Migration and Gender Dynamics of Irrigation Governance in Nepal

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Abstract

Nepal has a long history of irrigation, including government and farmer-managed irrigation systems that are labor- and skill-intensive. Widespread male migration has important effects on Nepalese society. How institutions such as Water Users' Associations (WUAs) respond and adapt, is therefore critical to the understanding of rural transformation and the likely impact on gender equality, food production, and rural livelihoods. This paper examines the effects of male migration on institutional change in WUAs, women's roles, technological change, and outcomes affecting effectiveness of irrigation systems based on a mixed methods study, combining a phone survey of 336 WUA leaders from all provinces in Nepal with qualitative data from case studies in 10 irrigation systems. Results indicate WUAs have adapted rules to increase women's participation, and to monetize the contributions for maintenance. Women exercise agency in whether and how to interact with WUAs. Mechanization has reduced the need for some male labor, though the ability to mechanize is limited by hilly terrain and small plot sizes. Overall, systems are adapting to male migration, with relatively low idling of land or labor shortages causing deterioration of the systems, though there are concerns with the high levels of women's labor burdens.

Introduction

Background and motivation

Nepal has a long history of irrigation, including not only government-built and -managed systems, but also a long history and widespread presence of farmer-managed irrigation systems (Martin and Yoder 1986; Paudel 1986; Joshi 2018) Many of these irrigation systems are both labor- and skill-intensive, in the operation and maintenance of both the physical infrastructure of the system and the organizational infrastructure of Water Users' Associations (WUAs) that is involved in delivering water from the source to farmers' fields (Benjamin et al. 1994; Lam 1998; Ostrom 2009, Pradhan 1989, Shivakoti and Ostrom 2002). While the features of irrigation systems differ according to the location of the systems and the technology, there are common tasks for irrigation systems, including those related to the physical infrastructure (design, construction, operation and maintenance), water use (acquisition, allocation, distribution and drainage), and organizational activities (decision making, resource mobilization, communication and conflict management) (Uphoff 1986; Yoder 1994).

Both the governance and management of irrigation systems in Nepal have historically been male domains (Ghimire 2008; Udas 2014). This reflects a combination of factors, both normative and practical. Patriarchal norms that define public decision-making spaces as male, notions that the heavy

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labor involved in building or repairing irrigation structures, and concepts that menstruating women would ritually or physically pollute the water combine with the practical difficulties of women finding time away from household chores to attend meetings or to travel long distances to work on irrigation canals to restrict women's participation in irrigation (Suhardiman et al., under review).

Government policies have encouraged greater women's participation both generally and particularly in the irrigation sector. The Irrigation Policy of 1992 required at least 20 percent women on the Executive Committee of all WUAs, which increased to 33 percent in the amended Irrigation Policy of 2003 (Goodrich et al. 2017). Although these provisions were not necessarily enforced, traditional limited roles of women in irrigation have also changed as a result of the introduction of new technologies like separate drinking water systems in the villages, cell phones that facilitate communication, and women learning new skills like bicycling to negotiate long distance for irrigation maintenance and exchanging agriculture products in the market, and broader social changes stemming from numerous factors, including women's empowerment through government and NGO programs, education, and exposure to outsiders through media and migration.

Widespread male migration from rural areas is a major force shaping agrarian transformation in Nepal (Adhikari and Hobley 2015; Gartaula, Niehof and Visser 2010; Maharajan, Siegfried and Knerr 2013; Slavchevska et al. 2020; Sugden et al. 2021; Thieme and Wyss 2005). This includes migration to the Gulf countries and Malaysia, which is relatively long-term (several years), international migration to India, which is often shorter-term, and migration within Nepal, especially to urban areas, with greater possibilities to return for festivals or even peak agricultural work seasons.

The 2010-2011 Nepal Living Standards Survey (NLSS) (NCBS 2011) estimates that 53% of households had at least one migrant, either within Nepal or internationally, and estimated total remittances as 259 billion NPR (about 2.61 billion USD), eight times as much as the total in 1995 in real terms. Of total remittances received by households, overseas remittances grew from 55% in 1995 to 80% in 2010. The proportion of households who received remittances also increased from 23% to 56% during the same period. Among remittance-receiving households, about 27–35% of their income came from remittances. The International Organization for Migration (IOM 2019) estimates that remittance flows were 25.4 percent of GDP (compared to 0.8% for foreign direct investment, or 5 percent from official development assistance).

Male migration has important effects on many facets of the physical, social, and institutional landscape in Nepalese society. One particularly important area affected is the governance and management of local public goods, especially irrigation systems. In a study of 118 irrigation systems in Nepal, China, Colombia and Thailand, Cárdenas et al. (2017) found that greater integration of the systems in the broader economy decreased contributions to public goods in the presence of collective risks. This raises important questions about how irrigation management changes with male migration, and what consequences this has for the performance of irrigation systems.[2] The resilience of systems to the effects of male migration is likely to depend on whether (and how) the men's contributions to the system are met. This highlights the importance of understanding how WUAs' organizational functioning evolves, internal and external factors driving the evolution process, the extent of technical and

[2] The data for this study was collected before COVID-19 prompted the return of many migrants. However, many of the changes in irrigation system management are long-term, and continue as migration patterns resume in the wake of the COVID-19 returns.

institutional innovation, and the outcomes in terms of system functioning. Given the crucial role of irrigation in agricultural productivity and food security (Khanal and Pradhan 2021) and concerns about the effects of male migration on reducing agricultural production (Tamang, Paudel and Shrestha 2014), attention to gender in irrigation governance is not only necessary for existing systems, but also for sustainable and inclusive development (Malla 2018).

Conceptual framework

To assess how male migration may affect irrigation system performance, it is important to consider the major aspects of (male) farmers' roles in the irrigation systems, and the key contributions that allow the systems to deliver water to the fields. Most prominent among these are the labor, cash, and in-kind contributions for construction or maintenance of systems (Sah et al 1998), which represent a substantial investment by farmers, especially in farmer-managed irrigation systems (FMIS). Less obvious, but still very important, contributions are the knowledge and decision-making in governance which keep the systems functioning.

The configurations of contributions and the decisions to be made are shaped by the technology. Mountain or hill irrigation systems are often run of river systems with a diversion weir and open canals or small aqueducts bringing the water long distances by gravity, which generally require detailed knowledge of the topography and regular mobilization of labor and resources for maintenance, as they are vulnerable to landslides and earthquakes. Where diversion weirs, canals, and aqueducts are made of brush, stones, or local materials, replacing them with concrete infrastructure may reduce the need for maintenance and replacement (Ostrom 2002). Systems in the Terai plains may be larger surface systems, or include lift irrigation, requiring energy for pumping and maintenance of equipment.

How these changes in governance, contributions, and technology affect irrigation system performance are likely to depend on the extent of technical and institutional (including normative) change at the system level, as well as the agency and strategic behavior of women and men—both migrants and those who remain (c.f. Rana, Bansakota and Sharma 2018; Zwarteveen and Neupane 1996). While government regulations have been introduced to improve gender-balanced participation, gender norms, as well as time and capacity constraints (both actual and perceived), may prevent female members from performing essential functions in the WUAs. Women may also strategically use the absence of men to avoid responsibilities in irrigation. However, remittances, transfer of land and water rights to women, and new technology and transport options can create different conditions for men's and women's participation in irrigation.

Irrigation system performance, in turn, affects agricultural productivity, but male migration also has a direct impact on agricultural productivity (along with many other factors), and agricultural productivity can affect rates of out migration. These broader linkages with agricultural productivity are beyond the scope of this study, which focuses on the effects of male migration on irrigation system performance.

Research questions:

To understand the effects of male migration on irrigation systems, we examine four sets of research questions:

1) *Institutional change:* What changes in formal rules of WUAs and in gender norms have been observed? How are these related to male migration?

2) *Women's roles:* How do male migration and these institutional changes relate to women's participation in irrigation? Do women take on membership and leadership roles in WUAs? Do women meet labor contributions through hiring labor, or contributing female labor, or not at all?

3) *Technological change:* What technologies are in use? How do these change demands for male and female labor? How are these related to male migration?

4) *Outcomes:* What consequences for effectiveness of irrigation systems and collective action are observed? Does the adaptation result in more inclusive decision making in irrigation system management?

To address these questions, we present findings from a mixed methods study, combining a phone survey of 336 WUA leaders from all provinces in Nepal with qualitative data from case studies in 10 irrigation systems. In the next section we present the research methods, followed by a section presenting the findings related to each of these questions. The final section provides a discussion and conclusions.

Methods

We adopt a mixed methods approach comprised of quantitative analysis of phone survey data and qualitative study of 10 irrigation systems. Mixed methods, which have been gaining traction in recent years, refer to research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or a program of inquiry (Tashakkori and Creswell 2007). In this study, a mixed methods approach allows us to quantitively assess the associative relationships between male migration and key variables to answer the research questions, while insights from the qualitative studies help deepen or further the understanding.

Quantitative analysis based on a phone survey of WUA heads

Phone survey

The survey was implemented via phone interviews during June-July 2019 in Nepali or local language of the respondent (see Appendix A for survey questionnaire in English). The sampling frame was derived from the Farmer Managed Irrigation System Promotion Trust (FMIST) database as well as that of Department of Irrigation of WUA contacts[3], which contains a total of 407 complete records at the time of the survey, covering 72 out of 77 districts[4] across three ecological zones (Terai, hills and mountain) in all seven provinces. A randomization was then carried out to select 50 records in each province. In four provinces it was not possible to get interviews with 50 WUAs, so we selected additional random draws in Provinces 1 and 4, which have a larger number of WUAs, to compensate for smaller WUA sub-samples in some provinces (Table 1). Although the FMIST database is the best available repository of WUAs for farmer managed irrigation systems in Nepal, it is not necessarily possible to obtain a nationally representative WUA sample on the basis of the FMIST database. Instead, our sampling strategy focused

[3] Founded in 1998 and registered under the Association Act of Nepal (1988), the Farmer Managed Irrigation System Promotion Trust (FMIST) is an NGO dedicated to the advocacy and promotion of farmer managed irrigation systems in Nepal (https://fmistnepal.wordpress.com/2014/04/09/introduction/).

[4] The five missing districts are mountain districts that have very few irrigation systems.

on constructing a sample that offers comprehensive geographic coverage and maximizes sample size for statistical power (relative to the resource available).

Respondents were WUA chairman or, where the chairman was not available, another member of the executive committee. A variety of challenges arose during the phone survey implementation, including phone numbers no longer working, connection issue due to remoteness of many WUAs, time constraints of respondents owing to paddy planting season or natural disasters, and unavailability or unwillingness of selected respondents to participate. As a result, our analytic sample size is 336 WUA heads, consisting of 7 largely balanced cross-sections (provinces), with between 45 and 51 WUAs in each of the 7 provinces.

As summarized in Table 1, survey respondents are predominately male and aged above 40. Primary, secondary, and higher secondary education combined represent the education achievement of the majority of the respondents, with about 13% of the respondents having a colleague or graduate degree. Over half of the respondents have worked in their posts as WUA chairman or executive member for 1-5 years, followed by 27% and 13% for work experience of 6-10 years and 10-20 years, suggesting a relatively dynamic leadership posts.

Table 1. Sample size and basic demographics of survey respondents by province

Provinces		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Sample Size		50	50	48	45	45	51	47
Gender	M	98%	100%	98%	96%	100%	94%	98%
	F	2%	0%	2%	4%	0%	6%	2%
Age	Below 40	6%	10%	8%	11%	4%	25%	32%
	40-50	38%	26%	19%	18%	20%	31%	34%
	50-60	28%	42%	44%	38%	42%	27%	23%
	Above 60	28%	22%	29%	33%	33%	16%	11%
Education	Primary or below	26%	12%	52%	29%	20%	43%	38%
	Secondary	46%	26%	27%	27%	18%	37%	32%
	Higher Secondary or above	28%	62%	21%	44%	62%	20%	30%
Work experience (in years)	1-5	52%	40%	42%	67%	36%	65%	70%
	6-10	34%	24%	31%	20%	44%	27%	13%
	11-20	12%	28%	17%	13%	11%	8%	4%
	Above 20	2%	8%	10%	0%	9%	0%	13%

Data analysis

Our dependent variables are grouped into categories aligning with the research questions.

For institutional variables, we focus on whether WUAs have the following rules:[5]

[5] The survey asked about current conditions and 10 years ago, to provide insight on trend of change in how irrigation systems are managed over time. However, one cannot attribute the differences over the past decade then to migration because large scale male out-migration has been taking place in Nepal for several decades, with substantial regional variations (IOM 2019).

- Women as members in their own right (as opposed to men being the only recognized members)
- Women taking membership when men are absent
- Women participating in meetings
- Type of contributions:
    - Labor only
    - Labor and cash
- Contracting for system maintenance

The first three are directly associated with greater accommodation of women's participation, while the last two are related to accommodating a wider range of contributions: if labor is scarce, is there provision for cash contributions that would allow the WUA to hire labor?

To assess women's roles, the phone survey asked about the proportion of men and women who attend meetings, speak in meetings and participate in canal maintenance, as increasing intensity of women's participation. The next set deals with women's participation in a range of key irrigation activities: maintenance, operation, water allocation, distribution, and supervising distribution.

Key dependent variables in technological change include whether women plow (when men are absent) or operate tractors, as well as whether there is adoption of sprinklers or drip irrigation, weeders, harvesters, and threshers—forms of mechanization that can reduce labor requirements.

The phone survey was not able to assess irrigation system performance in great depth, but asked about a number of outcomes that provide indications of irrigation system adaptation:

- Women playing role in irrigation management
- Women taking decision role
- Women becoming the manager of agriculture production system
- From labor contribution to cash contribution for O&M
- Women contributed in maintenance which was not allowed earlier
- Women were made to pay cash instead of labor contribution for maintenance

The following set of outcomes are indicators of negative outcomes that may be associated with male migration:

- Over burdening the workload to women in irrigation management
- Labor shortage at HH level
- Labor shortage causing the deterioration of the system
- Women deprived to be member of executive committee, not owning the land
- Uncultivated land

The ten-year timeframe used in the survey questions may or may not overlap with the time when major changes took place in relation to male out-migration each site. Furthermore, the WUA chairmen who responded to the survey may not have been involved in the systems 10 years ago, so responses to that question may not be as reliable. The regression analysis, therefore, focuses on the "now" responses (not the differences between now and 10 years ago) and explores how variations across WUAs are explained by the key explanatory variable (male out-migration

Our key explanatory variable in the regression analysis is a binary variable for male out-migration at the irrigation system/WUA level.[6] Across the irrigation systems surveyed, 78.6% of systems have had substantial male out-migration 5 years prior.

Our control variables include:

- Irrigation system management: Farmer Managed Irrigation System (FMIS) vs Agency or Joint managed
- System size (log ha)
- System type (Gravity vs Lift or Groundwater)
- Topography (Hill, Mountain vs Terai plains)
- Caste/ethnicity (Executive committee members from high caste)
- Respondent's education (Secondary and above)

Irrigation system management type is included because of the likely greater autonomy and role of collective action in FMIS (Benjamin et al. 1994; Lam 1998). System size and type reflect the likely degree of complexity of management. Topography also reflects the greater complexity of managing hill or mountain systems, as well as their greater remoteness compared to the Terai plains. Caste of the executive committee is a proxy for dominance of patriarchal values associated with high castes. Panta and Resrreccion (2014) found that as WUAs became more inclusive of lower castes, it increased security of water access by women and men of all castes, but it did not necessarily increase participation of women, especially of lower castes. Respondent's education is included to control for potential biases of the respondent in reporting.

Table 2 presents the overall means of the control variables, along with the means for sites with and without strong male migration. We note that male migration is significantly less prevalent in farmer-managed and gravity systems, and less prevalent in the Terai. Sites with male migration were significantly more likely to have respondents (WUA chairmen) with higher education (secondary or above) and have fewer high-caste executive committee members. While a cross-section from a phone survey is not equipped to address endogeneity, the analysis nevertheless explores the associative relationships between male out-migration and a wide range of indicators of system governance and performance, which is particularly insightful when combined with qualitative analysis.

Table 2: Control variables, by migration status

	Overall mean	Mean without migration	Mean with migration	T-test
Irrigation System managed by =FMIS	0.628	0.861	0.564	***
Area in ha	765.1	806.8	753.8	
Irrigation system=Gravity	0.893	0.986	0.867	***
Topography: Hill	0.440	0.389	0.455	
Topography: Mountain	0.125	0.083	0.136	
Topography: Terai	0.435	0.528	0.409	**

[6] Survey respondents estimated the percentages of male vs. female WUA members who had migrated 5 years prior, based on which we generated the binary variable for whether these was male out-migration in the WUA or not. A quantitative variable for the extent of male out-migration at the community level would be useful for a more refined analysis of "dose" effect of migration, but would require more data than could be accurately obtained from a single phone interview.

WUA chairman education: Secondary and above	0.685	0.514	0.731	***
# executive committee members Brahmin or Chhetri	1.598	1.931	1.508	***
N	336			

or binary dependent variables, we run probit regressions to examine how male out-migration helps explaining the difference in the probability of observing the concerned outcomes. For dependent variables expressed in percentages, including the male and female percentages for "Who attend the meetings", "Who speak at the meetings", and "Who participate in canal cleaning", we run tobit regressions to examine the how male out-migration helps explaining the variations across systems/WUAs.

Qualitative study

The other major component of this study was a qualitative study of 10 irrigation systems, which were originally interviewed November 2014- February 2015 by the authors as part of a study on Improving Performance of Irrigation Water Users Association (WUA) in Changing Demographic Landscapes of Rural Nepal (Pradhan, Joshi, Pradhan 2015) and then re-visited in the current study. Sites for the original study were selected to include 10 irrigation systems in 10 districts, covering four development regions. The systems selected were both large and small, hill and Terai systems, agency managed and farmer managed systems as well as ground water systems (see Table 3, Figure 1). Several of these sites (Argeli, Chhatis Mauja, Jamara) have been studied repeatedly, dating back to the 1980s (Martin 1986; Yoder 1986; Pradhan 1983, 1989; Pradhan, Giri and Tiwari 1988). Two of these sites ("deep dive" sites) with contrasting experiences of male migration and WUA responses (Janakalyan, Kalleritar) were visited a second time in the current study for further exploration of system dynamics (Suhardiman et al. under review).

Table 3: Characteristics of case study irrigation systems

Irrigation system Town/ Village	**District**	**Province**	**Terai/ Hill**	**Size (ha)**	**System Type**
Mahakali Block 2 of Mahendranager	Kanchanpur	7 Sudurpashchim	Terai	300 ha part of large system	Canal system
Jamara Kulo, Tikapur	Kailali	7. Sudurpashchim	Terai	4500 ha	Canal system
Deep tubewell, Nepalgung	Banke	5. Lumbini	Terai	40 ha each	Ground water irrigation
Itura	Surkhet	6. Karnali	Inner Terai	60 ha	Canal system
Kasi Kulo	Pyuthan	5. Lumbini	Hill	40 ha	Canal system
Chhatis Mauja, Butwal	Rupendehi	5. Lumbini	Terai	3500 ha	Canal system
Argeli	Palpa	4. Gandaki	Hill	60 ha **	Canal system
Janakalyan *	Chitwan	3. Bagmati	Terai	116 ha	Canal system
Kalleritar *	Dhading	3. Bagmati	Hill	120 ha	Canal system
Ghetephant, Jogbura	Dadeldhura	7. Sudurpashchim	Hill	60 ha	Canal system

* indicates system revisited for "deep dive"

** service area changes by season

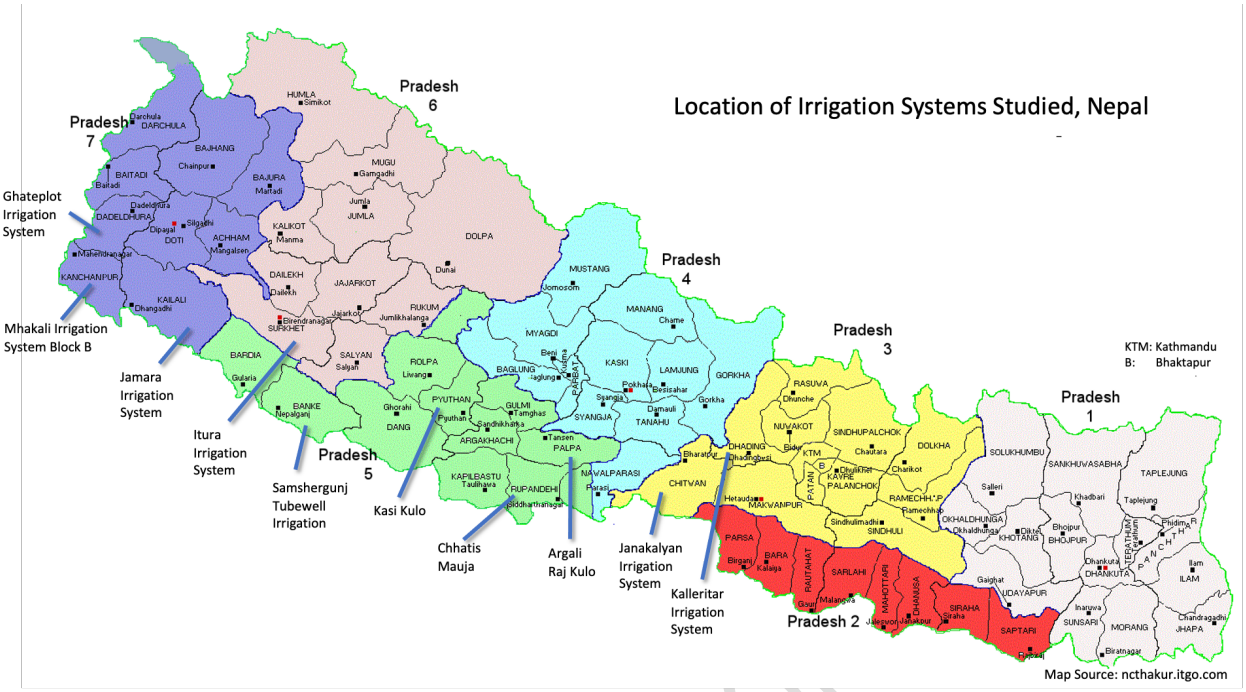

Figure 1: Case study irrigation system locations

Each case study combines background data collection, key informant interviews, and focus group interviews. Background information on the physical, social, and institutional arrangements was collected based on secondary records as well as previous studies (e.g. Pradhan 1989; Yoder 1986; Pradhan et. al 2015). Wherever possible, information on changes over time were included.

For entrée into the system, FMIST contacted the relevant District Irrigation Office (DIO) via the Institutional Management Division (IMD) of Department of Water Resources and Irrigation (DWRI). The District Irrigation Office (DIO) then contacted WUA chairmen. Association Organizers (AO) of DIO, one who have regular contact with WUAs, would usually help in the field. At least a day or two before visiting the system, the WUA chairman was contacted and requested to call a meeting with WUA members for a focus group discussion (FGD), and particularly to include WUA member households whose family members have emigrated. The FGD used a checklist to guide the questions. Notes from the FGDs were then written up in English, including key quotations, following the broad outline of the checklist, and reviewed by the authors. We draw upon these notes in conjunction with the results of the quantitative analysis of the phone surveys.

Results

The following sections address each of our research questions by presenting quantitative analysis of the phone survey data, followed by additional information from the qualitative studies.

Descriptive statistics on the outcome and control variables

Table 4 presents the means of the various dependent variables, by migration status in the systems. In terms of the rules, we see that provisions for women's membership and participation are fairly high overall, but women being members in their own right and participating in O&M or member meetings

are significantly higher with male migration, as are rules for both cash and labor contributions for maintenance and contracting for maintenance. For gendered participation in meetings, we see that a significantly higher percentage of women and men participate in meetings and speak in meetings with irrigation, but the increases are greater for women than for men. Somewhat surprisingly, there is a significantly lower proportion of women participating in maintenance in systems with strong male migration, perhaps because those systems have adopted rules for cash contributions and/or contracting labor. Turning to specific irrigation activities, we see an overall high percentage (90 percent or more) of sites reporting that women are involved in all activities, but it is significantly higher for participating in maintenance in place of men, participating in water distribution, or supervising water distribution.

Table 4. Dependent variables, by migration status

	Overall mean	Mean without migration	Mean with migration	T-test	N
Rules regarding irrigation management					
Women as members in their own right	0.946	0.889	0.962	**	336
Women taking on membership role if men are absent	0.863	0.833	0.871		336
Woman participating in O&M or member meetings	0.813	0.736	0.833	*	336
Provisions for maintenance: Labor contribution only	0.330	0.389	0.314		336
Provisions for maintenance: Both labor and cash contribution	0.765	0.528	0.830	***	336
Provisions for maintenance: Contract system	0.289	0.139	0.330	***	336
Gendered participation in meetings and maintenance					
Attending meetings: % men	67.881	61.912	69.367	***	286
Attending meetings: % women	48.788	38.772	51.270	***	287
Speaking in meetings: % men	65.762	61.537	66.763	**	282
Speaking in meetings: % women	43.339	38.278	44.533	**	283
Participating in irrigation maintenance: % men	60.606	58.323	61.188		320
Participating in irrigation maintenance: % women	41.589	49.438	39.596	**	316
Women's participation in specific irrigation activities					
Are women allowed to participate in maintenance in place of male WUA members	0.967	0.931	0.977	**	336
Do women participate in irrigation operation	0.929	0.903	0.936		336
Do women participate in water allocation	0.926	0.889	0.936		336
Do women participate in water distribution	0.923	0.875	0.936	*	336
Do women participate in supervision of water distribution	0.899	0.792	0.928	***	336
Technological changes					
Women plough in the absence of men	0.095	0.083	0.098		336
Women operate tractors	0.054	0.028	0.061		336
Sprinkler or drip irrigation	0.214	0.278	0.197		336

Mechanical weeders	0.060	0.083	0.053		336
Mechanical harvesters	0.119	0.097	0.125		336
Mechanical threshers	0.554	0.486	0.572		336
Potential outcomes associated with male migration					
Over burdening the workload to women in irrigation management	0.752	0.848	0.739		290
Labor shortage at HH level	0.693	0.455	0.724	***	290
Labor shortage causing the deterioration of the system	0.048	0	0.054		290
Uncultivated land	0.159	0.091	0.167		290

In terms of the key outcomes, we see that sites with male migration are significantly more likely to have labor shortages at the household level and labor shortages are perceived to cause the deterioration of the irrigation systems. Indeed, the latter is so highly correlated with male migration that we cannot include it in the probit regression equations. Sites with male migration also more likely to report leaving land uncultivated, but the difference is not significant.

Institutional change:

Male migration is not the only process affecting institutional change in WUAs. As discussed above, several government policies have been enacted to encourage women's participation in WUAs, in addition to government and civil society programs to encourage women's empowerment and the overall effect of greater education, especially of women. To address the question of how institutional changes in WUAs are related to male migration, the phone survey results focus on formal rules, whereas the qualitative study draws on local respondents' interpretations of how they perceive migration to have contributed to changes, particularly changes in gender norms.

The phone survey results in Table 5 show that across systems, the presence of male out-migration is associated with significantly higher presence of rules allowing women to participate in member meetings, and allowing both cash and labor contributions. Farmer managed irrigation systems have significantly fewer rules for women to be members in their own right or in the absence of men. This may reflect the higher influence of government requirements for women's participation in the agency or jointly managed irrigation systems. Farmer managed systems are also less likely to have labor contributions only or contract systems, and more likely to have combinations of labor and cash contributions. Larger systems are less likely to have rules for women to be members in their own right or to have labor contributions only (perhaps because there are enough other members available to meet), and more likely to have both labor and cash contributions for maintenance, or to contract out the maintenance, which is consistent with the higher transactions costs of mobilizing members' labor over large systems. Compared to terai, hill and mountain systems are less likely to have labor contributions only, and hill systems more likely to contract maintenance. Mountain systems are less likely to have women members, either in their own right or to replace men. A higher proportion of high caste executive committee members is associated with less labor contributions only and more contracting for maintenance.

Table 5. Rules regarding irrigation management. (Probit results on estimated marginal effects)

	(1)	(2)	(3)	(4)	(5)	(6)
				Provisions for maintenance		
	Women as members in their own right	Women taking on membership role if men are absent	Woman participating in O&M or member meetings	Labor contribution only	Both labor and cash contribution	Contract system
Male out-migration	0.0714	0.0139	0.148*	-0.107	0.362***	0.123*
	(1.85)	(0.31)	(2.39)	(-1.68)	(5.61)	(2.22)
Irrigation system management =FMIS	-0.0434*	-0.149***	-0.0202	-0.230***	0.195***	-0.178**
	(-1.98)	(-4.60)	(-0.45)	(-4.29)	(3.78)	(-3.27)
System size (log ha)	-0.0304**	-0.0247*	-0.00921	-0.0532***	0.0397*	0.0621***
	(-3.18)	(-2.13)	(-0.66)	(-3.32)	(2.44)	(4.05)
Irrigation system=Gravity	0	-0.0692	0.109	0.114	-0.0432	-0.124
	(.)	(-1.08)	(1.39)	(1.76)	(-0.60)	(-1.42)
Topography: Hill	-0.0841	-0.0749	0.111*	-0.371***	0.0348	0.258***
	(-1.86)	(-1.48)	(2.21)	(-6.89)	(0.61)	(4.20)
Topography: Mountain	-0.389***	-0.308**	-0.0255	-0.297***	0.0304	0.101
	(-3.37)	(-3.27)	(-0.33)	(-7.05)	(0.40)	(1.12)
WUA chairman education= Secondary and above	0.0183	-0.0591	-0.0890*	-0.0134	0.000908	0.0581
	(0.71)	(-1.79)	(-2.16)	(-0.25)	(0.02)	(1.14)
# executive committee members Brahmin or Chhetri	-0.0161	-0.0305	0.0217	-0.0566**	-0.00556	0.0475*
	(-1.50)	(-1.81)	(1.20)	(-2.97)	(-0.32)	(2.43)
Observations	299	335	335	335	335	335
chi2	40.35	30.19	25.35	63.01	41.32	60.42
p	0.00000108	0.000196	0.00136	1.19e-10	0.00000181	3.85e-10
r2_p	0.215	0.139	0.0841	0.159	0.127	0.150

Notes:
t statistics in parentheses
* significant at 0.10 probability level
** significant at 0.05 probability level
*** significant at 0.01 probability level
Source: Authors' calculations based on FMIST phone survey of WUA chairmen, 2019

Our qualitative work indicated that policy efforts to promote women's land ownership are not having a great effect, but women are still becoming WUA members even if they are not land owners. The quotas for women's membership and leadership are not always met, in practice, and do not necessarily

translate into active participation in WUA decision-making or activities. The case studies also show that women are not always interested to participate in WUAs. Women have many responsibilities, which tend to increase when men are absent, thus finding time to go to WUA meetings is difficult. Many women hesitate to speak in the presence of men, either because of social norms that define public meetings as "men's space", or because they feel they don't know enough knowledge of the irrigation systems to participate effectively. Thus, they may rely on male relatives or other informal channels such as male relatives as their link to the WUAs. This is particularly the case in places like Janakalyan, where water is relatively abundant and women feel confident of getting water, even if they do not participate in the WUA. But in other sites, women have pushed for greater voice in the WUAs. This may be associated with the influence of other organizations raising women's confidence in participating in meetings, or a greater perceived dependence on WUAs meeting their irrigation needs (as in Kalleritar—see Suhardiman et al., under review).

Similarly, the choice of mechanism (labor, cash, or contracting) for system maintenance varies depending on men's and women's preferences, system infrastructure, as well as local labor markets. In Janakalyan, women with reliable remittances preferred to give cash contributions, and the availability of labor crews from neighboring villages made it possible to hire labor for system maintenance, whereas in Kalleritar women lobbied the WAU to be allowed to contribute their own labor, instead of allowing only male labor or paying a fine for not sending a man. Even within a system, women from wealthier families may prefer to use remittances to hire laborers to meet WUA labor contributions, while poorer families have trouble hiring labor. Where it has been possible for systems to hire equipment like bulldozers or excavators and contract out some of the maintenance, it reduces the labor requirements for men and women, and facilitates the monetization of maintenance contributions. The phone survey results show a correlation between male migration and contracting for system maintenance; in-depth interviews with WUA members in Janakalyan confirm that they did this in response to labor shortages that they associated with male migration.

The Jamara system shows how many of these factors come together. This farmer managed irrigation system of over 4,000 ha has Badghars (traditional Tharu village chiefs) representing each village and responsible for infrastructure. Because WUA membership is based on land ownership and few women are land owners, there are only 8 percent women in the general membership and 19 percent on the Executive Committee. This is less than the government-mandated quotas for women, and those who are there are not in decision making positions. Badghar is a traditionally male role. A few women have been selected as Badghars, with the understanding that their husbands will undertake the role in the name of their wives, although one woman reported that she is responsible for maintenance of irrigation and road infrastructure and settling disputes. Many women in the FGDs were not aware of the existence of the WUA and its activities. However, they know about Desawar (mass mobilization of labor for desilting the canal) and participate when their household men have migrated. Riding bicycles allows women to reach the canal headworks and return home by night. Using an excavator to desilt the mouth of the canal also reduces the difficulty of the labor, and women who cook or provide drinking water to the laborers are also acknowledged as contributing labor. Thus, technical change (e.g. bicycles and heavy machinery) have enabled women to contribute labor.

Women's roles:

To examine how women's participation in irrigation may differ when there is substantial migration, Table 6 presents results from the phone survey on the gender composition of three indicators of participation: attending meetings, speaking in meetings, and participating in canal maintenance.[7] Attending meetings can be a relatively nominal level of participation; speaking in meetings represents more active participation, and may represent a greater challenge to norms that women should not speak in public (in the presence of men). Participation in maintenance is a yet more active level of participation, particularly in light of norms described above. Migration is significantly associated with both men's and women's attendance and speaking in meetings. Women's greater involvement is consistent with expectations that women will take on greater roles when men are absent; the higher percentage of men who attend and speak in meetings may be because when there is substantial male migration, more of the men who are left need to be active in WUAs. We do not see a higher proportion of women participating in irrigation maintenance with male migration, perhaps because systems have gone to cash contributions or contracting for maintenance when there is more migration. As with the rules (Table 5), FMIS have significantly lower proportions of women attending and speaking in meetings. That higher proportion of high caste executive committee members is associated with greater participation of women in meetings, speaking in meetings, and participating in maintenance is surprising, given that high castes are generally associated with more patriarchal norms, but it might be due to the level of education and political exposure of this group of women.

[7] We also asked about percentages five and ten years ago, but this data was not as reliable, because not all WUA chairmen could recall this from the past.

Table 6. Gendered participation in meetings and maintenance (Tobit results)

	Attending meetings		Speaking in meetings		Participating in irrigation maintenance	
	% men	% women	% men	% women	% men	% women
Male out-migration	7.243***	14.30***	3.825*	7.277***	-0.744	0.244
	(3.37)	(5.09)	(1.99)	(3.39)	(-0.31)	(0.10)
Irrigation system management =FMIS	-0.826	-9.198*	-1.644	-7.633**	0.638	-1.403
	(-0.35)	(-2.45)	(-0.84)	(-3.13)	(0.29)	(-0.62)
System size (log ha)	1.732*	0.0211	1.045	-0.138	1.370	-1.366*
	(2.49)	(0.02)	(1.81)	(-0.17)	(1.89)	(-2.08)
Irrigation system=Gravity	-6.700	-2.557	-3.360	5.237	-4.754	3.973
	(-1.88)	(-0.38)	(-1.16)	(1.22)	(-1.30)	(1.11)
Topography: Hill	-0.759	-6.024	-1.230	-6.276*	-5.221	5.326*
	(-0.26)	(-1.58)	(-0.53)	(-2.29)	(-1.88)	(2.06)
Topography: Mountain	-11.14**	-7.506	-7.898*	-6.003	-8.048*	6.647
	(-3.12)	(-1.63)	(-2.44)	(-1.61)	(-2.24)	(1.92)
WUA chairman education= Secondary and above	1.732	2.592	0.841	2.163	6.527**	-5.285*
	(0.78)	(0.87)	(0.44)	(1.05)	(3.11)	(-2.54)
# executive committee members Brahmin or Chhetri	0.629	6.461***	-0.698	4.376***	-5.867***	6.189***
	(0.67)	(4.78)	(-0.90)	(4.52)	(-7.06)	(7.64)
Constant	60.15***	37.90***	63.62***	33.39***	66.86***	34.21***
	(9.61)	(3.91)	(12.37)	(4.90)	(10.64)	(5.87)
Observations	286	287	282	283	320	315
chi2						
p	2.52e-09	9.35e-09	0.0000375	0.00000973	4.22e-21	3.07e-21
r2_p	0.0192	0.0179	0.0124	0.0163	0.0342	0.0337

Notes:
* significant at 0.10 probability level
** significant at 0.05 probability level
*** significant at 0.01 probability level
Source: Authors' calculations based on FMIST phone survey of WUA chairmen, 2019

The ten case studies showed how technology has also played a role, with women learning to ride bicycles giving them greater mobility (especially in the Terai), and cell phone ownership allowing them greater access to information, which could affect their participation in WUA activities. The qualitative work also pointed to the importance of other organizations, notably Mother's Clubs, women's cooperatives, savings groups, drinking water committees and forest users groups (e.g. Suhardiman et al., under review).

Table 7 presents more detailed breakdown of the roles that women currently participate in. From the descriptive statistics in Table 4, we see very high percentage of WUAs report that women participate in a variety of irrigation activities, with and without migration. With over 90 percent of women participating in operation, maintenance, and water allocation, it is not surprising that migration does not have a significant effect, though we do see a significant effect of male migration on women's participation in supervising the distribution, which is still slightly less common as a role for women.

Table 7. Women's participation in specific irrigation activities (Probit results on estimated marginal effects)

	(1) Are women allowed to participate in maintenance in place of male WUA members	(2) Do women participate in irrigation operation	(3) Do women participate in water allocation	(4) Do women participate in water distribution	(5) Do women participate in supervision of water distribution
Male out-migration	0.0315	0.0268	0.0367	0.0657	0.149**
	(1.00)	(0.64)	(0.91)	(1.53)	(2.74)
Irrigation system management =FMIS	-0.0204	-0.0109	-0.0395	-0.0574*	0.00646
	(-0.97)	(-0.30)	(-1.30)	(-2.14)	(0.18)
System size (log ha)	-0.00336	-0.00378	-0.0249*	-0.00936	0.00231
	(-0.53)	(-0.31)	(-2.15)	(-0.88)	(0.17)
Irrigation system=Gravity	0	0	0	0.167	-0.0450
	(.)	(.)	(.)	(1.95)	(-0.86)
Topography: Hill	0.0113	-0.00526	-0.124**	-0.0872*	-0.0626
	(0.41)	(-0.12)	(-2.62)	(-1.97)	(-1.25)
Topography: Mountain	0.00558	0.0594	-0.0819	-0.170	-0.103
	(0.16)	(1.62)	(-0.84)	(-1.78)	(-1.15)
WUA chairman education= Secondary and above	0.0115	-0.00734	0.0273	0.0165	0.0246
	(0.46)	(-0.21)	(0.80)	(0.56)	(0.70)
# executive committee members Brahmin or Chhetri	0.00703	0.0200	-0.0108	-0.0116	0.00775
	(0.82)	(1.49)	(-0.81)	(-0.99)	(0.56)
Observations	299	299	299	335	335
chi2	10.36	7.073	10.81	21.32	20.30
p	0.169	0.421	0.147	0.00635	0.00926
r2_p	0.0528	0.0321	0.0713	0.0821	0.0782

Notes:
* significant at 0.10 probability level
** significant at 0.05 probability level
*** significant at 0.01 probability level
Source: Authors' calculations based on FMIST phone survey of WUA chairmen, 2019

Examining the covariates in the probit results, we see that gravity irrigation systems are associated with significantly lower women's participation in maintenance, operation, and allocation, perhaps because the gravity systems often require going long distances for operation and maintenance, and draw on detailed knowledge of the local topography, which is often passed down among men. Hill and mountain systems are more likely to have women allowed to do maintenance and hill systems have women participate in operation. The positive association of high caste executive committee members with women being allowed to do maintenance and participate in operation is somewhat surprising, given that high castes are generally associated with more patriarchal norms.

The qualitative work indicates that in many places women were previously prohibited from engaging in many of the irrigation activities. The case studies provide insights on why hill and mountain systems may have more provisions for women's participation in maintenance and operations. In the Terai, even when there is male out-migration, it is often possible to hire other men to do the work, either from within the village or poor men migrating from nearby villages, sometimes coming as labor gangs. Availability of mobile phones have helped women to contract such laborers, even from outside the village. However, in more isolated hill and mountain communities, there is less alternative male labor available, hence more need for women's participation.

The qualitative work provides further nuance on the roles of women in different parts of the system. The Chhatis Mauja system of 3,500 ha has tiers of organization. Women comprise 30 percent of the general membership; 25 percent of the village-level (Mauja) committee, but only 14 percent of the Central committee that provides overall coordination and direction. This is consistent with greater difficulty of women to attend meetings away from the village, and to speak in front of strangers.

Technological change:

In addition to institutional responses to the labor shortages created by male migration, technological changes may also reduce the labor requirements. Irrigation system or aqueducts intakes constructed of boulders, tree branches, and logs were temporary, requiring frequent repairs during paddy cultivation and additional time to collect materials to reconstruct the intakes. Rehabilitation of irrigation systems with concrete can thus reduce labor requirements. Such physical improvements of the irrigation system reducing labor requirements were reported in Jamara, Chhatis Mauja, and Itura systems, and contracting for construction equipment to repair the headworks has further reduced labor requirements, as discussed above.

In addition to the labor intensity of operation and maintenance of many traditional irrigation systems, the agricultural production systems themselves are labor intensive, using manual labor and animal traction. Caring for the bullocks or buffalos, in turn, requires additional year-round labor. Our qualitative study confirmed that much of the manual labor for planting, weeding, harvesting, and caring for animals is women's labor. Thus, it is important to look not only at changes in irrigation technologies, but also a more holistic view of agricultural technologies, including direct and indirect labor saving impacts.

Mechanization of farm processes have a direct effect in reducing labor requirements, while change from bullock ploughing to tractors saves women time in collecting fodder and feed preparation for bullocks. Remittances from absent men are often used to pay for mechanization—either through purchase or rental of equipment services, especially for plowing or threshing. But the qualitative work also shows

that remittances are not always reinvested in agriculture: much of the remittance money goes for children's education and improved housing in the village, or even to reduce their dependence on agriculture and move to larger towns (see also Adhikari and Hobley 2011; CG and Hall 2020; Tamang et al. 2014).

Our qualitative work provides insights on why there may not be significant correlations between migration and mechanization. The case studies confirmed that it is more difficult to mechanize the production systems in hill or mountain areas because of small plot sizes, steep slopes, and difficult terrain to get machinery to the plots. Conversely, even sites like Ghateplot, with low migration but flat terrain and good connections to roads may adopt mechanization. Similarly, the qualitative work indicates that improved transportation through improved infrastructure and the acceptability of women riding bicycles can also save women's time.

These patterns are broadly confirmed by analysis of the phone survey data. Table 4 shows that mechanization rates are low overall, and it is rare for women to be involved in land preparation with plow or tractors. Probit results in Table 8 show that there is no significant relationship between male migration and mechanized weeding, but there is for harvesting and threshing. Weeding and harvesting are traditional female tasks, while threshing is a traditionally male-associated task. There is also some flexibility in timing of weeding, whereas harvesting and threshing are intensive, time-critical tasks. Thus adopting mechanized harvesters and threshers is a logical response to migration-induced male labor shortages at harvest time.

Table 8. Technological changes (Probit results on estimated marginal effects)

	(1) Women plough in the absence of men	(2) Women operate tractors	(1) Sprinkler or drip irrigation	(1) Mechanical weeders	(2) Mechanical harvesters	(3) Mechanical threshers
Male out-migration	0.0214	0.0241	-0.0707	0.000983	0.0898***	0.176***
	(0.64)	(0.89)	(-1.17)	(0.03)	(3.41)	(3.46)
Irrigation system management =FMIS	0.0413	0.0000703	0.0453	0.0223	0.0498	0.0646
	(1.36)	(0.00)	(0.95)	(0.96)	(1.56)	(1.57)
System size (log ha)	-0.00122	0.00867	0.0441**	0.0274**	0.0527***	0.0631***
	(-0.10)	(0.98)	(2.73)	(2.99)	(5.35)	(4.02)
Irrigation system=Gravity	0.0672	-0.0428	0.00998	0.0296	0.00295	0.00923
	(1.87)	(-0.77)	(0.12)	(0.88)	(0.06)	(0.13)
Topography: Hill	-0.0247	0.0533	0.162*	0.00182	-0.0913*	-0.436***
	(-0.55)	(1.48)	(2.48)	(0.06)	(-2.40)	(-7.59)
Topography: Mountain	0.165	-0.000530	0.134	0.0635	-0.0540	-0.489***
	(1.81)	(-0.01)	(1.28)	(0.98)	(-1.25)	(-8.80)
WUA chairman education= Secondary and above	0.0448	0.0186	-0.0492	-0.0386	-0.0755*	0.0109
	(1.51)	(0.75)	(-1.00)	(-1.42)	(-1.98)	(0.25)
# executive committee members Brahmin or Chhetri	0.0111	-0.00393	0.0175	0.00822	0.0306*	-0.00218
	(0.85)	(-0.37)	(0.94)	(0.75)	(2.52)	(-0.13)
Observations	335	335	335	335	335	335
chi2	20.75	7.598	13.43	14.33	62.59	140.6
p	0.00784	0.474	0.0978	0.0734	1.44e-10	1.77e-26
r2_p	0.0861	0.0377	0.0448	0.118	0.268	0.408

Notes:
* significant at 0.10 probability level
** significant at 0.05 probability level
*** significant at 0.01 probability level
Source: Authors' calculations based on FMIST phone survey of WUA chairmen, 2019

The use of sprinkler or drip irrigation is not associated with male migration. These are not necessarily labor-saving technology, and both men and women may be involved in managing these micro-irrigation systems (e.g. installing and cleaning the systems, filling the drip tanks) and the associated horticultural production. Moreover, women often do the marketing of vegetable crops and control the income from such production (see also GC and Hall 2020).

Mechanization is related to topography: hill and mountain systems are significantly less likely to have harvesters or threshers. Larger irrigation systems are also associated with more adoption of weeders, harvesters, and threshers, perhaps because of economies of scale in such systems.

Outcomes:

Although it was not possible to obtain clear indicators of irrigation system performance changes and their association with migration patterns based on the phone survey, we do consider several potential negative outcomes, and whether these are associated with male migration. [8] We first consider whether women are overburdened with workloads in irrigation management specifically, then whether there are overall labor shortages at the household level, and finally whether there is uncultivated land in the systems, which could indicate that either the system is not able to deliver enough water, or members could not provide enough labor and inputs to cultivate. Descriptive results in Table 4 indicate that 75 % of WUA chairmen reported high workloads for women in the irrigation management, but it was actually higher for sites without male migration (84%) than those with migration (72%), and the difference was not significant. Reported labor shortages at the household level are, however, significantly associated with male migration (Tables 4 and 9), reflecting the many responsibilities that remaining household members, particularly women, take on.

Although less than five percent of WUA chairmen overall reported that labor shortages had caused deterioration of the systems, all of these were in sites with male migration. We were therefore not able to include it in the probit regressions on Table 9. Uncultivated land is reported in approximately 16 % of the systems, but is not significantly associated with male migration, though it is significantly higher in hill and gravity irrigation systems. This may be because the returns to irrigation are less in hill systems with less market linkages, and in gravity systems with less water control (compared to groundwater or pumping systems). The case studies confirm that in cases of labor shortages, smallholders rent out their land or find sharecroppers rather than letting the land uncultivated. In cases like Janakalyan where migrant labor from adjoining districts is available, women from large land owning households take on a management role and hire laborers for cultivation to keep the land in production. Overall, the relatively low reporting of deteriorating systems or uncultivated land indicate that systems are adapting to prevent these negative outcomes.

[8] The wording of the question asked for the top five direct impacts of male out-migration on irrigation management, but it was difficult in a phone survey to get respondents to consider all the options and rank them, so respondents indicated whether they had observed each type of change. It was also difficult for respondents to say to what extent changes were direct consequences of male migration, so the question was asked of all WUA chairmen in the sample.

Table 9. Potential outcomes associated with male migration

	(1) Over burdening women's workload in irrigation management	(2) Labor shortage at HH level	(3) Uncultivated land
Male out-migration	-0.111	0.255**	0.0658
	(-1.64)	(2.82)	(1.15)
Irrigation system management = FMIS	0.0701	0.0981	-0.0254
	(1.26)	(1.68)	(-0.54)
System size (log ha)	-0.00580	0.0496*	-0.00238
	(-0.28)	(2.38)	(-0.13)
Irrigation system=Gravity	-0.0264	-0.109	0.127**
	(-0.31)	(-1.45)	(2.85)
Topography: Hill	-0.124	0.290***	0.141**
	(-1.70)	(4.58)	(2.58)
Topography: Mountain	0.0973	0.101	0.0551
	(1.10)	(1.29)	(0.57)
WUA chairman education = Secondary and above	0.00730	0.0168	0.0508
	(0.13)	(0.28)	(1.22)
# executive committee members Brahmin or Chhetri	-0.0339	-0.0351	-0.0235
	(-1.59)	(-1.56)	(-1.46)
Observations	290	290	290
cmd	margeff	margeff	margeff
chi2	16.31	26.71	15.82
P	0.0382	0.000793	0.0451
r2_p	0.0519	0.0892	0.0772

Notes:

* significant at 0.10 probability level

** significant at 0.05 probability level

*** significant at 0.01 probability level

Source: Authors' calculations based on FMIST phone survey of WUA chairmen, 2019

Conclusions

Key findings and implications

Our overall findings show a range of responses to migration. Sites with substantial male migration are more likely to have adapted WUA rules to allow for women's participation, and to monetize the contributions for maintenance or even contract out least some of the major maintenance.

Women's participation and speaking in meetings is also higher in sites with male migration. A relatively high proportion of all systems (90% or more) report women being involved in the various irrigation roles of system operation, maintenance, water allocation and distribution, but those with male migration are significantly more likely to report women also being involved in supervising water distribution.

The qualitative work shows that women exercise agency in whether and how to interact with WUAs: while there are some cases where women seek to change WUA rules, e.g. to allow them to contribute labor, in other cases they do not feel it is worthwhile to engage, and may prefer indirect interaction such as via male relatives or giving monetary contributions rather than participating in the meetings or maintenance activities.

Migration is also associated with mechanization of harvesting and threshing—time-critical tasks usually associated with male labor—though the ability to mechanize is limited by hilly terrain and small farm sizes. Overall, systems seem to be adapting to male migration, with relatively low reported cases of land being left idle, or labor shortages causing deterioration of the systems, though there are concerns with the high levels of women's labor burdens.

But agrarian transformation is a complex process, and migration is only part of the story. Government programs such as quotas for women's participation in WUAs have also had a profound effect (even if they are not always followed). Likewise, the development of transportation, including roads and bicycles, have increased women's mobility and ability to take on greater roles in the irrigation systems.

Mobile phones have made it easier for women to coordinate hiring of laborers on the farm and in the irrigation maintenance, and also allow migrant men to continue to be involved in decision-making. Mechanization has not only reduced the male labor required for particular tasks like plowing and harvesting, but also women's labor for tending bullocks throughout the year.

Limitations

While the phone survey of WUA leaders was a more cost-effective means to reach a large number of sites compared to face to face field work, particularly sites that are remote or in less accessible terrains, the phone survey as implemented in this study does have some methodological drawbacks. The primary limitation is that phone survey cannot be as detailed as face to face. Thus we have tried to stick to basic facts about the systems, and complement this with a qualitative study that provides more nuance and explanation of what is happening behind the statistical relationshipos. The other drawback is that it is not always clear how questions were heard and interpreted by the respondents. The effectiveness of communication through audio phone can be reduced by poor sound quality, lack of other communication-enhancing tactics such as hand gesture, and respondent fatigue.

Although there is no single authoritative source of registrations of WUAs that would allow us to construct a nationally representative sample for statistical inference at the national level, this study builds on the strong relationship with FMIST (the longest serving NGO supporting local communities on irrigation systems) and availability of FMIST inventory of the irrigation systems/WUAs, supplemented by information from government lists, to draw a sample that is geographically and topographically comprehensive, while eliminating possible human-induced bias in the selection of respondents whenever feasible.

Finally, migration has been taking place for decades in Nepal. In addition to the typical recall problems, capturing changes in this complex landscape over such a long period is challenging, especially given the dynamic WUA leadership posts. Measuring and reporting on migration is also complicated, which is not helped by the fact that we interviewed WUA leaders, not those community leaders who may be better equipped to report on migration. Our analysis focuses on whether there is substantial male migration in the irrigation system, based on the opinion of the WUA chairmen.

Future research

Migration and impact of migration are "messy" subjects to study, but critical drivers of socioeconomic changes at the household, community, and local economy levels. How institutions such as WUA respond and adapt, is therefore critical to the understanding of rural transformation and the likely impact on gender equality, food production, and rural livelihoods. Future research is needed to further unpack women's views in relation to their envisioned roles in irrigation system management, following male out migration, and how the latter are linked with WUA's organizational characteristics and historical origins. Research that dives into the heterogeneity of women farmers/WUA members (e.g., by poverty, castes, age, intra-household roles, etc.) is critically needed to better identify gendered responses to adapt to the changing rural sector and its implications for women empowerment within WUA and beyond.

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