Farmer-led Small-scale Irrigation Systems Management in Highland Vegetable Farming in the Cordillera Region, Philippines

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ABSTRACT

Much has been said about large-scale and pump irrigation systems but not much published research is available on small-scale farmer-led irrigation systems supporting highland farming. This study described the management of irrigation sources and farmer-led irrigation systems, and conveyance and distribution technologies supporting highland farming. Data were based on FGDs in 30 barangays and a survey of 279 farmers in three highland provinces. Findings show that 91% of farmers use irrigation from springs, rivers, and creeks; 70% of the conveyance and distribution facilities are farmer-initiated and managed, and micro-irrigation technologies such as sprinklers and drip irrigation are accessible. National irrigation development agenda need to include and Cordillera region needs to prioritize support for small- and micro-scale irrigation systems, conservation of watershed and riverine systems, and rethink irrigable area policy to sustain the highland vegetable industry. Policy, R&D, infrastructure, and multi-agency convergence support to farmer-led irrigation development are paramount.

Keywords: *spring, small-scale irrigation, highland vegetable farming, farmer-led irrigation, Cordillera region*

Introduction

Availability of irrigation water and water-use efficiency are critical factors for increased production, productivity, and lower food prices. Worldwide, 70% of total water use is for agriculture, 8% is for domestic use, and about 22% for industry (World Bank 2016). For low and middle-income countries, 82% of freshwater is used for agriculture, 8% for domestic use, and 10% for the industry. In the Philippines, as much as 73% of the total consumptive and 31% of non-consumptive water demand is for irrigation (David and Abaño 2019). It is estimated that the country's 26 BCM/year agricultural water demand in 1995 will increase, with business-as-usual scenarios, to 73 BCM/year by 2025, or 2.8 times the 1995 level (JICA 1998). IPCC (2007) also estimated that in Asia, by the 2050s, freshwater availability in Central, South, East, and Southeast Asia, is projected to decrease. Improved agricultural water management is thus a significant and potential impact area for adaptation. With scarce water, it is crucial to ensure that every drop of water counts for crop production.

Worldwide, farmers' ability to develop their own irrigation is increasingly being recognized, but farmer-initiated irrigation is still unnoticed in regional or national policy circles (Woodhouse *et al.* 2017 as cited by De Bont *et al.* 2019). In the Philippines, much technical and policy research has been done on irrigation and irrigation development. However, these research focused on the large or small-scale pump and tube well irrigation systems applied to rice and rice-based farming systems (Briones 2021, David 2003, Moya and Valencia 2002, Inocencio and Barker

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2006, Luyun 2015, Launio and Manalili 2016). Not much published information about farmer-led irrigation development, small-scale irrigation systems, and technologies supporting farming systems in mountainous terrain or high elevation regions are available.

Studies on farmer-led irrigation development are crucial since most irrigation sources such as springs, small-scale diversion dams, micro-irrigation systems, and irrigation distribution systems, such as drip and sprinkler irrigation, are in the context of Philippine highland vegetable farming systems being managed by farmers or group of farmers. While the irrigable areas in the country are defined as those with slopes not exceeding 3% (David 2000), also including a 3% to 8% slope in the 2020-2030 National Irrigation Masterplan, three-fourths of the total land area of the Cordillera Administrative Region (CAR) have slopes of 30% and above (National Economic Development Authority [NEDA] 2017). Its farming landscape is comprised of terraced fields or patches of farmlands on rolling and steep terrains. Hence, closer documentation of the irrigation landscape supporting such a vital highland farming industry is in order.

Moreover, the CAR and the highland farming industry are comprised of indigenous peoples still governed by customary laws. One issue related to irrigation is the Regalian doctrine, which provides ownership and control over natural resources to the state, versus the Indigenous People's Rights Act or IPRA, which upholds customary water laws that equate the right to access the use of waters with land ownership, which is communal (Lapong and Fujihara 2008, Prill-Brett 2003). The Water Code does not mention customary water rights and appears to operate only under the Regalian doctrine, giving the state power to grant rights to extract and utilize water sources.

In addition, there is almost no discussion on farmer-led irrigation development in the country. Irrigation development in the Philippines is traditionally large-scale irrigation with a lack of participation of farmers in the planning and design stage (Rola *et al.* 2021, David 2000). It is focused on systems that require collective investment, operation, and maintenance of irrigation developed mainly for the rice sector (David 1995). While statistics on private irrigation systems are available, these data are mostly in the nomenclature of shallow aquifer utilization or shallow tube wells, small, portable low-lift pumps, and small water impoundments. These private irrigation systems are still largely about supporting rice and corn programs.

The main contribution of this descriptive paper is to build a case for farmer-led and small-scale irrigation systems beyond irrigation pumps and shallow tube wells by taking the case of private irrigation systems in the CAR. It provided evidence for the need to do more research concerning irrigation sources, small-scale and farmer-led irrigation, and water management technologies for highland vegetable farming in the Philippines and other highland regions in other developing countries. Ultimately, it hopes to contribute to the sustainable development goals of responsible production, climate action, and sustainable communities and indirectly to no poverty, zero hunger, and good health and well-being, particularly in mountainous farming regions.

This paper aims to provide a general overview of the management of farmer-led irrigation systems in the CAR highland farming based on a farmer survey, focus group discussions with barangay local government units, and case examples. Specifically, it describes the existing water sources, briefly considering the concept of water rights; determines how farmers manage these water sources and cope with scarcity in water supply; determines the water conveyance and distribution technologies and associated problems and management practices.

Small-Scale and Farmer-led Irrigation Systems in the Philippines

There is no single global definition of small-scale irrigation since what can be considered small in one country might be considered large in another. Small-scale irrigation systems can also be classified according to size, source of water, management style, degree of water control, source of innovation, landscape niche, or type of technology (Gujit and Thompson, 1994; Vincent, 1994). Turner (1994), looking at "small-scale irrigation" (SSI) in developing countries, stated that most authors agree that the best definition is that which combines concepts of local management, simple technology, and size. He cited as the best working definition that of the UK Working Group on SSI as quoted by Carter and Howsam (1994): "Irrigation, usually on small plots, in which farmers have the major controlling influence and using a level of technology which the farmers can effectively operate and maintain."

In the Philippines, the National Irrigation Administration (NIA) generally categorizes the country's irrigation systems as national, communal, and private. Accordingly, national irrigation systems (NIS) are large and medium schemes constructed by NIA, with a service area usually greater than 1,000 hectares, while communal irrigation systems (CIS) are usually constructed by NIA with farmers' participation, maintained by irrigators' associations, and with service area less than 1,000 hectares. Private irrigation systems (PIS) are built, operated, and maintained by private individuals or groups with or without technical assistance from NIA or other government agencies.

While almost all private irrigation systems and many CIS are small-scale in terms of size, management, and simplicity of technology as defined above, NIA usually does not use the term "small-scale irrigation" or SSI. The Bureau of Soils and Water Management (BSWM) under the Philippine Department of Agriculture (DA), on the other hand, is explicitly mandated to implement small-scale irrigation projects. These SSI projects include small water impounding projects (SWIP), small farm reservoirs (SFR), small diversion dams, pump irrigation system open-source (PISOS), shallow tube wells (STW), spring development projects, and alternative prime movers for pump irrigation systems such as solar-powered irrigation pumps (BSWM 2018).

The NIA's regular reporting of irrigation development status uses the NIS, CIS, PIS, and other government agency assisted (OGA) classification. Other government agency-assisted irrigation development includes the BSWM-supported, LGU-funded, and other government agency-assisted irrigation projects. Assuming that the CIS, PIS, and OGA are small-scale, the SSI systems' total service area would be 54% in the Philippines (Table 1). However, according to Inocencio, David, and Briones (2013), the NIA records of the service area of pumps or private systems are significantly understated because it does not include private investments in irrigation pumps. In the case of the irrigated area being reported in the Food and Agriculture Organization (FAO) Aquastat (2013), it used the difference in the Philippine Statistical Authority agriculture census data on total area supported by NIS, CIS, and individual irrigation systems and the total NIS and CIS irrigated area based on NIA as the estimate for area equipped with irrigation from private schemes.

The importance of understanding the farmer-led small-scale irrigation systems is even more pronounced in the case of the CAR, particularly Benguet and Mountain Province, where most of the irrigation developed are SSI, and the proportion of total irrigable area irrigated is more than 100% indicating that areas beyond 3% slope are being developed (see Table 1). This scenario seems inevitable, considering that terraced fields or farmland patches in rolling or steep terrains beyond 3% slope mostly comprise the highland farming landscape.

According to key informants from the CAR, conveyance and distribution facilities such as hoses, reservoirs, irrigation pumps, and micro-irrigation technologies such as sprinkler irrigation distribution systems in highland vegetable areas were introduced in the 1970s and 1980s in the region. Drip irrigation came much later from 2001, although most of those using drip irrigation started using it after 2010. Before the advent of irrigation pumps, hoses, and sprinkler irrigation systems, most highland vegetable farmers depended only on gravity earth canals for distribution, rivers, creeks, springs, and rain. Those with available irrigation sources used hoses manually to water the plants, while others dug small canals and used hand watering cans and cups.

Table 1. Status of irrigation development in the Philippines and CAR, 2020

Region/ Province	ETIA* (ha)	Service Area (ha)					% of SSI	% Developed**
		NIS	CIS	PIS	OGA	Total		
PHILIPPINES	3,128,631	933,008	725,794	177,506	169,747	2,006,055	53	64.12
CAR	111,296	19,362	57,858	21,575	3,538	102,331	81	91.95
Abra	184,98	3,329	10,176	5,671	651	19,830	83	107.20
Apayao	10,862	4,261	5,722	209	427	10,619	60	97.76
Benguet	15,316	-	11,661	3,676	511	15,849	100	103.48
Ifugao	19,019	3,478	9,488	2,244	346	15,555	78	81.79
Kalinga	34,980	8,294	11,930	6,025	1,093	27,341	70	78.16
Mt. Province	12,621	-	8,880	3,750	507	13,137	100	104.09

Source: NIA (2021)
**Estimated Total Irrigable area (ETIA) is based on the 3% slope criteria.*
***For provinces with more than 100%, they developed areas beyond a 3% slope*
NIA-National Irrigation System; CIS-Communal Irrigation System; PIS-Private Irrigation System; OGA-Other Government Assisted irrigation projects

Methodology

Data and Sources

A household survey using face-to-face and key informant interviews and focus group discussions (FGDs) were used to obtain data for the study. For the household survey, two-stage sampling was used. In the first stage, the highland vegetable farming barangays were identified and served as the sampling population. The data on the area planted for highland vegetables from the Office of the Provincial Agriculture (OPAG) and the barangay agriculture profile survey of the Philippine Statistical Authority (PSA) were used to determine the top municipalities that planted highland vegetables in the region. The number of farmers in these municipalities was then used as the sampling population. The sample size calculated considering a 95% confidence interval and confidence level of 6 was 264 households. The formula used in calculating the sample size is:

$$\frac{ss = Z^{2*}\ (p) * (1-p)}{c^2}$$

where Z = 1.96 for 95% confidence level;
P = 0.5
c = confidence interval 6, expressed as decimal

Sampling distribution per municipality was determined based on the proportion of area planted for highland vegetables (see Table 2). In the second stage, a list of farmers in the sampled barangay was obtained either from the barangay records or the barangay health unit. Farming households were randomly sampled from the list considering the major crops planted in the sampled barangay. For the drip irrigation, complete enumeration was planned, but only 15 farmer-users agreed to be interviewed.

Table 2. Survey area and sampling size

Municipality	No. of Household Survey Respondents	No. of Drip Irrigation Respondents	No. of FGDs
Atok, Benguet	36	8	5
Buguias, Benguet	96		13
Kibungan, Benguet	54	4	4
Mankayan, Benguet	42	2	3
Bauko, Mt. Province	26	1	3
Tinoc, Ifugao	10		2
TOTAL	264	15	30

The survey data was complemented with FGDs in 30 barangays in Benguet, Mt. Province, and Ifugao, largely highland provinces in the CAR. The FGDs aimed to elicit general information on the available irrigation sources and systems and management in the area, including practices in conflict management and overall irrigation problems. Key informant interviews were also conducted with selected NIA personnel. At least two case examples of farmer-led irrigation management were also covered—one for spring source and another for creek source. Secondary data from the NIA and BSWM were also used in the study.

Data Analysis

The study used descriptive analysis such as frequency distribution, means, and range using STATA software. Coding and thematic analysis were employed for the FGD and data from open-ended questions in the farmer survey.

Results and Discussion

Water Sources for Highland Vegetable Farming

Based on rough estimates by key informants and barangay officials in 30 highland vegetable-producing barangays, 220 creeks and 188 springs were identified where 93% are privately developed and managed, while 7% are managed by or have interventions implemented by the NIA or Department of Agriculture-Cordillera Administrative Region (DA-CAR) (see Table 3). There are also reported communal irrigation systems (CIS), reservoirs, and small diversion dams, but many of these NIA- or DA-CAR-assisted irrigation systems were built to support rice-based areas or rice fields turned into vegetable fields. Some 13 NIA-managed CIS were identified in the selected municipalities covered in the FGDs.

Table 3. Estimated Number of Irrigation Water Sources in 30 Highland Vegetable Farming Villages in CAR, 2018

Typology of irrigation sources	Selected Highland Vegetable Farming Municipalities												All	
	Benguet								Mt. Province		Ifugao			
	Atok		Buguias		Kibungan		Mankayan		Bauko		Tinoc			
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Spring														
Private	49	51.58	68	39.08	38	61.29	4	11.43	5	19.23	10	62.50	174	42.65
NIA-managed	0	0.00	8	4.60	1	1.61	1	2.86	4	15.38	0	0	14	3.43
Rivers/creeks														
CIS	1	1.05	5	2.87	3	4.84	0	0.00	4	15.38	0	0	13	3.19
Private	45	47.37	93	53.45	20	32.26	30	85.71	13	50.00	6	38.50	207	50.74
All	95	100	174	100	62	100	35	100	26	100	16	100	408	100

Source: FGDs, 2018

The household survey corroborates the barangay-level results since most of the respondents claimed that their highland vegetable farms are being supported by spring (44%) and rivers/creeks (44%) (see Table 4). In terms of sufficiency, only 45% of the respondents claimed that their farms are fully irrigated while the other 45% are partially irrigated, meaning while there is an irrigation facility, it cannot fully support the dry season and third cropping. Calora *et al.* (2011), in a vulnerability and adaptation capacity assessment project in Benguet, also identified lack or no irrigation as a third rank farming problem in the province. They identified the use of modern irrigation equipment, high-density polyethylene (HDPE) pipes, and improved water management techniques to improve water use efficiency.

According to NIA data in 2019, there are 1,010 CIS projects in CAR. BSWM (2018) on the other hand, reports about 44 SSI projects established in Benguet, 56 in Mountain Province, and 111 in Ifugao. Based on the BSWM data, most of the funding sources in the CAR were from the National Rice Program, which indicates that most of these irrigation systems are established in the rice-based areas in the province. The CIS being referred to in this study are those supporting vegetable farming systems, which the barangay local government units were aware of.

Table 4. Irrigation status and irrigation source, 2018

Item	Frequency (*n=264*)	Percentage Distribution (%)
Irrigation status		
Purely rainfed	27	10.23
Partially irrigated	118	44.70
Fully irrigated	119	45.07
Source of irrigation*		
Spring	116	43.94
River/creek	115	43.56
NIA canal	4	1.52
NIA tank	5	1.87
Groundwater	1	0.38
None	27	10.23

Source of data: Farmer survey, 2018; *multiple answers

The above-mentioned irrigation sources are largely natural, which may or may not be within any private property. According to key informants, such natural resources are usually considered as *"magay mangin-uka"* (owned by nobody), although priority use is usually accorded to the family or clan who owns the land where the water source (e.g., spring) is located and the community where the resource is situated. Prill-Brett (2003) distinguished what is called a communal property regime, where each community owns the unrestricted right to the water from springs, rivers, and brooks within the communal domain, from an indigenous corporate property regime where ownership rights are restricted to members of a "clan" or descendants of a founding ancestor who first put improvement on a portion of the communal land, have usufructuary rights to the property, owned in common by the group.

Management of Irrigation Sources

Overall, most of the irrigation sources for highland farms are managed by farmers either as private individuals, as a small group, or coming together in the form of irrigator association (see Table 5), with barangay local government interference only in rare cases of conflicts. Regarding water scheduling, most irrigation systems are used continuously, meaning users have unlimited access to the water as long as it is available. For some irrigation systems, mainly those governed by irrigator associations, there is some form of rotation or rationing either through a maximum number of hours watering per farm or limit in terms of area to be planted in the dry season when water is scarce.

Table 5. Irrigation management

Item	Frequency (*n=232*)	Percentage Distribution (%)
Who is managing the irrigation system?		
NIA	11	4.74
Private individual	178	76.72
Communal/ Irrigators' Association	38	16.38
NIA/private individual	3	1.29
Others	2	0.86
Water scheduling		
Continuous	121	52.16
Rotation	110	47.41
Continuous/rotation	1	0.43

Source of data: Farmer survey, 2018

<u>Springs</u>

Springs are the most critical water source in the Benguet highlands for domestic use and irrigation. Farmers, in general, manage by themselves the springs where they get their irrigation water. Property rights are not exactly defined for springs used as irrigation water sources. A common understanding or practice among users of specific springs is that tapping the water for irrigation is on a *first-come, first-serve* basis. The first one to tap into the spring has priority locating his hose and using the water for irrigation (see Figure 1). This understanding is still the common management practice even while water permits are now being given for irrigation use based on the Water Code of the Philippines Amended Implementing Rules and Regulations (National Water Resource Board [NWRB], 2015). Despite the law, water permits exist only for some springs, especially those used for domestic water sources (NIA-CAR personnel, personal communication, March 12, 2021).

According to key informants, depending on the spring source, location, and the farm size of the users, most springs in the region can support at least two to five farmers with 3,000 m^2 to 5,000 m^2 farm sizes. Water tapping in springs is generally free and based on shared understanding and verbal agreements among users or the community. For example, in Case 1 spring water source for this study, water drains or flows through one small creek; at least 28 households or around 5.6 hectares of farms are benefitted; the farthest farm the water can support is located around 3 km from the main water source (see Table 6). Most households using water from the creek asked permission from the main spring owner and the landowner adjacent to the stream. For this particular case, which is typical for spring sources in Benguet, the farmer-landowner has priority over the use of the spring and creek water; beneficiary or user-farmers have no association or formal rules. Aside from the first-come-first-served basis for access and no new tapping before or higher than an already existing tapped hose, when water is scarce during the dry season and no water supplies your hose, *pasensiya ladtan* (just accept). According to the landowner, there are cases during the dry season when farmers share and personally negotiate with each other, for example, borrowing of "source and hose" if one user's hose has available water and the hose-owner has finished irrigating his field.

Table 6. Case 1 of farmer-led irrigation system: spring irrigation source

Item	Case 1: Spring/creek in Paoay, Atok, Benguet
Landowner	Private land of a resident
No. of farmer-beneficiaries	28 households; hose of the landowner is tapped in the spring and topmost from the creek
Total no. of hectares supported	~5.6 hectares; crops planted mostly
Year started to use	1966
Distance to farms supported	Nearest: 10 meters; Farthest: 3 km
Months usually used	September to April
Water right/permit	No water permit; understood by the community to be owned by a specific individual
Distribution system	hose; gravity

At least three spring and hose renting cases were reported during the FGDs in the 30 survey barangays. The rental rates for the spring and hose charged by the farmers managing the spring are: Php2,500 per year, Php3,000 per year, and Php5000 per year. This finding has many possible implications. It possibly indicates that while irrigation water from springs is generally abundant and free mainly in the wet season, water may be getting relatively scarce, as explained by this observed farmers' willingness to pay to access or use the spring. It can also mean that irrigation water from springs, in some instances, transition from a public or social good to a private or economic good. For example, according to one informant, in one seemingly isolated case in Atok, Benguet, a landowner sold a spring water source for PHP 200,000 and is renting out another spring to users with a rate ranging from PHP 7,000 to PHP 15,000 per person. As defined by Briscoe (1996) in Perry and Seckler (1997), the idea of "water as an economic good" is that water has value to users, and that value is the maximum amount the user would be willing to pay for the use of the resource. This system is similar to some local water markets in areas where pump irrigation and shallow tube wells are rented (Launio and Manalili 2016). Since most of the spring sources are far from the actual farm area necessitating the use of long high-density polyethylene (HDPE), sometimes hanging through cables across ridges, the repair and maintenance of the pipes can be difficult which may justify the fees. However, based on the FGDs, renting out or even selling water sources are still shunned or largely looked upon negatively in Benguet communities.

According to the respondents, the users are responsible for cleaning, fixing, and maintaining the springs. Cleaning the springs varies widely from two to three times a month to once a year, depending on the location and weather. Some group-owned springs have rotation schedules for cleaning the springs.

Conflicts and arguments also sometimes occur among farmers. For example, conflicts on not sharing water sources; using water sources without permission; stealing hose from the source; disconnecting the hose from a source; throwing garbage in the water source; excessive use of water; conflict in the scheduling of irrigation. These conflicts are usually settled by merely talking with each other or discussing with the barangay officials to resolve them. Rotation and scheduling among users usually happen in some of the bigger springs, but these are not formal arrangements but rather farmer-to-farmer negotiations considering the circumstances such as crop types, stage of crops, and other considerations.

a. Tapping in a creek with stilling basin located downstream from a spring

b. Hose tapped in a creek downstream coming from a spring (with natural stilling basin)

c. Spring with tapped hoses

d. Contact spring with tapped hose and cemented reservoir

Figure 1. Tapping of hose in springs or creeks, which are the most common water source

Rivers/Creeks

The next most significant source of irrigation water is the rivers and creeks from watersheds and springs. These creeks have adequate flows for small areas during the wet season but not during the dry season. Like the springs, vegetable farmers who tap irrigation water from rivers or creeks manage the sources themselves. The users themselves clean the river sources and location or path of their own hose in the case of creeks, especially after strong storms. However, in major calamities, landslides, or erosions, the farmers help each other automatically restore the banks by removing debris and riprapping when necessary.

Similar to springs, top conflicts or problems encountered in rivers or creeks as a source of irrigation include tapping from the water source without permission from the landowner or community, stealing hose from the source, overlapping of hoses, disconnecting and lifting-up of hose from the source, pollution from garbage, and erosion that destroys fields.

Based on FGDs, conflicts are generally resolved with parties talking with each other; in very few cases, disputes are resolved with the barangay *lupon* or selected barangay officials facilitating the dialogue. The farmer-led irrigation system management for the case of a river or creek where a small diversion dam is created and access is through pump irrigation systems is usually via an irrigators' association with officers managing the operations and ensuring proper monitoring and maintenance of the assisted irrigation system. In the particular case of a river in Paoay, Atok, at least 50 households organized an irrigator association with elected officers (see Table 7).

Table 7. Case 2 of farmer-led irrigation system: river irrigation source

Item	Case 2: River/creek in Paoay, Atok, Benguet
Landowner	Various residents
No. of farmer-beneficiaries	50 households organized as an irrigator association
Total no. of hectares supported	~30 hectares (association members); ~70 hectares (other areas)
Year started to use	1960s
Distance to farms supported	Nearest: 3 meters; Farthest: 3-4 km
Months usually used	downstream (supplement to wet season; some for the dry season December to April); those in upstream (whole year round)
Water right/permit	No water permit; understood to be for the use of the community, especially the association members
Distribution system	cemented canals; water pump

Communal Irrigation Systems (CIS)

The beneficiaries of CIS projects are organized into an irrigator association tasked with the maintenance - cleaning and repair from the source to the farms. NIA constructed these irrigation systems in collaboration with the community and turned them over to the Irrigator Associations (IAs) for operation and maintenance. Key informant interviews with irrigation association officers show that the frequency of cleaning depends on the CIS, ranging from weekly cleaning by assigned groups to twice a year, one during wet and one during the dry season. Also, according to FGD respondents, funds for maintaining the CIS were not always available. The majority of the IAs experience is on non-cooperation among members relying solely on their IA officers. In some cases, only the president and some officers are active in the IA. However, IA officers acknowledge that most members cooperate in the cleaning and maintenance activities of the CIS. Launio and Dilla (2020), in a more detailed study of CIS in Benguet, found that the majority of the CIS in Benguet do not have water scheduling during WS, and 29% have a water rotation schedule during the DS.

<u>Other Irrigation Sources</u>

The respondents' other irrigation sources are groundwater lifted using tube wells and rainwater harvesting. However, the FGDs and household survey indicate that both sources are not common in vegetable farming areas. Rainwater harvesting through water impounding structures or earth embankments lined with plastic or *tolda*, locally termed *coilo*, is used in rainfed areas (see Figure 2). These human-made structures have an embankment height of 2 m to 4 m and an average pond area of 5 m to 10 m, and they can only serve a limited extent on a farm. According to farmers, a *coilo* is designed to become an integral part of individual rainfed farms established in some parts of Benguet and is deemed inexpensive and easy to maintain. Farmers commonly use them to provide the water required for early planting, seedbeds, a seedling nursery for vegetable farming, and spraying. Water stored in these reservoirs is often captured as rainwater, but sometimes waters from springs are stored during the wet season. These sources are farmer-led or family-led irrigation systems and privately managed without cooperation with neighbors or co-farmers.

Figure 2. A rainwater or springwater harvesting embankment (4" x 8" x 5") or *coilo*

Management of Conveyance and Distribution Facilities

<u>High-Density Polyethylene Hoses and Irrigation Canals</u>

The primary system for conveying water from springs and creeks in the study areas is through HDPE hoses (see Table 8 and Figure 3) and, for some farmers, rubber hoses for distribution within the farm. Most of these HDPE hoses are farmer investments. The hose size depends on how much water is available from the farmers' source, although most farmers use ¾ inch to 1 inch-HDPE hose. Water from springs is conveyed from a distance of 10 m to 50 m to farms as far as 3 km from the source spring. The NIA in the CAR also sometimes assists in irrigation sources and distribution systems by constructing a reservoir near the beneficiary farms and installing HDPE pipes from the source (see Figure 3e). In this case, the NIA takes care of the water source lines to the reservoir, and the farmers take care of the hose from the reservoir tank to individual farms. In one location in Buguias, Benguet, some respondents mentioned that there are three reservoir tanks where water from a faraway source is stored, so when water is scarce, the community schedules which tanks will be opened on a rotation basis. On the other hand, water from diversion dams or small water impounding projects (SWIP), considered small-scale irrigation and communally managed, is conveyed through lined irrigation canals or earth canals.

Table 8. Irrigation distribution facilities

Items	Frequency (*n* = *232*)	Percentage Distribution (%)
Distribution system from water source to farm		
hose	225	96.98
earth canal	5	2.16
NIA canal	1	0.43
hose/lined canal	1	0.43
% of respondents using pump to access water from the source		25.00
Distribution system on farm*		
sprinkler	197	84.91
hose	68	29.31
hand watering can	1	0.43
drip	1	0.43
% of respondents using pump for distribution on farm (wet season)		4.74
% of respondents using pump for distribution on farm (dry season)		22.41
% of sprinkler users using reservoir tank for sprinkler		25.79

Source of data: own household survey, 2018; *multiple answers

Based on FGDs in Atok, Benguet, some farmers also use water delivery trucks to deliver irrigation water to their farms on rare occasions during the dry season. According to the FGDs in Paoay, this method is the last resort, particularly during the start of the planting season or when no water is available during the crucial time of crop growth.

a. wires are used to support HDPE hoses

b. HDPE used to convey water from creeks

c. several HDPE hoses conveying water

d. HDPE hoses connected from group reservoir to individual farms

e. HDPE passing by farms need to be watched for leaks from springs to individual farms

Figure 3. High-density polyethylene (HDPE) hose used to convey water from springs or creeks to the vegetable farms or a reservoir on the farm

For water distribution on the farm, 60% of the respondents used sprinklers during the 2018 dry season survey. Some 22% of the respondents who used sprinklers used a pump to access irrigation water from the source. This practice is usually the case when the water source is lower than their farm. Using pumps to distribute water on the farm is more prevalent in the dry season. According to the farmers, the water pressure is less during the dry season because of the lower level of water in the creeks during this season. About 16% of the respondents also used a reservoir tank to store water for their sprinklers (see Table 8).

Based on the Case 1 farmer-led irrigation system above, managing the conveyance of water and ensuring a continuous supply of domestic or irrigation water from spring or creek to the farm is an individual farmer's responsibility. Accordingly, they sometimes put some special marks on the black hose to distinguish their hose from the many hoses tapping from one spring or one creek (see Figure 3). During extreme weather events such as typhoons and continuous monsoon rains, they usually start tracing the hose from the source to the farm when they notice that water is cut off from the source. They first clean the filter, which is usually improvised from black nets, screens, plastic net bags, or plastic bottles. Tracing the hose is generally undertaken by the male farmer or family member as sometimes it involves passing by ridges or risky areas. One farmer whose farm is near the creek for which more than ten hoses pass by her farm (see Figures 3c and 3d) mentioned that they only have to ask permission from her and ensure that they closely monitor the hoses for potential strong leaks which may flood or compromise her crop.

Sprinklers, Drip, and Other Irrigation Distribution Facilities

Table 9 presents estimates of the total number or percentages of farmers using sprinklers, drip, and the number of reservoir tanks and irrigation pumps based on barangay-level FGDs. An estimated 91% of farmers in highland vegetable farming communities are using sprinklers to irrigate their farms. The average open cultivated area supported by sprinkler irrigation is 2,882 m^2 per household. Sprinklers are commonly used during the dry season and for supplementary irrigation during the wet season, especially for early planting or transplanting. Table 10 presents when these facilities started to be used in the region. These types of irrigation distribution facilities are 100% farmer-controlled and managed.

Table 9. Estimated total number and percentages of irrigation distribution facilities, 30 highland vegetable-producing barangays, CAR

Irrigation Technique	Benguet				Mt. Prov	Ifugao	All
	Atok	Buguias	Kibungan	Mankayan	Bauko	Tinoc	
% of farmers using a sprinkler	84	92	89	95	98	100	91
Ave. no. of sprinkler heads per farm household	2	2	2	2	3	2	2
No. of farmers using drip irrigation	12	3	3	0	2	0	20
No. of reservoir tanks	77	97	4	18	20	5	221
No. of irrigation pumps	65	64	14	84	15	1	243

Source: Barangay-level data elicited using FGD/Key informant interviews, 2018

Table 10. Adoption period of sprinklers, drip irrigation, and irrigation pumps in the Cordillera region

Year	Sprinklers	Drip	Irrigation pumps
1960-1970	5	-	-
1971-1980	11	-	1
1981-1990	36	-	1
1991-2000	55	-	7
2001-2010	84	5	18
2011-2018	46	10	24
Total	237	15	51

Source: Household survey, 2018

Farmers use sprinklers for easy irrigation of crops and to save time as it allows multiple tasking. Some farmers claim that sprinklers help control pest populations or prevent pests like diamondback moth (DBM). Another advantage is that it can be used regardless of farm terrain or topography, whether hilly, terraced, or not. Further technical studies are recommended to examine ways to capitalize on these advantages and develop scientific protocols for using sprinklers or water management in general. Local studies on water management for pest control, frost control, and increasing crop productivity in different highland farming systems are limited. Other reasons for using sprinklers mentioned by respondents are even water distribution, available and affordable, easy to use method, and compatible with a hose, the most common water conveyor from the source.

Of around 60 farmers known to be drip irrigation users, only about 15 were interviewed in the sampled municipalities. The most common reasons for farmers using drip irrigation are: it can save water, labor, and time; allows more uniform irrigation since it is targeted only to the root system of the plant; and can likewise prevent soil erosion and particular diseases such as blight, and results to better and quality harvest. Again, these advantages mentioned by the respondents can be further studied to provide more concrete recommendations on water management to reduce crop damage due to pests, increase productivity, and prevent soil erosion in highland vegetable farming areas.

The drip irrigation users interviewed commonly plant carnation, lettuce, strawberry, Japanese cucumber, and tomato. One farmer reported using drip for potatoes in an open field but discontinued it. According to an experienced agricultural educator and cut flower grower, some carnation growers invest in drip irrigation because using sprinklers may exacerbate frog eye, a disease of carnation; carnation fetches a high price; and can be harvested until up to two years, so that the high investment cost for drip irrigation can be more likely recuperated (C. Galagal, personal communication, October 1, 2021). Also, lettuce, Japanese cucumber, and tomato have relatively high-water requirements. Drip irrigation will allow continuous irrigation since drip irrigation is targeted only to the plant root system.

Sprinklers

The most common sprinkler model used by highland vegetable farmers is locally called "automatic." It is made of plastic with full-circle impact type installed mostly as portable or semi-permanent. A few use a locally fabricated steel called "*kutsara*" which can be moved or transferred easily (see Figure 4). On average, each sprinkler can service 1,713 m^2. Most respondents report that the diameter of the wetted area of the sprinkler is around 10 m but ranges from 6 m to 40 m. Regarding the hose or riser pipe size where the sprinkler head is attached, most farmers reported using 0.50 in. (1.27 cm), and 95% use the fine droplet setting.

Clogging and nondurability are the most critical problems for sprinkler irrigation distribution systems. Another problem associated with sprinkler use is the water shortage in the dry season and when the sprinklers do not function due to low pressure. Other issues reported for sprinklers are: plants are damaged when sprinkler pressure is not correctly adjusted.

Drip irrigation

Most of the drip irrigation used in the CAR's highland vegetable farming areas is distributed by Harbest Agribusiness Company in the Philippines and imported from Jain Company from India (60%), the rest coming from Netafim which is an Israel design. The average farm size supported by drip irrigation is slightly more than 500 m^2. The drip irrigation users installed their facilities between the periods 2008 to 2015. On the use of associated technologies, 44% of the drip users interviewed use an irrigation pump for their drip irrigation, and 20% use a timer so that the irrigation time is automatically regulated. The HDPE Moldex brand is the most common hose used in drip irrigation. Farmers use filters such as metal screens and plastic nets to prevent clogging in their drip irrigation systems. According to the respondents, they bought the accessories also from their drip irrigation supplier. It ends up cheaper and the quality is more durable. Others said they bought accessories or parts from their first drip supplier because they had already established rapport and communicated easily. The advantage of drip irrigation systems in terms of management is they are farmer-controlled. Farmers can normally fix clogging problems but it takes additional investment and time.

a. Automatic (plastic) | b. Butterfly-like, locally fabricated (made up of steel) | c. Locally fabricated (made of steel) | d. *Kutsara*

Figure 4. Models of sprinkler used by farmers in highland vegetable areas

Reservoir tanks

Of the 16% who use the reservoir, most farmers use concrete tanks, followed by plastic tanks. Other vegetable farmers also use galvanized iron (GI) tanks. These tanks are used to impound water from creeks or springs but can only support small areas depending on their size. The average total volume capacity of the farmers' tanks is around 600 m3, with an average height of 9 m. Most of the plastic and GI tanks are owned by the farmers and are purchased at their initiative. These tanks are mostly operated and managed by individual farmers except when the tanks are NIA-funded, in which case the tanks are group-managed.

Earth embankments

Two percent of the respondents also use pond or earth embankments lined with either black polyethylene plastic or tarpaulin to store irrigation water. Water stored comes from springs or creeks or rainfall harvested. It is usually located and constructed at the flatted upper portion of the farm. Some farmers strategically place GI sheets directed to the pond-like reservoirs to help catch rainwater.

Irrigation or water pumps

Farmers whose farms are located higher than the water source use water pumps to lift the water from the source to the farm. Water pumps also act as a booster when the water supply is low in a sprinkler or drip irrigation. The major problem for the farmer-owned irrigation pump is the additional fuel and maintenance cost.

Summary, Conclusion, and Recommendations

This paper used data from focus group discussions, case studies, and household surveys to argue that small-scale and farmer-led irrigation be given space in the national and prioritized in the Cordillera regional irrigation development agenda. Specifically, it documented that spring and river irrigation sources support most highland farming and farmers invest in small- and micro-scale irrigation facilities and distribution technologies. Most irrigation sources and conveyance and distribution facilities are farmer-managed or farmer group-managed, implying that strengthening farmer-led irrigation development is a major pathway to sustain the highland vegetable industry. Both spring and creek irrigation are beset with problems on shortage of water during the dry season, disruptions from source to farms, especially during extreme weather events, illegal tapping and overlapping hoses, and clogging and nondurability of distribution facilities were perceived by farmers.

Improving statistics on irrigation sources and facilities

The above account of irrigation sources in selected barangays is not an exhaustive inventory. It merely provides evidence that irrigation systems supporting highland vegetable farms in the Cordillera region are mainly small-scale, privately developed, and managed. This finding implies that irrigation status monitoring, reporting, planning, and development in the CAR must be adapted to the nature of private irrigation systems relative to large national and communal irrigation systems. Ambler (1994) mentioned that many countries have quite poor statistics concerning the number, location, coverage, type, productivity, and networking of small-scale irrigation. Conducting inventories is not only helpful in devising programs that can assist farmers and communities, but it is also necessary for developing appropriate legal frameworks that will protect or limit the right to water or prevent future conflicts. It is also a mandatory first step for any water conservation program for domestic and irrigation water. While some LGUs have inventory and water quality tests of the major or larger springs providing domestic water, there is generally a lack of awareness among barangay officials on the status of irrigation water sources in their area of responsibility.

Another use for accurate inventories is for research and development efforts in small-scale irrigation, particularly for spring water sources in the CAR. Anecdotal accounts of “disappearing” springs and water rights, even for irrigation water sources, point to the need for more technologies and social and management or governance research concerning natural sources of irrigation water. While full authority on most of these water sources is vested in the farmers and irrigation distribution technologies have advanced, the science of spring maintenance and spring water conservation in the context of CAR and the anthropogenic activities surrounding the watersheds is crucial. Kafle *et al.* (2022), taking the case of sub-Saharan Africa, concluded that policies aiming to facilitate farmer-led irrigation development would have to combine biophysical information on land and water suitability for irrigation with household socioeconomic characteristics and existing agricultural systems. Such analysis requires accurate location and characterization of such sources.

Focus on farmer-led irrigation development as a regional priority

Findings show the critical role of springs, rivers, and creeks as irrigation water sources for highland vegetable farming in the Philippines. The protection and conservation of these irrigation sources should be a paramount agenda not only of the government units developing irrigation and managing water resources, such as the NIA and NWRB, but also of the Department of Environment and Natural Resources (DENR) and the provincial, municipal, and barangay local government units. The Department of Agriculture, through its regional office and the BSWM, is on top of providing irrigation programs and projects through special projects. Still, DENR and NIA also need to rethink their priorities regarding investments in watershed management and infrastructure development of farmer-led irrigation systems. As identified in the investment needs for resource assessment capability in the Philippines, water supply protection is a major challenge (NWRB, Philippine Nuclear Research

Institute [PNRI], International Atomic Energy Agency [IAEA] 2012). Understanding the current and potential vulnerability of spring and mountain creek water sources in relation to watersheds is critical. Assessment of water supply sources is crucial in defining irrigation potential (Inocencio and Inocencio 2021). If the forests or watersheds supporting these springs, creeks, and rivers are not preserved, the highland vegetable industry will be greatly at risk. Recognition of these forms of natural sources in national policies can be a primary step. Given the region's vegetable areas' topography, the option of large-scale irrigation systems and the use of groundwater sources are more challenging and invasive options. The cost to farmers of lifting water from the low-lying rivers to the vegetable farms is already high.

Furthermore, the finding that less than 50% of the farms are fully irrigated or with irrigation that can fully support dry season and third cropping implies that, although a significant percentage of farms are already planting two to three crops per year, improvement of cropping systems and cropping intensity in highland vegetable farming is still possible, when farms are fully irrigated. This finding is relevant because it is inconsistent with the implication of the regional reports on irrigation development, which is measured by the percentage of developed irrigable areas. For example, as of 2020, 92% of the irrigable areas in the CAR are already reported to be developed (NIA 2021). Accordingly, irrigation development in three provinces in the region is already over 100%, 103.48% in the case of Benguet, 104.09% in Mountain Province and 107.20% in Abra. However, the definition of irrigable areas, in this case, may be "lands with less than 3% slope." It should be noted that 93.3% of the total area of the CAR, which is the largest highland vegetable supplying provinces, has slopes of more than 3%. Even with the newer definition of irrigable areas now including 3% to 8% slope based on the irrigation roadmap, the majority of the farms still will not be covered; hence, fund allocation for irrigation in the region will still be limited.

There were also isolated accounts of farmers renting out their hoses to other farmers or paying some amount to use a specific spring for a season; one case of selling spring water sources; and two of using water delivery trucks to transport irrigation water. Such instances indicate the potential future scenario if these farmer-led irrigation systems development are not focused upon within the region and irrigation water sources are not adequately conserved.

NIA's efforts to develop communal irrigation systems by providing HDPE, reservoir tanks and sprinklers should be sustained and focused on areas with potential for increases in cropping intensity and are not within geographically hazardous areas. However, the concern of farmers regarding the maintenance of such irrigation systems is important, considering that these systems are prone to damage, particularly during typhoons and floods. For example, 5 of 52 CIS completed under the Cordillera Highland Agricultural Resource Management Project (CHARMP) have become non-operational less than a year after the project completion owing to damages by floods caused by Typhoon Igme (ADB 2006). In 2018, Typhoon Rosita, due to many landslides, greatly damaged newly built irrigation systems supporting rice farming in Natonin, Mt. Province (Sacyaten, 2018). Therefore, NIA rehabilitation priorities need not be focused on the large-scale or communal irrigation systems but on the SSIS, at least in the context of the Cordillera region.

Infrastructure support for farmer-led and private irrigation systems

Findings from this study show that many highland vegetable farmers in the CAR invested in their own irrigation systems and facilities without external support. They also shoulder maintenance costs by themselves. While as a priority, farmer-led irrigation development should focus on catalyzing private infrastructure development (Izzi, Deniso, and Veldwisch 2021), public funds must help infrastructure development, particularly the accessibility to water sources. For example, based on the FGDs, there are cases when the water source is located in another mountain several kilometers away from the farm areas requiring major irrigation infrastructure. While the literature is at odds regarding the relative economic returns to small-scale versus large-scale irrigation systems, this paper argues that there is no choice in the case of highland vegetable farmers since large-scale irrigation systems are not technically or economically feasible. In addition, while minimal investments in pumps or drip kits do not have real direct economic justification, they may have significant nutritional and household food security impacts (Department for International Development [DFID] 2003, as cited by Facon 2010). Supporting farmer-led irrigation in the CAR is equivalent to sustaining the country's major sources of highland vegetables.

Strengthening support for the adoption of small-scale irrigation technologies

In terms of the adoption status of small-scale and micro-irrigation technologies, while sprinklers' use is widespread, drip irrigation is not common. Drip irrigation is usually applied only under protected cultivation or the greenhouse system and by innovative farmers planting crops with high crop intensity, such as lettuce. While drip irrigation has been long a subject of DA promotion strategies, Cordillera region farmers rarely use such technologies in the open field. The promotion of technologies such as the low-cost greenhouse technology of Benguet State University may increase farmers' likelihood of adopting drip irrigation. The finding that adopting drip irrigation is associated with the type of crops planted is also relevant. Extension efforts to promote drip irrigation need to ensure the availability of the replacement parts and markets for high-value crops being produced with greater crop frequency. Doss (2003) also concluded that farmers do not adopt technologies because the technologies are not profitable, given the complex set of decisions that they are making about how to allocate their land across agricultural and non-agricultural activities. She also identified misconceptions and non-availability of the technologies when they would be needed. Another area where the government can support farmers could be facilitating increased contact between farmers and knowledgeable technical support staff in the field (De Lance 1997).

The finding that the fast spread of sprinklers resulted from hose availability and affordability indicates that the adoption of complementary technology is a factor in irrigation technology adoption. In the case of drip irrigation, promoting low-cost protected cultivation complements water-saving drip irrigation technology, especially in vegetable-producing villages facing severe water scarcity. This result supports adoption literature in which larger technology complementation increases the benefits of adopting and thereby induces faster adoption (Smith 2004, Jovanovic and Stolyarov 2000).

The most common problems and constraints reported by farmers on sprinkler and drip irrigation are clogging, water shortage, and low water pressure during the dry season. While local practices and indigenous knowledge systems in irrigation and water management have been documented and promoted as appropriate, scientific studies that foster innovation, particularly in preventing clogging; reducing the cost of drip irrigation installation and maintenance; improving the durability of sprinklers, and providing irrigation techniques and recommend rates of water application or frequency per crop will be useful.

Strengthening R&D in small-scale irrigation systems and technologies

The result that conflicts occur even in SSI systems, especially during the dry season, indicates that while water is abundant during the wet season and springs are left free-flowing, water shortage still occurs in the study areas during the dryseason. Since SSI systems are the only option for farmers in the CAR's highland vegetable farming systems, more research and extension efforts on these systems are essential. With the increasing fuel scarcity, conveying water from lower areas to more elevated areas are costly. It is critical to ensure that necessary controls, mechanisms, and farmers' practices will enhance and sustain the currently available irrigation water from springs, rivers, and creeks. To do this, mapping the exact locations of the many minor springs and instituting policies to monitor and maintain them can be a starting point. Vigorous promotion and support of water-saving strategies and technologies such as rainwater harvesting, and the use of reservoir tanks and other small-scale irrigation practices are also needed. This study has shown that only 10% of this study's respondents are presently practicing water conservation using concrete tanks, drums, and earth embankments lined with black plastic or tarpaulin *tolda*. Still, there is room for expansion with proper research-based information dissemination.

Further S&T studies on how to optimize water management when using springs and rivers/creeks as irrigation sources, and hoses, sprinklers, and drip irrigation as distribution systems must be pursued considering the principles of balanced water management techniques and strategies; and for more optimal use of water resources in the field. For example, Soriano and Herath (2018) quantitatively reaffirmed through detailed field monitoring and physically-based mathematical modeling the effectiveness of well-maintained rice terraces in regulating water resources by enhancing groundwater recharge. Such research undertakings in highland vegetable farming systems, small-scale irrigation schemes, and spring and creek irrigation sources would benefit water resources management and conservation. Further technical studies are also needed to examine how to capitalize on the advantages and develop protocols in using sprinklers or water management in general for increasing crop productivity in different types of highland farming systems. In addition, other unique use of irrigation for certain crops (e.g., for pest control and sprinkler irrigation for mites' control in strawberries) also need to be further studied in a multidisciplinary setting.

The establishment of drip irrigation in an open field is not yet typical in the region, and more studies should be conducted locally. A more detailed analysis of drip irrigation's economic costs and benefits is recommended considering the value of reduced costs and better-quality production. The early adopters of drip irrigation are carnation growers, lettuce, cucumber, and tomato producers. If coupled with data from technical, environmental, and economic impact analysis for early adopters, the information from this paper can inform the promotional strategies and management for drip irrigation and other advanced irrigation technologies.

These S&T topics need to be coupled with management and policy R&D for individual and farmer-led irrigation management. National programs are geared toward this paradigm, especially in mountainous regions in the country. Bukidnon and Davao del Sur highland vegetable areas are also largely supported by springs and creeks. Farmer-led irrigation is a cost-effective and scalable agricultural water management solution for smallholder farmers (World Bank 2018), and it is the only option that can best contribute to sustaining highland crop food security and rural development in the country.

Convergence efforts among line agencies and LGUs on watershed conservation

Findings imply that the government and local stakeholders need to discuss how to effectively preserve and sustain the conservation of the watersheds which support springs and rivers to make such sources sustainable. African Union (2020) mentioned that planning for intensifying water use in rainfed farming and irrigation needs is best considered through a watershed or landscape approach. Also, Dublin principles (1992), as cited by Kirshen (2007), which served as a guide for global water dialogue, recommends that water management and development be based upon a participatory approach including all stakeholders. As it is, while DENR is tasked with watershed conservation and preservation of protected areas, the NIA, DA, Department of Agrarian Reform (DAR), including the Department of Social Welfare and Development (DSWD), which has a livelihood improvement mandate, and LGUs may all need to converge in working together for sustaining the watersheds, which are the lifelines of springs, rivers, and creeks providing irrigation.

Lessons learned on the policy level include the definition of irrigable area is less applicable to the CAR's agriculture landscape. The monitoring of statistics of private irrigation sources and systems beyond pumps and government-assisted irrigation is vital. Other implications from the results include farmer-led irrigation development on the national agenda, prioritizing farmer-led irrigation development in highland regions, increasing infrastructure and R&D support for farmer-initiated irrigation, the necessity of convergence of stakeholders to strengthen small-scale irrigation systems and associated technologies, and inevitably, conserve, and manage watershed and riverine systems to ensure a sustainable highland vegetable industry.

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