An assessment of returns to irrigation infrastructure investment: Hurulu wewa

MGD Abeysekara
Department of Agricultural Economics and Business Management, Faculty of Agriculture, University of Peradeniya, Sri Lanka

DS Munasinghe
Human Settlement Planning and Training Division, National Building Research Organisation, Sri Lanka

J Weerahewa
Department of Agricultural Economics and Business Management, Faculty of Agriculture, University of Peradeniya, Sri Lanka

ABSTRACT: The life expectancy of the infrastructure in a typical gravity irrigation system varies depending on many factors. Good preventive maintenance can extend a system's longevity, but eventually the system will need to be renovated or replaced. The objective of this study is to assess returns on investment of renovations of infrastructure in Hurulu wewa major irrigation system. The specific objectives are to estimate the relationship between paddy production and irrigation water using a production function and to calculate the net benefits of increased irrigation efficiency due to renovation using cost benefit analysis. A primary survey was conducted to collect data about the paddy cultivation for 2015 Yala in the Right Bank Main Canal of Hurulu wewa scheme. Data on water issues and costs of renovation in the system was obtained from related government publications. Irrigation water, machinery, urea and labour were found to have a statistically significant effect on paddy production. The incremental value of paddy production due to increase in a cubic meter of irrigation water was estimated to be 0.2 kg per acre. These results were then used to simulate the incremental value of paddy production due to increased efficiency of irrigation infrastructure under different degrees of irrigation efficiencies. Cost benefits analysis revealed that benefits from the paddy production only could cover the 0.7 of the total cost including initial investment, operation and maintenance cost and the essential improvements over the 40 years of the life cycle of the irrigation system with a discount factor of 12%.

1 INTRODUCTION

Irrigation plays a vital role in agricultural production in the Dry Zone (DZ) area, which covers three-fourths of Sri Lanka. As water is a scarce resource in the DZ, optimizing the water usage to achieve increased crop production has a great importance. As the performance of the irrigation system decides the available water for agriculture, in recent years it has become a growing concern of the researchers, irrigation policy makers and donor agencies.

Since independence, investment in irrigation sector has received a high priority in the Public Investment Program (PIP) in Sri Lanka. It is not surprising that such large allocations were made for investment in irrigation, as the country is experiencing traditionally a predominantly agricultural economy. Although GDP share of agriculture sector in the economy has dropped to 11.1 percent in 2012 from 17.2 in 2005, due to faster growth in manufacturing and service oriented sectors, it continued to remain the bedrock in the economy. Moreover, water resources in the country have been intensively used for securing the livelihood of the rural community and the food security of the country. Therefore, the public investment towards agriculture and irrigation has been increased by two fold in 2012 over 2007(Ministry of Finance and Planning, 2012). Nearly 81.7 percent of the total population (World Bank, 2014) live in rural areas and earns a livelihood from agriculture and related activities. The government of Sri Lanka, as one of the strategies to alleviate rural poverty while ensuring food security is making investments on large irrigation systems. Irrigation is an input that helps not only in the expansion of area under agriculture, but can also facilitate technological change and therefore, help to increase productivity.

In Asia, almost 84 percent of the water withdrawal is used for agricultural purposes,

compared to 71 percent for the world. The Indian subcontinent has the highest level of water withdrawal for agriculture with 92 percent (FAO, 2005). In Sri Lanka paddy being the staple food crop accounts for 25 percent of total cultivable land and is grown on nearly 730,000ha of land, and 243,000 of this total is grown under major irrigation systems. Paddy uses 90 percent of the 96 percent of available irrigation water (Amarasinghe, et al., 1998) . Most researches (Lakmali, et al., 2015) on water management activities of several major irrigation schemes in the Dry Zone indicate that the irrigation water distribution does not meet the demands of farmers in terms of adequacy, reliability & timeliness. Furthermore, it was said that there is considerable potential to increase paddy yield in these systems through improved irrigation water management, especially by enhancing the irrigation system performance. Inefficiencies in irrigation systems create various issues in the national economy while affecting the social cohesion of the society due to water scarcity in terms of irrigation water deficiencies and low irrigation water reliability. Implementation of properly planned renovations and rehabilitation activities should be carried out at the correct time and it is important to maintain the performance of an irrigation system continuously at a desirable level.

1.1 *Irrigation Systems in Sri Lanka*

Three types of irrigation systems can be identified in Sri Lanka based on the land extent served (command area) by these schemes namely major, medium and minor. Major irrigation systems are defined as those that have command area of more than 1000 ha. The command extent is between 80 and 1000 ha in medium irrigation systems. The Department of Irrigation has the responsibility of managing those two systems. Minor irrigation systems have command area of 80 ha or less and they come under the management of Department of Agrarian Development (Merry, et al., 1988). The total irrigated land area is about 744,983 ha of which, 311,195 ha is fed by the minor irrigation schemes while the remainder is fed by major and medium scale irrigation schemes (Ministry of Finance and Planning, 2012).

1.2 *Emphasis on Irrigation Rehabilitation*

Expansion of the land area under cultivation through the development of irrigation systems and land settlement has been a principal investment strategy of all governments in Sri Lanka for achieving the national goal of food self-sufficiency and food security. The process of expanding the land area has been dominated by investments in the construction of new irrigation systems and rehabilitation works on the existing irrigation system infrastructure. Most of the present irrigation systems in Sri Lanka are 30-50 years old and some of them, for a variety of reasons, are currently showing the need for rehabilitation and improvements (Abeysekara, 1993). This issue has been addressed at different levels of the irrigated agriculture system by the professionals of different disciplines (Molden, et al., 1998).

With the development of most of the easily irrigable land, the cost of irrigation construction has increased tremendously. Several studies on irrigation system performances suggested that existing irrigation systems in Sri Lanka are substantially under- performing (Aluwihare & Kikuchi, 1991). More or less coinciding with the completion of Mahaweli works, Sri Lanka's irrigation sector appears to have entered a new development phase, distinguished by the heavy emphasis on the rehabilitation and management of the existing irrigation resources, rather than on constructing new systems (Abeysekara, 1993).

Rehabilitation of irrigation infrastructure usually means a restoration of the physical system to its original design specification; expanding systems to irrigate an additional area, and modernization to achieve objectives set at the time of construction. However, it is a broad context which goes beyond the physical construction as rehabilitation should provide an opportunity to reap the benefits from the advances in the technology that have taken place since the inception of the project.

1.3 *Problem Statement*

The challenges for increasing the productivity of irrigation systems have forced the country to think of new strategies. Thus, the diagnosis of existing irrigation services and modernization options are needed. As the opportunities available for further expansion of irrigated lands in the country are very limited, investing on the existing irrigation infrastructure rehabilitation is important. Investment for irrigation development is considered to be the responsibility of the government, especially in a welfare state like Sri Lanka. The available literature on the irrigation investments emphasize on the increasing need for pursuing cost-effective rehabilitation strategies, and the usefulness of management-oriented strategies as a means of achieving greater project viability. Therefore, prior to an investment it is worthwhile to assess whether the investment decisions will bring positive returns.

There are various types of benefits, which are associated with irrigation systems. Agricultural production accounts for the largest proportion of

these benefits. The research question derived was to assess the potential benefits of investment on irrigation infrastructure. Research Objectives are to estimate the relationship between total paddy production and irrigation water supply; to simulate the incremental value of paddy production due to increased efficiency of irrigation infrastructure and to evaluate the net benefits of investment on irrigation infrastructure in the life cycle of irrigation system over a period.

2 METHODOLOGY

2.1 *Study Area*

The *Huruluwewa* major irrigation scheme which is in the jurisdiction of the *Galenbidunuwewa* Divisional Secretariat Division of the Anuradhapura District in the North Central Province of Sri Lanka was restored to a full supply capacity of 55,000 acre feet in 1953 by the Department of irrigation at a capital cost of approximately Rs.7million. The reservoir is located in the *Yan Oya* river basin. The irrigation scheme has been planned to provide irrigation facilities for 4,453 hectares. The Irrigation Department (ID) and the Irrigation Management Division (IMD) jointly manage the scheme's irrigation and related socioeconomic resources, respectively. The management of field-level irrigation infrastructure and other related water activities is the responsibility of the relevant farmer organizations (FOs).

Some of the important technical data of *Huruluwewa* Scheme are as follows. The land extents in acres for the three Main Canals (MC) are 3,200 in Left Bank (LB), 7200 in Right Bank (RB) and 27 acres in Centre sluice. The tank bund length is 2.37km and bund lop width is 6.7m. The total length of Main Canals (MC), Branch Canals (BC), Distributary Canals (DC) and Field Canals (FC) are 31.6km, 5.0km, 38.62km and 168.25km respectively. The total length of the agricultural roads in the system is 178.8 km.

2.2 *Theoretical Approach*

Under certain assumptions, the production function can be used to derive a marginal product for each factor, which implies an ideal division of the income generated from output into an income due to each input factor of production (Cobb & Douglas, 1928). Furthermore, it allows to explain the output value generated by either company, industry or the whole economy based on diverse combinations of factors determining the existing technology (Suchankova & Bezdekovska, 2012).

Selection of functional form for production analysis is a particularly important and critical consideration. As cited by Weligamage, et al (2014) previous researchers have used a wide variety of functional forms. For example, agricultural production functions related to rice farming in other irrigation systems in the Sri Lankan Dry Zone were previously estimated by Abeygunawardena (1986) using a linear functional form and by Wijayaratne (1986) and Jegasothy et al. (1990) using a quadratic functional form. However, the Cobb–Douglas production function is the most widely used functional form in agricultural production and has been used in variety of applications ranging from farm level to international comparisons. This functional form imposes the strong assumptions that a constant percentage change in inputs leads to a constant percentage change in output at all levels of inputs and that the elasticity of substitution between inputs is 1.

Empirical model can be written as follow, where Y denotes the output and X_i denotes the different inputs.

$Y_i = A X_i^{a1}$

It can be linearized and further re-written as,

$\ln Y = \ln a_0 + a_1 \ln X_i$

It is further expanded in accordance with the assumption that the yield is a function of different inputs,

$\ln Yi = a_0 + a_1 \ln X_1 + a_2 \ln X_2 + a_3 \ln X_3 + a_4 \ln X_4 + a_5 \ln X_5 + a_6 \ln X_6 + a_7 \ln X_7 + a_8 \ln X_8$

A linear production function can be written as follows where $ß_{xi}$, which is the production coefficient, denotes the marginal productivity.

$Y = ß_0 X_1 + ß_1 X_2 + ß_2 X_3 + ß_3 X_4 + ß_4 X_5 + ß_5 X_6 + ß_7 X_8 + ß_8 X_9$

Here in the production function approach, production (paddy yield) per acre was considered as the dependent variable. Per acre labour, machinery, fertilizer (Urea, MOP and TSP), chemicals (weedicides and pesticides), irrigation water and seeds usage were considered as the quantitative independent variables. As the coefficient of irrigation water expresses the incremental value of paddy production due to increase of irrigation water availability, it was used to value the benefit stream in the Cost Benefit Analysis.

2.2.1 Primary Data Collection

From the two main canals (RB-MC and LB-MC) the RB-MC was selected for the study. In the right bank main canal (RB-MC), there are 9 Farmer Organizations (FO) representing 13 Distributary canals (DC). Farm households were selected from these 13 D canals. 15 farmers were then randomly selected from each DC using the membership lists. All together 210 interviews were conducted. Primary data related to 2015 *Yala* cultivation was collected through a pre tested structured questionnaire. Through that survey instrument, farmers' recall data were collected for the

dependent variable paddy production and the all other independent variables including seeds, fertilizer, chemicals, labour and machinery except the variable irrigation water.

2.2.2 Water Measurements

Water is a multi-purpose resource and agriculture is only one of its many uses. The quantity of water applied and its timing largely determine crop output of a farm. Although water is one of the most important inputs in irrigated agriculture, water input is rarely carefully quantified at the farm level. Water used at the farm level can be best-expressed using real-time measurements of water inflow to a given field. Alternatives to real-time measures that have been used for economic analysis include the number of irrigations (Hussain and Young 1985; Young 2005) and an index of water availability (Wijayaratne 1986) as mentioned by Weligamage et al (2014). For this study irrigation water availability was calculated by using the flow measurement data collected during the water issues for the *Yala* season by the *Hurulu wewa* scheme.

In this process, the flow measurements were taken from different points along the MC, which is 16km long. Then flow measurements were taken at the different points from each DC. As there are considerable number of FC in one DC water flow was measured in only selected FCs. Then the water curves were developed for each canal with the distance, which was calculated using the GPS points. With the help of these curves, the amount of irrigation water that was received by each plot was calculated.

2.3 *Assessment of Financial Profitability of Investment on Irrigation Infrastructure Rehabilitation.*

2.3.1 Methods of Analysis

Project analysis procedure was used to analyse the financial profitability of the investment. Cost-benefit analysis (CBA) provides the technical tool to assess whether involvement in a certain project is economically beneficial. In general, two types of cost-benefit analyses can be distinguished as social and financial CBA (Little & Mirrless, 1980) . Both analyses make use of the same concept and calculation procedures. Their main difference is that of the point of view adopted.

The basic principle of a CBA is to list all input into and output from a project, express them in monetary terms, and subtract the costs from the benefits to obtain a net value for the project. The decision criterion is if the net value is positive, the project is accepted – if it is negative, then the project is rejected. Higher the NPV higher the project is beneficial. In order to be a worthwhile project B/C ratio should be greater than one.

NPV and B/C ratio can be calculated using the following formulas.

$$BCR = \frac{\sum_{t=1}^{r} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{r} \frac{C_t}{(1+r)^t}} \qquad 1$$

$$NPV = \sum_{t=1}^{T} \frac{(Benefit_t - Cost_t)}{(1+r)^t} \qquad 2$$

Where,

B_t is the benefit in time t

C_t is the cost in time t

r is the discount rate

To measure the project worth, NPV and B/C ratio were calculated for the typical life span of an irrigation system, which is 40 years. The costs elements for investments on irrigation infrastructure including initial investment consisting head works and downstream works, the operation and maintenance cost and the preventive and essential improvements to the system were considered. Benefits were estimated in terms of the increased paddy production due to increase of irrigation water availability in the system because of the investment made on the irrigation system.

2.3.2 Data

Both primary and secondary data was collected in order to calculate Benefit Cost ratio and NPV of the investment made. Primary data was collected related to the amount of irrigation water received by the selected farm plots during the 2015-Yala water issues in the system. Secondary data related to irrigation infrastructure and different costs associated with the renovation and rehabilitation and water issues were collected from the internal records of the *Hurulu wewa* Irrigation Engineer's (IE) office. The cultivation and production data of the system were collected from the Residential Project Manager's (RPM) office.

3 DISCUSSION

3.1 *Results of the Production Function Estimation*

The parameters of a production function explain the contribution of each input affecting production levels including irrigation water. For this study both linear and log functional form of production

functions were estimated. Descriptive statistics of the collected data are shown in Table 3.1.

Here the independent variable inputs which are under consideration are water (m^3/acre), fertilizer usage including Urea, Murate of Potash (MOP) and Triple Supper Phosphate (TSP) (kg/acre), chemical usage including weedicides and pesticides (Rs/acre), labour (man days/acre) and the usage of machinery (Rs/acre). In the case of fertilizer, by adding subsidized fertilizer and additional quantity of fertilizer that the farmers have bought, the total quantity of fertilizer used was estimated. The labour component includes both family labour and hired labour. In the variable machinery rent and the fuel cost were taken under the consideration. For the chemical input the total cost were used as it was difficult to collect data regarding to the active ingredient. Because the farmers did not have clear idea about that and types or the brands of chemicals vary in a large range.

Table 3-1 Descriptive statistics of the data used

Variable	Unit	Mean	Std. Dev.
Seeds	Kg/acre	53.43	14.49
Urea	Kg/acre	98.97	20.73
MOP	Kg/acre	24.93	5.91
TSP	Kg/acre	24.17	5.58
Chemicals	Rs/acre	2,304.86	929.97
Machinery	Rs/acre	16,322.63	5,360.46
Labour	Mandays/acre	22.05	7.43
Paddy yield	Kg/acre	1,791.21	319.21
Water	m^3/acre	2,824.87	639.39

According to the regression results which are shown in table 3.2 and 3.3, the contribution of water input is quite high in the *Hurulu wewa* system. The coefficient of water is significant at the probability level of 0.05. Other than water, machinery is significant at 0.05 probability level and the Urea and labour input are significant at 0.1 probability level. The results suggest that the water, machinery, labour availability and the application of urea for the paddy cultivation restrict the paddy production of the *Hurulu Wewa* irrigation system. Furthermore, it is evident that the effect of fertilizer except urea and the agro chemicals are very low for the further increment of the paddy production. From the above results, the incremental value of paddy yield due to improvement of water availability can be obtained as 0.2 kg/acre. Therefore, it is evident that increasing the availability of water will bring to returns on the production.

Table 3-2 Regression Results of the Linear Model

Independent variable	Coefficient	Std. Err.	t	P>t
Irrigation water	0.21	0 .03	6.87	0.000*
Seeds	-0.85	1.38	-0.62	0.537
Urea	1.66	0 .93	1.79	0.075**
MOP	-0.42	3.71	-0.11	0.909
TSP	3.76	4.00	0.94	0.349
Chemicals	0.002	0.02	0.10	0.921
Machinery	0.014	0.004	3.75	0.000*
Labour	4.69	2.73	1.72	0.087**
Constant	649.29	159.55	4.07	0.000*

**Significance at 95% confidence interval
*Significance at 90% confidence interval
$R^2 = 0.31$ Adj. $R^2 = 0.2805$ F(8, 197) = 10.99
Prob > F = 0.0000 N = 206.

Table 3-3 Regression results for the Cobb-Douglas model

Independent variable	Coeffic-ient	Std. Error	t	p>t
Irrigation water	0.3385	0.0526	6.43	0.000**
Seeds	-0.0169	0.0433	-0.39	0.695
Urea	0.1112	0.0589	1.89	0.061*
MOP	0.0030	0.0624	0.05	0.961
TSP	0.0221	0.0652	0.34	0.735
Chemicals	-0.0035	0.0506	-0.07	0.945
Machinery	0.1261	0.0281	4.50	0.000**
Labour	0.0456	0.0416	1.10	0.274
Constant	1.2792	0.2642	4.84	0.000

**Significance at 95% confidence interval
*Significance at 90% confidence interval
$R^2 = 0.3168$ Adj. $R^2 = 0.2863$ F(8, 179) = 10.38 Prob > F = 0.0000 N = 188

Many researchers who conducted research in the related disciplines and the respective institutions have identified the limitation of the available water for the cultivation in the *Hurulu wewa* system. As the condition of the system's infrastructure is in poor condition farmers cannot take the maximum use even from the available water. Therefore, there is an emerging need to make investments on irrigation infrastructure to enhance the efficiency of the system and thereby the available water for the farming practices.

3.2 *Simulating the Incremental Value of Paddy Production due to Increased Efficiency of Irrigation Infrastructure- Valuing the Benefit Stream*

According to many studies Irrigation efficiency, which is an indicator of effective water resources management, varies in different irrigation schemes in Sri Lanka, but is low in general. A systematic assessment of irrigation efficiencies across regions is not available. However, the available literature suggests that the efficiency of the present irrigation systems in the country varies in between 30 percent to 35 percent. Therefore, we assumed that the existing efficiency of the *Hurulu wewa* system is 30

percent. According to the FAO the efficiency level of a well-functioning gravity canal irrigation system is 80- 90 percent. Therefore, we assumed that through the investments we could uphold the efficiency level of the system up to different efficient levels such as 40,50,60,70 and 80 percent from the current efficiency level of 30 percent with the investments in irrigation infrastructure renovations. Along with the improvement of the efficiency level through the rehabilitation of the irrigation infrastructure, water availability will increase which subsequently enhances the paddy production. With this background, we derived the benefit stream of the irrigation investment as the incremental value of paddy production due to increase irrigation efficiency. The estimated values are shown in the table below. The calculations have been done for the total cultivable land extent in the RB-MC considering two cultivation seasons.

Table 3-4 Incremental values of production due to increased irrigation efficiency

Scenario	Efficiency	Water availability (m^3/yr)
Present efficiency	30%%	15,224,762.49
With improved irrigation efficiency	40%	19,378,139.17
	50%	24,222,673.96
	60%	29,067,208.75
	70%	33,911,743.54
	80%	38,756,278.34

According to the Central Bank (2014), the average market price of 1kg of paddy is Rs.32.6 and that value was used to estimate the total value of the production.

3.3 *Valuation the Cost Stream*

The main components of the total cost associated with the irrigation infrastructure rehabilitation can be categorized as initial investment, Operation and Maintenance (O&M) and essential improvements to the system.

3.4 *Cost- Benefit Analysis*

The project analysis procedure was used to calculate Benefit cost ratio, and NPV ratio for the investment made on the rehabilitation of the irrigation system. The project has given a B/C ratio of 0.7 and a positive NPV value at the discounting rate of 12 percent. The time period of project was considered as 40 years which is the usual life span of an irrigation system.

The cost benefit analysis revealed that benefits from the paddy production only could cover the 0.7 of the total cost including initial investment, operation and maintenance cost and the essential improvements over the 40 years of the life cycle of the irrigation system with a discount factor of 12%. The other benefits of the irrigation system need to be explored in detail so that the investment decisions could be validated considering all the aspects.

4 CONCLUSION AND RECOMMONDATION

4.1 *Summary and Conclusions*

This study assessed the returns to irrigation infrastructure investment. It is a case study in *Hurulu wewa* major irrigation system. In order to estimate the relationship between irrigation water input and the paddy yield, production function approach was used. The returns on the irrigation system rehabilitation investment were assessed using the C/B ratio and NPV.

According to the results, following general conclusions can be drawn. It can be clearly identified that the water availability significantly contributes to the paddy production as the coefficient of water is significant ($p<0.05$). The estimated production function supports the hypothesis that rice yields increase with quantity of water applied. Other than water, improvement of machinery and labour can create a significant effect on the improvement of the production level. Further increment of agro chemicals may not have an effect on yield improvement.

System efficiency, which is an indicator of the water supply from the system, can be improved through investments on irrigation infrastructure renovations. When investments are made on irrigation infrastructure, they give positive returns within the considered period, which is equal to the life cycle of a typical canal irrigation system. In the study only the benefits from the production improvement was valuated due to the increased irrigation efficiency. The results showed that the benefit from the paddy production only can accounts for recovering 70 percent of the total cost incurred for the system rehabilitation. Results of the study indicate the importance of water in determining profitability of paddy cultivation. Prior to an investment, it is worthwhile to assess whether marginal cost of providing irrigation water does not exceed the marginal benefit of water when it is used in paddy cultivation.

4.2 *Recommendations and Implications*

Irrigation system impacts are as complex as the multi-dimensional, dynamic socio-ecological systems from which they emerge. Mutually reinforcing impacts manifest themselves at the

individual-, community-, and system-levels. Crop production is one of the impacts associated with the irrigation and in the Sri Lankan context, it accounts for around 90 percent of the total irrigation supply. Among the irrigated crops, paddy is the dominant crop. Dry-zone districts account for 80 % of the gross rice area, and 91 % of the irrigated rice area. As the majority of rural population depends on the irrigated agriculture, decisions on the irrigation sector is very crucial. There is a growing consensus that Sri Lanka needs an agricultural productivity revolution if it is to achieve the food security for all and stimulate economic growth sufficiently to reduce poverty.

Most of the rehabilitation works in the country appears to be centred on irrigation development, more specifically, on physical improvement of the cannel system and the head works. However, it is important to pursue cost-effective rehabilitation strategies, and implement useful management-oriented strategies as a means of achieving greater project viability. Not only that the other benefits from the irrigation systems should be further evaluated along with the agricultural production in order to go for a proper policy implications. The sustainability of an irrigation scheme wholly depends on the degree of maintenance and the nature of operations by the owner and the beneficiaries. The contribution to the national economy by an irrigation scheme is much higher than the investment in O&M by the government. Inputs from farmers for O&M are also significant in major and medium irrigation schemes where well-organized farmer organizations exist. Frequent rehabilitation requirements arise due to the failure to attend to repairs in a timely manner and inadequate maintenance due to the lack of funds. Therefore, in order to maintain the systems longevity, O &M activities and renovations should be carried out at the correct time.

REFERENCES

Abeysekara, W. A. T., 1993. Rehabilitation of Irrigation Systems in Sri Lanka: A Literature Review, Colombo: IWMI.

Aluwihare, P. B. & Kikuchi, M., 1991. Irrigation Investments Trends in Sri Lanka:New Construction and Beyond, Colombo: International Water Managemnet Institute.

Amarasinghe, U. A., Muttuwatte, L. & Shakthivadivel, R., 1998. Water Scarcit Variations within a Country:A Case Stud in Sri Lanka, Colombo: IWMI.

Bouman, B. A. M. & Tuong, T. P., 2001. Field Water Management to Save Water and Increase Its Productivity in Irrigated Lowland Rice. Agricultural Water Management, Volume 49, pp. 11-30.

Cobb, C. B. & Douglas, P. H., 1928. A Theory of Production. s.l., American Economic Association, pp. 139-165.

Hussain, I. & Bhattarai, M., n.d. Comprehensive assessment of socio economic impacts of agricultural water uses: concepts, approaches and analytical tools, Colombo: International Water Management Institute.

Lakmali, W. A. S., Gunawardana, E. R. N. & Dayawansa, N. D. K., 2015. Comparative Performance Assessment of Major Irrigation Systems in Upper Deduru Oya Basin. Tropical Agricultural Research, 26(2), pp. 343-354.

Little, I. M. D. & Mirrless, J. A., 1980. Project Appraisal and Planning for Developing Countries. London: Heinemann Educational Books.

Merry, D. J., Rao, P. S. & Martin, E., 1988. Irrigation Management Researches in Sri Lanka:A Review of Selected Literature, Colombo: International Water Management Institute.

Molden, D. et al., 1998. Indicators for comparing performances of irrigated agricultural system, Colombo: International Water Management Institute.

Sivakumar, S. S., 2002. Water Resource and Agriculture Development Strategy for North East with Special Reference to Water Availability Study for North River Basins. A post conflict needs assessment, s.l.: s.n.

Suchankova, T. & Bezdekovska, R., 2012. Crop production Function-Study. s.l., s.n., pp. 842-847.