landing and Cattle Ownership on Families across Countryside India, classifies data on rural households according to their main means of livelihood. According to this poll, 58.3% of rural families cited agriculture as their main means of livelihood. Poor and intermediate functional proprietors made up around 86% of all functional proprietors in the nation, according to the Farm Survey 2015–16. Therefore, the development of the agriculture sector is essential to attain sustainable development of the Indian economy. India is the most populated country in the world, having recently surpassed China in 2023 (Maheshwari & Pillai, 2001). However, water availability cannot be increased in the same proportion, leading to a rapid increase in demand for irrigation facilities to boost farmers' income (Maheshwari & Pillai, 2001). Therefore, there is a rapid increase in demand for irrigation facilities for agricultural purposes & to boost farmers' income. It is because, without an irrigation system, farmers have to only depend on the monsoon, which badly affects agriculture. This Situation demands proper management of water distribution for irrigation purposes & the policymakers have given great priority to the development of irrigation. In this context, It is crucial to have an effective and current system in place for allocating water reserves for feeding the population and also to meet the requirements of agriculture and other purposes.

The Department of the Ministry of Water Resources has continued to push agriculturalists to participate part in officially sponsored administrative region improvement programs since 1985. These initiatives cover tertiary system management and water distribution. The water policy (1987) emphasizes the inclusion of farmers for irrigation purposes, resolving financial conflicts, and providing education, training, and capacity building. Participatory Irrigation Management (PIM) is also incorporated to reduce potential creation and utilization gaps (GOI, water policy, 1987).

In the 1980s, Water Users Groups (WUAs) were the primary means by which institutions such as the World Bank and Asian Development Bank engaged farmers in regulating irrigation. PIM aims to improve cooperation between farmers and irrigation agencies, addressing conflict resolution and enhancing stakeholder synergy. Around 60 countries with significant irrigated areas have adopted PIM, but results vary, leading to debates on the sustainability and viability of different WUA models (Kulkarni et al., 2012). The PIM approach is a very prominent concept related to the agriculture sector, especially in the irrigation field. It is also well-known among researchers and academicians. The involvement of irrigation users, or farmers, in the administration of irrigation systems, takes place when a group of different people develops an association that uses water judiciously for irrigation and forms a formal or informal user group for irrigation activity. This concept rationalizes the applicability of water for agricultural purposes through local people's participation. The PIM is broadly classified into two types- formal Pani Panchayat and informal Pani Panchayat. A formal water user group is a registered user group with the government whereas an informal water user group is not registered but follows its own rules/ principles of common benefits framed by them. The legal structure permits the establishment of farmer groups under distributing committees, project committees, and pani panchayats/WUAs at various irrigation system levels. WUA will have an administratively feasible, hydraulically defined command region. A WUA would typically cover a minor or a set of outlets. The Distributary Committee's general body will be made up of all WUA presidents.DC will comprise 5 or more WUAs. The leaders of the subsidiary boards within the work zone will comprise the general body of the project committee.

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The importance of PIM lies in various drivers and their determinants like the involvement of users and how efficiently they handle operation and maintenance activities like adequate and timely distribution of water to farmers etc. However, to what extent PIM is effective and whether PIM is the ultimate solution needs to be investigated. PIM's Theoretical Foundation is very crucial because the irrigation system plays a crucial role in ensuring water supply and promoting economic use. It involves efficient operation and maintenance, maximizing water utilization, and ensuring equity in water distribution. By utilizing natural precipitation and groundwater, the system can increase cropping intensity. Users can choose crops, timing, and frequency of water supply, maximizing incomes and returns. Producers who are engaged in PIM have been shown to significantly increase their water usage (Gandhi and Namboodri 2002). Uphoff (1986) argued that PIM has led to a greater proportion of the amount of land irrigated and the provision of water supply to many farmers.

The evidence demonstrates that both the user groups have shown positive results in developed as well as in developing countries. Kulkarni and Tyagi (2012) Pre 1960s draw attention to the local models that have emerged in industrialized nations such as Portugal, France, and the Netherlands, which serve as excellent examples of participatory governance achieved through democratic collaborative procedures in the 1960s. In Asia Countries that are developing including India, Pakistan, Bangladesh, Nepal, etc., managed pond irrigation, canal irrigation, and river irrigation for centuries in informal ways with their active participation(Groenfeldt, 2000).

Water User Associations have been widely promoted to improve governance and decision-making in water management, particularly for irrigation systems. However, the performance of these organizations to achieve long-term sustainability remains a challenge, as illustrated by the case study of non-operational WUAs in the Nalbari district of Assam, India (Douglas & Aloyce, 2018; Tischbein et al., 2013). The Water Users Association monitors irrigation schedules, maintenance plans, water usage regulations, landowner registries, water flow evaluation, and the resolution of conflicts between members and users in its service region. It also maintains a landowner registry. The Water Users Association has the authority to provide non-members with timely information regarding water availability, distribution, and allocation, as well as to charge fees for maintenance, management, and other expenses. They also have the right to learn about new crop kinds and buy inputs for their fellow citizens (Upadhyay, V. 2006).

In India, PIM has received much attraction. In 2002, the government of India updated the National Water Policy with the following modifications regarding the participatory approach to water resources management involving multiple stakeholders involved in the management, design, and planning of water resources. This approach ensures appropriate roles for women and promotes a more inclusive water system. The policy also emphasizes the importance of local bodies in managing water infrastructures. (GOI, water policy, 2002)

Assam is the gateway to India’s Northeast. Assam is such a state where, every year, it receives adequate rainfall, but the problem is the uneven allocation of rainfall. It Creates problems like flood and drought; hence it adversely affects agricultural development. In Assam, 57 percent of the cultivated area is under rice, the main staple food of the population which requires plenty of water. Considering several factors, the custom of leaving the paddy fields empty until the following winter continues. Thus, in Assam importance of irrigation lies in the fact that stabilizes and sets up agricultural output. During British colonial rule, formal irrigation infrastructure was introduced, but management remained largely under government control. Post-independence, Assam saw significant investments in irrigation projects under various Five-Year Plans. These projects were largely state-managed with minimal farmer participation. Recognizing the limitations of state-managed systems and inspired by international trends, the concept of Participatory Irrigation Management (PIM) began to gain traction.

Participatory irrigation management, or PIM, has been practiced in Assam throughout the beginning of the 1990s. According to the Government of Assam's Department of Irrigation, 1581 WUAs had been established as of March 31, 2018. 893 WUA have been identified in line with the Society Regulation legislation of 1860,

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even with 683 WUA are unregistered. Approximately 170 schemes have previously been given to WUA. The Assam Irrigation Water Users Act, of 2004, was enacted to provide farmers more control over their irrigation networks and to encourage community involvement regarding their management. The success of PIM varies across the state. While some WUAs are functioning effectively, others struggle due to issues like inadequate training, lack of resources, and weak institutional support. Many WUAs face difficulties in maintaining infrastructure and ensuring equitable water distribution without ongoing support from government agencies. The equal distribution of water plays a major role that depends on techniques like PIM that further increase employment in the rural sector (Sharma, 1992). Hence, the Researcher has chosen the Nalbari district of Assam as a case study to check the effectiveness of PIM.

1.1. Major Research Works Reviewed:

When we talk about the requirement of an efficient water management system, infrastructure development and equal distribution of water are crucial for agriculture development, but the government's Command Area Development Programme (CADP) has not yielded significant results due to inefficiencies, low yields of crops, and inadequate financial viability. The participatory irrigation management (PIM) approach aims to improve these issues. Patel (2015) A study by Ricks (2016) examines the critical role of local political contexts and state farmer engagement in determining the effectiveness of efforts to establish participatory resource management institutions. Drawing on a controlled comparison of different regions of Indonesia. The study reveals that participatory irrigation schemes' efficacy is dependent on the local political environment (Ustriyana et al., 2021). Local elected officials frequently put pressure on bureaucrats to interact with farmers more actively when irrigation is a contentious political issue (Djamres et al., 2018). Furthermore, the results demonstrate that regular interactions between officials and farmers are more helpful in promoting water user organization engagement than training programs alone. These results highlight how crucial it is to improve the relationship between farmer organizations and government officials by having regular interactions and how local politics play a significant role in determining the effectiveness of participatory initiatives. (Speranza et al., 2016; Ponok et al., 2021). Based on the information available, it appears that although training programs have certain advantages, their primary objective of encouraging participation is often rarely achieved. Training programs that are transitory or may even work against the growth of institutions and the establishment of a cooperative relationship between farmers and state actors. Instead, the frequency of engagement between state authorities and group leaders had a significant effect on the extent of participation within water user associations. (Ponok et al., 2021). Policymakers seeking to promote participatory approaches must carefully consider the local political landscape and invest in sustained interaction between government officials and community members, rather than relying solely on training programs. The importance of PIM has been growing rapidly in India in recent years due to the scarcity of water. The availability of water per person is declining, and groundwater level has become a serious issue. So, researchers and policymakers have looked at the PIM as one of the solutions to rationalize the use of water. One of the aspects leading to the effective implementation of WUA is the involvement of stakeholders in irrigation operations and agricultural enterprises (Rustinsyah & Prasetyo, 2019). Another study (Ustriyana et al., 2021) examines the long-term reliability of irrigation administration in Bali. Data were collected through interviews, focus groups, and literature reviews. The results showed weak sustainability prospects in Mongolia in multiple dimensions. However, the economic and social dimensions were relatively sustainable. In contrast, Saba Watershed in Bali Province showed adequate sustainability in economic, socio-cultural, and policy-institutional dimensions. The study finds that socialized agricultural services help to slow down the negative effects of rural labor migration. Community authority enhances the effects of SASs on group behavior, while resource dependency mediates the relationship. The study further reveals the cultural environmental program's self-regulatory mechanism, which allows it to adjust and rebuild equilibrium in the face of outside shocks (Wang & Huan, 2023). According to an empirical assessment by Leroy, D. (2023), in Mexican irrigation districts, social organizations are essential to the governance of water resources, given that

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they permit individual irrigators to get water from a centralized supply. However, there are notable variations in the administration of irrigation institutions' performance. within these institutions, which can be explained by biophysical attributes, community characteristics, and social capital. According to the study, water administrators must collaborate with local communities to establish farmer's associations, as this could strengthen farmers' social capital and, in turn, the effectiveness of community agriculture. It also highlights the need for micro-sprinkler irrigation technology, which is more water-efficient. Furthermore, the modest degree of fulfillment among farmers on irrigation facilities' (WUA) service supply highlights the need for improved arbitration processes and a more equitable distribution of resources within the irrigation area. In eastern India, particularly in the states of Assam and Bihar, Khandker et al. (2020) emphasize the vital need for increased female participation in participative irrigating organizations. Men predominantly address meetings and make decisions based on family traditions, cultural restrictions, lack of time, and interest in water management in Bihar compared to Assam, which tends to reduce with education. Education and training are seen as crucial in reducing social barriers and enhancing female participation in participatory irrigating organizations. According to the research, women's inclusion in Water User Associations (WUAs) is generally very low, except in Bihar, where inclusion is mandated due to inadequate leadership skills. Women have limited independent involvement. Formal participation of women in water institutions can lead to improved water management, greater awareness, better social status, the ability to influence rules limiting their participation, and enhancement of rural development, particularly for lower castes, small farmers, and wage earners, though they note little direct positive impact on women themselves. In Assam, women and men participate in joint decision-making at a higher rate related to irrigation and income use. To overcome the difficulties, the study emphasizes the inclusion of women in WUA executive committees, implementing government schemes, and training programs focused on water management. Sedogo et. al. (2000) provide valuable insights into the strategy of collaborative governance of land, emphasizing the importance of stakeholder engagement and socio-cultural incentives based on a case study of a region in West Africa. The collaborative governance of land includes enduring partnerships among property and its tenants as well as logical, responsible judgments that address regional planning requirements and interests. Appropriate management unit identification is necessary for successful leadership, and that identification is predicated on stakeholders' perceptions and understanding of natural resources as well as sociocultural incentives. Geographic Information Systems (GIS) methodologies and participatory rural assessment (PRA) tools are used in this work to generate an information system. However, the study does not address the role of policy and institutional frameworks in supporting participatory land management. Kulkarni et. al. (2012) analyzed local water management models through social cooperative processes, as many developed countries such as the Netherlands, France, and Germany already applied such practices for efficient water management. On the other hand, the water supply and farming practices are frequently backed by regional governments in developing nations like India, Iran, and Indonesia. The effectiveness of WUAs requires strong organization, business plans, legal support, conflict resolution through cooperation among various levels of stakeholders, and institutional backing. The study suggests the formation of WUA federations, innovative irrigation financing, cost recovery, impact assessment, technology transfer, asset management, collaboration between international and national institutions, modernization of systems, and private sector support services. Srivastava et. al. (2014) provide valuable insights into the variations in inter-regional water supply and its influence on agriculture in India, though they highlight the importance of technological interventions across India. India has the largest irrigated area globally, and the northern region performs better in both allocations of water resources and thereby agriculture as compared to the eastern region, even though it has abundant water resources. This disparity highlights the need for more equitable and sustainable water resource management practices. The study emphasizes the need for technological interventions, institutional restructuring, and policy reframing to improve water use efficiency and crop productivity.

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1.2. Identification of Research Gaps:

Efficient water management is a crucial aspect of agricultural development, as highlighted by Patel. The Indian government has implemented various schemes, such as the CADP, to address the challenges related to irrigation purposes. However, these efforts have yielded unsatisfactory results due to issues such as the lack of efficient water legislation, water conservation, and equal water distribution, as well as inadequate infrastructure development and low-cost recovery. To address these challenges, the participatory approach to water resources management came into place in the late 1980s. Yet, the performance of this approach has been unsatisfactory due to a lack of legal backup, modifying existing laws, structural inadequacy, water scarcity, monetary constraints, inadequacy of skill management, and a and a lack of guidance among stakeholders (Gandhi & Johnson, 2019).

A study by Ricks (2016) examines the critical role of local political contexts and state-farmer engagement in determining the effectiveness of efforts to establish participatory resource management institutions (Behera & Mishra, 2018). According to the study, local politicians are more inclined to press administrators to interact with producers more actively when irrigation is a contentious political issue. This can improve the efficacy of participatory irrigation policy (Behera & Mishra, 2018).

A study by Sedogo et. al. (2000) identifies the importance of stakeholder perceptions and knowledge but does not delve deeply into the methods for effectively engaging stakeholders or resolving conflicts. It also emphasizes sustainable development, but there is a lack of longitudinal data to assess the long-term sustainability of the implemented strategies and refine the approach in varied socio-cultural and environmental settings. Further studies should monitor the long-term impacts of participatory land management on both land resources and local communities and evaluate methods for enhancing stakeholder engagement and addressing conflicts. There is scope for research to quantify the economic, environmental, and social impacts of the participatory land management approach, which would provide a more robust assessment of its effectiveness. There is an ongoing debate on various WUA models, which necessitate more focused research and analysis about emerging challenges such as financing, cost recovery, impact assessment, and technology transfer.

Kulkarni et. al. (2012) analyzed local water management models through social cooperative processes. According to the study, the strong, ongoing, and sincere governmental commitment to PIM that characterizes many public-managed irrigation schemes is lacking. In many developing nations, the operation and maintenance of WUAs receive insufficient attention, which contributes to their inconsistent success.

While Srivastava et. al.'s (2014) analysis spans from 1950 to 2007, it lacks a comprehensive examination of the long-term impact of the development of irrigation on crop production and sustainability. It reveals gaps that require further research, including regional strategies, sustainable practices, long-term impact assessments, technological solutions, policy effectiveness evaluations, and equitable water distribution mechanisms. The study highlights regional disparities but does not provide detailed strategies for reducing problems faced across different regions. This study underscores unsustainable aquatic resource development but lacks an in-depth analysis of sustainable practices that could be implemented and does not evaluate the effectiveness of existing policies.

2. Objective of the Study

The present study attempts to measure the effectiveness of water user associations on agriculture productivity in the state of Assam, with special emphasis on Nalbari district.

The major objectives of the proposed study are:

1. To measure how the establishment and functioning of WUAs influence the efficiency of water distribution and utilization and agricultural performance in the district.

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2. To comprehend the degree of farmers' participation in water administration, as well as their duties, responsibilities, and the success of their engagement in WUA initiatives.
3. To identify the challenges faced by WUAs in managing irrigation systems and explore the opportunities for improving their effectiveness through better policies, training, and support.
4. To explore the socio-economic benefits of WUAs for local farmers.
5. To provide recommendations for policymakers on how to strengthen WUAs and improve participatory irrigation management, contributing to sustainable agricultural development.

2.1. Research Questions:

The proposed study tries to find out the answer to the major research question as-

1. How effective are the existing WUAs in managing and distributing water resources among farmers?

2. What is the impact of WUA formation on irrigation coverage and agricultural productivity?

3. What is the operational status of various irrigation schemes in Nalbari District?

4. Has there been any significant change in agricultural productivity following the formation of WUAs or the implementation of irrigation schemes?

5. What are the primary causes of some WUAs' non-operational status?

6. To what extent do local communities participate in decision-making within WUAs?

7. How does the governance structure of WUAs influence their operational effectiveness and sustainability?

3. Methods

A pilot study is a very important step in research that is conducted and executed to plan the intended study. It helps to determine the possible research design, make any changes in the research methodology, and determine important parameters of participatory irrigation management. The methodology involves a participatory approach, engaging community members in every phase of the study. The sampling method will be adopted instead of the census method. In this study, formal interviews with WUA members were conducted. The researcher has done a pilot study and presented the results in the discussion section of the research paper. For the data collection process, both primary and secondary techniques have been utilized. Secondary sources include stakeholders, including government reports, registration records of WUAs, and historical data on irrigation schemes websites of the government of Assam, the Directorate of Statistics and Economics, etc. The study area for the proposed research study in Assam includes specifically Nalbari district. Regarding the sampling strategy in the proposed research study, random sampling was used to ensure each respondent had an equal chance of being selected. For the proposed research study in Assam focusing on the water user association, a comprehensive data collection approach is essential. The study collects primary data, likely through structured surveys or interviews with key stakeholders such as WUA members (farmers, presidents, and secretaries), local authorities, and possibly government officials responsible for irrigation schemes. The primary data was collected from both formal and informal water user associations and groups in Nalbari district (Assam). To save time and study more effectively, the researcher has used the snowball sampling method for data collection. The researcher visited a member of WUA in the Nalbari district, and with the help of that member, the researcher reached out to the other five members of WUAs. The researcher has used a formal face-to-face interview method to get a rough idea of the project undertaken. It involves comparing operational and non-operational WUAs to understand differences in irrigation coverage, cropping patterns, and productivity changes. During the study, some variables were considered, including whether WUAs are registered, active, or inactive, command areas, registration numbers, water supply reliability, crops grown under different schemes, Assessing changes in agricultural productivity (yield) before and after the formation of WUAs, Studying the roles of office bearers

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(presidents, secretaries) and issues related to management and decision-making.

There are numerous tools for data analysis. In this proposed research study, different analytical data analysis tools (which will be discussed below) were used to analyze the data that has been collected. It will help to figure out important insights, identify trends, and make informed decisions for policy and other purposes.

- Conducting a thematic investigation of descriptive information gathered from conversations or open-ended survey answers to understand governance issues, community dynamics, and challenges faced by WUAs.
- Comparing findings between operational and non-operational WUAs to identify factors influencing their effectiveness and sustainability.
- Ensuring the confidentiality and anonymity of respondents.

During this process, the researcher faced multiple challenges, including biases in self-reported data from stakeholders, difficulty in accessing accurate historical data or records, and variability in responses and perceptions among different WUAs and stakeholders.

4. Results:

The Nalbari district is located between 26°N and 26.51°N latitude and 91°E and 91.47°E longitude, on the borders of the Brahmaputra Valley. The district spans 1009.57 square kilometers and is made up of 3 civil subdivisions, 7 community development blocks, and 65 gaon panchayats, which together comprise 471 villages. The district comprises seven revenue circles, including Nalbari Circle, Ghograpar Circle, Tihu Circle, Barbhag Circle, Barkhetri Circle, Paschim Nalbari Circle, and Banekuchi Circle. Out of these 7 circles, a pilot study was conducted in 3 circles, which are Paschim Nalbari Circle, Nalbari Circle, and Ghograpar Circle. In total, there were 73 Water Users Associations (WUAs) located in the Nalbari District of Assam, in accordance with the pilot research undertaken there between 2017 and 2018; four of them were registered, and the rest were in the process of becoming one. The earlier practice of the irrigation department was to supply water directly to the farmers. Water User Associations and all the relevant information about WUAs were collected from the Regional Irrigation Office of Nalbari District. Thereafter, consider some of the water user associations based in villages like CHATMA, SOLMARA, and SANDHA and observe their working activities.

The duties and responsibilities of the irrigation department extend beyond just supplying water; they also include overseeing the use of water. Following this, the irrigation and agriculture departments decided to collaborate completely. This approach rationalizes water use while simultaneously enhancing water utilization. WUAs manage minor irrigation facility issues, while the irrigation department handles more significant issues. During the 2015–16 year, the Irrigation Department (ID) launched several new initiatives, such as the Pradhan Mantri Krishishincai Yojana's block-wise irrigation scheme. The irrigation department gives farms in the tail end extra attention because they too deal with water shortages. In the Nalbari District, there are many plans for installing deep tube wells for agricultural use. These include the Banekuchi Deep Tube Well, which has a 30-hectare total command area, and the Mugkuchi D.T.W., which has a 30-hectare TCA. The cost of water charges for Kharif crops is Rs 37.50 per bigha and Rs 281.24 per hector, while the rate for wheat and Rabi crops is Rs 75 per bigha and Rs 567.50 per hector, according to a notification issued by the irrigation department (Govt. of Assam) on March 30, 2000. Following the collection of water costs, WUAs keep track of this list, which includes the candidate's name, the scheme name, and the amount received. They then provide the candidate with a receipt for the water charges they have paid, and they also create a bank statement following the payment. The Irrigation Department introduced new programs, such as the block-wise irrigation program under the Pradhan Mantri Krishishincai Yojana, and focused on tail-end farmers to address water crises. Deep tube wells are also being set up for agriculture in Nalbari District.

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Table1 (a) :Irrigation profile of Nalbari district (2016-2021)

SlNo.	Block	GrossIrrigated Area (Area in Ha) 2016-2021	Net Irrigated Area(Area in Ha)2016-2021
1	Barbhag	905	818
2	Barkhetri	11728	6256
3	BorigogBanbhag	1390	794
4	Madhupur	1085	746
5	PaschimNalbari	1243	1152
6	Pub Nalbari	1082	914
7	Tihu	1301	636
8	Total	18734	11316

Source: Agriculture Statistics, DMP, Nalbari

Table 1 (b) : Existing type of irrigation sources (Numbers)

SlNo.	Name of the Block	Govt. Canal	Tube wells (Govt.)	Bore Well (Govt.)	Electricity Pump	Diesel pump
1	Barbhag	1	324	3	4	324
2	Barkhetri	0	3098	2	2	3098
3	BorigogBanbhag	1	312	3	4	312
4	Madhupur	4	183	2	6	183
5	PaschimNalbari	1	461	5	6	461
6	Pub Nalbari	3	292	3	6	292
7	Tihu	2	163	5	7	163
8	Total	12	4833	23	35	4833

Source: Irrigation department, Nalbari

The Nalbari district's gross and net irrigated areas for each of the blocks from 2016 to 2021 are shown in Figure 1(a). Regardless of whether the same region receives irrigation more than once a year, the concept of "gross irrigated area" refers to the entire region that has been irrigated. Net Irrigated Area indicates the actual area irrigated at least once, without double-counting areas that receive multiple irrigations within the year. From the data, it was observed that Barkhetri has the highest gross and net irrigated areas, indicating significant irrigation activities. PaschimNalbari shows a high ratio of net to gross irrigated area, suggesting efficient use of irrigation resources. Barbhag, BorigogBanbhag, Madhupur, and Pub Nalbari have similar patterns with relatively lower irrigated areas than Barkhetri. Compared to the net irrigated area, the total amount of irrigated land is significantly greater. which is typical as some areas are irrigated more than once. Table 1(b) provides the

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existing types of irrigation sources in different blocks of Nalbari district, Assam. The analysis of this data can provide valuable insights into the irrigation infrastructure and its utilization in the region. From the table, it has been observed that the data reveals that tube wells are the predominant source of irrigation, with a total of 4,833 units across the eight blocks. This highlights the significant role that groundwater resources play in supporting agricultural activities in the region. The presence of electric and diesel pumping systems suggests that farmers have access to both electric and fuel-powered pumping systems to extract groundwater for irrigation purposes (Jibran and Mufti 2019). While the reliance on tube wells is notable, the varying number of these irrigation sources across the different blocks indicates an uneven distribution of groundwater utilization for agricultural purposes. The data also shows the presence of government . canals and bore wells, although in smaller numbers compared to tube wells. The existence of these alternate irrigation sources suggests that the region has a diverse water supply infrastructure, which can potentially be optimized to enhance the overall irrigation efficiency (Bhuyan & Husain, 2013). Interpreting the data from an empirical perspective, it is evident that the Barkhetri block has the highest number of tube wells, followed by the Paschim Nalbari block. This uneven distribution of irrigation sources across the blocks may be influenced by factors such as groundwater availability, soil characteristics, and historical irrigation development patterns (Srivastava et al., 2013). Additionally, the presence of government . canals, which are more prominent in the Madhupur and Pub Nalbari blocks, indicates the role of government interventions in enhancing surface water-based irrigation (Srivastava et al., 2013). The data analysis highlights the need for a comprehensive understanding of the regional water resources, their utilization, and the factors influencing irrigation development across the district (Mudiasa et al., 2017). This information can inform the formulation of targeted policies and interventions to address the disparities in irrigation access and promote sustainable water management practices in the region (Hadidi et al., 2016).

Table-2: List out visited no's of schemes and water user associations in Nalbari District (Pilot Study)

Sl.No.	Name of schemes	Names of WUAs	Command Area	registration No	Facility of timly water supply
1	GHILAJARI D.T.W.I.S Plot No.1	PRAGATI PANI UPABHOCTA SAMITTEE	30 hectors	RS/NAL/246/I/ 342	Yes
2	CHATMA CHAMARKUCHI DTWIS(Point No.6)	CHATMA PANI UPABHOKTA SAMITTEE	30 hectors	applied for registration	Yes
3	BALILECHA ELECTRICAL LIFE IRRIGATION SCHEME (SANHA Point No.1)	SEUJI PANI UPABHOKTA SAMITTEE	40 hectors	applied for registration	No (stop working since heavy flood in Assam 2004)
4	BALILECHA ELECTRICAL LIFE IRRIGATION SCHEME (SANDHA Point No.2)	PANI UPABHOKTA SAMITTEE	40 hectors	applied for registration	Yes
5	CHATMA CHAMARKUCHI	DHURKUHI PANI UPABHOKTA SAMITTEE	30 hectors	applied for registration	Yes

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	DTWIS (Point No.5)				
6	GHILAJARI D.T.W.I.S Plot No.2	MILIJULI PANI UPABHOCTA SAMITTEE	30 hectors	applied for registration	No (lack of infrastructure)

Source-Field Survey data Nalbari district during 2017-18

Table 2 provides information about six irrigation schemes and their corresponding Water User Associations (WUAs) in the Nalbari District. This table depicts the summary of various PIM schemes undertaken in Nalbari districts of Assam where the researcher did a pilot study. Throughout this pilot study, the researcher tried to assess water availability, whether people benefit from their respective WUAs, the areas covered by WUAs, the production of crops and awareness of water user associations, irrigation potential, and irrigation covered by each WUA. During the pilot study, formal interviews were conducted with two helpers, ten presidents, and two secretaries, covering 12 numbers of WUAs, which include Nalbari District (11 WUAs) and Baska District (1 WUA). Out of the six schemes, only one (Pragati Pani Upabhocta Committee) has a registered number, and its performance is rated as better as compared to earlier. Four WUAs have applied for registration but have not yet received their registration numbers. Despite this, their performance is mostly rated as average. One scheme (the Seuji Pani Upabhokta Committee) has stopped working since the heavy flood in Assam in 2004, indicating the vulnerability of the irrigation infrastructure to natural disasters. The lack of infrastructure is a significant issue for the Milijuli Pani Upabhocta Committee, leading to poor performance. The halted operations of the Seuji Pani Upabhokta Samittee highlight the need for resilient infrastructure capable of withstanding natural calamities. The command areas of the schemes range from 30 to 40 hectares, indicating small to medium-sized irrigation projects. The schemes with a 40-hectare command area have mixed performance, with one being rated as "good" and the other having stopped working due to flooding. Despite some WUAs not being officially registered, they still perform well, suggesting that formal registration may not be the sole determinant of effective water supervision.

Before the canal's establishment, it was noted that the WUA cultivators were dependent upon monsoons for cultivation. Thus, seasonal cultivation was the only possible way for their livelihood. However, after the construction of the canal, people could cultivate cereals, paddy, etc. throughout the year, which resulted in increased agricultural production.

Moreover, it was found that in areas covered by Chatma Chamarkuchi DTWIS (Point No. 5), Balilecha Electrical Life Irrigation Scheme SANDHA (Point No. 2), Chatma Chamarkuchi DTWIS (Point No. 6), Ghilajari D.T.W.I.S. (Plot No. 1), canals are there, but still, the length of the canal must be increased; it isn't sufficient at all (see Table 2). However, the lack of land agreement for the canal, lack of government support, lack of awareness among the farmers, lack of interaction between farmers and executive engineers, and lack of training facilities resulted in poor performance of WUAs. During the interview, it was clear that people are involved in fulfilling their personal needs; there is a lack of motivation to work for the community as a whole. During visits, apart from collecting published material/data, formal interviews were carried out with members of WUAs and with the competent authorities and knowledgeable farmers.

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Table-3 : List of operational Water User Association (Pilot study)

Name of WUAs (registered or not)	Irrigation Scheme	Irrigation potential	Irrigation covered	Cropping pattern	Changes in production after formation of WUA	Water charges	Non-utilisation of irrigation potential	year of formation	District & Block & village
kali Mandir PaniUpobhokta Samity	Balilecha Electrical Lift Irrigation Scheme point no 31	5 hectors	2.5 hectors	Mustard, paddy, Rabi crops (vegetables), Jute	no changes in production	no water charges	2.5 hectors	2015	district-Nalbari, Block-Pub Nalbari Block, Vill-Balilecha
LakhimiPaniUpobhokta Samity	Mugkuchhi Deep tube well Irrigation Scheme, Point No-4	53.33 hectors	10.67 hectors	paddy	production increases by 18.5 quintal after formation of WUA	farmers paid Yearly Rs-37.5 per bigha	42.66 hectors	2015	district-Nalbari, Block-Paschim Nalbari Block, Vill-amoniChamata
AmoniPaniUpobhokta Samity	Amoni Electrical Lift Irrigation Scheme	53.5 hectors	13.5 hectors	paddy, water melon, Rabi crops(potato, brinjal, Bhindi)	no changes in production	farmers are not ready to pay	40 hectors	2015	district-Nalbari, Block-Pachim Nalbari Block, Vill-AmoniChamata
kali Mandir PaniUpobhokta Samity	Balilecha Electrical Lift irrigation Schem	8 hectors	6 hectors	Paddy	production increases by 10 quintal after	Yearly Rs-37.5 per bigha	2 hectors	2015	district-Nalbari, Block-Pub Nalbari Block, Vill-BalaMugk

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	e				formation of WUA				uchi
Niz- Banekuchi Water User Association	Banekuchi electrical Lift Irrigation Scheme	80 hectors	49 hectors	paddy, mastard, rabi crops	production of Paddy increases by 11.3 quintal and production of masterd raise by 450 kg per hector	Yearly Rs-37.5 per bigha	31 hectors	2015	district-Nalbari, Block-Pub Nalbari Block, Vill-NizBanekuchi
ShaymasriPaniUpobokta Samity	Mugkuchhi Deep tube well Irrigation Scheme, Point No-3	9 hectors	4 hectors	paddy, mustard, rabi crops	production of Paddy increases by 7 quintal per hector	Yearly Rs-37.5 per bigha	5 hectors	2015	district-Nalbari, Block-Pub Nalbari Block, Vill-Mugkuchi
PaniUpabhokta Samity	Gobaradol Deep tube well Irrigation Scheme	13.3 hectors	6.67 hectors	paddy, mustard	no changes in production	no water charges	6.63 hectors	2015	district-Nalbari, Block-Nalbari Block, Vill-Gobradal
Burinagar Water User Association, Chancharghat	Burinagar ELIS point no 1	100 hectors	on the construction process	Paddy, mustard, potato	no changes in production	no water charges	100 hectors	2015	district-Nalbari, Block-Nalbari Block, Vill-Burinagar

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Ek Number Chowki Bandha PagaliaEk No. group committee (Registration No- 421 of 1981-82)	Uttarkachi FIS, Phase-I	935-1066.67 hectors	935-1066.67 hectors	paddy, mustard, Rabi crops	Production of paddy per hector is around 36- 45 quintals and production of mustard is around 15 -18 quintal per hector.	no water charges from farmers, Rs-200 is collected for not following the rules	0	1982	district-Baska, Block-Nikashi, Vill-Hastinapar

Source-Field Survey data Nalbari district during 2017-18

Table 3 provides detailed information about operational Water User Associations (WUAs) in the Nalbari District, focusing on various aspects such as the names of farmers, WUAs, irrigation schemes, cropping patterns, production changes, water charges, non-utilization of irrigation potential, year of formation, and district, block, and village locations. From the pilot study, the researcher found that most WUAs have significant irrigation potential, but the actual coverage varies, with some covering less than half of their potential due to various reasons such as non-utilization or ongoing construction. The formation of WUAs generally shows mixed results in production changes, with some areas seeing increases while others show no significant change. From Table 3, it was observed that paddy is a common crop across most schemes, with additional crops like mustard, vegetables, and Rabi crops also being cultivated.

There are a few water user associations, namely: Lakhimi Pani Upobhokta Samity (Mugkuchhi Deep Tube Well Irrigation Scheme Point No-4), Kali Mandir Pani Upobhokta Samity (Balilecha Electrical Lift Irrigation Scheme), Niz-Banekuchi Water User Association (Banekuchi Electrical Lift Irrigation Scheme), Shaymasri Pani Upobokta Samity (Mugkuchhi Deep Tube Well Irrigation Scheme, Point No-3), and Ek Number Chowki Bandha Pagalia Ek No. group committee (Uttarkashi FIS, Phase-I) have experienced positive results after the formation of the water user association. During a formal interview with the president and secretary of the WUAs, they said that many causes didn't show fruitful results even after the formation of WUAs. Water charges vary, with some WUAs facing challenges in collecting fees from farmers, and non-utilization of irrigation potential is a prevalent issue across several schemes, indicating potential barriers to full agricultural productivity. Considering all these benefits and constraints, the study recommended developing strategies to maximize irrigation coverage, provide training and support to WUAs to enhance crop productivity and optimize water use efficiency, address challenges related to water charge collection to ensure financial sustainability for WUAs, implement robust monitoring mechanisms to track production changes and ensure effective utilization of irrigation schemes, and promote community participation to improve governance and decision-making within WUAs, ensuring

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long-term sustainability.

Table-4: List of non Operational Water User Association (Pilot study)

Non operational WUAs	Irrigation Scheme	Irrigation potential	Irrigation covered	Cropping pattern	Changes in production after formation of WUA	water Charges	Unutilisation of irrigation potential	Year of formation	District & Block & village
PaniUpobhokta Samity	Buradia Electrical Lift Irrigation Scheme point no3	53.3 hectores	0	paddy	no changes in prouction	no water charges	53.3 hectors	2015	District-Nalbari, Block-paschim Nalbari, Vill-Kashimpur
PaniUpobhokta Samity	Buradia Electrical Lift Irrigation scheme point No 4	80 hectors	0	paddy, rabi crops	no changes in prouction	no water charges	80 hectors	2015	District-Nalbari, Block-paschim Nalbari, Vill-Rupiapathan
Krishi PaniUpobhokta Samity	Buradia Electrical Lift Irrigation scheme point No 1	53.3 hectors	13.33 hectors	paddy, mustard, Rabi crops(all vegetables)	no changes in prouction	no water charges	around 40 hectors	2015	District-Nalbari, Block-paschim Nalbari, Vill-Saplilucchi
BuradiaPaniUpabokta Samity	Buradia Electrical Lift Irrigation	40 hectors	0	paddy, mustard, Jute	no changes in prouction	no water charges	40 hectors	2015	District-Nalbari, Block-paschim Nalbari, Vill-

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	scheme point No2								Kashimpur

Source-Field Survey data Nalbari district during 2016-17

Table 4 provides details about non-operational Water User Associations (WUAs) in the Nalbari District, including the names of farmers, non-operational WUAs, irrigation schemes, irrigation potential, irrigation covered, cropping patterns, changes in production after WUA formation, water charges, non-utilization of irrigation potential, year of formation, and district, block, and village locations. From the pilot study, it was found that although many WUAs have formed, there are some WUAs that are not functional. For example, Buradia Pani Upabokta Samity Point No. 1, Buradia Pani Upabokta Samity Point No. 2, Buradia Pani Upabokta Samity Point No. 3, and Buradia Pani Upabokta Samity Point No. 4 have been dysfunctional since formation. The table provided highlights several key issues faced by these non-operational WUAs, including the lack of community participation, limited financial resources, and inadequate technical and managerial skills. These findings align with existing research, which suggests that community ownership and ongoing support from institutions are critical factors for the sustainability of community-managed water supplies (Bhandari et al., 2005). Harvey & Reed, 2006)

The table indicates that the formation of WUAs in the Nalbari district did not result in any significant changes in agricultural production, despite the potential for increased irrigation coverage. Moreover, the WUAs did not implement any water charges, leading to a lack of financial resources and potentially contributing to the organizations' non-operational status (Bhandari et al., 2005; Douglas & Aloyce, 2018). The limited involvement of the community, particularly women, in the planning and management of these WUAs is a significant barrier to their long-term sustainability (Bhandari et al., 2005; Tisbein et al., 2013). Capacity building and ongoing support from relevant authorities are necessary to empower WUA members and ensure effective decision-making and governance (Douglas & Aloyce, 2018; Harvey & Reed, 2006; Tischbein et al., 2013). The President of the Water User Associations (WUAs) reported uncertainty about water availability, poor leadership quality, poor coordination with local authorities, a lack of canals and tubewells, and insufficient awareness campaigns for farmers. However, this pilot study in Nalbari district found good relations between regional irrigation departments and WUAs. Although WUAs often struggle to submit necessary data, this hinders the successful implementation of irrigation schemes. Investment in canal irrigation takes time, while tank irrigation is managed by user associations.

To address these challenges, policymakers and practitioners should focus on promoting community participation and stakeholders to understand reasons for non-operation and garner support for reactivation efforts, strengthening the financial and managerial capacities of WUAs, and ensuring the provision of technical assistance and monitoring from overseeing institutions (Harvey & Reed, 2006) (Tischbein et al., 2013). Mechanisms for coordination among various stakeholders, such as government agencies, community organizations, and the private sector, can contribute to an enabling environment for the sustainable management of irrigation systems (Maleza & Nishimura, 2007). Capacity building is another crucial aspect of strengthening WUAs to ensure efficient operations and address financial constraints by promoting timely payment of water charges and sustaining WUA operations.

5. Discussion:

This study assesses the effects of water user groups (WUAs) on irrigation and agricultural productivity in Assam, with a particular focus on the Nalbari District. It also attempts to quantify the influence of WUAs on farmers' involvement, overall farming performance, and the efficiency of water distribution. It was observed that

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the success of participatory irrigation management (PIM) varies across Assam. WUAs have the potential to provide significant socio-economic benefits to local farmers, including better water management and increased agricultural output. Some WUAs function effectively, while many struggle due to inadequate training, a lack of resources, and weak institutional support. Many farmers (members of WUAs) have a positive mindset regarding the current schemes and are aware of the importance of PIM schemes for irrigation, which implies a positive correlation between the establishment of WUAs and improvements in irrigation coverage and farming performance. However, farmers urge the expansion of the canal, as the capacity of the channel is not sufficient to fulfill the need for irrigation for the entire area. The study found that these initial results are the tip of the iceberg, and there is a lot to explore. To realize the full potential of WUAs, it is important to address issues like weak institutional support, uncertainty of water availability, collection of water channels, poor coordination with local authorities, repairing of canals and tubewells, infrastructure maintenance, lack of sufficient awareness campaigns, training for the farmers along with strong organizational structures, and consistent support from government agencies. The study recommends continuous policy reforms, updates, and enhancements of community participation to address the evolving challenges in PIM. Implement regular monitoring and evaluation mechanisms to identify issues promptly, address them effectively, and enhance the effectiveness of WUAs in Assam. The study highlights the importance of proper water resource allocation for feeding the population, meeting the requirements of agriculture, and other purposes. There is also a need to speed up the construction of canals, ensure better involvement of stockholders in the management and maintenance of the schemes, spread awareness in the rural part of the state where communication is the main hindrance, and make them join in the various water user associations.

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