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Factors Influencing the Success of Tank Rehabilitation Projects in India and Sri Lanka: A Meta-Analysis

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ABSTRACT

To increase crop production in water-scarce areas, rehabilitation of tank systems is been used as an effective tool. This study conducts a meta-analysis on 48 economic impact analysis studies on the topic of tank rehabilitation. The performance of the tank rehabilitation is measured through the benefit-cost (B/C) ratio, and the factors affecting the performance of tank rehabilitation are analyzed through the meta-analysis. The results of the study reveal that the mean B/C ratio of the rehabilitation projects carried out in Sri Lanka is 2.49, while it is 2.52 for India. The regression analysis highlights that the rainfall, farmer participation, and conducting operation and management (O&M) activities along with the physical rehabilitation in the tank rehabilitation have significant positive impacts on the B/C ratio of tank rehabilitation projects. The significance of rainfall explains the fact that in areas with less rainfall, the success of rehabilitation projects was found to be low due to the inability of increasing cropping areas and cropping intensity due to water scarcity. The involvement of farmers in multiple stages of rehabilitation projects including planning, developing, and executing showed a significant impact on tank rehabilitation proving that the active and voluntary participation of all stakeholders guarantees the successful implementation and post-management of the rehabilitation. The rehabilitation projects focused on implementing O&M strategies showed high B/C ratios comparatively, which also implied the importance of farmer involvement.

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INTRODUCTION

Paddy is the most prominent and widespread cultivation in Asia where 90% of the world's rice is produced. The staple food of most Asian people is rice which has impacted the cultivation of paddy in Asia (Papademetriou, 2000). Irrigation is one of the most important factors affecting paddy growth. There are several methods of providing irrigation for paddy cultivation. One of the most widely used methods in Sri Lanka and India is tank irrigation. Tanks are called '*wewa*' in Sinhala and '*Ery/Kulam'* in Tamil languages. These are constructed structures arranged in a cascade-like fashion along shallow valley courses. They are connected by canals and spillways and build a complex system of floodwater harvesting, water storage, and water distribution (Jayatilaka *et al*., 2003). Tanks are built to conserve water for dry months and ensure the year around cultivation.

According to the supply of irrigation for paddy cultivation, paddy farming systems in Sri Lanka are divided into three main categories as Paddy land under major irrigation schemes, Paddy land under minor irrigation schemes, and Rain-fed lands (Adhikarinayake, 2005). The tanks with command areas larger than 80 hectares fall under major irrigation schemes, while tanks with command areas smaller than 80 hectares fall under minor irrigation schemes. In India, three main types of irrigation schemes can be identified major, medium, and minor irrigation works where major irrigation works are generally built on perennial rivers, and constitute large dams; medium irrigation works constitute reservoirs and tanks and minor irrigation includes all small surface and groundwater sources (Oppen and Rao, 1987). In India, the water tanks are commonly found in the *Decan* plateau and eastern part of India (Jana and Lise, 2013). The highest concentration of tanks is found to be in Tamil Nadu state. Most of them were built before the 18th century, and their development in northern Tamil Nadu is mainly due to two dynasties that reigned from the 6th to 13th century (Aubriot and Prabhakar, 2011).

The history of the tank systems in both Sri Lanka and India extends back centuries. The history of tanks in Sri Lanka runs back to the hydraulic civilization around 450 B.C. (Fernando, 1980). These are made by ancient kings for dry zone irrigation and have always been publicly managed systems. The management system was called the '*Rajakariya* system' which is a compulsory labour system of 40 days a year. The villagers were not indentured labourers nor were they employed by the State. On the contrary, the work was organized at the local level (Panabokka, 2009). '*Rajakariya'* and associated customs maintained the successful management of small tank systems for centuries. It contained different social, moral, and legal requirements with which certain agricultural communities had to comply. Besides this, there were numerous customary laws, rules, and sanctions that were used to manage scarce water resources (Aheeyar, 2000). This system was abolished by the British in 1832 without introducing an alternative system of governance which led to the downfall of the tank system (Kekulandala *et al*., 2020). According to the *Arthasasthra* (an ancient treatise on statecraft), India had a similar system of tank management to ancient Sri Lanka. Tanks were governed under an officer known as "*Nadipala*" who was appointed by the king and the labour work was carried out by the villagers (James and James, 2013). These are farmer-managed systems that had been sustainable in the past. But after the independence, the decline of the tank systems started. The major reasons for that are the disappearance of tank managing institutions in villages and the transformation of farmers into land owners (ADB, 2006). But recently, due to the scarcity of water, the importance of the tank systems has come to the light.

Tank systems have faced a decline over time due to ecological, social, and political reasons, and the rehabilitations have been started in the 20th century. The concern of managing the tank ecosystem came to light in Sri Lanka in 1900 after establishing the department of irrigation. The rehabilitation of tank systems was started after inaugurating the department of irrigation with the involvement of government and nongovernmental organizations (NGOs) (Wijekoon *et al*., 2016). There were several tank rehabilitation projects conducted in Sri Lanka to date including the tank irrigation modernization project (TIMP), Small Tank Rehabilitation Project of the Freedom from Hunger Campaign (FFHC), Anuradhapura dry zone agriculture project (ADZAP), Village irrigation rehabilitation program (VIRP), Major irrigation rehabilitation project (MIRP), Irrigation system modernization project (ISMP), National irrigation rehabilitation project (NIRP), Ten thousand tank rehabilitation project and the Plan Sri Lanka project (Abeysekara, 1993; Aheeyar, 2012; Weerawardena *et al.,* 1996).

In India, Tamil Nadu is the state where most of the tank rehabilitation projects have been carried out. The first rehabilitation project in Tamil Nadu was carried out by The Centre for Water Resources (CWR) and Anna University, Chennai with the funding of the Ford Foundation as a pilot study for future tank rehabilitation programs in the late 1970s in *Pillaipakkam* and *Padianallur* tanks (ADB, 2006). India has carried out projects such as EEC Tank Modernization Project, *Vayalagam* Tank fed Agricultural Development Program (VTADP), and NABARD Tank Rehabilitation Project in Tamil Nadu and many others in *Maharshtra, Orissa, Karnataka, Pondichery*, and *Rajasthan* states.

The tank rehabilitation projects were conducted mostly by the governments alone or with the support of NGOs. The first tank rehabilitation projects in both Sri Lanka and India have focused on the physical rehabilitation of the tank systems and attention has been received to implementing water management strategies later on. (Reddy *et al*., 2018; Jinapala *et al*., 1996). In the beginning, farmer participation in the rehabilitation projects was only limited to the project plans as the officials conducting the projects paid no attention to farmers' opinions. This started disputes between the authorities and the farmers, and the refusal of farmers in implementing newly introduced water management strategies has caused the failure of some of the major tank rehabilitation projects such as TIMP and VIRP in Sri Lanka and the EEC Tank Modernization Project in India. (Padmajani *et al.,* 2012; Palanisami *et al*., 2008).

With the experiences from failures, it has been realized that farmer participation in tank rehabilitation is extremely important. As tank systems are farmer-managed systems to implement projects and manage the system, the involvement of farmers through farmer organizations was taken into consideration in later rehabilitation projects which turned out to be successful. The FFHC and NIRP projects in Sri Lanka and VTADP in India are examples of success stories in community-based tank rehabilitation (Abeysekara, 1993; Groenfeldt *et al*., 1987; Roy and Kumari, 2019).

Economic analysis of tank rehabilitation projects is an important tool to analyze the economic viability of the interventions and the socioeconomic benefits (Reddy and Behera, 2009a). Even though multiple tank rehabilitation programs were carried out in both Sri Lanka and India, comprehensive economic analyses of the rehabilitation projects are very few in number. Also, there are hardly any studies assessing the economic success of tank rehabilitation projects and the socioeconomic factors affected. Therefore, the current study is designed as a meta-analysis of the economic impact analysis studies of tank rehabilitation projects conducted in Sri Lanka and India with the objectives to assess the economic performance of the projects conducted and analyze the determining factors of economic performance.

METHODOLOGY

A meta-analysis or a systematic review involves a statistical synthesis of data. In a meta-analysis, the weights assigned to each study are based on mathematical criteria that are specified in advance (Borenstein *et al*., 2011). It is a powerful methodology that collates research findings from previous studies and distills them for broader conclusions and therefore, is termed the "analysis of analyses" (Joshi *et al.*, 2008). This is used in many research streams such as medicine (Jenicek, 1989), psychology (Hyde, 1990), criminology (Wilson, 2001), education (Kulik and Kulik, 1989), and environmental studies (Joshi *et al*., 2008). The meta-analysis studies are carried out in two different manners which are tests of the statistical significance of combined results and methods for combining estimates across studies (Hedges, 1992). The current study follows the method of combining estimates across economic analysis studies of tank rehabilitation to identify the factors affecting the success of tank rehabilitation.

In this study, primary publications up to May 2021 were discovered by searching for the following terms using the search engine Google Scholar (Keywords: economic analysis or cost-benefit analysis or economic performance or economic viability of tank or reservoir rehabilitation). >200 publications were manually screened by title, abstract, and full text. Additional were discovered using informal exploratory searches by reading the reference lists of all relevant articles returned by our initial search.

For inclusion, all the publications were required to have conducted a cost-benefit analysis in the form of the ratio between the net benefit gained from the tank rehabilitation and the overall cost of the project and to include key details of the project such as location, project purpose, major interventions, farmer participation, etc. Evidence from 48 studies (of projects in the time frame of 1976-2010) in which the economic analysis of the tank rehabilitation projects was conducted through the benefit-cost analysis was considered in the current study. Through the analysis, these micro-level studies were critically reviewed and analyzed to achieve a meta-picture of the performance of rehabilitation programs and the impact of socioeconomic factors.

The benefit-cost ratio (B/C ratio) of tank rehabilitation projects indicates the success of the project (Amarnath and Raja, 2006). This was calculated as the ratio between the net benefit gained by the farmers from the tank rehabilitation (In the form of income from crop cultivation, fisheries, and animal husbandry) and the overall cost of the rehabilitation project. In this analysis, the factors affecting the B/C ratio of the tank rehabilitation projects were considered. The performance of tank rehabilitation projects under different degrees of farmer participation was highlighted in this study. Along with farmer participation, several other background factors were considered. All the parameters considered were measured or estimated using a similar methodology. The regression function used in the meta-analysis is as follows.

$$BCR = f(L, C, I, E, R, F, P)$$

Where BCR is the benefit/cost ratio of the project, L is the location, C is the command area (ha), I is the implementing institution (Dummy variable), E is elevation from sea level (m), R is rainfall (mm), F is farmer participation (Dummy variable) and P is the purpose of intervention (Dummy variable). The variables were selected based on the studies of Bardhan (2000), Joshi *et al*. (2005), Joshi *et al*. (2008), and Mishra *et al*. (2011). The specification of the explanatory variables is given in Table 1.

The linear equation derived from the regression equation is,

$$BCR = \beta_0 + \beta X + \varepsilon$$

Here, β_0 is the intercept, β is the vector of slope coefficients, X is the vector of above mentioned explanatory variables included in the model and ε is the error term.

Farmer participation in rehabilitation projects was considered as high, when the farmers actively participated in the planning, developing, implementation, and post-management stages of the projects, and the low participation indicated farmers were involved only in the implementation and/ or post-management stages. For the purpose of the intervention, projects focused only on physical rehabilitation and projects focused on tank operation and management strategies along with physical rehabilitation were considered.

Table 1: Specification of explanatory variables

Variable	Details
Location	Sri Lanka (1) India (0)
Implementing institution	Government (1) Government and NGO (0)
Farmer participation	High (Participation in planning, developing, implementing and post-management stages of the project) (1) Low (Participation only in the implementation and/or post-management stages of the project)
Purpose of intervention	Physical Rehabilitation and Implementing O&M strategies (1) Physical rehabilitation (0)

RESULTS AND DISCUSSION

The benefit-cost analysis of the rehabilitation projects that have been carried out in both Sri Lanka and India are rarely been conducted. Further, reviews on the economic analysis of these projects are also very rare. In this study, it has been revealed that the mean B/C ratio of the rehabilitation projects carried out in Sri Lanka is 2.49 when it is 2.52 for India. According to Palanisami and Flinn (1988), rehabilitation projects with a B/C ratio higher than 1.5 can be considered successful projects. When considering the mean values of the rehabilitation projects in both Sri Lanka and India, it seems that the overall rehabilitation projects are at a successful level. But when the B/C ratios were considered, it showed that 69.23% and

40.00% of B/C ratio values respectively in Sri Lankan and Indian projects lie between 0-1.49, which implies that a considerable number of projects were unsuccessful in both countries(Table 2). The tank rehabilitation projects in both Sri Lanka and India have always been criticized for these low B/C ratio values (ADB, 2006; Shakthivadivel *et al.,* 1997; Groenfeldt, 1990). The lack of coordination between the authorities and the farmer communities is considered the major reason for these failures (Palanisami and Flinn, 1998; Groenfeldt, 1990). The water scarcity, which limits the increase of cropping areas and cropping intensity, and the poor understanding of the tank hydrology are considered as other reasons (Shakthivadivel *et al*., 1997).

Meta-regression analysis

According to the results of the regression analysis, the B/C ratio of tank rehabilitation projects is significantly affected by the rainfall, farmer participation, and the activities performed in the rehabilitation project. The location, command area, implementing institution, and elevation resulted to have insignificant relationships with the B/C ratio (Table 3).

The average rainfall of the rehabilitated area showed a positive impact on the B/C ratio with a coefficient of 0.001. The same observation is mentioned in (Shakthivadivel *et al*., 1997) where the rainfall is mentioned as one of the key factors deciding the success of a tank rehabilitation project. According to Shakthivadivel *et al*. (1997), even though comprehensive tank rehabilitation programs are implemented for some areas as the rainfall is minimal, the cropping area and the cropping intensities cannot be increased. According to Joshi *et al*. (2008), if required water and soil management strategies are not implemented for the areas with less rainfall, the intended success of rehabilitation projects cannot be gained.

Table 2: Distribution of the B/C ratios of tank rehabilitation projects in Sri Lanka and India

	B/C Ratio			
Country	**0.00-1.49**	**1.50-2.99**	**3.00-4.49**	**>4.5**
Sri Lanka (%)	69.23	15.38	0.00	15.38
India (%)	40.00	37.14	5.71	17.14

Participation of farmers in rehabilitation activities showed a significant positive correlation with the B/C ratio. According to Brewer *et al*. (1992), effective management decisions in tank rehabilitation projects requires farmer input. As the tank systems have been farmer-managed systems from the past, they are the people who have built up the practical knowledge of these systems while living with the system. Therefore, a multilevel participatory approach is needed in tank rehabilitation programs (Shakthivadivel *et al*., 1997). There are several advantages of involving farmers in all stages of the rehabilitation projects. Farmers have a piece of good knowledge of the water distribution of their village irrigation systems and the associated issues which need solutions from the authorities. Even though they have limited knowledge of tank hydrology, the practical knowledge they have is useful in project designing stages (Jinapala *et al.,* 1996). When there is no coordination between the farmers and the engineers, the projects could end up as failures. TIMP project is an example of one such project where farmers rejected and neglected to follow up with the rehabilitation projects as they claimed the implementations of the project have no use for them (Abeysekara, 1984).

Table 3: Results of meta-regression analysis

Variable		**Coefficient (Standard error)**
Location (India=0)		-0.325 (1.350)
Command area (ha)		0.001 (0.000)
Implementing Institution (Government=0)		-0.122 (1.020)
Elevation (m)		-0.001 (0.001)
Rainfall (mm)		0.001 (0.000)**
Farmer participation (low=0)		2.912 (0.610)**
Purpose of intervention (Physical Rehabilitation =0)		0.599 (0.450)*
R^2	0.539	
N	48	

**Significant in 5% probability *Significant in 10% probability

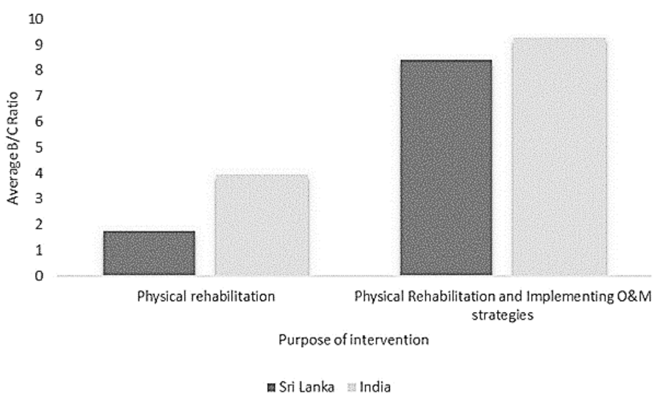

Figure 1: Average B/C ratios for different purposes of intervention

Involving farmers in the construction process has advantages such as low-cost labour, and good quality construction as farmers have an interest in the quality and farmers get a good knowledge of the project, which in a way helps in the management process (Brewer *et al*., 1992). This has been proven to be successful in MIRP and ISMP rehabilitation projects in Sri Lanka (Padmajani *et al*., 2012). In the implementation stage, the bottom-up approach where farmers have to take the management decisions and be responsible for their tank system is considered effective as the top-down approach in which the authorities take the management decisions. In the bottom-up approach, the farmer organizations are given the highest importance and this has been proved to be the most effective method in tank rehabilitation projects (Jinapala *et al*., 1996; ADB, 2006). This importance is proven from the results of the current studies as well.

The purpose of intervention in tank rehabilitation projects has a significant positive correlation with the B/C ratio. According to figure 1, the average B/C ratios are highest in the rehabilitation projects focused on water management and lowest in the projects focused on physical rehabilitation. The reason for this also could be the difference in farmer participation in rehabilitation. In the rehabilitation projects with the focus on physical rehabilitation, the farmer involvement seems to be minimal as most of the work is done by the engineers; for example, TIMP and ADZDP in Sri Lanka (Brewer *et al.,* 1992). However, when the rehabilitation projects with the focus on implementing O&M strategies are considered, they seem to have a high farmer participation level the engagement of farmers in the project for the implementation of the plans and further management is compulsory. This is evident in NIRP and Plan Sri Lanka projects in Sri Lanka (Aheeyar, 2012) and NABARD project in India (Wood, 1998). Therefore, the high B/C ratios of the tank rehabilitation projects with a focus on water management could be due to the high level of farmer participation in these projects.

The meta-analysis of the tank rehabilitation projects conducted in Sri Lanka and India revealed that the most important factor behind the success of the tank rehabilitation projects is farmer participation. As tank systems have a very strong and sensitive relationship with the farmers who live around with their livelihoods depending on the tanks, this shows the need for rehabilitation to comply with the farmers' requirements. According to Brewer *et al.* (1992), even though a rehabilitation project is designed and constructed without the involvement of farmers, when it comes to the implementation and management stages farmers' decisions become the most important factor. If farmers are not happy with the project and reluctant to carry out the management plans, it could fail the whole project. That is why the participatory approach in tank rehabilitation is considered to be the best approach in present-day rehabilitation programs. Still, there are many obstacles to the implementation of participatory tank rehabilitation projects such as lack of institutional support, the resistance of government officials, limited knowledge of farmers on tank hydrology, and less funding (Jinapala *et al*., 1996). If these issues are resolved success in tank rehabilitation could be achieved through farmer participation.

CONCLUSIONS

This study documents the factors affecting the success of tank rehabilitation through a meta-analysis. The analysis reveals that the factors affecting the success of tank rehabilitation (measured through B/C ratio) are rainfall, farmer participation, and the purpose of intervention in the project. The rainfall shows a positive impact proving the fact that the rehabilitations in areas with high rainfall are more successful as the cropping extends and cropping intensity can be increased. Farmer participation shows a significant positive correlation which implies that the active involvement of farmers in all stages of tank rehabilitation projects is effective in achieving success. The activities performed in tank rehabilitation reveal that the projects focusing on implementing O&M strategies result in high B/C ratios.

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