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Expansion of Groundwater Irrigation and Transition in Traditional Water Management System in Sri Lanka

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Introduction

Shallow wells equipped with small pumps to lift up groundwater have rapidly spread since 1980 among many agricultural regions of South Asia. Over 80 per cent of the increase in irrigated areas that took place in India, Pakistan and Bangladesh during the period 1980-92 was the result of groundwater irrigation. The diffusion of agro-wells and pumps has also been significant since 1990 in Sri Lanka. Yet little is known why wells and pumps have spread so rapidly, what the impact has been on farmers' cropping patterns, their incomes and the prospect of their future diffusion. The first aim of this paper is to address these issues through observations and data collected through field surveys in Sri Lanka.

Common property resources (CPRs), such as forests and fisheries, are public goods with the unique features of non-excludability and rivalry. The institution and organization of sustainable use, maintenance and management of CPRs is important in developing countries. A traditional tank irrigation system has been in existence in Sri Lanka for hundreds of years (Mahendrarajah and Warr, 1991). Such tanks can also be considered as CPRs because everyone in a community has access to water from the tank. A farmer who has land within the tank irrigation system may use the water (non-excludability) and the amount of available water will decrease if it is overused (rivalry). *Bethma* is a traditional water management system in Sri Lanka. It is implemented when the village water supply is insufficient to irrigate all of its farmland. The available water in the tank is divided among the farmers under this system. Kono and Somarathna (2000) find that *bethma* has recently been transformed due to the rapid diffusion of groundwater irrigation. A subsequent field survey has indicated that population growth in rural villages is also a cause of the *bethma* transformation. The expansion of cultivated areas during the wet season, due to the population growth in rural villages, has increased the amount of water use in the tanks. We hypothesize that this decreases of the amount of water in the tank during the dry season has caused difficulties in implementing the *bethma* system. This paper attempts to test this hypothesis from a field survey data collected in Sri Lanka.

The Research Method

Sri Lanka has two significantly different climatic zones. The dry zone accounts for about two thirds of the total land area and the remainder consists of a wet zone. There are two cultivation seasons in Sri Lanka, one is the *Maha* (wet) season from October to March and the other is the *Yala* (dry) season from April to September. In the wet season, there are a lot of rains in the area. But in the dry season, there is almost no rain in the dry zone, whereas there is much rain in the wet zone.

In order to collect information on groundwater irrigation as well as the *bethma*, we conducted two sets of field survey in the dry zone. First set of field survey is the intensive survey about the diffusion of groundwater irrigation at the farm level and second survey is the extensive survey about transformation of the *bethma* at the village level.

The intensive field survey at farm level was conducted from December 2000 to January 2001 to collect information about the impact of the spread of groundwater irrigation in the dry zone. There are two types of tank irrigation system in Sri Lanka based on the size of command area: major irrigation system and minor irrigation system. Major irrigation refers to the irrigation systems with a command area of 200 acres or more, and minor irrigation are those with less than 200 acres of a command area (1 acre = 0.4047 ha). The origin of the tank irrigation system in the dry zone of Sri Lanka can be traced back to twenty-five centuries. We selected two villages in Anuradhapura district. One is in the Galnewa Block of Mahaweli System H (here in after referred to as O village), with 78 farmers cultivating 195 acres of paddy and 39 acres of highland (major irrigation scheme). The other is in the sub-district of Palagala (here in after referred to as H village) and it manages four minor tank schemes, with 70 farmers cultivating 50 acres of paddy and 80 acres of highland (minor irrigation scheme). The use of agro-wells and pumps has spread extensively in both villages. We interviewed 85 per cent of the farmers in each village, using a structured questionnaire designed to collect information on the costs of installing and operating of agro-wells and pumps, and the benefits associated with changes in crop patterns before and after adopting the well-pump system. Section 3 presents the result of the intensive survey.

An extensive survey at village level was also conducted in the Anuradhapura district, which consists of many traditional villages. The district is divided into 17 divisional secretary areas. Considering available time and other resources, we selected the divisional secretary areas of Ipalogama and Kekirwa, which are located 25 km south and 40 km southeast of Anuradhapura city, respectively. We selected these two divisions because they contain many traditional tank irrigation systems. In addition, these divisions are located closer to each other, which facilitated fieldwork. We randomly selected 30 traditional villages from the lists provided by respective divisional secretariat offices. Furthermore, we randomly selected eight farmers from the lists provided by the village leaders of the selected villages. Historical statistics about *bethma*, cultivation areas and population at the village level are not available in Sri Lanka. We collected this information from key informants such as elderly villagers and officials of farmers' organizations in each village through a structured questionnaire. Obviously such data depended on memory and were therefore somewhat unreliable. However, it was our only means of collecting any past information about the subject. To obtain as much accuracy as possible, two or more elderly farmers per village participated in the investigation. Because of data inconsistency and unreliability, we focused 44 sample villages in analysis. Field survey was conducted between mid April and the end of September 2001. Section 4 presents the results of the extensive survey.

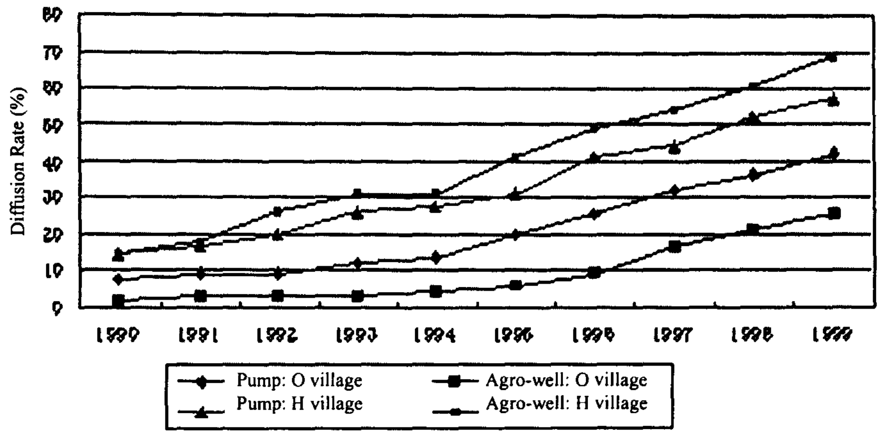

Figure 54.1: Diffusion of Pump and Agro-well in Two Survey Villages

Diffusion of Groundwater Irrigation

The diffusion of agro-well and pump irrigation in Sri Lanka has been increasing since early 1990s. The possession of agro-well and pump provide farmers an opportunity to utilize their land, usually with other field crops (OFCs) rather than paddy such as chilli and onion, in dry season. The net returns from chilli and onion cultivation is quite high and it is about three times higher than that of paddy cultivation. Figure 54.1 shows the trend of diffusion of both agro-well and irrigation pump over time in two survey villages. The diffusion rate of both agro-well and pump is higher in H village than that of O village. Relative water scarcity in the dry season and government subsidy for construction of agro-well in minor irrigation scheme areas may have contributed to the higher diffusion rate in H village.

The agro-well constructed in the area can be classified into two types; lined dug-well and unlined dug-well. These two types are open dug well of 14ft to 22ft diameter and 14ft to 40ft deep. The lined agro-well has its wall lined with cement, whereas the unlined agro-well leaves its wall just as dug. The typical construction cost of agro-well is Rs 40,000 – 50,000 for lined agro-well (diameter 14ft, depth 23ft) and around Rs 6,000 in unlined one (diameter 14ft , depth 23ft). Water is usually lifted up by 2-inch pump operated by diesel or kerosene engine of 2.5 to 5HP, with which 2-inch pipe is used for conveying and distributing water to field. The typical installation cost of a pump is around Rs 30,000 (2 inch diesel 3.5HP). The number of farms with agro-well and pump is 42 and 34 in H village and 17 and 27 in O village respectively (Table 54.1). Majority of agro-well in H village is lined type (35) and unlined type (15) in O village. Some farmer rent agro-well and pump from relatives or other farmers in the same village. However, small capacity of agro-well and pump limit the incidence of water market, which is seen in India or Bangladesh. Unlike in India and Bangladesh, where a set of well and pump irrigates as much as 5 – 10 acres of crop land, in the case of Sri Lanka it can only irrigate 0.5 – 2 acres of crop land and usually no water is left after a well-pump owner irrigates his field (Kikuchi, *et al.*, 2002).

Table 54.1: Number of Farms with Agro-well and Pump in Survey Villages

	O village	H village
Pump and agro-well (lined)	2	24
Pump and agro-well (unlined)	10	3
Pump only	15	7
Agro-well (lined) only	0	11
Agro-well (unlined) only	5	4

Before the diffusion agro-well and pump, usually farmers could not cultivate all their land due to shortage of water and such situation is more often in minor system (H village) than major irrigation schemes (O village). Farmers were allowed to cultivate only paddy under *bethma* in the dry season in both villages before the diffusion of agro-well and pump. The diffusion of agro-well and pump made it possible for farmers to cultivate OFCs, mainly chilli and onion. Table 54.2 shows the crops cultivated and irrigation methods of two sample villages. The number of farmers who cultivate chilli and onion with agro-well and pump is 11 and 9 in O village; and 46 and 5 in H village respectively. This indicates that the majority of farmers who possess both agro-well and pump cultivate chilli and onion. The cultivated area per farmer in both villages ranged from 0.4 – 0.6 acre.

Table 54.2: Irrigation Method and Crop Cultivated in Sample Villages - 1999 Dry Season (Number of Farms)

		Irrigation method			
Village	Crop	Agro-well + Pump	Cannal water[1] + Pump	River water[2] + Pump	Canal water
O village	Paddy	1	2	0	24
	Chilli	11	1	0	0
	Onion	9	2	4	1
	Others	2	0	0	0
	Total	23	5	4	0
H village	Paddy	1	1	0	1
	Chilli	46	2	0	0
	Onion	5	0	0	0
	Others	4	3	0	0
	Total	56	3	0	1

Note:
1 Canalwater from the scheme.
2 Water from natural river.

Table 54.3 shows the costs and returns of crop production in sample villages. The profit of onion and chilli production using agro-well and pump ranged from 27,400 Rs/acre (H village) to 28,710 Rs/acre (O village). The profitability of onion and chilli production under canal irrigation is 13,952 Rs/acre and 8,670 Rs/acre in O and H village, respectively. The profit of paddy cultivation by using canal water is 11,457 Rs/acre (O village) and 6,205 Rs/acre (H village).[1] These results indicate that the investment in agro-well and pump to cultivate chilli and onion in the dry zone of Sri Lanka gives high returns for the farmers.

Table 54.3: Costs and Returns from Crop Cultivation in Survey Villages (Rs/ac)[-1]

	O village			H village		
	Onion	Onion	Paddy	Chilli	Chilli	Paddy
	Agro-well + Pump	Canal	Canal	Agro-well + Pump	Canal	Canal
Profit	28,710	13,952	11,457	27,400	8,670	6,205
Value of production[2]	62,100	50,077	20,500	65,636	45,550	18,026
Cost of production						
Current inputs[3]	9,180	10,329	3,171	8,273	6,050	3,136
Labour[4]	18,659	18,586	4,685	23,496	24,230	6,959
Rental cost[5]	1,472	1,919	1,187	1,914	2,175	1,726
Irrigation cost[6]	4,080	5,291	0	4,553	4,425	0

Note:
1 Average value calculated from surey data.
2 Value of paddy is the data of 1999/2000 wet season cultivation and value of onion and chilli is the data of 2000 dry season cultivation.
3 Fertilizer, agro-chemical weedicide and seeds.
4 Labour input inlude family labour imputed by market wage rate.
5 Tractor rental cost.
6 Fuel cost of irrigation pump.

To asses the benefit of the investment for agro-well and pump economically, we estimated the internal rate of return (IRR), using the following formula:

$$C = \Sigma_{i=1}^{n} (R-O)/(1+r)^i$$

where C = investment cost on well and pump, R = increase in gross value-added or farmers' net income due to the investment, O = operating and maintenance cost of well/pump, r = internal rate of return, n = the usable life of the well/pump. R is estimated by deducting the income from crops grown before the introduction of the well and pump from the income from new crops after the introduction. Farmers' net income are obtained by deducting capital depreciation of the well and pump from the farmers' gross income that is defined as total output value less paid-out costs. Table 54.4 summarizes the results of the private IRR. The IRR of cultivating onion with agro-well (unlined) and pump in O village is 50 per cent and the IRR of cultivating chilli with agro-well (lined) and pump in H village is 33 per cent. The

1 The profit of paddy using canal water in H village is about half of O village and the profit of chili using canal water in H village is less than the normal season. This was mainly due to severe water shortage experienced by the H village in the wet season. Otherwise, there is no difference in paddy yield between the two villages. Also the profit of chili in H village is almost same as that of onion in O village if there is no water shortage.

lower IRR figure in H village is mainly due to the high construction cost of lined agro-well. Many farmers of the H village have obtained a subsidy (30,000 Rs/well) from the government for the construction of agro-well. Even without the subsidy, the IRR in H village amounted to 18 per cent. These IRR figures are higher than the interest rate of development loans (15% per year) provided by the government. Therefore, returns from crops that generated through agro-well and pump are sufficiently high to induce farmers' to invest. Based on these analyses, it is reasonable to speculate that the diffusion of agro-well and pump will continue in the water scarce dry zone of Sri Lanka.

Table 54.4: Private Internal Rate of Return (IRR) of Investment on Irrigation

	O village	H village
Irrigation type	Agro-well (unlined) + pump	Agro-well (lined) + pump
Crop	Onion	Chilli
IRR (%)1	50	33

Note:
Calculations are based on: Pump price (diesal 13.5 HP) 30,000 Rs, cost of agro-well (unlined) 6,000 Rs, cost of agro-well (lined) 45,000 Rs, Government subsidy for construction of lined agro-well 30,000 Rs and size of agro-well (lined or unlined) - 15 ft diameter and 20 ft depth. In case of unlined agro-well, additional digging cost required every 5 years is included as a part of operation and maintenane cost per year.

Transformation of the *bethma*

Water released from a tank is administered by an elected village-level body known as the Cultivation Committee (CC) in traditional minor tank irrigation system. The CC also plays a leading role in steering village cultivation programs by convening pre-season meetings. Land below the tank is divided into Puranawela (PW) and Akkarawela (AW) types of land (Figure 54.2).

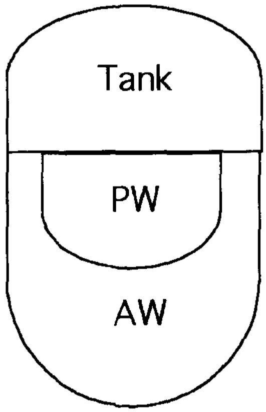

Figure 54.2: Layout of Land Use under Traditional Tank Irrigation System in Sri Lanka

PW is located near the tank whereas AW is located around PW and was developed after AW development. Diffusing agro-well is normally located in AW, not in PW. One reason is the soil condition. PW area is good for paddy, but not good for OFCs. All PWs are generally cultivated during the wet season, but in the dry season only one third to half of the PW can be cultivated using water available in the tank. However, water shortages during the dry season render AW impossible to cultivate and occasionally the entire PW area cannot be irrigated. *Bethma* is a traditional institutional arrangement that shares the cultivable PW area due to available tank water among farmers during the dry season. All decisions regarding *bethma* are determined by the CC, who selects the cultivable PW and abandons all the remaining land in the command area. The selected PW is now divided equally among the farmers or according to the holding area of each farmer (Ijsbrand, 1989). The PW holding area per farm has been decreasing since such land is inherited by children upon the death of their parents and subdivided into small parcel. In contrast, the AW holding area is larger than that of the PW. The cultivable crop of *bethma* areas is restricted to paddy. Interpersonal conflicts that could potentially arise under a drought during the dry season are avoided by the *bethma* system. Hayami argues that a sharing principle prevails in the rural sector of South East Asia (Hayami, 2001). He pointed out that income and work-sharing mechanism should be especially valuable in economies where the market is underdeveloped so that villagers have no other means of insuring against risk in farm production, such as formal insurance and credit systems. The *Bethma* shares cultivation opportunities among farmers under the condition of high production risk in dry season. We can also consider the *bethma* as one kind of sharing principle observable in South East Asian villages.

If the amount of water in the tank is sufficient to cultivate all the PWs, it is not necessary to implement the *bethma*. If the tanks are empty, the *bethma* is impossible. Some villages apply the *bethma* every year whereas others only do so once every three or four years, depending on climatic conditions. The survey data indicated that 15 (34%) villages implemented the *bethma* over the past 12 years (1990 – 2001). Eleven (25%) villages implemented the *bethma* over the past 7 years (1995 – 2001). All 44 villages we surveyed have implemented the *bethma* at least once over the past 40 years. It is reasonable to suppose that the implementation of the *bethma* has declined recently.[2] Some farmers could not answer the question, "When the bethma was last applied in your village?" The oldest record according to our survey, the *bethma* was last applied in 1960.

Table 54.5 shows changes in cultivation areas and in the number of farms over the past 40 years according to the elderly farmers interviewed. The cultivation area of AW during the wet season over the past 40 years has increased in 28 villages and remained unchanged in 16 villages, respectively. The average cultivation area in AW has increased 70.7per cent from 19.5 acres 40 years ago to 33.3 acres now, while the PW area during the wet season has not changed. In contrast, the cultivation area of PW during the dry season has decreased in 15 villages and remained unchanged in 28 villages over the past 40 years. The average PW cultivation area per farm household in dry season has decreased by 15 per cent, from

[2] The key informants of each village also confirmed this change.

Table 54.5: Change of Cultivated Land Area and Number of Farm Households in Sample Villages[1]

	40 years ago	Now
Cultivation area of PW in wet season (a)	71.5	70.5
Cultivation area of AW in wet season (a)	19.5	33.3
Cultivation area of PW in dry season (a)	47.4	40.1
Number of farm household	24.2	103.5
Owner and owner-tenant farmer	22.4	78.3
Owner and landless farmer	1.8	25.2
Cultivation area per farm household (ac)[2]	6.97	1.37

Note: 1. Average of 44 sample villages.
2. Cultivation area of PW and AW in wet season is divided by the number of farm households.

47.4 acres to 40.1 acres over the past 40 years. The PW area has increased in only one village. This is because the tank in the village is connected to the canal of Mahaweli irrigation project, which is largest irrigation and settlement project in the dry zone of Sri Lanka. Thus, the water supply is reliable during the dry season. The number of farm households, which include owner-farmers, owner-tenant, tenant and landless farmers, has increased in 43 villages. The average number of farm household per village was 24.2 forty years ago compared with 103.5 now. The increasing rate of farm households is faster than that of the increase in the cultivation area (PW + AW) in the wet season. Thus, the average cultivation area per farm household has decreased from 6.97 acres 40 years ago to 1.37 acres.

We assumed that one of the factors involved in expansion of the AW over the past 40 years is the population increase in rural villages. That is, the increasing numbers of new farmers who cannot possess land in the PW have developed AW around the PW. This has caused an increase in water use during the wet season and a decrease in the amount of water remaining in the tank during the dry season (Figure 54.3). We assumed this has decreased the cultivable PW area that has been using the *bethma* for hundreds of years. We identify this hypothesis based on the surveyed data. Table 6 indicates the variables used in the analysis. First, we estimated the determinant of change of AW and PW areas in the past 40 years by Tobit model. Second, we estimated the determinant of transformation of the *bethma* in the past 40 years by probit model[3]. To find out the factor that effects the transformation of the *bethma* clearly, two kinds of dependent variables are used in the analysis, BETHMA1990 and BETHMA1995.

[3] Some values of AW and PW are 0. Value of BETHMA1990 and BETHMA1995 takes only two values (1 or 0). In this case we cannot estimate by OLS method, but used tobit or probit method. See Maddala (2001) for details.

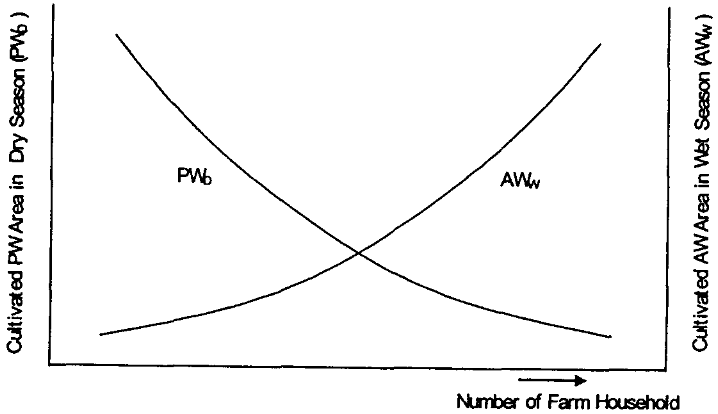

Figure 54.3: Change of Cultivated Area in PW and AW

Table 54.6: Dependent and Independent Variables of Tobit and Probit Analysis

	Mean	Minimum	Maximum	Description of Variables
BETHMA 1990	0.36	0	1	If village implemented Bethama at lease once over the past 12 years (1990-2001)*
BETHA 1995	0.25	0	1	If village implemented Bethama at lease once over the past 7 years (1990-2001)*
PW	7.35	-8	68	Derease in PW area in the dry season over the past 40 years per village (ac)
AW	14.32	0	82	Inrease in AW area in the wet season over the past 40 years per village
FARMER[1]	79.95	-14	262	Increase in number of farmers over the over past 40 years per village
FARMER-OWNER[2]	56.02	-14	235	Increase in number of owner farmers over the past 40 years per village
REHABILI.	0.72	0	1	If village tank has been rehabilitated past time*
TANK	2.29	1	6	Number of tank per village
PUMP	26.29	0	87.5	Diffusion rate of pump per village (%)
LAND-OUT	19.62	0	75	Ration of farm household with land outside the village (%)
OTHER-INCOME	25.00	4.38	60	Non-agriultural income share for total income per year per village (%)

Note:

1. FARMER include owner, owner-tenant, tenant and landless farmer.
2. FARMER-OWNER include owner and owner-tenant farmers.
3. *indicates that the variable takes only two values, 0 and 1.

Table 54.7 shows an estimation of the determinant of changes in the AW and PW areas over the past 40 years using the tobit model. First, we start with AW as dependent variable. The coefficient of FARMER is positively significant at the 10 per cent level. As indicated in Table 54.5, the number of farm households has increased fourfold compared with 40 years ago. This indicates that farmers who cannot own land in the PW have recently developed AW around PW. This finding is same as those of Farmer (1957). The coefficient of AW is positively significant at the 1% level when PW is the dependent variable. This implies that the cultivable PW area during the dry season has decreased according to the expansion of cultivable AW as shown in Figure 54.3. Furthermore OTHER-INCOME is positively significant at the 5 per cent level in the second column of Table 54.7. This implies that farmers neglect dry season cultivation if the village has an opportunity to get non-agricultural income. This is because the risk of crop failure is very high during the dry season even in the *bethma* areas. Furthermore, the expected return of the *bethma* area is not so high due to subdivision of the land brought about by population increases. The coefficient of REHABILI is positive in the second column and negative in the first column. Though the coefficient is not significant, it suggests that tank rehabilitation has increased in the command area of AW during the wet season and decelerated the decrease of PW during dry season.

Table 54.7: Determinants of Change of AW and PW Area in Past 40 Years: Tobit Regressions

Independent variable	Dependent variable	Independent variable	Dependent variable
	AW		PW
Constant	-7.69	Constant	-38.97
	(-0.527)		(-2.54)***
FARMER	0.09	AW	0.72
	(1.37)*		(2.77)
OTHER-INCOME	0.044	OTHER-INCOME	0.76
	(0.14)		(2.05)**
REHABILI.	9.51	REHABILI	-2.44
	(1.01)		(-0.21)
Log likelihood	-143.56	Log likelihood	-85.38

Note:
1 Numbers in parentheses are t-statistics. Number of sample = 44.
2 ***, **, * Significant at the 1%, 5% and 10% respetively.

We estimated the determinants of transformation of the *bethma* over the past 40 years using the probit model (Table 54.8). To find out the factors that affect the transformation of the *bethma*, we used the dependent variables, BETHMA1990 and BETHMA1995. The sign coefficient of each variable is the same in both equations. The PW has a negative coefficient, suggesting that the smaller the PW area over the past 40 years, the larger was the possibility of practicing the *bethma*, even though it was not significant. FARMER-OWNER has a significant negative coefficient, indicating that the larger the number of owner-farmers over the last 40 years, the smaller was the possibility of practicing the *bethma*. This indicates that collective irrigation management is probably more difficult to organize in a larger population. This finding is similar to Bardhan and Udry (1999). LAND-OUT is significantly negative in BETHMA1995 as dependent variable, suggesting that the larger the rate of farm households owning land outside village, the smaller the possibility of implementing the *bethma*. This suggests that a farmer, who owns land outside the village, can cultivate that land instead of his land in the village when water is scarce during the dry season. Therefore the incentive is low for farmers to cooperate for water management under the *bethma*. OTHER-INCOME has negative coefficients in both equations, suggesting that a larger opportunity of acquiring non-agricultural income in the village will increase the possibility of not implementing the *bethma*, though it was not statistically significant. Even in the *bethma* areas, the risk of crop failure is high. Farmer neglects the paddy cultivation under the *bethma* if the village can get non-agriculture income. TANK is significantly positive in the second column, suggesting that the more tanks the villages have, the more likely they are to carry out the *bethma*. This indicates that if there is no water in a tank, it is possible to select another tank for the *bethma* practice if village has several tanks. The PUMP has a significantly negative coefficient, indicating that the larger the rate of pump diffusion in the village, the larger will be the possibility of not implementing the *bethma* in that village. This result is reasonable because if farmers have a private pump, he can cultivate his own land by using groundwater in the dry season and the incentive to cooperate under the *bethma* is low in that village. We conclude that the transformation of the *bethma* will be accelerated by the spread of pumps.

Table 54.8: Determinants of Transformation of Bethma: Probit Regressions

Independent variables	Dependent Variable	
	BETHMA 1990	BETHMA 1995
Constant	0.92	0.38
	(1.92)	(0.49
PW	-0.0079	-0.004
	(-0.50)	(-0.24)
FARMER-OWNER	-0.01	-0.01
	(-1.78)**	(-1.33)*
LAND-OUT	-0.144	-0.5
	(1.19)	(-2.06)**
OTHER-INCOME	-0.014	-0.003
	(-0.79)	(-0.14)
TANK	0.22	0.32
	(1.17)	(1.32)*
PUMP	-0.03	-0.02
	(-2.25)**	(-1.75)**
% of correct prediction	0.77	0.87
Log Likelihood	-23.5	-17.9

Notes:

1 Numbers in parentheses are *t*-statistics.

2 Number of sample = 44.

3 ***, **, * Significant at the 1%, 5% and 10% respectively.

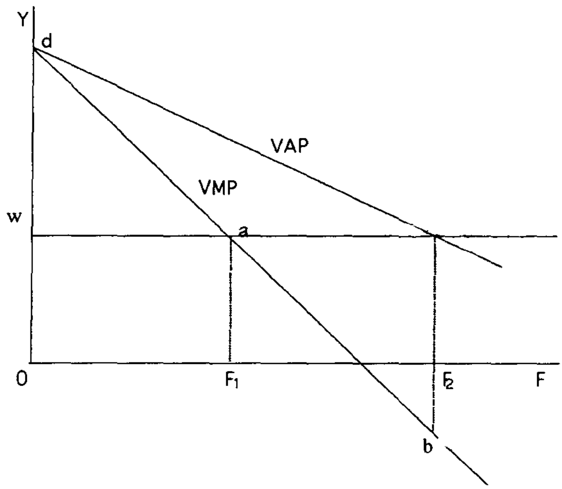

Figure 54.4: Transformation of Bethma in Sri Lanka

These findings provide substantial evidence to support our hypothesis that the expansion of cultivated areas during the wet season due to population growth in rural villages has increased the amount of water use in tanks, which decreases the amount of water that can be used during the next dry season. This in turn has made the implementation of the *bethma* difficult. The process of the *bethma* transformation is explained in Figure 54.4. In this model we consider the transformation of the *bethma* as dissipation of rent of CPRs. We assumed that each village has one tank and that all farmers cultivate paddy under the *bethma*. This assumption is realistic because nearly 50 per cent of the sample villages have only one tank and that paddy is the only crop farmer can cultivate under the *bethma*. The horizontal axis in Figure 54.4 shows the time or the increase in farm households and the vertical axis shows the value of the average and marginal product (VAP and VMP), which can be earned from cultivating PW areas under the *bethma* during the dry season from one tank in one village. If the number of farm households is F_1 and all farmers cooperate under the *bethma*, the rent will maximize at *w = VMP,* (wad), where w is the unit cost required to cultivate paddy under the *bethma*. We assume that the *bethma* is a system that distributes this rent among farmers in villages when water is scarce during the dry season. According to the expansion of cultivated AW areas during the wet season due to population increases, the rent also gradually decreases. That is, if the number of farm households increases to F_2 where w = VAP, rent will dissipate (Δwad =Δabc). Actually, a population increase might cause subdivision of cultivation areas in PW under the *bethma* and a scarcity of water during the dry season destabilizes paddy cultivation in rural Sri Lankan villages. We suppose that the transformation of the *bethma* in Sri Lanka is similar to "the tragedy of commons" as described by Hardin (1968). Furthermore, we can consider that agro-well and pump made it possible to cultivate high profitable crop such as chilli and onion in AW area, which raised the opportunity cost to join the *bethma* that can cultivate only paddy under small PW area. We can understand this move w upward and decrease the rent (Δwad) in Figure 54.4, which accelerate the change of the *bethma* further.

Concluding Remarks

The diffusion of agro-well and pump has been significant since early 1990s in Sri Lanka. A feature of agro-well and pump in Sri Lanka as compared to other South Asian countries is the small size of pumps and thereby the small size of irrigable area for a set of agro-well and pump. The great majority of farmers who own agro-well and pump use pumped-up water to irrigate OFCs, such as chilli and onion. The diffusion of agro-well and pump has changed the cropping pattern of the dry season from no or very extensive cultivation of paddy to the intensive cultivation of high value crops such as chilli and onion. The profit of chilli and onion cultivation with agro-well and pump is about three times higher than that of paddy cultivation using canal water.

The IRR of investment in set of lined agro-well and pump is estimated to be 33 per cent (with subsidy) and 18 per cent (without subsidy) for chilli cultivation in H village. The IRR of investment in unlined agro-well and pump is estimated to be 50 per cent for onion cultivation in O village. These IRR figures are higher than the typical interest rate (15% per year) of development loans provided by the government. Therefore, returns from crops that generated through agro-well and pump are sufficiently high to induce farmers' investments. Based on these results, it is reasonable to suppose the diffusion of agro-well and pump will continue in the water scarce dry zone of Sri Lanka.

The cultivable PW area during dry season has decreased according to the expansion of cultivable AW area in wet season. The expansion of AW area is mainly attributed to the population increase in rural villages. Furthermore, farmers tend to neglect dry season cultivation in PW area when they have access to off-farm income.

The number of villages that implement the *bethma* is 15 (24%) over the past 12 years and 11(25%) over the past 7 years in the villages sampled. Thus, the implementation of the *bethma* in rural village has been declined recently in Sri Lanka. An effort was made to find out factors that influenced the transformation of the *bethma* practice over the past 40 years. The results show that decreasing and subdivision of PW area due to population increase made the cultivation under the *bethma* not attractive for farmers. This is further supported by the fact that the smaller the decrease of the PW area over the past time, the larger the possibility of implementation of the *bethma*, though it was not significant. The increased accessibility to off-farm income sources in rural villages has lowered the socio-economic advantage of practicing the *bethma*. Moreover, the larger the rate of farmers who own land outside the village, the smaller the possibility to implement the *bethma*. In contrast, the more tanks the village has, the more likely they are to implement the *bethma*, which indicates that it is possible to select another tank for the *bethma*. The larger the rate of pump diffusion in a village, the larger will be the possibility of not practicing the *bethma*. Ownership of a private pump and agro-well made it possible to cultivate high profitable OFCs in the dry season. It lowers the incentive for farmers to cooperate under the *bethma*. The diffusion of the pump and agro-well and increasing opportunity to get non-agricultural income has raised the opportunity cost to join the *bethma* and decreased the rent of the *bethma*, which accelerate the transformation of the *bethma*.

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