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ISSUES IN SUSTAINABLE WATER MANAGEMENT OF IRRIGATION SYSTEMS IN SRI LANKA

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ABSTRACT

As the largest consumer of water, the irrigation sector has to play a critical role in managing water resources. Nevertheless, the current water management practices of irrigation are not achieving the benefits of sustainable use of water. The failure in achieving the expected performance of irrigation infrastructures urges the need for Sustainable Water Management (SWM). Therefore, the purpose of this research is to investigate the issues in existing Irrigation Water Management (IWM) practices towards SWM of irrigation systems in Sri Lanka. The research aim was approached through a qualitative survey strategy. Expert interviews were conducted as the data collection technique. Twelve experts were selected through a purposive sampling strategy, who had experience in water management and technical development in irrigation systems. The collected data were analysed using the manual content analysis method. Findings of the research revealed that though numerous techniques are being practiced in IWM, there is a failure in water management in the current context. It was identified, water losses throughout the system, improper system operation and poor maintenance of structures, inefficient practices of irrigation, dis-integration of system components and lack of government intervention as major issues to achieve sustainable use of water in the case of irrigation. The identification and assessment of issues provide a range of their impacts to reveal the constraints in achieving SWM of irrigation.

Keywords: *Irrigation Systems; Irrigation Water Management; Sri Lanka; Sustainable Water Management.*

1. INTRODUCTION

Equitable use of the available resources to manage the consumers' needs is a common problem in most of the countries (Tsirogiannis *et al*., 2017). The increasing growth of the population directly affects the current water demand due to the higher competition over the limited resources, which has led to severe water shortages (Sun *et al*., 2016). Therefore, being the largest consumer of water, the irrigation sector has to play a critical role in the sustainable use of water (Calzadilla *et al*., 2010). However, the inequity of water distribution, uneconomic and inefficient use of irrigation water and failure to achieve the expected performance of irrigation infrastructures are continuing the problem of sustainable management of water resources (Buyukcangaz and Korukcu, 2007). Even

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though the previous studies have proposed various methods for practicing Sustainable Development (SD) principles in the process of implementing infrastructure projects, the lack of effective assessment indicators presents a barrier to the effective assessment of sustainability in infrastructure projects (Greenland *et al*., 2017). Therefore, the study aims to investigate issues towards SWM of irrigation systems in Sri Lanka.

2. LITERATURE SYNTHESIS

Irrigation systems are associated with various types of structures starting from water retaining structures to water distribution channels. The requirement of water distribution systems is being increased due to the higher demand for irrigation water (Cai *et al*., 2003). As per the findings of Phadnis and Kulshrestha (2012), the total quantity of annual water consumption of irrigation systems was reported to be around 60-70% in the global context. Hence, the provision of irrigation systems remains important as it provides water for agricultural production, especially in arid and semi-arid regions, to ensure a more productive yield (Singh, 2016). Therefore, as a major consumer of water, the irrigation systems have to play a critical role in water sustainability (Greenland *et al*., 2017).

2.1 DEFINING SUSTAINABLE WATER MANAGEMENT

Water is considered a scarce and critical resource, which is a part of environmental, social and economic systems, as stated by Sun *et al*. (2016). Further to the authors, the increasing population is directly affected by the current water demand due to the higher competition over the limited resources, which has led to severe water shortages worldwide. Moreover, this is going to worsen due to the climatic changes and deterioration of the water quality (Qu *et al*., 2013). According to Peterson and Schoengold (2008), the disparity between the availability of water and the increased demand for water is a persistent issue in the world. Therefore, it is essential to move for improved management of natural water resources as a solution for this global crisis (Oelkers *et al*., 2011), which is a crucial challenge of the 21st century (Emelko *et al*., 2011).

2.2 SIGNIFICANCE OF IRRIGATION IN SRI LANKAN CONTEXT

The irrigation system plays a major role in the agricultural sector in Sri Lanka (Sivayoganathan and Mowjood, 2003). Since ancient times, the agricultural sector in Sri Lanka has been placed at a predominant place in the country's economy, a higher proportion of the public investment is given to the development of irrigation systems (Shand, 2002).

According to Sivayoganathan and Mowjood (2003), Gravity Irrigation is the main irrigation system in Sri Lanka, which can be classified according to the source of water; such as tanks and reservoirs, and size of the system as a major, medium and minor irrigation systems. Further, the authors mentioned the main components of an irrigation system as the water storage system, water conveyance system including main channel, branch channels, distribution channels, field channels and command area, which refers to the farm plots that are receiving water through the channels.

Large-scale irrigation systems, which are extensively invested by the government and foreign donors are contributing to the socio-economic development in most of the developing countries in Asia (Lam, 2006). However, Shantha and Ali (2014) reported that only around 4% out of the total irrigation investment is dedicated to the operational

and maintenance purposes of the irrigation systems in Sri Lanka. Thus, the authors identified the need for an improvement in irrigation management regarding investment to achieve optimum resource allocation. Moreover, Lam (2006) reported that in most of the cases, these projects are not economically viable, since they have failed to perform at a satisfactory level. Thus, Singh (2016) recognised that the efficiency and long-term success of irrigation systems largely depend on the appropriate planning and management by the relevant authorities.

2.3 ISSUES ASSOCIATED WITH IRRIGATION WATER MANAGEMENT

Due to the higher needs of crop production, it is difficult to sustain the traditional practices of farming with the use of canals and rivers (Zhen *et al*., 2005). Hence, the expansion of the irrigation system by constructing new dams and canals is needed to cope with the high demand for crop production (Hussain and Bhattarai, 2005). Thus, Ugwu *et al*. (2006) identified the need for a sustainable assessment of those techniques and practices, which is to be implemented in different project levels, starting from conceptual design, operational process and up to the maintenance and decommissioning stages.

Most importantly, the lack of proper irrigation management in the operational and maintenance stages can adversely affect the environment and imperil to sustainability (Howell, 2006). Previous researchers have identified the issues IWM, which raise the challenge of water scarcity under different categories. Accordingly, Ahmad (1999) categorised the issues of IWM as in-efficiency, in-equity, and un-sustainability. Further, Cai *et al*. (2003) identified the issues of IWM in their case study under the risk in the water supply system, ecological system degradation, conflicts in water sharing and infrastructure deterioration. Furthermore, Buyukcangaz and Korukcu (2007) found technical, socio-economic and environmental issues with regards to the IWM in their case study. Given all, the issues identified in IWM practices in the global context are categorised into three main sections in this study namely efficiency, equity, and environmental integrity.

Water losses in conveyance channels and field applications are highly impacting the efficiency of irrigation systems (Donaldson, 2013; Poddar *et al*., 2014). The inadequate and unstable water supply is a problem towards the equity of water distribution as described by Zaman *et al*. (2017). The increasing environmental issues associated with the development and management of existing irrigation practices have led to a debate on the impacts of them on the environment (Shand, 2002). Waterlogging, salinization and groundwater depletion are common issues to the environmental integrity associated with irrigated areas. Therefore, a deep insight into the issues towards SWM in irrigation systems is highly needed in the current context. The next section elaborates the methodology adopted in this study.

3. METHODOLOGY

Qualitative research methods are representing the views, experiences, believes, and attitudes of a specific set of people and it is ideal for research on emerging conceptions through in-depth investigations (Ritchie *et al*., 2013). The concept of sustainability has been evolving over centuries. The knowledge, believes, attitudes, and opinions towards this concept are subjective. Hence, a qualitative approach was undertaken in this study.

The expert survey method was selected as the research strategy. Twelve semi-structured interviews were conducted to collect data. The experts were selected based on purposive sampling, who had knowledge and experience on water management and technical development on irrigation systems in Sri Lanka. The profile of each respondent is given in Table 1. The collected data were analysed through content analysis method.

Table 1: The profile of the respondents

Respondent	Discipline	Industry Experience
R1	Director in Technical Services Division (Engineer)	33 years
R2	Director in River Base Management (Engineer)	32 years
R3	Director in Water Management Secretariat (Engineer)	32 years
R4	Resident Project Manager (Engineer)	32 years
R5	Deputy Director of Technical Services Division (Engineer)	24 years
R6	Project Engineer	15 years
R7	Project Engineer	5 years
R8	Project Engineer	5 years
R9	Resident Project Manager (Engineer)	10 years
R10	Resident Project Manager (Engineer)	6 years
R11	Geo Technician	8 years
R12	Senior Technical officer	7 years

4. RESEARCH FINDINGS

The adoption of SWM involves various considerations such as technical aspects, economic constraints, social behaviour, institutional and legal framework, which ultimately affects the SD of the country. All the respondents used their proficient knowledge and experience gained in explaining the current practices of IWM. However, all of them agreed that the current practices of water management are not sufficient to deal with increasing water demand. Therefore, there is a need for identifying, assessing and prioritising the issues to come up with strategies to minimise the impact of them. The issues of IWM in the Sri Lankan context were identified under the following categories.

- Issues towards the efficiency of irrigation infrastructure
- Issues towards the equity of water distribution
- Issues towards environmental integrity

4.1 ISSUES TOWARDS THE EFFICIENCY OF IRRIGATION INFRASTRUCTURE

The issues will be discussed following the four major structures in irrigation systems namely, water retaining structures, water conveyance channels, water distribution channels, and field applications.

4.1.1 Issues towards the Efficiency of Water Retaining Structures

The primary uses of dams and reservoirs are to provide water for irrigation, hydropower generation, and domestic and industrial uses. In the case of irrigation, water storage is

very much important, when the river flows are not enough, where there is a higher demand for irrigation water. Having adequate, reliable and secure water storage is necessary to maintain the water demand consistently.

Most of the respondents highlighted 'silting' as the main reason for the inefficiency of water retaining structures, which was happening due to earth collapsing in the catchment area. As a result of silting reservoirs, the water holding capacity of the structures going to be reduced. Evaporation due to exalted global warming was another issue, which reduces the efficiency of reservoirs. The reduction of water level due to evaporation depends on the size and depth of the reservoir. The large open surfaces of reservoirs easily enable water losses by evaporation.

Sedimentation was another problem, which causes the diminution in water flow while decreasing the potential water storing capacity of the structures. It decreases the carrying capacity of silt and nutrients to the down streams. Besides, the structural issues of reservoir bed and foundation lead to inefficiency of the whole system. For example, cavities in the reservoir bed is a serious problem, which often led to water leakages.

4.1.2 Issues towards the Efficiency of Conveyance Channels

The efficiency of water delivery in an irrigation system is measured by the difference between the amount of water diverted at the dam and the amount recorded in measuring devices at distribution channels. According to the literature findings, a proportion of water diverted from reservoirs was lost during its conveyance to the receivers.

All the respondents agreed that water losses, which were happening during the conveyance effects the efficiency of the channels. Due to bund erosion and leakages, water losses were happening through bunds whereas, silting and vegetation decrease the efficiency of conveyance channels by reducing the speed of water flow.

The 'trapezoidal section' is the optimal section for conveying water in canals, as signified by the respondents. The advantage of having a trapezoidal section is the friction force of water is less in these types of canals than the canals having a rectangular section. However, because of certain reasons such as the growth of vegetation along the canals and earth collapsing due to animal crossing the slope of canals get changed. Moreover, water losses were happening in outdated canals, which are still using in for irrigation water conveyance, especially in places having 'single bank canals'.

4.1.3 Issues towards the Efficiency of Distribution Channels

The distribution channels convey water from main conveyance channels to the fields, which comprise open channels and pipelines or a combination of both. Through the expert survey, it was identified that 'seepage' as a common issue in distribution channels, which led to water losses. Though the seepage losses are less in open channels than the pipelines, channel distribution is commonly used since it consumes less capital and less maintenance cost. Nevertheless, the main disadvantage in open channels is the inability to respond to the changes in demand for water, due to the inefficient conveyance through the channels.

Silting was again identified as an issue towards the inefficiency of distribution systems. This can be happened due to drainage and corrosion of the canal bed, when flowing water inside the canal. Due to this problem, the canals may not be able to carry water for the fields in an efficient manner.

4.1.4 Issues towards the Efficiency of Field Application

The application method shall provide an adequate amount of water to meet the requirement of crops consistently without unnecessary wastage. When choosing the best method for applying water into the fields, the consideration has to be given not only for the technical viability but also for the ease of operating and maintaining such a method.

Most of the respondents agreed that the traditional practices of water application lead to huge losses of water in the fields. For example, flood irrigation method, which was commonly used in Sri Lanka was identified as a low efficient method of water application in fields. In this method, the water will be received to the topmost basin in the field through pipes or field canals. After the top basins get filled with water, it will gradually flow to the basins at the next level. In such a way, all the basins will get irrigated in the land. This method leads to a huge wastage of water than the direct application of water to each basin.

Besides, though the water has been allocated as per the crop water requirement in each area, some people are not satisfied with that system. Then they make trouble for the operators in particular authorities. Therefore, it was confirmed that the unawareness of water receivers is another problem, which raises water losses in-field applications.

Improper levelling and not following the precise contour patterns cause huge water losses in fields as highlighted by the respondents. In places having larger slopes in the land, the water will run-off rapidly without collecting and remaining in the field. Moreover, due to the low water holding capacity of the soil, a certain amount of water would be lost in the fields. Further, this low water holding capacity of soil would impact the deep percolation of water into the ground.

4.1.5 Issues towards the Equity of Water Distribution

The water shall be delivered in sufficient quantity and quality at the right time to ensure the equity of water distribution in the case of irrigation. Therefore, the system has to maintain the required flow rate up to the tail end users. According to the expert review, it was identified that the inefficiency of the system, inadequacy of water supply, inequity of canal water distribution, and the sequence of water delivering as the main causes of the inequality of water distribution.

Most of the respondents stated that deteriorated canals due to improper maintenance as a problem in this regard. The tail end water shortage was another issue for the in-equal water distribution of the system. While up-stream water receivers are getting more water, downstream users or the tail end users are troubling with water shortage. As a result, conflicts can happen among downstream water users. Water loss during the conveyance was the main cause of this problem.

The risk of water scarcity affected political risk in the country. Therefore, managing geopolitical issues regarding water scarcity are difficult in practice. Furthermore, the influences coming from various authorities and regulatory bodies troubles the integration of different sub-components in the system.

4.2 ISSUES TOWARDS ENVIRONMENTAL INTEGRITY

The irrigation systems denote modification to the existing eco-system by extracting water from available water resources and diverting water for dry zones using built structures.

Therefore, there can be impacts on the environment due to the establishment of irrigation infrastructures. Construction of irrigation infrastructures is complex since it needs advanced technologies of construction methodologies and a large number of resources. The construction of irrigation structures devastates the natural equilibrium of biodiversity in a particular region. Due to the inundation of large areas with significant hydraulic pressure, destructions can occur to the associated eco-system in such areas.

Irrigated lands receive water from surface water supplies or extracted groundwater. According to the literature findings, the quality of water in water sources and the method of delivering water to the fields affect the environmental integrity. Most of the respondents highlighted that the water pollution impacts the quality of irrigated lands and subsequently for the crops in the fields. Diversion of drainage into rivers and other streams was the main cause of water pollution during the water conveyance.

Besides, it was evident that improper management and operation of water distribution also affect environmental sustainability. As per the expert review, the raising water tables could be happened due to water losses during the conveyance. It leads to waterlogging in certain areas due to deep percolation of water into the ground.

The efficient irrigation practices and water application methods used in the fields contributes to the efficiency of irrigation systems. The poor irrigation practices impact the environment by changing the quality of water and the soil. Overuse of water and the poor IWM led to waterlogging and a rise in the ground-water table in irrigated lands. Similarly, the traditional practices of irrigation reduce the efficiency of the system and raise unnecessary wastage of water. Besides, soil erosion was another issue occurred due to improper management of irrigation water, which ultimately impact the environmental integrity.

4.3 ASSESSMENT OF ISSUES

Identification of issues provides a clear idea of the barriers that prevent managing water resources in irrigation. Assessment of issues in terms of causes for issues and their implications provide the range of their impacts and a statement of effects associated with identified issues. In addition, it demonstrates that those issues are constraints in achieving the SWM of irrigation. Table 2 signifies the assessment of identified issues with their causes and implications.

Table 2: Assessment of issues

Category	Identification of Issues	Causes for Issues	Implications of Issues
Inefficiency of water retaining structures	Silting	Earth collapsing in the catchment area	Reduces the water holding capacity of the structures
	Evaporation	Exalted global warming	Reduction of water level
	Sedimentation		Diminution of water flow
			Decrease the potential water storing capacity of the structures
	Cavities in reservoir bed	Structural failures	Water leakages

Category	Identification of Issues	Causes for Issues	Implications of Issues
Inefficiency of water conveyance channels	Silting	Earth collapsing in the catchment area	Reduces the speed of water flow
	Vegetation	Poor maintenance	Reduces the speed of water flow
			Changes in canal slope
	Earth collapsing	Animal crossing	Changes in canal slope
	Water losses in outdated canals	Single bank canals	Water losses
Inefficiency of water distribution channels	Seepage in open channels	Improper drainage lines	Water losses
	Silting	Drainage	Canals may not be able to carry water for the fields in an efficient manner
		Corrosion of the canal bed	
Inefficiency of field water application	Low efficient methods of water application e.g. Flood irrigation	Unawareness of users	Wastage of water than the direct application of water
		Reluctant to adapt new methods	
	Not following irrigation schedules	Unawareness	Wastage of water due to overuse
	Water run-off rapidly through the fields	Improper leveling and not following the precise contour patterns	Huge water losses
	Deep percolation of water into the ground	Low water holding capacity of the soil	Waterlogging
Inequity of water distribution	Deteriorated canals	Poor maintenance	Water losses
	Geo-political issues regarding water scarcity	Tail end water shortage	Conflicts among water users
			Political risk for country
	Influences coming from various authorities	Political issues	Troubles the integration of different sub-components in the system
Impact to environmental integrity	Devastate the natural equilibrium of biodiversity	Inundation of large area with a significant hydraulic pressure	Destructions to the natural eco-system
	Water pollution	Diversion of drainage into rivers and other streams	Quality of irrigated lands and subsequently for the crops in the fields

Category	Identification of Issues	Causes for Issues	Implications of Issues
	Waterlogging	Water losses	Deep percolation of water into the ground
	Poor irrigation practices	Unawareness	changing the quality of water and the soil
	Overuse of water	Rise in ground-water table in irrigated lands	Waterlogging
	Soil erosion	Improper management of irrigation water	

5. CONCLUSIONS

This paper presented the findings on the identification and assessment of issues towards SWM of irrigation systems in Sri Lanka. A literature review was carried out to identify the need for SWM of irrigation systems in the global context. According to the previous studies, the issues in IWM were categorised into three main components namely, efficiency, equity and environmental integrity. The issues towards the efficiency were further categorised into another three sub-components namely, the efficiency of water retaining structures, water conveyance channels, water distribution channels, and field applications.

The performance of irrigation systems is measured by its efficiency. Further, it can be applied to each subsystem of irrigation infrastructures such as water retaining structures, water conveyance channels, water distribution channels, and field applications. As a whole, the expert review revealed that the water losses in canal conveyance and field application as major issues, which reduce the efficiency of irrigation systems. The improper maintenance of structures and associated catchment area was the reason for water losses in channels. Further, inefficient water application methods in fields worsen the problem of water loss.

The water shall be delivered in sufficient quantity and quality at the right time to meet the needs of the users. Nevertheless, the inequity of water allocation affected the water sharing rights of the users. Conflicts among water users, especially the people down-stream, aggravate the problem of water sharing rights. Moreover, the establishment of irrigation infrastructures destructs the natural eco-system of irrigated areas. In addition, depletion of groundwater and waterlogging were recognised as major issues towards environmental integrity due to poor practices of IWM.

The identified issues were assessed to give an idea of their impact on the achievement of SWM in irrigation. The findings can be helpful for the decision-makers to identify the drawbacks of their system management. Therefore, it can be recommended that to investigate more on them to identify the burning issues, which need urgent solutions to mitigate their influence on the management of irrigation water. Further, the issues can be prioritised by comparing the information collected based on their extent of the impact on system management. Then the industry practitioners can implement strategies to overcome the issues based on their relative importance in achieving the ultimate goal of SWM in irrigation.

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