IWMI Working Paper

188

# Mechanizing Water Lifting through Pumps: A Case Study in Sri Lanka

Mohamed Aheeyar, Herath Manthrithilake, Chathuranga Ranasinghe, Manooj Rengaraj, Yasas Gamagedara and Jennie Barron

IWMI International Water Management Institute

CGIAR

RESEARCH PROGRAM ON Water, Land and Ecosystems

### Working Papers

The publications in this series record the work and thinking of IWMI researchers, and knowledge that the Institute's scientific management feels is worthy of documenting. This series will ensure that scientific data and other information gathered or prepared as a part of the research work of the Institute are recorded and referenced. Working Papers could include project reports, case studies, conference or workshop proceedings, discussion papers or reports on progress of research, country-specific research reports, monographs, etc. Working Papers may be copublished, by IWMI and partner organizations.

Although most of the reports are published by IWMI staff and their collaborators, we welcome contributions from others. Each report is reviewed internally by IWMI staff. The reports are published and distributed both in hard copy and electronically (www.iwmi.org) and where possible all data and analyses will be available as separate downloadable files. Reports may be copied freely and cited with due acknowledgment.

### About IWMI

IWMI's mission is *to provide evidence-based solutions to sustainably manage water and land resources for food security, people's livelihoods and the environment.* IWMI works in partnership with governments, civil society and the private sector to develop scalable agricultural water management solutions that have a tangible impact on poverty reduction, food security and ecosystem health.

**IWMI Working Paper 188**

# Mechanizing Water Lifting through Pumps: A Case Study in Sri Lanka

*Mohamed Aheeyar, Herath Manthrithilake, Chathuranga Ranasinghe, Manooj Rengaraj, Yasas Gamagedara and Jennie Barron*

International Water Management Institute

*The authors*: Mohamed Aheeyar is a Researcher - Agricultural Water Management at the headquarters of the International Water Management Institute (IWMI), Colombo, Sri Lanka; Herath Manthrithilake is Head, Sri Lanka Development Initiative, and a Senior Researcher at IWMI, Colombo, Sri Lanka; Chathuranga Ranasinghe, Manooj Rengaraj and Yasas Gamagedara contributed to the fieldwork and this paper as research interns at IWMI, Colombo, Sri Lanka; and Jennie Barron is a Professor – Agricultural Water Management at the Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden. She was Strategic Program Leader - Building Resilience at IWMI, Colombo, Sri Lanka, at the time this research study was conducted.

Aheeyar, M.; Manthrithilake, H.; Ranasinghe, C.; Rengaraj, M.; Gamagedara, Y.; Barron, J. 2019. *Mechanizing water lifting through pumps: a case study in Sri Lanka. Colombo,* Sri Lanka: International Water Management Institute (IWMI). 61p. (IWMI Working Paper 188). doi: 10.5337/2019.206

*/ water lifting / water supply / water management / water quality / water scarcity / pumps / agricultural credit / small scale farming / market prices / hydrological factors / farmers / investment / taxes / tariffs / wells / irrigation programs / microirrigation / state intervention / groundwater extraction / groundwater irrigation / cultivated land / seasonal cropping / intensification / women's participation / case studies / Sri Lanka /*

ISSN 2012-5763
e-ISSN 2478-1134
ISBN 978-92-9090-886-9



Please direct inquiries and comments to: *IWMI-Publications@cgiar.org*

**A free copy of this publication can be downloaded at**
**www.iwmi.org/publications/iwmi-working-papers**

## Acknowledgements

The authors would like to thank the farming community, key informants and government officers in the case study areas for providing support to conduct the study. Special thanks are due to the officials of the Sri Lanka Customs and the private sector water pump manufacturers for sharing data on water pumps imported into the country and assembled locally. Meredith Giordano (Peace Corps, Washington, DC, USA, formerly International Water Management Institute [IWMI]), Nicole Lefore (Borlaug Institute for International Agriculture at Texas A&M University, USA, formerly IWMI), Sanjiv de Silva (Researcher – Natural Resources Governance, IWMI, Sri Lanka), Upali Amarasinghe (Senior Researcher, IWMI, Sri Lanka), Shilp Verma (IWMI-Tata Water Policy Research Program, India), and Ian W. Makin (Director Asia, IWMI, Sri Lanka) critically reviewed an earlier draft of this paper and provided useful comments, which helped us to improve the content of the final paper.

### Project

This research study was conducted under the *Agricultural Land and Water Management (ALWM) investment options for scaling solutions* project.

### Donors

CGIAR | RESEARCH PROGRAM ON Water, Land and Ecosystems

This research was carried out as part of the CGIAR Research Program on Water, Land and Ecosystems (WLE) and supported by Funders contributing to the CGIAR Trust Fund (https://www.cgiar.org/funders/).

# Contents

# Summary

A reliable supply of water is critical for agricultural intensification and yield improvement. Technological devices that lift, transport and apply water contribute to increased yield from improved crop varieties and high input cultivation. Using such devices to shift to high-value cultivation has become an important source of wealth accumulation in Asia and Africa. In particular, the increasing use of motor pumps is a significant contribution to the development of small-scale irrigation. The objective of this study was to identify and analyze the trajectories of technological innovations and uptake for agricultural water management in farming systems in Sri Lanka, with a special focus on identifying impacts, emerging issues and potential responses to the rapid proliferation of motor pumps in the intensification of agriculture in the country.

The Government of Sri Lanka promoted the rapid adoption of water pumps through interventions such as the development of groundwater wells for agriculture; provision of subsidies and credit facilities for purchasing micro-irrigation equipment; and government policies on tax, tariffs and extension support. At the same time, the high profit margin realized from cash crop cultivation motivated farmers to invest in water lifting and related technologies. Finally, water scarcity and restrictions on the use of surface water, i.e., canals, prompted a shift to using water-lifting technologies to pump groundwater.

The use of water pumps in agriculture has expanded the area under cultivation; increased cropping intensity, especially during the dry seasons; changed the cropping pattern from low-return rice cultivation to high-return cash crop cultivation; and enhanced household incomes. Expanded and intensified cultivation has provided more opportunities for women to participate in agriculture, generating additional income, and enhancing their purchasing power and decision-making at the household level.

Some farmers do not have groundwater wells and water pumps because they lack the necessary capital to make the initial investment. Smallholder farmers, in particular, are reluctant to risk their limited income on new technologies. This may lead to the further marginalization of poor farmers. Inclusive intensification will require helping farmers to access irrigation technology, for example, through carefully targeted subsidies and access to credit.

Using water pumps can provide benefits to both users and non-users, but uncontrolled groundwater extraction may also create new problems by putting enormous pressure on common property resources. The government will need to take on a dual role to both promote the inclusive growth of small-scale irrigation, and to prevent and mitigate its negative environmental impacts. This second role may include establishing a regulatory system, setting standards for well construction, and monitoring and enforcing standards on extraction and water quality. There is an urgent need for institutional measures and governance arrangements to guide and regulate groundwater irrigation, especially in the context of intensive cultivation using shallow aquifers.

## INTRODUCTION

Sri Lanka has predominantly been an agricultural country since ancient times. Irrigation development, coupled with new technological innovations, provided the engine of growth for the food crop sector and supported food and nutrition security. Sri Lanka has reached near self-sufficiency in the production of rice, the country's staple crop, but malnutrition is an obstacle to socioeconomic development. High levels of acute malnutrition – ranging between 14% and 35% – exist across the country (http://www1.wfp.org/countries/sri-lanka - accessed in April 2018). The growing number of natural disasters has further increased the vulnerability of the people.

Sri Lanka's tropical monsoon and bimodal rainfall pattern limit cultivation activities to particular seasons. Rainfall is the primary source of water for agriculture, either directly or indirectly through surface water and groundwater for irrigation. There are two major cultivation seasons: the '*Yala*' (dry season or minor season from May to August) and the '*Maha'* (wet season or major season from September to February). Sri Lanka's dependence on rainfall makes farming risky. Predicted increases in the variability of precipitation in the country, due to climate change, may increase the challenges for irrigated and rain-fed farming in terms of drought mitigation and adaptation (Eriyagama et al. 2010; Punyawardena 2011). At present, rain-fed farmers are the poorest group of farmers in the country.

Water management is critical for agricultural intensification and yield improvement (Brauman et al. 2013; Zainudeen 2007). Technological devices to lift, transport and apply water support the production of improved crop varieties across seasons and boost the use of other inputs, such as fertilizers, and chemical pesticides for the management of pests, diseases and weeds. Irrigated agricultural production has become an important source of cash and wealth accumulation in Asia and Africa. Therefore, government organizations, development agencies, donors and nongovernmental organizations (NGOs) promote water pump technology as a poverty alleviation tool.

The Government of Sri Lanka provides substantial subsidies for surface water and gravity irrigation, with farmers paying almost nothing for gravity irrigation services. In contrast, groundwater users and lift irrigators typically pay at least the marginal cost of extraction in terms of energy, because the costs of groundwater operations are borne by the users. Despite the operational cost, many farmers select groundwater over surface water for irrigation for several reasons. First, the individual farmer controls water use directly and thus avoids the often strenuous task of negotiating access to surface water with other farmers and government officers. Second, the energy cost associated with groundwater extraction motivates farmers to use the resource more judiciously, which generally results in greater water productivity and better returns on their investment. Many farmers depend on groundwater for the irrigation of cash crops, either entirely or in conjunction with surface water. Finally, groundwater aquifers provide greater resilience in dry periods when surface water supply is not reliable.

Despite the many benefits of groundwater, there is limited knowledge about the most effective approaches to improving access to labor-saving, water-lifting technologies for groundwater irrigation. Furthermore, no studies of the social and environmental impacts of farmer-led groundwater irrigation are available. Consequences of high water use, together with the increased use of agrochemicals, generate concerns regarding the damage caused to the environment and the potential to create conflicts between users. In terms of equity issues, women and resource-poor farmers face significant financial and informational hurdles that limit their access to available technologies. To date, most work on the mechanization of Sri Lankan agriculture has focused on tillage, field operations and post-harvest technologies (Abeyratne 2017; Pathirana et al. 2010). Few studies have explored the potential for mechanized water lifting (i.e., innovations for pumping and distribution of water) as an entry point to the sustainable intensification of agriculture.

## OBJECTIVES

The main aim of the study was to identify and analyze the trajectories of technological innovations and adoption for agricultural water management in farming systems in Sri Lanka, with a special focus on identifying positive and negative impacts, emerging issues, and potential responses for the rapid proliferation of motor pumps for intensification of agriculture. The specific objectives of the study are given below.

1. Understand and analyze the trends in the diffusion of agricultural water pumps.
2. Identify the major drivers behind the adoption and use of agricultural water pumps.
3. Analyze the types of technological innovation and development around water management that have contributed to increasing crop productivity, cropping intensity and area expansion that enhances farmer income.
4. Explore gender and equity issues triggered by the rapid spread of water-lifting technologies in agriculture.

## METHODS AND MATERIALS

The study used a mixed methods approach. Data was collected from multiple sources, including the Sri Lanka Customs, pump manufacturers and importers, and from existing literature. The study also employed key informant interviews (KIIs) with customs officials, private sector actors involved in the importing and distribution of pumps, leaders of farmer organizations (FOs) and other knowledgeable leaders in the communities. Detailed, multidisciplinary case studies in four areas where the use of motor pumps is expanding rapidly complemented the information obtained from KIIs. In addition to KIIs, sample surveys were conducted in eight villages in four case study locations (Figure 1) using a structured questionnaire (Annex 1).

To enable comparison, the selected case study locations were in areas where groundwater use is developing but where differences in geography, past irrigation practices, crop selection and social context exist. For example, Medawachchiya and Karadiyan Aru are located in an area affected by the civil war. Summaries of the selected study sites are given below.

*Mahaweli System H* (conjunctive surface water and groundwater irrigation) is a major irrigation command area in the North Central Province. The case study was concentrated in two villages: New Hanguranketha (Canal 411-D2) and New Teldeniya (Canal 411-SD6) located in the Thalawa Block. There are over 4,000 large diameter shallow wells (agro-wells) in Mahaweli System H which were constructed for conjunctive irrigation with surface water supplies. The main source of groundwater is seepage from irrigation canals and rice fields. Pumps are used to irrigate high-value crops, such as chili, onion, vegetables, etc., especially during dry seasons.

*Thirappane* (conjunctive surface water and groundwater in a small tank cascade system[1] [TCS]) is located in Anuradhapura District in the North Central Province. The detailed survey focused on the Mawathawewa and Puliyankulama villages. In the past, agriculture was predominantly rain-fed and comprised of low-value crops, such as sesame, black gram, pumpkin and other vegetables. The

[1] A ‘tank cascade system’ is described as a “connected series of tanks organized within a micro-catchment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet” (Madduma Bandara 1985).

TCS also allowed irrigated rice cultivation. However, groundwater irrigation in the area expanded after the 1990s, and cropping systems introduced high-value crops such as chili, onion and pulses. Farmers now use agro-wells in the hard-rock, shallow aquifer with depths of 4.3 meters (m) to 12.2 m (Kikuchi et al. 2003) for irrigation.

*Medawachchiya* (groundwater in a small TCS) is located in the North Central Province bordering the Northern Province and is an area affected by the civil war. The area is remote, located in the northern part of the province and was previously affected by the civil war. The detailed study focused on Moragoda and Etaweeragollawa villages. Lifting groundwater from the hard-rock aquifer at a depth of 4 m to 12m has become popular for cash crop cultivation (e.g., chili, onion and vegetables), mainly in the upland areas of the TCS.

*Karadiyan Aru* (conjunctive use of groundwater with surface water from the river) is located in the Batticaloa District (an area affected by the civil war) in the Eastern Province, 11 km west from Chenkalaldy Junction. The villages selected for the detailed study were Mavalai Aru and Puttam Veli. Farmers cultivate rain-fed rice during the wet season and, to a limited extent, non-paddy crops during the dry season using groundwater. Farmers have also started to cultivate groundnut in the areas near the riverbank, lifting water from the Mundeni Aru River, especially since the end of the civil war. Farmers lease land in a location called Puttam Veli, near the Mundeni Aru River, about 5 to 6 kilometers (km) from the village.

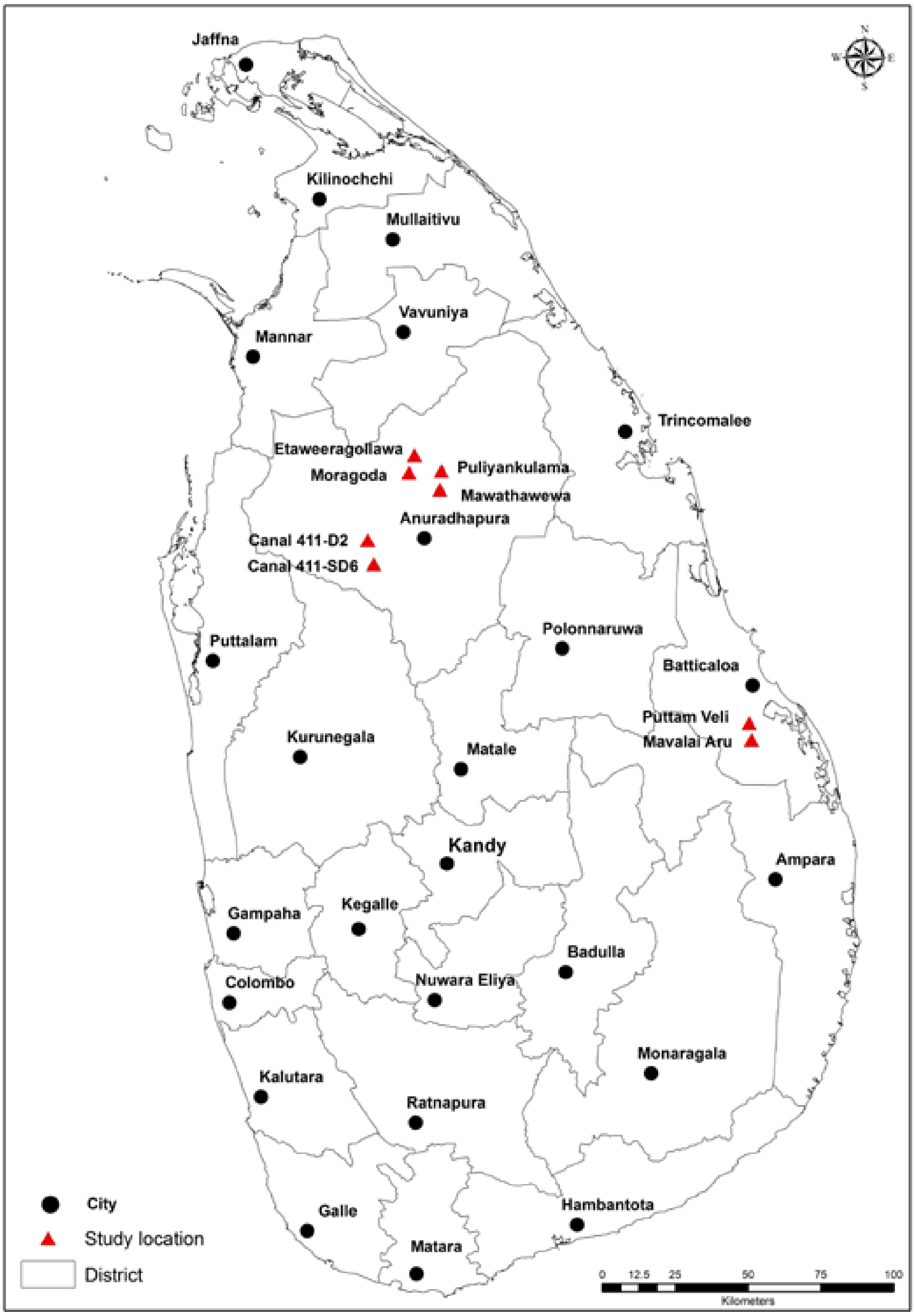
Both the field surveys and KIIs took place during October 2017. The survey sample size was 198 farmers, including 158 water pump users (around 40 farmers from each location) and 40 non-users (10 farmers from each location). The selected farmers were from the four locations described above. The study used a pre-tested questionnaire in the local languages of Sinhala and Tamil to gather information on household demographic characteristics, land-use patterns, labor allocation, source of water for cultivation, household assets and income, gender dimensions of different types of cultivation, water pump use and the impacts of groundwater irrigation.

Implementation of KIIs at selected locations included FO leaders, village-level agricultural officers, representatives of women groups, and influential and knowledgeable people in the villages, such as government employees and school principals. The purpose of the KIIs was to elicit information on the changes experienced in the area due to innovations and mechanization in water management technologies, and the prospects for and constraints to further expansion of the pump technology. KIIs also included questions related to gender and the use of water pumps.

## AGRICULTURAL WATER PUMP MARKET IN SRI LANKA

Starting in the 1960s, the use of motor pumps expanded rapidly in Sri Lanka (Figures 2 and 3) (Kikuchi et al. 2003). Important enabling factors include simplicity of design, relatively low cost, easy application and high profitability. Irrigation using a motor pump is an individualized undertaking, with typically little or no coordination or restriction from public institutions (Shah et al. 2013; Dessalegn and Merrey 2015). In South Asia, the price of motor pumps and the cost of well drilling have declined considerably in recent decades, placing the technology within the reach of smallholders (Molle et al. 2003, cited in de Fraiture and Giordano 2014). These factors have made the individual water-lifting technology an attractive option for smallholders.

FIGURE 1. Location of case study sites.




*Source:* International Water Management Institute (IWMI).

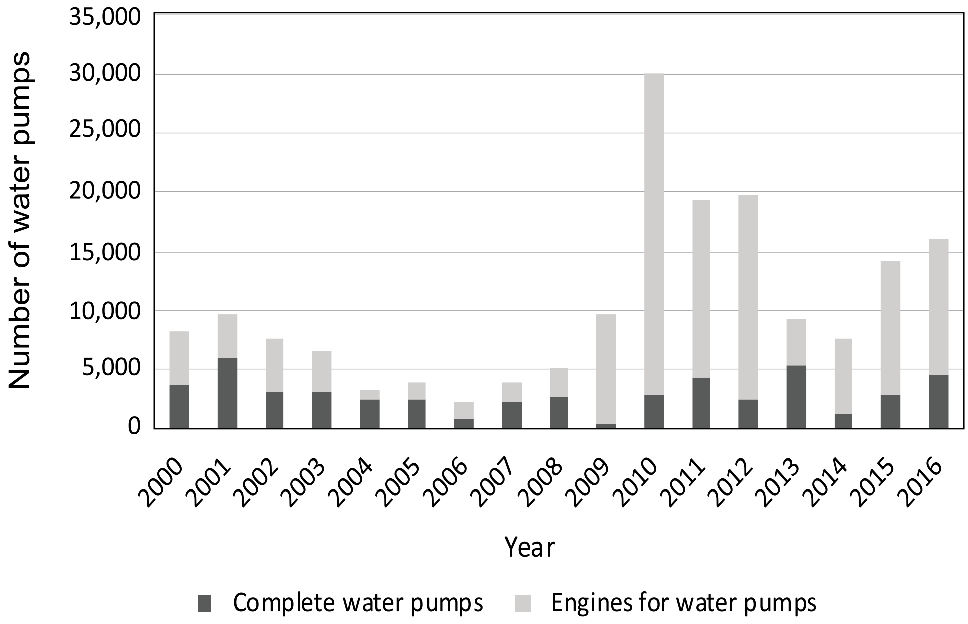
Specific data on water pumps for agriculture in Sri Lanka are not available. Therefore, estimates were made on the number of agricultural water pumps from other data. In Sri Lanka, two types of agricultural water pumps are available in the market: (i) imported water pumps (pump including the motor) from India, China and Japan; and (ii) locally manufactured or assembled water pumps.

Both categories include engine-driven pumps (diesel, kerosene and electric). The analysis of data from the Sri Lanka Customs on imports from 2000 to 2016 collected under the specific Harmonized System (HS) codes[2] identified water pumps. The basic data included pumps used for domestic and industrial purposes as well as agricultural purposes; therefore, we applied a two-step filter to the data. First, separation of industrial pumps from agricultural and domestic water pumps based on pump inlet/outlet diameter. Pumps used for agricultural and domestic purposes usually have an inlet/outlet diameter of less than 15 centimeters (cm) (6 inches). Next, separation of agricultural water pumps from domestic water pumps using customs data on Cost, Insurance and Freight (CIF) values as described below. The data was converted into the estimated market price of the pumps (estimated market price = CIF price + taxes at the port + value-added tax [VAT] + company profit 15% + distributor profit 15% + dealer profit 15%). Information gathered through the KIIs enabled the estimation of profit margins. Interviews with local companies involved in assembling water pumps provided information on the range of market prices for agricultural pumps in period 2000-2016. The estimate of locally assembled pumps was determined from the estimated number of water pump engines imported to the country. These details were extracted from customs data. Assembly of water pumps in Sri Lanka include locally manufactured pumps and imported motor units.

**Overview of the Water Pump Market, 2000-2016**

Figure 2 illustrates the number of water pumps imported to Sri Lanka during the period 2000-2016. This included both complete water pumps and engines for the local assembly of water pumps. The number of imported water pumps dropped from 2001 to 2006, and started to increase again in 2007, peaking in 2010. The import of engines for local assembly of water pumps gained momentum after 2009 and now makes up the largest share of agricultural water pumps sold in the country.

FIGURE 2. Water pump imports to Sri Lanka, 2000-2016.

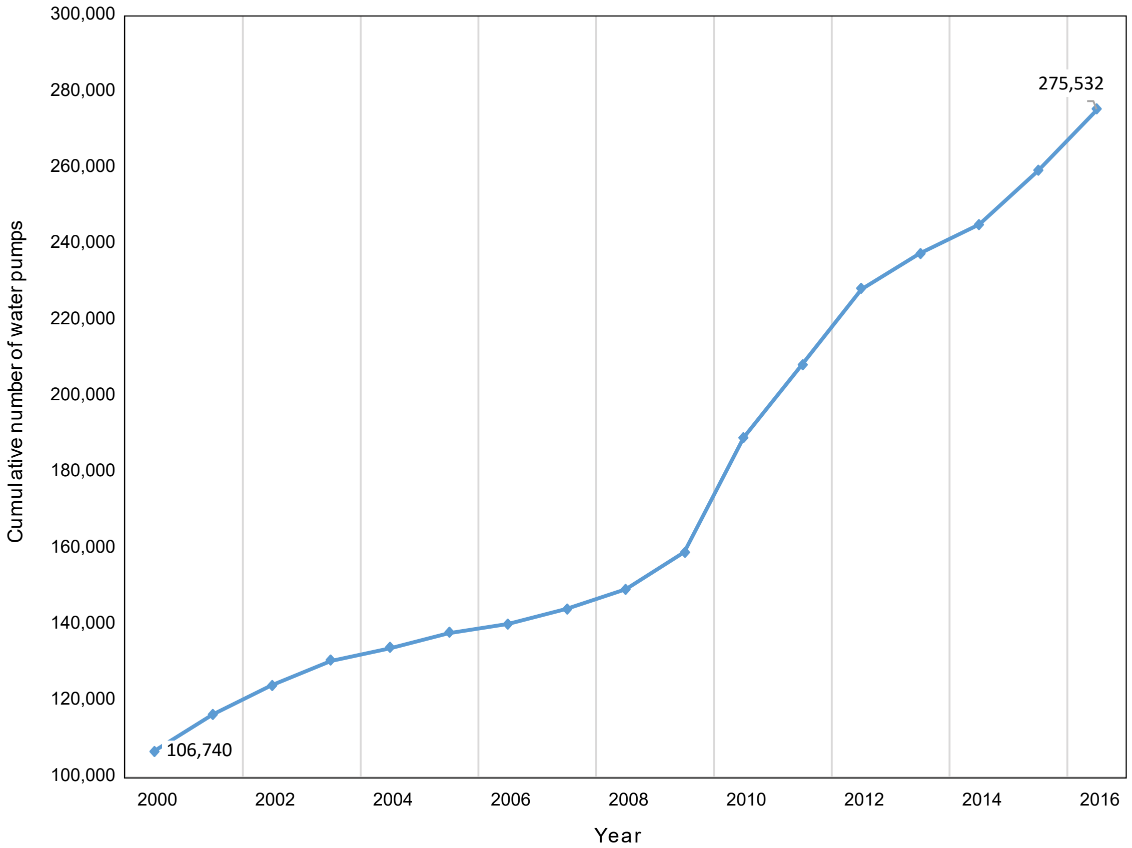



*Source:* Authors using data from the Sri Lanka Customs Department.

[2] Meaning of the HS code system: Refer *Understanding HS code in international trade* (available at https://cargofromchina.com/hs-code/ - accessed in April 2018).

According to an estimate by Kikuchi et al. (2003), around 100,000 water pumps were in use for agricultural purposes in the Dry Zone of Sri Lanka in 2000. This effectively represents the entire country, as agricultural pumps are largely used only in the Dry Zone. By 2016, the estimated number of water pumps used for agricultural purposes in the entire country increased to around 275,000 (see Figure 3).

FIGURE 3. Increase in the number of water pumps used for agricultural purposes in Sri Lanka (2000-2017).

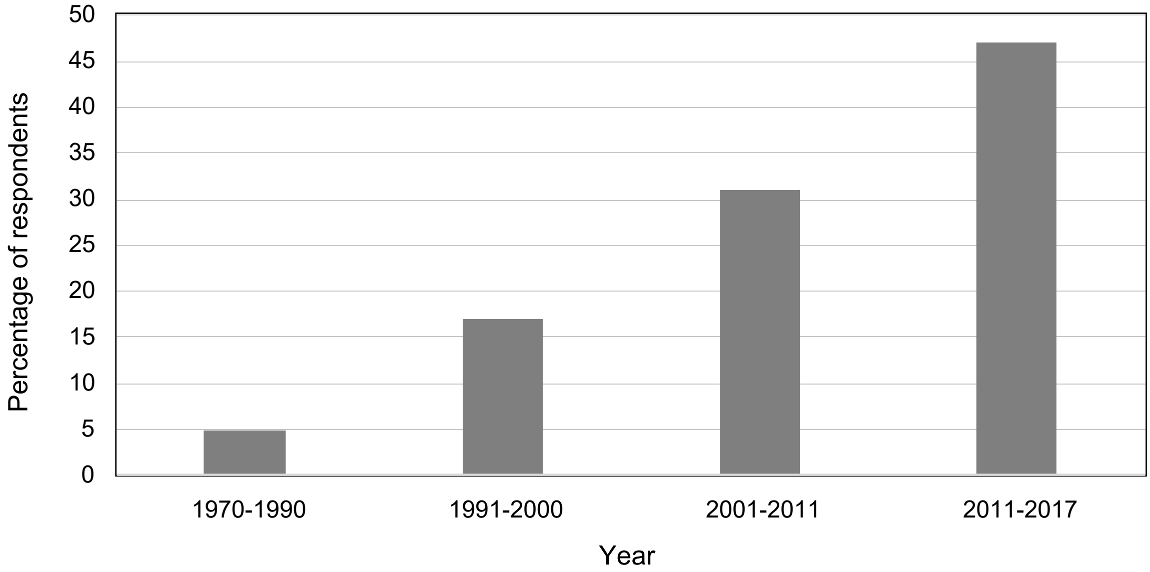



*Source:* Sri Lanka Customs.

Figure 4 illustrates the increase in the use of water pumps between 2000 and 2017 in the case study areas; This indicates that almost half of the sample farmers adopted the technology since 2011.

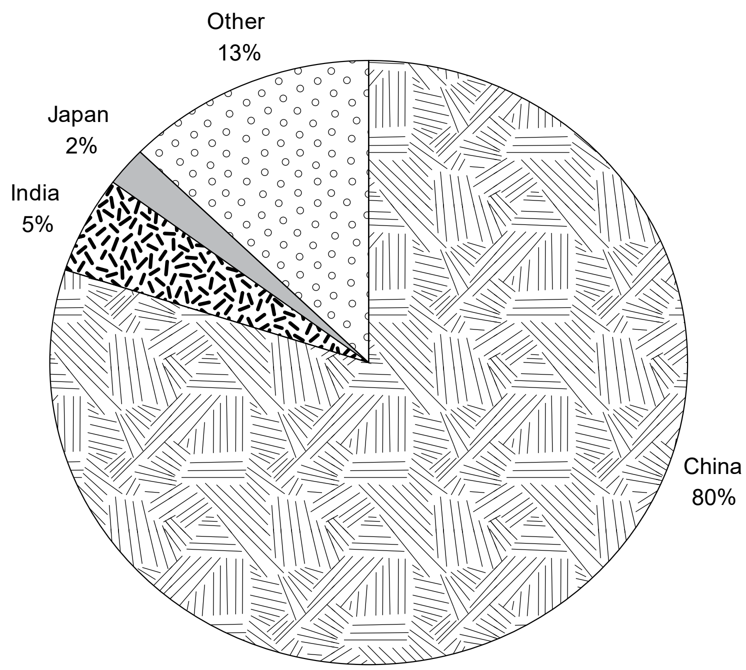
In Sri Lanka, the import of complete water pumps and engines for local assembly increased rapidly after 2009. Data from the Sri Lanka Customs department indicate that there was a large inflow of cheap, light, portable and efficient Chinese motor pumps. Chinese pumps accounted for 80% of the water pumps (with kerosene, diesel or electrical power units) imported as complete units during the period 2000-2016 (Figure 5). The actual number of Chinese pumps may be higher, as some of the pumps categorized under 'other' may have included Chinese pumps, which were imported to Sri Lanka from intermediary countries such as Vietnam.

FIGURE 4. Initial or 'first' use of water pumps in the case study areas according to the survey (n=158) (1970-2017).




*Source:* Authors' survey data, 2017.

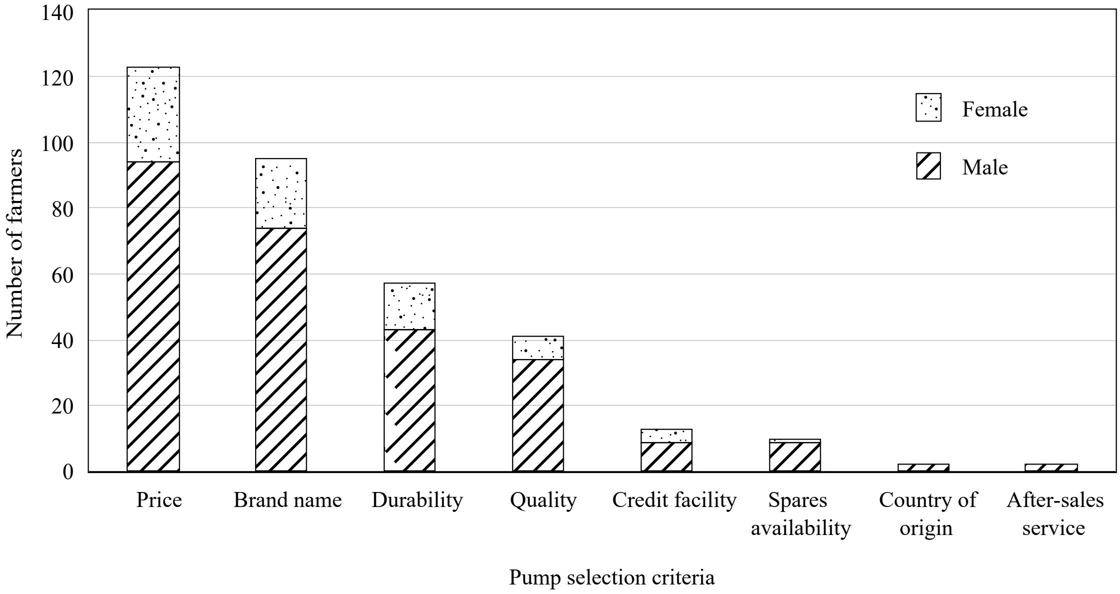
FIGURE 5. Imported water pumps (complete units) by country of manufacture (2000-2016).




*Source:* Authors using data from the Sri Lanka Customs department.

The three major factors reported to influence decisions by farmers to purchase a particular water pump are: (i) price, (ii) brand name, and (iii) durability of the pump (Figure 6). Although Chinese pumps are less durable than pumps imported from other countries (mainly India and Japan), they are less expensive. Various donor-funded projects have imported Japanese water pumps, although these are usually more expensive than pumps from other countries. According to the survey findings, even though the Chinese pumps are lower quality, less durable, and require frequent repair and maintenance, the lower purchase price and operating costs better suit smallholder budgets than pumps of a higher quality. However, a farmer with more financial resources tends to choose a more expensive, more durable option.

FIGURE 6. Factors influencing farmers' selection of a water pump in the case study areas (n=158).



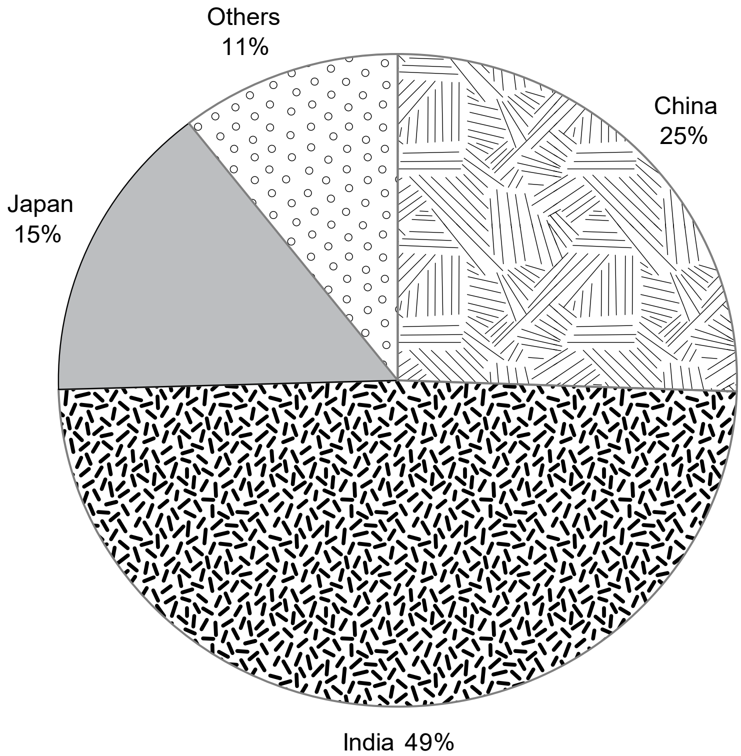

*Source:* Survey data, 2017.

Responding to market forces, local pump manufacturers assemble small pumps imported from India, Japan and other countries that are more durable and cheaper than the Chinese pumps (Figure 7), with almost 50% of the engines imported from India. Promotion of locally assembled water pumps use a local brand name which encourages manufacturers to focus on durability to establish a trusted name.

## Size of Motors

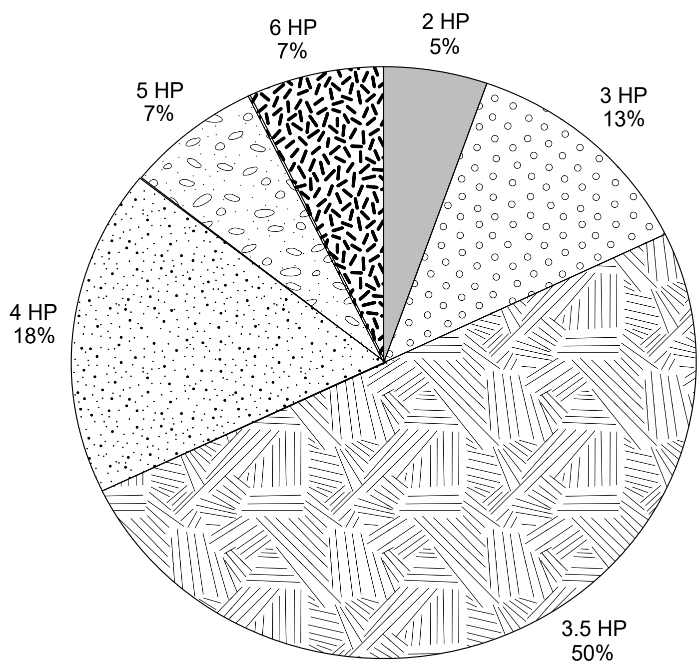
The horsepower (hp) required by the pump depends on the total lift and flow rates needed (Kikuchi et al. 2003). Agricultural water pumps powered by diesel motors generally use 2 to 6 hp engines. Over 80% of the pumps used in the Northwestern Province have a motor unit in the range of 3 to 4 hp (Figure 8). The survey confirmed that most of the pumps in the case study areas are in the range of 3 to 5 hp, but almost 40% of the pumps are 2 hp or less (Figure 9). This is due to the large number of small electric pumps provided by donor-funded projects, particularly in Medawachchiya. The price of the pumps varies depending on the brand and country of origin. Table 1 provides details of price ranges of different pumps depending on the inlet size and the pumping head (at 2017 LKR prices).

FIGURE 7. Countries that export water pump engines, which are imported for local assembly (2000-2016).



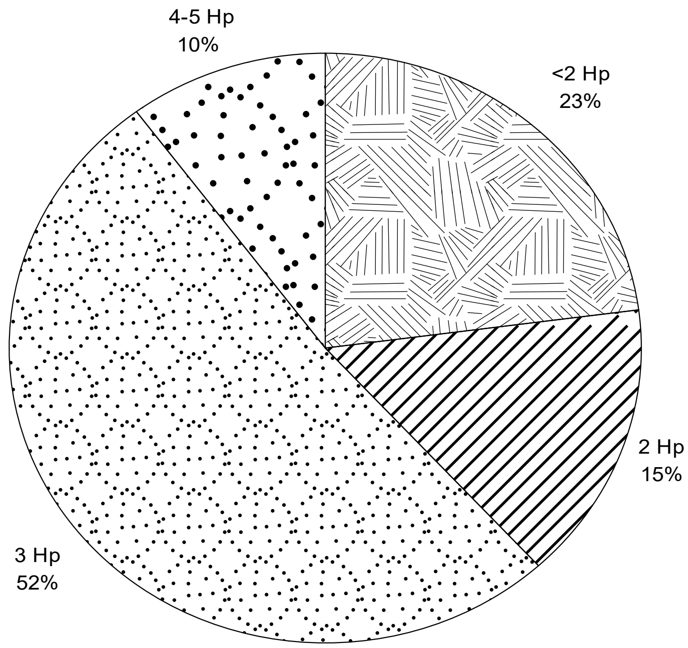

*Source:* Authors using data from the Sri Lanka Customs department.

FIGURE 8. Horsepower of water pumps used by farmers in the Northwestern Province (2000/2001).




*Source:* Kikuchi et al. 2003.

FIGURE 9. Horsepower of water pumps used by all sample farmers (n=158).




*Source:* Survey data, 2017.

TABLE 1. Price ranges of different types of water pumps by source of energy.

| Horsepower | Energy source | Market price (2017 LKR prices) |
|---|---|---|
| 3.5 hp | Kerosene/diesel | 82,000-93,000 (USD 543-616) |
| 0.5 hp/75 feet (0.5 hp/23 m) | Electric | 20,000 (USD 132) |
| 3 hp/300 feet (3 hp/92 m) | Electric | 135,000 (USD 894) |

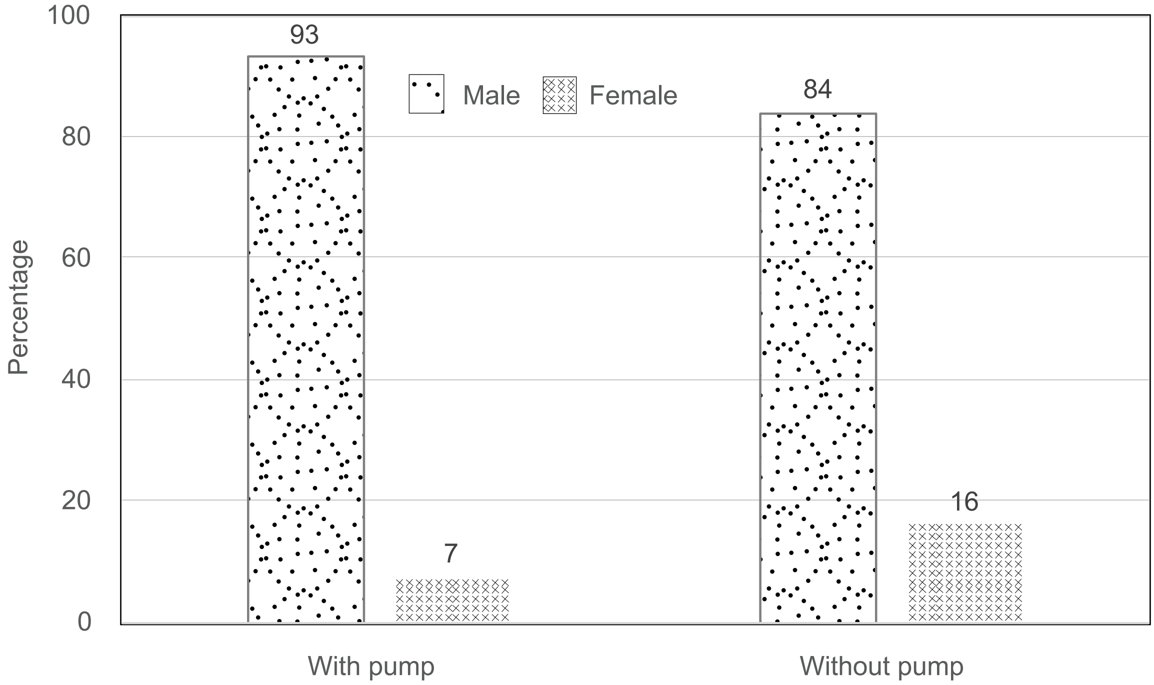
*Source:* Authors using local market data.
*Notes:* USD 1 = LKR 151 (2017), LKR – Sri Lankan Rupees.
1 Foot = 0.3 meters

When asked about pump replacement needs over the past 5 years, about 81% of the farmers responded that they had never replaced their pump, while 14% replaced the pump once during that period. Only 5% of the farmers replaced their pump two or three times during that period, and those were mostly the cheaper pumps. The findings indicate that most farmers purchased pumps that were durable, despite the higher price, and some farmers maintained cheap pumps better.

## SOCIOECONOMIC CHARACTERISTICS OF WATER PUMP USERS AND NON-USERS

The majority of the households sampled - both water pump users and non-users - are headed by males. The number of female-headed households is higher among non-users (see Figure 10). About 93% of the water pump users are involved in agricultural activities on a full-time basis. As suggested in Figure 11, part-time farmers tend to be non-users. Part-time farmers include small-scale landowners who do not fully engage in farming, and farmers who have off-farm employment in skilled jobs, which provide the major source of household income. Most of the part-time farmers that use water pumps are government or private sector employees. Among the water pump users, 16% adopted micro-irrigation systems.[3]

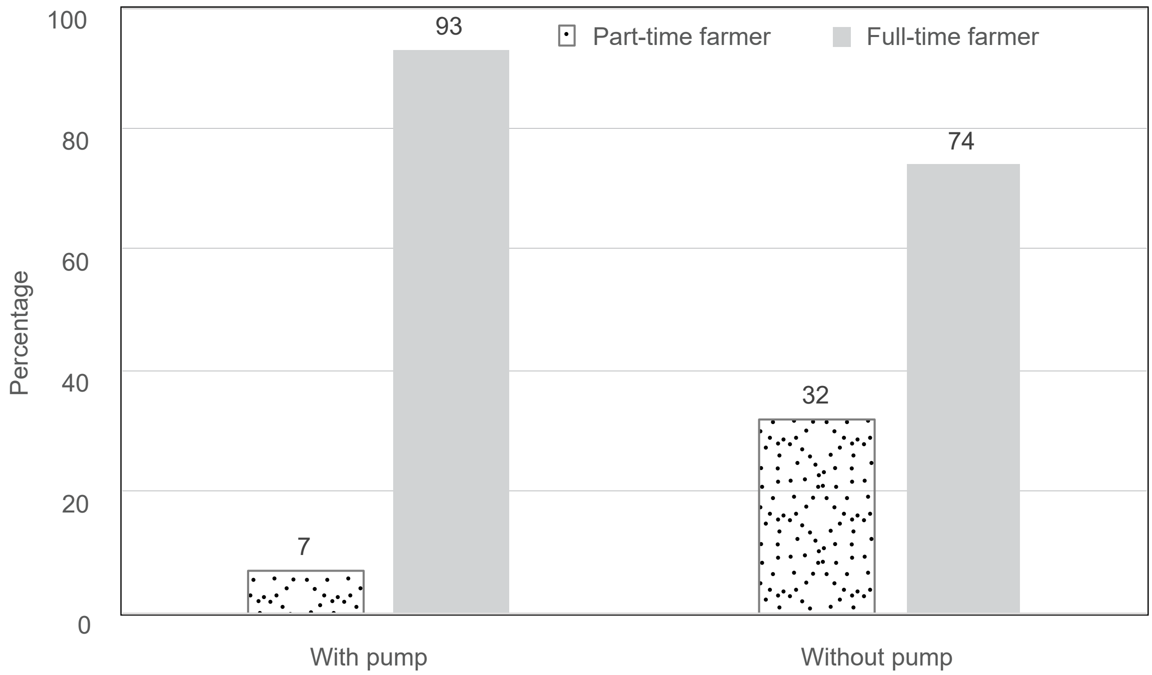
FIGURE 10. Sex-disaggregated pump ownership (n=198).




*Source:* Survey data, 2017.

[3] In this case, micro-irrigation includes drip and sprinkler irrigation.

FIGURE 11. Pump ownership by employment status of the farmer (n=198).

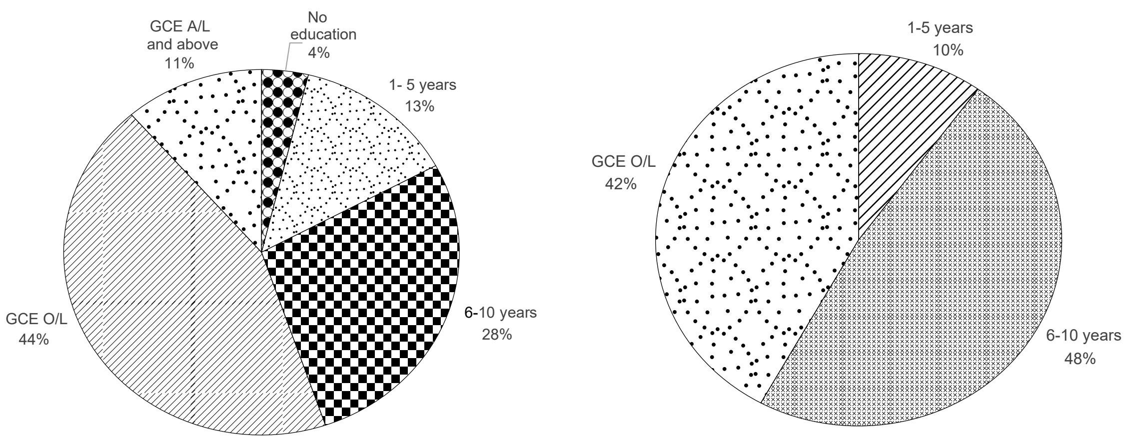



*Source:* Survey data, 2017.

Figure 12 summarizes education levels of water pump users and non-users. Figure 12(a) shows that about 55% of water pump users received an education up to the General Certificate of Education (GCE) (Ordinary Level) or higher. Figure 12(b) shows that all the non-users have received an education up to or below GCE (Ordinary Level).

FIGURE 12. Level of education of water pump users and non-users.

(a) Pump users (n=158) (b) Non-users (n=40)

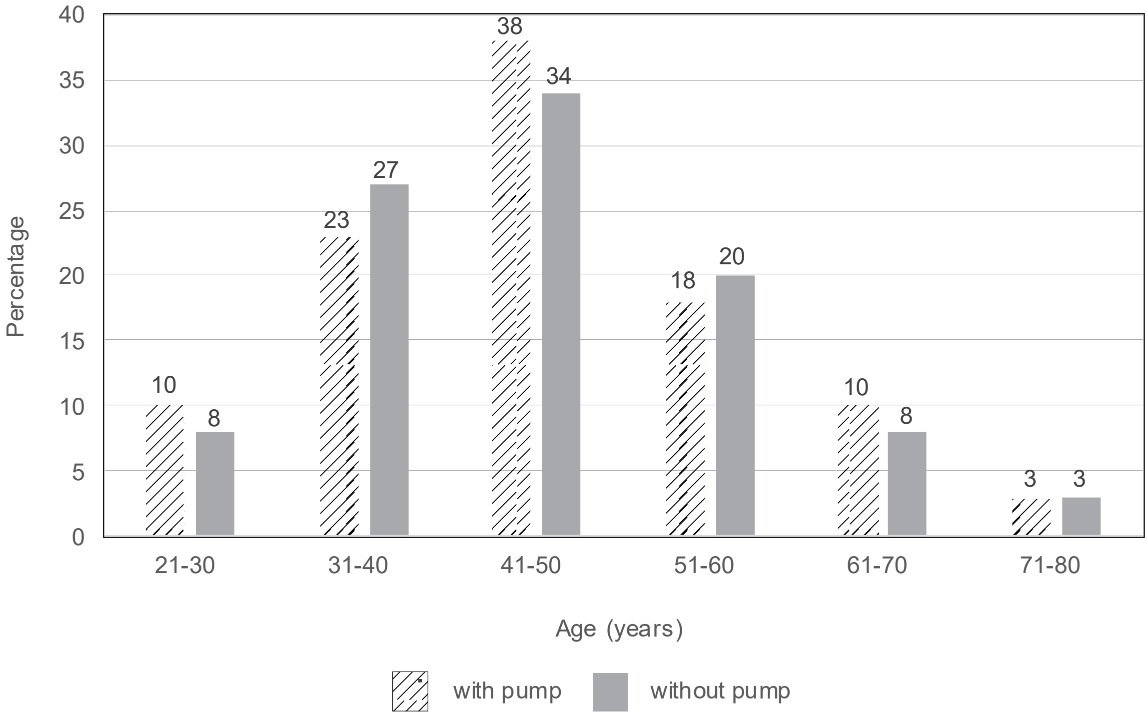



*Source:* Survey data, 2017.

*Notes:* A/L – Advanced Level; O/L – Ordinary Level

The age of the farmers does not seem to influence use or non-use of water pumps, as shown in Figure 13; however, the highest concentration of farmers are in the 41-50 age range.

FIGURE 13. Age of sample farmers (n=198).




*Source*: Survey data, 2017.

## HYDROLOGICAL FEATURES OF AGRO-WELLS

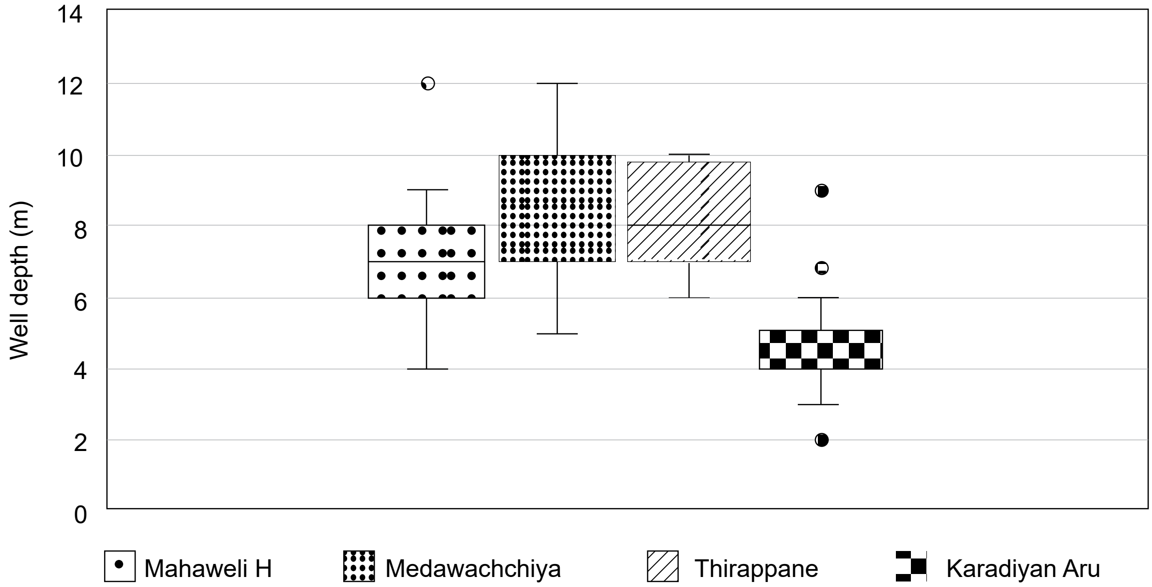
The majority of farmers in the case study areas have access to water even during the *Yala* (dry) season. Seepage of water from the canal and river in Mahaweli System H and Karadiyan Aru helps to recharge the water table, resulting in lower well depth (see Figure 14). The wells are comparatively deeper in the rain-fed/small tank cascade areas of Thirappane and Medawachchiya.

There are two types of agro-wells: lined and unlined wells. The dimensions of the wells usually range from 14 feet (4.3 m) to 22 feet (6.7 m) in diameter and 14 feet (4.3 m) to 40 feet (12.2 m) in depth (Kikuchi et al. 2003). Wells are lined using brick and cement; however, the majority of wells are unlined with an exposed cut surface of gravel or rock (Figure 15).

Using agro-wells, farmers are able to cultivate in both the *Maha* (wet) and *Yala* (dry) seasons, and some farmers (24%) cultivate a third-season (mid-season) crop. Figure 16 illustrates the average area cultivated using agro-wells during the *Maha, Yala* and mid seasons. The area cultivated during the *Yala* season varies from 0.25 to 5 acres[4] (0.1 to 2 ha), but most farmers (57%) cultivate 1 to 2 acres (0.4 to 0.8 ha). The average area cultivated during the *Yala* season in the Thirappane and Medawachchiya areas is higher or almost equal to rainy season cultivation, where small tank-based/rain-fed cultivation is most prominent. The area cultivated during the third season (mid-season) varies from 0.25 to 4 acres (0.1 to 1.6 ha) in the study area, but 80% of the mid-season farmers cultivate from 0.5 to 2 acres (0.2 to 0.8 ha).

[4] 1 acre = 0.4 hectares

FIGURE 14. Depth of wells in the case study locations.

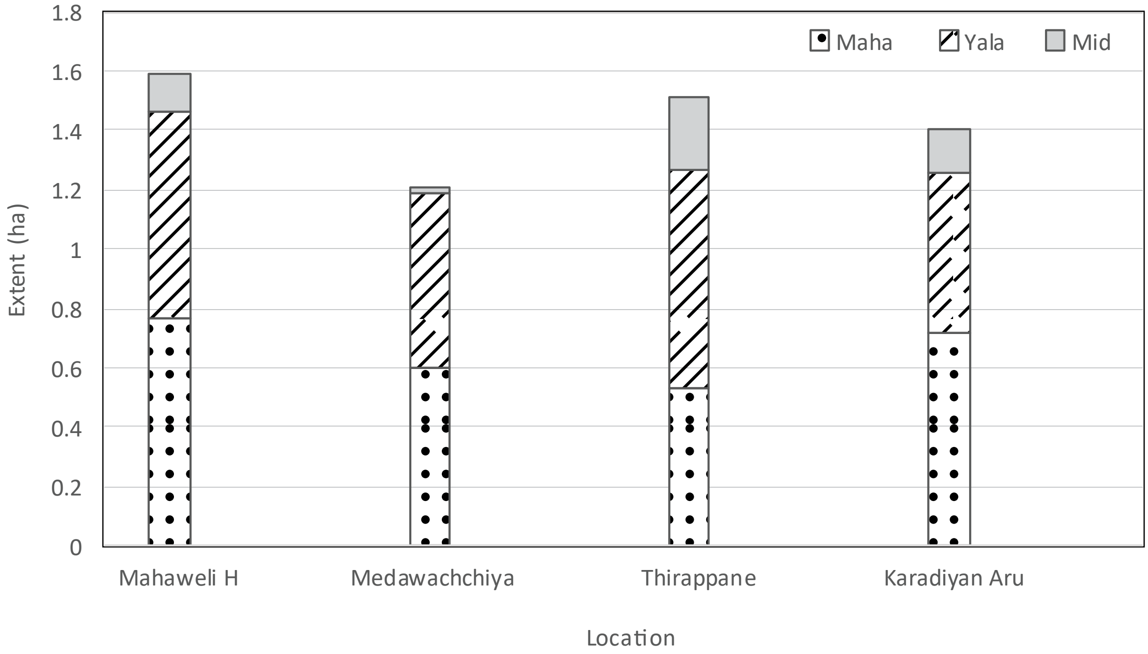



*Source:* Survey data, 2017.

FIGURE 15. Unlined agro-well.

*Photo:* W. W. Premachandra

FIGURE 16. Average area cultivated per well in case study locations (n=158).



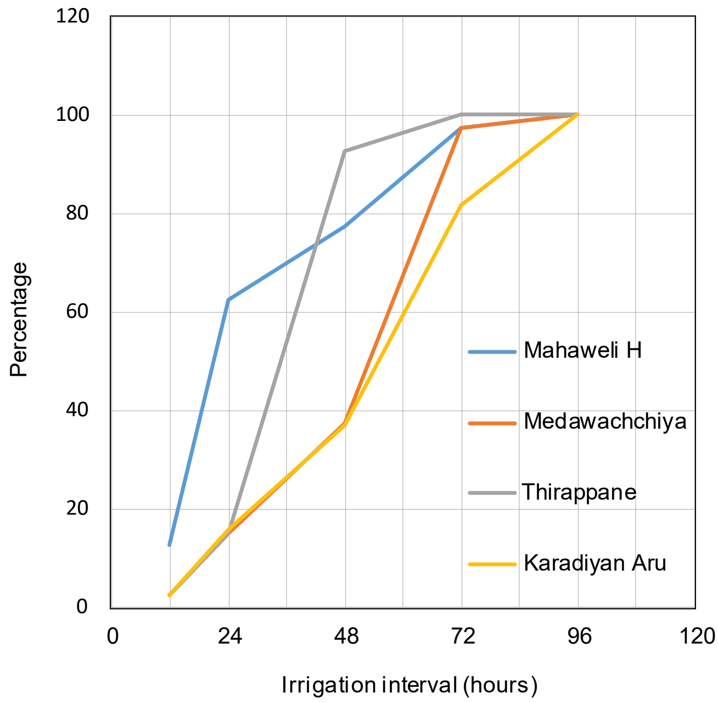

*Source:* Survey data, 2017.

Most of the farmers in the rain-fed areas irrigate every other day or once every 3 days. The agro-wells take little more than a day to recharge to the original water level during the dry season. However, farmers in Mahaweli System H mostly irrigate once a day with the water available in their wells; the wells recuperate within a day (Figures 17 and 18). Despite the relatively quick recharge rate of the wells, there may be scope to improve water and energy use efficiency by reducing the frequency of irrigation in Mahaweli System H to cope with the increasing popularity of groundwater irrigation.

Most farmers do not experience any issues with groundwater irrigation, such as wells drying out. However, the problem most often reported by farmers was the collapse of the walls of the wells (that lack a lining) during the rainy season (Figure 19). The water level rarely reaches the bottom of the well, even during the dry season.

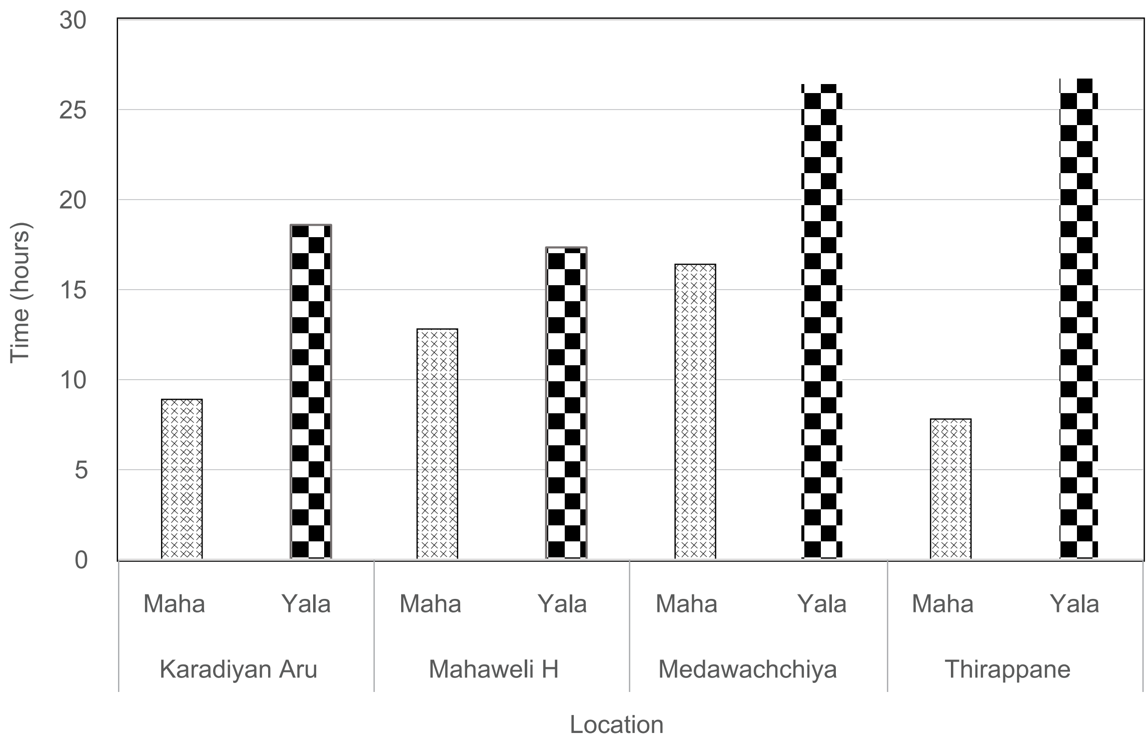
When asked to give their reasons for not adopting groundwater irrigation, non-agro-well cultivators stated that they lack the necessary capital needed to construct the well and related expenses (Figure 20). For example, in Karadiyan Aru, five neighboring farmers who lack the capital to construct their own wells, but who have pumps, share a common well, constructed by an NGO, on a rotating basis.

FIGURE 17. Frequency of pumping for irrigation in each case study location (n=158).



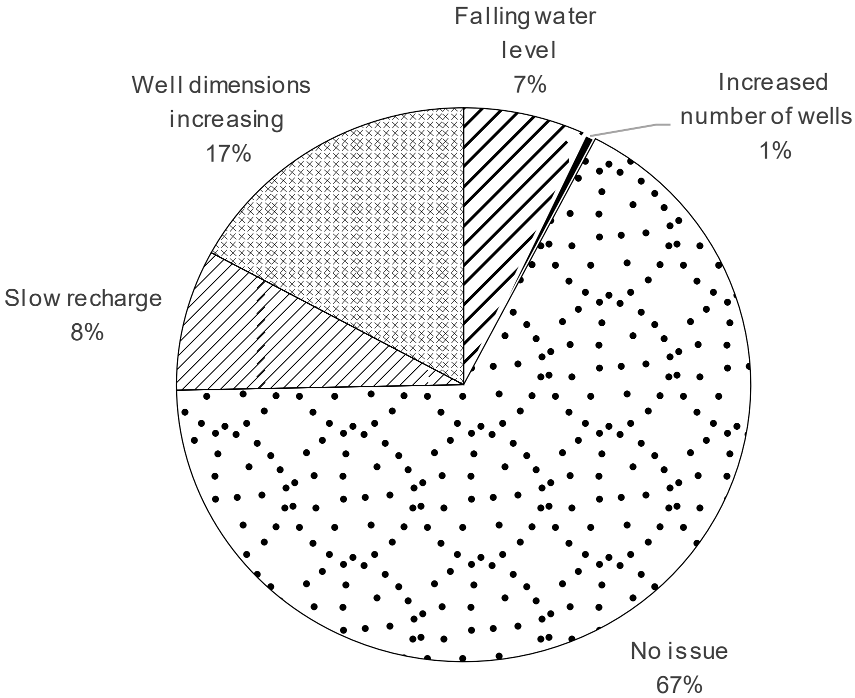

*Source:* Survey data, 2017.

FIGURE 18. Average time for the well to recharge to the original level for agro-wells in the four study locations (n=158).



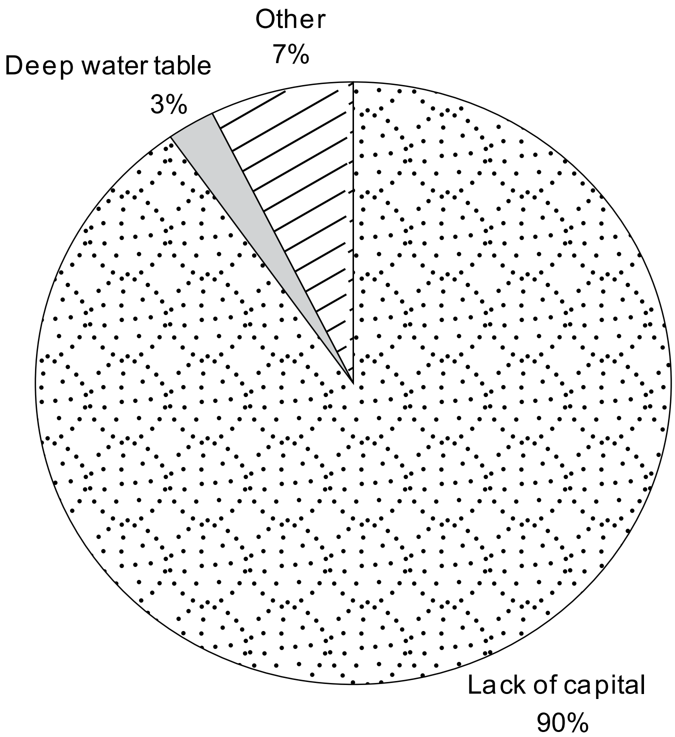

*Source:* Survey data, 2017.

FIGURE19. Major problems experienced by farmers using agro-wells for cultivation (n=158)




*Source:* Survey data, 2017.

FIGURE 20. Reasons for non-adoption of agro-wells (n=40).




*Source:* Survey data, 2017.

## ENABLING FARMERS TO INVEST IN WATER PUMPS

This section discusses the major drivers of water pump adoption in Sri Lanka based on expert interviews, secondary data and household surveys.

### Agro-well Construction Projects and Programs

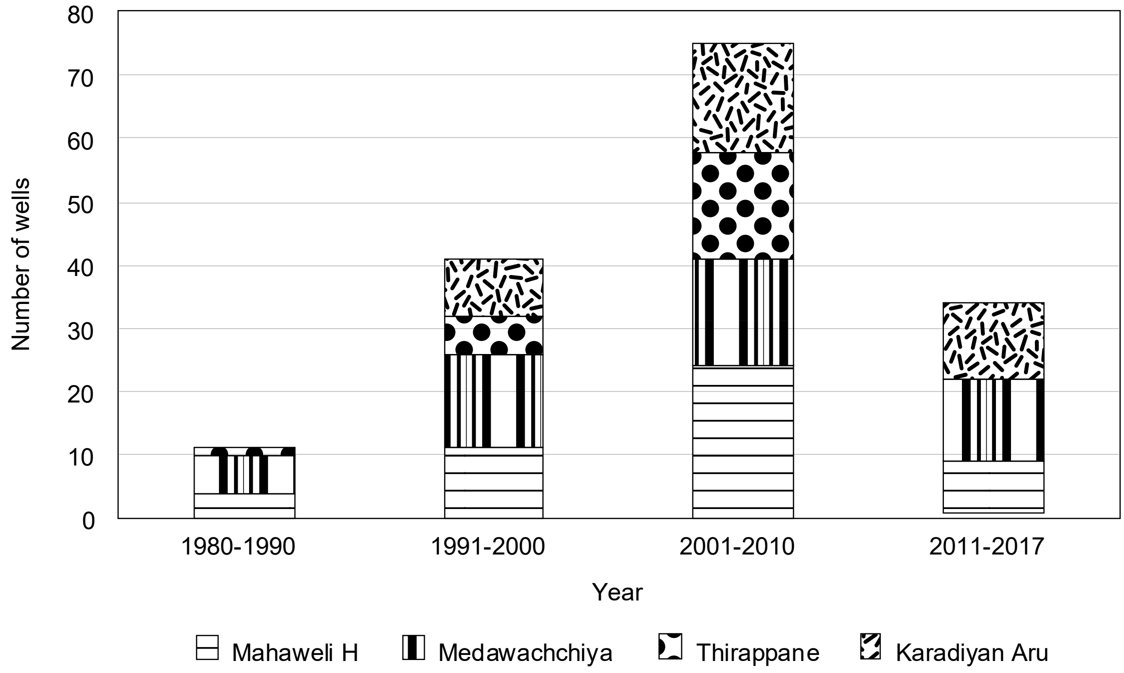
Availability and access to a reliable water source are two key factors in a farmer's decision on whether or not to invest in irrigation technologies. In the case study areas, availability of groundwater and river water for irrigation was important to farmers with adequate capital for investment in technology.

Since shallow groundwater is the major source of water for lift irrigation, the government and NGOs have promoted agro-wells through various subsidy programs. Investments by public and non-profit organizations in agro-wells indirectly promoted the adoption of motorized pumps for irrigation. Farmers observed the benefits gained by those who had received subsidized technologies. Although the use of agro-wells and pumps began in 1970, especially in the Dry Zone areas, the construction of agro-wells intensified with the government-sponsored, national agro-well program initiated in the late 1990s (Figure 21) (Kikuchi et al. 2003). Under the agro-well program, the government subsidized the construction of 18,300 wells. Subsequently, various donor- and NGO-funded projects constructed agro-wells to enhance the livelihoods of farmers in the Dry Zone. According to Kikuchi et al. (2003), there were around 50,000 agro-wells in Dry Zone areas by 2000, with a well density of 3.5 to 6.3 per square kilometer. Kikuchi et al. (2003) noted that there were almost twice as many water pumps as wells.

Agro-well development programs have continued with support from the government, NGOs and donor-funded projects. From 2013 to 2017, the construction of agro-wells was an important component of three different programs of the Ministry of Agriculture: (i) Commercial Farm Program, (ii) Youth Agriculture Entrepreneurship Program, and (iii) projects executed under the Farmers' Trust Fund. The government provided a subsidy of 50% of the cost of well construction. If the farmer already had a well, the government provided a subsidy for lining the well with masonry or for the purchase of an agricultural water pump.

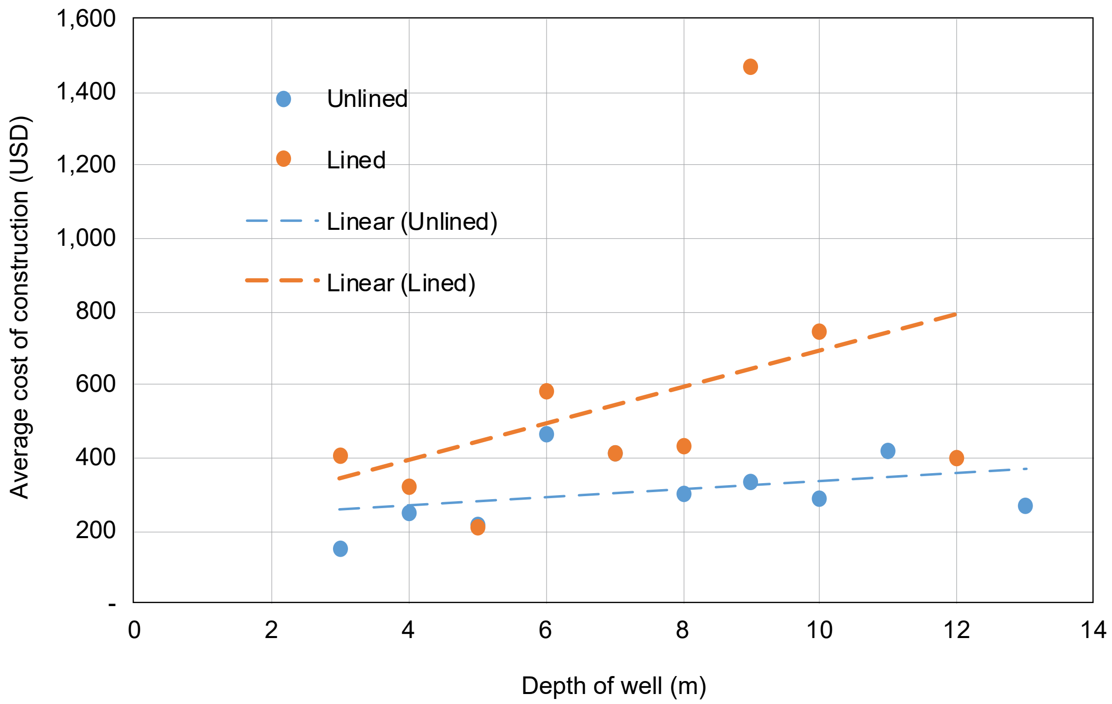
This study revealed that about 83% of agro-well owners in the study areas constructed wells without government subsidies and about 60% of the agro-wells are unlined. Lining is imperative to prevent the collapse of walls and to minimize siltation; however, farmers do not line wells because of the cost. The average construction cost of an unlined well is USD 300, while the cost of the lined well is USD 550, varying with the depth of the wells (Figure 22). In addition to lining, well depth and aquifer characteristics also have a bearing on the cost of construction. The number of farmers that invested their own resources in agro-well construction is much higher than investment by the sponsored programs. Farmers, officials and political authorities observed the performance and benefits of the subsidized agro-wells, which motivated farmers to adopt the technology and officials to continue to support groundwater development in the area (Karunarathne and Pathmarajah 2002).

FIGURE 21. Trends in the construction of agro-wells in the study areas (1980-2017).




*Source:* Survey data, 2017.

FIGURE 22. Difference in the cost of construction between lined and unlined wells in the study areas.




*Source:* Survey data, 2017.

### Micro-irrigation Promotion Projects and Programs

In 2000, the Government of Sri Lanka initiated a subsidy program to encourage the installation of micro-irrigation (MI) with agro-wells. Owning a water pump was an eligibility criterion for receiving the subsidy. The program facilitated the adoption of micro-irrigation systems by over 900 farmers. From 2005 to 2010, the Ministry of Agriculture promoted drip irrigation systems, which included a solar panel, solar-powered water pump and drip irrigation kit (Box 1).

**Box 1. Solar-powered drip irrigation project.**

The Ministry of Agriculture, in partnership with BP Solar Australia Pty Ltd., installed 10,000 units of 150-watt solar-powered drip irrigation (SPDI), valued at USD 33 million, in selected areas of the Dry Zone and some parts of the wet zone in Sri Lanka. Farmers selected to receive the units already owned agro-wells with a capacity of 6,000-7,000 liters/day.

The SPDI units cost LKR 300,000 (USD 3,225) each through a loan scheme where the beneficiaries made an initial down payment of LKR 5,000 (USD 54) at a designated bank. Repayment of the balance of the loan is required within 10 years – after a one-year grace period – through 20 biannual payments. Each SPDI unit can irrigate half an acre (0.2 ha). However, farmers do not value the product and 80% of them do not repay the balance of the loan other than the initial down payment. Only 12% of beneficiary farmers utilize the SPDI systems.

*Source:* Aheeyar et al. 2012; Bandara and Padmajani 2014.

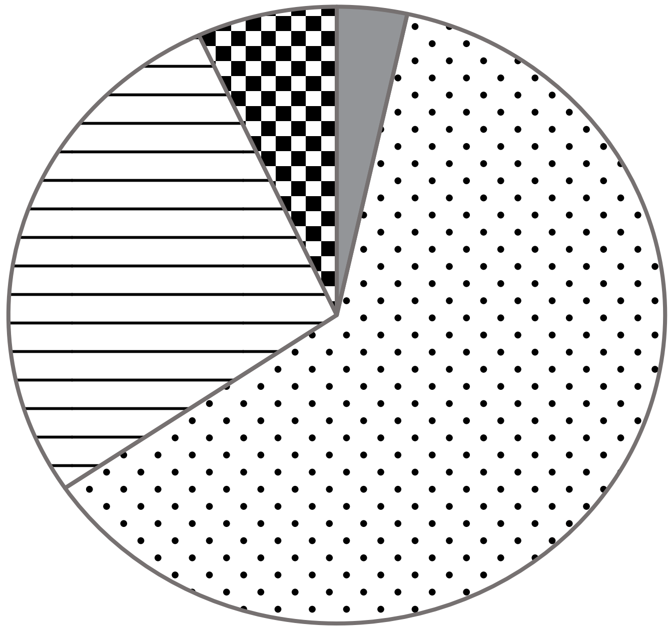
*Note:* In 2005, USD 1 = LKR 93

The Department of Agriculture established another program in 2013, with the objective of expanding the adoption of drip and sprinkler technology in the dry and intermediate zones of Sri Lanka. The promoted micro-irrigation systems include a water pump, filter, related accessories and a half an acre (0.2 ha) drip irrigation set. The amount payable depends on the price that was decided at the end of the process of open quotation calling by the government for the systems exclusive of the pump. The beneficiary deposits 50% of the total cost with the Department of Agriculture. Participants are required to procure a pump, thus allowing farmers to select a pump taking into consideration uses in addition to operation of the drip irrigation system. Beneficiaries that could prove procurement of a pump within 3 months of obtaining the system could reduce their contribution to the cost by up to LKR 50,000 (USD 472).[5]

Providing a government subsidy to install MI systems generated substantial benefits to the selected farmers. These benefits include reduced labor, water and energy use for water lifting, and the technology enabled the changing of cropping patterns, allowing a shift to high-value crops and expanded cultivation (Annex 2). These benefits motivated neighboring farmers to adopt MI systems at their own cost, with 62% of farmers with MI systems investing their own funds (Figure 23). The study found that no female farmers received subsidized MI systems, and half of the women farmers used loans to procure the MI system.

[5] Exchange rate in 2013: USD 1 = LKR 106.

FIGURE 23. Funding for micro-irrigation in the case study sites (n=27).




*Source:* Survey data, 2017.

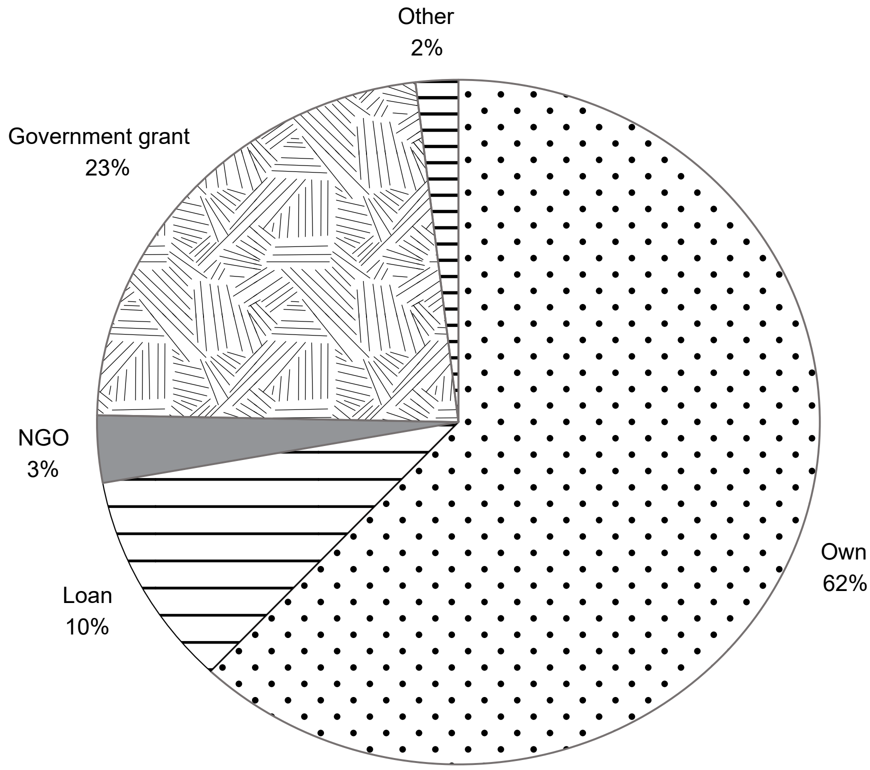
**Capital Availability and Donor Assistance to Purchase Water Pumps**

In addition to the capital requirement for the development of a water source (e.g., agro-well), funds are needed to invest in irrigation equipment (e.g., motor pump, micro-irrigation equipment). The investment requirement determines the ability and incentive of a household to adopt the technology. According to the survey, 72% of pump users invested their own resources (own money, loan, etc.) in water pumps, and only about 25% benefited from the government subsidy (Figure 24). This suggests that the subsidy programs may have helped upscale the technology by leveraging a larger community to self-finance the technology. The subsidy program did not focus on addressing social equity issues. Only about 10% of the farmers had access to credit facilities for the purchase of pumps. The problem of lack of capital is a serious matter for smallholders when public support programs and subsidy mechanisms are weak or missing. The availability of cheaper pumps alone is not sufficient to enable farmers to adopt new technologies. Therefore, other interventions will be needed to accelerate the adoption of water pumps and related irrigation technologies.

Under the Japanese grant aid program called the 'Second Kennedy Round' (2KR), funded through the Japanese International Cooperation Agency (JICA), 400 irrigation water pumps with engines were provided to farmers. This was carried out as part of the post-conflict resettlement and reconstruction process in the Northern and Eastern provinces of Sri Lanka under an agreement signed with the government in 2009.

The adoption of pumps in the Northern Province accelerated following the end of the civil war in 2009, with the resettlement of people in their original lands, and supported by government and NGO interventions to boost livelihood development activities. The government started two main development projects in the Northern and Eastern provinces: 'Northern Spring' and 'Eastern Revival'. Under these projects, the government provided resettled farmers with water pumps to start irrigated cultivation using groundwater. The government provided farmers in the Northern Province with 10,069 agricultural water pumps between 2009 and 2012. In addition, the then Ministry of Economic Development distributed 3,543 and 222 water pumps in 2014 and 2016, respectively, for farmers to cultivate 1.25-2.5 acres (0.5-1 ha) of land under the 'Divineguma Development Program' for poverty alleviation (Department of Samurdhi Development, pers. comm., November 2017).

FIGURE 24. Funding provided to purchase water pumps in the case study areas (n=158).




*Source:* Survey data, 2017.

## Government Tax and Tariff Policies

Customs duty imposed on the new pump (complete unit) imports is 37.5% of the CIF price (30% general duty and 7.5% ports and airport development levy). However, the general duty is 15% on engines imported for local assembly of water pumps. All pumps are subject to taxes, including 15% VAT, 2% Nation Building Tax (NBT) and 5% cess. The government provides support to local water pump assemblers through the reduced general custom duty. The government could reduce the cost of pumps for farmers by lowering the duty and taxes on pumps, assuming these reductions are passed on to consumers.

The National Agricultural Policy (2012-2015) provides clear directions for the development and manufacture of agricultural machinery, and the promotion of agricultural mechanization through public and private sector participation (Ministry of Agriculture n.d.). One of the main objectives of the policy is to increase farm profits through the application of innovations and environmentally friendly techniques in agriculture. In 2006, the government introduced a reduction of 50% of the tax payable on the profit for 5 years for companies importing drip irrigation equipment (through amendments to the Inland Revenue Act No. 10 of 2006). The amendment promotes the use of water pumps. More generally, the policy of the government's Vision 2025 states, "We will encourage the private sector to modernize the agriculture sector, and to introduce efficient and stable modern value chains through models such as trader-farmer contracts, contract grower systems, and agriculture mega zones" (Government of Sri Lanka 2017).

Providing tariff concessions for agricultural machinery and the open economic policies adopted by successive governments encouraged the private sector to import water pumps from China and other countries. Low-cost pumps in turn increased the ability of smallholders to access agricultural technologies. Yet, the relatively high cost of pump and irrigation technology packages, alongside the lack of capital or access to loans for investment, are major constraints to the adoption of these packages for many smallholder farmers. Additional policy mechanisms, such as targeted subsidies, concessional loan schemes, etc., may be needed.

### Government Extension Services

Exposure to information on new technologies and the availability of extension services play important roles in promoting innovative technologies to the farming community. Witnessing the success of their neighbors can persuade poor farmers to adopt water pump and micro-irrigation technologies. This was clear in the villages selected in Thirappane area (Mawathawewa and Puliyankulama), where almost all the farmers in the villages have adopted water pumps.

## USE OF PUMPS IN THE STUDY AREAS

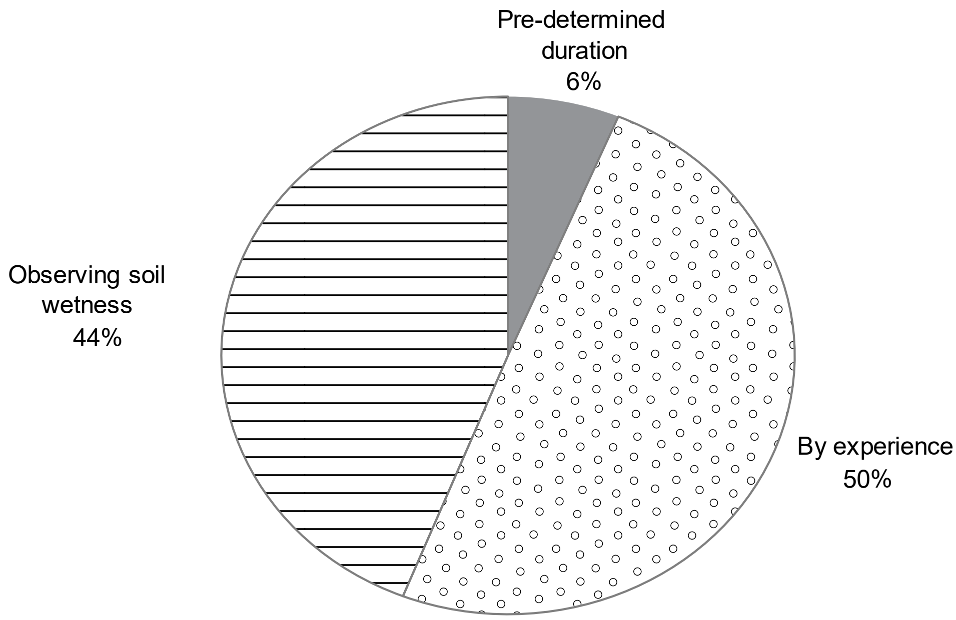
### Main Features of Pump Use and Cultivation

The application of the correct amount of water at the right intervals is important for conserving water, energy and labor; reducing depreciation of pumps and equipment; obtaining a good yield; reducing nutrient losses; and increasing the profitability of irrigation. During the study, farmers were asked how they determine irrigation intervals and the duration of applications. Most of the farmers use their own experience to determine the irrigation interval, depending on the type of crop and stage of growth (Figure 25). There may be scope to implement better irrigation scheduling approaches to minimize water use, and increase land, labor and crop productivity to improve farmers' incomes.

Diesel pump users have the highest fuel costs, while pumping costs are the lowest for electric pump users (Figure 26). However, electric pumps are not popular among farmers, as grid power tends not to be available at field level and high horsepower electric pumps are more expensive than fossil fuel pumps. The kerosene pump is most popular among farmers across the four surveyed areas. Figure 27 illustrates the average annual maintenance cost of different types of pumps.

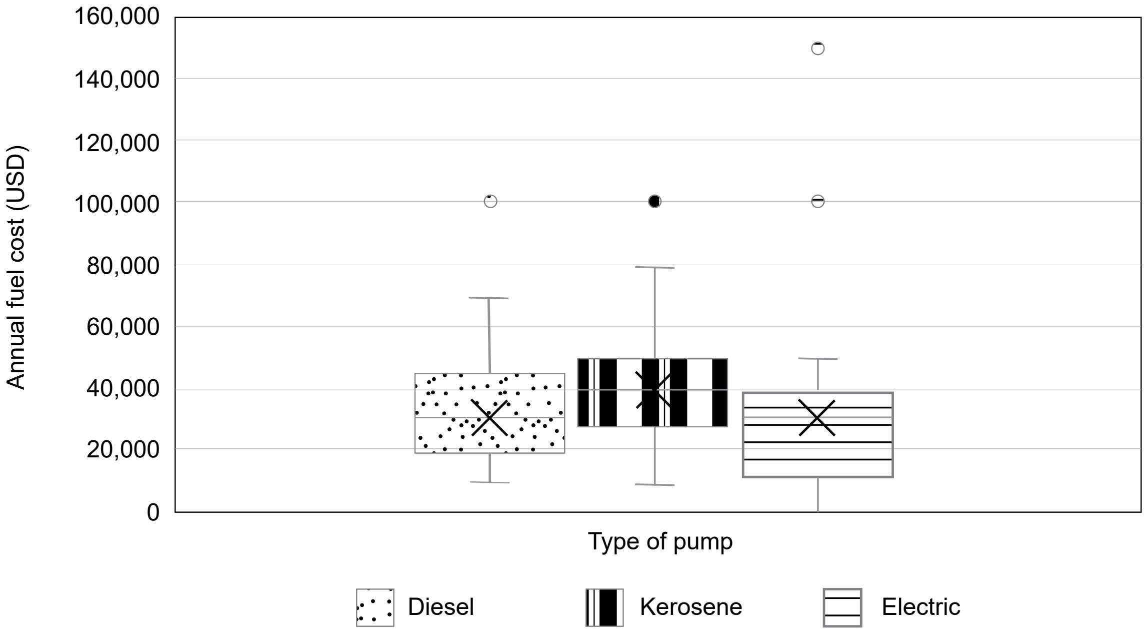
Asked to identify the major challenges experienced in using water pumps, the majority of farmers stated that they had not experienced any problems to date and were doing very well (Figure 28). About 10% of the farmers reported the need to deepen their wells over time, mainly due to siltation and collapse of the unlined walls. Only 4% reported problems with rapid drawdown of water levels.

FIGURE 25. How farmers in the case study areas determine pumping and irrigation intervals (n=158).



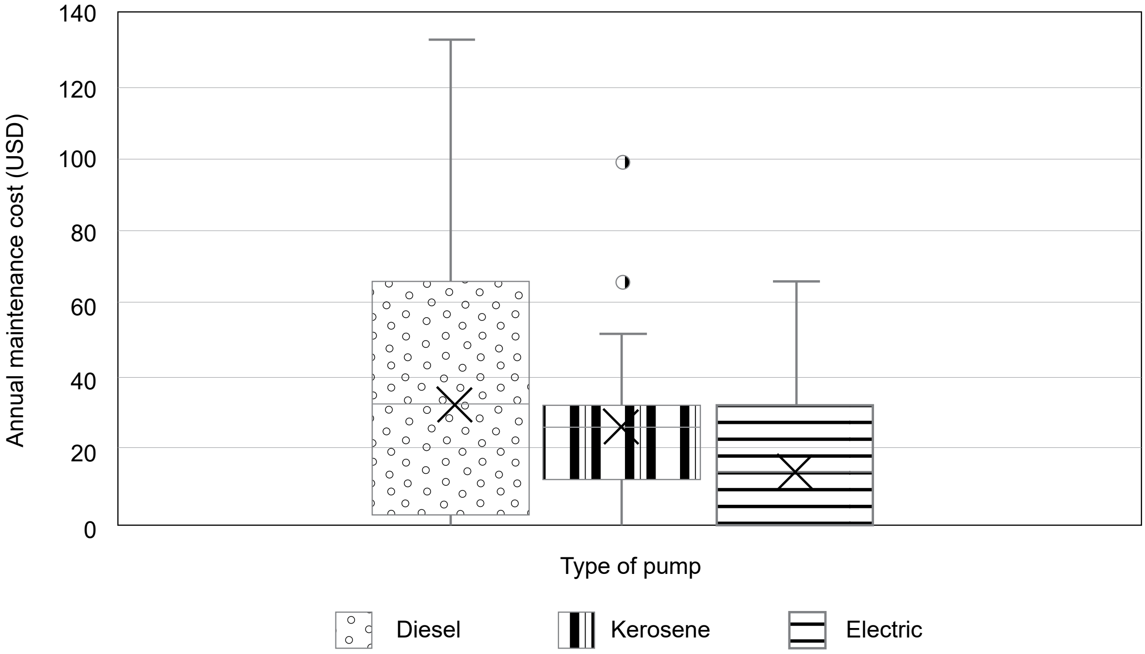

*Source:* Survey data, 2017

FIGURE 26. Annual fuel cost for lifting water (n=158).



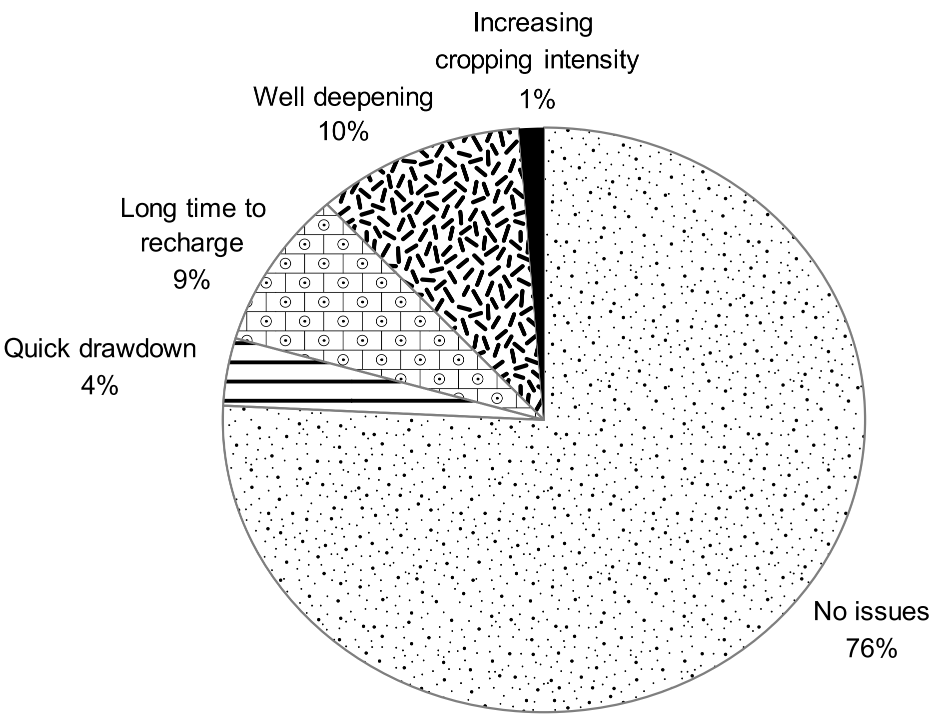

*Source:* Survey data, 2017

FIGURE 27. Maintenance cost of water pumps (n=158).




*Source:* Survey data, 2017.

FIGURE 28. Technical issues experienced in using water pumps for cultivation (n=158).




*Source:* Survey data, 2017

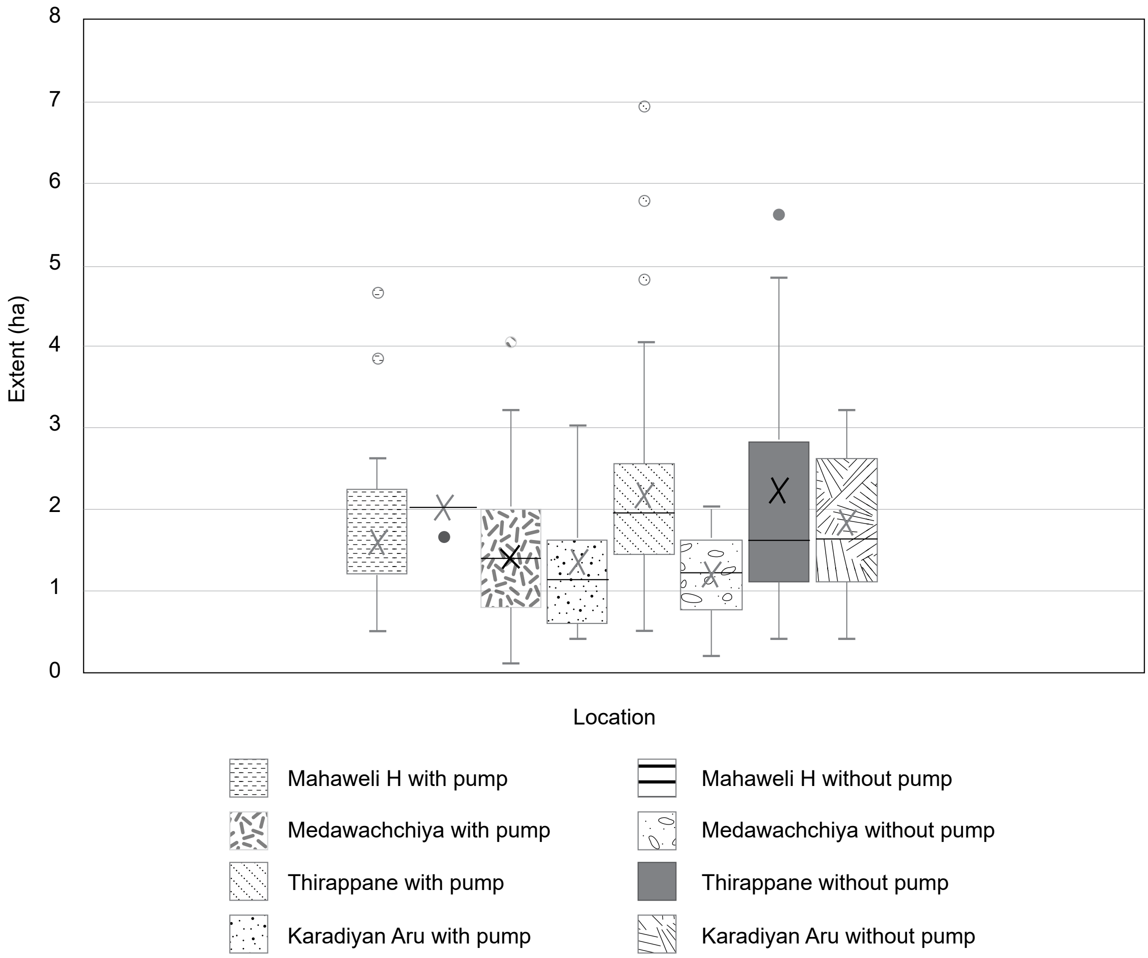
## IMPACTS OF WATER PUMPS

### Positive Impacts of Water Pumps on Farming Activities

#### *i. Cultivated land*

Farmers are cultivating more land using available lands or accessing lands through various tenure arrangements, such as leased-in, mortgaged-in and illegal encroachment onto government property. Figure 29 illustrates the average area cultivated by pump owners and non-pump owners, which shows that generally pump users cultivate more land relative to non-pump users in the same area.

FIGURE 29. Land area cultivated, including lands accessed through tenure arrangements (with pumps: n=158; without pumps: n=40).




*Source:* Survey data, 2017

#### *ii. Cropping intensity*

The average size of landholdings in the study areas, particularly in rain-fed areas, is not more than 2.5 acres (1 ha). Therefore, households try to intensify cultivation through pump-based irrigation. The results of the study show that farmers increased the cropping intensity across the seasons from 100% to 300% in a year in Thirappane, Medawachchiya and Karadiyan Aru, and from 150% to 300% in a year in Mahaweli System H. Reporting on a study of the Kalpitiya Peninsula, Aheeyar et al. (2016) showed that groundwater farmers are cultivating their lands with short-duration vegetables throughout the year (achieving four to five crops per annum), with a fallow period of 15-30 days between crops.

### *iii. Cropping patterns*

Rice is the staple diet of Sri Lanka. Farmers cultivate rice for household food security and sell the excess production. Rice is also the most widely irrigated crop in Sri Lanka, covering most of the major irrigation command areas, including the Mahaweli systems. During the *Maha* season, there is generally sufficient rainfall to fulfil the water requirement of rice, although dry periods in the monsoon season may lead to crop stress without irrigation. Pumps have enabled smallholders to diversify their farming systems with the cultivation of high-value crops. The study reveals that, with the introduction of groundwater pumps, 52% of the farmers changed their cropping pattern, especially in the *Yala* season. Figure 30 illustrates differences in cropping patterns by farmers with water pumps and those without during the period 2016/2017. It is interesting to note that, despite the availability of water for rice cultivation in Mahaweli System H, up to 35% of the farmers using water pumps have cultivated high-value, non-paddy crops. None of the farmers using water pumps in the study areas cultivated water-intensive rice crops during the *Yala* season; instead, they chose to cultivate less water-intensive, high-value cash crops. The findings clearly indicate that pump users shift from a focus on self-sufficient food security to more market-oriented commercial cultivation.

Up to 20% of the farmers in Thirappane and 8% of the farmers in the Mahaweli System H and Medawachchiya areas cultivated a mid-season crop on an average area of 1 acre (0.4 ha). Survey respondents reported that many farmers abandoned cultivation during the countrywide drought in 2016-2017, which extended over three consecutive seasons and caused massive crop damages (Sunday Times 2017). Other farmers accessing groundwater with pumps successfully cultivated crops in at least two seasons per year during the drought.

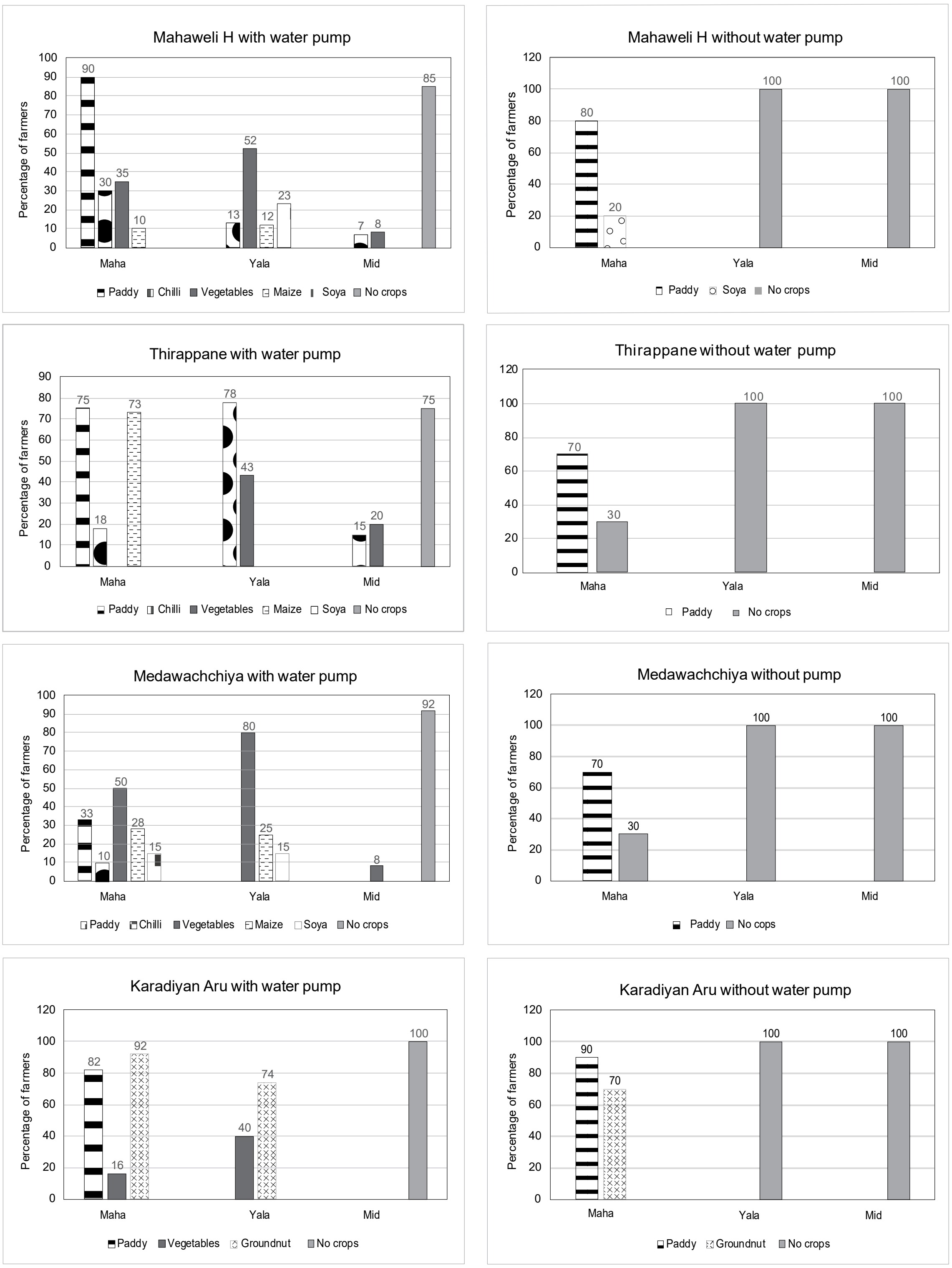
Vegetables such as brinjal, okra, pumpkin, long beans, chilli, maize and soybean are the most frequently cultivated crops in the study areas. The benefits of growing high-value cash crops have led neighboring farmers to shift from their traditional crops (rice and sesame, millet and foxtail millet) to crops such as onion and chilli (Figures 31 and 32). Vegetable cultivation is popular throughout the year and depends on market demand. Farmers have adopted raised beds in the ill-drained lowlands to enable vegetable cultivation in areas that would otherwise be used to cultivate rice under waterlogged conditions. The limited supply of vegetables during the rainy season brings a higher market price and extra income from vegetable cultivation.

### *iv. Income changes*

Figure 33 illustrates the extent of land owned by farmers using water pumps and non-users. Notably, farmers with water pumps are able to cultivate crops during the dry and, in some cases, mid seasons. The expanded cultivation of high-value crops across seasons brings higher income than rain-fed cultivation and surface irrigation. Therefore, pump users are relatively better-off and generally own more land than non-users.

Figure 34 illustrates the gross income levels of farmers using pumps and non-users during the mid, *Yala* and *Maha* seasons. Most farmers cultivate traditional rice during the *Maha* season, which has a relatively low return. More entrepreneurial farmers use water pumps during the Maha season to cultivate vegetables and other cash crops in uplands or in raised beds in lowlands, when there is a low market supply and therefore higher prices and additional income.

FIGURE 30. Cropping patterns in the study areas (with pumps: n=158; without pumps: n=40).




*Source:* Survey data, 2017.
*Notes:* 1. Due to the cultivation of multiple crops, the sum of percentages is more than 100;
2. There was no indication that cultivation had not taken place for any crop.

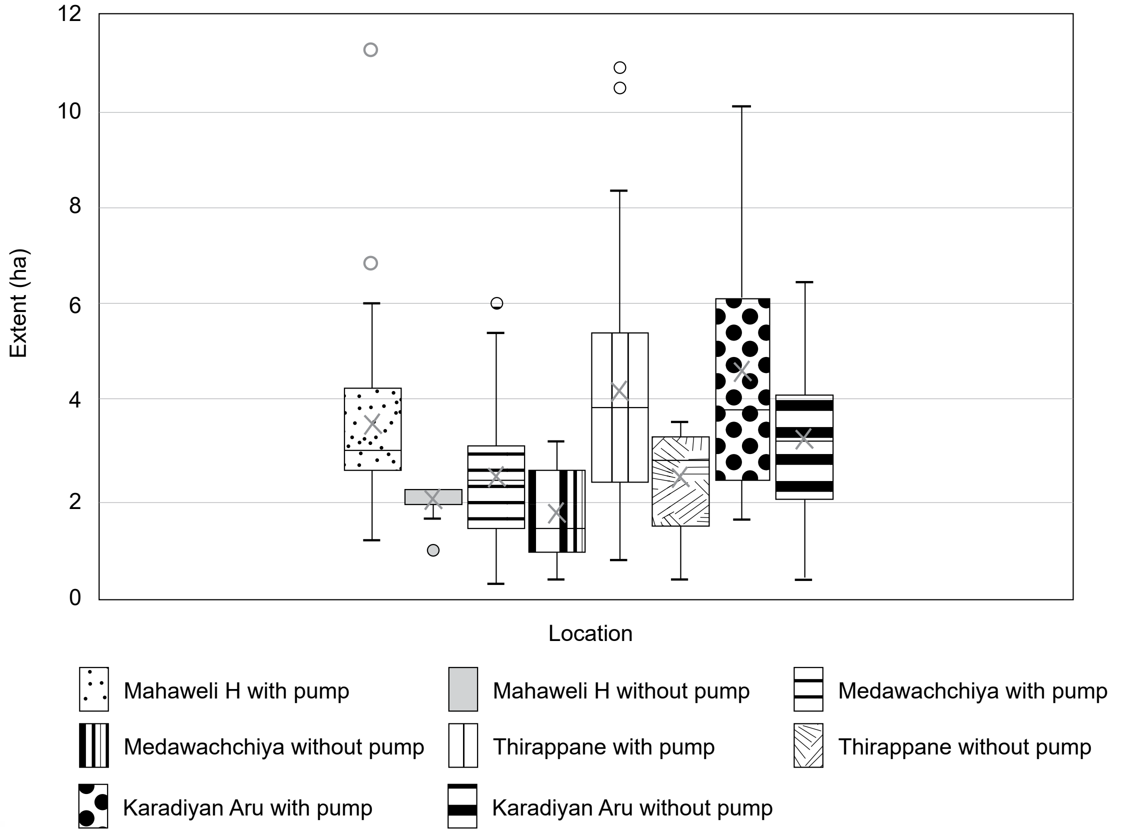
FIGURE 31. Onion cultivation in Mawathawewa.

*Photo:* W. W. Premachandra (IWMI).

FIGURE 32. Chilli cultivation in Puliyankulama.

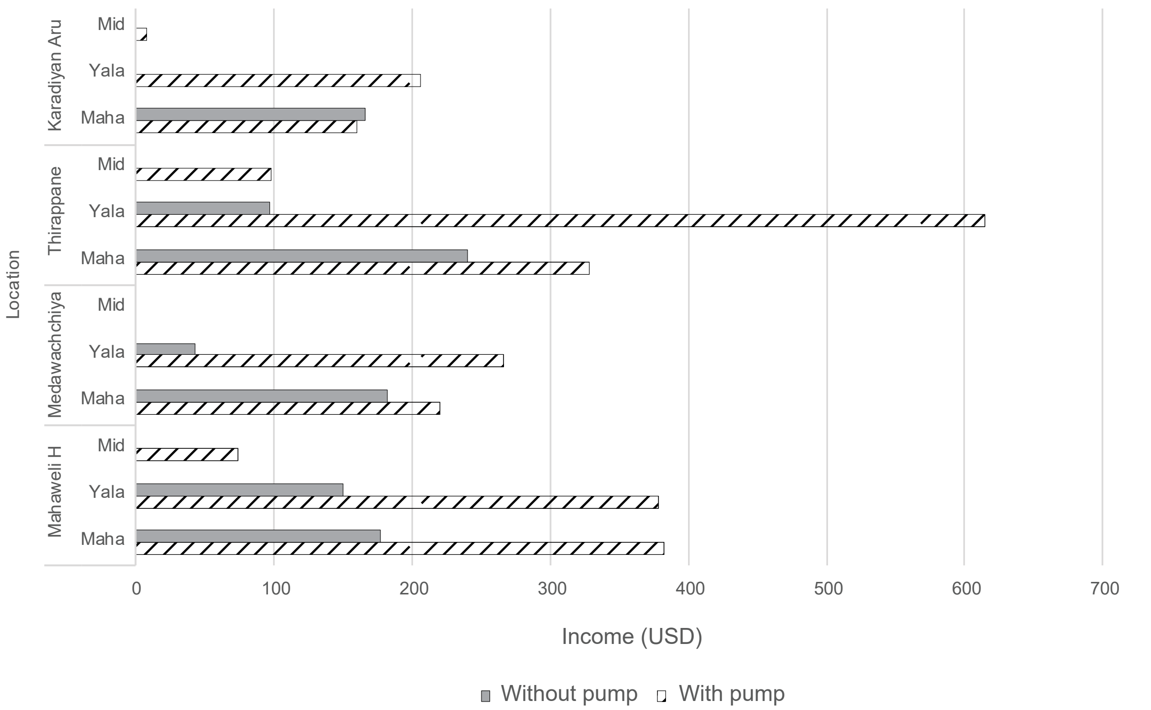
*Photo:* W. W. Premachandra (IWMI).

FIGURE 33. Extent of land area owned by farmers (with pumps: n=158; without pumps: n=40).




*Source:* Survey data, 2017.

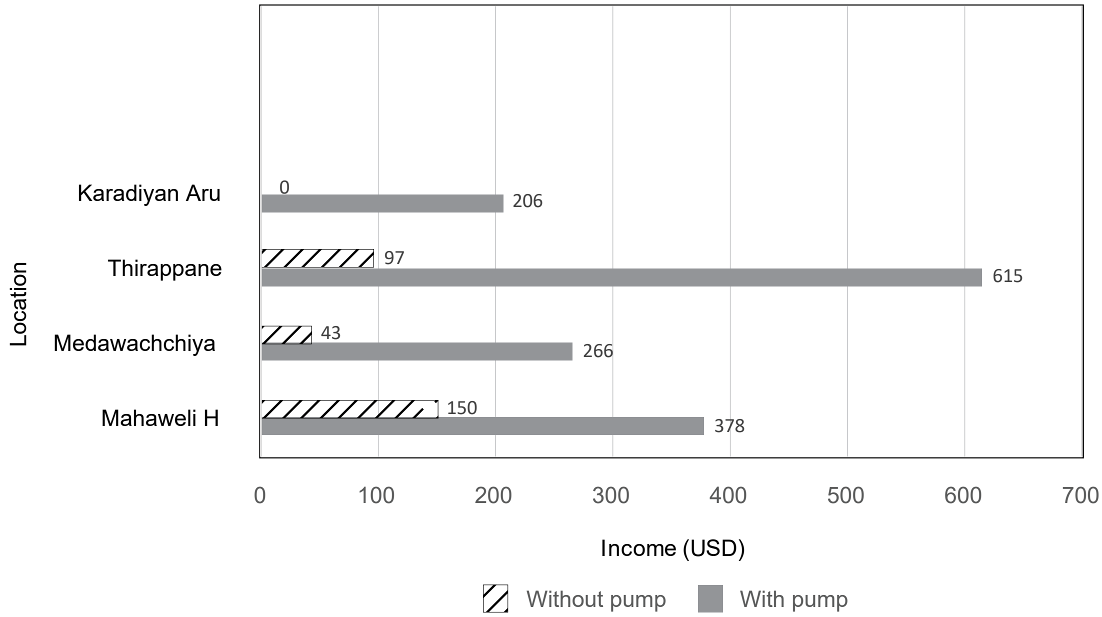
FIGURE 34. Mean seasonal gross agricultural income (with pumps: n=158; without pumps: n=40).




*Source:* Survey data, 2017.

Farmers that use a water pump are able to select *Yala* season crops based on market demand. Most farmers not using a pump do not cultivate any *Yala* season crops, or they cultivate rice or other low-risk crops taking into consideration water availability. Non-irrigated cultivation during the *Yala* season provides either no income or a minimum income, e.g., Karadiyan Aru and Medawachchiya (Figure 35). Pump-using farmers in the Thirappane area cultivate more land during the *Yala* season gaining a high income from high-value crops. Some farmers in the area earn up to LKR 600,000 (USD 3,975) during the *Yala* season by cultivating a few hectares of land. Some farmers in Karadiyan Aru temporarily migrate to a village adjacent to the Mundeni Aru River, Puttam Veli, and lease lands that they irrigate by lifting water from the river. Farmers without water pumps in Karadiyan Aru usually cultivate only in the wet season and tend to work as wage laborers during the dry season. Growing high-value crops has improved the income of farmers with pumps compared to non-users. Cultivation of high-value vegetables also provides improved cash flow with farmers able to market vegetables throughout the season without waiting over 3 months for the harvest of paddy rice.

FIGURE 35. Average dry-season agricultural income in 2017 (with pumps: n=158; without pumps: n=40).

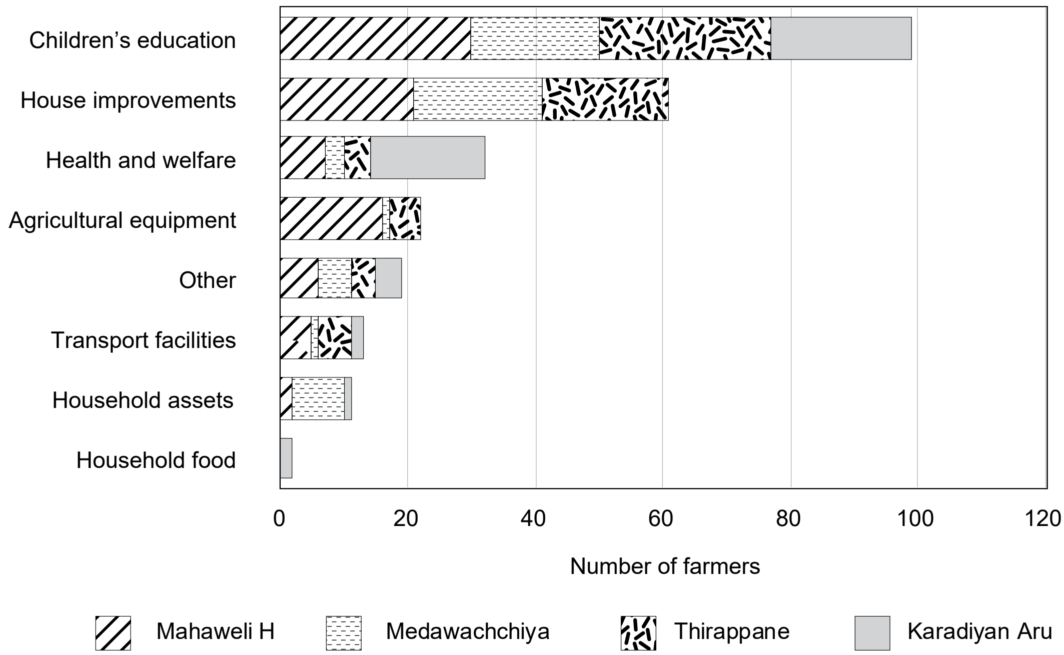



*Source:* Survey data, 2017.

*v. Asset creation and enhancement of family welfare*

The aspirations of farmers have changed as their livelihoods transformed from near subsistence to market engagement. Farmers primarily use their higher income to provide better education for their children, followed by improving their housing conditions, and providing better health and welfare (Figure 36).

FIGURE 36. Investment/expenditure patterns as a result of increased income (n=158).




*Source:* Survey data, 2017.

Table 2 summarizes the impacts of water pump use on asset creation. The table shows that water pump users have more of all types of assets than non-users, especially in terms of improved household transport facilities. Access to a vehicle – even a motorcycle – helps farmers to sell their products more easily in the surrounding local markets. In addition to the assets listed in Table 2, pump users own harvesting machines, agricultural equipment (e.g., sprayers, weeders and threshers) (Figure 37), and additional agro-wells and tube wells.

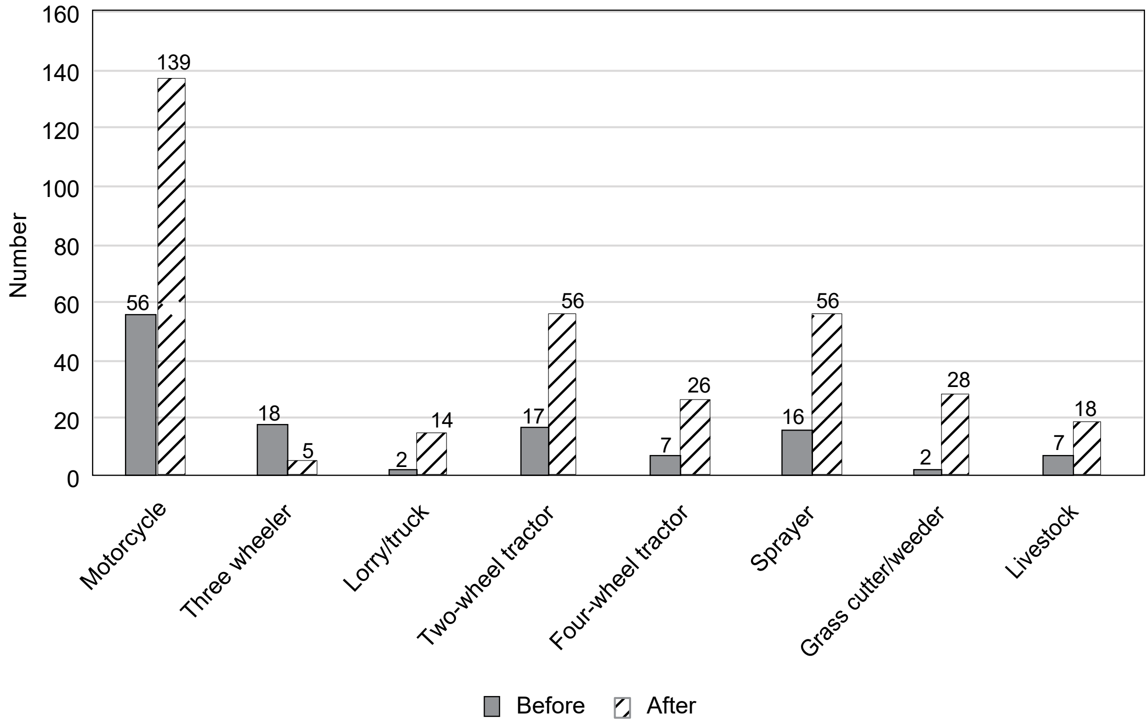
TABLE 2. Impact of access to water pumps on household assets.

| Type of assets available to households | Non-users (n=40) | Users (n=158) |
|---|---|---|
| Average total land area cultivated, including lands accessed through tenure arrangements | 3.42 (1.70) | 6.22 (2.94) |
| Households that own a two-wheel tractor (%) | 20.00 | 60.00 |
| Households that own a four-wheel tractor (%) | 10.00 | 42.50 |
| Households that own a truck/lorry (%) | 0.00 | 10.00 |
| Households that own a three-wheeler (tuk-tuk) (%) | 0.00 | 17.50 |
| Households that own a motorcycle (%) | 15.00 | 70.00 |

*Source:* Survey data, 2017.
*Note:* Values within parentheses indicate the standard deviation.

The ability to earn higher incomes, relatively quickly, from groundwater-based highland farming has motivated young men to undertake cultivation in order to purchase a motorcycle or three-wheeler (tuk-tuk) within a short period (6 months to 1 year). Figure 37 shows the increase in the number of assets owned by farmers in the study areas after using water pumps.

Figure 37. Asset ownership reported by farmers before and after the use of pumps (n=158).




*Source:* Survey data, 2017.

***vi. Empowerment of women***

The surveys indicate that the availability of water pumps in households has increased the participation of women in agricultural activities. Women in pump-using families have started to cultivate home gardens with irrigated, high-value crops. Discussion with women farmers and farmer leaders revealed that irrigated home gardens provide additional income and empowerment for women, enhancing their purchasing power and decision-making in the household. The extra income enables women to spend money on more nutritious food and to improve the well-being of their families, such as health costs and educational expenses. In addition, some women farmers purchase jewelry and household furniture, which can be sold in case of an emergency when there is a need for cash. A woman farmer purchased a sewing machine to earn extra income during the off-season.

Access to pump technology also affects the inter- and intra-household division of labor with an assured water supply enabling farmers to engage in high-input agriculture, which demands more labor per unit area (Table 3). Figure 38 summarizes the participation of women in irrigation in the selected areas. There is greater participation of women in irrigation-related activities in groundwater-dependent areas, with notably less female participation at Mahaweli System H where surface irrigation is dominant. Table 4 compares the average number of women involved in agricultural activities in households that use and do not use water pumps. Groundwater irrigation has generated income-earning opportunities for women farmers as noted above, but the research also suggests that it adds to their labor and time burden.

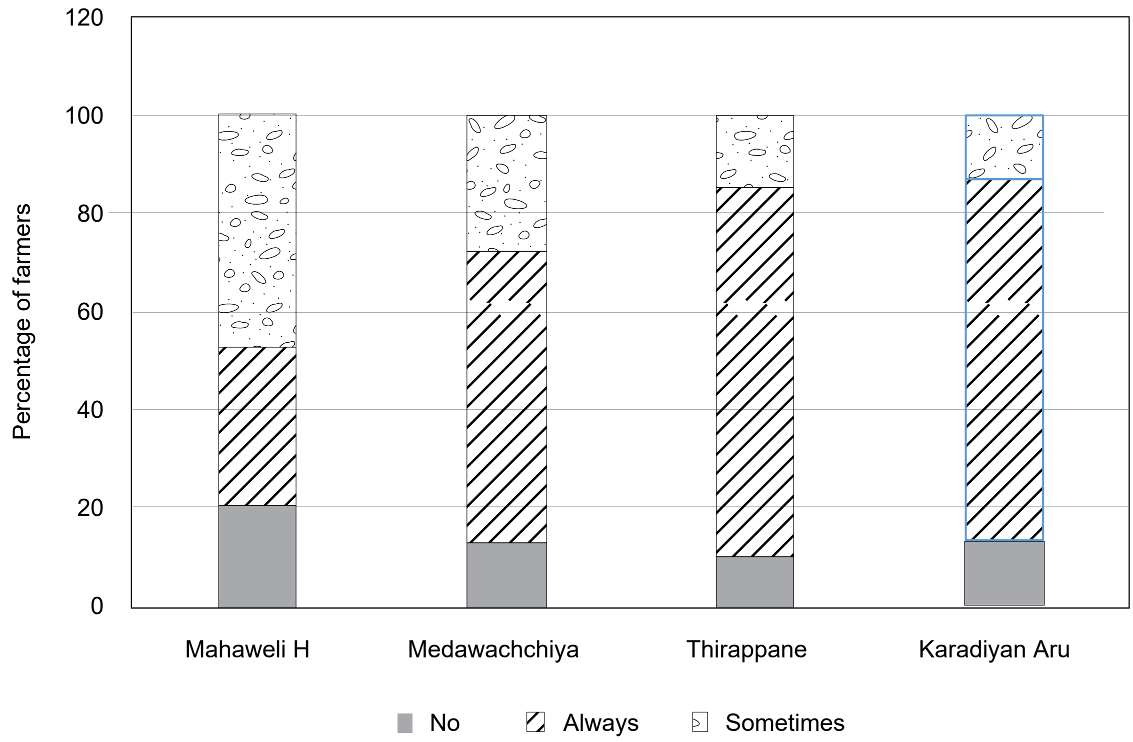
TABLE 3. Labor requirement in person-days according to farmers in the study areas (per acre of cultivation).

| Crop | Surface irrigation | | | Groundwater irrigation | | |
|---|---|---|---|---|---|---|
| | Male days | Female days | Total days | Male days | Female days | Total days |
| Paddy rice | 21 (52) | 6 (15) | 27 67) | 19 (47) | 8 (20) | 27 (67) |
| Soybean | 38 (94) | 16 (40) | 54 133) | 40 (99) | 24 (59) | 64 (158) |
| Onion | 84 (207) | 82 (203) | 166 (410) | 95 (235) | 90 (222) | 185 (457) |

*Note:* Values within parentheses provide the labor requirement per hectare.

*Source:* Survey data, 2017.

FIGURE 38. Participation of women in irrigation (n=198).




*Source: Survey data, 2017.*

TABLE 4. Involvement of women and men in cultivation (person equivalents).

| | Men | Women |
|---|---|---|
| With water pump (n=158) | 1.4 | 1.2 |
| Without water pump (n=40) | 1.4 | 0.9 |

*Source:* Survey data, 2017.

Using water pumps has a mixed impact on women in the study areas. The labor-intensive nature of non-paddy crop cultivation provides employment for rural, unskilled, landless workers, especially women. However, increasing farm size and intensified activities also mean more agricultural work for women – both paid and unpaid – which limits the time they have available for other activities.

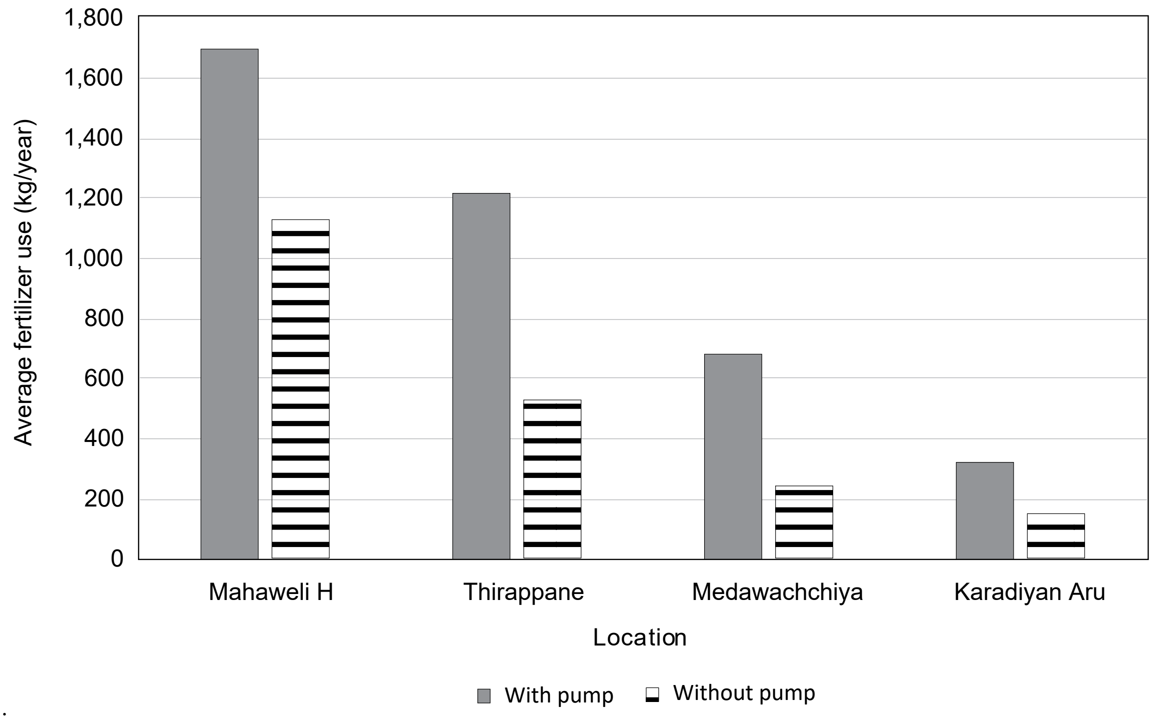
**Other Consequences of Water Pump Use**

***i. Use of fertilizers and agrochemicals in cultivation***

The intensified cultivation of cash crops involves the use of more fertilizer and other agrochemicals to achieve higher returns. Using chemical fertilizers and pesticides, potentially, has negative consequences for the environment, including pollution of shallow groundwater and surface water bodies. Figure 39 illustrates average fertilizer use by water pump users as compared to non-users in 2016/2017. Farmers in Mahaweli System H and Thirappane areas used the highest amount of fertilizer, reflecting the increase in the cultivation of vegetables than the other areas; in addition, some farmers cultivate an additional crop in the mid-season. Farmers in Karadiyan Aru use the least amount of fertilizer because they commonly cultivate groundnuts, which require less fertilizers and agrochemicals (Figure 40).

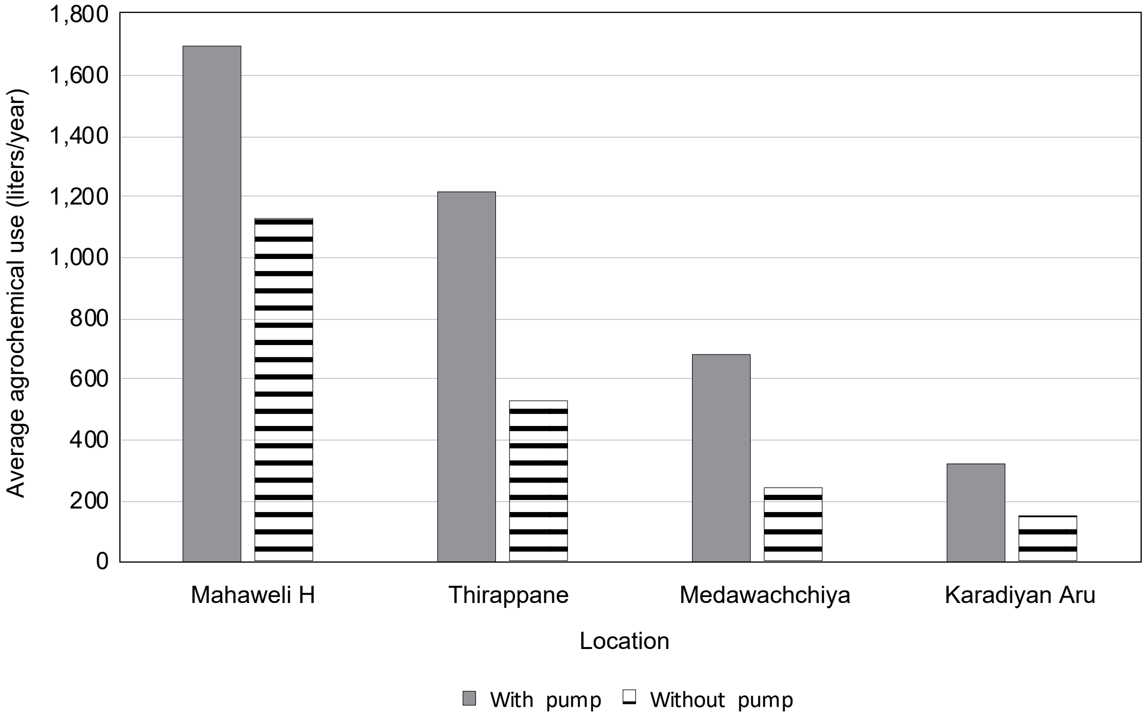
The level of input use (e.g., fertilizer and agrochemical use) varies between locations for other reasons. In some locations, data suggest insufficient input use, whereas in others, there is substantial use. Data from this study suggest that there is scope to improve input use in both high and low user locations to enhance production and profitability. However, additional information is needed to understand whether current fertilizer and agrochemical use is effective and optimal in these production systems, or whether it represents a risk to water sources and the health of humans and wildlife.

FIGURE 39. Average fertilizer use, 2016/2017 (with pumps: n=158; without pumps: n=40).




*Source:* Survey data, 2017

FIGURE 40. Average agrochemical use, 2016/2017 (with pumps: n=158; without pumps: n=40).




*Source:* Survey data, 2017.

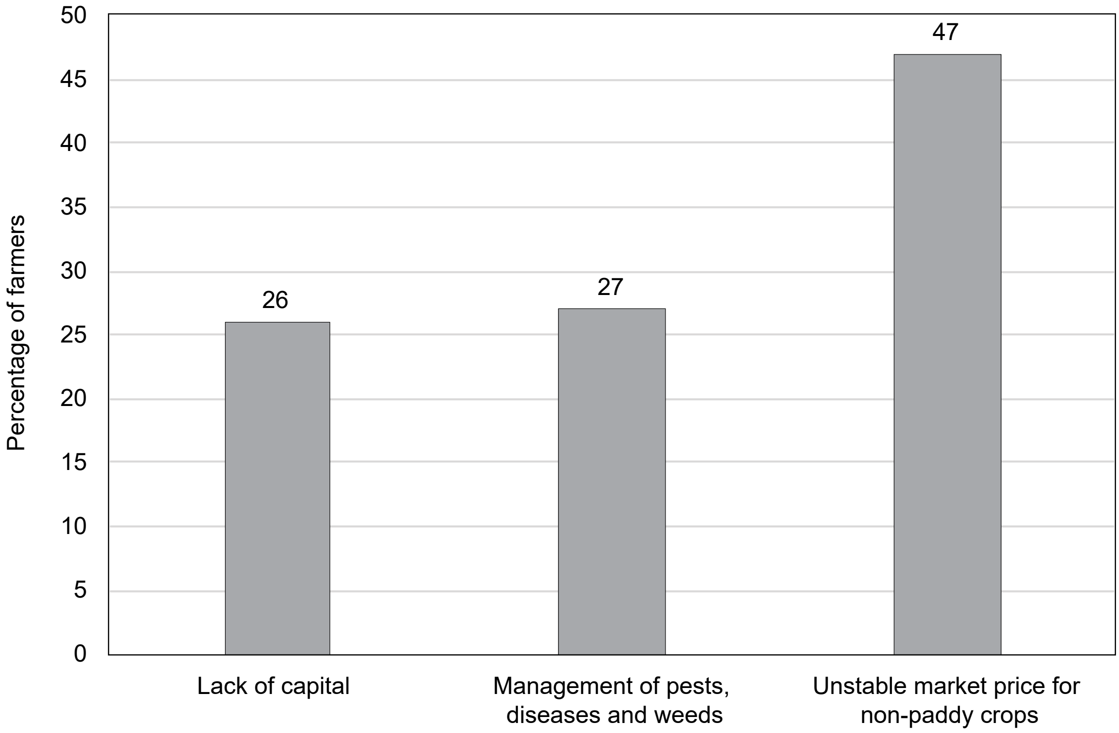
### *ii. Encroachment in reservations and forestlands*

The economic returns from high-value crop production motivate farmers to invest in expanded cultivation. However, a lack of available land appears to be a limiting factor. As a result, farmers have encroached on government-reserved forestland and have engaged in illegal highland cultivation in many areas, as reported in KIIs conducted in Thirappane and Karadiyan Aru. This encroachment has caused the loss of forest area, and has accelerated the siltation of small tanks downstream of the watershed due to intensified cultivation without proper conservation measures (De Silva et al. 2016). Traditionally, these forestlands were used for shifting cultivation (i.e., slash and burn), which allowed the natural forest vegetation to regenerate after the harvest and between periods of cultivation. However, agro-well development has stabilized cultivation across seasons and years, such that forest vegetation no longer has time to regrow. Government officials do not enforce encroachment laws because of the high poverty and vulnerability of people in these areas. In some places, granting of usufruct rights for encroached lands legalized cultivation but did not stretch to land sales or transfers. It is notable that there is evidence of an increasing threat of human and elephant conflict in Thirappane area due to the reduction of forest areas customarily inhabited by the wildlife.

Irrigation using a pump requires a range of complementary inputs and services, including extension support and facilitation of marketing by government agencies, private sector institutions, NGOs, and community and FOs. Such institutions can play an important role in supplying irrigation equipment, facilitating credit, linking farmers with the private sector and empowering FOs. The high costs of marketing and the normal risks such as pests, diseases and weather associated with farming are likely to limit the benefits of adopting new technologies.

During this study, farmers were asked about their major agricultural problems and challenges, excluding access to water. Respondents noted three major challenges (Figure 41). About 25% of farmers lack adequate capital to invest in cultivation. About 90% of the farmers without water pumps do not have enough money to invest in agro-wells. Smallholder farmers, in particular, are unlikely to invest their limited funds in new technologies, given the risks. This means that disadvantaged farmers are not really benefiting from agro-wells and water-lifting technologies. Unlike elsewhere in South Asia (India, Bangladesh and Nepal), there is no arrangement or practice of a well/pump rental system between farmers in Sri Lanka to extend the benefit to the non-well owners. Resource-poor farmers need assistance to access credit and other financing mechanisms that will allow them to purchase irrigation technologies. Extension services can also minimize the uncertainty of adopting a new technology through the provision of information and farm demonstration visits.

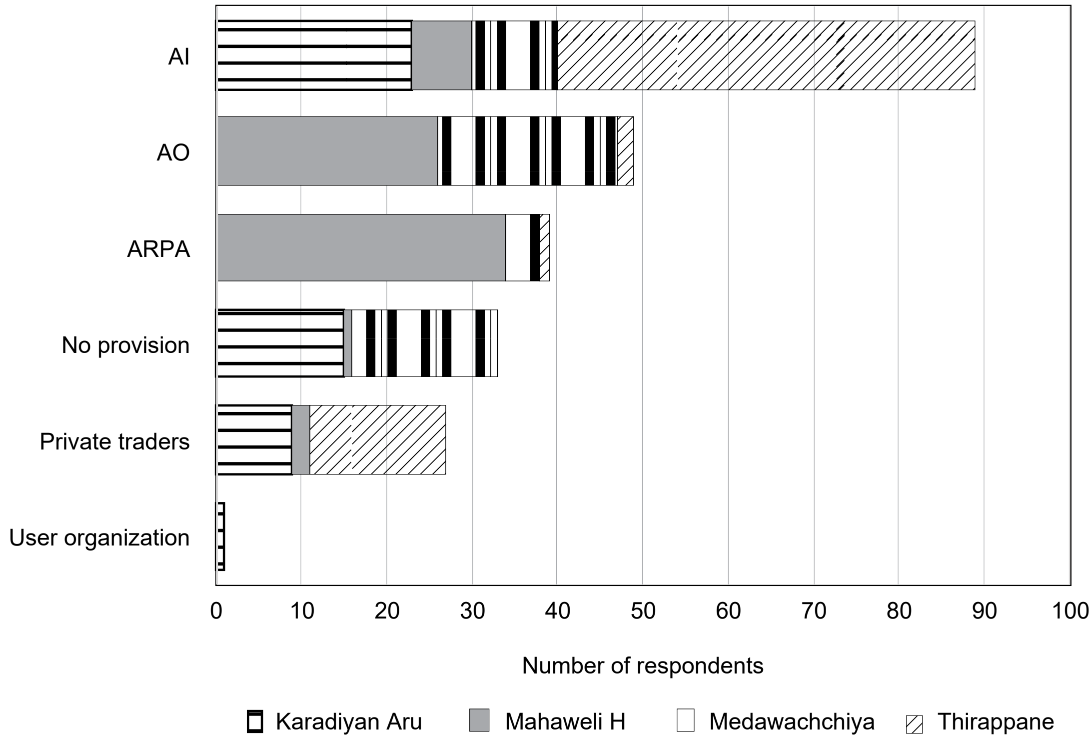
FIGURE 41. Major challenges in performing agricultural activities as perceived by farmers (n=198).




*Source:* Survey data, 2017.

The management of pests, diseases and weeds requires appropriate extension services. Figure 42 summarizes the sources of technical advice reported by farmers in the study areas. Agricultural instructors (AIs) and agricultural officers (AOs) are formally trained extension agents, while agricultural research and production assistants (ARPAs) are non-technical, field-level coordinators. Figure 42 reveals that a considerable number of farmers in the study areas do not receive formal extension support and must rely on informal channels, such as private traders and ARPAs, or do not receive any information services. Around 75% of farmers in Mahaweli System H and over 50% of farmers in Karadiyan Aru depend on informal sources for extension services and advice.

FIGURE 42. Major sources of technical advice in the case study areas (n=198).



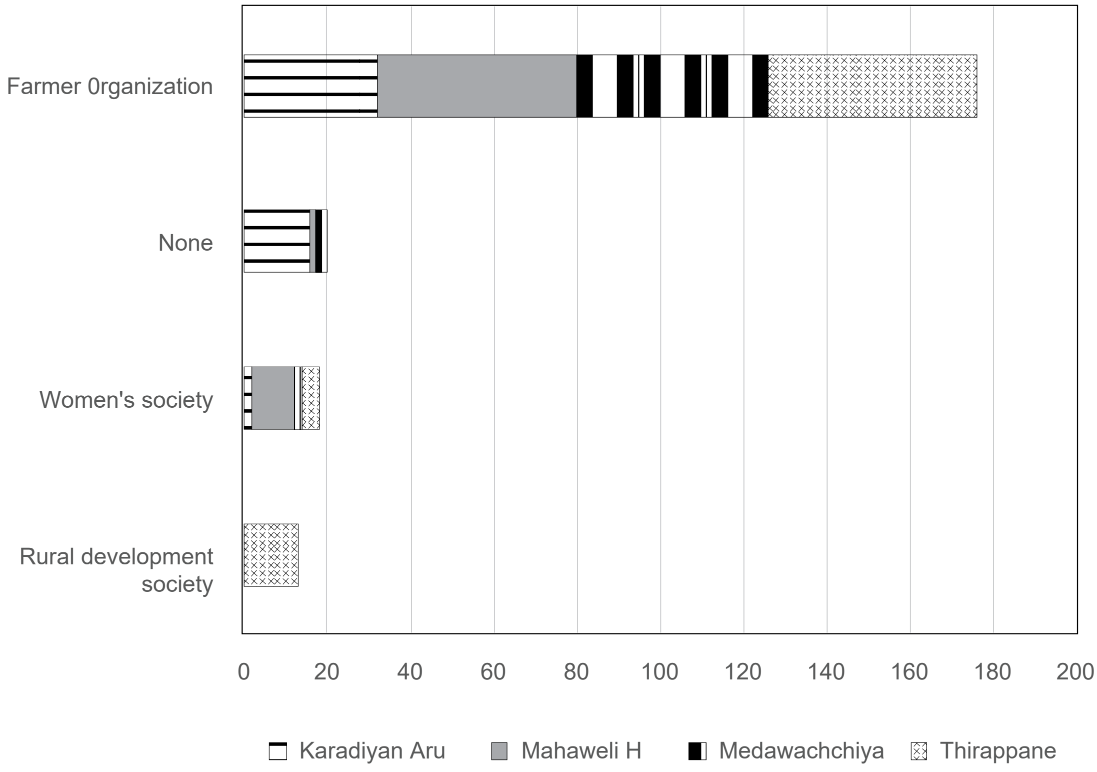

*Source:* Survey data, 2017.

*Notes:* AI = agricultural instructor; AO = agricultural officer; ARPA = agricultural research and production assistant.

The farmers cited the risk of low and fluctuating market prices for non-paddy crops as their most important concern. Most smallholders produce in small quantities; the absence of institutional arrangements for collective marketing or affordable transport restricts their ability to sell in local markets. The marketing channels for non-paddy crops are not well established. Additional market-related problems experienced by farmers include too many intermediaries and flooded markets.

Community-based organizations can help farmers to overcome the common problems discussed. Almost 90% of the farmers belong to FOs, which are not active in all study locations (Figure 43). A success story reported in Karadiyan Aru described a seed producers' society, formed by the farmers in an effort to create collective bargaining power over their popular groundnut crop, which has brought positive benefits to the community. The organization has established links with the private sector to market the produce both as raw and value-added products. Similarly, farmers in Mahaweli System H have signed agreements to sell maize and soybean to the private sector.

FIGURE 43. Farmer involvement in community-based organizations (n=198).




*Source:* Survey data, 2017.

## CONCLUSIONS

The study found that, between 2003 and 2015, the use of individually owned water pumps more than doubled (110% increase) in Sri Lanka. Water pump technology has enabled smallholders to grow high-value cash crops under intensive cultivation. Major drivers behind the adoption of water-lifting technologies included easy availability of affordable pumps, availability of spare parts and fuel in local markets, higher profit margins afforded by cash crop cultivation, government support for development of agro-wells and supply of micro-irrigation equipment, and extension support for the adoption of water pumps. Other major factors supporting adoption were water shortages and restricted availability of canal irrigation. Interventions by the government and NGOs in several rain-fed and irrigated areas demonstrated the benefits of the irrigation technology, which led other farmers to invest in pumps. In addition, individual control and flexibility in crop selection and water use decisions appear to be strong incentives for adoption of the pump technology.

Currently, the adoption of water-lifting technologies is predominantly by male farmers. Adopters tend to have a higher level of education than non-adopters. A lack of investment capital is the most frequently cited constraint to the adoption of water pumps, followed by challenges in accessing groundwater. The use of motor pumps has facilitated water lifting from surface water bodies, such as rivers and canals, for irrigation.

Despite the challenges, many farmers are using the technology without any measures for social cooperation and no governance arrangements for sharing common resources in the groundwater and the river systems, similar to other countries in South Asia. The spread of the technology has been, and continues to be, mostly spontaneous and unregulated, often without any or with limited external support, guidance and monitoring.

Better links between actors in agricultural value chains and farmer organizations to increase access to markets for non-paddy crops would drive a more inclusive adoption of water pumps. The government is required to play a dual role; on the one hand, the government should continue to provide incentives to promote the adoption of pump technology to access groundwater for agriculture. On the other hand, there is a need to establish a regulatory system to ensure sustainable operation of wells. This will include setting standards for well construction, and controlling extraction and pollution. Currently, the government is only playing the first role of promoting adoption and expanding the use of groundwater.

The areas selected for the study represent different methods of groundwater uses in the agriculture sector representing different regions and agro-ecological zones in Sri Lanka. All four sites have shifted production towards intensification of land, labor and water use relatively recently, with water-lifting technologies as a critical innovation.

The enhanced income from intensified, irrigated production improves farm livelihoods. In the study areas, pump users were able to improve their housing and living standards. Intensified production also created increased employment opportunities for landless farmers and women.

The use of water pumps presents a new set of problems related to the management of scarce water and common property resources. Currently, there is no reported threat to groundwater availability from shallow aquifers, which appear to recharge seasonally with monsoon rains and surface irrigation inflows. However, the study suggests that pump users utilize a higher amount of fertilizer and chemicals.

Institutional measures and governance arrangements to guide and regulate groundwater irrigation, especially in the context of intensive cultivation in shallow aquifers, remains a gap in agricultural development. This may lead to further marginalization of poor farmers, particularly where natural resources are degraded, water availability and quality is declining, and land for irrigated production contested.

## KEY MESSAGES AND RECOMMENDATIONS

1. Shallow groundwater irrigation with motorized water-lifting pump technology enables farmers to avoid the challenges of canal irrigation and seasonal production.
2. Farmers have increasingly intensified agriculture using water-lifting and agro-well technologies. Irrigated production helps to transform the livelihoods of smallholders and provides higher incomes.
3. Multiple drivers encourage farmers to adopt irrigation technologies, with limited external or public support. The farmers that invest in technologies tend to be more educated and have more assets than farmers who do not invest in pumps or agro-wells.
4. Increased and inclusive access to irrigation technologies requires supporting interventions. The Government of Sri Lanka may consider: (i) reducing import duties and taxes to make pumps more affordable; (ii) promoting financial products to enable credit for the purchase of pumps; (iii) facilitating improved linkages across value chains for better market access; and (iv) increasing support to farmer-based organizations. In addition, the government may consider new approaches to improve access to information on best practices related to crop irrigation

and the use of agricultural inputs. The government should provide advice on actions required to address the potential negative impacts of irrigation technologies on the environment, including water availability and quality.

5. The current lack of governance mechanisms to regulate groundwater use is a social and environmental risk. Social cooperation and institutional arrangements must be facilitated and supported to enable the sustainable distribution and management of common resources in both groundwater and river systems.

## REFERENCES


Abeyratne, F. 2017. *Small farm agriculture mechanization in Sri Lanka: Its growth and constraints*. Paper presented at the International Conference "South-South Knowledge Sharing on Agricultural Mechanization", Hilton Hotel, Addis Ababa, Ethiopia, October 31-November 1, 2017.

Aheeyar, M.M.M.; Bandara, M.A.C.S.; Padmajani, M.T. 2012. *Assessment of solar powered drip irrigation project implemented by Ministry of Agriculture - phase 1*. Colombo, Sri Lanka: Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI). 50p. (HARTI Research Report 148).

Aheeyar, M.; Manthrithilake, H.; Pathmarajah, S.; Makin, I.W. 2016. Groundwater development through sprinkler irrigation: Consequences of a lack of a governance structure in Kalpitiya, Sri Lanka. In: *Proceedings of the Symposium on Groundwater Availability and Use in the Dry Zone of Sri Lanka, Peradeniya, Sri Lanka, July 22, 2016*, (ed.) Pathmarajah, S. Peradeniya, Sri Lanka: Cap-Net Lanka; University of Peradeniya. Postgraduate Institute of Agriculture (PGIA). Pp. 115-127.

Bandara, M.A.C.S.; Padmajani, M.T. 2014. *Evaluation of solar powered drip irrigation project - Phase 2*. (project report of the Sustainable Agriculture Water Management done under the Ministry of Agriculture). Colombo, Sri Lanka: Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI). 52p. (Research Report 166).

Brauman, K.A.; Siebert, S.; Foley, J.A. 2013. Improvements in crop water productivity increase water sustainability and food security—a global analysis. *Environmental Research Letters* 8: 024030. http://dx.doi.org/10.1088/1748-9326/8/2/024030

de Fraiture, C.; Giordano, M. 2014. Small private irrigation: A thriving but overlooked sector. *Agricultural Water Management* 131: 167-174. https://doi.org/10.1016/j.agwat.2013.07.005

De Silva, S.; Curnow, J.; Ariyaratne, R. 2016. Resilience and prosperity through agro-well driven cultivation in the north central province, Sri Lanka: A case study on its evolution, structure and impacts. In: *Proceedings of the Symposium on Groundwater Availability and Use in the Dry Zone of Sri Lanka, Peradeniya, Sri Lanka, July 22, 2016*, (ed.) Pathmarajah, S. Peradeniya, Sri Lanka: Cap-Net Lanka; University of Peradeniya. Postgraduate Institute of Agriculture (PGIA). Pp. 33-49.

Dessalegn, M.; Merrey, D.J. 2015. Motor pump revolution in Ethiopia: Promises at a crossroads. *Water Alternatives* 8(2): 237-257. http://www.water-alternatives.org/index.php/alldoc/articles/vol8/v8issue2/289-a8-2-12/file

Eriyagama, N.; Smakhtin, V.; Chandrapala, L.; Fernando, K. 2010. *Impacts of climate change on water resources and agriculture in Sri Lanka: A review and preliminary vulnerability mapping*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 43p. (IWMI Research Report 135). Available at http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB135/RR135.pdf (accessed on February 18, 2019).

Government of Sri Lanka. 2017. Vision 2025 - vision roadmap. Available at https://www.news.lk/images/pdf/2017/sep/Vision_2025_English.pdf (accessed in April 2018).

Karunaratne, A.D.M.; Pathmarajah, S. 2002. Groundwater development through introduction of agro-wells and micro-irrigation in Sri Lanka. In: *Proceedings of Symposium on the Use of Groundwater for Agriculture in Sri Lanka, September 30, 2002*, (ed.) Pathmarajah, S. Peradeniya, Sri Lanka: Agricultural Engineering Society of Sri Lanka (AESSL); University of Peradeniya. Faculty of Agriculture. Department of Agricultural Engineering. Pp. 29-41.

Kikuchi, M.; Weligamage, P.; Barker, R.; Samad, M.; Kono, H.; Somaratne, H.M. 2003. *Agro-well and pump diffusion in the dry zone of Sri Lanka: Past trends, present status and future prospects*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 53p. (IWMI Research Report 66). Available at http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub066/Report66.pdf (accessed on February 18, 2019).

Madduma Bandara, C.M. 1985. Catchment ecosystems and village tank cascades in the Dry Zone of Sri Lanka: A time-tested system of land and water resource management. In: *Strategies for river basin management: Environmental integration of land and water in a river basin*, (eds.) Lundqvist, J.; Lohm, U.; Falkenmark, M. Dordrecht, Holland: D. Reidel Publishing Company. Pp. 099-113.

Ministry of Agriculture. n.d. *National agricultural policy*. Colombo, Sri Lanka: Ministry of Agriculture, Government of Sri Lanka. Available at http://www.agrimin.gov.lk/web/images/docs/1277294350E%20NATIONAL%20AGRICULTURAL%20POLICY.pdf (accessed in April 2018).

Pathirana, P.H.S.; Bandara, P.C.; Ratnaweera, A.C.; Balasooriya, C.P.; Bandara, M.A. 2010. Sustainable farming through mechanization: Development of a bund making machine. In: *Proceedings of the International Conference on Sustainable Built Environment (ICSBE-2010), Kandy, Sri Lanka, December 13-14, 2010*. Pp. 461-467.

Punyawardena, B.V.R. 2011. *Country report: Sri Lanka*. Presented at the Workshop on Climate Change and its Impact on Agriculture, Seoul, Republic of Korea, December 13-16, 2011.

Shah, T.; Verma, S.; Pavelic, P. 2013. Understanding smallholder irrigation in Sub-Saharan Africa: Results of a sample survey from nine countries. *Water International* 38(6): 809-826. https://doi.org/10.1080/02508060.2013.843843

Sunday Times. 2017. *Unprecedented crop failures, extreme weather destroy rice harvest*. Online version of Sunday Times, October 8, 2017. Available at http://www.sundaytimes.lk/171008/news/unprecedented-crop-failures-extreme-weather-destroy-rice-harvest-262974.html (accessed in April 2018)

Zainudeen, M.Y. 2007. Water resources development / management for agriculture in Sri Lanka; Past and future. *Engineer* XXXX(01): 07-16.

## ANNEX 1. HOUSEHOLD SURVEY ON THE USE OF TECHNOLOGICAL INNOVATIONS IN WATER MANAGEMENT IN SRI LANKA

We are from the International Water Management Institute (IWMI) in Colombo, Sri Lanka, and have come here to conduct a study on the 'use of water management technologies'. We would like to talk to you and gather information on agricultural development. The survey takes approximately 30 to 45 minutes to complete. If you agree to participate, the information you provide is for research purposes only. Your answers will not affect any benefits or subsidies you may receive now or in the future. Your responses to these questions will be anonymous and remain strictly confidential. Your name will not appear in any data that are made publicly available. However, we would like to write down your phone number in case some issues in the questionnaire are unclear and we need to follow up with you for more information or clarification. Do you consent to provide information for this study? You may withdraw from the survey at any time. If there are questions that you would prefer not to answer then we respect your decision not to answer them. Has consent been given for the respondent? (1 = Yes, 2 = No)

1. Name of the enumerator: ……………………………………
2. Date of interview: ………………..
3. Georeference of the location: ……………………………

*Notes for enumerator:*

- *If the person is not willing to participate, please go to the next household.*
- *Circle codes corresponding to the correct answers.*

**1. Basic information of the respondent farmer**

1.1 Name of the informant:
1.2 Address:
1.3 Telephone number:
1.4 Study location: 1. Medawachchiya 2. Mahaweli System H 3. Thirappane 4. Karadiyan Aru
1.5 Village: 1.6 Grama Niladhari Division:
1.7 Agrarian Development Centre Division: 1.8 Name of the farmer organization:
1.9 Availability of following;
1. Agro-well 2. Tube well 3. Motor pump 4. Micro-irrigation 5. Not available

**2. Socioeconomic information of the respondent farmer**

2.1 Type of the respondent: 1. Household head 2. Household member
2.2 Status of the informant: 1. General farmer 2. Farmer leader/representative
2.3 Type of farmer 1. Full-time farmer 2. Part-time farmer
2.4 If you are a part-time farmer, what is the primary source of income?
1. Government employment 2. Private sector employment 3. Skilled job 4. Self-employment 5. Remittance 6. Wage labor 7. Other ……
2.5 Gender: 1. Male 2. Female
2.6 Level of education: 1. No schooling 2. 1-5 years 3. 6-10 years 4. GCE (Ordinary Level) 5. GCE (Advanced Level) 6. Higher education
2.7 Age (years)………….

**3. Household information**

3.1 Household head 1. Husband/male 2. Wife/female
3.2 If the household head is female, what is the reason?
1. Unmarried 2. Widow/separated 3. Husband is weak/disabled/sick 4. Other
3.3 Number of household members: 1. Male: ………. 2. Female …………
3.4 Number of family members involved in farming: 1. Male ……….. 2. Female …………

**4. Land ownership information, 2016/2017 (lands within the study area only)**

| **Land type** | **Owned land (acres)** | **Tenancy/share cropping (acres)** | **Leased in/mortgaged in (acres)** | **Other (encroached, etc.) (acres)** | **Total (acres)** |
|---|---|---|---|---|---|
| Lowland (paddy land) | | | | | |
| Highland | | | | | |
| Homestead | | | | | |
| *Chena*/shifting cultivation | | | | | |
| Other | | | | | |
| **Total (acres)** | | | | | |

**5. Current land use information, 2016/2017 (total including owned land, encroached and land under different tenure categories)**

| **Land utilization** | **Land ownership (code 1)** | **Land user (code 1A)** | **Extent cultivated (acres)** | **Area cultivated (%)** | | | **Type of crop (code 2)** | | | **Source of water (code 3)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Maha* | *Yala* | Mid | *Maha* | *Yala* | Mid | *Maha* | *Yala* | Mid |
| Home garden | | | | | | | | | | | | |
| Lowland | | | | | | | | | | | | |
| Upland | | | | | | | | | | | | |
| *Chena land* | | | | | | | | | | | | |

**<u>Code 1</u>**

1. Male 2. Female 3. Joint ownership

**<u>Code 1A</u>**

1. Husband 2. Wife 3. Son 4. Daughter 5. Other

**<u>Code 2</u>**

1. Paddy 2. Vegetables 3. Maize 4. Chilli 5. Onion 6. Other field crops 7. Other cereals 8. Biannual crops 9. Tuber crops. 10. Perennials 11. Others

**<u>Code 3</u>**

1. Irrigation reservoir/tank 2. River/canal 3. Agro-well 4. Tube well 5. Rain-fed 6. Other

**6. Irrigation problems experienced during the 2016 *Yala* season**

| Crop | Cultivation phase | | |
|---|---|---|---|
| | **Land preparation (code 4)** | **Crop growth (code 4)** | **Crop maturity/harvesting (code 4)** |
| Paddy | | | |
| Vegetables | | | |
| Maize | | | |
| Chilli | | | |
| Onion | | | |
| Other field crops | | | |
| Other cereals | | | |
| biennials | | | |
| Tuber crops | | | |
| Perennial crops | | | |
| Other | | | |

**Code 4**

1. Inadequate water 2. Untimely issues 3. Unreliable irrigation supply 4. No water problems 5. No water problems arose due to the use of groundwater

6.1 Other associated agronomic challenges in your cultivation

1. Lack of seeds/planting materials 2. Fertilizer unavailability 3. Pest and disease control 4. Weed infestation 5. Marketing of products 6. Lack of credit facility 7. Other

**7. Do you currently have functioning agro-well/s or tube wells?**
1. Yes **(If yes, please go to question 8)** 2. No

7.1 If not, why?
1. Lack of capital 2. Groundwater is not available at an accessible distance 3. Labor scarcity 4. Problems in marketing non-paddy crops 5. High risk involved in non-paddy crop cultivation 6. Other **(If not, please go to question 12)**

**8. If yes, details of the current functioning wells, and those being constructed and utilized**
1. Agro-well 2. Tube well

| | **Details** | **Well 1** | **Well 2** | **Well 3** |
|---|---|---|---|---|
| 8.1 | Type of well (1. Agro-well 2. Tube well) | | | |
| 8.2 | Year of construction | | | |
| 8.3 | Subsidies received (1. Yes 2. No) | | | |
| 8.4 | Source of subsidy, if any (1. Government 2. NGO 3. Donor projects 4. Other) | | | |
| 8.5 | Cost of construction (LKR) | | | |
| 8.6 | Well dimension at the time of construction - from ground to bottom (m) and diameter (m) | | | |
| 8.7 | Depth of well now - from ground to bottom (m) and diameter (m) | | | |
| 8.8 | Is the well lined? (1. Yes 2. No) | | | |
| 8.9 | Is your well dry in some parts of the year (1. Yes 2. No) | | | |
| 8.10 | Average extent cultivated in last 3 years - *Maha* (acres) | | | |
| 8.11 | Average extent cultivated in last 3 years – *Yala* (ha) | | | |

| | Details | Well 1 | Well 2 | Well 3 |
|---|---|---|---|---|
| 8.12 | Average extent cultivated in last 3 years - Mid-season (acres) | | | |
| 8.13 | Depth to water level in *Maha* (from ground to water surface [m]) | | | |
| 8.14 | Depth to water level in *Yala* (from ground to water surface [m]) | | | |
| 8.15 | Water level drop when pumping water (dynamic head) in *Maha* (m) | | | |
| 8.16 | Water level drop when pumping water (dynamic head) in *Yala* (m) | | | |
| 8.17 | Average time taken to recuperate to original water level in *Maha* (hours) | | | |
| 8.18 | Average time taken to recuperate to original water level in *Yala* (hours) | | | |
| 8.19 | Adequacy of water in the well (**code 5**) | | | |
| 8.20 | Water salinity (**code 6**) | | | |
| 8.21 | Other water quality issues (1. Taste 2. Turbidity 3. Color 4. Odor 5. Other | | | |
| 8.22 | Use of well water for other purposes (1. Drinking 2. Livestock 3. Domestic needs 5. Other) | | | |

**Code 5**: 1. Adequate for continuous pumping throughout the year 2. Adequate only in some parts of the year 3. Inadequate for continuous pumping throughout the year 4. Need to pump several times to complete irrigation of the cultivated land block 5. Other

**Code 6**: 1. No salinity observed 2. Seasonal salinity observed 3. Salinity during pumping observed 4. Other

**9. How do you decide the duration of pumping for a given crop?**

1. Pre-determined duration
2. By experience
3. Observing soil wetness
4. Quantity of water applied
5. Other

**10. Issues experienced in relation to agro-well/tube well utilization**

1. Increasing number of wells
2. Falling water levels
3. Decreasing water quality
4. Slow recharge
5. Increasing well dimensions/deepening
6. No issues
7. Other

**11. If the groundwater irrigation helped to increase the household income, how the increased income benefitted the household?**

1. Improve the quality/nutritious value of food
2. Improve the housing conditions
3. Increase the household assets/consumer durables
4. Increase the expenditure on children’s education
5. Increase the expenditure on health care and well-being
6. Purchasing agricultural machinery
7. Improved transportation facilities
8. Hiring of labor for agriculture
9. Reduced indebtedness
10. Other

**Water pump**

**12. Do you use a motor pump for lifting water?**

1. Yes (**If yes, please go to question 13**) 2. No

12.1 If not, why?

1. Lack of capital 2. Absence of suitable water source 3. Lack of knowhow 4. Labor scarcity 5. Other

12.2 If not, what technology was used to lift/transport and spread the water

1. Hand pump 2. Manual lifting 3. Siphoning 4. Use of tractor 5. Other

(**Please go to question 24**)

**13. If yes, year of first use …….**

**14. Availability of pumps in working condition and their characteristics (please check the pump datasheet)**

| | **Details** | **Pump 1** | **Pump 2** | **Pump 3** |
|---|---|---|---|---|
| 14.1 | Motor power (kW or hp) | | | |
| 14.2 | Pump size (1. One inch [1”] 2. Two inch [2”] 3. Three inch [3”] 4. Other) | | | |
| 14.3 | Source of energy (1. Diesel 2. Petrol 3. Kerosene 4. Electricity 5. Solar) | | | |
| 14.4 | Year of purchase | | | |
| 14.5 | Price of the pump (LKR) | | | |
| 14.6 | Source of funds (1. Own 2. Loan 3. NGO 4. Government subsidy 5. Other.......................) | | | |
| 14.7 | Country of origin (1. Locally assembled 2. China 3. India 4. Japan 5. Europe 6. Other) | | | |
| 14.8 | Flow rate ($m^3$/hour) | | | |
| 14.9 | Average use per week (hours) | | | |

**15. Factors influenced in the choice of pump**

1. Price 2. Quality 3. Brand name 4. Credit facility/installment payment 5. Country
6. Spare parts availability 7. After-sales service 8. Durability 9. Other…………..

**16. How many pumps you have replaced for agricultural purposes during the last 5 years?.......**

**17. If you are having multiple pumps, reason/s? ………………**

1. Use as backup pump 2. Staggered land parcels 3. Having multiple wells
4. Irrigated land area is bigger to limit to a single pump 5. Other …………

**18. Cost of pumping**

18.1 Frequency of irrigation/pumping

1. Twice a day 2. Once a day 3. Every other day 4. Once in three days
5. Once in four days 6. Once in 5 days 7. Other

18.2 Number of labor hours needed per irrigation rotation/acre ………………….

18.3 Did you use female labor for irrigation? 1. No 2. Always 3. Occasionally

18.4 Cost of labor for irrigation/day 1. Male ............................ 2. Female .............................

18.5 Cost of maintenance of water pump/year LKR ……….

18.6 Cost of maintenance of irrigation system/year LKR ……….

18.7 Cost of fuel/energy (LKR/year) ………….

**19. Availability of water storage tank at the site? 1. Yes 2. No**

19.1 If yes, what is the capacity? ______ Liters

19.2 If yes, type of tank 1. Plastic/Polyethylene (PE) 2. Cement tank 3. Other

**20. What are the benefits experienced due to the use of motor pumps for lift irrigation?**

1. Increase in the extent of cultivation in *Maha*
2. Increase in the extent of cultivation in *Yala*
3. Increase in the extent of cultivation in mid-season
4. Increase in the number of seasons per year
5. Reduced crop failures
6. Increased income
7. Reduced water conflicts
8. Increased reliability of water
9. Reduced external dependency for water
10. Other

**21. When having/obtaining motor pump: did you change the crops to cultivate/irrigate?**
1. Yes 2. No

21.1 If yes, what were the crops you changed?

21.2 *Maha*…………………….to……………..

21.3 *Yala*…………………….to………………

21.4 Mid-season……………to…………………

**22. CROP PRODUCTION using motor pumps – Season 1, 2016/2017 (*Maha* season)**

| | Three main crops (*based on acreage*) | Area (acres) | Quantity of chemicals/acre | | Irrigation method (code 5) | Total yield (kg/acre) | Unit price (LKR) | Income (LKR/acre) |
|---|---|---|---|---|---|---|---|---|
| | | | Fertilizer (kg) | Agro-chemicals (liters) | | | | |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| | Total | | | | | | | |

**Code 5**: 1. Furrow 2. Flood 3. Drag hose 4. Sprinkler 5. Drip 6. Manual 7. Other

**23. CROP PRODUCTION using motor pumps – Season 2, 2016 (last *Yala* season)**

| | Three main crops (*based on acreage*) | Area (acres) | Quantity of chemicals/acre | | Irrigation method (code 5) | Total yield (kg/acre) | Unit price (LKR) | Income (LKR/acre) |
|---|---|---|---|---|---|---|---|---|
| | | | Fertilizer (kg) | Agro-chemicals (liters) | | | | |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| | Total | | | | | | | |

**Code 5**: 1. Furrow 2. Flood 3. Drag hose 4. Sprinkler 5. Drip 6. Manual 7. Other

**24. CROP PRODUCTION – Season 3, 2016 (last mid-season)**

| | Three main crops (*based on acreage*) | Area (acres) | Quantity of chemicals/acre | | Irrigation method (code 5) | Total yield (kg/acre) | Unit price (LKR) | Income (LKR/acre) |
|---|---|---|---|---|---|---|---|---|
| | | | Fertilizer (kg) | Agro-chemicals (liters) | | | | |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| | Total | | | | | | | |

**Code 5**: 1. Furrow 2. Flood 3. Drag hose 4. Sprinkler 5. Drip 6. Manual 7. Other

**25. Issues experienced in relation to motor pump utilization**

1. Increasing number of wells 2. Reducing water levels/quick drawdown
3. Decreasing water quality 4. Slow recharge
5. Collapse of well/well deepening 6. Increasing cropping intensity
7. No issues 8. Other

**26. If water quality has reduced (answer 3 for question 25) what is/are the reason/s?**

1. Heavy use of fertilizer 2. Heavy use of agrochemicals 3. Saltwater intrusion
4. Muddy water due to over-pumping 5. Other

**27. Use of micro-irrigation (MI) 1. Yes 2. No** (if you are not using MI, **please go to question 28**)

27.1 Total extent under MI ……….

27.2 What was the irrigation method used before the adoption of MI

1. Manual 2. Drag hose 3. Drag hose and furrows 4. Furrows 5. Rain-fed 6. Other

27.3 When did you switch to MI (year) …….

27.4 Reason/s for the switch?

1. Scarcity of water 2. High labor cost 3. Scarcity of labor 4. High energy cost 5. Subsidy 6. Other

27.5 Cost of the system (LKR/acre) .........

27.6 Source of funds

1. Own 2. Loan 3. Subsidy 4. NGO 5. Other

27.7 Reduction of labor per unit of land due to MI

1. No reduction 2. One-fourth 3. Half 4. Three-fourths 5. Other

27.8 If labor requirement was reduced, who had mostly benefitted at household level?

1. Men 2. Women 3. Children

27. 9 Reduction in water use

1. No reduction 2. One-fourth 3. Half 4. Three-fourths 5. Other

27.10 Reduction in the cost of pumping

1. No reduction 2. One-fourth 3. Half 4. Three-fourths 5. Other

27.11 Did you change the amount of fertilizer applied?

1. No 2. Reduced 3. Increased

27.12 Did you change the cropping system

1. Yes 2. No

27.13 Did you expand the cultivation area due to reduction in water/labor requirement?

1. Yes 2. No

**28. Household income sources**

| | **Income source** | **Year 2014/2015** | | | | | | | | | | | | **Annual income (LKR)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Maha* | | | | Mid-season | | | | *Yala* | | | | |
| 1. | Crop cultivation-surface irrigation | | | | | | | | | | | | | |
| 2. | Crop cultivation-lift irrigation | | | | | | | | | | | | | |
| 3. | Crop cultivation-Rain-fed | | | | | | | | | | | | | |
| 4. | Home garden and perennial | | | | | | | | | | | | | |
| 5. | *Chena* / other | | | | | | | | | | | | | |
| 6. | Livestock | | | | | | | | | | | | | |
| 7. | Fishery | | | | | | | | | | | | | |
| 8. | Monthly salary earning jobs | | | | | | | | | | | | | |
| 9. | Daily wage jobs | | | | | | | | | | | | | |
| 10. | Skilled job (masons, carpenter, etc.) | | | | | | | | | | | | | |
| 11. | Self-employment | | | | | | | | | | | | | |
| 12. | Foreign remittances | | | | | | | | | | | | | |
| 13. | Rental income (machinery, house, etc.) | | | | | | | | | | | | | |
| 14. | Pensions | | | | | | | | | | | | | |
| 15. | Government subsidies | | | | | | | | | | | | | |
| 16. | Total | | | | | | | | | | | | | |

**29. Ownership to household/agricultural assets**

| | Asset | Yes/No (1/2) | No. | Year of purchase | Owner (code 6) | User (code 6) |
|---|---|---|---|---|---|---|
| 1 | Two-wheel tractors | | | | | |
| 2 | Four-wheel tractors | | | | | |
| 3 | Weed cutters | | | | | |
| 4 | Threshers | | | | | |
| 5 | Sprayers | | | | | |
| 6 | Combined harvesters | | | | | |
| 7 | Truck/lorry | | | | | |
| 8 | Three wheelers | | | | | |
| 9 | Motorcycles | | | | | |
| 10 | Livestock (1. Cattle 2. Goat 3. Poultry 4. Other) | | | | | |
| 11 | Other | | | | | |

**Code 6:** 1. Men 2. Women 3. Both

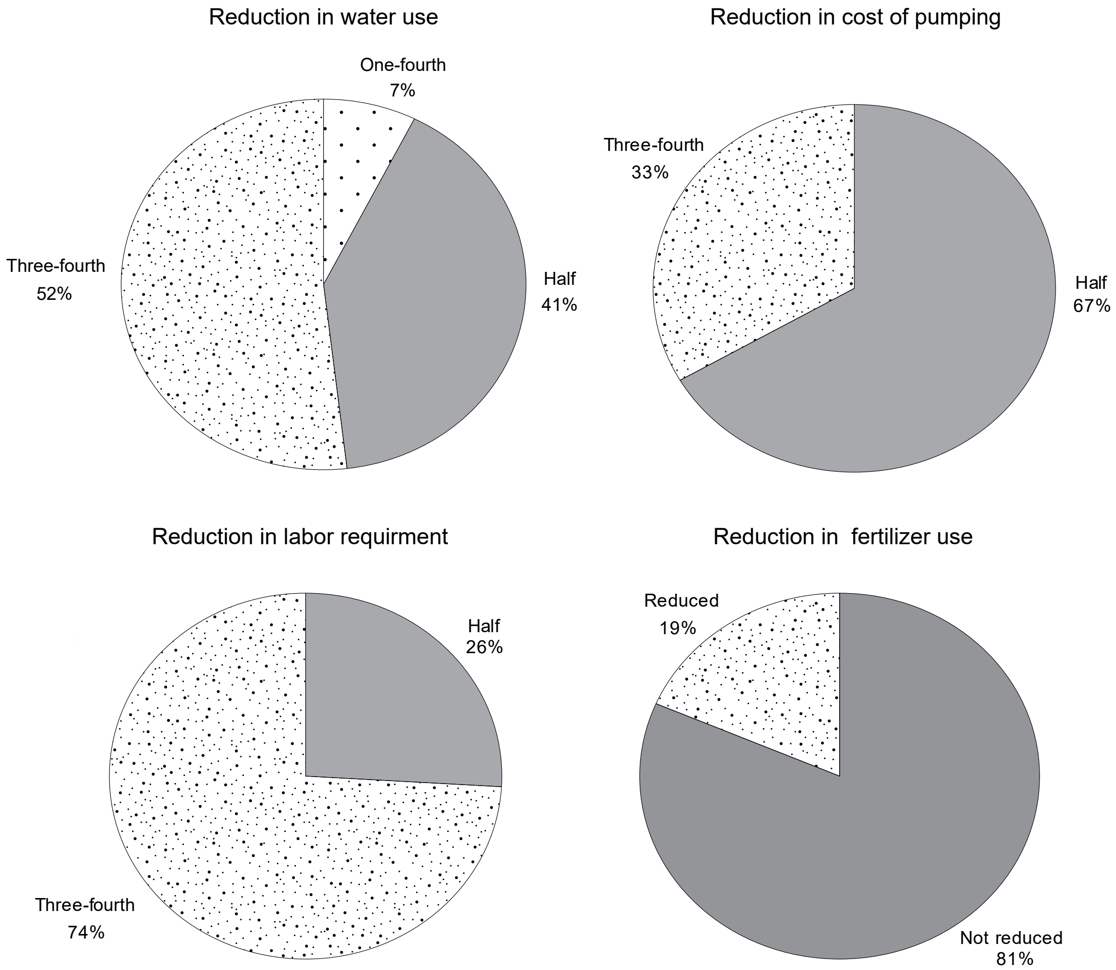
**30. Do you or your household members have membership in a community-based organization in the village?**

1. None 2. Farmer organization 3. Rural development society 4. Women's society 5. Sellers' organization 6. Other

**31. How do you receive extension support/technical advice for your cultivation?**

1. Agricultural Instructors (AIs) 2. Agricultural Officers (AOs) 3. Agricultural Research and Production Assistants (ARPAs) 4. Private traders 5. User organization 6. Private network 7. No such service

## ANNEX 2. BENEFITS REALIZED WITH THE USE OF MICRO-IRRIGATION (AS A PERCENTAGE OF USERS)



## *IWMI Working Papers*

188 *Mechanizing Water Lifting through Pumps: A Case Study in Sri Lanka*. Mohamed Aheeyar, Herath Manthrithilake, Chathuranga Ranasinghe, Manooj Rengaraj, Yasas Gamagedara and Jennie Barron. 2019.

187 *From the Mountains to the Plains: Impact of Climate Change on Water Resources in the Koshi River Basin.* Luna Bharati, Utsav Bhattarai, Ambika Khadka, Pabitra Gurung, Luis E. Neumann, David J. Penton, Sanita Dhaubanjar and Santosh Nepal. 2019.

186 *Unpacking the Water-Energy-Environment-Food Nexus: Working Across Systems*. Aditya Sood, Alan Nicol and Indika Arulingam. 2019.

185 *Improving the Availability and Effectiveness of Rural and "Micro" Finance for Small-scale Irrigation in Sub-Saharan Africa: A Review of Lessons Learned.* Douglas J. Merrey and Nicole Lefore. 2018.

184 *Gender Dimensions of Community-based Groundwater Governance in Ethiopia: Using Citizen Science as an Entry Point*. Likimyelesh Nigussie, Jennie Barron, Alemseged Tamiru Haile, Nicole Lefore and John Gowing. 2018.

183 *Community-managed Groundwater Irrigation on the Vientiane Plain of Lao PDR: Planning, Implementation and Findings from a Pilot Trial.* Corentin Clément, Jordan Vinckevleugel, Paul Pavelic, Kong Xiong, Lengya Valee, Touleelor Sotoukee, Binaya Raj Shivakoti and Khammai Vongsathiane. 2018.

182 *Highlights of Soil and Water Conservation Investments in Four Regions of Ethiopia*. Zenebe Adimassu, Simon Langan and Jennie Barron. 2018.

181 *Investigation of the Modalities for an Innovative Financing Mechanism for Participatory Natural Resource Management in the Bale Eco-region, Ethiopia.* Fitsum Hagos, Daniel van Rooijen, Amare Haileslassie, Habtamu Yehualashet and Husien Indries. 2018.

180 *Water User Associations: A Review of Approaches and Alternative Management Options for Sub-Saharan Africa.* Eefje Aarnoudse, Alvar Closas and Nicole Lefore. 2018.

179 *Dependence of Riparian Communities on Ecosystem Services in Northern Ghana.* Marloes Mul, Laetitia Pettinotti, Naana Adwoa Amonoo, Emmanuel Bekoe-Obeng and Emmanuel Obuobie. 2017.

**Postal Address**
P O Box 2075
Colombo
Sri Lanka

**Location**
127 Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

**Telephone**
+94-11-2880000

**Fax**
+94-11-2786854

**E-mail**
iwmi@cgiar.org

**Website**
www.iwmi.org

IWMI is a CGIAR Research Center and leads the: RESEARCH PROGRAM ON Water, Land and Ecosystems

ISSN: 2012-5763
e-ISSN: 2478-1134
ISBN: 978-92-9090-886-9