RESEARCH
REPORT

66

# Agro-Well and Pump Diffusion in the Dry Zone of Sri Lanka

## Past Trends, Present Status and Future Prospects

M. Kikuchi, P. Weligamage, R. Barker, M. Samad, H. Kono
and H. M. Somaratne

International
Water Management
Institute

FUTURE HARVEST
IWMI is a Future Harvest Center
supported by the CGIAR

## Research Reports

*IWMI's mission is to improve water and land resources management for food, livelihoods and nature.* In serving this mission, IWMI concentrates on the integration of policies, technologies and management systems to achieve workable solutions to real problems—practical, relevant results in the field of irrigation and water and land resources.

The publications in this series cover a wide range of subjects—from computer modeling to experience with water user associations—and vary in content from directly applicable research to more basic studies, on which applied work ultimately depends. Some research reports are narrowly focused, analytical and detailed empirical studies; others are wide-ranging and synthetic overviews of generic problems.

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's own staff and Fellows, and by external reviewers. 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.

*Research Report 66*

# Agro-Well and Pump Diffusion in the Dry Zone of Sri Lanka: Past Trends, Present Status and Future Prospects

*M. Kikuchi, P. Weligamage, R. Barker, M. Samad, H. Kono and H.M. Somaratne*

**International Water Management Institute**
P O Box 2075, Colombo, Sri Lanka

IWMI receives its principal funding from 58 governments, private foundations, and international and regional organizations known as the Consultative Group on International Agricultural Research (CGIAR). Support is also given by the Governments of Ghana, Pakistan, South Africa, Sri Lanka, and Thailand.

This research was made possible through generous support from the Ford Foundation, New Delhi, SIDA (Swedish International Development Agency) and the Dutch Government.

*The authors*: M. Kikuchi is a Professor of Agricultural Economics, at the Chiba University, in Japan, and a former IWMI Research Fellow. P. Weligamage, R. Barker and M. Samad are Agricultural Economist, Principal Economist, and Leader of the Research Theme on Water Institutions and Policies, respectively, at the International Water Management Institute, Colombo, Sri Lanka. H. Kono is a Lecturer in Agricultural Economics, at the Obihiro University of Agriculture and Veterinary Medicine in Japan. H. M. Somaratne is a Senior Lecturer in Agricultural Extension at the University of Peradeniya, Sri Lanka.

The authors gratefully acknowledge the valuable comments made by Thushar Shah, C.R. Panabokke and C.M. Madduma Bandara in preparing this report.

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.* Research Report 66. Colombo, Sri Lanka: International Water Management Institute.

*/ irrigated farming / irrigation systems / tubewells / pumps / private investment / cropping patterns / agro-wells / Sri Lanka / Kalpitiya / minor irrigation schemes /*

ISBN: 92- 9090- 507- 7

ISSN 1026-0862



Please send inquiries and comments to: *iwmi@cgiar.org*

*Cover photograph by* A.D.M. Karunaratne

# Contents

# Summary

Diffusion of the use of shallow wells equipped with small pumps to lift groundwater has spread rapidly since around 1980 in many agricultural regions in tropical monsoonal Asia. This enabled individual peasant farmers to irrigate their crops at their discretion leading to an increase in crop yields and facilitating agricultural diversification.

In Sri Lanka too, rapid and pervasive diffusion of agro-wells and pumps has been attracting the attention of policy makers and researchers. Yet, many questions were left unanswered due to lack of research in the area. This study aims to fill this gap of knowledge based on observations and data obtained in field surveys conducted in major and minor irrigation schemes in the dry zone of Sri Lanka.

Agro-wells, defined as wells used at least partially for agriculture, are typically shallow and are of three types: lined dug-well, unlined dug-well, and tubewell. The distribution of agro-wells is not uniform over river basins, regions, and districts, and also among major and minor irrigation schemes. With few exceptions, most farmers use small pumps to lift groundwater from agro-wells, and some also use pumps to lift water from surface sources thereby making the use of pumps greater than that of agro-wells.

A typical agro-well with a small pump can irrigate 0.2 to 0.8 ha. They are mainly used to pump water to irrigate non-paddy crops in the dry or *yala* season. With agro-wells and pumps, the cropping pattern in the *yala* season changes from the minimal, extensive cultivation of low-value-drought-resistant crops to the intensive cultivation of high-value crops such as onion, chili and banana. They have also contributed to an increase in the *yala* season cropping intensity from 20 to 80 percent in the command areas of major schemes and in the highlands of minor schemes.

Historically, the diffusion of pumps preceded the use of agro-wells by about a decade. The widespread use of pumps among individual farmers began in the early 1970s. The expansion of lined dug-wells accelerated in the early 1990s. The establishment of lined open wells has been promoted by a government subsidy, while the diffusion of unlined dug-wells and tubewells has occurred mainly through the farmer's own initiative. By the end of 2000, the total number of agro-wells in the irrigation schemes of the dry zone was estimated at 50,000. The total investment in agro-wells and pumps made by farmers is estimated to amount to Rs 0.8 billion at current prices. At present, it is estimated that private investment in agro-wells and pumps accounts for as much as 20 percent of the total annual investment and expenditure in the irrigation sector.

Private internal rate of return to investment in agro-wells and pumps suggests that profits from unlined dug-wells, tubewells and pumps for lifting surface water are sufficient to induce farmer investments. There are cases in which subsidies given to the construction of lined dug-wells, the rate of return to which is relatively lower, make the construction of the wells feasible in privately unprofitable situations and are, therefore, socially desirable. However, ensuring that subsidies are provided only to appropriate cases is important. A subsidy is not necessary in many cases. In some cases well construction is privately unprofitable even with subsidy, or even environmentally undesirable.

Groundwater resources in Sri Lanka, as in many other parts of South Asia, are limited. The extensive survey, which we conducted is not an appropriate method for collecting information to judge the groundwater conditions and, hence, the potential for further sustainable groundwater exploitation. This is a subject for further study by other disciplines, including hydrology, engineering and soil science.

# *Agro-Well and Pump Diffusion in the Dry Zone of Sri Lanka: Past Trends, Present Status and Future Prospects*

*M. Kikuchi, P. Weligamage, R. Barker, M. Samad, H. Kono and H. M. Somaratne*

## Introduction

In the history of irrigation and irrigated agriculture in the monsoonal tropics of Asia, the last few decades of the twentieth-century would be remembered as the period of well and pump diffusion. It was a trend that enabled individual peasant farmers to irrigate their crops at their discretion, as opposed to the practice in gravity irrigation systems where decision making as to water allocation and distribution rests on groups of farmers or on government agencies. In many agricultural regions in tropical monsoonal Asia, the use of shallow wells equipped with small pumps to lift groundwater has spread rapidly since the 1980s, increasing crop yields and facilitating agricultural diversification.[1]

Sri Lanka is not an exception in this trend; the diffusion and use of agro-wells and pumps has been significant since the 1990s.[2] As in other countries in Asia, the diffusion of agro-wells is commonly found in the command and catchment areas and in the highland parts of existing irrigation schemes. In particular, the diffusion of agro-wells has been very rapid and pervasive in minor irrigation schemes situated in the northwestern part of the dry zone, attracting the attention of policy makers and researchers (Wijesinghe and Kodithuwakku 1990, Abeyratne 1993, Panabokke 1998b, HKARTI 2000). Yet, little is known about agro-wells and pumps except the fact that the use of agro-wells fitted with pumps for irrigation has been mushrooming in a wide scale during the last decade in two northwestern districts, namely, Anuradhapura and Kurunegala. Many questions, such as when and where the diffusion began, why wells and pumps diffused so rapidly, what are the impacts of their

[1]In India, for example, irrigation from agro-wells accounted for less than 30 percent of the total irrigated area in 1960 but now exceeds 50 percent of the area (Dhawan 1982; Fertilizer Association of India 2000). Groundwater exploitation before the 1970s was done mainly by deep tubewells that were generally installed by public investments and operated and maintained by government agencies. In contrast, in the last two decades, groundwater usage increased mainly by the use of shallow tubewells that were installed and operated by individual farmers (Shah 1993). During this period, the shallow tubewell became the most important means of irrigation in Bangladesh (Morris et al.1997).

[2]It should be noted that the use of groundwater through agro-wells for agricultural purposes was studied and advocated in Sri Lanka long before its rapid adoption in recent years. For example, as early as in the 1950s, Farmer (1951 and 1957) pointed out the possibility of introducing agro-wells in the dry zone of Sri Lanka, considering the geological similarity of the region to some parts of South India, where the use of agro-wells was already popular. Following this, Panabokke (1959) conducted some experiments to use groundwater for agriculture in the hard rock areas in the dry zone. In the 1970s, Fernando (1973) and Madduma Bandara (1973, 1977a) studied the possibility of using groundwater in the hard rock areas of the dry zone. Also see Foster, Yearwod and Carruthers (1976) and Basnayake and Madduma Bandara (1985).

introduction on farmers' cropping patterns and incomes, whether the diffusion has been limited to these two districts, and what are the impacts on groundwater resources and the prospects for future diffusion, are all left unanswered.

This report intends to give a broad sketch of the diffusion of agro-wells and pumps in irrigation schemes in the entire dry zone of Sri Lanka, and tries to answer some of the aforementioned questions, based on observations and data obtained in our field surveys.

## Field Surveys

To collect information on the degree, extent, as well as the impacts of the diffusion of agro-wells and pumps in the dry-zone irrigation schemes, we conducted two sets of field surveys from December 2000 to January 2001.[3]

### *Extensive surveys*

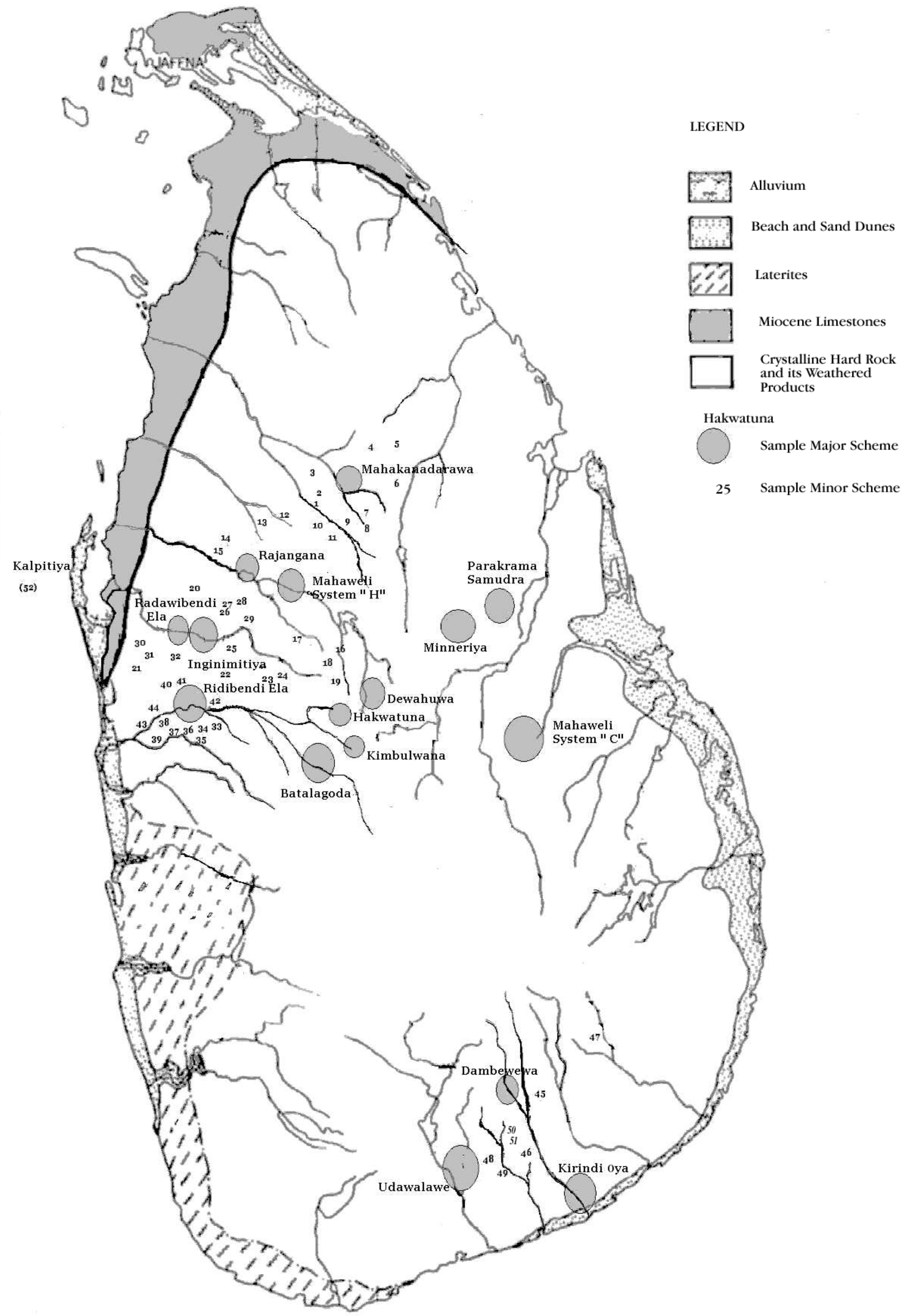
The first set of extensive field surveys was intended to collect information on the degree and extent of the diffusion of agro-wells and pumps. Major schemes with a command area of more than 80 ha and minor schemes with a command area of less than 80 ha were included in the study.[3] Sixteen major schemes and 51 farmer organizations/villages managing 143 minor schemes were selected for our survey (figure 1).[4]

The selection of the 16 major schemes was made purposively. The dry zone was divided into three regions, northwest, northeast and south, and a few representative schemes were selected from each region.[5] The Irrigation Department manages 14 of the selected major schemes and the Mahaweli Authority of Sri Lanka manages the other 2 (Mahaweli System H and Mahaweli System C). In terms of command area, the selected 16 schemes represent more than 30 percent of the major irrigation schemes in the country. In each of these sample schemes, we selected up to seven farmer organizations (FOs) to interview and obtain information on the diffusion of agro-wells and pumps.[6] Wherever possible we interviewed the president or other senior officials of these FOs. In terms of command areas of the FOs surveyed, our major scheme samples represent about 2 percent of the total command area of major irrigation schemes in the country.

The minor schemes were selected at random; interviews were carried out in any minor scheme found while traveling in the dry zone. As in the case of major schemes, we interviewed, wherever possible, the president or senior officials of a FO or the Water Master (*Velvidane*) of a village. Our minor scheme samples represent about 1.5 percent of the minor schemes in the country both in terms of the command area and the number of schemes.

[3]In Sri Lanka, major irrigation schemes are managed by the Irrigation Department and the Mahaweli Authority of Sri Lanka, while Farmer Organizations (FOs) are responsible for managing minor schemes.
[4]Lists of sample major and minor schemes are given in Appendix tables 1 and 2, respectively.
[5]The northwest region in this study includes Kurunegala, Anuradhapura, Puttalam, Matale, Vauniya and Mannar, the northeast includes Polonnaruwa and districts in northern and eastern provinces, and the south includes Badulla, Monoragala, Hambantota and Ratnapura.
[6] We tried to select more than one FO in each scheme to obtain unbiased information on the scheme as a whole. In five schemes, however, we interviewed only one FO. This was partly because of time constraints and mostly because of the uniformity of the situation in regard to wells and pumps in these schemes.

FIGURE 1.
Locations of the sample major and minor irrigation schemes and major groundwater aquifers in Sri Lanka.




*Source*: Based on Maps in Cooray 1984 and Wijesinghe and Kodithuwakku 1990.

Since the primary purpose of the survey was to assess the extent of the diffusion of agro-wells and pumps, the data collected from all the samples are limited to their intensity and diffusion pattern of the past. In addition, detailed information on changes in cropping patterns and costs and benefits associated with the introduction of agro-wells and pumps was obtained through extended interviews with some of the respondents.

It should be reiterated that our survey was confined to irrigation schemes in the dry zone. The only exception was the Kalpitiya Peninsula in the Puttalam district, where a massive concentration of wells and pumps for upland vegetable cultivation is found. Besides this area, all other samples were drawn from irrigation schemes and the information obtained was on wells and pumps in the command area, the catchment area and the highland area cultivated by rice farmers in the sample schemes.

As shown in figure 1, in terms of hydro-geological aquifers, all the sample schemes, both major and minor, belong to the area of crystalline hard rock and its weathered products, which cover nearly the entire non-coastal area of the island. Exceptions are Kalpitiya and the tail end of the Kirindi Oya Scheme in the south where the aquifer is the beach and sand dunes of high groundwater yield.[7]

The use of pumps has also become popular in some areas outside irrigation schemes in the country, such as the highland areas in Jaffna in the northern dry zone, Moneragala in the southeast dry zone, and in vegetable growing areas in the up-country wet zone.[8] The diffusion of pumps in these areas is not discussed in this report.

### *Intensive surveys*

In order to check and supplement the information obtained from the extensive survey, we conducted intensive surveys in two villages in the Anuradhapura district, one in the Galnewa Block of Mahaweli System H and the other in the sub-district of Palagala. The latter manages four minor tank schemes. These two villages were selected purposively to represent the typical villages found in major and minor irrigation schemes, respectively, In the former village there were 78 farmers cultivating 79 hectares[9] of paddy land and 15.8 ha of highland. The village in Palagala had 70 farmers cultivating 20.2 ha of paddy land and 32.4 ha of highland.[10] The diffusion of agro-wells and pumps is extensive in both villages. In each village, 85 percent of the farmers was interviewed using a structured questionnaire designed to collect information on the costs of installing and operating an agro-well with pump, and the benefits associated with the changes in cropping patterns before and after the well-pump adoption.

[7]As to the hydro-geological groundwater aquifers in Sri Lanka, see Wijesinghe and Kodithuwakku 1990 and Panabokke 1998a. It should be noted that figure 1 shows hydro-geological aquifers as rough sketches without details. As mentioned later, groundwater conditions are quite diverse within the wide area that falls into the water-bearing formation of crystalline hard rock and its weathered products, shown in the figure.

[8]Particularly well-known is the high-diffusion of agro-wells and irrigation pumps in the Jaffna Peninsula that is endowed with plentiful groundwater resources of Shallow Karstic Aquifer (Miocene Limestone in figure 1) (Wijesinghe and Kodithuwakku 1990; Panabokke 1998a). In the last two decades, however, the pump-irrigated upland farming in the peninsula has been devastated by the conflict situation in the north.

[9]1 hectare (ha) = 2.47 acres

[10] #16 in figure 1 is the sample minor scheme for the intensive survey.

## Present Status of Agro-Well and Pump Diffusion

In the context of the dry zone in Sri Lanka, agro-wells that lift groundwater for crop cultivation can be classified into three types, lined dug-wells, unlined dug-wells and tubewells. The first two types are open dug-wells of 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.[11] In a lined dug-well, the wall is lined with cement whereas the unlined dug-well has the cut surface of gravel or rock exposed. A wall half a meter to one meter high usually, but not always, protects the mouth of a lined dug-well. In contrast, the mouth of an unlined dug-well is usually left unprotected. A tubewell makes use of a 2-inch (5 cm) to 6-inch (15 cm) plastic pipe implanted vertically into the ground to reach the underground water table that is 15 ft (4.6 m) to 60 ft (18 .3 m) deep.[12]

The shape of a lined dug-well is the same as that of an open dug-well for domestic use though the diameter of the latter is generally smaller. Other than that the distinction between domestic dug-well and lined dug-well for agricultural use is often not clear. Regardless of the size of diameter, wells are often used for both purposes. In this report, a well is defined as an agro-well as long as water from it is used at least partly for agricultural purposes. The type of well that has been promoted by the government and nonprofit organizations through subsidies and assistance is mainly the lined dug-well.[13] In contrast, unlined dug-wells and tubewells have diffused mostly due to farmer initiatives.[14]

A 2-inch (5-cm) pump operated by a diesel or kerosene engine of 2.5 to 5 HP usually lifts water from all three types of wells. Pumps with 3.5 HP engines are the most popular. A 2-inch (5-cm) pipe is used for conveying and distributing water to the fields. The virtual nonexistence of electric pumps for pumping groundwater in irrigation schemes is a salient feature of well-pump diffusion in Sri Lanka as compared to other countries in South Asia.[15] Unlike a tubewell for domestic purposes, which is usually operated by a manual pump, a tubewell for agricultural purposes is always operated with an engine or a motor driven pump. In the case of the dug-well too, water is lifted usually by a mechanical pump, but there are some farmers, though limited in number, who still adopt manual water lifting for agricultural purposes. Farmers also use pumps for lifting water from rivers, canals or tanks (dead storage in particular) to irrigate their crops. Irrigation pumps in this study include all pumps that are used for agricultural purposes and not those used purely for domestic purposes.

In the following section we discuss the present pervasiveness of the agro-well and pump diffusion in major and minor irrigation schemes in the dry zone, based on our surveys.

[11]1 foot = 0.3048 m. The foot and the inch (1 foot = 12 inches) are the standard units used in Sri Lanka by farmers and construction engineers in designing and building/making wells and pumps.

[12]1 inch = 2.54 cm.

[13]The most popular government agencies that give farmers subsidies for constructing lined dug-wells are the Agricultural Development Authority (ADA) and the Provincial Councils. Various nonprofit organizations and nongovernmental organizations, such as International Fund for Agricultural Development (IFAD), Asian Development Bank (ADB), OISCA-International and Isuru Foundation, also extend subsidies and subsidized loans for the construction of wells. There has been no subsidy program for irrigation pumps, except for some loan programs.

[14]An exception to this is found in the Kalpitiya Peninsula in Puttalam where a loan program for installing tubewells was implemented in 1999.

[15]Kalpitiya Peninsula, where the number of wells with electric motor pumps has been increasing rapidly in recent years, is a significant exception.

### *Major Irrigation Schemes*

Table 1 presents data on the spread and use of agro-wells and pumps in the sample major irrigation schemes at the time of our survey, in terms of the density per 100 ha of the command area. Agro-wells in major irrigation schemes are found both in the paddy command area and in the highland area allotted to the paddy farmers in these schemes. The first estimate of the density of agro-wells is obtained by dividing the total number of agro-wells in the command and highland by the size of the paddy command area. Similarly, the density of pumps is obtained by dividing the total number of pumps owned by farmers in these schemes by the size of the command area. It should also be noted that in computing the well density in this study, non-functional or dried dug-wells that are found throughout the dry zone are included in the total number of wells.[16]

TABLE 1.
Average density of dug-wells, tubewells and pumps in the command and highland areas of selected major irrigation schemes in the dry zone of Sri Lanka, by river basin and region, as at the end of year 2000.

| | | | No. per 100 ha of command area | | | |
|---|---|---|---|---|---|---|
| River basin | Scheme | Region | All dug wells, total | Dug wells, unlined | Tube wells | Pumps |
| Malvathu Oya | Mahakanadarawa | Northwest | 27.4 | 0.0 | 0.0 | 24.9 |
| Kala Oya | Rajangana | Northwest | 0.0 | 0.0 | 0.0 | 30.9 |
| Kala Oya | Dewahuwa | Northwest | 14.3 | 7.1 | 0.0 | 16.5 |
| Mi Oya | Inginimitiya | Northwest | 1.7 | 0.0 | 0.0 | 8.3 |
| Mi Oya | Radawi Bendi Ela | Northwest | 4.9 | 0.0 | 0.0 | 9.9 |
| Deduru Oya | Hakwatuna | Northwest | 22.1 | 13.0 | 0.0 | 22.9 |
| Deduru Oya | Kimbulwana | Northwest | 0.7 | 0.0 | 0.0 | 29.1 |
| Deduru Oya | Batalagoda | Northwest | 0.6 | 0.0 | 0.0 | 4.6 |
| Deduru Oya | Ridi Bendi Ela | Northwest | 0.0 | 0.0 | 0.0 | 2.1 |
| Northwest: Average [a] | | | 8.0 | 2.2 | 0.0 | 16.6 |
| Mahaweli Ganga | Minneriya | Northeast | 3.3 | 1.5 | 0.0 | 5.9 |
| Mahaweli Ganga | PSS | Northeast | 2.0 | 0.2 | 0.0 | 12.8 |
| Northeast: Average [a] | | | 2.6 | 0.9 | 0.0 | 9.4 |
| Kirindi Oya | Dambewewa | South | 0.0 | 0.0 | 0.0 | 29.7 |
| Kirindi Oya | Kirindi Oya | South | 0.7 | 0.0 | 2.5 | 12.2 |
| Walawe | Uda Walawe | South | 0.9 | 0.3 | 0.0 | 10.8 |
| South: Average [a] | | | 0.7 | 0.1 | 1.0 | 15.9 |
| Mahaweli System | System H | Northwest | 20.9 | 19.8 | 0.0 | 28.5 |
| Mahaweli System | System C | Northeast | 0.5 | 0.2 | 0.0 | 2.0 |
| Average [b] | | | 6.6 | 4.6 | 0.2 | 14.5 |

[a]Averages are simple averages over individual schemes, except for the south region where Dambewewa Scheme is treated as a subsample of the Kirindi Oya Scheme.
[b]Simple average over the regions and two Mahaweli systems.

[16]We adopt this, because one of the purposes of our survey is to estimate the extent of farmer investments in wells and pumps.

The agro-well density differs very much across regions and across individual schemes in a region. However, in the major schemes in the northwestern region of the dry zone, there is usually a high agro-well density. For example, the dug-well density is as high as 27 and 22 per 100 ha of the command area in Mahakanadarawa in the Malvathu Oya river basin and Hakwatuna in the Deduru Oya river basin, respectively. Dewahuwa in the Kala Oya river basin has a dug-well density of 14 per 100 ha. Moreover, in Mahaweli System H, which is also situated in the Kala Oya basin but in the northwest region as defined in this study, has a dug-well density of 21 per 100 ha. The densities of dug-wells in major schemes in the northeastern and the southern regions are low; less than three per 100 ha in the former and less than one in the latter. The dug-well density of Mahaweli System C, situated in the northeast, is as low as 0.5 per 100 ha. The diffusion of dug-wells at present is thus quite a region-specific phenomenon, concentrated especially in parts of the river basins in the northwestern part of the dry zone.

While the density of wells is the number of wells per 100 ha of the paddy command area, the rate of diffusion of wells is the number of wells per 100 farmers.

On average, a farmer in the sample major schemes cultivates 1.2 ha, consisting of 1.0 ha of paddy land and 0.2 ha of highland. Since the density is the number of wells per 100 ha of paddy command area and an average farmer cultivates 1.0 ha of paddy land, the value of the density is equal to the rate of dug-well diffusion (number of wells per 100 farmers).

On average, 8 percent, 2.6 percent and 0.7 percent of farmers own dug-wells in non-Mahaweli major irrigation schemes situated in the northwest, the northeast and the south, respectively.

In the major schemes, where well density is high, the prevalent type of dug-well varies. In Mahakanadalawa, for example, all the dug-wells are lined. In contrast, virtually all the dug-wells in Mahaweli System H are unlined, as is the case for the majority of dug-wells in Hakwatuna and Dewahuwa.

Tubewells are not found in major schemes except in the Kirindi Oya Scheme in the south. In this system, tubewells using 6-inch (15 cm) tubes are found only in the two downstream tank areas near the sea where the groundwater table of the Beach and Sand Dune aquifer (see figure 1) is 15 ft (4.6 m) from the ground surface. Because of this shallow groundwater table and the type of soil in the area, farmers can install tubewells quite easily on their own by using simple self-made tools. The only problem they face is, because the areas are so close to the sea, that the water tapped is saline due to the infiltration of the fresh water aquifer by seawater. Tubewells are installed both in the paddy command and in the highland. While tubewells in the command are used for paddy cultivation only in drought seasons when there is a severe scarcity of surface water, water from those in the highland is used for growing bananas and vegetables.

Since wells are almost always fitted with pumps, the density of pumps is also high in schemes where the density of wells is high (table 1). However, pump density is high even in schemes where there are few agro-wells. Indeed, among the sample major schemes, the highest pump density is recorded in Rajangana in the northwest and the second highest in Dambewewa in the south, both of which don't have agro-wells. In the absence of agro-wells, pumps in these schemes are used exclusively for lifting water from rivers, canals, and tanks. It should be noted that this type of pump use exists throughout the dry zone, though the rate of diffusion differs significantly from scheme to scheme. On average, for the sample major schemes, the rate of pump diffusion is about 17 percent in the northwest, 9 percent in the northeast and 16 percent in the south. It is remarkable that the rate of pump diffusion in the south, where there are few agro-wells, is nearly at the same level as that of the northwest.

## *Minor Irrigation Schemes*

Table 2 summarizes the density of wells and pumps in the sample minor irrigation schemes by river basin and by region. Dug-wells found in minor schemes are mostly lined. Some dug-wells are "partially" lined.[17] The type of unlined dug-well found in Mahaweli System H and Hakwatuna Scheme, i.e., open dug-wells with no lining at all, are rare in minor schemes. Therefore, the data in table 2 refer mainly to lined dug-wells and tubewells.

As for the major irrigation schemes, the density of dug-wells varies significantly across river basins and over regions. The tendency for dug-wells to be concentrated in the northwestern region is clearly found in the case of minor schemes too. In particular, the three river basins in the northern part of the northwest, i.e., the Malvathu Oya basin, the Kala Oya basin, and the Mi Oya basin, have dug-well densities as high as 32, 23 and 20, respectively, per 100 ha of the command area. This ratio incidentally is much higher than that of major schemes in the same basins. In the other three river basins in the northwest, the dug-well density is less than 10 per 100 ha.

In the minor schemes in the south, dug-wells are almost nonexistent, except in the Kirindi Oya basin. The density of dug-wells in the minor schemes in the Kirindi Oya basin is as high as those in the river basins in the northwest. It

TABLE 2.
Average density of dug-wells, tubewells and pumps in the command and highland areas of minor irrigation schemes in the dry zone of Sri Lanka, by river basin and region, as at the end of year 2000.

| | | No. per 100 ha of command area | | |
|---|---|---|---|---|
| River basin | Region | Dug wells | Tube wells | Pumps |
| Malvathu Oya | Northwest | 32.1 | 0.0 | 20.5 |
| Kalagamu Oya | Northwest | 8.2 | 0.0 | 8.2 |
| Modaragam Aru | Northwest | 1.5 | 0.0 | 4.0 |
| Kala Oya | Northwest | 22.6 | 0.0 | 36.5 |
| Mi Oya | Northwest | 19.6 | 0.0 | 24.4 |
| Deduru Oya | Northwest | 5.0 | 30.7 | 99.0 |
| Northwest: Average [a] | | 14.8 | 5.1 | 32.1 |
| Kirindi Oya | South | 20.6 | 0.0 | 88.3 |
| Kumbukkan Oya | South | 0.0 | 0.0 | 2.9 |
| Malala Oya | South | 2.7 | 0.0 | 4.0 |
| South: Average [a] | | 7.8 | 0.0 | 31.7 |
| Average for all basins [a] | | 12.5 | 3.4 | 32.0 |

[a]Simple average over river basins.

[17]In "partially" lined wells, usually, the wall above the ground surface and a few feet below it, not to the bottom, are lined with cement.

should be noted, however, that in the Kirindi Oya basin, the density of minor tank schemes itself is far less than that in the northwest; one comes across minor tanks frequently in the northwest, whereas it is rather difficult to locate minor tanks in the Kirindi Oya basin, as in other parts of the south. Furthermore even if the dug-well density is high, the total number of wells in the Kirindi Oya basin is absolutely negligible as compared to that in the northwest. Also, the dug-wells are found in the highland areas and the highland area cultivated by farmers in some minor schemes in the Kirindi Oya basin is disproportionately large in comparison to the area of paddy fields. Since the well density is defined in terms of the paddy command area, the estimated well density in this basin is to a great extent exaggerated as compared to that in the northwest. It should also be noted that high well densities are not found in all minor schemes in the Kirindi Oya basin. One of the two sample schemes in the basin has no dug-wells at all while in the other two river basins in the south, the dug-well density is zero. All this suggests that the Kirindi Oya basin is rather exceptional in the south in terms of dug-well diffusion.

The Deduru Oya basin is characterized by the heavy concentration of tubewells. In this basin, the dug-well density is only 5 per 100 ha, whereas the tubewell density is 31 per 100 ha. The density of both dug-wells and tubewells in the Deduru Oya basin is as high as 36 per 100 ha, which is higher than that in the Malvathu Oya basin. However, tubewells are nonexistent in minor schemes in other river basins in the south as well as in the northwest.[18]

In the northwest, the well density of minor schemes, on average, is higher than that of major schemes, except in System H (tables 1 and 2). It should be noted, however, that the difference becomes less in terms of the rate of diffusion of wells among farmers. The average area of paddy land cultivated by a farmer in the sample minor schemes is about 0.5 ha (area of highland cultivated is 1.0 ha). Therefore, the rate of diffusion of wells is half the value of the well density. The rate of diffusion of wells (dug-wells and tubewells) among farmers in the northwest is thus estimated to be about 10 per 100 farmers (one-half of 14.8 + 5.1; table 2), while it is 8 per 100 farmers in major schemes (table 1).

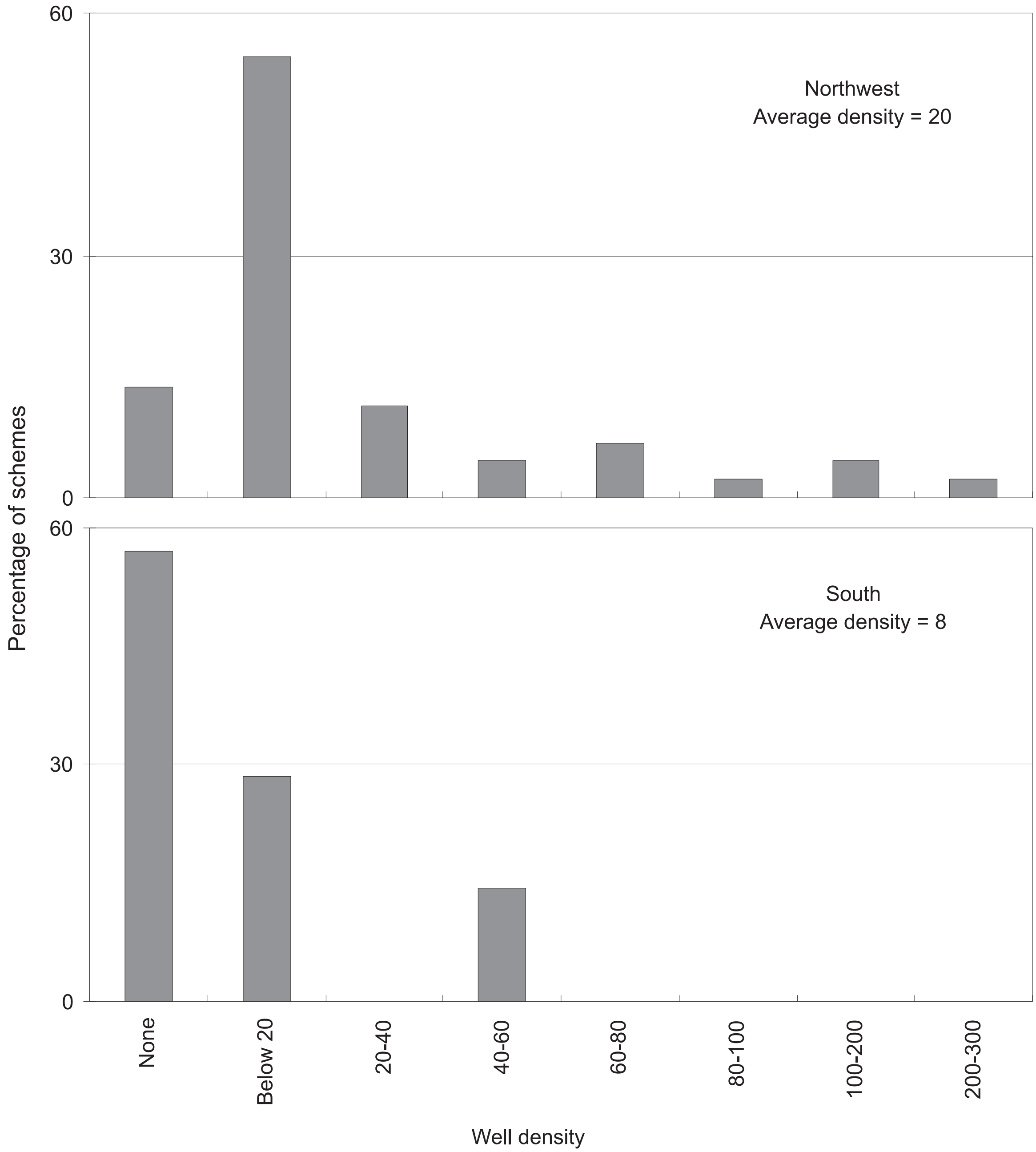
It should be noted that the diffusion of dug-wells and tubewells is not uniform within the river basins with a high well density, as it is across basins. Indeed, the distribution of minor irrigation schemes of high well density is significantly biased in favor of certain areas within the basins. Figure 2 shows the percentage distribution of sample minor schemes by the level of well density (dug-well + tubewell) in the northwest and the south. In the northwest, the distribution is skewed towards lower density classes with the mode found in the density class second to the lowest (below 20 per 100 ha), and the right tail is stretched thinly and widely towards higher density classes. Even in river basins with favorable groundwater conditions, areas suited for developing dug-wells or tubewells are limited, and the majority of areas are unsuitable or below average.

Figure 2 also indicates that, if provided with favorable groundwater conditions, the well density could be as high as 100–300 per 100 ha. The “irrigable area” of a well with pump ranges from 0.2 ha to 1.2 ha, with the prevalent range between 0.2 ha and 0.8 ha.[19] Farmers in favorable areas may be able to irrigate more than their entire cultivated area of paddy fields and highland.

[18]In the Deduru Oya basin, tubewells in minor schemes are mostly found in the downstream parts of the basin (see figure 1). Though not detailed in figure 1, thick layers of alluvial deposits are found in these parts of the basin.

[19]Irrigable area of a well depends on various factors, such as the availability of groundwater, recharge capacity, the size of pump used for lifting water, and crops to be irrigated. This range is when a 2-inch (5-cm) pump is used. If manual methods are used for water lifting, the irrigable area becomes less than one half of this. Abeyratne (1993) reports that an agro-well in the northwest can irrigate no more than 0.34 ha.

FIGURE 2.
Percentage distribution of sample minor irrigation schemes by well density (dug-well + tubewell) in the northwestern and the southern regions of the dry zone, as of the end of 2000.



The pattern of this distribution in the south is different from that in the northwest. The mode of the distribution is at the density class of “none,” indicating that there are no dug-wells at all in nearly 60 percent of the sample minor schemes. Moreover, sample schemes with wells are found only in two density classes, and, unlike in the northwest, no sample scheme is found in the density class of 60–80 and higher. Such a density distribution seems to indicate a general unsuitability in groundwater conditions to dug-well development in the south in comparison to the northwest.

The density of pumps also varies significantly among the river basins and across regions. The pump density in the northwest ranges from 4 per 100 ha in the Modaragam Aru basin to 99 per 100 ha in the Deduru Oya basin.[20] In the south, it ranges from 3 per 100 ha in the Kumbukkan Oya basin to 88 per 100 ha in the Kirindi Oya basin.[21] On average, the pump density is nearly the same in the northwest and in the south, while in contrast the well density is nearly 50 percent higher in the northwest than in the south. Also on average, the pump density is higher in minor than in major schemes. Given that on average a farmer in a minor scheme cultivates 0.5 ha of paddy and that the pump density of both regions is 32 per 100 ha, the diffusion rate is 16 per 100 farmers in major schemes of both regions.

## *Density by Type of Land and by District*

So far we have observed the density of agro-wells and pumps in terms of the number of units in the paddy command and the highland per 100 ha of the paddy command area. Table 3 shows, by river basin and by type of irrigation scheme, the density of agro-wells in the paddy command and in the highland separately. In the northwest, on average, both major and minor schemes have in the paddy command area about 9 units of agro-wells, lined dug-wells, unlined dug-wells and tubewells combined, per 100 ha of the command area, and about 5 to 6 units in the highland per 100 ha of highland. As will be shown later, the number of agro-wells is more in the highland than in the paddy command, but the well density is slightly higher in the former than in the latter. In the major schemes in the northeast, agro-wells are found in the highland, with a density similar to that in the northwest. In the south, the well density is low in both types of land.

The pump density in table 3 is obtained in terms of the number of units in irrigation schemes per 100 ha of paddy command and highland areas combined. With the inclusion of the highland area, the pump density becomes less than the density per 100 ha of the paddy command area on its own. This reduction is more distinct for minor schemes where the proportion of highland in the total cultivated area is larger than that for major schemes. More importantly, the reduction in the pump density is greater in minor schemes in the Kirindi Oya basin, where farmers cultivate large tracts of highland by means of pump irrigation than in major schemes.

Table 4 shows the density per 100 ha of the command area of dug-wells, tubewells and pumps by district. The density of dug-wells is highest in Anuradhapura for both major and minor schemes. For major schemes, the density in Kurunegala is the second highest, followed by Polonnaruwa and Puttalam, respectively. In the

[20]The highest pump density of 281 per 100 ha is reported in a minor scheme in the Deduru Oya basin.

[21]For the same reason mentioned in regard to the well density, the pump density in the Kirindi Oya basin may be exaggerated.

TABLE 3.

Well and pump density in irrigation schemes by river basin, by type of scheme and by type of land, in the dry zone of Sri Lanka, as at the end of year 2000.

| River basin | Region | Well density[a] | | | | Pump density[b] | |
|---|---|---|---|---|---|---|---|
| | | Major schemes[c] | | Minor schemes | | Major | Minor |
| | | Command[d] | Highland[e] | Command[d] | Highland[e] | | |
| Malvathu Oya | Northwest | 10.3 | 21.8 | 16.4 | 7.7 | 14.1 | 7.1 |
| Kalagamu Oya | Northwest | | | 8.2 | 0.0 | | 3.8 |
| Modaragam Aru | Northwest | | | 0.0 | 0.9 | | 1.5 |
| Kala Oya | Northwest | 16.5 | 0.3 | 18.6 | 8.7 | 15.1 | 16.7 |
| Mi Oya | Northwest | 0.1 | 3.0 | 3.5 | 5.8 | 4.7 | 5.9 |
| Deduru Oya | Northwest | 9.0 | 0.5 | 10.4 | 5.9 | 14.5 | 35.5 |
| Northwest: Average [f] | | 9.0 | 6.4 | 9.5 | 4.8 | 12.1 | 11.7 |
| Mahaweli Ganga | Northeast | 0.0 | 6.3 | | | 4.1 | |
| Kirindi Oya | South | 1.5 | 3.3 | 0.0 | 1.2 | 9.7 | 6.4 |
| Kumbukkan Oya | South | | | 0.0 | 0.0 | | 1.3 |
| Malala Oya | South | | | 0.0 | 1.5 | | 1.2 |
| Uda Walawe | South | 0.4 | 1.3 | | | 7.2 | |
| South: Average [f] | | 1.0 | 2.3 | 0.0 | 0.9 | 8.4 | 3.0 |
| Average for all basins[f] | | 5.4 | 5.2 | 6.3 | 3.5 | 9.9 | 8.8 |

[a]The density of three types of agro-wells combined.
[b]The density of irrigation pumps per 100 ha of the paddy command area plus the highland.
[c]Mahaweli System H is included in the Kala Oya basin and System C in the Mahaweli Ganga basin.
[d]The density of agro-wells in the paddy command per 100 ha of the command area.
[e]The density of agro-wells in the highland per 100 ha of highland.
[f]Simple average over river basins.

TABLE 4.

Average density of dugwells, tubewells and pumps by district, in irrigation schemes in the dry zone of Sri Lanka, as at the end of year 2000.

| District | Region | Number per 100 ha of paddy command area[a] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Major schemes | | | | Minor schemes | | |
| | | Dug wells | Dug wells unlined | Tube wells | Pumps | Dug wells | Tube wells | Pumps |
| Anuradhapura | Northwest | 23.9 | 12.5 | 0.0 | 28.2 | 31.2 | 0.0 | 24.7 |
| Kurunegala | Northwest | 7.2 | 4.2 | 0.0 | 17.7 | 14.0 | 1.0 | 58.3 |
| Puttalam | Northwest | 3.3 | 0.0 | 0.0 | 9.1 | 14.4 | 49.5 | 61.2 |
| Polonnaruwa | Northeast | 4.2 | 1.4 | 0.0 | 7.4 | | | |
| Badulla | Northeast | 0.0 | 0.0 | 0.0 | 3.9 | | | |
| Ampara | Northeast | 0.0 | 0.0 | 0.0 | 0.0 | | | |
| Monaragala | South | 0.8 | 0.0 | 0.0 | 17.3 | 9.3 | 0.0 | 36.9 |
| Hambantota | South | 0.9 | 0.2 | 1.4 | 11.3 | 2.7 | 0.0 | 5.5 |
| Ratnapura | South | 0.0 | 0.0 | 0.0 | 12.4 | | | |

[a]Simple averages over the sample schemes.

other districts in the northeast and in the south, the dug-well density is almost negligible. For minor schemes, it is equally high in Kurunegala and Puttalam in the northwest and in Monaragala in the south. Unlined dug-wells are found in Mahaweli System H, and tubewells cluster around in Puttalam over the lower reaches of the Deduru Oya basin. The pump density is highest for minor schemes in Puttalam, followed by Kurunegala and Anuradhapura in the northwest. The pump density in Monaragala is high as a result of the high pump density in the Kirindi Oya basin. Among major schemes, Anuradhapura has the highest pump density, and the density is relatively high in Kurunegala, Monaragala, Hambantota and Ratnapura. In these four districts, where the pump density exceeds the well density considerably, the use of pumps for lifting water from rivers, canals and tanks is a significant feature.

Altogether, it is clear that the incidence of agro-wells, including lined dug-wells, unlined dug-wells and tubewells, is at present high in the three districts of Anuradhapura, Kurunegala and Puttalam in the northwest and moderate in Monaragala, in the south. The densities of agro-wells in other regions are negligible. It is also clear that the well density is higher in minor schemes than in major schemes. The density of irrigation pumps is also high in the three districts in the northwest and in Monaragala in the south, but it is not insignificant in other districts in the northeast and in the south except for Ampara.[22] The incidence of pumps, therefore, is far more pervasive throughout the dry zone than agro-wells.

Our observations on the regional differences in agro-well density seem to reflect the regional differences in groundwater conditions. Although the entire non-coastal dry zone is included in the water-bearing formation of crystalline hard rock and its weathered products (figure 1), the area well endowed with groundwater resources is the northwest. A vast proportion of the area in the dry zone is shallow regolith aquifers on the metamorphic hard rock (Panabokke 1998a). Other major sources of groundwater suitable for shallow agro-wells are alluvium aquifers and coastal sand aquifers. The alluvium aquifers in Sri Lanka constitute one of the most diversified forms of aquifers in the tropical world and major rivers, such as the Malvathu Oya, Kala Oya, Deduru Oya and Kirindi Oya, have broad and deep alluvial beds. However, the rivers in the northwest generally have larger alluvium aquifers than in the south. The same is true of the coastal sand aquifers.

It is worth noting that the regional differences in the agro-well density correlate with the regional differences in the density of minor tank irrigation schemes. The density of minor schemes is highest in the northwest as compared to the northeast and the south (Panabokke et al. 2002). More interesting is the fact that the incidence of abandoned minor schemes is higher in the northeast and the south than in the northwest. These facts indicate that hydro-geological conditions, including both groundwater and surface water, are more favorable in the northwest than in the other two regions. Since shallow regolith aquifers are closely linked with the surface water in streams, canals and tanks, the same hydro-geological conditions would determine the usability of agro-wells to a large extent.

[22]It should be noted that data for Ampara are from Zone 4 in Mahaweli System C, and that no data from non-Mahaweli major schemes in the district are included in our survey.

## Some Features of Agro-Wells and Irrigation Pumps

### *Subsidies for pumps*

As mentioned earlier, to promote lined dug-wells in major and minor irrigation schemes in the dry zone, the government provided subsidies for their construction, while the farmers on their own made unlined dug-wells and tubewells. In major schemes, 70 to 80 percent of dug-wells, most of them lined, in the northwest and the south were constructed with subsidies provided by the government (table 5). In contrast, only 2 percent received subsidies in System H, where nearly all the dug-wells are unlined. Also, a relatively lower percentage of farmers in major schemes in the northeast received subsidies for the construction of wells. For minor schemes, the percentage of dug-wells constructed with subsidies is 61 percent in the northwest, and many farmers have not yet received the subsidy even after completing work on their lined dug-wells.[23] In minor schemes in the south, however, not only is the density of dug-wells low but also the percentage of dug-wells that were subsidized. Though not shown in table 5, farmers in the Deduru Oya and the Kirindi Oya basins also do not receive a subsidy for their tubewells.

TABLE 5.
Percentage of subsidized wells and in highland, depth of wells, sources and purposes of pumping water, in irrigation schemes in the dry zone of Sri Lanka, as at the end of year 2000.

| | | Major irrigation schemes | | | | | | Minor irrigation schemes | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | North-west | North-east | South | System H | System C[a] | Total | North-west | South | Total |
| I. | % of dug-wells | | | | | | | | | |
| | subsidized (%) | 69 | 38 | 79 | 2 | na | 47 | 61 | 38 | 50 |
| II. | % of wells in highland | 52 | 100 | 53 | 0 | na | 51 | 66 | 100 | 83 |
| III. | Depth of dug-well (feet) | | | | | | | | | |
| | Min | 14 | 20 | 15 | 16 | na | 14 | 18 | 20 | 18 |
| | Max | 28 | 28 | 28 | 25 | na | 28 | 40 | 30 | 40 |
| | Average | 22 | 23 | 19 | 20 | na | 21 | 24 | 23 | 24 |
| IV. | Source of water (%) | | | | | | | | | |
| | Groundwater | 55 | 41 | 12 | 68 | 0 | 35 | 56 | 10 | 33 |
| | River, canal or tank | 45 | 59 | 88 | 33 | 100 | 65 | 44 | 90 | 67 |
| V. | Purpose of well/pumping (%) | | | | | | | | | |
| | Paddy cultivation | 12 | 1 | 1 | 10 | 0 | 5 | 17 | 9 | 13 |
| | OFC cultivation | 88 | 99 | 99 | 90 | 100 | 95 | 83 | 91 | 87 |

[a]In System C, dug-wells are found in cashewnut areas only, and they are not included here.

*Note*: na = not applicable; OFC = other field crops.

[23]In many cases, the pledged subsidy was given to farmers after they had constructed the lined dug-wells, not before.

## *Distribution between paddy command and highland*

In irrigation schemes, agro-wells can be dug either in the paddy command area or in highland. The percentage of lined dug-wells in the highland is between 50 and 100 both in major and minor schemes (table 5); more agro-wells are found in the highland than in the paddy command.[24] On average, the percentage in highland is higher in minor schemes than in major schemes. In the case of unlined dug-wells in Mahaweli System H, in contrast, nearly 100 percent of the wells are dug within the paddy command area. Though not listed in the table, the percentage distribution of tubewells between the command and the highland is about 50:50.

## *Depth and diameter of wells*

The dug-wells are generally shallow, ranging from a minimum of 14 ft (4.3 m) to a maximum of 40-ft (12.2 m) in depth (table 5). It is interesting to observe that the minimum and the maximum depths are both higher in the minor schemes than in the major schemes. The minimum depth for major schemes is 14 ft (4.3 m), while it is 18 ft (5.5 m) for minor schemes. The maximum depth, on the other hand, is 28 ft (8.6 m) for major schemes, and 40 ft (12.2 m) for minor schemes. Accordingly, the average depth is 21 ft (6.4 m) for major schemes and 24 ft (7.32 m) for minor schemes. In the case of tubewells, the depth ranges from 20 ft to 60 ft (6 m to18.3 m) for minor schemes situated in the Deduru Oya basin in the northwest, but the depth is only 15 ft (4.6 m) for tubewells found in the Kirindi Oya scheme in the south. These facts may suggest that farmers in major schemes generally enjoy better groundwater conditions than farmers in minor schemes.

Indeed, the depth of well or the level of groundwater table is the most critical factor that determines the economic performance of agro-wells in general, and of dug-wells in particular. As will be explained in a later section, the cost of digging agro-wells depends mainly on the depth. A common feature in the dry zone is abandoned dug-wells. At least 10 percent of the dug-wells are abandoned or left unused in both major and minor schemes.[25] The reason for this is more often than not the low economic profitability of the wells, the depth of well being a critical factor that determines profitability.[26]

Although the diameter of a dug-well is not as important as its depth in determining its economic performance, the diameter distinguishes agro-wells from domestic wells. As mentioned earlier, the diameter of a dug-well for agricultural purposes ranges from 14 ft (4.3 cm) to 22 ft (6.7 m). The mode is 20 ft (6 m), and more than 70 percent of dug-wells in our sample schemes are of this size. Throughout the dry zone, there are many small dug-wells with a diameter of 8 ft (2.4m) or even less, but these are for domestic use, and rarely used for agricultural purposes. There are large domestic dug-wells, but hardly any small agro-dug-wells.

[24]This observation is supported by the findings of agro-well census surveys conducted in minor irrigation schemes in Anuradhapura and Kurunegala by the Hector Kobbekaduwa Agrarian Research and Training Institute (HKARTI). According to these surveys, farmers set up agro-wells more often outside the paddy command area than inside it, and the most popular location is the boundary between the paddy command and the highland (Panabokke 2001).

[25]Abandoned dug-wells are found more in regions with unfavorable groundwater conditions such as in the south, but it is not rare to come across abandoned wells even in the northwest where groundwater conditions are considered favorable.

[26]Many farmers say that if the depth of the groundwater table is more than 30 ft (9.2 m), there would be little chance of an agro-well being profitable. This is in sharp contrast with the fact that there are many wells in non-agro-well areas used for domestic requirements of water, which are as deep as 70 to 100 ft (21.3 to 30.5 m).

### *Sources of pumped water and usage*

Water for irrigation purposes is pumped not only from agro-wells but also from rivers, canals and tanks. The percentage distribution of the source of water for pumping— groundwater for agro-wells and surface water for rivers, canals and tanks—differs among the regions, but on average is almost similar between major and minor schemes in the same region (table 5). Farmers in the northwest, for both major and minor schemes, pump 55 percent groundwater and 45 percent surface water, whereas in the south, farmers use as much as 90 percent surface water and only 10 percent groundwater. These observations are consistent with the fact that the availability of groundwater is generally better in the northwest than in the south.

In major and minor schemes alike, farmers use pumped water mostly for irrigating non-rice crops (other field crops or OFCs) regardless of the source of water (table 5). Farmers also use pumped water for irrigating the paddy cultivation. However, this is practiced occasionally, when water from the gravity system is inadequate and the rice plants are critically in need of water. The use of pumped water for paddy is somewhat higher in minor schemes as compared to major schemes. This practice is more common in the northwestern region than in other regions. Farmers in the northwest, including System H and the minor schemes, apply pumped water for paddy more frequently than farmers in other regions. This may be related to the fact that many minor as well as major schemes in the northwest experience scarcity of water. Except for such emergency use for paddy, however, the purpose of pumping water is almost exclusively for irrigating OFCs.

### *Reasons for abandonment of wells*

No overt depletion of groundwater or an adverse impact on water quality due to the pumping of water from agro-wells was reported in the sample schemes, both major and minor. The only exception was in the Hakwatuna Scheme, where farmers in the lower reaches complained that heavy water-pumping from unlined dug-wells in the upper reaches had an adverse impact on groundwater as well as surface water in the lower reaches. There are many abandoned wells, lined dug-wells in particular, in the paddy command and highland of these irrigation schemes. But the major reasons for abandonment of wells are poor groundwater conditions of the area and low profitability, not the depletion of groundwater due to pumping. The samples of this study are small and that the incidence of agro-wells in Sri Lanka has a relatively short history of about only a decade. Whether this is the general trend in the entire dry zone and whether the same situation will prevail in the future as the diffusion of agro-wells continues need further careful study.[27]

### *Pump rental market instead of a water market*

A salient feature in the diffusion of agro-wells and irrigation pumps in India and Bangladesh is the concomitant evolution of a water market, where pumped water is sold to farmers who do not own wells with pumps (Shah 1993; Morris et al. 1997). In spite of the rapid diffusion of agro-wells and pumps in Sri Lanka, there is no evidence of the existence of a water market as in other countries in the region. A reason for

[27]In India and Bangladesh, where the diffusion of agro-wells began much earlier than in Sri Lanka, the receding of the groundwater table due to over-pumping has been reported in many places (Shah 1993; Morris et al. 1997).

the non-development of a water market may be the small capacity of agro-wells and pumps used in Sri Lanka. Unlike in India and Bangladesh, where a well with pump irrigates as much as 2 to 4 ha of cropland, in Sri Lanka a well with pump can irrigate only 0.2 to 0.8 ha of cropland. As this irrigable area is often smaller than the cultivated area of an average farmer, it is usually the case that no water is left for sale after a well-pump owner irrigates his fields.

Instead of a water market, a pump rental market is well established in irrigation schemes in the dry zone of Sri Lanka. The rent for a pump without fuel ranges from Rs 25 per hour to Rs 85 per hour, [28] the most common rate being Rs 50 to Rs 60 per hour.[29] The rental depends on various conditions, including the water supply and demand. For instance, the cheapest pump rental is found in the Deduru Oya basin where the pump density is the highest among the sample schemes.

## Past Trends and Investment

So far we discussed the current status of the spread and use of agro-wells and pumps in irrigation schemes in the dry zone, based on the data obtained from sample irrigation schemes. Using this data, we present in this section the historical diffusion patterns of agro-wells and pumps and try to estimate farmer investments in agro-wells and irrigation pumps.

### *Estimation Procedures*

The past diffusion pattern for each type of agro-well and pump is traced back for each sample irrigation scheme to the year when a well or pump was first introduced, and aggregated annually into the average density for the respective river basin. Based on the annual time-series thus compiled for each type of well and pump, the number of well and pump units in each year is estimated for the respective river basin by multiplying the total command area in the river basin by the average density of the basin. Applying this procedure for major and minor schemes separately, and summing up over river basins and two types of irrigation, the national level time-series of well and pump units are obtained.[30]

For river basins where no sample is available, an average density is assumed for the region to which the river basins belong. As defined earlier, we divide the dry zone into three regions, northwest, northeast and south. Districts that are included in the northwest, other than those shown in table 4, are Matale, Mannar, and Vavuniya. Districts that belong to the south are those listed in table 4. All other dry-zone districts are included in the northeast. For the Mahaweli Systems, the estimation is made separately from non-Mahaweli major schemes, and the densities in Mahaweli Systems B and G are assumed to be the same as that of System C. For minor schemes, the same densities as for the south are assumed for the northeast.

[28]There are cases in which the pump rental is determined with the inclusion of the operator's wage.

[29]One Sri Lankan rupee was equal to 0. 0125 US dollars at the time of our survey.

[30]The total command areas of major and minor schemes in the river basins in the dry zone are compiled from Arumugam 1968, Sri Lanka Irrigation Department 1975, and Sri Lanka Department of Agrarian Services 2000.

Farmer investments in agro-wells and pumps are estimated by assuming standard/average rates for costs of installing agro-wells and irrigation pumps. The following rates at year 2000 prices are assumed:

| | |
|---|---|
| Lined dug-well, diameter = 20 ft (6 m), depth = 23 ft (7 m): | Rs 98,000 |
| Unlined dug-well, diameter = 20 ft (6 m), depth = 16 ft (4.8 m): | Rs 6,500 |
| Tubewell, diameter = 4-inch (10 cm), depth = 24 ft (7.3 m): | Rs 6,600 |
| Pump, 2-inch (5 cm), diesel, 3.5HP with 200 ft (61 m) long 2-inch (5 cm) pipe: | Rs 38,400[31] |

## *Number of Agro-Wells and Pumps*

The total number of agro-wells and irrigation pumps for the entire dry zone, as at the end of the year 2000 (table 6), is estimated as about 30,000 lined dug-wells, 8,000 unlined dug-wells, 10,000 tubewells, and 110,000 irrigation pumps.

We do not claim that these estimates are accurate, but would like to emphasize that they provide a rough idea of the magnitude of well and pump diffusion. Here, let us check the degree of accuracy of our estimates, though data that can be used for such a purpose are rather

TABLE 6.
Numbers of dug-wells, tubewells and irrigation pumps by region and by type of irrigation scheme, in the command and highland areas of irrigation schemes in the dry zone of Sri Lanka, as at the end of year 2000[a].

| | Northwestern districts [b] | Other districts [c] | Total | |
|---|---|---|---|---|
| Lined dug-wells: | | | | |
| Major schemes | 5,961 | 2,865 | 8,826 | (27) |
| Minor schemes | 18,499 | 5,140 | 23,639 | (73) |
| Total | 24,460 | 8,005 | 32,465 | (100) |
| | (75) | (25) | (100) | |
| Unlined dug-wells: | | | | |
| Major schemes | 6,813 | 1,423 | 8,236 | (100) |
| | (83) | (17) | (100) | |
| Tubewells: | | | | |
| Major schemes | 0 | 282 | 282 | (3) |
| Minor schemes | 9,473 | 0 | 9,473 | (97) |
| Total | 9,473 | 282 | 9,755 | (100) |
| | (97) | (3) | (100) | |
| Irrigation pumps: | | | | |
| Major schemes | 10,875 | 27,932 | 38,807 | (36) |
| Minor schemes | 46,962 | 21,094 | 68,057 | (64) |
| Total | 57,837 | 49,027 | 106,864 | (100) |
| | (54) | (46) | (100) | |

[a]Estimated based on the density by river basin. Numbers in parenthesis are percentages.
[b]For river basins in Anuradhapura, Kurunegala, Puttalam, Matale, Mannar, and Vavuniya.
[c]For river basins in other dry zone districts other than those listed above.

[31]Details of the costs and prices of agro-wells and pumps will be given under Costs and Benefits.

scanty. The Hector Kobbekaduwa Agrarian Research and Training Institute (HKARTI 2000), using data of census surveys conducted in minor irrigation schemes, has found that there are 10,000 and 5,400 dug-wells in Anuradhapura and Kurunegala districts, respectively. These numbers can be translated into well densities per 100 ha of 27 and 15, which are roughly comparable to our estimates of 31 and 14, respectively (table 4). HKARTI (2000) also finds that more than 50 percent of dug-wells in these two districts were constructed without a subsidy. If this rate can be applied to the entire dry zone, the number of dug-wells supported by the Agricultural Development Authority (ADA) being 16,000 as at year 2000 (table 7), the total number of lined dug wells is more than 32,000, which is precisely our estimate for lined dug-wells for the entire dry zone (table 6).

Table 7 shows the regional distribution of ADA-supported dug-wells in the regions defined in this report. Sixty three percent of the ADA-approved wells ("started wells") on which work commenced (67% of the wells completed or being completed) are in the northwest and 37 percent of the started wells (33% of wells completed or being completed) are in the northeast and the south. The comparable figures for the total number of lined dug-wells in table 6 are 75 percent and 25 percent, respectively. Since construction of wells without subsidies would have been more popular in the northwest, which is generally endowed with more favorable groundwater conditions than the other two

TABLE 7.
Number of dug-wells supported by the Agricultural Development Authority in the dry zone for the period of 1989-2000, according to region and district [a].

| | | Started | | Completed or being completed | |
|---|---|---|---|---|---|
| Region | District | No | % | No | % |
| Northwest | Anuradhapura | 4,593 | 29 | 3,861 | 37 |
| | Kurunegala | 2,872 | 18 | 1,745 | 17 |
| | Puttalam | 1,027 | 6 | 310 | 3 |
| | Matale | 1,158 | 7 | 586 | 6 |
| | Vauniya | 472 | 3 | 454 | 4 |
| | Total | 10122 | 63 | 6956 | 67 |
| Northeast | Polonnaruwa | 1,091 | 7 | 812 | 8 |
| | Trincomalee | 311 | 2 | 188 | 2 |
| | Batticalao | 317 | 2 | 150 | 1 |
| | Ampara | 615 | 4 | 349 | 3 |
| | Total | 2334 | 15 | 1499 | 14 |
| South | Badulla | 685 | 4 | 308 | 3 |
| | Monaragala | 2,220 | 14 | 1,115 | 11 |
| | Hambantota | 261 | 2 | 112 | 1 |
| | Ratnapura | 427 | 3 | 353 | 3 |
| | Total | 3,593 | 22 | 1,888 | 18 |
| Total (Dry Zone) | | 16,049 | 100 | 10,343 | 100 |

[a]Dug-wells in the wet zone, which comprise less than 1 percent of the total, are not included.
*Source:* Agricultural Development Authority.

regions, our estimates differ from the number of ADA-supported dug-wells in the expected direction. It may be worth noting that, outside the northwest, Monaragala in the south records a relatively large number of agro-wells constructed with subsidies (table 7), which is detected by our sample as a relatively high density of agro-wells in minor schemes in the district (table 4).

As for pumps, two major pump manufacturers in Colombo estimated that there were about 150,000 pump units in use as of February 2000 in Sri Lanka, including the wet zone, and that the annual demand for engine-driven pumps for irrigation is around 8,000 (Sally 2000). The former figure compares reasonably with our estimate of 107,000 pumps in the dry zone alone, and the latter figure tallies with the annual addition of 7,000 to 8,000 irrigation pumps in the dry zone in recent years.[32] Considering that our estimate of total irrigation pumps includes those that were purchased in the past but not in use at present, our estimate falls on the side of underestimation than overestimation.

In any case, all these data suggest that our sample, though very small, succeeds reasonably well in showing the current configuration of agro-wells and irrigation pumps in the entire dry zone.

## *Diffusion Patterns over Time*

Table 8 presents changes over time in the numbers of agro-wells (lined dug-wells, unlined dug-wells and tubewells) and irrigation pumps in irrigation schemes of the dry zone. Their diffusion trends are depicted in figure 3. The incidence of agro-wells in the dry zone is of relatively short history. Lined dug-wells were first adopted in 1975 in the Hakwatuna

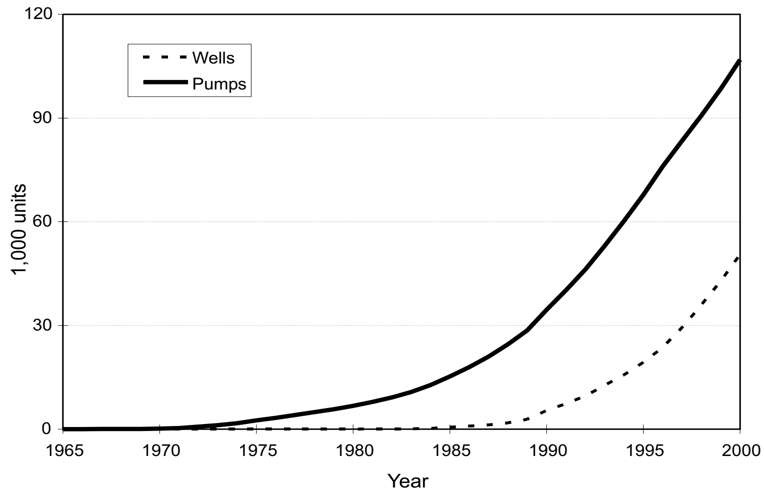
TABLE 8.
Numbers of wells and irrigation pumps in irrigation schemes in the dry zone of Sri Lanka,1970-2000[a].

| | Lined dug wells | Unlined dug wells | Tubewells | Irrigation pumps |
|---|---|---|---|---|
| | Number (in 1,000 units) | | | |
| 1965 | - | - | - | 0.0 |
| 1970 | - | - | - | 0.2 |
| 1975 | 0.0 | 0.0 | - | 2.5 |
| 1980 | 0.0 | 0.0 | 0.0 | 6.7 |
| 1985 | 0.4 | 0.0 | 0.1 | 15.2 |
| 1990 | 4.8 | 0.1 | 0.5 | 34.5 |
| 1995 | 13.9 | 2.1 | 3.2 | 67.8 |
| 2000 | 32.5 | 8.2 | 9.8 | 106.9 |
| | Difference (in 1,000 units/year) | | | |
| 1965-70 | - | - | - | 0.0 |
| 1970-75 | 0.0 | 0.0 | - | 0.5 |
| 1975-80 | 0.0 | 0.0 | 0.0 | 0.8 |
| 1980-85 | 0.1 | 0.0 | 0.0 | 1.7 |
| 1985-90 | 0.9 | 0.0 | 0.1 | 3.9 |
| 1990-95 | 1.8 | 0.4 | 0.5 | 6.6 |
| 1995-00 | 3.7 | 1.2 | 1.3 | 7.8 |

[a]Estimates are based on the data obtained in our survey.
*Notes*: - stands for none, and 0.0 have a value to the second place of decimal or later.

[32]On average, for the last 5 years, the number of irrigation pump units increased by 7,800 every year.

FIGURE 3.
Diffusion of agro-wells and irrigation pumps in the paddy command and highland areas of irrigation schemes in the dry zone of Sri Lanka, 1965-2000.




Scheme in the Deduru Oya basin among the sample major irrigation schemes, and in 1980 in a minor scheme in the Kala Oya basin among the sample minor schemes.[33] However, the diffusion of lined dug-wells in the dry zone, including the northwest, became significant only in the late 1980s, in particular, after 1989 when the ADA commenced the well-subsidy program.

The type of unlined dug-well found in the Mahaweli System H has an even shorter history of diffusion starting in the late 1980s, followed by the Hakwatuna scheme in the early 1990s. Tubewells first appeared in 1980 in a minor scheme in the Deduru Oya basin, and other minor schemes in the basin adopted them in the 1990s. Its diffusion in the Kirindi Oya Scheme in the south began after the mid-1990s. The first tubewell in the Tissawewa area appeared in 1991 and in the Yodawewa area in 1996, and the rate of diffusion in these areas has accelerated in the last few years.

Irrigation pumps have being in use before the use of agro-wells. Its earliest adoption by individual farmers among the sample schemes dates back to the mid-1960s and occurred in the Dewahuwa Scheme of the Kala Oya basin. But pumps owned by some agricultural cooperatives have been used for irrigation even earlier than that in the 1950s in the Ridi Bendi Ela Scheme of the Deduru Oya basin. In quite a few sample schemes, farmers insist that a series of severe droughts around 1970 triggered the adoption of irrigation pumps.[34] As shown in figure 3, the diffusion of pumps picked up toward the mid-1980s, and then further accelerated with the rapid spread of agro-wells.

[33]Madduma Bandara (1979) reports that most of the large-diameter agro-wells found in the northernmost part of the hard-rock areas in the dry zone were constructed between 1972 and 1977, though the earliest record of construction dates back to 1948.

[34]It seems that there was no special program, such as provision of subsidies, to promote pump diffusion in the 1970s, except for the usual bank loan schemes. Some farmers recall how only those who owned 2-wheel tractors were allowed to buy irrigation pumps during that time.

Agro-wells and irrigation pumps have thus spread simultaneously and rapidly since the mid-1980s (figure 3). This is reflected in the rate of increase as measured by the average annual increase in the number of units (table 8). In the case of lined dug-wells, the rate of increase also increased from 1,800 units per year in the early half of the 1990s to 3,700 units per year in the latter half of the 1990s. Similarly, for the same period, the rate leaped from 400 to 1,200 for unlined dug-wells, from 500 to 1,300 for tubewells, and from 6,600 to 7,800 for pumps. It should be noted, however, that the yearly rates of increase have been decreasing in recent years for lined dug-wells with pumps. This point shall be clarified in the section on investment that follows.

## Investment in Agro-Wells and Pumps

Estimated private investments by farmers in agro-wells and irrigation pumps are presented in table 9 and depicted in figure 4. It is estimated that the total private investment in wells and pumps is about Rs 0.8 billion at present, of which 55 percent is in lined dug-wells and 42 percent in pumps. Investments in unlined dug-wells and tubewells are negligible in terms of comparative value, mainly because of their cheap construction costs. The percentage share of the investment in lined dug-wells in the total private investment in irrigation has been increasing rapidly, exceeding 50 percent in 1997.

It should be noted that the investments for lined dug-wells in table 9 includes subsidies given to farmers by the government, donor organizations and NGOs, which should be considered as "public" investments. A rough adjustment for this can be made by assuming that the average percentage of farmers in major and minor sample schemes who received a Rs 30,000 subsidy per dug-well for their lined dug-well is 65 percent. As footnoted in table 9, the total amount of subsidies given to farmers is estimated to be Rs 85 million in 2000, or 12 percent of the total private irrigation investment in the year 2000.

The investments in agro-wells and pumps began to increase rapidly after the mid-1980s (figure 4). It is apparent that the commencement of the government subsidy program for lined dug-wells had significant impacts on farmer investments in pumps as well as in agro-wells. The rate of increase in investments, as measured by the average annual increase in investments, shows that the investment in pumps experienced the largest increase in the late 1980s (table 9).[35] However, the rate of increase has been declining since then. For lined dug-wells, the largest rate of increase in investment is recorded in the late 1990s, after a decline in investment from the late 1980s to the early 1990s. The investment has been at the same level since 1998. As observed in figure 4, there is a decrease in the rate of growth in the investment in agro-wells. Such a trend has been

[35]Because, in estimating investment, we apply the standard rates for costs of installing wells and pumps, the difference in table 9 is a conversion of difference in table 8 into value terms.

TABLE 9.

Private investments on agro-wells and irrigation pumps in irrigation schemes in the dry zone of Sri Lanka, in 2000 prices, 1970-2000[a].

| | Lined dug-wells[b] | | Unlined dug-wells | | Tubewells | | Irrigation pumps | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (Rs million) | (%) | (Rs million) | (%) | (Rs million) | (%) | (Rs million) | (%) | (Rs million) | (%) |
| Investment: | | | | | | | | | | |
| 1970 | - | - | - | - | - | - | 3 | 100 | 3 | 100 |
| 1975 | 0 | 1 | 0 | 0 | - | - | 32 | 99 | 32 | 100 |
| 1980 | 0 | 1 | 0 | 0 | 0 | 0 | 37 | 99 | 37 | 100 |
| 1985 | 35 | 26 | 0 | 0 | 0 | 0 | 96 | 73 | 131 | 100 |
| 1990 | 227 | 50 | 0 | 0 | 1 | 0 | 229 | 50 | 458 | 100 |
| 1995 | 209 | 41 | 4 | 1 | 5 | 1 | 290 | 57 | 509 | 100 |
| 2000 | 427 | 55 | 11 | 1 | 11 | 1 | 323 | 42 | 772 | 100 |
| Difference (Rs million/ year): | | | | | | | | | | |
| 1970-75 | 0.0 | | 0.0 | | - | | 5.8 | | 5.8 | |
| 1975-80 | 0.0 | | 0.0 | | 0.0 | | 1.0 | | 1.0 | |
| 1980-85 | 6.9 | | 0.0 | | 0.1 | | 11.8 | | 18.7 | |
| 1985-90 | 38.5 | | 0.1 | | 0.1 | | 26.7 | | 65.4 | |
| 1990-95 | -3.6 | | 0.8 | | 0.9 | | 12.2 | | 10.3 | |
| 1995-00 | 43.5 | | 1.3 | | 1.1 | | 6.6 | | 52.4 | |

[a]Estimates are based on the data obtained in our survey.

[b]Including subsidy. Assuming 65 percent of lined dug-wells are subsidized for the amount of Rs 30,000, the total amount of subsidy is estimated to be as follows:

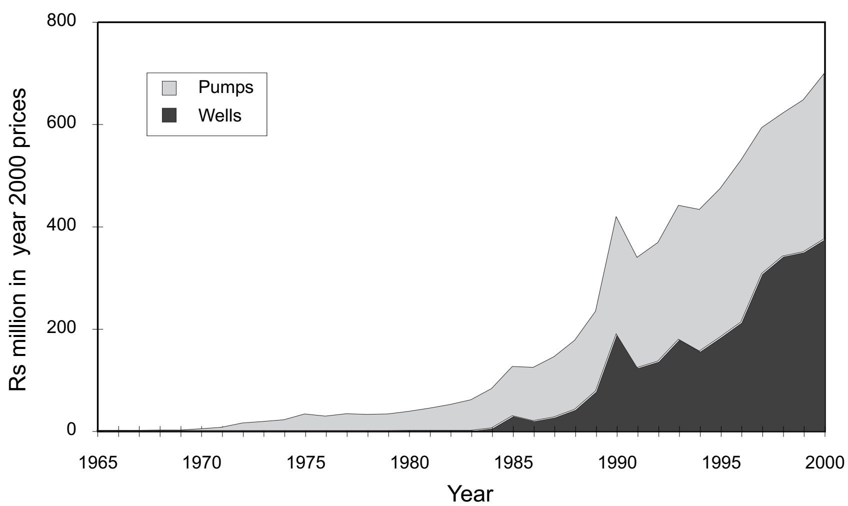
1980 Rs 0.1 million (0.3%)
1985 Rs 4.6 million (4%)
1990 Rs 26.8 million (6%)
1995 Rs 47.4 million (9%)
2000 Rs 84.9 million (11%)

where figures in parenthesis are the percentage of subsidy in the total investment on agro-wells and pumps.

*Notes:* - stands for none, and 0 have a value to the second place of decimal or later.

FIGURE 4.

Private investments in agro-wells and irrigation pumps of irrigation schemes in the dry zone of Sri Lanka, in year 2000 prices, 1965-2000.



brought about by the deceleration of the increase in lined dug-wells.

These findings may indicate that the "initial" diffusion phase wherein the investments increased at explosive rates is over for lined dug-wells and pumps, and it is moving toward a "matured" phase where investment is made just to replace abandoned or worn out agro-wells and pumps so that their working stock is kept constant. If their abandonment or replacement needs are taken into account, the working stock of lined dug-wells and pumps, seems to be increasing only slowly, if not decreasing.[36] In contrast, the diffusion of unlined dug-wells and tubewells appears to be still in their "initial" phase. Considering the random nature of our estimation, however, further careful studies are required to confirm whether the diffusion of lined dug-wells and pumps has reached the "matured" phase.

How large is the private investment in agro-wells and pumps compared to the public investment in irrigation? Starting from a nearly negligible percentage share around 1970, private investments in irrigation now comprise nearly 20 percent of the total irrigation investments (table 10). A reason for the share of private investments in the total irrigation investment increasing in the last decade and a half is the sharp decline in the total investments, which is due largely to the decline in the investments in construction of new irrigation schemes. By the mid-1990s, the private investments in agro-wells and pumps exceeded the operation and maintenance (O&M) expenditures for the existing irrigation schemes as a whole. Admittedly our estimations of standard rates for costs of installing agro-wells and pumps in estimating investment are approximate. It should be mentioned, however, that the estimates are sufficiently accurate to keep our statement invariant under possible sensitivity tests. The maximum and the minimum costs of installing agro-wells and pumps obtained in our surveys all fall within a range of 25 percent around the standard rates. So, even when we adopt the minimum cost rates for agro-wells and pumps, the private investment re-estimated for 1997 exceeds the public O&M expenditure with a wide margin.

TABLE 10.
Irrigation investment (Rs billion in 2000 prices) in Sri Lanka, by type of investment and their share in the total investment, 1970-97[a].

| | Public investment | | | Private investment[b] | Total | Share (%) in total investment: Public investment | | | Private investment | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | New construction | Rehabi-litation | O&M | | | New construction | Rehabi-litation | O&M | | |
| 1970 | 3.67 | - | 0.29 | 0.01 | 3.97 | 93 | - | 7 | 0 | 100 |
| 1975 | 4.13 | 0.02 | 0.47 | 0.03 | 4.64 | 89 | 0 | 10 | 1 | 100 |
| 1980 | 11.18 | 0.83 | 0.51 | 0.04 | 12.56 | 89 | 7 | 4 | 0 | 100 |
| 1985 | 10.24 | 1.67 | 0.57 | 0.11 | 12.59 | 81 | 13 | 5 | 1 | 100 |
| 1990 | 2.49 | 0.74 | 0.38 | 0.31 | 3.93 | 63 | 19 | 10 | 8 | 100 |
| 1995 | 1.00 | 0.88 | 0.41 | 0.49 | 2.78 | 36 | 32 | 15 | 18 | 100 |
| 1997 | 0.90 | 1.33 | 0.37 | 0.57 | 3.16 | 28 | 42 | 12 | 18 | 100 |

[a]Five-year averages centering on the years shown.
[b]Farmers' investments on agro-wells and irrigation pumps, subsidies inclusive.
*Source:* Data on public investments are from Kikuchi et.al. (2002).

[36]As mentioned earlier, the ratio of abandoned lined dug-wells is at least 10 percent. As to the usable life of an irrigation pump, farmers insist that it is more than 10 years, often lasting as long as 30 years. Assuming a 15-year lifetime and straight-line depreciation, the rate of depreciation per year is 6.6 percent. These rates can be compared to the investment-stock ratio in 2000 of lined dug-wells and pumps, which is 13 percent and 8 percent, respectively.

## Diffusion of Wells and Pumps in the Kalpitiya Peninsula

Kalpitiya Peninsula in Puttalam is famous for its productive vegetable farming, based on the intensive use of dug-wells, tubewells and irrigation pumps. The heavy reliance of vegetable farmers in this area on groundwater resources is worth mentioning, though this study targets only the agro-wells and pumps owned by farmers in dry-zone irrigation schemes.

The Kalpitiya Peninsula refers to the narrow corridor that forms the western coast of the Puttalam Lagoon stretching from the town of Mampuri in the south to the town of Kalpitiya in the north. This is an 1,800-hectare area of fertile upland cultivated by about 1,500 farmers who produce vegetables and other crops, such as red onion, chili, string bean, sweet potato and tobacco, the cultivation of which involves the use of water from agro-wells.[37] The type of agro-well these farmers have been using since long ago is an open dug-well 8 ft (2.4 m) in diameter and as shallow as 10 ft (3 m). In the past, water was lifted and irrigation done manually using pots of 4-gallon (15-liter) capacity. Pumps operated by diesel or kerosene engine began to appear around 1970 and diffused throughout the area by 1990.

In the mid-1990s, tubewells, 6-inch (15 cm) in diameter, 20-35 ft (6–10.7 m) in depth, with pumps driven by 1.5–2 HP electric motors, were introduced. Their use grew rapidly and by the end of the year 2000, about 40 percent of farmers in the area were using tubewells. Many farmers installed underground 2-inch (5-cm) pipe networks to distribute water to their fields. The pervasiveness of agro-wells and pumps in the Kalpitiya Peninsula is reflected in their high density: 82 for dug-wells, 33 for tubewells, and 115 for pumps, all per 100 ha of upland.

The irrigable area for a dug-well or a tubewell is about 1.2 ha. Groundwater conditions in the area allow year-round irrigation with maximum flexibility to farmers, and make it possible for them to practice innumerable combinations and rotations of a wide variety of crops at one time as well as over a period of time.

## Costs and Benefits of Wells and Pumps

The rapidity of the diffusion of agro-wells and irrigation pumps clearly implies high profitability of their use. In this section, the economic performance of agro-wells and pumps is examined. Throughout this section, costs and returns are all measured at year 2000 prices.

### *Changes in Cropping Pattern with Agro-Wells and Pumps*

As shown in table 5, more than 50 percent of agro-wells have been constructed in the highland and the rest in the paddy command area of irrigation schemes. It is also shown that the

[37] Groundwater aquifers in Kalpitiya are shallow coastal sand aquifers (see figure 1).

primary purpose of farmers in setting up agro-wells and pumps is to irrigate OFCs and, when necessary, to irrigate paddy as a supplement to surface water irrigation.

Before the adoption of agro-wells and pumps, in both major and minor irrigation schemes, the cropping pattern practiced in the command was either “paddy-paddy” in maha and yala seasons[38] when surface water was available in both seasons, and paddy in maha and fallow in yala when surface water was available only in the maha season. The only difference between major and minor schemes in this respect was that the cropping intensity (multiple cropping ratio) was generally higher in major schemes than in minor schemes. On average, the cropping intensity in major schemes was about 1.4 and in minor schemes it was 1.0 or less. A cropping intensity of less than 1.0 indicates that surface water is not sufficient to grow paddy in the entire command area even during the maha season. There were irrigation schemes where OFCs were planted in the yala season, but their extent was negligible despite government efforts to promote crop diversification.

The introduction of agro-wells and pumps changed the cropping pattern in the command area to one of higher cropping intensity by making it feasible to grow OFCs on hitherto fallowed paddy fields during the yala season. Water from agro-wells is used to supplement surface water during the maha season when there is a serious shortage of surface water. Except in such a situation, which arises more often in minor schemes, well water is used to irrigate OFCs in the yala season. Popular OFCs grown in the command with well water are chili, onion, various pulses, banana and many kinds of vegetables such as eggplant, cucumber, okra, bitter gourd, and brinjals (eggplant). Paddy is rarely cultivated with well-water irrigation during the yala season.

Crops grown in highland areas of irrigation schemes differ in major and minor schemes depending on the area of highland available for cultivation.[39] In small highland areas in major schemes, farmers grow OFCs during the maha season using well water, as they did even before the introduction of agro-wells and pumps. In addition to the common OFCs cultivated by farmers in major schemes, larger tracts of highland in minor schemes are cultivated with crops such as *kurakkan* (finger millet), maize and tobacco during the maha season. No significant cultivation could be practiced on highland during the yala season, in both major and minor schemes, before the adoption of agro-wells and pumps. Without irrigation it is difficult to grow crops in the climatic conditions of the dry zone during the yala season. The only exception is gingelly, which is cultivated in small tracts of highland during the yala season, particularly in minor schemes.

With agro-wells and pumps, the yala season cropping pattern in the highland has changed significantly in both major and minor schemes. Fallow or extensive cultivation with gingelly has been replaced by intensive OFC cultivation in the area irrigated by well water. The “irrigable area” of a well with pump being about 0.2–0.8 ha, an average major-scheme farmer who owns an agro-well in the highland may be able to irrigate more than the entire extent of his highland. The cropping intensity attained by an average minor-scheme farmer may range from 20 to 80 percent in the yala season. The variety of OFCs planted with well water in the highland in the yala season overlaps that of OFCs planted in the

[38]*Maha* is the wet agricultural season from September to March and *yala* is the dry agricultural season from April to August.

[39]The average highland area cultivated by a farmer is less than 0.2 ha in major schemes and 1.0 ha in minor schemes.

paddy command area. There is a remarkable similarity in the variety of OFCs grown with well water between major and minor schemes, among the irrigable areas of the different types of agro-wells and across river basins.

Table 11 shows the irrigation performance in the cultivation of a few selected OFCs irrigated by water pumped from agro-wells, rivers, canals and tanks. The first three cases listed in the table represent the ones with high performance observed in the sample irrigation schemes of our survey.[40] The fourth case illustrates the situation in the Kalpitiya Peninsula where the groundwater conditions are probably the best in the country. The fifth case, gingelly cultivated under rain-fed condition, indicates the decrease in income when OFCs irrigated by agro-well and pump replaced this traditional crop.

## *Cost of Well Construction and Pump Installation*

The cost of digging "dug-wells" could vary depending not only on the type of well but also on its depth, type of soil, etc. We estimate the cost according to the type of well constructed, using data obtained from extensive as well as intensive surveys.

**Unlined dug-well:** An open well is dug by using a machine shovel (locally called "bako"). As long as the well is not too deep, the digging is quite easy taking only a few hours to finish. It is necessary to maintain the depth by digging or de-silting using a machine shovel once in every three years or so. Using data obtained from the intensive survey, the cost of an unlined dug-well is estimated to be a function of well depth as follows:

$$C = \underset{(19.8)}{273.8}\,(\text{Depth})^2 \qquad (1)$$

$$R^2 = 0.555 \quad N = 19$$

where C = total digging cost (Rs), Depth = the depth of well (m), $R^2$ = the coefficient of determination, N = the number of observations, and the figure in parenthesis is t-ratio.

It is estimated that the digging cost increases progressively as a well becomes deeper.[41] The data on diameter of wells are available, but its inclusion does not improve the regression result. At the mean depth of 16 ft (4.88 m) among our sample schemes, the digging cost is estimated to be Rs 6,500. The cost obtained from the extensive survey Rs 5,600. For our cost-benefit analysis, we assume Rs 6,500 to be the construction cost of an unlined well. The maintenance cost per year is assumed to be Rs 580, based on the information received from farmers in the extensive survey.

**Lined dug-well:** After digging the well using a machine shovel, the inside surface of the well is lined with brick and cement, which is done manually. In case the depth of the well is beyond the reach of a machine shovel, further digging is done manually using a hoe, shovel and an iron pick. Digging a deep well requires about 60 person days of labor and 20-40 person days of mason's work. Once constructed, there is no need for de-silting a lined dug-well. The construction cost is estimated by dividing it into the cost digging and cost of lining. Data from the intensive survey give the following regression equations:

[40]The data for the first case in table 11 was obtained from Mahaweli System H. This is the case of best performance of well-pump irrigation among the sample irrigation schemes (except Kalpitiya that does not belong to any irrigation scheme). It should be noted that the irrigation performance of lined dug-wells in the northwest is far less than this level attained in System H with unlined dug-wells.

[41]The cost function of linear form also gives a significant result, but the goodness of fit is significantly less than the case of the quadratic form. The same is true of higher order functions.

TABLE 11.
Crops irrigated by wells and pumps, and irrigation performance[a].

| | Type | Crop irrigated | Number of cropping | Yield | Value-added ratio[b] | Income ratio[c] | Output price | Capacity[d] Irrigation | Rates | Data obtained in |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Well with pump | Big onion | x 1 in yala | 3.0 | 85 | 70 | 25 | 1 | 4 hrs/day for 75 days; 4 block rotation | System H and minor schemes in Kala Oya basin |
| 2 | Well with pump | Rice | x1 in yala | 2.1 | 80 | 70 | 8 | 2 | 18 hrs per irrigation; x24 per season | Minor schemes in Deduru Oya basin |
| 3 | Pump (river-lift) | Red onion | x1 in yala | 3.0 | 70 | 60 | 40 | 1.25 | 24 hrs per irrigation; x9 per season | Kirindi Oya Scheme |
| 4 | Well with pump | Red onion | x3 in year [e)] | 4.0 | 50 | 40 | 40 | 2 | 6 hrs/day for 65 days per season | Kalpitiya |
| 5 | Rain-fed | Gingelly | x1 in yala | 0.2 | 97 | 97 | 15 | -[f] | - | Minor schemes in the Dry Zone |

[a]Data are from our surveys.
[b]Gross value-added = total output value - current inputs.
[c]The ratio of farmers' income to total output value.
[d]Irrigated area by a set of well+pump (for #3, by pump alone).
[e]Assume that one additional crop of red onion can be grown by a tubewell with electric pump.
[f]Assume to be planted to 50 percent of area now irrigated by pump water.

$$C_D = 938.5\ (\text{Depth})^2 \qquad (2)$$
$$(17.7)$$
$$R^2 = 0.531 \qquad N = 27$$

and

$$C_L = 7{,}338\ \text{Depth} \qquad (3)$$
$$(19.8)$$
$$R^2 = 0.437 \qquad N = 31$$

where $C_D$ = the digging cost (Rs) and $C_L$ = the lining cost (Rs). $R^2$ = the coefficient of determination, N = the number of observations, and the figure in parenthesis is t-ratio.

For the digging cost, the quadratic form is the best fit, while the linear form is the best fit for the lining cost. As in the case of the unlined dug-well, the diameter of well gives no significant coefficient in both equations. With the typical depth of 20 ft (6.1 m), the digging cost and the lining cost are estimated to be Rs 35,000 and Rs 45,000, respectively. Thus the estimated total cost is Rs 80,000.[42] This estimate is comparable to the estimate obtained from the extensive survey, which is Rs 75,000. Using equations (2) and (3) The cost of constructing a well of 23-ft (7-m) depth, which is the average depth of wells in our sample schemes, is calculated to be Rs 98,000. This is also consistent with the fact that in the northwestern region of the dry zone, the farmers' rule-of-thumb estimate of the total construction cost of a lined dug-well is Rs 100,000. For a well of 40-ft (12.2-m), the deepest we came across in our surveys, the total cost is estimated to be Rs 230,000. For cost-benefit analysis, let us assume that the construction cost of a lined dug-well of 20-ft (6-m) depth is Rs 80,000 and that of a 40-ft (12.2-m) depth well is Rs 230,000.

**Tubewell:** A tubewell is installed by using a drilling (boring) machine. The boring cost depends on the depth as well as the diameter of the well. According to our extensive survey, in Kalpitiya Peninsula, it takes only 2 to 6 hours to drill a tubewell of 6-inch (15-cm) diameter and 25-ft (7.62-m) depth, at a cost of Rs 7,700.

In the Deduru Oya basin, a tubewell of 4-inch (10 cm) diameter and 24-ft (7.32-m) depth, the typical size in the basin, can be installed within a day at a cost as low as Rs 6,600. Rs 4,300 of this cost is for rental of the drilling machine and the balance (Rs. 2,300) is the cost of the 4-inch (10-cm) tube and labor.[43] There are well-established standard rates for drilling in this area, which are set according to the depth of drilling. The charge for the first 6 ft (1.8 m) is Rs 700, the second 6 ft is charged Rs 950, while the charges for the third and the fourth 6 ft are Rs 1,200 and Rs 1,450, respectively. Assuming the same rate of increase as for dug-wells, the boring cost for a tubewell of 60-ft (18.3-m) depth, which is the maximum depth of a tubewell in our sample schemes, is estimated to be Rs 18,250.

In the Kirindi Oya Scheme of the south, it costs only Rs 3,900 for installing a tubewell of 6-inch (15-cm) diameter and 30-ft (9.2-m) depth. Rs 2,500 of this cost is for machine drilling and the rest (Rs 1,400) is the cost of the 6-inch (15-cm) tube, 30 ft in length. Some farmers in this scheme drill their tubewells of about 15-ft (4.6-m) depth using a simple homemade drilling machine, which costs them only Rs 200, inclusive of iron material and welding. In this case, the installation cost of a tubewell of 6-inch (15-cm) diameter and 15-ft (4.6-m) depth is merely Rs 1,600, including the costs of drilling machine rental, 6-inch (15-cm) tube of 15-ft (4.6-m) length and 2 person-days of labor.

For cost-benefit analysis, we assume a cost of Rs 6,600 for a tubewell of 4-inch (10-cm) diameter and 24-ft (7.32-m) depth, and

[42]Wijesinghe and Kodithuwakku (1990) estimated that the construction cost of an agro-well of 16-ft (4.8-m) diameter and 25-ft (7.62-m) depth is Rs 25,000, which is about Rs 80,000 at year 2000 prices. Abeyratne (1993) reports that the construction cost ranges from Rs 30,000 to Rs 60,000, or from Rs 61,000 to Rs 123,000 at year 2000 prices.

[43]In this report, labor inputs are valued at the agricultural wage rate of Rs 325 per day.

Rs 30,200 for a tubewell of 4-inch (10-cm) diameter and 60-ft (18.3-m) depth.

**Pumps**: Various sizes of pumps are used by farmers for lifting water from agro-wells, rivers, canals and tanks. The number of pumps in the two sample villages in our intensive survey is shown in table 12, by horsepower of pump. The power of diesel-operated pumps range from 2 to 6 HP, and more than 80 percent of the pumps are of 3–4 HP. Here, we consider 3.5 HP pumps as the typical power of pumps used by farmers. Though the price of a pump of this power also varies depending on the brand, the most common price at present is Rs 32,000.[44] Aside from diesel-operated pumps, farmers in Kalpitiya Peninsula use electric pumps of 1.5 HP and 2 HP for pumping water from tubewells. The prices of these electric pumps are Rs 14,500 and Rs 22,000, respectively.

Operation and maintenance costs for diesel pumps are estimated by assuming a fuel efficiency of one-hour operation per liter of diesel and the use of 3 liters of oil per crop season for greasing, with unit prices of Rs 15 per liter and Rs 100 per liter, respectively. In the case of electric pumps, the cost of electricity for operation in one season (2 1/2 months) is assumed as Rs 3,000. Maintenance of electric pumps is considered as unnecessary.

**Pipes for water distribution**: Except when pumped water is distributed from paddy to paddy, farmers use PVC pipes, usually of 2-inch (5-cm) diameter, to carry water to their fields. Typically, the total length of a pipe necessary to carry water from a dug-well to irrigate OFCs in a field of about 0.8 ha in extent is 200 ft (61 m), which would cost about Rs 6,400 at the unit pipe price of Rs 32 per foot of pipe. In the case of lifting water from rivers, canals and tanks, the length of pipe may need to be much longer. A farmer in the Kirindi Oya basin, interviewed in the extensive survey, said that he uses a 2-inch (5-cm) pipe 1,200 ft (365 m) long (costing Rs 38,400) to convey water from the river to his fields and to distribute within his fields. In the Kalpitiya Peninsula, farmers use underground 2-inch (5-cm) pipe networks to irrigate OFCs in the upland, the extent of which is about 0 8 ha per farmer. The total length of a network is approximately 200 ft. (61 m) and the total investment in it, including a labor input of 3 person-days for installation, amounts to Rs 3,600.[45]

TABLE 12.
The number of pumps by power in two intensive survey villages in the northwest.

| | System H | | Minor Scheme | | Total | |
|---|---|---|---|---|---|---|
| Power | No. of pumps | % | No. of pumps | % | No. of pumps | % |
| 2 HP | | | 3 | 7 | 3 | 5 |
| 3 HP | 4 | 27 | 3 | 7 | 7 | 13 |
| 3.5 HP | 11 | 73 | 17 | 41 | 28 | 50 |
| 4 HP | | | 10 | 24 | 10 | 18 |
| 5 HP | | | 4 | 10 | 4 | 7 |
| 6 HP | | | 4 | 10 | 4 | 7 |
| Total | 15 | 100 | 41 | 100 | 56 | 100 |

[44]There are three popular brands, Kubota, Honda and Robin. The first two are Japanese brands and the last is a Chinese brand. Of these, the price of a Kubota or a Robin pump is Rs 32,000, and that of a Honda pump is Rs 40,000.

[45]The price of PVC pipe used for this underground network is Rs 13 per foot, which is much less than that used on the ground surface.

## Rates of Return to Wells and Pumps

We assess the rates of return to farmer investments in various types of agro-wells and irrigation pumps by estimating the internal rate of return (IRR) that satisfies the following formula:

$$C = \sum_{i=1}^{n} (R-c) / (1+r)^i = (R-c) \{[(1+r)^n - 1] / [r (1+r)^n]\} \qquad (4)$$

Where:

C = investment cost on well and pump,

R = increase in gross value-added or in net income due to the investment,

c = operating and maintenance cost of well/pump,

r = internal rate of return,

n = the usable life of the well/pump (assumed to be 15 years).[46]

R is estimated by deducting the gross value-added generated from crops grown before the introduction of wells with pumps from the gross value-added generated from new crops after the introduction. Farmer's net income is obtained by deducting capital depreciation of the well and pump from the farmer's gross income, which is defined as total output value less paid-out costs. The rate of return based on increase in gross value-added can be considered as the social rate of return, while the rate of return based on the increase in farmer's net income is the private rate of return.

Table 13 summarizes the results of estimations made for eight different cases of well-pump investment. Since water from wells is almost always lifted using either diesel or electric pumps, the estimation is made for the combined investment in a pump and a well, except for case 7, which is for a pump for lifting river water. For the first seven cases, the pump used for lifting water is assumed to be a 2-inch (5-cm) diesel pump of 3.5 HP. In the last case, we assume the use of a 2-inch (5-cm) electric pump of 1.5 HP.

Both social as well as private rates of return are shown in table 13. Needless to say that the investment in well and pump is made by farmers, and their investment decisions depend on the private rate of return to the investment. The rate of return to the farmer differs from that to society. Criteria for judging whether investments in well and pump are economically viable are also different for farmers and society. A criterion popularly adopted among international donor agencies for investments in public infrastructure, such as investments in construction and rehabilitation of gravity irrigation systems, is whether the IRR of these investments exceeds 10 percent. Ten percent is a typical interest rate adopted for public international loans and it is considered as a measure of opportunity cost to society of such funds for public investments. All the estimated social IRRs in table 13 far exceed this threshold interest rate, which makes it clear that investments in agro-wells and pumps generate positive benefits to society, even for the case with the lowest level of IRR.

However, this does not necessarily mean that the well and pump investments are all satisfactorily profitable to farmers. The criteria for farmers' investments must be the opportunity costs to them, not that to the society at large, of their investment funds. If farmers mobilize investment funds from their own savings, the opportunity cost of the funds might be the interest rate of commercial banks for saving deposits, which is about 12 percent per year. If farmers have to finance the funds by borrowing, the rate of return to their investment must exceed the interest rate of that borrowing.

[46]A 15-year life span for a dug-well, tubewell and pump may sound too long, particularly for a pump. However, in many cases, farmers have been using irrigation pumps for more than 20 years.

TABLE 13.
Internal rate of return (IRR) for 8 cases of well-pump investment

| | | | Specifications | | | | IRR (%) [a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Well | | Pump [b] | | | | |
| | | Lined/ Unlined | Diameter | Depth | | Crop grown [c] | Social | Private | With subsidy |
| 1 | Dug-well+pump | Lined | 20 ft | 20 ft[d] | 2" diesel 3.5HP | B onion (row 1) | 56 | 36 | 49 |
| 2 | Dug-well+pump | Lined | 20 ft | 30 ft[d] | 2" diesel 3.5HP | B onion (row 1) | 26 | 11 | 13 |
| 3 | Dug-well+pump | Unlined | 20 ft | 16 ft[e] | 2" diesel 3.5HP | B onion (row 1) | 150 | 110 | - |
| 4 | Tubewell+pump | - | 4" | 24 ft[f] | 2" diesel 3.5HP | B onion (row 1) | 154 | 114 | - |
| 5 | Tubewell+pump | - | 5" | 60 ft[h] | 2" diesel 3.6HP | B onion (row 1) | 112 | 81 | - |
| 6 | Tubewell+pump | - | 4" | 24 ft[f] | 2" diesel 3.5HP | Rice (row 2) | 36 | 22 | - |
| 7 | Pump (river-lift) | - | - | - | 2" diesel 3.5HP | R onion (row 3) | 137 | 110 | - |
| 8 | Tubewell+pump | - | 6" | 25 ft[g] | 2" electric 1.5HP | R onion (row 4) | 588 | 460 | - |

[a]Social rate of return based on gross value added and private rate of return based on the increase in farmers' income. "With subsidy" is the private rate of return with a government subsidy for dug-well of Rs 30,000.

[b]Price of pump: Rs 32,000 for Kubota/Robin, and Rs 14,500 for electric pump. Also assume that for Cases 1 through 5, 200 ft long 2" PVC pipe Rs 32 per foot except case 7, Rs 13 per foot for case 7 is used for water distribution to the fields, and 1,200 ft 2"PVC tube (Rs 32/ft) for Case 6. Fuel consumption of a diesel pump is assumed to be 1 litre (Rs 15/l) for 1 hr operation, and 4 litres of lubricating oil (Rs 120/per litre) are required per season.

[c]For details, see Table 11*. Row numbers refer to the corresponding row numbers in Table 11. For cases 1 through 6, assume gingelly (row 5 in Table 11) as the crop grown under the rain-fed condition.

[d]The cost of digging and lining of a dug-well is estimated from equations (2) and (3).

[e]The digging cost of an unlined dug-well: Rs 5,600. Including the cost of 200 ft 2" pipe for water distribution, the total cost is Rs 12,000. Maintenance digging cost of Rs1,750, required every three years, is included as a part of operation and maintenance cost.

[f]The digging cost: Rs 13,000, including the cost of 200 ft 2" pipe for water distribution.

[g]The digging cost: Rs 11,300, including the installation cost of an underground water distribution system using a 200 ft long 2" PVC pipe.

[h]The digging cost: Rs 30,200, including the cost of 200 ft 2" pipe for water distribution.

Although there are numerous lending sources, including government lending institutions, commercial banks, and various informal moneylenders, farmers' access to these sources is rather limited.

The typical interest rate of development loans for which the government grants concessions is 12-20 percent per year, but the availability of such funds to farmers is limited. Because of the difficulty in providing collateral, loans from commercial banks that lend with collateral at an interest rate of 15-25 percent per year are seldom available to farmers. It may not be too difficult, but not so easy either, for farmers to obtain loans without collateral from commercial banks with interest rates ranging from 25 to 35 percent per year. There are only a very few successful credit cooperatives in rural areas, but where they exist, they offer loans to farmers at an interest rate of 2.0-2.5 percent per month, or 27-34 percent per year. Lending sources that farmers have easy access to are unregistered moneylenders in rural areas, but their interest rates are as high as 5-10 percent per month, or 80-200 percent per year.[47]

Such a configuration of rural financial markets suggests that the opportunity cost of investment funds to farmers is 12 percent or higher. Depending on the financial markets that farmers are actually exposed to, the threshold interest rate could be from 12 percent to 80 percent, or even higher. In many cases, the criteria for farmers in deciding whether or not to invest are definitely higher than for society at large.

In table 13, the first two cases refer to investment in a lined dug-well with pump. The difference between the two cases lies in the depth of the well; 20 ft (6 m) for case 1 and 40 ft (12.2 m) for case 2. For a lined dug-well of 20-ft (6-m) depth, the social IRR is estimated to be 56 percent. Compared to the social opportunity cost of 10 percent, the investment in dug-wells with pumps is socially very profitable. The private IRR for this case is 37 percent. Even if high risks inherent in well investment and in OFC cultivation are taken into consideration, it could be said that this level of rate of return to farmers is sufficiently high to make repayment of loans without collateral extended from commercial banks possible. If we take into account the subsidy of Rs 30,000[48] given to a lined dug-well, the private IRR increases to nearly 50 percent. The depth of the great majority of lined dug-wells is 20 ft (6 m) or less, which means that the private IRR, when a subsidy is provided, is higher than this level in many cases. Such high rates of return to farmers explain the great proliferation of lined dug-wells in the northwestern part of the dry zone in the last decade.

As we have already observed, however, the cost of digging a lined dug-well increases progressively as it becomes deeper. This means that the economic viability of a lined dug-well decreases quickly as the well becomes deeper. If the depth of a dug-well is 40 ft (12.2 m), the social IRR decreases to 24 percent and the private IRR to 9 percent. The investment is still economically viable to society, but the incentive for farmers to make this investment is totally inadequate. A subsidy for the well increases the private rate to 11 percent, but with the high risks involved this level of private profitability would scarcely warrant farmers investing in this opportunity. The benefit of a dug-well with pump

[47]It is not rare to find usurious moneylenders in rural areas, who charge interest rates of 20 percent per month, or 800 percent per year, but these high-interest loans are usually taken by farmers for urgent domestic needs.

[48]The ADA subsidy for a lined dug-well, since 1999. It was Rs 15,000 during 1989-91 and Rs 20, 000 during 1992-98.

was estimated in the case of very favorable groundwater conditions (table 11). For less favorable cases, the economic performance of this well-pump investment could be far less than the level assumed here. For such cases, even the economic viability to society could be easily negated.

Such results are consistent with our finding that there are no lined dug-wells deeper than 40 ft (12.2 m), and that there are many lined dug-wells that are left unused. At least one out of ten lined dug-wells in the dry zone, including the northwest, are in a state of abandonment, and in some schemes 50 percent to 100 percent of the wells are unused. On the other hand, the number of lined dug-wells has been increasing. These facts suggest that, while investments in lined dug-wells can attain a moderate level of rate of return in areas with favorable groundwater conditions, there are many other areas where the use of lined dug-wells is not economically viable, socially as well as privately. The relatively low level of economic performance of a lined dug-well with pump thus underlies the observation that the “initial” diffusion phase of lined dug-wells with pumps is over, and is now entering into the “matured” phase.

Case 3 in table 13 refers to an unlined dug-well with pump, which is commonly found in some parts of Mahaweli System H and in other major irrigation schemes in the northwest. Case 4 refers to a tubewell with pump, usually found in minor irrigation schemes in the Deduru Oya basin. The investment in well-with-pump in these cases is economically profitable; not only the social IRR but also the private IRR is more than 100 percent. Even if risks are taken into account, this level of private IRR would be more than sufficient to induce farmers who are exposed only to the informal money market to invest in a well with pump. Even for case 5, where the depth of a tubewell is at 60 ft (18.3 m), the deepest case we came across in our extensive survey, the private IRR is more than 80 percent. Such high rates of return to farmers have been the impetus for the rapid diffusion of unlined dug-wells and tubewells in the northwest, under the sole initiative of farmers with no government intervention whatsoever.[49]

It is interesting to observe that in case 6, similar to case 4 except that the crop is paddy, the results are much inferior to those of case 4. Similar results are obtained if the estimation is made for the case of unlined dug-wells with rice as the crop. It should be noted that the level of rice yield assumed in the estimation is 5.2 t per ha (100 bushels per acre), about 50 percent higher than the average yield in minor irrigation schemes. Even with such a high yield level, the IRRs are far less impressive than those with high-value OFCs. Such estimation results come about partly because of the low price of paddy at present (a price of Rs 8 per kg is assumed), and partly because of the heavy water requirement for paddy cultivation. As the possibility of conjunctive use of pumped water with surface water becomes less, the IRR with rice as the crop declines quickly. This is the main factor that underlies the fact that the overwhelming majority of farmers with agro-wells use the pumped water for OFC cultivation rather than for rice cultivation.

Case 7 examines the economic performance of pumps used for lifting water from rivers, canals and tanks for OFC cultivation. Investment costs being cheap, the private IRR is high enough to induce farmer investment. As long as a sufficient amount of water is available within a reasonable distance for pumping, farmers will always be tempted to invest in pumps.

[49]While interviewing farmers, one can recognize the clear difference between farmers who invested in lined dug-wells and those who invested in unlined dug-wells or tubewells, in the way they answer the question, “How profitable is the investment on an agro-well?” The former would say “okay” or may even sound somewhat resentful, whereas the latter would category reply positively and enthusiastically.

The final case study is for a tubewell with electric pump in the Kalpitiya Peninsula where, investment and running costs, including costs of well-boring, electric pump, and electricity for operating the pump, are cheapest among the cases in table 13. Also, the use of groundwater by means of a tubewell and electric pump enables farmers to grow high-value OFCs such as red onion three times a year, providing them with a high income. The combined result is an extremely high rate of return to the investment.[50]

As far as we have observed in our surveys, the use of electricity as a source of power for lifting water is confined to the Kalpitiya Peninsula.[51] The underdeveloped state of rural electrification in Sri Lanka may explain this nonexistence of electric pumps in irrigation schemes in the dry zone. An electric pump is cheaper than a diesel-operated one and so are the running costs. If electricity became available to farmers in irrigation schemes, the rate of return to investment on well with pump would improve. In fact, one of the reasons for the rapid diffusion of agro-wells and pumps in India over the past two decades or more is the promotion of rural electrification, which has made it possible for farmers to use electricity for lifting water. Electricity being heavily subsidized by the Indian government, the use of electric pumps resulted in high rates of return to the investment in agro-wells and pumps (Shah 1993).

How better will be the economic performance of the investment in agro-wells and pumps if farmers are able to use electricity as the source of power for pumping water? The private IRR of a lined dug-well of 20-ft (6-m) depth, re-estimated under the assumption that the diesel pump for case 1 in table 13 can be replaced by an electric pump used in the Kalpitiya Peninsula, is 48 percent without a subsidy for the pump and 68 percent with a subsidy. Similarly, for case 2, with a lined dug-well of 40-ft depth, under the same assumption, the private IRR improves to 13 percent and 16 percent, respectively. The availability of electricity certainly improves the economic performance of lined dug-wells with pumps, but the degree of improvement is not so impressive, particularly for deep wells.

## Concluding Remarks

In this report, we have investigated the pattern, extent and causes of the spread and use of agro-wells and pumps in irrigation in the traditional villages and irrigated settlement schemes in the dry zone of Sri Lanka. The key findings of the study and their implications are summarized below.

1. Agro-wells, defined as wells used at least partially for agriculture, are of three types: lined dug-well, unlined dug-well, and tubewell. The government, through subsidies, since 1989, has promoted the establishment of open lined wells, whereas the diffusion of unlined dug-wells and tubewells have been

[50]In the case of the Kalpitiya Peninsula, only one-third of the gross value-added or income is taken into account as the return to the investment on tubewell and electric pump, with the other two-thirds assumed to be foregone. Should there be no foregone income, the private IRR of the investment in tubewell and electric pump in Kalpitiya Peninsula would exceed 1,000 percent with a wide margin.

[51] In some areas in the dry zone, electric pumps are used in domestic wells.

through the initiatives of farmers. With few exceptions, farmers lift groundwater from agro-wells with the use of small pumps operated with diesel or kerosene. Thus, in most cases, wells are used with pumps. But, there are instances where farmers use pumps to lift surface water from rivers, canals and tanks rather than from wells. As a result, the diffusion of pumps is greater than that of agro-wells. Electric irrigation pumps, which are popular in other parts of South Asia, are limited only to a single area in the northwestern dry zone where there is relatively easy access to the main grid. There are hardly any electric pumps in the irrigation schemes in the dry zone.

2. The diffusion of agro-wells is not uniform over river basins, study regions, and districts, and across major and minor irrigation schemes. A heavy concentration of lined dug-wells is found in the northwestern part of the dry zone, especially in the Anuradapura and Kurunegala districts, and particularly in the Malvathu Oya and the Kala Oya basins. Unlined dug-wells are densely diffused in some major schemes in the Kala Oya basin and in the Deduru Oya basin. Tubewells are widespread in the minor irrigation schemes (with a command area of less than 80 hectares) in the Puttalam District, the Deduru Oya basin in the northwestern province and in the tail-end area of the Kirindi Oya Scheme in the south. The rate of diffusion of all three types of agro-wells among farmers in major and minor irrigation schemes in the northwest is estimated to be between 8 and 10 per 100 farmers. About 16 percent of farmers in major and minor schemes in the northwest and the south own irrigation pumps.

3. Open dug-wells are typically shallow, and are 4-8 m deep. There is a high possibility of agro-wells being uneconomical, abandoned or left unused if the depth exceeds this range. Tubewells are also shallow in general, but there are some that are 13-20 m deep. The majority of pumps used for lifting water for irrigation are of 3-4 HP with 2-inch (5-cm) pipe. More than 50 percent of agro-wells are located in the nonirrigable highland and the rest in the irrigated areas of the schemes. The majority of farmers who own agro-wells and pumps use pumped water to irrigate non-paddy crops in the dry or yala season. Typically, with agro-wells and pumps, the cropping pattern in the yala season changes from minimal cultivation or the cultivation of low-value, drought-resistant crops on an extensive scale to the intensive cultivation of high-value crops such as onion, chili and banana. A typical agro-well can irrigate 0.2 to 0.8 ha. This results in an increase in the yala season cropping intensity from 20 to 80 percent in the command area of major schemes and in the highland of minor schemes.

4. A salient feature of agro-wells in Sri Lanka, compared to other South Asian countries, is the general shallowness of the wells. Consequently, low horse-power pumps are used to irrigate small areas. This may explain another specific feature in the Sri Lankan groundwater sector that, except for isolated cases of pump rental markets, water trading is virtually nonexistent

5. Historically, the diffusion of pumps preceded the diffusion of agro-wells by about a decade. The introduction of irrigation pump units by the government or cooperatives dates back to the 1950s or even further and was confined to certain government established irrigation schemes. The diffusion of pumps among individual farmers, however, began in the early 1970s, triggered by a series of severe droughts. With trade liberalization beginning in the late 1970s, there were more pumps available in the

market at prices affordable to farmers. This too was an important contributory factor in the diffusion of pumps. The use of all three types of agro-wells by farmers began around 1980, but their diffusion became significant in the early 1990s. The diffusion of lined dug-wells accelerated in 1989 when the government launched a subsidy program to promote agro-wells.

6. The total number of agro-wells in the irrigation schemes in the dry zone, by the end of 2000, is estimated to be 50,000, of which 32,000 (64%) are lined dug-wells, 8,000 (16%) are unlined dug-wells and 10,000 (20%) tubewells. About 80 percent of these agro-wells is found in the northwest dry zone, 20 percent being in the rest of the dry zone. Thirty-five percent of the agro-wells is in the major schemes and 65 percent in the minor schemes. The number of pumps is estimated to be 100,000, and 54 percent is in the northwest and 46 percent in the northeast and the south. Thirty six percent of the pumps is in the major irrigation schemes and 64 percent in minor irrigation schemes.

7. The total investment in agro-wells and pumps made by farmers is estimated to be Rs 0.8 billion in the year 2000 at current prices. Of this amount 55 percent is investment in lined dug-wells and 42 percent in pumps.Investment in unlined dug-wells and tubewells each constitutes only 3 percent of the total farmer investment in agro-wells and pumps, partly because of the cheap installment cost of the former. By the late 1990s, the private investment in agro-wells and pumps exceeded the total public expenditure for the operation and maintenance of all existing major irrigation schemes in the country. At present, it is estimated that the private investment in agro-wells and pumps constitutes as much as 20 percent of the total investment and expenditure in the irrigation sector.

8. The private internal rate of return to the investment in lined dug-wells of 20-ft (6-m) depth is estimated to be 37 percent. This level of the rate of return is sufficient to induce farmer investment, regardless of the high opportunity costs of the investment funds to farmers. As the depth of lined dug-well increases, however, the economic performance of the investment is eroded. If the depth is 40 ft, (12.2 m), the private rate of return is as low as 9 percent without a subsidy for the well and 11 percent with a subsidy, which is far below the level that would induce farmers to invest.

9. The private rate of return to the investment in an unlined dug-well and pump is estimated to be more than 100 percent, and so is the private rate of return to the investment in a tubewell of average depth. The investment in a pump for lifting water from rivers, canals, and tanks could also give a private rate of return of 100 percent or more.

10. These estimates of the rate of return to the investment in agro-well with pump suggest that unlined dug-wells, tubewells, and pumps for lifting surface water have prospects for further diffusion. The diffusion of lined dug-wells, which has the lowest rate of return to farmers among three types of agro-wells, will continue, but only in areas with favorable groundwater conditions that allow a depth of a well to be 20 ft (6 m) or less. To the extent that unlined dug-wells and tubewells can replace lined dug-wells, even in areas with favorable groundwater conditions, unlined dug-wells and tubewells will become the dominant types of agro-well.

11. On the basis of the findings of the study we argue that, particularly in the coastal areas with sandy soils, the dominant type of agro-well in the future will be tubewells, as in India and Bangladesh. The basis of this inference is simple. Although, at present, the

economic performance of unlined dug-wells is high, its diffusion is confined to areas with a shallow underground water table. As the depth increases, not only the cost of digging progressively increases but also the cost of de-silting would become prohibitively high. In the case of tubewells, the cost escalation in relation to the depth of well is not as progressive as in the case of an open dug-well Therefore, high rates of return to tubewell investment could be sustained at a depth of 60 ft (18.3 m) or even more. Hence, where there is sufficient groundwater and favorable soil conditions to install tubewells, their high economic performance would make them dominate other types of agro-wells. However, in the predominantly hard rock subsurface found in much of Sri Lanka, the potential for expansion of tubewells is much more limited. Furthermore, the limited market demand for high-valued crops may serve as a constraint to future expansion.

12. The government, donor agencies and NGOs extend subsidies, both as grants and as concessionary loans, to help farmers in constructing lined dug-wells. Subsidies are socially desirable as long as they are utilized to construct agro-wells, which are privately unprofitable but socially profitable and feasible. However, it would be very difficult to ensure that subsidies are provided only to appropriate cases, since the range that subsidies can convert socially profitable but privately unprofitable cases to privately profitable ones is rather limited and narrow. In most cases the private profitability of agro-well construction is high enough to do without subsidies. However, in some other cases it is privately unprofitable even if they are subsidized. In the cases of unlined dug-well and tubewell with favorable groundwater conditions, a subsidy is generally not necessary.

13. The shallowness of agro-wells established by farmers suggests that groundwater aquifers are linked with the flow of surface water in river basins and in the respective irrigation schemes. Unlike other South Asian countries, so far there have been few reports that suggest agro-well development leads to the depletion of groundwater. For the conjunctive use of surface water and groundwater to be efficient and equitable, a basin-wide joint management system for surface water and groundwater would be appropriate.

14. The proliferation of agro-wells and pumps gives farmers more discretion over water use and thereby enhances farmers' individualistic behavior. On the other hand, the government policy is to promote farmers' cooperation and collective actions through farmer organizations, especially for O&M of irrigation schemes. The reconciliation of these two seemingly conflicting strategies for the development of irrigated agriculture will be an important policy issue in the future.

15. In our extensive field survey, we came across few cases that showed an overt deterioration of groundwater resources due to the diffusion of agro-wells. As pointed out by Maddduma Bandara (1977b, 1984) and Panabokke (1998b), the groundwater resources in Sri Lanka, as in many other countries in South Asia, are limited. It should be remarked that the type of extensive survey we conducted is not an appropriate method to collect information on detailed groundwater conditions and the potential for further exploitation. This study, therefore, leaves many critical questions unanswered, such as the relationship between agro-well diffusion and hydrological conditions, and the sustainability of groundwater use in the areas where we found that the diffusion of agro-wells is significant. These are questions that should to be studied carefully in the future.

# Appendix

APPENDIX TABLE 1.
Major irrigation schemes surveyed (as of Dec. 2000 - Jan. 2001) [a].

| River basin | Name of scheme | Farmer organization | Location in the system | District | No. of farmers | Area in acres[b] Com-mand | High-land | No. of dug-wells | No. of tube-wells | No. of pumps |
|---|---|---|---|---|---|---|---|---|---|---|
| MalvathuOya | Mahakanadarawa | Track 4 G | LB Tail | Anuradhapura | 37 | 74 | 74 | 6 | 0 | 7 |
| | | Samagi | RB Tail | Anuradhapura | 80 | 160 | 100 | 14 | 0 | 20 |
| | | Unknown | RB Tail | Anuradhapura | 243 | 486 | 364 | 80 | 0 | 40 |
| Kala Oya | Rajangana | Wijeya | RB Tail | Anuradhapura | 200 | 400 | 100 | 0 | 0 | 50 |
| Kala Oya | Dewahuwa | Tract 3 | MC Top | Anuradhapura | 89 | 445 | 237 | 2 | 0 | 0 |
| | | Tract 9 | MC Tail | Anuradhapura | 45 | 225 | 136 | 25 | 0 | 30 |
| Mi Oya | Inginimitiya | Mahausuwewa | LB Mid | Puttalam | 608 | 894 | 500 | 6 | 0 | 30 |
| Mi Oya | Radawi Bendi Ela | East | Mid | Puttalam | 77 | 250 | 350 | 5 | 0 | 10 |
| Deduru Oya | Ridi Bendi Ela | Balagollagama | MC Top | Kurunegala | 300 | 600 | 300 | 0 | 0 | 5 |
| Deduru Oya | Hakwatuna | Thalakolawewa | LB Top | Kurunegala | 105 | 350 | 50 | 80 | 0 | 80 |
| | | Dagama | LB Mid | Kurunegala | 130 | 400 | 100 | 8 | 0 | 10 |
| Deduru Oya | Kimbulwana | No. 7 | RB Tail | Kurunegala | 65 | 175 | 70 | 1 | 0 | 10 |
| | | No. 1 | RB Top | Kurunegala | 70 | 140 | 70 | 0 | 0 | 25 |
| Deduru Oya | Batalgoda | Wadupota | MC Top | Kurunegala | 50 | 70 | 40 | 0 | 0 | 0 |
| | | Seeradunne | MC Mid | Kurunegala | 175 | 400 | 200 | 2 | 0 | 15 |
| Mahaweli | Minneriya | No. 2 | MC Top | Polonnaruwa | 250 | 800 | 400 | 7 | 0 | 40 |
| | | No. 15 | MC Tail | Polonnaruwa | 216 | 648 | 432 | 4 | 0 | 10 |
| | | No. 19 | Anicut Top | Polonnaruwa | 260 | 1,600 | 300 | 40 | 0 | 10 |
| Mahaweli | PSS | LB-RB2 Laksha Uyana | LB MC Top | Polonnaruwa | 350 | 260 | 156 | 0 | 0 | 15 |
| | | LB 313 Kegarugama | LB MC Mid | Polonnaruwa | 350 | 720 | 500 | 4 | 0 | 15 |
| | | LB 313 Somapura | LB MC Tail | Polonnaruwa | 45 | 225 | 150 | 5 | 0 | 11 |
| | | LB-D1-RB12-300 | LB D1 Tail | Polonnaruwa | 250 | 250 | 200 | 1 | 0 | 20 |

(Continued)

APPENDIX TABLE 1 (CONTINUED).

| River basin | Name of scheme | Farmer organization | Location in the system | District | No. of farmers | Area in acres Com-mand | High-land | No. of dug-wells | No. of tube-wells | No. of pumps |
|---|---|---|---|---|---|---|---|---|---|---|
| Kirindi Oya | Dambewewa | FO No1 Samagi | MC Top | Monaragala | 60 | 60 | 100 | 0 | 0 | 6 |
| Kirindi Oya | Kirindi Oya | RB Tract 1 DC5 | RB Top | Hambantota | 226 | 565 | 113 | 7 | 0 | 75 |
| | | RB Tract 5 DC1-2-3 | RB Mid | Hambantota | 150 | 375 | 75 | 1 | 0 | 10 |
| | | RB Tract 6 DC1-2 | RB Tail | Hambantota | 268 | 676 | 134 | 0 | 0 | 10 |
| | | Waladora-Suhanda | Tissawewa | Hambantota | 130 | 800 | 300 | 0 | 15 | 10 |
| | | Yodawewa D2-5 | Yodawewa | Hambantota | 75 | 250 | 100 | 0 | 8 | 15 |
| Uda Walawe | Uda Walawe | RB D2 FO | RB Top | Ratnapura | 143 | 286 | 143 | 0 | 0 | 6 |
| | | Chandrikawewa | RB Mid | Ratnapura | 57 | 126 | 84 | 0 | 0 | 10 |
| | | LB MD 8-9-10 | LB Top | Monaragala | 150 | 300 | 150 | 2 | 0 | 12 |
| | | Suriyawewa Block | LB Tail | Hambantota | 119 | 300 | 86 | 3 | 0 | 15 |
| | | Gotabaya | LB Tail | Hambantota | 65 | 125 | 150 | 1 | 0 | 7 |
| | | Suriyawewa Block | LB Tail | Hambantota | 120 | 250 | 50 | 0 | 0 | 15 |
| | | RB Tract 11 D1 FO | RB Tail | Hambantota | 400 | 354 | 100 | 0 | 0 | 0 |
| Mahaweli | System H | Ekamutu | Galnewa Block | Anuradhapura | 78 | 195 | 39 | 14 | 0 | 30 |
| System | | 309 D-2 | Galnewa Block | Anuradhapura | 32 | 80 | 16 | 23 | 0 | 15 |
| | | Ekamuthu 304 D-2 | Galnewa Block | Anuradhapura | 320 | 800 | 160 | 50 | 0 | 100 |
| | | 312 D1 | Miigalawewa Block | Kurunegala | 217 | 543 | 109 | 1 | 0 | 50 |
| | | Medinnoruwa Unit D-1 | Miigalawewa Block | Kurunegala | 126 | 315 | 63 | 0 | 0 | 6 |
| Mahaweli | System C | Veheragala Block | Zone 6 | Polonnaruwa | 300 | 750 | 150 | 0 | 0 | 1 |
| System | | Sandagalalenna D15 | Zone 5 | Polonnaruwa | 112 | 280 | 66 | 0 | 0 | 4 |
| | | Sandupula Block D2 | Zone 4 | Ampara | 150 | 375 | 75 | 0 | 0 | 0 |
| | | Belaganwewa D6 | Zone 2 | Badulla | 128 | 320 | 128 | 0 | 0 | 5 |
| | | Cashewnut area | Zone 6 | Polonnaruwa | 400 | na | 1,500 | 150 | 0 | 10 |
| | Total | | | | 7,821 | 17,697 | 8,720 | 542 | 23 | 865 |

[a]Total command areas of the sample schemes are as follows: Mahakanadarawa (2,460 ha), Rajangana (6,970 ha), Dewahuwa (958 ha), Inginimitiya (2,645 ha), Radawi Bendi Ela (208 ha) Hakwatuna (1,435 ha), Kinbulwana (615 ha), Batalagoda (2,050 ha), Ridi Bendi Ela (2,000 ha), Minneriya (5,873 ha), PSS (7,442 ha), Dambewewa (94 ha), Kirindi Oya (9,020 ha), Uda Walawe (14,321 ha), System H (31,303 ha) and System C (20,748 ha). The total command area of the sample schemes is 108,142 ha, which is about 30 percent of the total command area of the major irrigation schemes in the country.

[b]1 ac = 0.4047 ha.

APPENDIX TABLE 2.
Minor irrgation schemes surveyed (as of Dec. 2000 - Jan. 2001)[a].

| | Name of scheme / farmer organization | River basin | District | Subdistrict | No. of tanks | No. of farmers | Area in acres[b)] Total command (paddy) | Highland | No. of dug-wells | No. of tube-wells | No. of pumps |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ihala wewa | Malwathu Oya | Anuradhapura | Nuwaragampalatha-East | 1 | 52 | 52 | 156 | 10 | 0 | 10 |
| 2 | Sucharitagama | Malwathu Oya | Anuradhapura | Nuwaragampalatha-East | 2 | 67 | 111 | 200 | 17 | 0 | 17 |
| 3 | Mankadawewa | Malwathu Oya | Anuradhapura | Nuwaragampalatha-Center | 1 | 80 | 260 | 120 | 3 | 0 | 3 |
| 4 | Helabagaswewa | Malwathu Oya | Anuradhapura | Medawachchiya | 2 | 200 | 210 | 200 | 20 | 0 | 12 |
| 5 | Etaweeragollewa | Malwathu Oya | Anuradhapura | Kahatagasdigiliya | 1 | 32 | 60 | 120 | 8 | 0 | 4 |
| 6 | Mahawewa | Malwathu Oya | Anuradhapura | Kahatagasdigiliya | 6 | 302 | 364 | 300 | 20 | 0 | 10 |
| 7 | Mudewa | Malwathu Oya | Anuradhapura | Mihintale | 1 | 20 | 25 | 45 | 5 | 0 | 5 |
| 8 | Karadikkulama | Malwathu Oya | Anuradhapura | Mihintale | 4 | 65 | 112 | 65 | 3 | 0 | 3 |
| 9 | Elappankulama | Malwathu Oya | Anuradhapura | Mihintale | 1 | 80 | 70 | 180 | 9 | 0 | 5 |
| 10 | Divulwewa | Malwathu Oya | Anuradhapura | Tirappane | 1 | 20 | 75 | 75 | 0 | 0 | 0 |
| 11 | Karabegama | Malwathu Oya | Anuradhapura | Tirappane | 1 | 35 | 37 | 100 | 16 | 0 | 4 |
| 12 | Ralapanawa | Modaragam Aru | Anuradhapura | Nochchiyagama | 1 | 50 | 250 | 400 | 3 | 0 | 8 |
| 13 | Bukahawewa | Modaragam Aru | Anuradhapura | Nochchiyagama | 1 | 35 | 65 | 100 | 0 | 0 | 0 |
| 14 | Kukunewa | Kala Oya | Anuradhapura | Nochchiyagama | 1 | 300 | 300 | 600 | 10 | 0 | 30 |
| 15 | Wariwewa | Kala Oya | Anuradhapura | Nochchiyagama | 1 | 40 | 60 | 80 | 4 | 0 | 2 |
| 16 | Hinguruwewa | Kala Oya | Anuradhapura | Palagala | 4 | 79 | 79 | 80 | 38 | 0 | 41 |
| 17 | Dissanangama | Kala Oya | Kurunegala | Ehetuwewa | 6 | 150 | 380 | 500 | 15 | 0 | 40 |
| 18 | Kumbukkadawala | Kala Oya | Kurunegala | Polpitigama | 4 | 300 | 71 | 600 | 3 | 0 | 10 |
| 19 | Thalakolawewa | Kala Oya | Kurunegala | Polpitigama | 1 | 140 | 105 | 495 | 7 | 0 | 35 |
| 20 | Ranapanawewa | Kala Oya | Puttalam | Kaluwaragaswewa | 1 | 22 | 40 | 100 | 12 | 0 | 7 |
| 21 | Kohomgaswewa | Kalagamu Oya | Puttalam | Mahakubukadewara | 1 | 65 | 60 | 70 | 2 | 0 | 2 |
| 22 | Pahala Vetiya | Mi Oya | Kurunegala | Mahawa | 6 | 80 | 60 | 100 | 3 | 0 | 10 |
| 23 | Medawewa | Mi Oya | Kurunegala | Mahawa | 7 | 60 | 37 | 200 | 1 | 0 | 9 |
| 24 | Thumbullegama | Mi Oya | Kurunegala | Mahawa | 9 | 180 | 144 | 450 | 40 | 0 | 50 |
| 25 | Elabadagama | Mi Oya | Kurunegala | Ambanpola | 12 | 100 | 125 | 200 | 6 | 0 | 10 |
| 26 | Weerasuriyagama | Mi Oya | Kurunegala | Galgamuwa | 1 | 3 | 10 | 30 | 0 | 0 | 0 |

(Continued)

APPENDIX TABLE 2 (CONTINUED).

| | Name of scheme/ farmer organization | River basin | District | Subdistrict | No. of tanks | No. of farmers | Area in acres[b] Total command (paddy) | Highland | No. of dug-wells | No. of tube-wells | No. of pumps |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | Karabewa | Mi Oya | Kurunegala | Galgamuwa | 2 | 90 | 37 | 100 | 13 | 0 | 2 |
| 28 | Kohombankulama | Mi Oya | Kurunegala | Galgamuwa | 2 | 250 | 67 | 600 | 3 | 0 | 6 |
| 29 | Madadambe | Mi Oya | Kurunegala | Galgamuwa | 6 | 100 | 117 | 700 | 2 | 0 | 6 |
| 30 | Gurugodawewa | Mi Oya | Puttalam | Mahakubukadewara | 2 | 36 | 40 | 200 | 0 | 0 | 0 |
| 31 | Kudawewa | Mi Oya | Puttalam | Mahakubukadewara | 3 | 200 | 225 | 800 | 10 | 0 | 10 |
| 32 | Periakulama | Mi Oya | Puttalam | Anamadua | 11 | 300 | 300 | 400 | 3 | 0 | 3 |
| 33 | Yakadapotawewa | Deduru Oya | Kurunegala | Kobeigane | 7 | 350 | 800 | 1,200 | 10 | 0 | 10 |
| 34 | Hingamuwa | Deduru Oya | Kurunegala | Kobeigane | 1 | 36 | 36 | 100 | 0 | 0 | 0 |
| 35 | Weeragoda wewa | Deduru Oya | Kurunegala | Kobeigane | 1 | 20 | 20 | 100 | 0 | 0 | 20 |
| 36 | Beliwewa | Deduru Oya | Kurunegala | Kobeigane | 2 | 150 | 67 | 450 | 3 | 0 | 20 |
| 37 | Talanparawewa | Deduru Oya | Kurunegala | Bingiriya | 1 | 85 | 85 | 300 | 2 | 0 | 10 |
| 38 | Wellangiriya | Deduru Oya | Kurunegala | Bingiriya | 1 | 49 | 196 | 25 | 0 | 4 | 150 |
| 39 | Muraeliya | Deduru Oya | Kurunegala | Bingiriya | 1 | 25 | 75 | 70 | 0 | 5 | 25 |
| 40 | Moragolla wewa | Deduru Oya | Kurunegala | Kotavehera | 1 | 50 | 25 | 150 | 3 | 0 | 3 |
| 41 | Maha Kirinda | Deduru Oya | Kurunegala | Kotavehera | 9 | 350 | 205 | 1,000 | 3 | 0 | 5 |
| 42 | Kumburupitiya | Deduru Oya | Kurunegala | Wariyapola | 1 | 380 | 150 | 200 | 1 | 0 | 100 |
| 43 | Wathupola | Deduru Oya | Puttalam | Pallama | 1 | 50 | 44 | 200 | 0 | 50 | 50 |
| 44 | Kolaeliyawewa | Deduru Oya | Puttalam | Pallama | 1 | 100 | 150 | 250 | 3 | 40 | 50 |
| 45 | Ethiliwewa | Kirindi Oya | Monaragala | Wellawaya | 1 | 60 | 60 | 1,000 | 10 | 0 | 40 |
| 46 | Bodagama | Kirindi Oya | Monaragala | Tanamalwila | 2 | 51 | 63 | 150 | 0 | 0 | 3 |
| 47 | Ittakatuwa | Kmbukkan Oya | Monaragala | Monaragala | 2 | 155 | 170 | 200 | 0 | 0 | 2 |
| 48 | Ihala Kumbukwewa | Malala Oya | Hambantota | Suriyawewa | 2 | 40 | 45 | 150 | 1 | 0 | 2 |
| 49 | Meegahajandura | Malala Oya | Hambantota | Suriyawewa | 1 | 30 | 185 | 200 | 0 | 0 | 0 |
| 50 | Galamuwa | Malala Oya | Monaragala | Tanamalwila | 2 | 40 | 95 | 118 | 2 | 0 | 2 |
| 51 | Mahanikawewa | Malala Oya | Monaragala | Tanamalwila | 3 | 47 | 47 | 250 | 0 | 0 | 0 |
| 52 | Kalpitiya | NA | Puttalam | Kalpitiya | na | 1,500 | na | 5,250 | 1,500 | 600 | 2,100 |
| | Total [a] | | | | 143 | 5,601 | 6,466 | 14,479 | 324 | 99 | 846 |

[a]Total does not include Kalpitiya (No. 52).

[b]1 acre = 0.4047 ha.

APPENDIX TABLE 3.

Number of and investemts by farmers on agro-wells and irrigation pumps in irrigation schemes in the dry zone of Sri Lanka, 1965-2000[a]

| Year | Number (1,000 units) | | | | Investment (Rs. Million in 2,000 prices) | | |
|---|---|---|---|---|---|---|---|
| | Lined dug-wells | Unlined dug-wells | Tube-wells | Pumps | Wells | Pumps | Total |
| 1965 | - | - | - | 0.0 | - | 0.4 | 0.4 |
| 1966 | - | - | - | 0.0 | - | 0.2 | 0.2 |
| 1967 | - | - | - | 0.0 | - | 0.5 | 0.5 |
| 1968 | - | - | - | 0.1 | - | 0.9 | 0.9 |
| 1969 | - | - | - | 0.1 | - | 0.9 | 0.9 |
| 1970 | - | - | - | 0.2 | - | 3.3 | 3.3 |
| 1971 | - | - | - | 0.3 | - | 6.4 | 6.4 |
| 1972 | - | - | - | 0.7 | - | 14.5 | 14.5 |
| 1973 | - | - | - | 1.2 | - | 17.7 | 17.7 |
| 1974 | - | - | - | 1.7 | - | 21.1 | 21.1 |
| 1975 | 0.0 | 0.0 | - | 2.5 | 0.2 | 32.0 | 32.2 |
| 1976 | 0.0 | 0.0 | - | 3.3 | 0.2 | 28.0 | 28.2 |
| 1977 | 0.0 | 0.0 | - | 4.1 | 0.2 | 32.4 | 32.6 |
| 1978 | 0.0 | 0.0 | - | 4.9 | 0.2 | 31.4 | 31.6 |
| 1979 | 0.0 | 0.0 | - | 5.8 | 0.3 | 32.2 | 32.4 |
| 1980 | 0.0 | 0.0 | 0.0 | 6.7 | 0.3 | 37.1 | 37.4 |
| 1981 | 0.0 | 0.0 | 0.0 | 7.9 | 0.4 | 43.3 | 43.6 |
| 1982 | 0.0 | 0.0 | 0.0 | 9.2 | 0.4 | 50.6 | 50.9 |
| 1983 | 0.0 | 0.0 | 0.1 | 10.7 | 0.4 | 59.7 | 60.1 |
| 1984 | 0.1 | 0.0 | 0.1 | 12.7 | 5.9 | 76.8 | 82.7 |
| 1985 | 0.4 | 0.0 | 0.1 | 15.2 | 34.8 | 96.1 | 130.9 |
| 1986 | 0.7 | 0.0 | 0.2 | 18.0 | 23.3 | 103.9 | 127.2 |
| 1987 | 1.0 | 0.0 | 0.2 | 21.0 | 31.8 | 117.5 | 149.3 |
| 1988 | 1.5 | 0.0 | 0.3 | 24.5 | 50.4 | 134.7 | 185.0 |
| 1989 | 2.4 | 0.0 | 0.4 | 28.6 | 93.5 | 155.9 | 249.4 |
| 1990 | 4.8 | 0.1 | 0.5 | 34.5 | 228.3 | 224.4 | 452.7 |
| 1991 | 6.2 | 0.3 | 0.8 | 40.2 | 148.0 | 215.6 | 363.7 |
| 1992 | 7.9 | 0.5 | 1.2 | 46.2 | 162.9 | 232.0 | 394.9 |
| 1993 | 10.0 | 0.9 | 1.7 | 53.0 | 214.5 | 261.5 | 476.0 |
| 1994 | 11.8 | 1.5 | 2.4 | 60.2 | 186.0 | 276.7 | 462.7 |
| 1995 | 13.9 | 2.1 | 3.2 | 67.8 | 219.1 | 290.2 | 509.3 |
| 1996 | 16.4 | 3.0 | 4.2 | 76.0 | 253.9 | 316.1 | 570.0 |
| 1997 | 20.0 | 4.0 | 5.4 | 83.4 | 368.1 | 285.4 | 653.5 |
| 1998 | 24.0 | 5.2 | 6.7 | 90.7 | 408.9 | 279.4 | 688.3 |
| 1999 | 28.1 | 6.5 | 8.1 | 98.5 | 418.9 | 296.8 | 715.7 |
| 2000 | 32.5 | 8.2 | 9.8 | 106.9 | 448.6 | 323.0 | 771.5 |

[a]Estimates are based on the data obtained in our survey.

## Literature Cited


Abeyratne, M.D.C. 1993. Utilization of groundwater resources in north western Sri Lanka: Some issues pertaining to sustainable development. In *Farmer Management of Groundwater Irrigation in Asia. Selected papers from a South Asian Regional Workshop*, eds., Abhayaratna, M.D.C.; Vermillion, D.; Jhonson, S.; Perry, C. Colombo: Sri Lanka. IIMI. 65-73.

Arumugam, S. 1968. *Water Resources of Ceylon.* Colombo, Sri Lanka: Water Resources Board.

Basnayake, B.K.; Madduma Bandara, C.M. 1985. Groundwater in hard rocks: Resources and challenges for development. In *Some Aspects of Water Resources of Sri Lanka,* Colombo, Sri Lanka: Sri Lanka National Committee of the International Hydrological Program.

Cooray, G.H. 1984. *Geology of Sri Lanka.* Colombo, Sri Lanka: Sri Lanka Department of National Museums.

Dhawan, B.D. 1982. *Development of Tubewell Irrigation in India*. New Delhi, India: Agricole Publishing Academy.

Farmer B.H. 1951. Some thoughts on the dry zone. *Bulletin of the Ceylon Geographical Society* (6) 3-16.

Farmer B.H. 1957. Land use lessons learnt in Madras and applicable to the dry zone of Ceylon. *Bulletin of the Ceylon Geographical Society* (10) 9-19.

Fernando, A.D.N. 1973. *Groundwater Resources of Sri Lanka*. Colombo, Sri Lanka: Planning Division. Sri Lanka Ministry of Irrigation, Power and Highways.

Fertilizer Association of India. 2000. *Fertilizer Statistics*. New Delhi, India

Foster, S.S.D.; Yearwood, Y.D.F.;.Carruthers, I. D. 1976. *Groundwater for Agricultural Development in Sri Lanka*. London: United Kingdom Ministry of Overseas Development.

HKARTI (Hector Kobbekaduwa Agrarian Research and Training Institute). 2000. *Status and Future of Agro-Wells in Sri Lanka.* Colombo, Sri Lanka.

Kikuchi, M., Barker, R.; Weligamage, P.; Samad, M. 2002. *The Irrigation Sector in Sri Lanka: Recent Investment Trends and the Development Path Ahead*. Research Report 62. Colombo, Sri Lanka: International Water Management Institute.

Madduma Bandara, C.M. 1973. Groundwater Resources in the Hard Rock Areas Proceedings of 29th Annual Session. Part I. Sri Lanka Association for the Advancement of Science.

Madduma Bandara, C.M. 1977a. The prospects for recycling subsurface water for supplementary irrigation in the dry zone. In *Agriculture in the Peasant Sector of Sri Lanka, Peradeniya*, ed., Samarasinghe, S.W.R. de A. Ceylon Studies Seminar. 87-99.

Madduma Bandara, C.M. 1977b. Hydrological consequences of agrarian change. In *Green Revolution?* **,** ed., Farme, B.H. London: Macmillan. 323-339.

Madduma Bandara. C.M. 1979. A Study of the practice of well irrigation in the county around Vavuniya in northern Sri Lanka. *Sri Lanka Journal of Social Sciences* (2) 65-88.

Madduma Bandara, C.M. 1984. Green revolution and water demand: Irrigation and groundwater in Sri Lanka and Tamil Nadu. In *Understanding Green Revolution, Agrarian Change and Development Planning: Essays in honor of B.H. Farmer* eds., Smith, T.B.; Wanmali, S. London: Cambridge University Press. 296-314.

Morris, Michael. L.; Chowdhury, N.; Meisner, C. 1997. *Wheat Production in Bangladesh: Technologiccal, Economic and Policy Issues*. Research Report 106. Washington DC: International Food Policy Research Institute.

Panabokke, C.R. 1959. A study of soils in the dry zone of Ceylon. *Soil Science* 87 (2) 67-84.

Panabokke, C.R. 1998a. Water resources in Sri Lanka; Present conditions and major conservation strategies. *Economic Review* May 1998. 7-11.

Panabokke, C. R. 1998b. Draft Groundwater Management Policy Paper (typescript).

Panabokke, C. R. 2001. Personal communication, January 2001.

Panabokke, C. R.; Sakthivadivel, R.; Weerasinghe, A.D. 2002. *Small Tanks in Sri Lanka: Evolution, Present Status and Issues.* Colombo, Sri Lanka: International Water Management Institute (IWMI).

Sally, H. 2000. Information on Engine Driven Pumps in Sri Lanka. Memorandum, February. 2000.

Shah, T. 1993. *Groundwater Markets and Irrigation Development: Political Economy and Practical Policy*. Mumbai, India: Oxford University Press.

Sri Lanka Department of Agrarian Services (SLDAS). 2000. *All Island Village Irrigation Survey: District Reports*. Colombo, Sri Lanka: SLDAS.

Sri Lanka Irrigation Department (SLID). 1975. *Register of Irrigation Projects in Sri Lanka.* Colombo, Sri Lanka: SLID.

Wijesinghe, M.W.P.; Kodithuwakku, K.A.W. 1990. Agro-well systems to harness available groundwater resources for small-scale farming. In *Irrigation and Water Resources* (Proceedings of a Symposium held in Kandy on 24-25 August 1989, ed., Gunawardena, E.R.N. Peradeniya, Sri Lanka: University of Peradeniya. 178-191.

54. *Wells and Welfare in the Ganga Basin: Public Policy and Private Initiative in Eastern Uttar Pradesh, India.* Tushaar Shah, 2001.

55. *Water Scarcity and Managing Seasonal Water Crisis: Lessons from the Kirindi Oya Project in Sri Lanka.* R. Sakthivadivel, Ronald Loeve, Upali A. Amarasinghe, and Manju Hemakumara, 2001.

56. *Hydronomic Zones for Developing Basin Water Conservation Strategies.* David J. Molden, Jack Keller, and R. Sakthivadivel, 2001.

57. *Small Irrigation Tanks as a Source of Malaria Mosquito Vectors: A Study in North-Central Sri Lanka.* Felix P. Amerasinghe, Flemming Konradsen, Wim van der Hoek, Priyanie H. Amerasinghe, J. P. W. Gunawardena, K. T. Fonseka and G. Jayasinghe, 2001.

58. *Fundamentals of Smallholder Irrigation: The Structured System Concept.* B. Albinson and C. J. Perry. 2001.

59. *A Gender Performance Indicator for Irrigation: Concepts, Tools and Applications.* B. van Koppen. 2001.

60. *Institutional Alternatives in African Smallholder Irrigation: Lessons from International Experience with Irrigation Management Transfer.* Tushaar Shah, Barbara van Koppen, Douglas Merrey, Marna de Lange and Madar Samad. 2002.

61. *Poverty Dimensions of Irrigation Management Transfer in Large-Scale Canal Irrigation in Andra Pradesh and Gujarat, India.* Barbara van Koppen, R. Parthasarathy and Constantina Safiliou. 2002.

62. *Irrigation Sector in Sri Lanka: Recent Investment Trends and the Development Path Ahead.* M. Kikuchi, R. Barker, P. Weligamage and M. Samad. 2002

63. *Urban Wastewater: A Valuable Resource for Agriculture.* Wim van der Hoek, Mehmood Ul Hassan, Jeroen H. J. Ensink, Sabiena Feenstra, Liqa Raschid-Sally, Sarfraz Munir, Rizwan Aslam, Nazim Ali, Raheela Hussain and Yutaka Matsuno. 2002.

64. *Use of Untreated Wastewater in Peri-Urban Agriculture in Pakistan: Risks and Opportunities.* Jeroen H. J. Ensink, Wim van der Hoek, Yutaka Matsuno, Safraz Munir and M. Rizwan Aslam. 2002.

65. *Land and Water Productivity of Wheat in the Western Indo-Gangetic Plains of India and Pakistan A Comparative Analysis.* Intizar Hussain, R. Sakthivadivel, Upali Amarasinghe, Muhammad Mudasser and David Molden. 2003.

66. *Agro-Well and Pump Diffusion in the Dry Zone of Sri Lanka: Past Trends, Present Status and Future Prospects* M. Kikuchi, P. Weligamage, R. Barker, M. Samad, H. Kono and H.M. Somaratne. 2003.

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

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

**Tel:**
+94-1-787404

**Fax:**
+94-1-786854

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

**Website:**
http://www.iwmi.org

International Water Management Institute

FUTURE HARVEST
IWMI is a Future Harvest Center supported by the CGIAR

ISSN 1026-0862
ISBN 92-9090-507-7