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An Analysis of the Effects of the Scale of Irrigation on Paddy Production in Anuradhapura District

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ABSTRACT. *Improving irrigated agricultural productivity has been a predominant strategy for meeting food security in developing countries. Various studies under taken in South Asia, including Sri Lanka, indicate that the welfare aspects of irrigation have not been realized. In this context, a comparative study was conducted to examine the nature of technological and input level impacts on paddy production through measuring the productivity difference in major, medium, and minor irrigation systems in Anuradhapura district. The data were collected from 180 farm-households using stratified random sampling method covering major (70), medium (70) and minor (40) irrigation systems in Rajangana wewa, Thuruwelie wewa and Kumbuk wewa areas respectively. A production function decomposition analysis was used to decompose the yield differences in paddy production in the three irrigation systems.*

The results revealed that, differences in paddy yield among major-medium and medium-minor irrigation systems were 15 and 43% respectively. The results of the empirical analysis revealed that the technological effect is the major factor that contributed to the yield difference between medium and minor irrigation systems, compared to the levels of other inputs used. In contrast, it was the levels of other inputs used that contributed to the major yield differences between major and medium irrigation systems. However, this indicates that in terms of the effect of the scale of irrigation systems in paddy production, major irrigation systems had no advantage over medium irrigation systems. The findings emphasis the need for promotion of relatively better investment on minor irrigation systems.

INTRODUCTION

Irrigated agriculture provides the bulk of food and food security in the Asian region. At present, 40% of the cropland in Asia is irrigated and accounts for 70% of total cereal production. The population of Asia which is the most populated region in the world is expected to grow over 4.2 billion by 2025 (World Bank, 2001). Poor people are the most vulnerable to variability in the quantity and quality of water supplied for agricultural uses. Irrigation sector interventions, therefore, must consider programmes that contribute most efficiently to livelihood of the population and food security.

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In Sri Lanka, expansion of agriculture over the last five decades has been made possible mainly through the investment in irrigation. Over the last decade, the focus of irrigated agricultural development has gradually shifted more towards increasing agricultural productivity than expanding the irrigated area. Irrigation systems under gravity irrigation are divided into major, medium and minor on the basis of the land extent served (command area) by these systems. Major irrigation system is defined as one that has a command area of more than 1000 ha and medium system is defined as between 80 ha and 1000 ha. Minor irrigation schemes are those having a command area of 80 or less (Merry *et al.*, 1988). About 37, 23 and 40% of about 0.75 million ha of the total cultivable land area is fed by major, medium and minor irrigation systems respectively. Various analyses have shown that the large investment made in these irrigation systems has contributed significantly to increase in food production and employment (World Bank, 2001). However, there is a general concern nowadays that the performance of these irrigation systems is well below the optimal level. Little information is available on the impact of scale of these schemes on improving the welfare of the farmers. This requires a proper analysis of the scale dynamics of the irrigation systems and the role played by irrigation rehabilitation projects in the well being of the people.

Irrigation primarily reduces the uncertainty of crop production and consequently increases agricultural productivity in a number of ways. First, it can increase crop yields even without any increased use of other inputs, i.e. yield effect. Second, lower risk and uncertainty of crop production are likely to encourage greater use of other inputs, i.e. input- level effect. Third, it makes possible growing crops year around and hence can increase the cropping intensity, i.e. cropping intensity effect. Fourth, cultivation of better varieties and high-value crops may become possible with irrigation i.e. market effect. Fifth, in the long run, assurance of irrigation may influence to increase farm size, i.e. area effect. Studies also indicate improved effects of irrigation on production efficiency, income distribution and employment generation (Hussain *et al.*, 2002).

The rate and extent of the occurrence of the above effects of irrigation depends on irrigation intensity. The irrigation intensity primarily depends on the scale of irrigation in Anuradhapura district. In this context, the three scales of irrigation systems were identified for investigating the scale effect as decision criteria for prioritizing and allocating investment within the irrigation sector other than the difference in the size of the command area as it is observed that large scale irrigation systems are more complex. There are generally new settlement schemes where the users are socially heterogeneous settlers. The medium irrigation systems are managed by the Irrigation Department. Minor irrigation schemes are much homogeneous in ethnicity and religion of settlers. Traditional village settlements are typically characterized by its communal system of irrigation management. According to the Irrigation Ordinance of 1946, minor irrigation systems have two main characteristics viz i) it was constructed by the proprietors without government aid, and ii) it is maintained by the proprietors. The Irrigation Department is responsible for its refurbishment, while the operation and maintenance are done by the Department of Agrarian Services. This indicates increased state intervention in such systems during the last several decades.

It is noted that other than descriptive comparisons of these major, medium and minor irrigation systems, no effort has been taken to compare agricultural economic variables (Thiruchelvam, 2004). There is very little research done in the sphere of scale effect in irrigation schemes in Sri Lanka. In 2002, Hussain *et al*., studied agricultural water and poverty linkages on large and small irrigation systems and found the impact of improved community/ household access to irrigation on poverty in large-scale surface irrigation systems in Sri Lanka and Pakistan. Such difference in the level of production may be due to the effects of higher availability and reliability of irrigation in a major irrigation system, which brings about increased yield and income of the rural poor. However, in terms of economic variable it may be due to differences in terms of economic efficiency in production, employment generation capability and income distribution patterns among major, medium and minor irrigation systems.

In the context discussed above, the general objective of the study was to compare the major, medium and minor irrigation systems to analyze the effect of scale of irrigation on agricultural production and economic variables in Anuradhapura district. The specific objectives of the study were as follows.

(i) To compare socio-economic characteristics of major, medium and minor irrigation systems
(ii) To decompose the effect of scale of irrigation on paddy productivity into technical effect and input level effect in major, medium and minor irrigation systems in Anuradhapura district.
(iii) To compare the inputs use in paddy cultivation and relative benefits of major, medium and minor irrigation systems through the study of technological differences in the production of paddy.

METHODS

The following null hypotheses were tested to accomplish the objectives of the study.

1. There was no difference in the level of input used for paddy cultivation among the three irrigation systems.
2. There was no difference in the paddy yield among the three irrigation systems.
3. The difference in paddy yield among the three irrigations systems cannot be attributed to difference in technological effect and input level effect.

Study area, sampling and data collection

Anuradhapura district in the North Central Province of Sri Lanka was selected for this study, because it has a good combination of all three irrigation systems and paddy is mainly cultivated in *maha* and other filed crops are grown in *yala*. Major irrigation system *Rajangana wewa* having a command area of 5668 ha and 7350 farm-households, medium system - *Thuruweli wewa* having a command area of 227 ha and 200 farm-households, and minor schemes - *Madawachchiya wewa* having a command area of 58 ha and 73 farm-households and *Kumbuk wewa* having a command area of 49 ha and 55 farm households were selected for the study

Stratified proportional sampling was used in the study, and the stratification was based firstly on the location of the farm in the irrigation systems with respect to water distribution and channel network. A proportional random sample of 70 farmers each in major and medium and 40 farmers in pooled minor irrigation tanks were selected. Overall, 180 farm-householders were interviewed by using a pre-tested questionnaire to collect primary data required for the study during January 2008. Secondary data such as cropping pattern, extent cultivated, input supply, irrigation operation and management, production etc. were extracted from the reports of the Department of Agriculture, Irrigation Department, and Department of Agrarian Services of Anuradhapura district.

Conceptual framework

In agriculture, the use of inputs and their efficiency largely depend on the different conditions faced by farmers. In order to explain the output variation through a production function for the three irrigations systems, a Cobb-Douglas production function was fitted in the data through standard multiple regression techniques. To sort out the contribution of these effects, separate production functions had been estimated for the three types of irrigation systems.

The components that constitute the yield difference are composed of a technological effect (effect of water) and a level of input use effect. The technological effect increases production because of shifts in the production function, while the input effect increases production by moving along the production function.

To discern the true impact of irrigation scale on gross income, a decomposition production function was used. Thiruchelvam and Pathmaraja (1999) used decomposition production approach to discern the true impact of soil salinity in the Mahaweli system H. The decomposition analysis model developed by them was employed in this study to decompose the difference of gross income per farm among major, medium and minor irrigation systems, into component elements viz. neutral technical difference, non neutral technical difference and difference in the level of inputs. The fitted log-log linear production functions for major, medium and minor irrigation systems the following procedure was used for the decomposition.

Major irrigation system (MA)

$$\text{Log } Y_{MA} = \text{Log } A_{MA} + \alpha_{MA} \text{ Log } S_{MA} + \beta_{MA} \text{ Log } F_{MA} + \mu_{MA} \text{ Log } L_{MA} + \infty_{MA} \text{ Log } K_{MA} \quad (1)$$

Medium irrigation system (ME)

$$\text{Log } Y_{ME} = \text{Log } A_{ME} + \alpha_{ME} \text{ Log } S_{ME} + \beta_{ME} \text{ Log } F_{ME} + \mu_{ME} \text{ Log } L_{ME} + \infty_{ME} \text{ Log } K_{ME} \quad (2)$$

Minor irrigation system (MI)

$$\text{Log } Y_{MI} = \text{Log } A_{MI} + \alpha_{MI} \text{ Log } S_{MI} + \beta_{MI} \text{ Log } F_{MI} + \mu_{MI} \text{ Log } L_{MI} + \infty_{MI} \text{ Log } K_{MI} \quad (3)$$

Where Y is Yield (kg/ha.), S is expenditure on seed paddy (Rs./ha), F is expenditure on fertilizer and agro-chemicals (Rs./ha), L is expenditure on labour (Rs./ha), and K is expenditure on farm power (Rs./ha). A is scale parameter and α, β, μ and ∞ are production elasticities with respect to different variables.

$$\text{Log } Y_{MA} - \text{Log } Y_{ME} = (\text{Log } A_{MA} - \text{Log } A_{ME}) + (\alpha_{MA} \text{ Log } S_{MA} - \alpha_{ME} \text{ Log } S_{ME} + \alpha_{MA} \text{ Log } S_{ME} - \alpha_{MA} \text{ Log } S_{ME}) + (\beta_{MA} \text{ Log } F_{MA} - \beta_{ME} \text{ Log } F_{ME} + \beta_{MA} \text{ Log } F_{ME} - \beta_{MA} \text{ Log } F_{ME}) + (\mu_{MA} \text{ Log}$$

L_{MA}- μ_{ME} Log L_{ME} + μ_{MA} Log L_{MA} - μ_{MA} Log L_{ME}) + (∞_{MA} Log K_{MA}- ∞_{ME} Log K_{ME} + ∞_{MA} Log K_{ME}- ∞_{ME} Log K_{ME}) ....(4)

Equations ME (2) and MI (3)

Log Y_{ME} – Log Y_{MI} = (Log A_{ME}- Log A_{MI}) + (α_{ME} Log S_{ME} - α_{MI} Log S_{MI} + α_{ME} Log S_{MI} - α_{ME} Log S_{MI}) + (β_{ME} Log F_{ME} - β_{MI} Log F_{MI} + β_{ME} Log F_{MI} - β_{ME} Log F_{MI}) + (μ_{ME} Log L_{ME}- μ_{MI} Log L_{MI} + μ_{ME} Log L_{ME} - μ_{ME} Log L_{MI}) + (∞_{ME} Log K_{ME}- ∞_{MI} Log K_{MI} + ∞_{ME} Log K_{MI}- ∞_{MI} Log K_{MI}) ......………………………………......……… ……(5)

Rearranging terms in equation (4) yield the following:

Log (Y_{MA}/Y_{ME}) = Log (A_{MA}/A_{ME}) + {[(α_{MA}- α_{ME}) Log S_{ME}] + [(β_{MA} - β_{ME}) Log F_{ME}] + [(μ_{MA} - μ_{ME}) Log L_{ME}] + [(∞_{MA} – ∞_{ME}) Log K_{ME}]} + {[α_{MA} Log (S_{MA} / S_{ME})] + [β_{MA} Log (F_{MA}/F_{ME})] + [μ_{MA} Log (L_{MA} / L_{ME})] + [∞_{MA} Log (K_{MA} / K_{ME})]} ....(6)

Rearranging terms in equation (5) yield the following:

Log (Y_{ME} / Y_{MI}) = Log (A_{ME} / A_{MI}) + {[(α_{ME} - α_{MI}) Log S_{MI}] + [(β_{ME} - β_{MI}) Log F_{MI}] + [(μ_{ME} – μ_{MI}) Log L_{MI}] + [(∞_{ME}- ∞_{MI}) Log K_{MI}]}+ {(α_{ME} [Log (S_{ME} / S_{MI})] + [β_{ME} Log (F_{ME} / F_{MI})] + [μ_{ME} Log (L_{ME} / L_{MI})] + [∞_{ME} Log (K_{ME} / K_{MI})]} .... (7)

The yield decomposition model (6) and (7) partition the total differences in paddy production between major and medium irrigation schemes, and medium and minor irrigation schemes into the following three components.

1. The first bracketed expression on the right hand side of the above equations is a measure of percentage change in yield due to technological change because of the status of irrigation system i.e. neutral change.

2. The second bracketed expression is the sum of the differences in the output elasticity weighted by the natural logarithms of the levels of the inputs used. This gives the measure of change in the yield due to non-neutral technology.

3. The third bracketed expression is the sum of natural logarithms of the ratio of the inputs used on the major, medium and minor irrigation systems each weighted by the output elasticity of that input. This expression measures the change in the yield due to changes in the levels of inputs at the given output elasticity of these inputs on the paddy crop by the farmers in major, medium and minor irrigation scheme i.e. changes in the levels of inputs.

Comparative mean analysis was done as a test of whether there exists a statistically significant difference among the means of variables among the three types of irrigation systems in the study area. Chow's test was also used to test the null hypothesis of no structural difference among the three production functions with respect to the irrigations systems.

RESULTS AND DISCUSSION

Demographic and socio-economic aspects of irrigation systems

Average ages of the farmers in the communities were 52, 48 and 54 years for major, medium and minor irrigation systems respectively. Their farming experiences ranged between 28 to 30 years. Economically active population was above 65% and there was a dependent population of 35 – 40% in all irrigation systems. About 18, 12 and 10% have studied above grade 10 and about 12, 9 and 29% of the farmers had not received primary education in major, medium and minor irrigation systems respectively. Nearly 95% of the sample population is engaged in full time farming and about 90% of the sample was involved in paddy cultivation in all irrigation systems.

The average monthly family income of sample population varies between Rs. 7,500 and Rs.13,000 in major irrigation and medium irrigation systems and Rs. 3,500 to Rs. 9,100 in minor irrigation systems. Further dependency ratio was high in minor irrigation system compared with major and medium irrigation systems. It was found that 9, 19 and 32% of the farmers were accounting for earnings less than Rs.3,500.00 per month in major, medium and minor irrigation systems respectively. Income distribution did not vary significantly between major and medium irrigation systems and comparatively higher inequity existed in the minor irrigation systems. The main reason was that land was equitably allocated in major and medium irrigation systems, whereas the land allotment size differed considerably in minor irrigation systems. Inequitable distribution of irrigation water was the major cause of the disparity in all irrigation systems. This is in agreement with the results obtained by Thiruchelvam (2004) in income inequality among farmers in Mahaweli system H.

Comparative mean analysis of paddy yields and inputs

Except labor and total cost, other inputs such as land extent, seed amount, and amount of fertilizer use, cost of chemical and machinery power used were significantly different at p=0.01 among the major, medium and minor irrigation systems (Table 1). Land holding sizes were 0.71, 0.69 and 0.23 ha in the major, medium and minor irrigation systems respectively. In minor irrigation system, lands were subject to more land fragmentation as a result of population increase, whereas in major and medium irrigation systems this was not prominent as legalities restrict land fragmentation.

The average paddy yields were 4.51, 3.74 and 3.12 mt/ha in major, medium and minor irrigation systems respectively. Cropping intensity which reflects the availability of irrigation water in the irrigation systems were 1.64, 1.34 and 0.71 for major, medium and minor irrigation systems respectively. This showed the existence of moderate, high and severe inadequacy of irrigation water in major, medium and minor irrigation systems respectively. The level of seed paddy use of the major scheme was 104 kg/ha. Seed paddy use was significantly high in medium and minor systems which may be due to poor seed quality and insecure water supply. Fertilizer application was as high as 334 to 458 kg/ha despite the low yield level of 4.5 mt/ha. It was due to application not being practiced at appropriate time in medium and minor irrigation systems. Agro-chemical use also varied according to the irrigation systems and water scarcity. It was significantly high in minor irrigation system. Labour used in paddy production was more in minor schemes compared to other two schemes where more machinery was used. Due to low availability of tractors, high cost and fragmented smaller scattered parcels in landholdings, most of the farmers in minor schemes prefer to use buffaloes for land preparation. The use of all the inputs was relatively higher in the case of major schemes followed by medium and minor schemes respectively.

Table 1. Comparative mean analysis of paddy cultivation input use *Maha* 2006/07 Anuradhapura District

Item		Major n_1=70	Medium n_2=70	Minor n_3=40	F value
Yield	(kg/ha)	4,510.00	3,952.00	3,112.00	6.23*
Seed paddy	(kg/ha)	104.00	123.00	137.00	7.34*
Seed Cost	(Rs./ha)	2,585.00	3,010.00	2,965.00	6.23*
Total labour	(md/ha)	82.00	84.00	90.00	2.02
Labour Cost	(Rs./ha)	27,375.00	30,630.00	31,720.00	4.22*
Fertilizer	(kg/ha)	458.00	368.00	334.00	5.34*
Fertilizer Cost	(Rs./ha)	3,120.00	2,950.00	22,255.00	5.12*
Agrochem.Cost	(Rs./ha)	3,130.00	2,729.00	2,640.00	5.52*
Power Cost	(Rs./ha)	12,000.00	10,320.00	8,150.00	4.45*
Total Cost	(Rs./ha)	48,210.00	49,639.00	47,739.00	2.11

*F table value at 5 percent level = 2.94

The means of the components of paddy *maha* 2006/07 production and their differences between major and medium, medium and minor irrigation systems are given in Table 2. Mean gross income difference between major and medium was 15.1% and the difference between medium and minor irrigation systems was 43.4%. Price received by major and medium irrigation systems was higher than minor irrigation systems due to timely cultivation, farm power availability and infrastructural facilities. High yield together with higher price and better market arrangement further contributed to higher gross income in major irrigation system. Low yield and low price for paddy were the factors that contributed to the low gross income in medium and minor irrigation systems. Scarcity of irrigation water was the main reason for this in minor schemes than medium irrigation systems. These results provide the justification to investigate further the relative difference among the three irrigation systems.

Table 2. Means and difference of components - paddy Maha 2006/07

Components	Major (MA) n_1=70	Medium (ME) n_2=70	Minor (MI) n_3=40	Difference	
				MA & ME[1]	ME & MI[2]
Cropping Intensity (%)	1.60	1.45	0.96	0.15 (10.3%)	0.49 (51.0%)
Cultivated area (ha)	0.71	0.69	0.23	0.02 (2.9%)	0.0.46 (200%)
Yield (kg/ha)	4510	3952	3112	558 (14.1%)	840 (27.0%)
Price of paddy (Rs./kg)	17.65	17.50	15.50	0.15 (0.9%)	2.00 (12.9%)
Gross Income (Rs./ha)	79602	69169	48235	10432 (15.1%)	20935(43.4%)

Figures in parenthesis are percentage difference based on medium in 1 and minor in 2 respectively.

Production function analysis

The results of regression analysis for each irrigation system are presented in Table 3. The value of adjusted R^2 ranges from 82% for major to 78% for minor irrigation systems. In major irrigation system, all factors of production, seeds, fertilizer, machinery power and labor were significant. This indicates the importance of these factors on production in major irrigation systems. Here, only labor had a negative impact on paddy production. Meanwhile, in medium irrigation systems all factors of production were significant except labor. According to the results, labor had no impact on paddy production in medium schemes. Positive sign of seeds, machinery power and fertilizer indicated its importance to production in medium schemes. In minor irrigation systems, only machinery power and fertilizer were significant on paddy production. Here, positive sign of fertilizer and machinery power indicated its importance to paddy production. Seeds and labor had no impact on paddy production in minor schemes in Anuradhapura district. Overall farm power use had impact on production in all the irrigation systems indicating the importance of mechanization in agriculture. These results reflect the response behavior with respect to input changes significantly with decrease in water reliability from major to minor irrigation systems. The three production functions of major, medium and minor irrigation systems were tested for structural difference using the Chow's test. The test revealed no significant differences between major and medium but significant difference between medium and minor systems at 5 percent significant level.

Table 3. Results of production function for major, medium and minor irrigation systems in Anuradhapura District

Schemes	Constant	Seed	Fertilizer	Labour	Power	R^2
Major	0.0418	0.1263*	0.2198*	-0.3137*	0.8648*	0.83
T-value	2.01	2.95	4.10	-5.85	5.91	(0.82)
P-value	0.050	0.005	0.000	0.000	0.000	n_1= 70
Medium	-0.1249	0.3532**	0.2086**	0.1325	0.8979**	0.77
T- value	-2.57	2.33	2.63	0.59	2.63	(0.75)
P- value	0.013	0.025	0.012	0.558	0.012	n_2= 70
Minor	-0.0016	0.0821	0.4185	-0.0157	0.5606	0.79
T-value	-0.05	0.95	3.46	-0.16	2.27	(0.78)
P-value	0.958	0.350	0.001*	0.876	0.028**	n_3= 40

* significant at $p < 0.001$ and ** significant at $p < 0.05$ respectively Figure in parentheses are adjusted R^2

Decomposition analysis

The decomposition equation provides the mechanism for decomposing the total yield difference among major and medium and medium and minor irrigation system farmers' paddy production. The results are reported in Table 4. Total change in the yield gap between major and medium systems as a percentage based to the medium system was 108%.

The corresponding figure for medium and minor irrigation systems based on minor irrigation system was 132%. The difference in the magnitude of the intercept of the three production functions is an indicator of the direct effect of the water in paddy yield. In this study, the direct effect was interpreted as the effect of the difference of the irrigation systems. This difference was negative and 64% for major and medium irrigation systems. This means that major irrigation systems had no clear advantage over the medium irrigation systems. The corresponding figure was positive and 45% for medium and minor irrigation systems shows significant neutral technical effect. This means that the medium irrigation system had a clear advantage over the minor irrigation systems.

Table 4. Decomposition of total difference in paddy yield among major, medium and minor irrigation systems in Anuradhapura District

Components	Percentage attributable			
	Major vs. Medium		Medium vs. Minor	
Technical Effect				
Neutral technical effect (Direct effect of water)	-0.640		0.454	
Non-neutral technical effect (Indirect effect of water)	0.611		0.261	
Input Level Effect	1.107		0.510	
Seed		0.684		0.214
Fertilizer		- 0.147		- 0.081
Labour		0.434		0.668
Farm Power		0.206		- 0.198
Net Total	1.083		1.320	

The non-neutral technical effect was 61% for major and medium irrigation systems and it was 51% for medium and minor irrigation systems. Since the neutral technical effect was ignored between major and medium irrigation systems, input used effect contributed more for yield in the former compared to the latter. The non-neutral technical effect was caused by the change of quality of inputs and the interaction among the inputs and finally by difference in productivity of inputs. In both cases, the contributions of seed and labour inputs were positive. While fertilizer effect between major and medium irrigation systems was positive, the corresponding figure for medium and minor irrigation system was negative. This implies that usage of fertilizer in medium irrigation systems had no advantage over the minor irrigation systems in paddy production. Negative impact of farm power in both indicates the problem of mechanization in agricultural production in general.

CONCLUSIONS

Compared to minor irrigation systems, major and medium irrigation systems were better endowed with irrigation infrastructure, agricultural resources such as irrigation availability and inputs. In terms of the effect of the scale of irrigation systems in paddy production, major irrigation systems had no advantage over medium irrigation systems. The contribution of input use (61%) was the major reason for higher income in the major than the medium irrigation systems.

In contrast, medium irrigation systems had clear advantage over minor irrigation systems. This implies that higher access to irrigation water in medium irrigation systems brought about an upward shift (32%) in paddy production compared to minor irrigation systems. Thus improving irrigation water management is important to exploit the potential of minor irrigation systems for paddy production.

Major and medium irrigation systems that had higher access to water tend to over-use inputs while minor irrigation systems with low access to water tend to under- use inputs for paddy production. The agricultural production capacity of minor irrigation systems should not be overlooked from the national point of view. Proper evaluation is required on ecosystems and socio-economic nature of minor irrigation systems.

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