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Studies of farmer-managed irrigation systems in Nepal in the 1980s documented the potential of farmers to use sophisticated technical and organizational practices to manage water. In the 40 years since the first studies, population growth, migration, urbanization, new transport networks, and technological change have brought dramatic change in rural communities. This paper reports on the functioning of six irrigation systems in the wake of these changes, based on a series of studies over the years, including a revisit to these systems in 2022.

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I. INTRODUCTION

Studies of irrigation have established that there are many long-enduring farmer-managed irrigation systems (FMIS), some of which are centuries old. In some cases these were built by the State or external benefactors; in other cases by the farmers themselves, but the defining characteristic of FMIS is that the irrigators have primary decision-making authority and responsibility for operation and maintenance of their systems. In the 1980s, detailed studies of FMIS in Nepal by Robert Yoder, Edward Martin and Prachanda Pradhan[1] challenged the prevalent notions that irrigation required substantial centralized control [Wittfogel 1957]. Their studies of hill irrigation systems in the villages of Argali and Chherlung of Palpa District and the Chhattis Mauja system of Butwal, in the terai (lowlands) Rupandehi District[2] demonstrated a wide range of local innovations in developing and managing irrigation systems with sophisticated hydrologic knowledge and management practices.

These were key studies in shaping understanding of the potential for self-governance of irrigation systems, such as Elinor Ostrom's [1990] Governing the Commons. The diversity of water rights systems that farmers had developed, and how water rights were linked to past investments and ongoing responsibilities laid the foundation for understanding of hydraulic property [Coward 1986]. But few studies have examined how FMIS have persisted in the face of contemporary transformations of rural society [Bastakoti.et.al. 2010]. In the four decades since the first studies of these systems in Nepal, there have been profound demographic, economic and technological changes in rural Nepal. How have these forces affected the irrigation, and how have these systems adapted?

This paper presents a unique combination of first-hand observations by researchers who have studied these systems repeatedly over forty years, along with a review of other studies, to identify how they have adapted in response to key changes, particularly urbanization, migration, changing gender roles, and technological change.

We begin with a brief description of our six case study sites and our methods. We then provide a broad history of the evolution of the systems and their water rights, followed by observations on

[1] Robert Yoder, an irrigation engineer and Ed Martin, an agricultural economist, spent 18 months studying the socio-institutional and physical aspects that have enabled irrigation success, as part of their Ph.D. dissertations in Cornell University.

[2] In the early 1980s, Prachanda Pradhan studied the organization and institutions used by the Chhattis Mauja farmers to manage a much larger *terai* system.

London Journal of Research in Humanities and Social Sciences

how urbanization, migration, physical infrastructure, markets and technological changes have affected them.

II. STUDY SITES

All our case studies are of surface irrigation systems diverting water from a river or stream, with open canals to bring water—often over long distances—to the command area.

In Argali, the Raj (royal) Kulo (canal) of 48 ha command area was constructed under the patronage of King Mani Mukunda Sen of Palpa about 400 years ago. This system is situated on a river terrace of the Kali Gandaki River. Argali's irrigation water is diverted from the Kurung stream and conveyed by canal to the command area. In several sections there are short stretches of tunnel to avoid the difficult, unstable slopes of the hill. [Yoder 1986; Martin 1986].

The Chherlung Irrigation systems were constructed in the 1930s and are called Thulo (large) Kulo of 40 ha command area and Tallo (lower, relative to intake) Kulo of 46 ha command area. Their source of water is the Bargandi stream. Both canals were constructed a few years apart, serving different command areas. Construction was undertaken by different ethnic groups of Chherlung village. They represent innovative construction management, water rights, water allocation and water distribution methods [Yoder 1986; Martin 1986; Pradhan 2010].

The Chhattis Mauja ("36 Villages") irrigation system is about 170 years old with a command area of over 3500 ha, one of the largest farmer-built and managed systems in Nepal. It diverts water from the Tinau River in the city of Butwal into the gently sloping land of the terai. The Tinau River is a calm stream in the dry season but often floods during the monsoon, requiring frequent canal intake maintenance during paddy cultivation season. The Chhattis Mauja system was constructed by households in Kumari village; the canal was built through the forested jungle to their village. As new settlers, mostly from hill areas of Nepal, moved in and removed the forest, Kumari village became the tail end of the system. When the research on this system began in the early 1980s, there was an elaborate four-tier organizational hierarchy to manage canal maintenance[Pradhan 1983; 2012]. A more detailed study of the system was carried out by the International Water Management Institute (IWMI) in the late 1980s that included measurement of how accurately the allocated shares of available water were delivered to each village unit [Yoder 1994].

The Andhi Khola Project was conceived as a hydropower project designed to feed into the national grid. When it was proposed for funding, donors indicated that they would not be interested in the project unless the local community also directly benefits [Liechty 2022]. As a result, the hydropower project was revised to include a community development component with an agreement that some percentage of the water diverted to the project would be reserved for hydropower and community development that made irrigation became the primary community activity. Robert Yoder, Ed Martin and Prachanda Pradhan were invited by the United Mission in Nepal to provide suggestions for the design of the irrigation system that would ensure that the largest possible number of project-affected households would benefit [Pradhan 1985; Van Etten et al. 2002].[1]

The Kallaritar Irrigation System of 120 ha. in Dhading district was constructed by the government with fund provided by Asian Development Bank in the late 1980s, with management responsibility given to the water users' association (WUA). It has an 11 km long canal from the intake to the command area. The command area has three sections, called: Ghartitar, Phosretar, and Kalleritar. A specified length of the main canal is allocated to each section for maintenance. Each section decides its own mechanism for allocating labor for its share of the maintenance [Brabben 2004; Pradhan et al. 2015]. A third party is hired to distribute the irrigation water during the paddy season, to match the established water allocation allotment for each farmer's field.

[1] Ornella, Sissa Jupiate, 2019, Male Migration and Feminization in Nepal: Bane or Boon. MSc. Thesis, Utrecht, Utrecht University

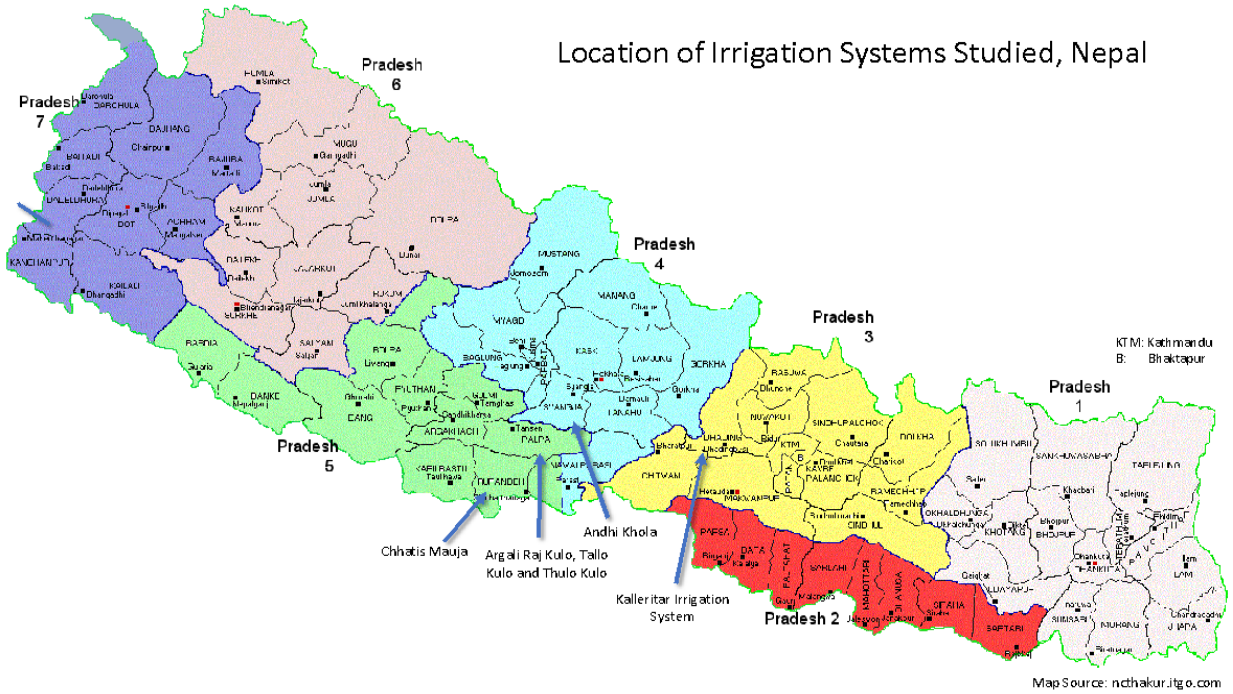

Figure 1: Location map of the systems

Table 1: Key features of case study irrigation systems

System Name	Argeli Raj Kulo	Chherlung Thulo Kulo and Tallo Kulo	Chhatis Mauja	Andhi Khola	Kallaritar
District	Palpa	Palpa	Rupandehi	Syangja	Dhadang
Hill or Terai	Hill	Hill	Terai (plains)	Hill	Hill
(Approximate) age	400 years	90 years	170 years	24 years	35 years
Constructed by	King	Farmers	Farmers	Development project	Government and ADB
Command area	48 ha during paddy season; almost twice as much in winter	Thulo Kulo 40 ha Tallo Kulo 46 ha	>3500 ha	280 ha	120 ha

Water rights	Primary (Barkhe) and secondary (Heude) water rights	Tradable shares based on original cash and labor investment	Based on shares each village holds, Labor contribution based on water share	Shares based on original labor investment	Shares proportional to land
Notable features	Self-managed system, linked with highway	Self-managed system, linked with highway	Built by and serves 36 (now 58) villages; major urbanization of Butwal	Nexus arrangement between hydropower and irrigation project	WUA allocates water and appoints separate group for water distribution

III. METHODS

Though the study of these systems started over forty years ago, the researchers continued to periodically visit and observe adaptation and changes. In 1994, IWMI published a study of Chhattis Mauja system [Yoder 1994]. In 2006, Pradhan, Yoder and Martin visited the Argali and Chherlung systems to compare the cropping pattern and yields between the 1980s and 2006 [Pradhan et al. 2007]. Similarly, Pradhan studied the community mill established in Thulo Kulo in Chherlung [Pradhan 2010]. Argali, Chhattis Mauja and Kalleritar irrigation systems included in two rounds of study (in 2010 and 2019) on changing women's roles in irrigation governance due to male out-migration and the impact of mechanization on agriculture activities [Pradhan et al. 2015; Meinzen-Dick et al. 2022]. The Andhi Khola system was studied under Pradhan's supervision by numerous M.Sc. and Ph.D. students. In late 2020, the International Center for Integrated Mountain Development (ICIMOD) sponsored a study of the hydropower and irrigation trade-off in the Andhi Khola project [Pradhan et al. 2018]. All these studies used a mixture of different methodologies, including qualitative interviews, in-person and telephone surveys, participant observation and hydrologic measurements. We draw on all these previous studies plus a revisit to all six systems in March 2022, when three of the coauthors of this study were able to meet with leaders of the systems and others whom they had known from previous studies and carry out direct observations of portions of the irrigation infrastructure.

We consider irrigation systems as socio-ecological systems (SESs) composed of biophysical and social components where individuals have self-consciously invested time and effort in developing an institutional infrastructure, and, in some cases, such as irrigation systems, are also physical infrastructures [Ostrom 2009].

Irrigation systems have multiple dimensions in their operations, and they change roles and functions over time in response to internal and external influences [Aubriot 2022]. Observations over the 40-year timespan have enabled a qualitative analysis of their adaptation to socio-ecological changes.

IV. EVOLUTION AND ADAPTATION OF WATER USERS' ASSOCIATIONS

Irrigation development in Nepal has traditionally been the community's responsibility. An edict issued by king Ram Saha (1666-1693) states:

...let the local water conflict issues be settled at the community level [Riccardi 1977].

Similarly, the National Statute of 1854, promulgated by Jung Bahadur, stated that irrigation systems can be constructed by the people, and no one is allowed to construct above an existing canal in any way that would disturb the water supply to the existing one.

The 1992 Water Resources Act declared that water is national property, a major change from previous laws and customs. Anyone wishing to access water requires a license from the government, which allows for private investment in irrigation development. The 1992 Act, however, also provides that customary law and practices will not be disturbed by the Water Resources Act. Hence, existing water rights in FMIS have continued, with one exception: the Act set out the order of priority, with drinking water as the highest priority. Due to population growth, the demand for drinking water has increased.

The World Bank made it a condition for a 1989 Irrigation Line of Credit that a WUA be formed before assistance is provided to an irrigation system, whether farmer-managed or government-managed. The Nepal government agreed to help form WUAs and register them under the 1975 Association Act. The 1992 Water Resources Act provided that irrigators' water right be registered in the District Water Resources Committee. This was made mandatory for all irrigation systems seeking financial assistance from a donor or from the government. The 2008 Irrigation Regulation and subsequent amendments allowed Irrigation Department and Cooperative Department to register WUAs.

Both Argali and Chherlung irrigation systems have had some form of WUA throughout their existence. In local terms, the committee responsible for irrigation management is called the "Kule Bhai" (community of irrigators). The Kule Bhai, like a family, need to manage the affairs of the irrigators to ensure that maintenance is carried out and water is delivered properly to the entire user group. In both, this traditional WUA continues to oversee operation and maintenance. The old terms are still used, and old practices still followed, such as Mukhiya and Baidar. The Mukhiya is the head of the irrigation system and makes decisions for the management of the Argali Irrigation System. The Baidar is the record keeper who keeps records on land and labor contributions from each landholder at the annual canal maintenance. A similar term is used for irrigation officials in Chherlung Thulo and Tallo Irrigation systems. The Argali system has an annual meeting of irrigators on the first day of Jestha (the Nepali month that falls in May\June) where major management decisions are made, including the selection or continuation of irrigation officials like the Mukhiya and Baidar. With the requirement to register WUAs, new terms like Chairman, Secretary and Treasurer are also used. It is compulsory for the members to be present at the Jestha (May-June) meeting.

After the Raj Kulo physical systems in Argali and the Chherlung systems were strengthened through successive investments, some new practices emerged, and some old practices were abandoned. Some routine practices, such as daily patrols of the canal to correct minor problems in both Argali and Chherlung, have been abandoned because the structures are now strong and stable. There is very little leakage, so daily patrolling of canals is unnecessary. Traditionally, women were not allowed to participate in the maintenance of the system in Argali; now, they are allowed to participate. In both Argali and Chherlung, over a third of the irrigation system Executive Committee members are women.

Both systems have defined irrigation water as community property. Membership of the community is defined by the investment during construction of the systems. This implies that all water related activities are to be decided collectively. Benefits and costs are shared collectively.

The Andhi Khola WUA was established under the Association Act in 1984. It was the first WUA registered at the Chief District Office of Syangja. Its management team was already organized in 1982 and worked together for many years before the canal became fully operational in 1998. The WUA was initiated by first getting farmers in the command area to discuss and determine how a WUA would function. They had to convince all the potential members on the idea of water shares and how they would be distributed to the entire area influenced by the project.

The Andhi Khola WUA (AKWUA) supervises annual maintenance of the system by the irrigators. The executive committee has four

London Journal of Research in Humanities and Social Sciences

women members out of the thirteen seats. The Andhi Khola hydropower component contributes about NRs. 400,000 annually to the operation of the system; and the District Irrigation office in Syangja has also provided some financial support. Major rehabilitation of some of the canals was undertaken with World Bank support.

Kalleritar Irrigation System initiated its WUA in 1994. At that time, it was registered under the Association Act. Later, it was also registered with the Irrigation Regulation in the District Irrigation Office of the District Headquarters. Annual operation and maintenance are undertaken by the WUA. The delivery canal is 11 km long and water leaks became serious enough to cause water shortages in the command area. Hence, they obtained a grant for repair of the canal annually.

Chhattis Mauja has a 3500-ha command area spread over 58 villages (mauja) at present. It has a four-tier irrigation organization: mauja WUAs, Regional WUAs, a Central Committee, a General Assembly, and a joint committee between Soraha and Chhattis Irrigation system [Yoder 1994, Appendix1: 105-110]. Chhattis Mauja has (a) a supportive policy, regulatory and legal environment that recognizes the irrigation community's water right, (b) a capacity to mobilize resources for O&M, (c) benefits exceed the costs of participation, and (d) an effective collective choice arrangement [Merrey 1996].

These six irrigation systems have survived, even thrived, for many years as self-governing, self-supporting systems. A decade long Maoist insurgency (1996-2006) brought many socio-political and cultural changes, yet these WUAs learned to adapt to the challenges and were able to maintain the irrigation systems' productivity.

They are governed and managed by the irrigators themselves through their representatives, selected for specific periods of time. Their general assemblies approve rules, regulations, and policies, and a workplan which is implemented by the executive committee. The executive committee members are accountable to the general assembly. Adherence to the rules and regulations is collectively supervised and punishment for non-compliance is decided collectively.

V. WATER RIGHTS AND OBLIGATIONS

The early studies of FMIS were groundbreaking in showing the variety of ways that communities had identified to allocate water rights and corresponding obligations for system construction, operation, and maintenance. Each of the irrigation systems discussed in this review uses a different method to allocate its limited irrigation water among members' farms.

In Argali, the Raj Kulo command area has some members with primary and others with secondary water rights. The canal was originally built for paddy irrigation. Presently, landowners with fields that were leveled for paddy cultivation long ago are entitled to the primary right (Barkhe pani) to use all the available water during the monsoon paddy growing season. Owners of nearly double the Raj Kulo's command have secondary water rights for winter crops (Hiude pani). Secondary right holders with fields downstream can use excess drainage water from the Raj Kulo also to grow paddy. In a dry year, when water supply is insufficient for continuous irrigation to all fields, primary water right holders switch from continuous irrigation to timed rotation based on the size of a farmer's plot as a percentage of the entire land area designated for primary rights holders. In such periods, secondary right holders get little or no water. The record keeper of Argali WUA establishes a water delivery schedule to rotated deliveries among the system's many branch canals. During the non-rice growing season, much less canal maintenance is required; it becomes the responsibility for those whose turn it is to irrigate to attend to the maintenance.

Since the 1980s, Raj Kulo infrastructure improvements, especially 2002/3 canal rehabilitation with financial support from the World Bank, have made water delivery very reliable, enabling a more diverse cropping pattern. The primary/secondary water rights have not changed, but excess water in the paddy growing period has increased and can be used

more effectively by the downstream secondary rights holders.

In Chherlung, water rights in both Thulo and Tallo Kulo are obtained by purchasing a share. The initial investment to build the Thulo canal was a payment made in 1928 to a contactor in the amount of NP Rs. 5000 plus 0.12 ha of land in the planned command area. The total investment cost for the canal by the time the first water was delivered was NP Rs. 5500 [Yoder 1986]. To share the water equitably among the contributing investors, a weir was installed in the canal just above the fields. The total opening in the weir was 50 inches, with each inch of opening representing NP Rs 100 investment. The opening for a famer who invested 100 Rs was one inch wide, and for Rs 500 investment five inches wide. The water from each individual opening is delivered to that farmer's field by a smaller canal which that farmer is responsible to maintain.

As the canal was improved and enlarged, the water supply became more than sufficient for the farmers who had invested the most to build the canal in 1933. Farmers who initially were skeptical that a seven km-long canal could be successfully built, offered to purchase a share of the water from those who had excess. The irrigation members agreed that adding members would help reduce each farmer's responsibility for the cash and labor necessary to maintain the canal and came up with the idea of selling shares of the water based on their initial investment. They established a system whereby anyone in the command area of the canal could purchase a share of water from any other farmer with irrigation rights in the canal that is willing to sell some of his/her share. The transaction is between the two farmers but also requires changing the number and size of openings in the proportioning weirs. They have now developed a system of share certificates for each irrigation member with a copy for the system WUA management which keeps the records.

Because of the ability to purchase and sell water rights, the irrigation system that was initiated by only a small group of farmers has, during the intervening years, spread irrigation access to every farm with land within the canal's command.

Chherlung irrigation water is now considered to be community property, but the water share owners have the right to use the water. Maintaining and managing the canal requires collective effort that is governed by the rules and regulations laid down by the WUA general assembly. In Thulo Kulo, after much deliberation, the WUA decided to install a community-owned mill powered by the irrigation water and managed by the WUA. The money earned was used to pay the loan taken to install the mill and is now used to strengthen and maintain the canal. With the electric grid connected to the village, there are now small electric mills in the community, but the hydro-powered mill still operates during the irrigation season.

In Chhattis Mauja, water rights and responsibilities of each of the 58 maujas are based on the number of kulara (shares) that each village holds. One kulara is equivalent to 17.5 ha. irrigated area. Kulara determine the number of votes that a mauja has at a meeting and determines both the number of persons that need to respond to a call for labor to maintain the main canal and how much water the mauja will receive. Each mauja, as far as possible, has a dedicated secondary canal from the main canal. The outlet size to the mauja is fixed according to each village's kulara. Depending on the water requirements in the mauja, the number of kulara can be increased or decreased and the outlet is then adjusted accordingly. The mauja manages the labor for kulara contributions when called for by the WUA and record is kept by the supervisor (Meth Muktiyar) of Chhatis Mauja.

Some sections of Chhattis Mauja are also part of Nepal's Lumbini-Bhairhawa Groundwater Project. Those mauja requested that their kulara (water share and contributions) be reduced. Similarly, Kumari village, which originally initiated building the canal, now receive enough seepage water from upstream irrigators that they don't need much canal water to meet their needs, so they only send nominal kulara to retain their membership in the system.

The Andhi Khola irrigation system was conceived in the 1980s as a pro-poor irrigation system, with water considered as the intervening factor for poverty reduction. To address poverty, the project designers made a clear separation between land and irrigation water. Inspired in part by Chherlung's Thulo Kulo, Andhi Khola water shares could only be obtained by contributing labor during construction of the irrigation system. Each landholder within the project area that contributed labor received a water share based on labor contribution. Also, landholders within the irrigated area with larger land holdings than estimated to be necessary for subsistence[2] were required to sell up to 10% of their land to the Andhi Khola WUA, which paid the owners the market price for the land. By this process, the Association collected 12 ha of land by 1999; this was distributed to 53 out of 137 applicants that were either landless or marginal farmers. Each family member in the command area owns at least 10 units of water shares.

Based on the project agreement, for the rice growing season, June to October, 642 liters/second of water is diverted from the headrace tunnel of the hydro project to the irrigation system. With this discharge in the main canal, the water per share was calculated to be 0.025 liters per second requiring 80 shares to achieve the expected 2 liters per second to irrigate a hector of rice. For the remainder of the year water delivery from the hydro project is reduced to 300 liters/second since wheat, maize and other crops grown in this period require about half as much water as rice. The WUA considers the inflow to the irrigation system as 25,000 units of water shares to be distributed to all parts of the defined project area. Shareholders who earned more shares from their labor working on the irrigation system construction than they had land to irrigate are free to sell their shares to households with more land than their construction labor-earned water allotment would cover.

Kalleritar Irrigation system has focused on paddy cultivation. The canal bringing water from the source is about 11 km from the command area. All the water users are required to contribute to maintenance of the physical infrastructure of the system. During paddy plantation time, a water distribution schedule is prepared for each tar (river terrace) by the WUA. Each tar appoints a person to distribute water according to the schedule agreed by the farmers at a WUA meeting.

VI. PHYSICAL IMPROVEMENTS RESULTING IN CHANGES IN RULES AND ROLES

All six irrigation systems have gone through major physical rehabilitations that improved difficult and weak sections of the channels. Argali's Raj Kulo received financial support for rehabilitation from various sources, including the World Bank and District Irrigation Office.

Chherlung Irrigation systems, with their own and some government funds, improved their canals by repairing leaks and rebuilding the canal through landslide prone areas. Similarly, Chhattis Mauja received funds from the Rupendahi District Irrigation Office to improve the structure.

The Butwal Power Company has provided funds to the Andhi Khola irrigation system for annual maintenance; and the World Bank has funded improvements in the physical infrastructure.

The 2015 earthquake in Nepal caused major damage to the Kalleritar irrigation system. Subsequently, earthquake reconstruction funds enabled rehabilitation of the entire system. This made the physical structures much stronger and cheaper to maintain [Liebrand 2019.

Whereas previously women and Dalits (low caste groups) were not allowed to participate in the maintenance work in all irrigation systems because they might ritually pollute the water, these restrictions have been dropped in all of our case study areas. Where males have migrated out

[2] Based upon a socio-economic survey report of families living in the area planned are for irrigation, food production for subsistence was estimated to require 0.036 ha of irrigated land or 0.25 ha of rainfed land per person. See Poppe, Joy, 1982, Socio-Economic Survey Report, Andhi Khola Project, Kathmandu: United Mission to Nepal.

for employment leaving women to manage farms, the women can pay cash instead of providing labor for maintenance. Women have played roles to influence WUA decisions in their favor, such as paying cash rather than contributing labor for maintenance by male out migrated households [Meinzen-Dick et al. 2022].

VII. ROAD ACCESS AND URBANIZATION

The road network in Nepal has expanded dramatically. Forty years ago, Argali and Chherlung were isolated hill villages, up to several hours' walk from the nearest market town. Argali is now served by the Tansen-Tamghas highway and linked by the Kaligandaki corridor to Mustang, as is Chherlung, enabling the sale of agricultural produce either to Gulmi District or to the large Butwal market center and to the northern districts. Andhi Khola is also connected to markets by the Sunauli-Pokhara Highway and Kali Gandaki Corridor. Kalleritar Irrigation system now has access to a road via a new vehicle bridge across the Trishuli River, linking it to markets along the road and in Kathmandu.

The effects of road expansion are even more dramatic in Chhattis Mauja, which is in Butwal and Tilottama Municipalities, located near the crossroad of two major roads, the East-West and Sunauli-Pokhara highways. The Butwal-Bhairawa corridor is an industrial area and young people can easily find employment. Many rural youths have out-migrated and many of those who remain are not attracted to agriculture. It is mostly the older generation who are engaged in agriculture in the Chhattis Mauja system.

Land values have risen tremendously, making the sale of land plots for housing attractive. By selling their land and putting the money in the bank, the annual interest from the cash deposits brings more income than they could earn from agriculture production. Within the command area, urbanization has taken place especially in the head end. Solid waste and household wastewater are dumped in the irrigation canals, polluting the water and blocking flows. However, because urban residents are not involved in irrigation management, they are not concerned about the problems this generates for the irrigators.

VIII. OUT-MIGRATION, CHANGING GENDER RELATIONSHIPS, AND IMPACTS OF AGRICULTURAL MECHANIZATION

By 2010-2011 over half of Nepali households had at least one migrant, either within Nepal or internationally [NCBS 2011]. Among our sites, migration is most prevalent in Argali. Of the previous 500-600 households in Argali, many men have migrated for the long term to the Indian Army or short-term employment in India, or to other parts of Nepal. There are also students who go out for higher education and a few go to the Middle East. There is therefore frequently a shortage of manpower for agricultural and irrigation activities; hence, women must take care of agricultural and irrigation activities.

Partial mechanization has enabled getting rid of oxen which were expensive to keep because of fodder requirements and reduced the burden of agricultural activities for women. The Irrigation Policy and WUAs encourage women to undertake winter vegetable cultivation to earn more, and the "paicho pasal" (Cooperative Shops) have become outlets for the sale of vegetable products and also access to seeds and fertilizer.

In Chhattis Mauja, out-migration for employment has caused a labor shortage which is largely met by mechanization. One alternative is to hire labor from other districts; another is to rent out the land on fixed rent or through share cropping. The big landholders tend to prefer mechanization. Smallholders depend on hired laborers of landless or small farmers who come in groups from adjoining districts.

Another important source of agricultural labor used to be the parma system of labor exchange among households, but it is no longer practiced in Chhattis Mauja or many in other systems. As a result agricultural activities are now primarily based on cash payment. Remittances have also played an important role in the monetization of irrigated agricultural activities in Nepal.

While out-migration has caused labor shortages, in many cases, a supply of labor may be available from adjoining districts. An agriculture-specialized labor force has emerged. Landowners contact such groups, especially for paddy cultivation. Gangs of laborers come to do land preparation, planting, weeding, and harvesting. In such cases, the role of women has become that of managing of laborers, reducing their burden of agricultural activities. The telephone has become an effective means for them to mobilize laborer gangs.

In Andhi Khola, it was reported that out-migration has declined considerably since the irrigation system was built. Irrigation water is easily available for three crops. Women report that their involvement in agricultural activities has increased due to the increase in cropping intensity.

A recent study of 336 WUAs by phone interview and 10 detailed case studies, including Argali, Chhattis Mauja and Kallaritar [Meinzen-Dick et al. 2022], found a range of responses to male migration. This included adapting WUA rules to allow for women's participation, and to monetize the contributions for maintenance or even contract out some of the major maintenance.

IX. ROLE OF NEW TECHNOLOGY

Forty years ago, draft animals were used for ploughing and land preparation. Now, particularly in the terai, some farmers own tractors and most communities have tractors available to rent for plowing and land preparation. In the hill systems, where plots are small, engine-powered tillers are widely used for land preparation.

The use of tractors and tillers has changed livestock raising practices. Since bullocks are no longer needed for plowing, they have been removed from most farms. Fodder collection, mostly done by women, has either been reduced or shifted to raising additional milk cows or buffalo to increase milk production.

All the communities have been connected to the national electric grid and the mobile phone system. Communication with family members who have moved to other areas or are working abroad keeps families connected.

X. CONCLUSIONS

A common feature across these cases is that maintaining and managing the canal remains a collective effort. Our study of these irrigation systems demonstrates the truth of Uphoff's [2006:387] observation that FMIS in Nepal.

… are not static entities, rather they are dynamic systems which are influenced for change both by internal and external factors.

The following are the most salient changes we observed in these six irrigation systems:

- The systems have been experiencing the impacts of urbanization. For example, the upstream area of the Chhattis Mauja canal is now an urban settlement. Due to the lack of control by the municipality, solid waste and sewage from households enters the canal, essentially turning the canal into a sewer. Here one sees a conflict between the jurisdictions of the local Municipality of Butwal and that of the Chhattis Mauja WUA.
- Out-migration of young people, changes in gender relationships, and impacts of agricultural mechanization have resulted in major changes across the six systems, with women assuming larger roles in some sites, and mechanization used to reduce labor burdens for system maintenance and agricultural production.
- Technological change and road networks connecting these systems have led to changes in agriculture practices and cropping patterns.

Despite these changes, the WUAs on all six systems have adapted and are still functioning as self-organized and self-regulating multi-tier organizations. If they continue as self-governing systems and self-regulating systems, they will be able to continue adapting and providing services for the next several decades.

An important strength of FMIS is their flexibility in rule formulation and implementation. For example, Chherlung introduced tradable water

shares. Andhi Khola at construction gave everyone water shares based on their contribution to construction and regardless of their landholding and included a hydropower system providing power to the community, thus integrating energy, food, water and poverty alleviation.

In analyzing the irrigation systems in the Nepal Irrigation Institution Systems (NIIS) database and other systems, Pokhrel [2016) concluded that the FMIS were able to continue because of inherent attributes, such as flexible rules and flexible rule enforcement. Their flexible governance has resulted in farmers perceiving fairness in rule enforcement and irrigation system governance. A longitudinal study of the performance of irrigation systems in the Indrawati River Basin found that those systems based on the consensus of large numbers of the members continued to survive during period of political uncertainties [Ostrom et al. 2011).

Argali, Chherlung and Chhattis Mauja have served as training centers under a pioneering Farmer-to-Farmer Training program [Pradhan and Yoder 1989]. In 1981, The World Bank provided financial assistance for irrigation system construction or rehabilitation. The researchers working at Argali, Chherlung and Chhattis Mauja facilitated visits from farmers in the new or rehabilitated systems to the three self-managed systems for direct interactions between the guest and host system farmers. The guest farmers asked many questions; the direct exposure to these systems' management gave the guest farmers the feeling that, "if they can do it, why not we?" Since then, the Institution Development Division of Department of Water Resources and Irrigation has adopted F-F training as a way to strengthen the capacity of farmers to manage irrigation systems, and these systems continue to host field visits.

Policymakers and researchers can continue to learn a lot about social transformations from these irrigation systems. They have not only successfully adapted to multiple changes occurring in rural areas but have pioneered farmer-to-farmer training programs for both other farmer-managed systems and for government irrigation schemes. The concept has been extended to other countries, including Pakistan, Nigeria and Bhutan. When the authors began their research careers 40 years ago, farmer managed-irrigation systems were not even recognized by the Government; they were perceived as "informal", inefficient, and unproductive. The consistent and quality research carried out by the authors and others has helped the Government and donors to recognize their importance for food production, job creation, and poverty alleviation.

Finally, as Liebrand [2019] observes in an otherwise critical review of the history of research on FMIS, the multiple researchers who have studied these systems over the past 40 years have demonstrated the potential for high-quality in-depth qualitative case studies to yield important insights into the realities of irrigation at local levels and to influence government policies. We believe that the new generation of researchers will continue this tradition, not only in Nepal or even Asia, but in Africa, where irrigation as practices are highly diverse.

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