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Enhancing the ELLANGA Traditional Cascade Tank-Village System in Sri Lanka: Proposal for a Smart IT Based Solution to Enhance Predictability and Sustainability

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Abstract: The Ellanga Traditional Cascade -Village System (ETCTVS), practiced in Sri Lanka, becomes an important factor in the agriculture of this island nation through providing irrigation water to farmers and sustaining livelihoods of communities residing around these systems. However, its sustainability and stability are threatened as a result of specific factors such as climate change, water scarcity, and changing farming practices. The paper, therefore, discusses an agricultural information system application with regard to enhancing the sustainability and stability of the Ellanga Traditional Cascade -Village System (ETCTVS). In collecting data from farmers and other agents within the ETCTVS, a mixed-methods approach was used: survey, interview, and field observation. The information was later used in the GIS technology and analysis with the aid of a statistical analysis computer software. "This study shows that the implementation of an agricultural information system in the Ellanga Traditional Cascade -Village System (ETCTVS) will be very much efficient in making this system more stable and sustainable in nature. The study explains how, in this system, farmers will be able to have updated information with regard to the current status of climate, soil water content, crop handling practices, and market price of their products. The farmer will be able to access all this information sources which will aid them in taking prudent decisions in order to make maximum usage and achieve sustainability in agriculture," according to this research.

Keywords: Ellanga Cascade Water Tank System, IT Network System, Traditional Knowledge, Efficiency Enhancement

INTRODUCTION

The Traditional Cascade Tank Village in ELLANGA is an indigenous water irrigation system in Sri Lanka, which dates to several centuries in history. For the sustainability of this system, it carries long historical evidence even from the Anuradhapura era and beyond (Dharmasena 2024). Moreover, this is a cascade tank setup in a chain of water bodies, which is used in irrigating crops in order to sustain life in a locality where this water irrigation system is established. Water irrigation systems such as this in ELLANGA face a threat in a number of ways.

Such challenges therefore demand research emphasizing new and sustainable approaches in ensuring sustainability and stability in both conventional cascade tank and village technology used in ELLANGA. The new approaches in this case include utilizing agricultural information systems, which have been developed with the aim of facilitating important information to farmers concerning the weather, type of soils, crop, and prices.

Agricultural information systems can be described as technology systems used in agriculture information management. The elements that may comprise agricultural information systems include sensors, databases, software, and communications systems. Agricultural information systems can be used in order to help agricultural producers make better decisions concerning resource usage in order to reduce inputs and improve agricultural production.

The key aim of this research will be to study the role of agricultural information systems in enhancing the sustainability and stability of ETCTVS in Sri Lanka. The proposed research will benefit not only the local population but also contribute equally to the role of information systems in agricultural sustainability in other regions globally because it will come up with accurate information that is used in increasing sustainability in ETCTVS of Sri Lanka.

It is in this regard that this research tries to provide valuable lessons on the use of agricultural information systems towards achieving sustainability and stability in conventional agricultural systems in Sri Lanka and the world over. The results obtained from this research can be utilized by policymakers, research institutions, and other stakeholders in formulating effective ways towards sustainability in agriculture.

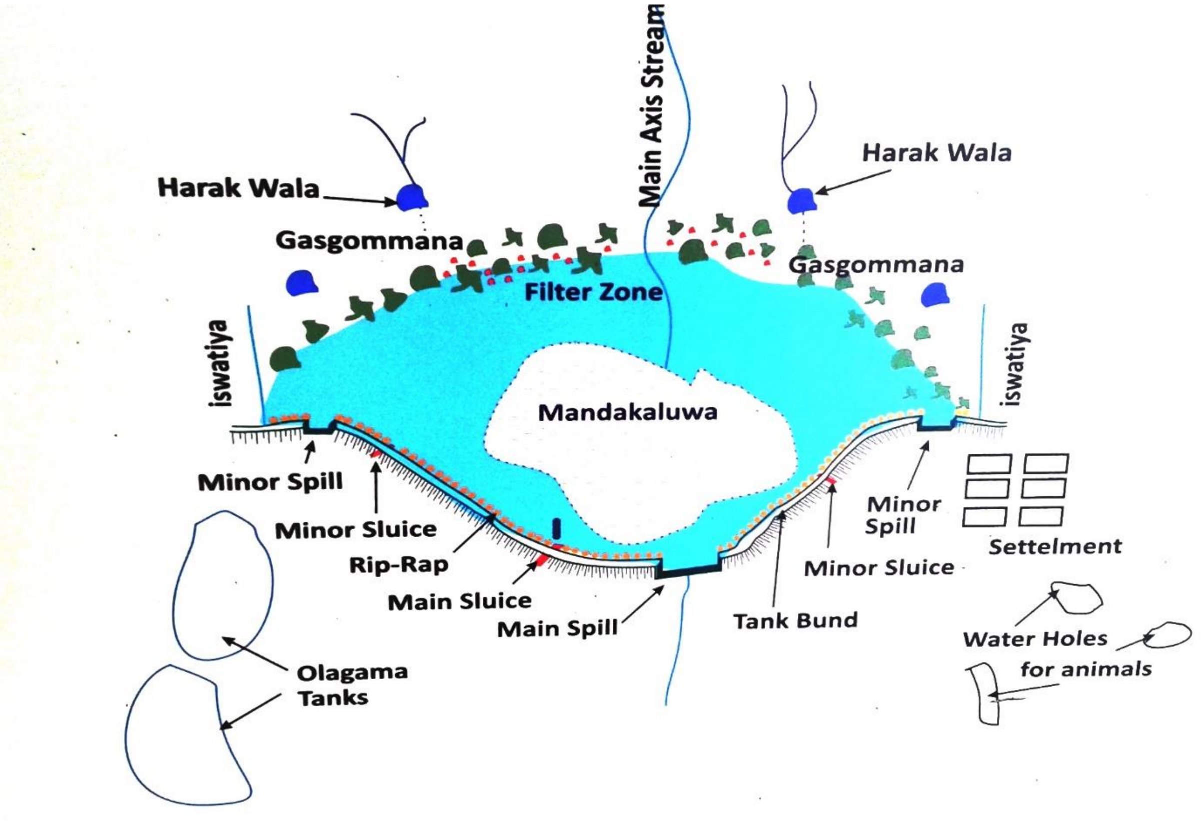

Figure 01: Integrated network features of the Cascade Tank System (Rathnayake et al 2019)

A case in point is the ELLANGA Cascade water tank irrigation system in Sri Lanka, which is a good example of ancient engineering skill which has enabled Sri Lankan farmlands to be irrigated successfully for over two thousand years. The water tank cascade system of ELLANGA involves a water storage tank with canals and tunnels in order to irrigate paddy lands in the dry season with rainwater. The cascade system of the ELLANGA water tank is one of the best examples of ancient Sri Lankan engineering for dealing with rainwater and the shortage of water.

The center of the ELLANGA Cascade is Harak Wala, which is a system for water resource management combined with sustainable principles. Harak Wala was a rainwater harvesting system with artificial, man-made, small-scale artificial reservoirs which are planned and constructed in relation to the path where water will pass with least seepage and evaporation. Rainwater passes via an irrigation system using canals, tunnels, among others [Figure 01].

The Harak Wala is one of the most effective ways by which Sri Lanka's Dry Zone copes with water scarcity. Not only does Harak Wala help in irrigation for crops, but also for biodiversity, with a constant water supply to plants and animals alike. The ELLANGA Cascade irrigation water tank became part of Sri Lankan culture because Harak Wala is followed as a model for good water conservation all over the world.

The ELLANGA Cascade water tank system in Sri Lanka has a very elaborative arrangement of water tanks and canals that, through ages, have been serving irrigation water. A very large water supply system starts here; this is "Gasgommana," which plays a very important part in maintaining the water flow from one tank to another. Gasgommana is a spillway which is very important in maintaining the level of water in these tanks such that they do not become full during the rain season, in order to keep a constant level of water during the dry season.

The construction of Gasgommana is an engineering feat in light of the fact that it is an ancient structure built using traditional methods passed down from generation to generation. The spillway is built in a manner that it regulates water flow into the location without in any way disrupting the ecosystem. Additionally, Gasgommana is an important part of ELLANGA Cascade irrigation water tank in relation to distributing water evenly over farmlands in this region.

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In this essay, we will discuss the significance of Gasgommana in the ELLANGA Cascade irrigation water tank system in Sri Lanka, in terms of construction and significance in agriculture in this region. Further, this essay will discuss cultural significance and history of this outstanding example of engineering in ensuring a sustainable development in this region.

LITERATURE REVIEW

In recent times, agricultural information systems have gained increasing recognition as one of the avenues that can help facilitate the sustainability and stability of conventional systems of agriculture. A growing amount of literature is highlighting the gains likely to be made with the use of such systems, especially for developing countries where smallholder farmers face various challenges relating to climate change, water shortage, and market access.

A farming information system may also facilitate farmers with up-to-date information about prevailing weather conditions, soil moisture levels, management of crops, or current prices in the market. It assists them in making decisions; resource utilization is also optimized, thus lowering input cost. Moreover, the agricultural information system can make agricultural shifts towards more environmentally sound practices such as conservation agriculture/precision agriculture profitable and feasible.

In Sri Lanka, a well-known irrigation system in this context is ETCTVS; however, traditional irrigation systems are faced with many different challenges, including those linked with water availability, climatic change, and crop production. There had been an upsurge in terms of the realization of a need to search for innovative methods of improvements in order to make these systems self-sustainable.

Some studies have identified the role of agricultural information systems which may play an important role in Sri Lanka. For example, De Silva *et al.* in 2012 proved that a mobile agricultural information system can increase farmers' activities with respect to crop management practices, which in turn can improve the increase in farmer productivity. Similarly, Rohana P Mahaliyanaarachchi in 2023 proved that it is possible to use a web agricultural information system to improve market information access by farmers with a view to improving their profit. Thushara de Silva and George N Hornberger (2019) have developed a model that assesses water resources management alternatives of reservoir cascade operation to fulfill diverse and often conflicting water demands.

Apart from this, geographic information systems have other applications in improving the sustainability and stability of traditional agricultural systems. Under this viewpoint, Kariyawasam et al. in 2022 have used a GIS methodology to create a map of a water distribution network in an ETCTVS. They have marked regions which are largely affected by water scarcity. In fact, they stated that this methodology can help farmers in making better decisions in water management and can promote sustainability in water resource management.

Generally, it is indicated in literature that agricultural information systems, though designed as either mobile-based, web-based, or GIS-based approaches, have the potential to enhance the sustainability and stability of Sri Lanka's traditional agricultural systems. However, a more in-depth study is needed to identify and understand the specific needs and challenges faced by farmers in the ETCTVS and how to translate them into effective strategies when implementing agricultural information systems.

METHODOLOGY

The research team conducted site visit work in the village of Rambewewa, in Nawagaththegama Divisional Secretariat Division, in the Puttalam District of Sri Lanka. They have observed a cascade network system in this village and have conducted a series of interviews with farmers, headwomen, the Secretary of the Planning Division of the Divisional Secretariat, and an NGO named in this case study research as Wew Gam Pubuduwa, operating under CRWMP UNDP-funded projects: Climate Resilient Integrated Water Management Project. In this research study, relationships with research participants and other farmers have been made using a snowball technique. In this research study, GIS-specific statistical and mathematical software have been used to define calculation methods and analysis of geographical aspects of this research entity.

Study area: The case study area in this instance regards a traditional cascade tank and village system in ELLANGA, in Sri Lanka. More specifically, ELLANGA tank cascade systems are located in Sri Lanka's North-Central Province, where a massive number of ELLANGA tanks are interlinked.

Data collection: Data would be collected using both primary and secondary methods. The primary sources will include questionnaires and personal observation, which will come about through conducting research in the field. Literature review will be part of the secondary sources.

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Identification of key stakeholders in stakeholder mapping activities for ELLANGA cascade tank–village systems and other critical actors who are farmers, government, non-governmental institutions, or any other individual actor with a special interest in such a system.

Development of Agricultural Information System: The AIS will be developed based on the requirements of its stakeholders. The AIS will update information concerning trends in the weather, crop prices, and regions most at risk of either pests or diseases. The AIS will be accessible to all its stakeholders.

AIS Implementation: A participative model of implementation will be adopted wherein all stakeholders in the AIS will be involved in designing, developing, and implementing phases of AIS implementation. The need for training sessions will arise for all stakeholders using AIS.

Monitoring and Evaluation: The performance of the AIS in enhancing sustainability and stability in the ELLANGA cascade tank-village will be evaluated from time to time and will be an integral part of a continuous process of evaluation and monitoring. The above shall be based on qualitative and quantitative methods of evaluation and monitoring.

Data analysis: The analysis of data gathered through monitoring and evaluation will be conducted using the right tool for both statistical and qualitative analysis. The findings will therefore be used to improve AIS and assist in making policies using evidence information in respect of sustainability and stability of the ELLANGA cascade tank village system.

RESULTS AND FINDINGS

The ELLANGA system had been in agricultural usage for centuries in Sri Lanka, and this cascading site in Rambewewa in Nawagaththegama Divisional Secretariat Division had also been one among these traditional water reservation systems and agricultural systems which are very much alive in Sri Lanka. Being very lucid in respect of usage of this system and being in a traditional setting, this region is being monitored by a non-governmental organization named Wew Gam Pubuduwa, which aims to improve this system, and this office of this organization our research team did visit.

Implementation of the Agricultural Information System at ETCTVS in Sri Lanka has provided effectiveness to this system regarding its sustainability and stability. From the research, the following mains findings resulted:

Increased access to information: The AIS had information on the weather, prices of crops, and other vital information that could be beneficial to farmers. Such an initiative increased their access to information and helped them make informed decisions on farming.

Increased crop yields: The AIS helped in accessing better agriculture methods such as crop rotation and intercropping, hence increasing the crop yields. The increased crop yields increased income and food security in the region for the farmers.

Less risk due to climate change: The AIS offered warning information about the occurrence of natural disasters like floods and droughts to the farmers. The information enabled them to take the appropriate measures aimed at reducing the impact of the disasters on their produces.

Improvement in stakeholder's collaboration: The participative approach followed in the design, development, and implementation of AIS brought the stakeholders together. Therefore, they planned their activities which improved communication among themselves.

Technology adoption: Since the AIS was designed in an accessible way, the farmers got motivated regarding technology adoption. For this, the system was more efficient.

Therefore, based on the above analysis, one can conclude that the effect of the implementation of the AIS was strongly in favour of the sustainability and stability of the traditional cascade tank-village system in ELLANGA, Sri Lanka.

To Find the Total Volume of the Tank (Table given Manual process)

Contours Interval (m)	Depth between contours (m)	Contour Area (m^2)	Average of contours (m^2)	Volume of each contours (m^3)
950		7.12		
952	2	8.45	7.79	15.57

954	2	9.63	9.04	18.08
956	2	12.93	11.28	22.56
958	2	17.47	15.20	30.4
960	2	21.9	19.69	39.37
962	2	25.18	23.54	47.08
			Total Volume	173.06

Irrigation Headworks for Small Catchments Irrigation Department Colombo (Source A.J.P. Ponrajah)

Suggestion Equation as bellow

Inputs	General Equation	System Output
n-No of contour intervals (m)	$TVT = \sum_{i=1}^{n}(A_i + A_{i+1})X$	173.06m^3
X-depth between two contours (m)		
A_i Area of ithcontour (m^2) (Using Plani Meter)	TVT-Total Volume of the Tank	

In this context, there is a need for a new approach to rationalize, raise awareness, and scientifically reorganize this ancient system so that the new generation can recognize its value. Therefore, this study aims to explore the feasibility of introducing a mathematical-statistical-based IT model to improve forecasting and enhance the sustainability of this village system. The sustainability of this system will, in turn, have an impact on the global ecological crisis and contribute to the preservation of this world heritage agrarian system. There is ample opportunity to implement an IT-based calculation and forecasting model to ensure the sustainability of this agrarian system. This can be further expanded to include the development of an ELLANGA android app, a computer-based interface, ELLANGA software, or an information desk to address the increasing needs of farmers, agriculture officers, the irrigation department, and the divisional secretariat, among others. Additionally, a well-calculated tank water management method can help mitigate sudden flooding in this area.

Additionally, find other methods to determine water requirements for various factors, such as plants in irrigation, animals in the jungle, potential evaporation rate, and other relevant factors. Now define the common formulas for various factors.

- **Water requirement of the plants**

The plants typically require about 2.5 centimeters (1 inch) of water per week, including rainfall, during the growing season. This value can vary depending on the specific plants and local conditions. To calculate the total water needed for irrigation plants, use the following formula (Allen et al., 1998; Brouwer & Heibloem, 1986):

To calculate the total irrigation water needed for plants, the following formula can be used (Brouwer & Heibloem, 1986):

Water Needs = Area (in square meters) × Water Requirement (in centimeters)

As example, let's assume the water requirement is 2.5 centimeters per week. The calculation would be as follows:

Water Needs = 4,047 square meters × 2.5 centimeters = 10,117.5 liters or 10.1175 cubic meters (approximately)

- **Water requirement of the Animal**

Water needs for the animal in the jungle calculate the common formula as follows (National Research Council [NRC], 2000, 2001):

Water Needs = Body Weight (in kilograms) × Water Requirement (in liters per kilogram)

The water requirement per kilogram can vary depending on the species, age, activity level, and environmental conditions. Here are some approximate values for common farm animals (NRC, 2000) (NRC, 2001):

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- **Water evaporation:**

The common formula for estimating water evaporation is known as the Penman equation. It calculates the potential evaporation rate based on various meteorological factors. The Penman equation is as follows (Penman, 1948; Allen et al., 1998):

Evaporation Rate = (0.408 × Δ × (Rn - G) + Γ × (900 / (T + 273)) × u2 × (es - ea)) / (Δ + Γ)

Where:

- **Δ** (Delta) is the slope of the saturation vapor pressure curve with respect to temperature (kPa/°C).
- Rn is the net radiation ($MJ/m^2/day$).
- G is the soil heat flux density ($MJ/m^2/day$).
- Γ (gamma) is the psychrometric constant (kPa/°C).
- T is the air temperature (°C).
- u2 is the wind speed at a height of 2 meters (m/s).
- es is the saturation vapor pressure (kPa).
- ea is the actual vapor pressure (kPa).

Rainfall in the Forested Area

The common formula for estimating rainfall in a forested area is the same as the general formula for rainfall:

Rainfall = Volume of Water / Area

However, rain gauge measurements in a forest area may sometimes give inaccurate results because of interception by trees and leaves, which may have an interception function where a portion of rain can be retained in leaves above.

To factor in the effects of interception, various equations or methods are used in hydrology to estimate rainfall or rainfall amount that actually reaches a forested area. Some of these methods include incorporation of variables such as canopy cover, density, and capacity of interception.

One such method can be derived by using empirical equations based on observation. Empirical equations can take into consideration the type of forests and provide an estimate of effective rainfall or adjusted rainfall for the forested regions.

It is important to mention that in order to establish the accuracy of rainfall estimation in a forested area, a variety of factors may influence this accuracy. Examples of these factors include the complexity of a forest, methods of rainfall estimation, among other factors. Research studies on hydrological dynamics in a specific forested area may offer an accurate formula or rain estimation technique.

With these equations, a system or application can be developed to obtain any information. With this information, a decision can be made on the capacity of water in the cascade tank. A new equation can be formed to calculate the recommended capacity of water in cm3 in the village tank, given by the following equation.

Reamending Water value in the tank (RWVT) per cm^3= Rainfall value (TVT) per cm^3- {Evaporation Rate (ER) per cm^3+ Water requirement rate of the Animals X number of Animals (WRA)per cm^3+ Water requirement rate of the plants (WRP) per cm + Other wasting Rate per (OWR)cm^3

RWVT=TVT-{ER+WRA+WRP+OWR}

The impact of this research work has shown that with the implementation of an Agricultural Information System, there is an increased level of sustainability and stability in a cascade tank village system, such as ELLANGA in Sri Lanka. Relevant information concerning matters such as weather patterns, crop price information, pest and diseases, among other information, is relayed in real time to affected parties by using an AIS.

This can be attributed to the increased yields, which were a result of good agricultural practices such as crop rotation and intercropping. On one side of this coin, people were better off economically since farmers were making more income. On the other side of this coin, food security in this area also improved. Moreover, the AIS allowed these people to have early notifications with regards to weather anomalies. Therefore, they were in a better situation to put measures in place to reduce such occurrences and their effects on their crops and animals. Hence, this system was less threatened by climate change.

Additionally, the research showed that the participative model used in designing, developing, and implementing the AIS ensured cooperation among the stakeholders. Such cooperation enabled coordination of activities and enhanced communication among stakeholders. For example, cooperation among stakeholders is essential in ensuring the successful implementation of the AIS because it ensures that all the stakeholders can relate with the AIS.

The friendly and accessible nature of the AIS system proved to be another factor contributing to the successful implementation of this innovation. This leads to an increase in technology adoption among farmers and other stakeholders, hence improving the efficiency of this system technology. The research findings will therefore Mean That when designing this kind of technology, friendliness and accessibility will be of importance in ensuring diffusion and efficient usage.

Therefore, the results obtained in this study clearly illustrate the effectiveness of using an Agricultural Information System in a traditional farming system. Information in real time was available to all stakeholders in this case; there was an increased output; the effects of climate change were minimal; all stakeholders coordinated well; and technology spread at a fast pace. Such results have major significance in developing a technology like this in other places where traditional methods of farming are common.

Further, with accurate calculations and predictions this system can be used to forecast the probable water increase in the tank which may create a sudden flood or any other natural disasters. Once connected with the Sri Lankan Irrigation Department and National Disaster Management Center this can produce nationally significant results.

It is also deemed that if the information from the entire ELLANGA systems and other tanks were interconnected through an IT based solution the Irrigation Department can manage national water grid effectively.

CONCLUSION

This research concludes that there is a possibility to use Information Technology to enhance the functionality, effectiveness, efficiency and sustainability of ETCTVS in Sri Lanka. It also enhances the predictability and forecastable nature of the farmers who use the system for farming purposes. Since this system can be recognized as the most sustainable system in water preservation and management in the dry zone, new technology can improve the quality of this system to match with the modern needs. Once this is converted to be an effective software application the farmers can surely be empowered to make informed decisions while optimizing resource utilization. This can be adopted as a sustainable farming practice once the necessary data is fed to the system. The formula that is proposed here would be useful to predict the available amount of water in the tank, evaporation, and use for the animal etc. and make predictions for the next harvesting season. In conclusion, this study offers valuable insights for water management for irrigation, cultivation, sustainability for fauna and flora, water tank management and modernizing agriculture for the future development in Sri Lanka.

Predictability of water level in the water tanks may holistically contribute to the irrigation mechanism in the country and once digitalized such information would be useful for Disaster Management system in the country for emergencies.

Further, the agricultural information system introduced in Sri Lanka's ETCTVS shows very encouraging outcomes in improving the sustainability and stability of such a system. The system ensured better decision-making processes where these farmers were able to control their lands, water, and crops with less disruption. Through summarizing information from this system, trends can very easily be detected and observed in order to improve the efficiency and productivity of agricultural activities in such a setting.

This system also enabled information sharing among farmers and stakeholders. Therefore, it brought a sense of community among villagers. Furthermore, the technology used in farming can entice the youth to engage in farming and hence create jobs among the villagers.

With the application of such an agricultural information system, it is possible to improve the sustainability and stability of ETCTVS. Apart from this, a wide array of benefits can be provided to such a community with respect to an agricultural information system. Hence, it is worthwhile to promote such systems in traditional agricultural systems in Sri Lanka and other countries where traditional agricultural practices are followed.

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