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Migration and Gender Dynamics of Irrigation Governance in Nepal

RESEARCH ARTICLE

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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.

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INTRODUCTION

BACKGROUND AND MOTIVATION

Nepal has a long history of irrigation, including not only government-built and -managed systems, but also widespread farmer-managed 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 organizational infrastructure of Water Users' Associations (WUAs) that is involved in delivering water from the source to farmers' fields (Benjamin et al. 1994; Joshi et al. 2000; 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).

The governance and management of irrigation systems in Nepal have historically been male domains (Shrestha and Clement 2019; Udas 2014). This reflects a combination of factors, both normative and practical. Patriarchal norms that define public decision-making spaces as male, notions that heavy labor is involved in building or repairing irrigation structures, concepts that menstruating women would ritually or physically pollute the water, and the practical difficulties of women finding time away from household chores to attend meetings or to travel long distances to work on irrigation canals have contributed to restricting women's direct participation in irrigation (Benda-Beckmann and Benda-Beckmann 2000; Meinzen-Dick and Zwarteveen 1998; Zwarteveen and Neupane 1995).

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% women on the Executive Committee of all WUAs, which increased to 33% 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, the Maoist movement, 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; Maharjan, Siegfried and Knerr 2013; Slavchevska et al. 2020; Sugden et al. 2021). 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 (NCBS 2011) estimates that 53% of households had at least one migrant, either within Nepal or internationally, sending an estimated 259 billion NPR (2.61 billion USD) in remittances. The International Organization for Migration (IOM 2019) estimates that remittance flows were 25.4% of GDP (compared to 0.8% for foreign direct investment, or 5% from official development assistance). The proportion of households who received remittances also increased from 23% to 56% from 1995 to 2010. Among remittance-receiving households, about 27–35% of their income came from remittances (NCBS 2011).

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.[1] 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 institutional innovation, and the outcomes in terms of system functioning.

CONCEPTUAL FRAMEWORK

Following the Institutional Analysis and Development (IAD) framework (Ostrom 2011; Tang 1992), Figure 1 shows that the performance of irrigation systems is shaped by contextual factors--physical attributes of the irrigation system, attributes of the community, and institutional arrangements. These, in turn shape the action situation, which, in turn, shapes the outcomes. But the contextual factors are neither static nor independent: a change in the attributes of the community (such as those caused by

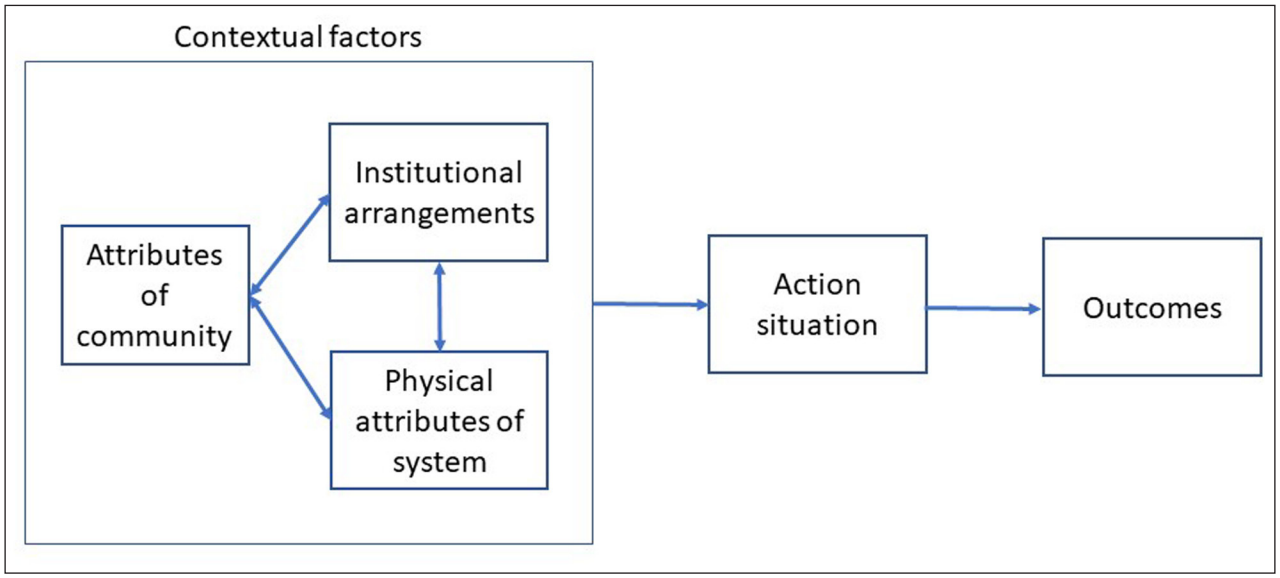

Figure 1 Conceptual framework (See OJS – Figure 1 Conceptual framework).

male migration) can prompt changes in the institutional arrangements, notably the rules of the system and roles played by various actors, and changes in the physical attributes of the system, notably the technology.

To assess how male migration may affect irrigation system performance, it is important to consider the major aspects of (male) farmers' roles and gender relations in the irrigation systems, and the key contributions by (male and female) farmers that allow the systems to deliver water to the fields. Most prominent among these are resource provisioning contributions--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 institutional provisioning contributions—the knowledge and decision-making in governance which keep the systems functioning.

The configurations of contributions and decisions to be made are also shaped by the physical attributes, particularly 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 require detailed knowledge of the topography and regular mobilization of labor and resources for maintenance, as they are vulnerable to landslides during monsoon and occasional natural disasters like earthquakes.

How these changes in governance, contributions, and technology affect irrigation system performance are likely to depend on the extent of technical and institutional change at the system level, as well as the agency and strategic behavior of women and men in the action situation—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, may prevent women from performing essential functions in the WUAs. Women may also perform functions without having any formally recognized roles or responsibilities in the WUAs, and may strategically use the absence of men to avoid responsibilities in irrigation (Zwarteveen and Neupane 1995). 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, which will also vary by caste, ethnicity, and class.

RESEARCH QUESTIONS

Following from the conceptual framework, our research questions examine how male migration, as a change in the attributes of the community, is associated with changes in the institutional arrangements (rules and women's roles), changes in the physical attributes of the system, notably technology, and the outcomes observed. Specifically, we examine four sets of research questions:

1. *Institutional change (rules):* What changes in formal rules of WUAs and in gender norms have been observed? How are these related to male migration?
2. *Institutional change (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:* Is migration associated with technological changes, especially mechanization? How does this relate to demands for male and female labor?
4. *Outcomes:* Are WUAs able to prevent negative consequences of male migration?

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. The large scale of the phone survey allows us to quantitatively control for physical attributes of the irrigation systems and attributes of the community, while the qualitative cases provide insights on the agency of women and men in the action situations.

METHODS

We adopt a mixed methods approach comprised of quantitative analysis of phone survey data and qualitative study of 10 irrigation systems. This 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

To understand how migration affects different types of irrigation systems, we conducted a phone survey with the leaders of 336 WUAs across three ecological zones (Terai, hills and mountain) in all seven provinces. The sampling frame was derived from the Farmer Managed Irrigation System Promotion Trust (FMIST)[2] database as well as that of Department of Irrigation of WUA contacts, which contains a total of 407 records, covering 72 out of 77 districts.[3] We planned for a sample size of 350, randomly selecting 50 systems in each province. In four provinces there were less than 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 other provinces.

Although the FMIST database is the best available repository of WUAs for farmer managed irrigation systems in Nepal, we cannot verify that it captures the entire "population" of systems. Instead, our sampling strategy focused on constructing a sample that offers comprehensive geographic coverage and maximizes sample size for statistical power, given the resource available.

The questionnaire was prepared in English, translated into Nepali language, and pretested. To increase the likelihood that emumerators would understand the functioning of irrigation systems and that WUA chairpersons would respond, many of the enumerators selected were employees of the Department of Water Resources and Irrigation, including some with sociology background and junior engineers. The enumerators were given training on the method of the questionnaire administration as well as the meaning of all those questionnaire in order to ensure the uniformity of asking questions to the chairpersons of WUA. The Senior Sociologist of Department of Water Resources and Irrigation supervised the questionnaire administration and checked the hard copy questionnaires for completeness before they were sent to FMIST for data entry in Excel.

The survey was implemented during June–July 2019 in Nepali or local language of the respondent (see Appendix A for survey questionnaire). Respondents were WUA chairpersons or, where the chairperson was not available, another member of the executive committee. A variety of challenges arose during the survey implementation, including phone numbers no longer working, connection issue, 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 almost exclusively male. The fact that almost all of the

	VAIABLES	TERAI	HILL	MOUNTAIN
Gender	F	1%	4%	2%
	M	99%	96%	98%
Age	Below 40	10%	13%	31%
	40–50	28%	26%	26%
	50–60	39%	32%	29%
	Above 60	23%	29%	14%
Education	Primary or below	25%	36%	36%
	Secondary	32%	29%	31%
	Higher Secondary or above	42%	34%	33%
Work experience (in years)	1–5	48%	55%	64%
	6–10	24%	32%	24%
	11–20	17%	11%	7%
	Above 20	11%	1%	5%
N		146	148	42

Table 1 Basic demographics of survey respondents by agro-ecological zone (AEZ).

WUA chairpersons are men is noteworthy in itself (as discussed below), and may also affect their responses. Even though the survey was done by FMIST, which has strong relationships with the WUAs, the enumerators' association with the Department of Water Resources and Irrigation provides another source of potential bias. For example, respondents may overstate the extent of women's participation. While such biases are unavoidable, given the limitations of the phone survey, they would apply across all cases, not necessarily associated with the extent of male migration.

For the overall sample, the majority of respondents were over 40 years old and had secondary education or above, with about 13% of the respondents having college or graduate degrees. Over half of the overall respondents have worked in their posts as WUA chairperson or executive member for 1–5 years, followed by 27% for 6–10 years, but there are 11% who have been in the position for over 20 years. Breaking down these statistics by AEZ, Table 1 shows that the Terai appears to have older, longer-serving, and more educated WUA heads than the hill and mountain areas.

Data analysis

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

For institutional variables, we focus on the reported presence of rules accommodating women's participation, notably whether women could be members in their own right (as opposed to men being the only recognized members); women could be members when men are absent; and women participate in meetings. We also ask about provisions for system maintenance, which affect the types of contributions required. This includes whether contributions are labor only or labor and cash, and whether they contract for system maintenance. The last two are related to accommodating a wider range of contributions: if labor is scarce, is there provision for cash contributions to allow the WUA to hire labor?

To assess women's roles, the phone survey asked about the proportion of women who attend meetings, speak in meetings and participate in canal maintenance, as indicators of intensity of women's participation. The next set deals with women's participation in other key irrigation activities: 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 potential negative outcomes that may be associated with male migration, including over burdening the workload to women in irrigation management, labor shortage at household level, labor shortage causing the deterioration of the system, and potentially irrigated land being left uncultivated.

Our key explanatory variable in the regression analysis is a binary variable for male migration at the irrigation system/WUA level.[4] Across the irrigation systems surveyed, 78.6% of WUA chairpersons reported systems having had male migration in the prior five years.

Our control variables include physical attributes of the irrigation systems and social attributes of the irrigation system management. For system attributes we include system management (comparing FMIS vs Agency or Joint managed systems (Lam 1998); system size (log ha); system type (gravity vs lift or groundwater); and topography (hill or mountain vs Terai plains). For social attributes we include caste/ethnicity, defined as number (out of four) members of the Executive committee members from high castes, and 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 Resurreccion (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. While other variables such as degree of dependence on irrigation systems could also be hypothesized to affect performance, these are more complex indicators than what we could collect during phone interviews.

Table 2 presents the overall means of the control variables, along with the means for systems 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. Systems with male migration were significantly more likely to have respondents (WUA chairpersons) 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

causality, the analysis nevertheless explores the associative relationships between male migration and a wide range of indicators of system governance and performance, which is particularly revealing when combined with qualitative analysis.

For binary dependent variables, we run probit regressions to examine how male migration helps explain the difference in probability of observing each outcome. For dependent variables expressed in percentages, including the female percentages who attend the meetings, who speak at the meetings, and who participate in canal cleaning, we run tobit regressions to examine how male migration helps explain 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 (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. All were canal systems except Nepalgung deep tubewell. The systems selected were both large and small, hill and Terai, agency managed and farmer managed as well as ground water systems (see Table 3, Figure 2). Several of these sites (Argali, Chhatis Mauja, Jamara) have been studied repeatedly, dating back to

	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	**
WUA chairperson education: Secondary and above	0.685	0.514	0.731	***
# executive committee members Brahmin or Chhetri	1.598	1.931	1.508	***
N	336	264	72	

Table 2 Control variables, by migration status.

Note: * p < .10; ** p < .05; *** p < .001.

IRRIGATION SYSTEM TOWN/ VILLAGE	DISTRICT	PROVINCE	TERAI/ HILL	SIZE (HA)	FOCUS GROUP PARTICIPANTS	
					MEN	WOMEN
Mahakali Block 2 of Mahendranager	Kanchanpur	7 Sudurpashchim	Terai	300 ha part of large system	14	18
Jamara Kulo, Tikapur	Kailali	7 Sudurpashchim	Terai	4500 ha	15	5
Deep tubewell, Nepalgung	Banke	5 Lumbini	Terai	40 ha each	6	2
Itura	Surkhet	6 Karnali	Terai	60 ha	6	7
Kasi Kulo	Pyuthan	5 Lumbini	Hill	40 ha	8	6
Chhatis Mauja, Butwal	Rupendehi	5 Lumbini	Terai	3500 ha	29	1
Argali	Palpa	4 Gandaki	Hill	60 ha **	3	10
Janakalyan *	Chitwan	3 Bagmati	Terai	116 ha	7	4
Kalleritar *	Dhading	3 Bagmati	Hill	120 ha	5	19
Ghetephant, Jogbura	Dadeldhura	7 Sudurpashchim	Hill	60 ha	10	10

Table 3 Characteristics of case study irrigation systems.

* Indicates system revisited for "deep dive".

** Service area changes by season.

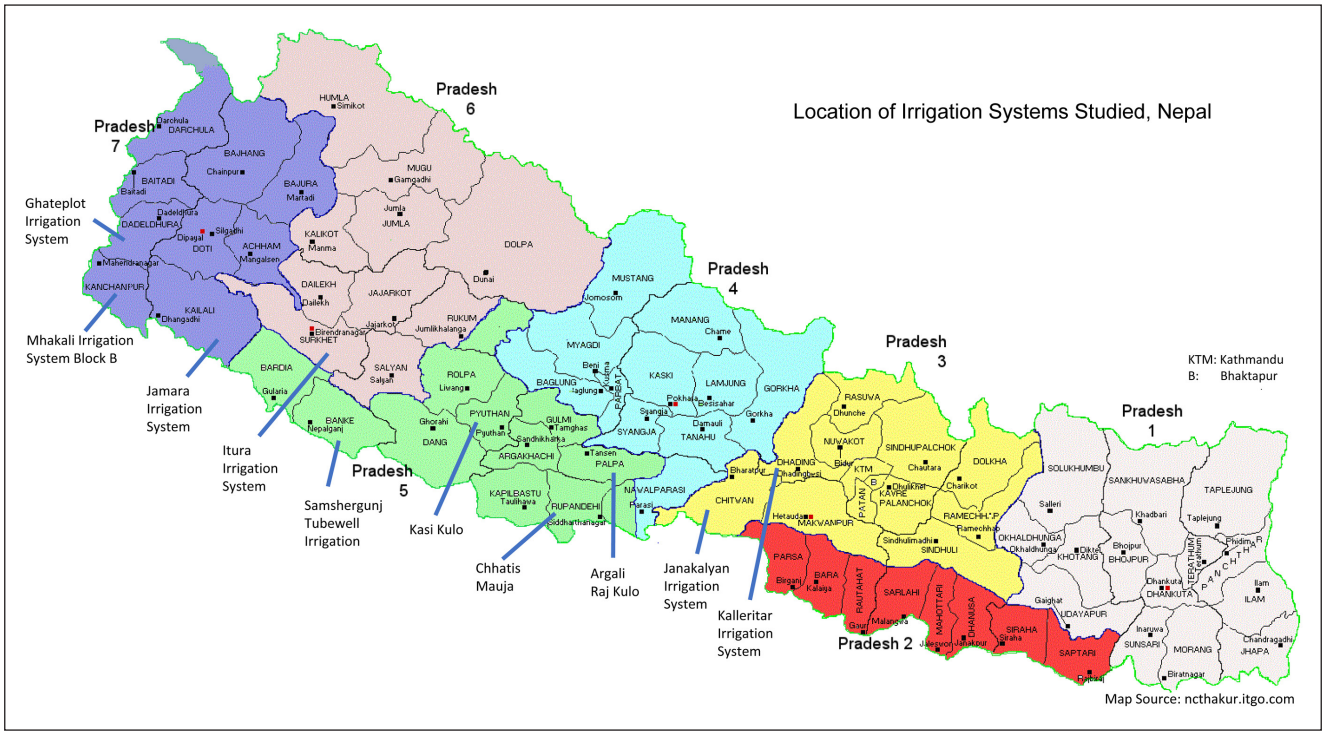

Figure 2 Case study irrigation system locations (See OJS – Suppl Files – Figure 2 Case study sites).

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).

Each case study combines background data collection, key informant interviews with chairpersons of the system, local leaders, and women members, and focus group discussions (FGDs). The case studies were led by Prachanda Pradhan, with a research assistant taking notes. In total, 44% of the qualitative respondents, including key informants and FGDs participants, were women. 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 Department of Water Resources and Irrigation (DWRI). The DIO then contacted WUA chairpersons. Association Organizers (AO) of DIO, who have regular contact with WUAs, would usually help in the field. At least a day or two before site visits, the WUA chairperson was contacted and requested to call a meeting with WUA members for a FGD, and particularly to include WUA member households whose family members have migrated. The FGD used a checklist to guide the questions (Appendix B). Notes from the FGDs were then written up in English, including key quotations, following the broad outline of the checklist. The notes were then read by all of the coauthors and analyzed according to the categories in the checklist.

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

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 operation and maintenance (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 participation in meetings, we see that migration is associated with a significantly higher percentage of women attending and speaking in meetings. Somewhat surprisingly, there is a significantly lower proportion of women participating in maintenance in systems with strong

	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: % women	48.788	38.772	51.270	***	287
Speaking in meetings: % women	43.339	38.278	44.533	**	283
Participating in irrigation maintenance: % women	41.589	49.438	39.596	**	316
Women's participation in specific irrigation activities					
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

Table 4 Dependent variables, by migration status.

Note: * p < .10; ** p < .05; *** p < .001.

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% or more) of sites reporting that women are involved in all activities, but migration is correlated with significantly higher women's participation in water distribution, or supervising water distribution.

In terms of the key outcomes, sites with male migration are significantly more likely to have labor shortages at the household level. Only 5% of sites report labor shortages cause the deterioration of the irrigation systems, but these are all sites with male migration. Sites with male migration also more likely to report leaving land uncultivated, but the difference is not significant.

INSTITUTIONAL CHANGE (RULES)

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.

Table 5 shows that across systems, the presence of male migration is associated with significantly higher presence of rules allowing women to participate in member meetings, and allowing both cash and labor contributions.[5]

Our qualitative work indicates 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. For example, in Kalleretar, membership and contributions are related to land ownership, but although many women do not own land in their name, women may participate if ther husband ownls land.

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 fact that all but one of the WUAs in our sample are headed by men indicates that there has

	(1)	(2)	(3)	(4)	(5)	(6)
	WOMEN AS MEMBERS IN THEIR OWN RIGHT	WOMEN TAKING ON MEMBERSHIP ROLE IF MEN ARE ABSENT	WOMAN PARTICIPATING IN O&M OR MEMBER MEETINGS	PROVISIONS FOR MAINTENANCE		
				LABOR CONTRIBUTION ONLY	BOTH LABOR AND CASH CONTRIBUTION	CONTRACT SYSTEM
Male 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 chairperson 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

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

Notes: *t* statistics in parentheses; * p < .10; ** p < .05; *** p < .001.

been limited change in top-level leadership in the WUAs. In the qualitative interviews, some WUA chairpersons from government-managed systems acknowledged that further progress is needed to meet government specifications that women should hold substantive positions in the leadership of WUAs. 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 have enough knowledge of the irrigation systems to participate effectively. Thus, they rely on male relatives or other informal channels 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 greater voice in the WUAs. For example, in Kalleritar, while the WUA chairperson is a man, the Vice Chairperson, treasurer, and Joint Secretary are women, and seven of the 15 Executive Committee members are women. There is also a woman representative from each of the four river terraces that comprise the system, who is designated as the communication link to relay decisions of the WUA to the terrace groups. The strength of women's participation in the WUA may be associated with the influence of other organizations, such as a women's cooperative in Kalleritar, raising women's confidence in participating in meetings, or a greater perceived dependence on WUAs for meeting their irrigation needs (see Suhardiman et al., under review).

The Argali case also illustrates how migration is not necessarily the driving factor in changing rules. They started having women patrolling and cleaning the canals in 1993, the year after the government mandated including women in the Executive Committee, even though there was little migration. Previously, concerns about women in the canals ritually polluting the water flowing by the shrine of a powerful goddess had precluded women's participation, but rules specifying that women would only clean the canals downstream of the shrine reduced those concerns. Women without a husband or son are exempt from providing labor as a sign of support to them.

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, the WUA hires contractors and machines for annual irrigation maintenance work using cash contributions by members based on area of land owned, instead of requiring labor contributions of (men or women) members. By contrast, in Kalleritar women contribute their own labor, instead of allowing only male labor or paying a fine for not sending a man. In explaining how this came about, a woman leader in Kalleritar said the women asked: "We women can work on farm, we can work in household, why can we not work in maintenance if there is no man?" She went on to explain that the WUA accepted this, but also allocated somewhat easier areas for women to work so that "in that way the men supported us." (The tasks alotted to women were not necessarily easy ones, as they carry sand and gravel up from the river, which is considerably below the system, but is closer to the village than the headworks of the system, which are 11 km from the main village.) Another Kalleritar women pointed out that "We don't go to maintenance to save money, but to bring water to the farms".

Even within a system, women from wealthier families may prefer to use remittances to hire laborers to meet WUA labor contributions as well as for on-farm labor requirements, while poorer families have trouble hiring labor. As the Janakakalyan WUA Chairperson explained, "Women of larger landholding play different roles to be managers of resources. Instead of over-burdening of worklod for themselves, they mobilize laborers to take care of agriculture activities at farm by the help of telephones."

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 FMIS of over 4,000 ha has Badghars (traditional Tharu village chiefs) representing each village who are responsible for infrastructure. Because WUA membership is based on land ownership and few women are land owners, there are only 8% women in the general membership and 19% 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.

INSTITUTIONAL CHANGE (WOMEN'S ROLES)

To examine how women's participation in irrigation may differ when there is migration, Table 6 presents results from the phone survey on percentage of female attendees at WUA meetings, percentage of female attendees speaking in meetings, and percentage of female participants in canal maintenance. 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. Tobit regression results show that migration is significantly and positively associated with women's attendance and speaking in meetings. Consistent with expectations that women will take on greater roles in irrigation governance via WUAs when men are absent, far more WUAs with male migration than those without (134 vs. 19; the rest are missing values) reported involvement of women in activities (such as participation in training, social work, and income-earning work) that they were not involved in 10 years ago. We do not see a higher proportion of women participating in irrigation maintenance with male migration, which may be partly because many systems have gone to cash contributions or contracting for maintenance when there is migration.

	ATTENDING MEETINGS (% WOMEN)	SPEAKING IN MEETINGS (% WOMEN)	PARTICIPATING IN IRRIGATION MAINTENANCE (% WOMEN)
Male migration	14.30***	7.277***	0.244
	(5.09)	(3.39)	(0.10)
Irrigation system management = FMIS	−9.198*	−7.633**	−1.403
	(−2.45)	(−3.13)	(−0.62)
System size (log ha)	0.0211	−0.138	−1.366*
	(0.02)	(−0.17)	(−2.08)
Irrigation system = Gravity	−2.557	5.237	3.973
	(−0.38)	(1.22)	(1.11)
Topography: Hill	−6.024	−6.276*	5.326*
	(−1.58)	(−2.29)	(2.06)
Topography: Mountain	−7.506	−6.003	6.647
	(−1.63)	(−1.61)	(1.92)
WUA chairperson education = Secondary and above	2.592	2.163	−5.285*
	(0.87)	(1.05)	(−2.54)
# executive committee members Brahmin or Chhetri	6.461***	4.376***	6.189***
	(4.78)	(4.52)	(7.64)
Constant	37.90***	33.39***	34.21***
	(3.91)	(4.90)	(5.87)
Observations	287	283	315
chi2			
p	9.35e−09	0.00000973	3.07e−21
r2_p	0.0179	0.0163	0.0337

Table 6 Women's participation in meetings and maintenance (Tobit results).

Note: * p < .10; ** p < .05; *** p < .001.

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. With over 90% of systems reporting that women participate in operation, water allocation, and distribution (Table 4), 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.

The qualitative work indicates that in many places women were previously prohibited from engaging in many of the irrigation activities, but that the attitudes and practices that prohibited women's involvement have been changing in response to a number of factors, including government policies, male migration, and broader social change. The case studies provide insights on why hill and mountain systems may have more provisions for women's participation in O&M. In the Terai, even when there is male 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 contact 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.

	(1)	(2)	(3)	(4)
	DO WOMEN PARTICIPATE IN IRRIGATION OPERATION	DO WOMEN PARTICIPATE IN WATER ALLOCATION	DO WOMEN PARTICIPATE IN WATER DISTRIBUTION	DO WOMEN PARTICIPATE IN SUPERVISION OF WATER DISTRIBUTION
Male migration	0.0268	0.0367	0.0657	0.149**
	(0.64)	(0.91)	(1.53)	(2.74)
Irrigation system management = FMIS	–0.0109	–0.0395	–0.0574*	0.00646
	(–0.30)	(–1.30)	(–2.14)	(0.18)
System size (log ha)	–0.00378	–0.0249*	–0.00936	0.00231
	(–0.31)	(–2.15)	(–0.88)	(0.17)
Irrigation system = Gravity	0	0	0.167	–0.0450
	(.)	(.)	(1.95)	(–0.86)
Topography: Hill	–0.00526	–0.124**	–0.0872*	–0.0626
	(–0.12)	(–2.62)	(–1.97)	(–1.25)
Topography: Mountain	0.0594	–0.0819	–0.170	–0.103
	(1.62)	(–0.84)	(–1.78)	(–1.15)
WUA chairperson education = Secondary and above	–0.00734	0.0273	0.0165	0.0246
	(–0.21)	(0.80)	(0.56)	(0.70)
# executive committee members Brahmin or Chhetri	0.0200	–0.0108	–0.0116	0.00775
	(1.49)	(–0.81)	(–0.99)	(0.56)
Observations	299	299	335	335
chi2	7.073	10.81	21.32	20.30
p	0.421	0.147	0.00635	0.00926
r2_p	0.0321	0.0713	0.0821	0.0782

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

Note: * p < .10; ** p < .05; *** p < .001.

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 four tiers of organization. Women comprise 30% of the general membership; 25% of the village-level (Mauja) committee, but only 14% 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 diversion weirs or 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, Argali 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 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. 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. As one woman in Argali explained: "My husband is in India for job. The remittance that I get from my husband's income helps run my household activities. Telephone has helped me to contact my husband almost everyday. We can make collective decisions." But the qualitative work also shows that remittances are not always reinvested in agriculture: much 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; Sunam and McCarthy 2016; Tamang et al. 2014).

Our case studies provide insights on why there may not be significant correlations between migration and mechanization: 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, and the availability of mobile phones improves communication, which allows migrants to continue to influence local and household decisions, as well as for women to coordinate the hiring of male labor.

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.

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).

POTENTIAL NEGATIVE OUTCOMES OF MALE MIGRATION

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. 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 chairpersons 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,

	(1)	(2)	(1)	(1)	(2)	(3)
	WOMEN PLOUGH IN THE ABSENCE OF MEN	WOMEN OPERATE TRACTORS	SPRINKLER OR DRIP IRRIGATION	MECHANICAL WEEDERS	MECHANICAL HARVESTERS	MECHANICAL THRESHERS
Male 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 chairperson 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

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

Note: * p < .10; ** p < .05; *** p < .001.

significantly associated with male migration (Tables 4 and 9), consistent with the findings of Sugden et al. (2021) and reflecting the many responsibilities that remaining household members, particularly women, take on.

Although less than 5% of WUA chairpersons overall reported that labor shortages had caused deterioration of the systems, because all of these were in sites with male migration, we were not able to include it in the regression analysis. Uncultivated land is reported in approximately 16% of the systems, but is not significantly associated with male migration. The case studies confirm that in cases of labor shortages, smallholders rent out their land or find sharecroppers rather than letting the land be 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 (Table 9).

CONCLUSIONS

Our overall findings show a range of responses to male migration. Sites with 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 some of the major maintenance.

Women's attendance and speaking in meetings is also higher in sites with male migration. A 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.

	(1)	(2)	(3)
	OVER BURDENING WOMEN'S WORKLOAD IN IRRIGATION MANAGEMENT	LABOR SHORTAGE AT HH LEVEL	UNCULTIVATED LAND
Male 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 chairperson 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
chi2	16.31	26.71	15.82
P	0.0382	0.000793	0.0451
r2_p	0.0519	0.0892	0.0772

Table 9 Potential outcomes associated with male migration (Probit results on estimated marginal effects).

Note: * p < .10; ** p < .05; *** p < .001.

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.

Importantly, 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 an 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.

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 interviews, particularly sites that are remote or in less accessible terrains, the phone

survey cannot be as detailed as in-person survey. 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 calls can be reduced by poor sound quality, lack of other communication-enhancing tactics such as hand gestures, and respondent fatigue.

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 and men's views in relation to women's envisioned roles in irrigation system management, following male migration, and how the latter are linked with 9 WUAs' organizational characteristics and historical origins, with more detailed ethnographic research on how irrigation management practices are negotiated. 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.

NOTES

[1] 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.

[2] Founded in 1998 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/).

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

[4] 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.

[5] For discussion of the coefficients of control variables in the phone survey results, see Appendix C.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **Appendices.** Appendix A to C. DOI: https://doi.org/10.5334/ijc.1165.s1

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COMPETING INTERESTS

The authors have no competing interests to declare.

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