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A Study of Key Challenges to Irrigation Engineering System Performance affecting Agro Food Security in Sri Lanka 2023, and introducing Partnering Strategy and Innovative Engineering Technologies etc. as Potential Solutions

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Abstract:

With population increase, environmental changes and socio-economic development, the demand for water and foods continues to increase and the water sector began to face many challenges worldwide. Sri Lanka has faced those challenges adequately in the last few decades but in 2019 - 2023 we can see a sudden setback in agriculture and hydropower sectors due to poor strategic policies and short-sighted political decisions taken by the government in the wake of the Covid19 pandemic.

According to the warnings of Food and Agriculture Organization and the World Food Program in 2022, Sri Lanka's food insecurity worsens mainly due to weak agricultural production. As the issue of food security is directly related to agricultural production and its irrigation systems, it is worthwhile to study the primary challenges and threats to achieve the achievements in the irrigation sector.

Through a literature review and case study, this paper recognized few primary challenges and factors affecting current irrigated agriculture in Sri Lanka and how to mitigate them. i.e. "inappropriate deviation from subsistence irrigation system", "lack of motivation, inadequate knowledge & organization/collaboration among farmers" which requires Partnering approach, "water scarcity" and "non-utilization of modern irrigation engineering technology" etc. "Non-utilization of modern irrigation engineering technology" is includes examining the applicability of emerging irrigation engineering theories such as "Canal automation", "Contingency theory", "Value Engineering approach" and "Block chain agriculture" etc, as adaptation strategies in the context of assessing water security, water conservation and absorbing environmental changes. Under performance of the case project (Mahaweli-MS) mainly due to socio-economics-cultural influence and the Supremacy of technical issues are reviewed.

Furthermore, the sample case study selected using the Sri Lankan and world largest agricultural development program of "Mahaweli System (MS)". Primary data collection through interviews of farmers and officials, and secondary statistical data collection from the MS database have been done.

Key words: Irrigation Engineering theories, Water scarcity, drought, Food security, agriculture partnering, and Crop production.

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1. Introduction:

Increasing population demands adequate food supply and irrigation water, which led to the initiation of new irrigation projects, renovation/rehabilitation of existing projects to achieve near self-sufficiency in rice and food production, access to safe drinking water and sanitation, protection of areas of high biodiversity and electrification to significant Population etc.

According to the literature, apart from the socio-cultural and political-economic issues, water scarcity and critical drought conditions play a important role in adequate irrigation supply and crop production, which may occur due to natural causes (such as geographically related climatic conditions) and underutilization of modern Irrigation Engineering Technology etc.

Significant and critical politico-economic issues include deficiencies among farmers (knowledge, coordination and motivation), lack of consensus on key policy issues, declining investment, competition between different water-using sectors, lack of water sharing mechanisms, and inadequate databases and early warning systems etc, which can be solved by applying a Partnering (as a collaborative approach) in the agriculture and irrigation industry as described further.

2. Methodology

Therefore, the article intends to study how the above mentioned issues developed from the ancient irrigation systems to the current irrigation systems by investigating the characteristics of the old irrigation system along with their geographical and hydrological characterizes by literature review, while investigating the important politico-economic and technological issues (primary challenges) and possibility of establishing partnering in the agriculture and irrigation industry via a case study.

The primary data collection done by field visit observations and key informant interviews vide unstructured open-ended questions. Both farmers and MS Officers are interviewed as selected samples from the respective population securing minimum biasness. Furthermore, secondary statistical data from the MS and relevant Departments of the Government have been qualitatively analyzed and synchronized.

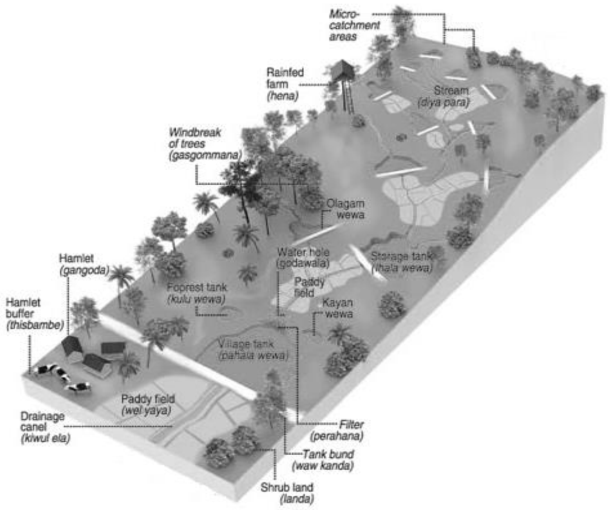
3. Introduction to the Subsistence farming system in the ancient Sri Lanka

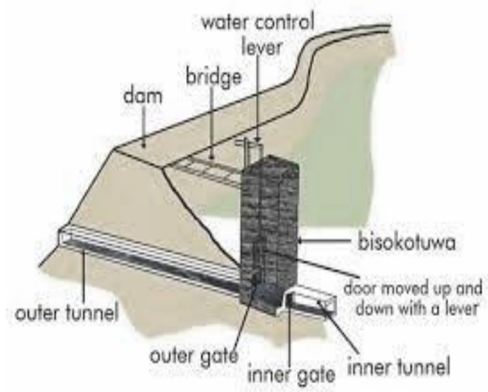
Before the case study, it is important to review the subsistence farming system of ancient Sri Lanka which was done through literature review as follows;

3.1 Characteristics of the Subsistence farming system in the ancient Sri Lanka

Since ancient times, Sri Lanka has continually been a predominantly agricultural economy, and the local irrigation engineering technology history goes back above two millennia. The main issue, despite the fact that the land was excellent for agriculture, was the difficulty in diverting enough water to their cultivation. As a result, excellent irrigation schemes were borne, and irrigation engineering developed creating advanced and ambitious irrigation projects. More than 10,000 small to medium village tanks with cascade systems & single channel systems, and large reservoirs evolved into advanced irrigation technology such as "Valve Pit" (i.e. Biso Kotuwa, Fig.3.1) and "Extremely Low Gradient Long Canal (i.e. Jaya Ganga) etc. These irrigation systems helped make Sri Lanka the "the Granary of the East" in ancient times, especially during the reign of "King Vasabha; reign: 66-110 CE) with gigantic reservoirs (eleven large reservoirs and two irrigation canals) and "King Mahasena; 277-304 AD" (sixteen reservoirs) etc.

Figure 3.1; village tank cascade system and Biso Kotuwa (Valve Pit). [31].





According to the literature and the authors' experience, the socio-economic culture of ancient Sri Lanka was largely based on the principles of partnering. Agriculture required the contribution of a large number of workers and the economy of the old agrarian peasants was very poor. So the farmers in the villages organized themselves into groups and helped each other as a group to get the crops and these small groups were called "KAIYA". Within the KAIYA, there was no exchange of money other than cooperation, transparency, mutual relations, trust, a wide range of behaviors, attitudes, cultures, values, good practices, due respect and enthusiasm for achieving common goals, as shown in the table 3.1, below;

Table 3.1; definitions and principles of the project partnering concept (source; various literatures)

Source	Partnering Definition
(Bennett and Jayes, 1995)	Partnering is defined as "a management approach used by two or multiple organizations to achieve specific objectives by improving the effectiveness of each participant's resources". As a result, it enables different enterprises to use it as a productive and mutually beneficial approach.
Bennett and Jayes (1998)	A collection of strategic activities that express the common goals of several organizations. These are attained by collaborative decision making with the goal of leveraging feedback to constantly enhance joint performance.
Barlow et al. (2000)	A set of business processes intended to improve collaboration amongst the organizations.
Matthews et al. (2000)	In addition to being a technique that establishes documentation, rules, regulations and procedures, partnering is a proactive approach to the business relationship management.
B. Marshall (2000)	A broad concept which enclosed a wide range of behaviors, attitudes, cultures, values, practices and Tools and techniques.
Kwan and Ofori (2001)	An approach based on the principles of mutual trust, due respect and enthusiasm to achieve a common goal.
Glagola and Sheedy (2002)	Its core for the effective business operations. It is built on the integrity, ethics, values of mutual trust, and mutual respect. Aims and objectives are achieved by shared risk taking, open communication and profit sharing.
Naoum (2003)	A concept that offers a framework for the development of mutual objectives amongst the construction team in order to attain an agreed-upon conflict resolution mechanism while also fostering the notion of continual improvement.
Sorell (2003)	A way for drastically lowering the cost of tendering and contracting. Those have been substituted by performance review and improvements for quality, timeliness, and cost.
Cheung et al. (2003)	A technique to managing construction projects that is seen as a key management tool for improving quality and time schedules, reducing conflicts between parties, and providing an opened and non-adversarial contractual environment.
Bayliss et al. (2004)	A technique for enhancing working relationships and project success in terms of quality, cost, and timeliness.
Beach et al. (2005)	A general wording for a number of formal and informal arrangements that incorporate a variety of activities intended to foster better collaboration and entail varying time spans.
Thomas (2005)	A team-working strategy to achieving higher value for all partners by avoiding redundancy & wasting resources, based on agreed objectives, a strong approach to problem solving, and a practical approach to continuous improvement.
Mason, (2006); p.07	Method of enhancing mutual trust, understanding and expectations/values among stakeholders. It prepares parties towards common goals and working collaboratively. It makes long-term commitment between parties to achieve their specific objectives by improving the effectiveness of each party's resources.
Manley et al. (2007)	A method that proposes a cultural transformation in which individuals realize how their obligations influence others and the success of the project and accept those obligations.
Ngowi (2007)	An alliance formed by groups who are not in direct conflict with one another.

Swan and Khalfan (2007)	Partnering is a most fundamental and non-adversarial method to acquiring and participating in building projects.
Lu and Yan (2007)	Respect, trust, collaboration, dedication, and shared goals underpin a productive relationship amongst stakeholders.
Eriksson et al. (2008)	A way for increasing collaboration and integration among participants by fostering trust and commitment while decreasing conflict.

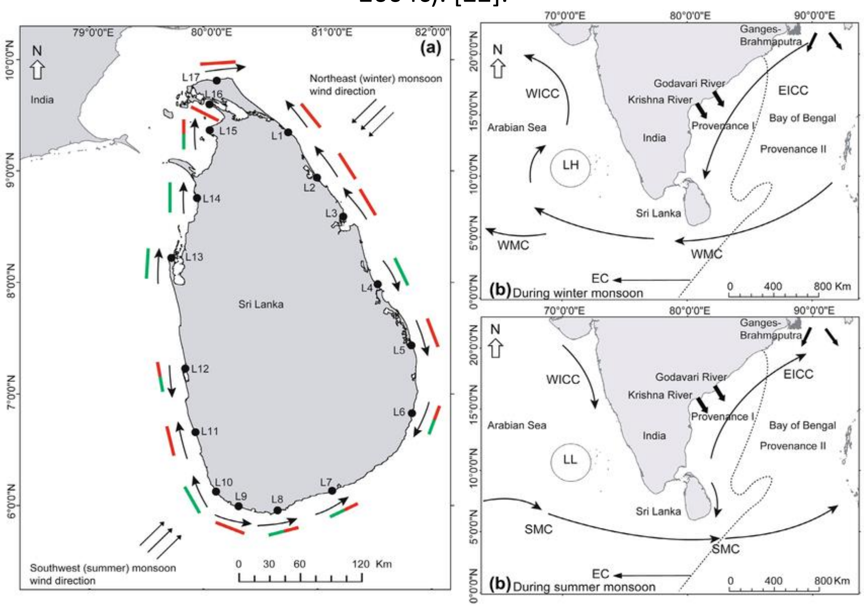
Table 3.1; definitions and principles of the project partnering concept (source; various literatures)

However, with the evolution and introduction of new agricultural systems in Sri Lanka, the traditional partnering-based cooperative system began to decline and suffer from major problems, as described in the following new case project.

3.2 Geography, Hydrology and Agriculture

Sri Lanka (SL) is an island which located in the Indian Ocean, close to the southern part of India (Fig. 5.2-1), between latitudes 6 N and 10 N and longitudes 80 E and 82 E. The physical features of Sri Lanka exhibit a very diverse terrain, resulting in many climatic variations within the island. The approximate area of the island is 65,610 km² and the population is about 21,605,915 as of Saturday 27th August 2022 (UN, 2022). SL has large nos of distinct natural river basins (Approximately 105) and small coastal basins (Approximately 100). Among these, there are about thirty-five major river basins and these watersheds comprise a catchment area of more than 256 square kilometers. A significant part of these water sources consists of artificial reservoirs (tanks) and this water body covers about 2,900 square kilometers (DCS, 2004c), [22].

Figure 3.2 1; climate change according to the location (Source; DCS, 2004c). [22].



Sri Lanka has a long history of irrigated agriculture, and 33% of the population is still engaged in agriculture. Agriculture and related industries, such as fisheries and forestry, contributed for 18% of GDP in 2014, with work force deployment accounting for around 26.4% (Gunda et al., 2015). The used agricultural land is increasing and the situation of the last decade is shown in Table.3.2-1, below;

Table 3.2 1; approximate land use for the agriculture (Source: DCS, 2013a). [22].

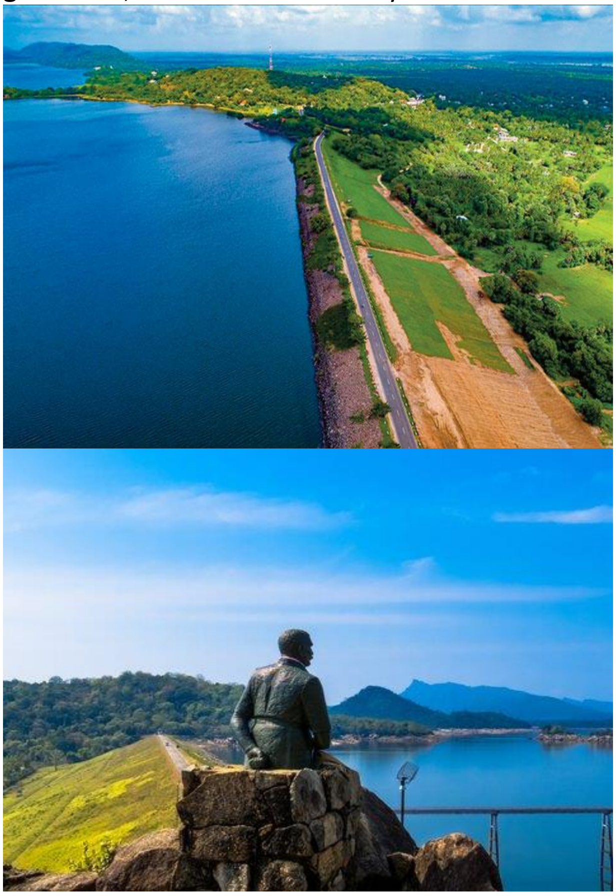
Type	Agricultural area		Land area (including agricultural)	
	Proportion(%)	Area (ha.)	Proportion(%)	Total
Paddy	39.8%	739,903		
Subsidiary crops	7.0%	131,120		
Coconut	23.9%	443,952		
Rubber	8.4%	157,100		
Tea	10.2%	188,971		
Other export crops	3.4%	62,330		
Other food crops	7.4%	137,060		
Total agricultural land	**100.0%**	**1,860,436**	**28.4%**	**1,860,436**
Forests			**23.1%**	1,516,414
Inland water			**4.4%**	290,500
Other			**44.1%**	2,893,650
Total land area			**100.0%**	**6,561,000**

This humid tropical island located close to the equator is faced to the path of two monsoons: the south-west and north-east monsoons. SL's climate is characterized by inter-monsoon periods of high rainfall, and it is the main useful precipitation source, with its uneven distribution governed by two monsoons as well as the orographic influence of the central mountain region. During the transition period between monsoons, some rain falls because of convection effects from local thunderstorms and depressions. During the inter-monsoon season, tropical cyclones impending from the Bay of Bengal also cause heavy rains. The greater part of this region receives from fifty to seventy-five inches of rain annually, which, though not scanty in a comparative sense, is confined to a few months of the year. Consequently, SL has significant water deficits, and a large portion of the country experiences prolonged dry spells. The only water surplus area in the country is the wet zone in the west. There are acute deficits in the northern, northwestern, north-eastern, and south-eastern regions. Surface water availability in the dry zone, which covers nearly 75% of the land area, is often affected by irregularity of the Northeast monsoon. Groundwater in the dry zone is also limited due to poor aquifer conditions (Jayatillake et al 2005).

The dry zone is very important in SL's commercial agriculture and it consists of three major complex irrigation systems namely Malwathu Oya-Kala Oya, Mahaweli-Amban Ganga, and Walawe-Kirindi Oya. There are 59 massive tanks supplying water to paddy cultivation in the dry zone of Sri Lanka. Giant ancient tanks in dry zone with high gross capacities are

Kantale Tank (114,000 Ac. ft.), Minneriya Tank (110,000 Ac. Ft), Parakrama Samudra (109,000 Ac. Ft) and Kaudulla Tank (104,000 Ac. ft.) etc., (See Fig. 3.2-2). Senanayake Samudra (770,000 Ac. Ft.) and Moragaha kanda reservoir (1.84×1010 Cu. ft) can be identified as modern tanks in the dry zone, and "Mahaveli" is the largest development project running across the dry zone.

Figure 3.2 2; Kanthale and Senanayake Samudra Tanks.

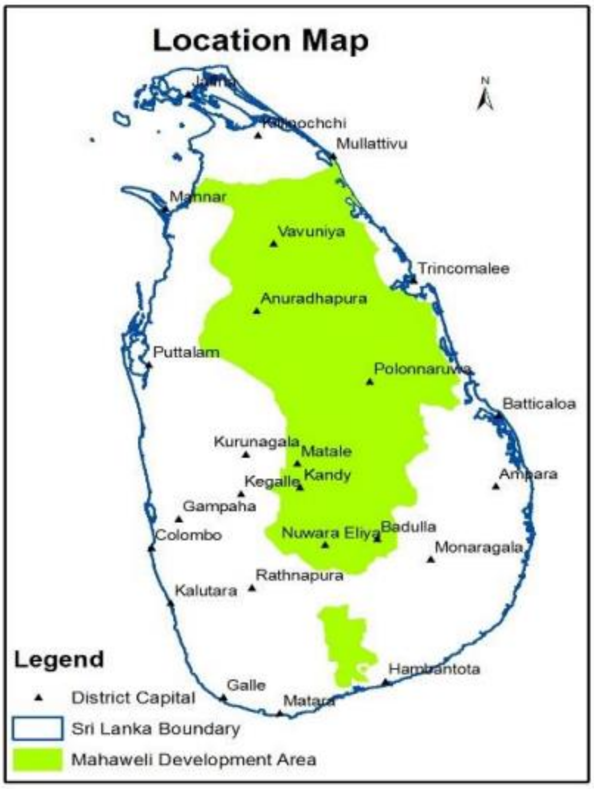


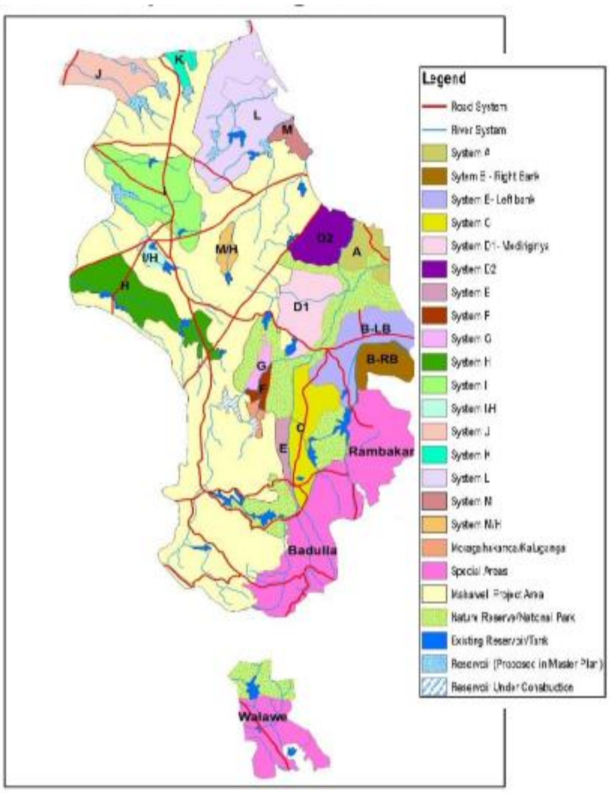
4. Sample Case Study

4.1 MAHAWELI System (MS)

The Mahaweli System (MS) is the country's largest irrigational agriculture advancing program first planned in the mid-1960s, roughly accounting for 365,000 hectares in SL (Dissanayake et al., 2016), as shown in the Fig.6.1, below. Nevertheless, despite hopes of success and overly optimistic predictions about the MS's future performance and potential, the project came under increasing scrutiny in the new millennium due to failure to meet expected irrigation targets and overall underperformance. The aim of this section is to critically assess the value-oriented narrative provided by the interviewees who directly interact with MS in order to elaborate those failures (site-based field research) and assess whether the partnering and other solutions suggested can provide answers to related failures/ challenges. The study found that the main reasons given by the interviewees for the MS's failure and poor performance were lack of knowledge organization and motivation among farmers, water scarcity and non-utilizing of latest irrigation engineering technology, which are often technical and culture in nature.

Figure 4.1; MAP of the mahaweli development system (Source; MASL Corporate Plan 2019-2023). [4].





Furthermore, several studies have shown that farming in the MS has faced a number of unexpected challenges, such as an increase in encroachers, farmer protests, and clashes between farmers and project officers in the field who are in charge of managing and operating project infrastructure (Paranage, 2017; 2018b).

Nevertheless, the most interesting aspect of the current study is not the failures themselves, but the value-oriented narrative advanced by successive governments to clarify these failures. As per the narrative advanced by the SL government and relevant development agencies, Crop cultivation failures can be occurred due to: (1). a lack of organization amongst farmers, (2). a lack of motivation and required skill sets amongst farmers, and (3). recent deficiencies in the SL climate, which resulted in scarcity of the water. (1) & (2) are directly related to the lack of partnering among the farmers as well as within the operations of MS system itself.

4.1.1 Lack of organization/collaboration amongst farmers;

The lack of organization / collaboration amongst the farmers is a main cause of the problems faced by the MS presented by the official narrative. A typical example is the following extract from the final evaluation report on the impact of farmer seminars held in Matale and Anuradhapura districts published by the Agricultural Research Institute (ARTI, 1999 – 2019);

“Forming and strengthen of Farmer organizations require to face the upcoming challenges in the agricultural sector. Furthermore, it is essential that establishing a base for those organizations and appointing their members as dynamic groups for planning and executing agricultural development programs at regional and district levels".

At the outset of the MS's development, the non-corporation of farmers and the requirement to organize them into farmer groups were also announced. The Mahaweli Master Plan, which was developed via cooperation between the government of Sri Lanka, Food and Agricultural Organization (FAO) and United Nations Development Program (UNDP), makes mention of unorganized farmers and the need to organize them. This concept is reaffirmed in extensive feasibility and operational studies created for the MS by the company call NEDECO, based in the Netherlands.

In Sri Lanka, a number of attempts have been taken to meet the perceived need for farmer groups. The Agrarian Services Act No. 4 of 1991, which mandates that all farmer organizations act as institutions with corporate/ collaborative standing/culture and the ability to sue or be sued, is the most notable of them. The MS established a constitution describing the collaborative framework through which farmers must organize collaborate and create farmer organizations based on this significant piece of law. This shows that the government has a desire to restore collaboration (partnering) among farmers. The fact that such laws may have a variety of effects is interesting to notice. One could argue that writing a constitution for farmers to govern themselves is a good thing that could eventually give farmers more authority.

The MS made attempts to organize/collaborate farmers into a unified group with partnering culture, but it is unclear whether these efforts were ultimately successful. The idea that farmer organizations have improved the overall productivity of agricultural systems is not well supported by the available data. Contrarily, there is some proof to support the claim that farmer groups are essentially "shell organizations" or support for political parties, which implies that the farmers' organizations had extremely negative effects on the farming communities, which required some cooperation (partnering). In fact, it appears that collaboration (partnering) is the most widely held opinion in the industry as said by one farmer as shown below:

"The purported farmer organizations are inefficient. They are frequently only a cover for political agendas. The local politicians merely want to ensure that the head of the farmer organization would back their political group. The politicians then attempt to persuade the rest of farmers through the committee chairman. Even fewer people show up to the meetings of the organization. We need to have cooperation, proper respect, trust, independence and strong relationship between farmers and government so that we can work for mutual goals apart from politicians' goals. We must obtain the cultivation timetable and water release date from the Mahaweli officers; neither the committee chairman nor the secretary informs us of these things in advance. So, no use of farmer committee/ association if it is unable to disseminate a farming schedule".

Another barrier is to formation of farmers' organizations accounts to the forces undermining its structure and design features. To create agricultural settlements commercially in SL, the MS has been followed and modeled the major commercial farming projects undertaken elsewhere in the world. As a result, the MS-encouraged farmer organizational structures are an attempt to imitate agro commercial situations in different nations those are purely based on the commercial farming system without any collaboration. This has been confirmed in the following conversation with a Mahaweli employee;

"Mahaweli is a combined concept of large-scale commercial farms initiated in different countries, such as Tennessee Valley farming projects of the United States operates by one entrepreneur. However, the conditions of the Tennessee Valley Plan must be created in MS for successful implementation, which is inconsistent in SL. Following the above plan, MP has formed Canal Based Farmers Associations (CBFO) with the expectation that CBFO will act as a self-motivated corporate body and manage water efficiently. However, the MS has not received the expected results in this regard. As their hypothesis did not work on the ground as expected, instead of critically analyzing what went wrong, innocent farmers became scapegoats for not being organized collaboratively to implement the system as expected".

Discussion above suggests that the act of creating farmers' organizations was overshadowed by a set of other unacknowledged forces in commercial nature. Also, it clearly shows the intention of the MS officer to establish cooperative/collaborative (Partnering) farmer organizations rather than the hostile/adverse culture of the current farmer's organizations.

As the MS focuses on the export market and restricts the types of crops giving priority to limited commodities (rice/chili), it can be assumed that market-oriented commodity-based organizations have been created among the farmers based on the interests of the state. Despite that, recent government policies have altered to focus on organic agriculture by prohibiting the import of fertilizers, especially urea, which is utterly contrary to the MS's aims, and as a result, MS farmers' harvests have abruptly decreased and become destitute. On the other hand, due to the SL government's currency crisis caused by financial mismanagement and corruption over the previous decade, farmers did not get adequate petroleum and agro infrastructure, which has had a detrimental impact on the MS's and its' farmers' stated aims. It also led to low crop production and deterioration of their crop quality.

Figure 4.1.1; organic farming went wrong in Sri Lanka (2020-2022)

As market-based farmer organizations have negative impacts on farmers compared to building community-based initiatives and collaboration (Partnering), the MS shall focus on subsistence farming and initiate a collaborative system (Partnering) and improved model of commercial farming in line with Sri Lanka's current conditions. Also, the MS/MDP shall reorganize/reform the existing market-oriented commodity-based organizations to suit subsistence farming and commercial farming separately. Furthermore, all farmer organizations should be free from political influence, self-sustainable and continuously distribute farmers' infrastructure (petroleum, fertilizers and suitable market etc.) among all farmers in order for high crop production. The above issues can be achieved through a collaborative approach (partnering) to achieve equal project benefits between farmers and society. as stakeholders (government, farmers and MS) have no objection to go with the collaboration.

4.1.2 A lack of knowledge and motivation in farmers (LKM)

This is the primary reason for low crop production within MS, as mentioned in the Report of "Impact of Cultivation Practices" generated by the Unit of Planning and Monitoring of the MS, 1984. This perspective was reinforced in 2002 by Participatory Technology Development Paper 6:4 on MS.

The same story was told in several interviews with MS officials, who not only recognized the LKM as a primary cause of decreasing agricultural productivity, but also offered viable remedies to the problem. According to one officer:

"The Mahaweli system's farmers are unmotivated, which is a huge issue. I observed a dependent mindset among farmers, who patiently awaited guidance. Another issue is that the sons and daughters of the original farmers, the second and third generations of farmers, appear to be even less interested in farming. Another issue is a lack of expertise. So it is urgently required an innovative approach to change this culture".

The above statement makes it clear that LKM is a symptom of an underlying reason rather than a cause. Thereby, MS also envisages a collaborative and motivated cultural change in farming, which means that partnering applications are needed.

According to Gunasena et al. (2015), LKM production actions depend on the political-economic factors involved as they operate within a field of social relations.

According to the MS officials, the MS was mostly adopted to turn SL's subsistence farming into a more financially successful export-oriented farming system, a shift that may be considered as a shift in the political-economic basis of Sri Lankan agriculture. Along with this transformation, MS was entrusted with delivering water to a vast number of agricultural fields via a complicated system of canals built according to irrigation engineering principles. But there is no attempt to bring back their lost cooperation, respect, trust and relationship (other than implementing partnering).

However as said by a farmer, “Before the MS, irrigation-based subsistence agricultural methods have been successful exited and each village had its own water tank that was utilized to meet cultivation (and non-cultivation) demands, and there was high cooperation between communities in terms of water management or cultivation choices”. The above discussion explores that the farmers are not happy with the current MS as the collaboration in the subsistence farming system has now deteriorated causing problems.

Likewise, those early agricultural communities worked closely together for common objectives (informally partnering) such as obtaining the necessary labor, machinery, equipment, water and fertilizer requirements, and many of them gathered as kin in the fields as well as on special occasions (see, Figure.6.1.2 below). As a result, they had a close relationship with each other, developed good cultural and socio-economic relations, having adequate knowledge & motivation and lived a very happy life despite not having much money. The Author has also experienced the same in my childhood village of Tambuttegama (a large town in MS system – H - Rajarata). With the emergence of MS, the government began to bring and settle farmers outside the MS areas, resulting in various socio-cultural and economic disparities and the decline of the entire subsistence agriculture system. The former local landowners lost their lands and were not properly compensated, leaving the locals away from the future farming. Thus they abandoned farming and gradually invaded government jobs and businesses. Meanwhile, under the MS, agriculture was treated as a macro issue at the state level and the government dominated the agricultural process as critical selections about water management, cultivation, land ownership and allocation were all made centrally and given to farmers. LKM was gradually generated among farmers about the new MS agriculture system by implementing MS without listening to the farmers and training them properly. An ideal solution to all these problems (with other solutions discussed) is the engagement of farmers and farmer organizations in partnering, as the principles of partnering described in Table 5.1 above are correlated with those farmers issues.

Figure.4.1.2; physical corporation/collaboration of the ancient farmers.

As per, Paranage (2018), before forming the MS Sri Lanka government gave farmers unlimited rights to their land, however the MDP strictly controlled land use (sale, succession, and sub-letting etc). In addition, the provision of water and deciding which crops to grow (based on water intensity) was decided by a central committee headed by the MS, based on national level / capitalist needs, without taking into account the needs of individual areas of the farming fields. As a result, the new generation of farmers (specially the subsistence farmers) has demotivated due to the loss of ownership and control over the management of their land, water and cropping systems. The above issues have been confirmed by a farmer of System-H as follows;

"We have no choice what to grow. Around 20-25 years ago, me and several of my neighbors came to this Mahaweli area. Before that we were farmed in Kothmale in central province wetlands. We experienced that the situation of these Mahaweli farm is totally different than our subsistence system; we feel It's like going to a day's job. Entirely our daily activities are regularized and there is nothing we can do except wait for water to reach. Earlier, we had enough land, now it is limited to one hectare which is not enough for our family to live. As if that was not enough, MS Officials keep telling us both what to do and how to do it, yet we farmers already instinctively know how to do it. There was no chance to argue so we kept quiet".

Mainly, it visualizes the politico-economic roots observed earlier and demoralizing farmers by realizing they have no control over their farms and a good relationship between farmers and MS officials has not developed. Above quote also discloses the tension among MS officials and farmers concerning proposed agriculture practices. Thus, while the MS officers claim that the farmers do not have the 'requisite knowledge' of 'proper' farming practices, the farmers claim that the officer lacks the 'requisite knowledge' for the same. In brief, MS officials and farmers have different agro system knowledge (as resettled farmers have different farming practices dedicated to the ecological structure of wetlands) and conflict in determining the 'correct' farming practices. Many farmers feel that the agricultural consultant has unusable knowledge gained from the outdated agricultural syllabus of seven universities and fifteen schools (which graduate more than 3000 students annually) and the government has to pay special attention to update the syllabus to suit the current problems. It should be noted that the knowledge conflict depicted here is in reality a political conflict in which one system of knowledge prevails over another, not a purely technical one. However as mentioned earlier, partnering brings about an environment where knowledge and resources are shared, minimizing conflicts and disputes between parties, and that is what the interviewees were ultimately looking for.

Taking control and land ownership away from farmers not only discourages the current generation of farmers from farming, but may even dissuade second and third generation farmers from considering the farming in future. Another downgrade is to limit the division of land parcels, at least among second and third generation farmers, to prevent land fragmentation. After the Covid19 pandemic, it is understandable that there is a huge shortage of labor hire for farming as all the younger generations have chosen to go for textile industry, military and defense jobs. On other hand, agriculture technology literature recommends that highly fragmented land parcels may limit overall agricultural production and land productivity. However, the restriction on farm subdivisions presents a real problem for farm families with more than one child and they question where my children will go?

Table.4.1.2; unemployed persons by industry groups, 2016 -2020 (Source- Annual report 2021; Sri Lanka Labor Force Survey, Department of Census and Statistics). [32].

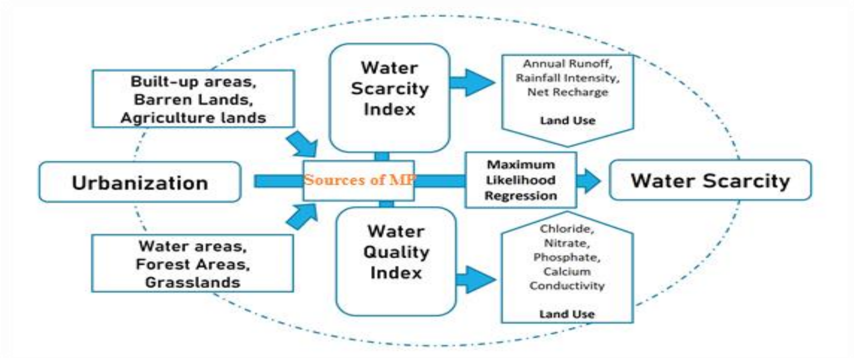
('000	Industry Group	2016	2017	2018	2019	2020
persons	Total Employed	7,948.00	8,208.00	8,015.00	8,181.00	7,999.00
1	Agriculture, Forestry and Fishing	2,154.00	2,140.00	2,044.00	2,072.00	2,170.00
2	Mining and Quarrying	60.00	63.00	62.00	61.00	57.00
3	Manufacturing	1,421.00	1,581.00	1,464.00	1,504.00	1,398.00
4	Construction, Electricity, Gas, Steam and Air Conditioning Supply, Water Supply,Sewerage,Waste Management and Remediation activities	617.00	688.00	713.00	693.00	698.00
5	Wholesale and Retail Trade, Repair of Motor Vehicles and Motor Cycles	1,102.00	1,160.00	1,141.00	1,134.00	1,095.00
6	Transportation and Storage	516.00	513.00	502.00	514.00	524.00
7	Accommodation and Food Services Activities	203.00	210.00	238.00	232.00	217.00
8	Information and Communication	62.00	70.00	55.00	64.00	58.00
9	Financial and Insurance Activities	159.00	160.00	173.00	188.00	183.00
10	Professional, Scientific and Technical Activities	55.00	70.00	86.00	90.00	86.00
11	Administrative and Support Service Activities	107.00	152.00	167.00	205.00	165.00
12	Public Administration and Defence Compulsory Social Security	609.00	527.00	434.00	436.00	447.00
13	Education	344.00	377.00	425.00	426.00	403.00
14	Human Health and Social Work Activities	142.00	149.00	143.00	169.00	156.00
15	Other Service Activities	138.00	119.00	117.00	135.00	123.00
16	Activities of Households as Employers; Undiffrentiated Goods and Services- Producing Activities of Households for Own Use	209.00	162.00	194.00	187.00	167.00
17	Other*	50.00	67.00	55.00	68.00	51.00

The above quotations and descriptions exemplify many of the problems faced by farmers regarding inheritance and succession. It is therefore clear why second and third generation settlers seek opportunities rather than farming or avoid farming altogether and it also revealed that this culture can be changed by applying partnering.

4.1.3 Water scarcity;

The third main reason advanced by the official narrative to explain the MS's underperformance is the issue of water scarcity. Water scarcity is described as a mismatch between water demand and supply across geographical and temporal dimensions, which can be graphically illustrated in terms of the home water supply system as shown in the Fig.4.1.3, below;

Figure. 4.1.3-1; water scarcity graphical illustration (Source; Socio – Eco Statistics 2018, MS). [33].



Water scarcity is strongly associated with recent efforts by the government to improve the performance of water infrastructure within the MS zones as evidenced by the project summarized in the Table.6.1.3-1, below.

Table. 4.1.3-1; effort of government to prevent water scarcity (Source; Mahaweli socio-economic statistics book 2018, Pg.151). [33].

No	2
Project Name	Uma Oya Multipurpose Development Project
Main Objective	Trans-basin diversion of 145 MCM of excess annually from Uma Oya basin for alleviating the water scarcity in the South Eastern dry zone without affecting the water users and environment in Uma Oya basin.
Main Project Components	• Head works and • Downstream Development works in Kirindi Oya basin.
Benefits of the Project	Generation of 290 GWh of electrical energy annually; Provision of irrigation facilities for 6000 ha of land and provision of 30 MCM of drinking water annually.
Project Duration	2010 – 2020
Funding Agency	GOSL
Funding Types	Domestic Fund
Estimated Project Cost	Rs.89,800 Mn (USD 514.5 Mn + LKR 15,474.25)
Implementing Agency	MMD&E/PMU - UOMDP
Location	Moneragala
No. of Beneficiaries	General Public of Monaragala, Wellawaya, Thanamalwila
Cumulative Expenditure up to 31st Dec 2018 (Rs.Mn)	68,584.20

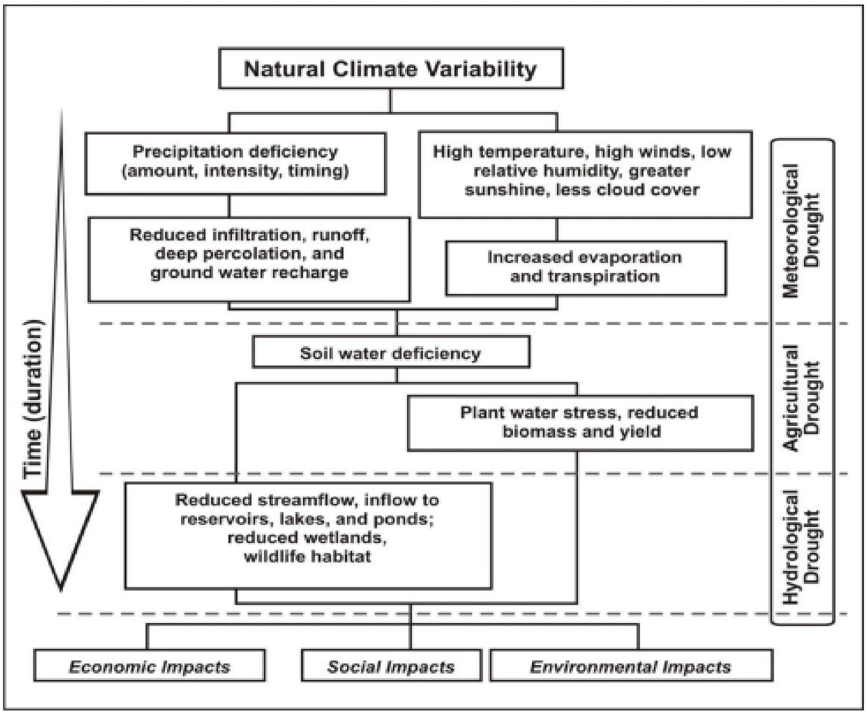
As per UNDP (2021) says, "due to the multiple consequences of climate change, Dry Zone of SL, which spans 70% of the country's geographical area, has endured some of the island's worst droughts, with the 2016 drought lasting over few years", and it signals that drought is the main cause of water scarcity in SL.
Furthermore, drought caused water scarcity is the most common disaster mentioned among the 21 natural or man-made disasters recognized in the Disaster Management Act No. 13 of 2005 of the Government of Sri Lanka, as statistically demonstrated by the data in the Table. 6.1.3-2, below;

Table. 4.1.3-2; peoples affected by natural disasters, 2017-2022 (Source; SL Disaster Mgt.C). [18].

Type of Disaster	2017	2018	2019	2020
Flood	666,244	490,295	579,960	121,236
Drought	2,440,290	2,044,780	969,689	416,276
Lightening (Thundering)	268	4,571	1,469	716
Cyclone/High Wind	128,653	45,640	66,158	175,349
Landslides	129,973	7,205	2,393	44

Sequence of drought occurrence and effects on commonly recognized drought types are graphically demonstrated in the Figure. 6.1.3-2, below;

Figure. 4.1.3-2; drought occurrence and impacts on drought types



(Source; Ministry of Environment Sri Lanka, 2020). [33].
Thus, a systematic and innovative collaboration strategy is required to lessen the impact of drought, as a substantial portion of the population relies mostly on agriculture for a living.

World food program -WFP (2022), says; Sri Lanka is suffering from a terrible economic and food catastrophe that has enveloped millions of people. Thus, WFP has proposed a strategy plan to minimize this issue, which includes only socio-economic aid (including partnering) to crisis-affected individuals rather than remedies to water scarcity. This means that water shortage is not the primary cause of the current food crisis as they understood.

However, the findings above do not quantify or illustrate whether there has been considerable water scarcity inside MS regions in recent years. Instead, when we looked at statistical information on water released to farmers in MS System H, between 2007 - 2019, this article found no reduction in water release (see Table. 6.1.3-3 and Table. 6.1.3-4, below). Accordingly, except for minor changes, it appears that system H (the MS's largest agricultural system) has gotten a consistent amount of water.

Tables. 4.1.3-3a: irrigation water issues, water duty and water productivity in Maha season

MAHA SEASON	Unit	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
System B												
Water Issues	**MCM**	**209.10**	**288.50**	**221.90**	**217.70**	**266.60**	**115.30**	**218.70**	**221.60**	**255.20**	**134.70**	**189.54**
Water Duty	M	1.27	1.54	1.19	1.10	1.42	0.61	1.17	1.19	1.33	0.72	0.96
Water Productivity	Kg/M-3	0.36	0.33	0.41	0.16	0.37	0.71	0.49	0.43	0.40	0.69	0.57
System C												
Water Issues	**MCM**	**270.50**	**340.60**	**260.70**	**241.60**	**288.60**	**171.80**	**286.50**	**267.10**	**290.70**	**178.60**	**304.47**
Water Duty	M	1.27	1.48	1.14	1.06	1.26	0.75	1.26	1.18	1.27	0.81	1.36
Water Productivity	Kg/M-3	0.39	0.38	0.48	0.27	0.43	0.55	0.46	0.42	0.44	0.66	0.42
System G												
Water Issues	**MCM**	**99.80**	**96.40**	**98.80**	**87.60**	**104.70**	**68.70**	**87.30**	**95.10**	**105.00**	**56.90**	**60.39**
Water Duty	M	1.90	1.80	1.80	1.74	1.57	1.16	1.24	1.57	1.57	1.22	1.16
Water Productivity	Kg/M-3	0.25	0.27	0.30	0.19	0.27	0.37	0.40	0.36	0.29	0.45	0.40
System H												
Water Issues	**MCM**	**360.70**	**364.40**	**369.40**	**251.80**	**334.90**	**235.20**	**333.80**	**273.70**	**328.40**	**118.30**	**225.27**
Water Duty	M	1.15	1.14	1.16	0.79	4.93	3.28	1.04	0.99	1.17	1.07	1.31
Water Productivity	Kg/M-3	0.47	0.49	0.52	0.58	0.39	0.52	0.53	0.59	0.47	0.48	0.41
System HU												
Water Issues	**MCM**								**85.60**	**64.00**	**32.00**	**167.82**
Water Duty	M								1.03	0.60	0.64	1.95
Water Productivity	Kg/M-3								0.70	0.95	0.96	0.27
System UW												
Water Issues	**MCM**	**278.10**	**391.50**	**381.00**	**409.80**	**327.70**	**328.80**	**324.50**	**316.80**	**421.00**	**82.40**	**304.71**
Water Duty	M	1.66	2.18	2.03	2.10	2.94	2.77	1.35	1.43	1.82	0.95	1.56
Water Productivity	Kg/M-3	0.48	0.38	0.40	0.37	0.26	0.23	0.81	0.29	0.21	0.19	0.28

(Source; Mahaweli socio-economic statistics book 2018, Pg.10). [33].

Tables. 6.1.3-3b: irrigation water issues, water duty and water productivity in Yala seasons

YALA SEASON	Unit	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
System B												
Water Issues	MCM	398.00	193.80	369.10	399.40	323.40	375.50	249.10	385.20	376.90	195.64	308.90
Water Duty	M	2.30	1.68	1.89	2.04	2.17	2.02	2.67	2.05	1.94	1.88	1.56
Water Productivity	Kg/M-3	0.21	0.27	0.26	0.29	0.22	0.21	0.26	0.26	0.26	0.27	0.31
System C												
Water Issues	MCM	433.60	177.10	426.00	513.60	358.60	415.30	328.90	456.30	461.10	217.45	383.44
Water Duty	M	2.02	1.85	1.94	2.31	1.97	1.81	1.44	1.99	2.02	1.73	1.74
Water Productivity	Kg/M-3	0.26	0.28	0.27	0.25	0.23	0.23	0.29	0.28	0.27	0.29	0.31
System G												
Water Issues	MCM	113.80	82.40	122.60	120.90	106.80	137.70	49.10	139.40	100.40	35.71	103.32
Water Duty	M	2.21	2.91	2.33	2.36	1.99	1.96	1.41	1.99	1.88	1.02	1.90
Water Productivity	Kg/M-3	0.23	0.17	0.23	0.22	0.23	0.13	0.33	0.22	0.19	0.50	0.31
System H												
Water Issues	**MCM**	**385.50**	**227.10**	**333.40**	**408.80**	**302.60**	**362.70**	**161.70**	**265.50**	**226.50**	**192.34**	**281.89**
Water Duty	M	1.23	1.72	1.04	1.28	5.53	5.32	0.94	1.01	1.56	1.29	1.42
Water Productivity	Kg/M-3	0.45	0.31	0.52	0.45	0.03	0.17	0.57	0.58	0.36	0.47	0.44
System HU												
Water Issues	MCM								114.70	67.10	287.61	325.55
Water Duty	M								1.30	1.14	4.91	3.75
Water Productivity	Kg/M-3								0.66	0.76	0.18	0.17
System UW												
Water Issues	MCM	458.90	397.70	495.70	506.30	278.80	420.70	389.30	402.80	537.90	266.90	424.79
Water Duty	M	2.51	2.41	2.51	2.52	3.56	3.77	1.66	1.43	2.48	1.69	2.15
Water Productivity	Kg/M-3	0.33	0.34	0.36	0.33	0.21	0.17	0.58	0.43	0.32	0.50	0.41

(Source; Mahaweli socio-economic statistics book 2018, Pg.11). [33].

The aforementioned numbers, acquired from the SL Water Management Secretariat, contradict the 'official narrative' of intermittent drought leading to a progressive drop in water provided to MS systems. Thus, this finding questions the validity of the drought narrative, as lack of water does not seem to explain the underperformance of the MS farming sector. Therefore, some other variables may play a significant role here (such as lack of partnering culture, non-use of latest irrigation engineering technology, agricultural land quantum, urbanization, natural climate variability, changes in farming and cropping intensity), so quantitative data for drought narrative should be studied analytically in depth. Conversely, alternative narratives found in the field search recommend that the problem is not the perception of water scarcity but its ineffective management.

Consequently, the MS releases a certain amount of water per farm, however, as the water is released through the canal network to reach the farm, the farms closer to the point of water release collect more water than their entitlement. As a result, farms located far away receive less than their entitlement of water for cultivation. This may operate on political economic pressures and therefore the MS's water management plan provides no incentive for farmers to act collectively on water management.

On the other hand, since the MS controls and distributes water, each farmer tends to get too much water for his own farm, which often affects the irrigation supply of neighboring farms. This phenomenon of resource control and distribution affects the field of farmers' social relations, leading to a more individualistic attitude among farmers towards water management, with water scarcity being a behavioral consequence of this shift rather than a correlate of drought in some MS systems. Partnering can help significantly in this matter by providing a relationship between farmers and officials and eventually establishing proper co-operation in distributing water equally with farmers.

Furthermore, refer to table. 6.1.3-4 below, it is understood that the increase in cultivated area (asweddumization) is due to the inclusion of new lands brought under paddy cultivation and not just water scarcity.

Table. 4.1.3-4, area and yield of paddy, 2011-2020. [32]

Cultivated Year	Asweddumized Area(a), Hect.	Season	Sown Area Hect.	Harvested Area Hect.	Production '000MT	Average Yield Kg/net Hect.
2011/12	789,428	Maha	702,075	684,636	2,717	4,444
2012		Yala	364,542	305,314	1,129	4,145
2012/13	845,844	Maha	779,635	741,591	2,846	4,408
2013		Yala	447,613	446,637	1,774	4,260
2013/14	877,858	Maha	651,289	579,875	2,236	4,222
2014		Yala	312,979	300,725	1,145	4,204
2014/15	885,110	Maha	772,626	734,967	2,877	4,364
2015		Yala	480,662	475,773	1,942	4,527
2015/16	886,202	Maha	756,005	742,724	2,903	4,349
2016		Yala	385,318	379,970	1,517	4,417
2016/17	892,945	Maha	542,556	382,856	1,474	4,301
2017		Yala	249,123	236,479	909	4,291
2017/18	857,611	Maha	667,191	619,928	2,399	4,302
2018		Yala	373,763	362,966	1,533	4,683
2018/19	865,827	Maha	748,027	724,120	3,073	4,747
2019		Yala	368,906	346,010	1,519	4,896
2019/20	869,111	Maha	752,248	739,911	3,197	4,531
2020		Yala	456,206	450,743	1,924	4,552

4.1.4 Non-utilizing of latest irrigation engineering technology

(a). Analysis of the interview;

In an interview, MS official stated, "We are still using old designed systems and equipment while other nations in the region have various efficient modern methods which we have observed during official visits. We also have no financial and knowledge sharing opportunities in order to share it with farmers for continuous improvements" The problem of implementing them in Sri Lanka is lack of funds and lack of skilled personnel. For example, booster pumps are still used to lift irrigation water especially for dry crops in high ground such as “Nallachchiya, Tambuttegama and Rajanganaya” due to the level difference between the canal and the crop land”. This leads to high fuel costs, timely watering and water scarcity. Although we offer guidance and support, farmers are not interested in going with sprinklers or SCADA systems that can alleviate the above problems.

So if there is an innovative approach of sharing knowledge, new technology and changing the adverse culture of farmers in the existing system, it can be a path of sea change (likely Partnering to be integrated with the innovative engineering technology).

The same context was confirmed by several farmers who perceived that the MS was operating with outdated technology that contributed to the low quantity and quality of crop production in Sri Lanka. They also expect someone to come up with a collaborative (Partnering) way to share new technology.

Thus, Section below attempts to introduce potential engineering theories to improve existing systems and new technologies to replace existing systems.

(b). Theories and New Technology to adopt;

While the issues explored under 6.2.1 could not be resolved only through the case study output, the issues were referred to the literature review and found solutions that have not yet been adopted in MS as follows;

Tushaar et al. (2012) applied “Contingency Theory” to resolve canal irrigation problems and proposed clusters of contingency factors that describe the external task environment of the canal irrigation systems in various regions of Asia.

El-Nashar et al. (2017) investigated the application of the “Value Engineering (VE) approach” to alleviate the recurring scarcity of irrigation water at the Canal Tail-end (CT) of canal irrigation systems. The VE methodology includes activities such as data collection on the water shortage in CT, functional analyzing of canals, developing and assess creative ideas using evaluation criteria, short listing of value alternatives and developing them using Life Cycle Cost (LCC) and Net Present Value (NPV), and so on. Further, He discovered that VE methodology is a problem-solving strategy that facilitates in the identification of solutions to achieve the system's core functions.

B. Wahlin (2022) investigated and found that “Canal Automation” using SCADA systems has always provided a solution to save water, increase the effectiveness of irrigation water supply projects, and allow more precise management of water distribution throughout an irrigation project. This engineering technology innovation process includes the following limitations and concepts; irrigation physical Infrastructure survey, SCADA systems, control of operation, study of canal hydraulic properties, performance verification and system implementation controlling etc.

The feasibility of “Closing the Distribution Channels at Night” with a modified surface irrigation system was recently explored and found good results.

In Kennedy's “Silt Theory”, R.G. Kennedy (2020) studied canal systems for twenty years and generated Kennedy's Silt Theory. The theory states that silt carried by water flowing in a channel is suspended by eddy currents that rising to the surface of the water. The vertical element of the eddy current tends to move the sediment upward, while the sediment load tends to pull it downward. Thus, if there is sufficient velocity to keep the sediment in suspension in the sludge, the formation of eddies is prevented. Accordingly, critical velocity (mean velocity) which keeps channel free of silt and scour. The critical velocity is a dependent variable on the water depth in the channel. Thus, critical velocity equation given is as follows:

V0 = CDn………………………….. (1)

Vo = Critical velocity, D = full water supply depth. Constants are 0.546 and 0.64, respectively. Equation (1) can be rewrite as follows;

V0= 0.546D0.64……………………… (2)

With the improvement of Equation (2), a factor called "critical velocity ratio" was introduced as follows;

V0= 0.546m$D^{0.64}$ …………………… (3)

Canal design procedure using Kennedy's silt theory can be done accurately by following its limits. Then, find the cross section area of the using the continuity equation:

Q= AV ……………………… (4)

Q: Discharge. A: cross section area. V: mean velocity. Find the hydraulic mean depth of the channel (R).

R= A/P ……………………… (5)

R; hydraulic mean depth. A; canal cross sectional area. P; perimeter of the section. Ultimately, the mean velocity (V) can be calculated using Kutter's formula:

$$V = \left(\frac{1/N(23+0.00155/s)}{1+(23+0.00155/s)(N/\sqrt{R})}\right)\sqrt{Rs} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

N; rugosity coefficient depends on canal lining material type. # S; bed slope, as 1 in 'n'. # V computed by equation 3 and equation 6 must be equal. If not, repeat it assuming another D value. Generally, the trial depth is 1m to 2m. Using this theory it is now worthwhile to design canals to conserve canal water and prevent scarcity.

Moreover, "Blockchain agriculture" provides data and information traceability in the food supply chain to improve food and water security. It enables the storage and management of data and information facilitating earlier innovations in smart farming as well as index-based agricultural insurance, a huge step forward in the modern agricultural world.

(c). Adverse organizational and human culture influencing on the technological issues;

The interview outputs of the MS officials were explored that various factors that focus on technical, cultural and legal problems rather than queries about the project's owned political-economic factors are causing the MSs' underperformance. Furthermore, technical explanations given by MS officials in order to systematically shift blame for failure (particularly in design and development) to innocent farmers. Thus, it is suggested that responsible parties first address the political-economic factors causing the MS's underperformance, followed by the resolution of technical and legal issues, in order to avoid political-economic influences on technical rendering.

While rendering technical issues, the article recommends that the design and planning team have a better understanding of the development's specific features and characteristics. Moreover, the article also offers new directions for design and development teams to critically investigate the development's design features in terms of their social consequences and to use the partnering principles. Also, this Article encourages decision makers and project experts to comprehend and avoid creating Supremacy by viewing technical problems as political problems and emphasizing individual factors over design features. This can prevent supremacy in applying their own knowledge and approach within the project, allowing for a diversity of 'knowledge' that is more sensitive to social dynamics and leads to innovative initiatives including the partnering etc.

Engaging in new technology helps a lot in improving productivity, but a collaborative approach (such as Partnering) of sharing knowledge and resources should be established for equitable distribution among farmers.

5. Conclusion

As discussed above, there are narratives which argue that poor agricultural production is one of the primary causations of Sri Lanka's food insecurity. Agricultural production is intimately linked to irrigation networks as they are dependent variables. So, using a case study and a literature review, this paper examined the primary challenges and threats to success the pending achievements in the irrigation sector and identified that applying collaborative approach (such as Partnering) may address those issues.

Prior to the case study, the article examined the literature on the ancient Sri Lankan subsistence farming system, exploring its performance, socio-economic culture & relations, organizational culture and significance before comparing it to the current agricultural system investigated in the case study.

Primary data for the case study were gathered through conversations with farmers and officials, and secondary statistical data were gathered from the MS departmental database. The results indicate that the current system (MS) is underperformance than the subsistence system described above.

Subsequently, through the case study and its literature review, this article identified the following key challenges and factors affecting the current irrigated agriculture performance in Sri Lanka and assessed the relevance of partnering in each situation:

1. Inappropriate deviation from the subsistence irrigation system;

2. Farmers' lack of motivation, inadequate knowledge, and poor organizing/collaboration (lack of application of the Partnering principles);
3. Lack of applying of modern irrigation engineering technology/ theories mixed with Partnering;
4. Water scarcity/ critical droughts.
5. The MS's underperformance due to socio-economic issues / influences and the Supremacy in the technical rendering etc. (found that Partnering can minimize these issues).

Accordingly, the article intended to identify and make a detailed review of the causations for the issues of the topic such as "organizational culture and suitability of partnering, and performances suitability characteristics and components of the subsistence agriculture systems", "pitfalls in improper migration from the subsistence agriculture systems", "wellness of the socio-cultural, geographical, and political-economic relations", and "water scarcity and critical drought conditions" etc., and possible solutions including the application of Partnering are explained.

Furthermore, the issue of "Non-use of modern irrigation engineering technology" was investigated, and analyzed for the applicability of emerging irrigation engineering theories such as "Canal automation", "Closing distribution channels at night", "Sludge theory", "Contingency theory", "Value Engineering approach" and "Block chain agriculture" etc. It was found that these should be adopted by MS during the reconstruction and rehabilitation process as adaptation strategies in the context of assessing water security, engineering water conservation and absorbing environmental changes. It is also recognized that engagement in new technology can be more effective if done through a collaborative system (such as a partnering), as recommended in this article.

MS officials' interview outputs suggest that technical, cultural and legal problems are causing the MSs' underperformance. It is suggested that responsible parties address the political-economic factors first, followed by technical and legal issues, and building partnering, to avoid political-economic influences on technical rendering.

The article recommends that the design and planning team have a better understanding of the development's specific features and characteristics. It also encourages decision makers and project experts to avoid creating Supremacy by viewing technical problems as political problems and emphasizing individual factors over design features. This will lead to a diversity of knowledge that is more sensitive to social dynamics and innovative project initiatives including application of Partnering.

Arguing for these socio-cultural and political-economic issues and water scarcity etc., following solutions are proposed;

- Lack of organization: Farmers can redress through the reformation of farmers' organizations providing them the unlimited rights, termed obligation and full authority with free of politics through establishing a collaborative system (such as partnering),

- Lack of motivation & knowledge in farmers can be eased by providing regular technical knowledge (via updated agricultural syllabus), continues workshops and incentives, through establishing a collaborative system (such as partnering),
- Drought-related water scarcity can be alleviated by systematic rationing of available water sources, through establishing a collaborative system (such as partnering).
- In addition, as part of developing a pragmatic groundwater abstractions strategy, developing innovative hydrogeological investigations for proper groundwater exploration in prospective water bearing areas (i.e., techniques such as seismic, induced polarization, electromagnetic, and VLF system, etc.) and introducing new technological system for construction of suit well structures to increase ground water supply for crops without affecting ground water table (i.e.; increase discharge volume using Spread Techniques, Induced Recharge Technique and Inject Techniques, while using efficient Helical Rotor Pump system working by solar power), are recommended through establishing a collaborative system (such as partnering).
- Use of latest irrigation engineering theories in designing and rehabilitating irrigation water supply systems discussed above for water conservation, quality and efficiency integrated with Partnering.

6. Future recommendations

Develop a Partnering Framework' for the Agriculture and Irrigation Engineering Industry in Sri Lanka independent of the socio-political complexities of MS, resulting in a more sensitive planning and design team free of supremacy and implementation consistent with a partnering approach, as discussed above.

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