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CONFLICTS OVER WATER FOR IRRIGATION IN BAJRABARAHI, NEPAL

L.C. Tremblay Lévesque*, N.L. Pandey, and M. Pokhrel

* Center for International Studies and Cooperation (CECI)
Bakundole -3 , Lalitpur, NEPAL
(E-mail: *laurentcharles.tremblaylevesque@outlook.com*)

ABSTRACT

Punctual but recurring conflicts over water for irrigation have emerged between farmers of Bajrabarahi, Nepal. This research assesses crop water requirements of farmland across Bajrabarahi as means of uncovering when and why are certain farmers facing water shortages. Crop water requirements were calculated using climatic and agricultural data. These variables were computed using CROPWAT 8.0, a computer software developed by the Food and Agricultural Organization (FAO) which relies on the Penman-Monteith equation. Forty-one interviews were conducted with farmers to compare and evaluate irrigation water use in both upstream and downstream areas. Results reveal that water resource competition tends to be most severe at the beginning of the monsoon season and in the middle of the spring planting period. Water shortages in downstream communities are primarily explained through a combination of agricultural and climatic factors but are also proven to be exacerbated by irrigation mismanagement upstream. This research shows the utility of modelling in disentangling water resource conflicts.

KEYWORDS

irrigation management, CROPWAT 8.0, crop water requirements, Nepal, water conflicts

INTRODUCTION

Nepal has vast water resources and approximately 67% of its cultivated land can be irrigated (MoAD, 2016). Out of the 1.7 million ha of Nepal's irrigable land, 78% has been provided with some irrigation infrastructure but it is estimated that about only two thirds of which are actually irrigated during the monsoon season (MoAD, 2016). Irrigation is vital to Nepal, especially as the country is facing climate change impacts such as rise in temperature and more erratic rainfall patterns, which is jeopardising the agricultural production nationwide (Malla, 2009). As the supply of water for agriculture becomes more variable, water resource competition and water conflicts across the country are equally becoming increasingly visible (Biggs et al., 2013). To prepare for these challenges, many have argued that efforts need to be directed not only towards developing the country's irrigation infrastructure but also towards changing water management practices (Manandhar et al., 2011, Gentle and Maraseni, 2012 and Chhetri et al., 2012).

This paper examines water resource management of farmers in the Bajrabarahi Village Municipality, Makwanpur District, Nepal. The broader aim of this paper is to examine the extent to which water demand for irrigation can be met both in terms of equity and sustainability in spite of limited or uncertain water patterns. This research gives a special attention to considering spatio-temporal dimensions in conducting its analysis. Water shortages in agriculture are recognisably a function between the seasonality of water resource availability and the demand for irrigation water. As such, one of the objectives of this study is to determine when severe stress on available water supplies is likely to occur. Furthermore, since terrace cultivation dominates Bajrabarahi's agricultural landscape, access to irrigation water is inevitably location specific; the further upstream a farmer is the more privileged her access to water resources is, and vice-versa. Another objective is therefore to assess the degree to which downstream communities, and ultimately the lowland ecosystems, are impacted by the water management practices of their upland counterparts.

This research compares actual water use of upstream and downstream communities against each other but also against software computed optimal irrigation water requirements. Information about the farmers' actual water use was collected through a questionnaire delivered to forty-one respondents in both upland and lowland areas. The irrigation water requirements were processed using CROPWAT 8.0, a computer software developed by the Food and Agricultural Organization (FAO). The agricultural information inputted into the model was obtained through the questionnaire survey and the climatic data was provided by the Department of Hydrology and Meteorology.

The results from the irrigation water requirements analysis reveal that water for irrigation demand spikes during the middle of the spring growing season and at the beginning of planting season in the summer. Moreover, it is found by comparing CROPWAT irrigation requirements and actual irrigation water use of farmers that the average farmer in Bajrabarahi over irrigates by 8% for rice, 12% for crucifers and 38% for potatoes. That said, while disaggregating the data between upstream and downstream communities we realise that most of this mismanagement actually comes from upstream farmers and that downstream farmers in fact typically under irrigate. Upstream farmers are thus shown to have a direct effect on the downstream farmers, further reducing water supplies during these period of intense water stress.

LITERATURE REVIEW

Irrigation infrastructure development and the irrigation management practices in Nepal have been well documented topics in the academic literature (Schreier and Shah, 1996; Pradhan 2012; Joshi et al., 2017; Chhetri and Easterling, 2010; Sujakhu et al., 2016). In their assessment of the potential impact of climate change on water resources development in the Koshi River Basin in Nepal, Bharati et al. (2014) illustratively conclude that infrastructure needs to be put in place to store and transfer water to manage the water deficits due to any changes in rainfall or flow patterns. In contrast, based on their analysis of water availability and variability in two watersheds of the Middle Mountains of Nepal's Hindu Kush-Himalayas region, Merz and al. (2003) argue that irrigation infrastructure alone will not resolve lack of water access for agriculture and that new water governance bodies are additionally needed.

The question of water management institutions and their ability to deal with water resource pressure and conflicts in Nepal is an equally impressive body of literature (Pradhan et al., 2000; Cifdaloz et al., 2010; Biggs et al., 2013). Upreti's (2004) analysis of natural and water resources conflict resolution practices in Nepal argues that existing formal legal procedures and informal systems are complicated, inherently biased towards those with power, and thus mainly dysfunctional. Similarly, Yates' (2011) comparative study of different water governance mechanisms in Nepal shows that water user committees generally lack the proportional representation and institutional capacity for sufficient responsiveness. Yet, Ostrom and Lam's numerous publications (e.g. Ostrom et al., 1994; 2011; Lam 1998; Lam and Ostrom, 2010) comparing agency-managed irrigation systems with farmer-managed irrigation systems have revealed how the later performs much better in terms of allocation and conflict management.

While water resource management and water conflicts in Nepal have attracted much academic attention, most of it has however come through the analytical lens of political ecology. This paper rather aims to apply a mix-methods strategy, grounded in modelling, to identify and assess the weight that different factors play in water resource management conflicts. So far, irrigation water requirement modelling has been used in the context of Nepal only to study the possible impacts of climate change (Pant, 2013; Shrestha et al., 2013) or to study climatic and agricultural water balances (Paudel and Pandey, 2013; Adhikari and Devkota, 2016). This paper contributes to the literature by highlighting the use of water resource modelling in disentangling water management conflicts in Nepal and elsewhere.

BACKGROUND ON BAJRABARAHI VILLAGE MUNICIPALITY

The Bajrabarahi Village Municipality is situated in Makwanpur District, about 50 kilometres southwest of Kathmandu. As of 2011, it had 1,630 households for a total population of 7,675 (CBS, 2014). Bajrabarahi is a predominantly agricultural community with small commercial activities as well (e.g. restaurants, convenience stores, and mechanic shops). Agriculture wise, the area is renown for its winter and spring production. Its products are mostly sold in the markets of neighbouring towns such as Markhu, Chandragiri and Dakshinkali and some higher value horticultural crops can be also found in the markets across the Kathmandu Valley.

The climate of Bajrabarahi is typical to what is found in any other hilly zones of southern Nepal (**Figure 1**). The summer months are warm and moist with average relative humidity maintaining itself over the 80% mark from June to September (DoHM, 2018). Temperature and humidity considerably drops during the winter months. The average precipitation in Bajrabarahi, 1747 mm/year, is relatively high for Nepal. Kathmandu, in comparison, receives 1343 mm/year (DoHM, 2018). The distribution of the rainfall conversely follows the same unimodal pattern which affects all of Nepal and which is centred around the monsoon season. Eighty-six percent of the annual rainfall which Bajrabarahi receives happens between May and September.

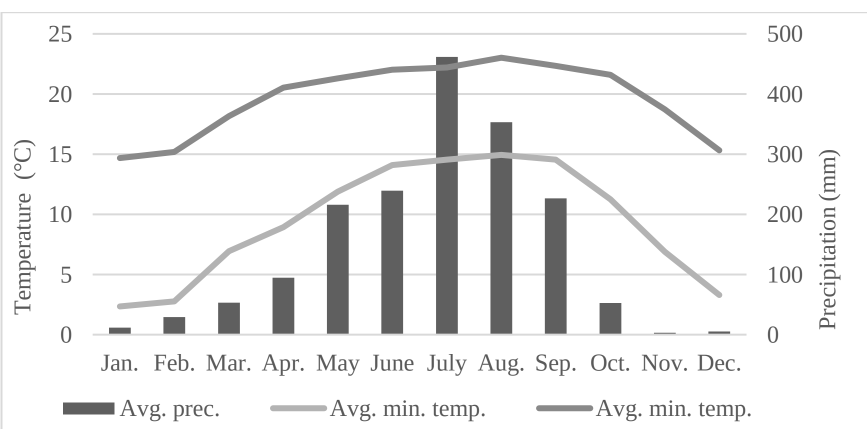

Figure 1. Precipitation and temperature patterns in Bajrabarahi (source: DoHM, 2018)

The village centre sits at approximately 1700 m a.s.l. and is surrounded by mountains going up to 2300 m a.s.l.. Most of the land cover is occupied by agricultural land but the uphill areas are still predominantly forested (**Figure 2**). The community is gifted with abundant natural water resources as several forest born springs run from the mountains into the agricultural lands. Mr. M. Subedhi, Chairperson of the Bajrabarahi Small Farmers Agricultural Cooperative Ltd., representing more than 1,302 farmer members in the village, estimates that around 85% of agricultural land in Bajrabarahi is irrigated (personal communication, 29/10/2018). Though water resources appear to be abundant, water shortages have become ubiquitous and water for irrigation competition in addition to conflicts are on the rise (M. Subedhi, personal communication, 29/10/2018). This paper's aim is to offer a clearer portrait of the factors behind these shortages and hopefully pave the way to resolve these conflicts.

Figure 2. Satellite imagery of the Bajrabarahi Village Municipality (source Google Earth)

METHODOLOGY

This paper utilises a mix method strategy composed of both quantitative and qualitative methods. Questionnaire survey was used to collect information on agricultural and water management practices while climatic data was obtained through meteorological station records and climatic databases. Irrigation water requirements were calculated through CROPWAT 8.0, a computer software developed by the FAO. Questionnaire results were reported in the form of averages and histograms and CROPWAT estimates on irrigation water requirements per crops per decades (ten days' interval) were presented in tables. Key determining variables used to calculate the irrigation requirements (crop specific coefficients (Kc coff.), evapotranspiration coefficients (ETc), and effective rainfall) were additionally reported in these tables.

The questionnaire contained twelve questions which were translated from English to Nepali and conducted in Nepali by a native speaker. As suggested by McLafferty (2016), open-ended questions always preceded close-ended ones in order to maximize flexibility and depth in the interviewees' responses. The questionnaire was conducted with forty-one respondents across the farmland of the Bajrabarahi community, interviewing farmers as they were encountered. Farmers were classified as either “upstream” or “downstream” depending on the ratio between the number of farmers they believed to be higher and lower than them *and* who depended on the same water resources for irrigation. This self-assessment was crossed-checked using maps to identify the location of each farmer. Out of the 41 farmers, 26 of them were identified as upstream farmers and the remaining 15 were classified as downstream. Results are presented so that differences between the upstream and downstream communities could clearly illustrated.

CROPWAT 8.0 was used to estimate the irrigation water requirements for the three main irrigated crops cultivated in Bajrabarahi. This software computes irrigation water requirements based on agricultural and climatic data and relies on the Penman-Monteith equation for evapotranspiration calculations. The climate data inputted into CROPWAT was obtained from records of the closest meteorological station to Bajrabarahi, the Daman Station (Lat. 27.36/Log. 85.05). Daily records from January 2000 to April 2016, including for maximum and minimum temperatures, precipitation, hours of sunlight, wind and relative humidity were provided by Department of Hydrology and Meteorology. Climate data was triangulated with the neighbouring stations of Hetauda and Khumaltar. Records for these two stations were obtained though CLIMWAT 2.0, a climatic database also developed by the FAO. The irrigation water requirements results were put against actual water usage of interviewed farmers to assess the water management practices in Bajrabarahi and to evaluate differences between downstream and upstream communities in that regard.

RESULTS AND INTERPRETATION

The nature of the hydrological cycle entails that water resource competition between farmers in Bajrabarahi (as elsewhere in Nepal) varies inter- and intra-seasonally. In this section, we first examine the agricultural calendar of Bajrabarahi to introduce which crops are irrigated and when are they grown exactly. Then, we make sense of when and for how long are water resource conflicts most prone to emerge by looking specifically at seasonality of water shortages. For that purpose, we begin by considering the farmers’ perceptions on this matter before comparing that with crop irrigation calculations as means of determining not only when water is needed but also how much farmers technically require for different periods of the year. We then turn to comparing actual water use against CROPWAT estimates for crop irrigation requirements and suggest how mismanagement, especially by the upstream farmers, has been contributing to these punctual water shortages. That said, we then finally seek to analyse the farmers’ perceptions on why their water requirements are sometimes not met—only to discover that the majority of them believe that that human mismanagement has very little influence on water scarcity in the area.

Agricultural calendar

The farmers of Bajrabarahi are agriculturally productive all throughout the year (**Table 1**). Farmers of Bajrabarahi traditionally grow maize, chili, peas and mustard on rain fed land and they grow rice, potatoes, cauliflower and cabbage on their lands with irrigation supplies. Irrigated crops grow continuously from mid-January to mid-November. The rice growing period stretches a little before and after months of the summer monsoon, approximately from mid-Jestha to mid-Kartik (late May/early June to late October). Potatoes and crucifers, which are the two other major irrigated crops types cultivated in the area are grown during the winter and springtime. The growing season for potatoes goes from mid-Magh (the first week of February) to the end of Jestha (early to mid-June). Crucifers, primarily cauliflowers intercropped with cabbages, are planted around the middle of Poush (early/mid-January) and harvested slightly after potatoes in mid-Āshādh (mid/late June). The growing period in Bajrabarahi ranges around 150 days for rice (including the nursing time), 130 days for potatoes and 165 days for crucifers.

Table 1 Agricultural calendar of major crops in Bajrabarahi

	Gregorian calendar	*Apr.-May*	*May-June*	*June-July*	*July-Aug.*	*Aug.-Sep.*	*Sep.-Oct.*	*Oct.-Nov.*	*Nov.-Dec.*	*Dec-Jan.*	*Jan.-Feb.*	*Feb.-Mar.*	*Mar.-Apr.*
	Nepali cal.	*Bai.*	*Jes.*	*Ash.*	*Shr.*	*Bha.*	*Ash.*	*Kar.*	*Man.*	*Pou.*	*Mag.*	*Fal.*	*Cha.*
Irr.	*Rice*		Plant				Harvest						
	Potato	Harvest									Plant		
	Crucifers		Harvest							Plant			
Rain fed	*Maize*				Harvest								Plant
	Chili		Plant					Harvest					
	Peas	Harvest								Plant			
	Mustard						Plant		Harvest				

The seasonality of water shortages based on farmers' perceptions

Natural water availability and water demand are in constant flux through the year in Bajrabarahi. Water shortages, and by extension water resource competition, are consequently bound to temporal variations as well. To get a better sense of the seasonality of water shortages, questionnaires were performed to understand farmers' perceptions on when and for how long are water for irrigation deficiencies generally experienced.

When asked to name the different periods of the year where water shortages are most acute in an open-ended question, both upstream and downstream farmers predominantly mentioned in similar proportions the month of Chaitra (**Figure 3**). Second and third are the months of Falgun and Baishakh, respectively. However, when asked to rank the most intense periods of the year for water shortages, both upstream and downstream farmers identified the month of Falgun, six times each for a total of twelve times. Closely follows Chaitra with five and five mentions, totalising ten times. Finally, Magh and Jestha were individually mentioned as the most intense month of water shortage seven and six times in total.

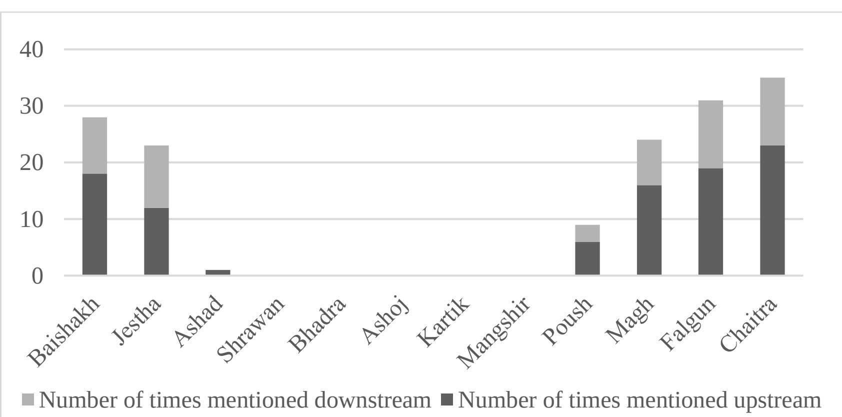

Figure 3. Farmers' perceptions on water shortages by month

CROPWAT results on crop irrigation requirements and on seasonal water demand

The CROPWAT analysis of the irrigation water requirements confirms the farmers' perceptions on the seasonality of water shortages and brings further precisions on the agricultural and climatic factors behind these temporal water deficiencies. The results show that the farmers' irrigation requirements peak at the beginning of the monsoon season and during the middle of the spring planting period. The perceptions of water resource shortages in Baishakh and Jestha are thus shown to relate to the high water demand for rice cultivation and the gradual increase in the perceptions of water resource shortage for Margh, Falgun and Chaitra (from mid-January to mid-April) is shown to correspond to rises in the irrigation water requirements for potatoes and for crucifers.

The perceptions of water shortages noted at beginning and just before the monsoon season mirror the large water requirements that are needed in the early stages of rice cultivation. Total irrigation requirements for rice are 227.4 mm (227.4 litres/m^2) and three quarters of that water (207 mm or 207 litres/m^2) are needed at the nursing and initial development stages of the plant (**Table 2**). Most farmers start to store water and to irrigate their land as early as the beginning of May in order to secure sufficient water resources for this period, hence explaining why farmers perceive there to be water scarcities from the mid/end of Baishakh to the end of Jestha. From the beginning of July until late September, precipitation is sufficient to meet the crop water requirements so no additional irrigation is needed. Perceptions on water shortages too fall to virtually zero for this entire five months' period. Irrigation water, although in much smaller quantities (20.4 litres/m^2), are once again needed when the rice reaches its late development stages in October. However, this increase in irrigation water demand was not reflected in the farmers' perceptions on water shortages. One of the possible reasons for that are the great amounts of water are sporadically released as farmers begin to selectively drain their rice paddies in preparation for harvest during these weeks.

Table 2 Crop water requirements for rice

Month	*Decade*	*Stage*	*Kc coeff.*	*Etc mm/day*	*Etc mm/dec*	*Eff rain mm/dec*	*Irr. Req. mm/dec*
May	*3*	Nurs	1.2	0.42	2.9	31.5	0
Jun	*1*	Nurs/LPr	1.11	2.58	25.8	48	49.1
Jun	*2*	Nurs/LPr	1.06	3.33	33.3	48.5	98
Jun	*3*	Init	1.09	3.29	32.9	51.3	59.9
Jul	*1*	Init	1.1	3.19	31.9	55.5	0
Jul	*2*	Deve	1.1	3.07	30.7	58.7	0
Jul	*3*	Deve	1.11	3.11	34.2	56.9	0
Aug	*1*	Deve	1.12	3.14	31.4	54.8	0
Aug	*2*	Mid	1.13	3.16	31.6	53.6	0
Aug	*3*	Mid	1.13	3.18	35	51.8	0
Sep	*1*	Mid	1.13	3.21	32.1	52.4	0
Sep	*2*	Mid	1.13	3.23	32.3	51.9	0
Sep	*3*	Late	1.11	3.11	31.1	40	0
Oct	*1*	Late	1.07	2.93	29.3	25.2	4.1
Oct	*2*	Late	1.02	2.75	27.5	13.7	13.8
Oct	*3*	Late	1	2.52	2.5	0.9	2.5

					444.5	**694.7**	**227.4**

The other months which farmers identified as periods of severe water shortage (basically from Poush to Chaitra or from mid-January to mid-April) match the months when the irrigation water requirements for potatoes and crucifers are highest. Irrigation water requirements begin to rise, especially for crucifers, from mid-January to February onwards. They reach their respective maximum in the months of March and April when effective rainfall is still below a 20 mm monthly average. Ninety-one percent of the total crop water requirements for potato (86.4 mm or 86 litres/m^2) are in fact concentrated in April and March (**Table 3**) and 53% of the total irrigation water requirements for crucifers are in these two months as well (**Table 4**). The aforementioned farmers' perceptions hence clearly echo the rising pattern in the irrigation water requirements for the period culminating to Falgun and Chaitra (mid-February to mid-April).

Table 3 Crop water requirements for potato

Month	*Decade*	*Stage*	*Kc coeff.*	*Etc mm/day*	*Etc mm/dec*	*Eff rain mm/dec*	*Irr. Req. mm/dec*
Jan	*3*	Init	0.5	0.96	2.9	1.5	2.9
Feb	*1*	Init	0.5	1.03	10.3	7.4	2.9
Feb	*2*	Init	0.5	1.1	11	9.2	1.8
Feb	*3*	Deve	0.55	1.36	10.9	11.5	0
Mar	*1*	Deve	0.74	1.99	19.9	13.6	6.3
Mar	*2*	Deve	0.95	2.79	27.9	15.7	12.2
Mar	*3*	Mid	1.11	3.55	39	19.4	19.6
Apr	*1*	Mid	1.13	3.85	38.5	22.3	16.2
Apr	*2*	Mid	1.13	4.13	41.3	25.4	15.9
Apr	*3*	Mid	1.13	4.12	41.2	32.6	8.6
May	*1*	Late	1.12	4.1	41	42	0
May	*2*	Late	1.02	3.73	37.3	49.6	0
May	*3*	Late	0.88	3.05	33.5	49.5	0
Jun	*1*	Late	0.75	2.48	17.4	33.6	0
					372.2	**333.4**	**86.4**

Table 4 Crop water requirements for crucifers

Month	*Decade*	*Stage*	*Kc coeff.*	*Etc mm/day*	*Etc mm/dec*	*Eff rain mm/dec*	*Irr. Req. mm/dec*
Jan	*2*	Init	0.7	1.25	8.8	2.4	7
Jan	*3*	Init	0.7	1.35	14.8	5.4	9.4
Feb	*1*	Init	0.7	1.45	14.5	7.4	7
Feb	*2*	Init	0.7	1.54	15.4	9.2	6.2
Feb	*3*	Deve	0.71	1.75	14	11.5	2.5
Mar	*1*	Deve	0.76	2.05	20.5	13.6	6.9
Mar	*2*	Deve	0.81	2.39	23.9	15.7	8.2
Mar	*3*	Deve	0.87	2.76	30.4	19.4	11
Apr	*1*	Deve	0.92	3.16	31.6	22.3	9.3
Apr	*2*	Deve	0.98	3.58	35.8	25.4	10.4
Apr	*3*	Mid	1.01	3.71	37.1	32.6	4.5
May	*1*	Mid	1.02	3.71	37.1	42	0
May	*2*	Mid	1.02	3.71	37.1	49.6	0
May	*3*	Mid	1.02	3.53	38.9	49.5	0
Jun	*1*	Mid	1.02	3.36	33.6	48	0
Jun	*2*	Late	0.99	3.1	31	48.5	0
Jun	*3*	Late	0.93	2.79	19.6	35.9	0

				444	**438.6**	**82.5**

CROPWAT irrigation requirements versus farmers' actual irrigation water use

The comparison between CROPWAT estimates for crop irrigation requirements and actual water use of farmers in Bajrabarahi reveals how mismanagement, especially by the upstream farmers, contributes to these seasonal water shortages. In fact, results from agricultural survey indicate that farmers tend to use much more water than CROPWAT's irrigation requirement estimations for each of the three major irrigated crop grown in the area (**Table 5**). Results also show that mismanagement is concentrated in the uplands and that downstream farmers actually tend to use much less than CROPWAT irrigation requirements.

Table 5 CROPWAT irrigation requirements versus actual irrigation water use

	*Rice (l/m^2)**	*Potato (l/m^2)***	*Crucifers (l/m^2)***
CROPWAT Irr. Req.	50	86.4	82.5
Total avg. water use	53.97 (n = 29)	119.3 (n = 29)	92.74 (n = 23)
Avg. water use up.	62.37 (n = 20)	126 (n = 20)	106.5 (n = 12)
Avg. water use down.	36.67 (n = 9)	104.4 (n = 9)	77.72 (n = 11)

*Average continuous flooding levels
**Total crop water use

Although the flooding levels will vary with the development stages of the plant, the FAO model recommends using 5 cm or the equivalent of 50 l/m^2 as threshold for continuous flood level for rice (FAO, 2006). The average continuous flooding levels for farmers that were interviewed was 53.97 l/m^2, which is almost 4 litres per square metre more than the software's standard optimal. The difference between actual irrigation water use and CROPWAT irrigation requirements estimations are even larger for the two other irrigated crops. Compared with CROPWAT estimates, the total average water use was 38% (or 32.9 l/m^2) higher for potatoes and 12% (or 10.24 l/m^2) higher for crucifers.

What appears from disaggregating the data, however, is that downstream communities not only use less water than their upstream counterparts but they also fall well below software irrigation requirements, at least for rice and cauliflower. The average actual water use for rice production for downstream farmers is 36,67 l/m^2, that is, 25.7 l/m^2 and 13.33 l/m^2 lower than upstream average use and the CROPWAT calculations, respectively. The average total demand for irrigation water in terms of cauliflower and cabbage production was 77.72 l/m^2 for downstream farmers, again much lower water use than for the uplands (106.5 l/m^2) and than what the suggested optimal (82.5 l/m^2). The data for potato cultivation shows a similar trend in the irrigation water use patterns between the upstream and downstream communities, whom, on average, require correspondingly 126 l/m^2 and l04.4 l/m^2. That said, the results for potatoes reveal that downstream farmers tend to over irrigate in the case of this particular crop. Still, the trend emerging from this exercise is that upstream farmers are generally over irrigating and that downstream farmers, in contrast, tend to fall short from their irrigation water requirements.

Farmers' perceptions factors behind shortages in water for irrigation

Over-irrigation by farmers (predominantly those upstream), leads to regular water shortages as seen in Bajrabarahi. Nevertheless, and perhaps contradictorily, mismanagement is not recorded as one of the primary reasons behind shortages based on the local farmers' opinion. In fact, when asked to state up to three causes for punctual lacks of irrigation water, farmers' have predominantly mentioned earthquakes, twenty-one times, while deforestation and increase in population came in second, being identified overall twenty times each. Climate change and the construction of roads (such as the Chandragiri-Chitlang link) were also perceived as factors, although minor being respectively mentioned seven and three times. Overall, human mismanagement of water resources and over-irrigation were mentioned only three times.

To refine these answers, farmers were then asked to rank five causes identified in the questionnaire, namely: (a) climate change; (b) rain failure; (c) water mismanagement by other farmers; (d) earthquakes and landslides and; (e) deforestation. Earthquakes and landslides were identified as the principal contribution to regular water shortages, at a total average of 1.59 (**Table 6**). Then followed in order: climate change, deforestation, rain failure, and mismanagement. The average ranking for the five factors remained unexpectedly the same across upstream and downstream farmers with no significant differences among the two groups. Interestingly enough, water mismanagement by other farmers was mentioned only once as the number one factor, and that by an upstream farmer, clearly coming in last position with a total average of 4.71. These results demonstrate the urgent need in raise awareness amongst farmers on irrigation mismanagement.

Table 6 Average of farmers' rankings of factors behind water shortages (scale from 1 to 5)

	Earthquakes	*Climate change*	*Deforest.*	*Rain failure*	*Mismanagement*
Average up. (n=25)	1.48	2.48	2.76	3.64	4.64
Average down. (n=16)	1.75	2.50	2.69	3.25	4.81
Average total (n=41)	1.59	2.49	2.73	3.49	4.71

CONCLUSION

This paper has shed light on the seasonality of water demand competition and showcased the main factors behind the punctual water shortages for agriculture occurring in the Bajrabarahi. Based on the farmers' perceptions and on CROPWAT estimates on irrigation water irrigation, it has been shown that water demand is highest during the beginning of the monsoon season and in the middle of the spring growing period. The surge in water resource competition around early/mid-May to mid-June was shown to closely correspond to the period when crop water requirements for rice are on the rise while effective rainfall is still relatively low. The second period of perceived water shortages stretching from mid/late January to mid-April was shown to match to peaks in water irrigation requirements for potatoes and for crucifers. This paper has argued that the water shortages, and by extension water conflicts in Bajrabarahi, can be primarily explained through a combination of agricultural and climatic factors.

This paper also demonstrated how human mismanagement has contributed to aggravating the levels of water stress in this agricultural community. By comparing CROPWAT irrigation requirements and actual irrigation water use of farmers that the average farmer tends to over irrigate by 8% for rice, 12% for crucifers and 38% for potatoes. Disaggregating the data between upstream and downstream communities however revealed that most of this mismanagement was actually concentrated in the upland communities and that downstream farmers in fact mostly fell short of their water requirements. Additionally, it was also found that most farmers of Bajrabarahi believe that human mismanagement of water resources has although little to do with water shortages. This paper has made a clear case of the extent to which water resource modelling, especially used in combination with a range of qualitative inputs, can be beneficial to disentangling water resource conflicts and identifying ways of moving forward with better understanding and education of more sustainable and equitable water resource management.

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