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Sustainable Development of Sri Lankan Water sector

[1]D.D.P. Preethika, [1]Choolaka Hewawasam, [1]D.J.Jayasanka, [2]Namita Maharjan

[1]University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka
[2]Nagaoka National Institute of Technology,888 Nishikatakai, Nagaoka, Niigata, Japan
[1]prabodhipreethika@gmail.com

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Abstract: The global water crisis is an emerging issue because of the less availability of global freshwater resources, and still, special attention is given to the financial crisis neglecting the global water issues. The root causes for these issues mainly rely on institutional and political choices. Exceptional cases like illegal sand mining, improper urban waster management, unusual agro fertilizer usage, and deforestation are the most severe impacts water sector. Like the global situation, Sri Lanka is also facing a critical condition where some people do not have safe drinking water facilities. Usually, same as hunger; poor people are also experiencing water shortage issues. So as Sri Lankans, the aim is to improve the present condition to make a better environment for the next generation. So this paper discusses the current state in the water sector by focusing on the institutional contribution and the legal arrangement towards sustainable water management. The later part of the paper will also investigate some of the Sri Lankan water-related issues. Furthermore, the paper addresses how people can overcome issues to improve sustainability efforts by enhancing ecosystem services, rainwater harvesting systems, reducing dependency on chemical-based water treatment, and examining some Sri Lankan water management suggestions.

Keywords: sustainable development, wastewater management, water treatment

1 INTRODUCTION

Water is essential to life. Clean water is the most sought-after resource on the planet. Therefore, ensuring sufficient water for the world to drink, grow crops, and keep clean now and into the future is a global challenge. Water takes up most of the space on the planet, but 97.5% of that water is saltwater [1]. Most researchers conclude that 1 out of 3 people lack access to clean water, and 2 out of5 people do not have water for basic handwashing facilities [1]. Only 2.5% of global freshwater was available for human consumption. This means 2.5% of the world's water at the hands of 7.8 billion people. From this 2.5%, approximately 70% of freshwater withdrawals for agriculture. The rest of the water exists as seawater. Human resource consumption is growing day by day, and some estimates show that water demand will be 40% more than the available supply of fresh water in the world. If this process continues, most of the population will suffer from water shortages by 2030 [2].

When moving on to the Sri Lankan context, around 21 million people are living up to 2019 with an area of 65,526 km2 [3]. Sri Lanka is one of the wealthiest countries in natural resources, with 103 natural river basins, hundreds of lakes, and an island covered by the Indian ocean. Furthermore, 72 % of the rural population still relies on natural water springs/groundwater bodies. So people might think that water should not be a matter of contention in a country like Sri Lanka. However, the major problem is that 14.9% of the rural population and 49.4% of estate households do not have access to clean, safe potable water [4].

In other respects, there are many different types of people who use that water, including industrial purposes, farming communities, fertilizer production, fishing in the lake, irrigation purposes, and many tourists going to visit some local water bodies, and much more activities are engaging in different sectors.

Currently, there has much pressure on the use of water and often notice that much municipal wastewater, irrigation return flow always runs back into the rivers, lakes thus cause to water pollution. So this unequal usage, distribution, and lack of policy enforcements are creating a significant obstacle for many of us. At the same time, climate change impacts are already being felt in the upper part of the country. More rain shortages and excess rainfall patterns can be experienced in various ways, especially in dry and wet seasons.

Early uses of water power begun from the past centuries, especially in China, Europe, Egypt, Rome, etc. Similarly, Sri Lankans are a proud nation that had the most incredible hydraulic system in the world. Ancient kings had primary hydro culture ecosystems, and their kingdoms were built around the systems. They saw the importance of this precious abundant resource. However, the difficulty is, even people are from a technologically and scientifically advanced era, they still unable to protect their resources. So, it is essential to come up with solutions to deal with the situation. Therefore, sustainable management of water has become crucial.

2 SRI LANKAN WATER RESOURCES

Sri Lanka receives high rainfalls throughout the year in North-west and South-west monsoon periods. Thus,it's not required to share or take water from other countries. Mainly, three different climatic zones, including wet, intermediate, and dry season and annual rainfall for each season, experience over 2000/mm year for the wet season while approximately 1500/mm year rainfall will result in the dry season [5]. However, due to the uneven rainfall distribution pattern, most areas in the dry zone are hit by water scarcity problems. In 2017, the average annual water precipitation depth was calculated as 1,712 mm/year or 112.3 billion m^3/year. Apart from that, per capita, water availability was estimated as 2,529 m^3/person /year [6]. Even though Sri Lanka has abundant water resources, uneven distribution from region to region creates most water shortage cases.

As mentioned previously, Sri Lanka consists of 103 river basins to fulfill the country's water demand, and all these are flowing from the central mountains through various directions towards the sea. These are covering 90% of island land. Mahaweli, Kelani, Kalu, and Walawe are significant rivers in Sri Lanka to cater to the country's surface water requirement. River pollution is becoming a critical condition that needs to be concerning seriously. This is because of the uneven urban waste discharge patterns, unethical human anthropogenic activities, and also due to climate change, etc.

Groundwater is another primary resource in the country, which consist of six major groundwater aquifers, namely shallow karstic aquifer of Jaffna peninsula, deep confined aquifers, coastal sand aquifers, alluvial aquifers, shallow regolith aquifer of the hard rock region, southwestern lateritic (cabook) aquifer are available to cover 72% of groundwater demand [7].

Coastal water, lakes, reservoirs are also contributed as Sri Lankan water resources. Nevertheless, water pollution in coastal areas, lakes, and reservoirs are increased at an alarming rate over the past decade. Besides that, more than 20 wetlands and six wetlands can be identified under the Ramsar convention, including Vankalai sanctuary, Wilpattu Ramsar wetland cluster, Annaiwilundawa tanks sanctuaryMadu Ganga, and finally Bundala &Kumana wetland cluster. All these are improving water quality and enhancing Srilankan water resource management.

However, relevant authorities do not have enoughdata on existing water resources. However, combining some common factors like population growth, urbanization, and industrialization results in securing and protecting existing natural resources to ensure a sustainable country for the present and future generations.

3 ANCIENT SRILANKAN WATER MANAGEMENT

Over 2400 years ago, Sri Lanka flourished as one of the finest hydraulic civilizations in the world. Ancient king's built a sophisticated network of small tanks connected by canals to large reservoirs (in the native tongue, these reservoirs called '*Wewa'*) to collect and redistribute every single drop of rain the land received. For example, Anuradhapura is one of the Kingdom surrounding various water tanks. So, because of the water tanks that kings were constructed, their economy and livelihood still survived. The tanks were built in cascading system, using natural inclination and topography of the land. They kept the natural cycle of water through the soil, vegetation, and atmosphere. Specific areas of the tank were dedicated to wild animals like endangered flora, fauna, and many other species from the nearby forests. It is one of the beautiful artificial ecosystems that managed to keep the perfect ecological balance for centuries. Those regulate the local weather, let animal and plant biodiversity survive, and nourish soils to cultivate rice throughout the year [8].

Nevertheless, today, climate change exposes Sri Lanka to higher temperatures, heavier and more irregular rains, and prolonged droughts. Many farmers accumulate to take debts, most of the cascade systems are in disrepair, and not take action to keep and adequately maintained our ancient king era. The key features of ancient's tank designs and those systems were neglected and abandoned day by day.Harvesting rainwater is another most outstanding achievement from the ancient era, which was used centuries ago. Sigiriya is one of the best examples, as in Fig. 1, rocks were cut into reservoirs to hold rainwater [9].

Fig. 1. Rainwater harvesting- Sigiriya [9]

Ancient tanks and cascade systems and these rainwater systems were perfectly adapted to cope with Sri Lanka's climate. They reduced floods and droughts, controlled the temperature, ultimately supported livelihoods, and allowed small weather fluctuations. Therefore, rehabilitating these tanks and reintroducing ancient tank's features that were dropped over the centuries is much more critical for a sustainable era.

4 SRI LANKAN WATER SECTOR- CURRENT STATUS

According to the Sri Lankan present water status review, we can identify 22% of water in canals, 21% in seas, 18% wells, 9% rivers, 4% lagoons, and 26% in other sources. According to the “Sanitation and water for all global partnership” data, 47.7% of the Sri Lankan population has pipe-borne water supply facilities, and 36.4% of people depend on protected dug wells, while 3.2% of people rely on tube wells/hand pumps, 0.5% of people depend on the rainwater systems, etc. Other than that, approximately 12.2% of people still depend on unprotected sources and do not have safe drinking water [10]. When it comes to the water

supply system, rural water schemes and urban water scheme processes are comparatively different.

4.1Rural water schemes in Sri Lanka

Water scarcity is a vital issue in rural areas. Usually, women crowding around the well like in Fig. 2 can be primarily seen in places, specially Anuradhapura, Polonnaruwa, Monaragala, Puttalam, etc. Most Sri Lankans have access to some source of water. Nevertheless, in some villages, lack of water availability remains a daily concern that ultimately affects people's lives. Women and children have the primary responsibility to collect water, and they carry the burden of providing water for the family. Some people are engaging in rainwater harvesting, and others received water from browser supply.

During the dry season, there is a big water problem throughout Sri Lanka. So the water level in the wells goes down, and some become completely dry. People have to walk long miles to collect water. They spend the whole morning fetching water, which interferes with their other activities like jobs, education, etc. However, in pandemic times, it would be much more difficult. Therefore, sustainability has should become a widely discussed matter in the rural water scheme process.

Fig. 2. Rural women fetching water [11]

4.2 Urban water schemes in Sri Lanka

NWSD operates 324 water schemes throughout the Sri Lankan to supply adequate portable water. Several centralized water treatment plants operated in each area and supply treated water to main reservoir tanks. Then water distribution is done based on the gravity concept through pipe networks [12].

If the area has the availability of piped water supply, people can take new water supply connection, and at the end of the month, water bill payment should have to be completed. Besides that, private sector organizations are working behind bottled water production to fulfill the country's drinking water requirement. Several institutional, organizational centers support achieving and exploring all these functions and the visions and missions of the Sri Lankan water sector.

5 INSTITUTIONAL CONTRIBUTION

Several institutions are working together to govern the Sri Lankan water sector, and Table1 presents some.

Table. 1. Institutional contribution for Sri Lankan water sector and main responsibilities

Institute	Functions/ Major responsibilities
National water supply and drainage board (NWSDB)	Piped-borne water is mainly supplied by the National water supply and drainage board (NWSDB), and private sector water supply schemes are taken primary responsibility to supply quality drinking water to Sri Lankan peoples. Several

	regional support centers are operated under NWSDB in each district namely western central, western south, eastern, Sabaragamuwa, north-central, etc. Under these centers, 3 to 4 or 5 regional drinking water treatment plants are controlled to provide an adequate potable water supply [12].
Irrigation department	It facilitates sustainable management to improve Sri Lankan land, water resources for food, livelihoods under the government policies. The department's primary function includes irrigation and drainage work, rainwater harvesting, flood control, river, stream pollution prevention, hydraulic modeling, river gauging, etc [13].
Water resources board (WRB)	WRB is also a government organization aiming to supply adequate access to clean and safe groundwater for all Srilankans while sustainably utilizing groundwater resources by using new technologies and modern tools. Hence, the services of the WRB were developed to cater to the growing demands of the country in various sectors (agriculture, domestic, industrial, etc). Primary functions of this organization including groundwater investigation, flowmeter installation, tubewell drilling, handpump installation, pumping tests, groundwater quality monitoring, etc [14].
Mahaweli Authority Sri Lanka (MASL)	MASL was also established to use land and water for sustainable agriculture, renewable energy generation, secure the environment and ensure the livelihoods of citizens. Mahaweli master plan mainly focuses on dry zone areas, and it's intended to construct reservoirs for hydroelectricity generation while facilitating new settlement and developments along the Mahaweli river and its tributaries like Abanganga, Elahera, Angamadill, etc [15].

Moreover, the Ministry of Environment and Natural Resources, Disaster Management Center, Coast Conservation Department, Ministry of Fisheries, and Aquatic Resources are other institutions that contribute toward Sri Lankan water management.

Apart from these government organizations, non-government organizations also contribute to the Sri Lankan water sector development. International water management institute (IWMI) is a global organization that works with several partners in Sri Lanka to enhance water management and support policymakers to improve the land and water resources for the betterment of the country [16].

6 LAWS AND REGULATIONS FOR SRI LANKANWATER MANAGEMENT

Central Environment Authority is the national regulatory institution for conserving the environment and its resources in Sri Lanka and functions under the National Environment Act no 47 of 1980. Therefore, this is the leading agency which involves in sustainable development in Sri Lanka. There are several acts, regulations, ordinances working towards Sri Lankan water management, represented in Table. 2. Furthermore, the government currently has committed to several regional and international agreements (Table 2) called multilateral environment agreements that legally bind agreements between three or more countries to protect the environment.

Table. 2. Different type of Acts, Ordinances, Policies, MEAs [17]

Type of Laws and regulations	**Names**
Acts, Policies, ordinances	Control of Pesticides Act No 33 of 1980
	Coast Conservation Act no.57 of 1981
	Water resource board Act
	Marine Pollution Prevention Act No 59 of 1981
	Mines and mineral Act No 33 of 1992
	Catchment and Land Protection Act 1994

	Fisheries and Aquatic Resources Act No 02 of 1996
	National Policy on Protection & Conservation of water resources, their catchments & reservations in Sri Lanka
	Coastal Zone Management Plan 2004
	National Watershed Management Policy 2004
	Cleaner Production Policy 2004
	National Policy on wetlands 2005
	National Fisheries and Aquatic Resources Policy 2006
	National Biosafety Policy
	National Agriculture Policy 2007
	National Policy on Sand as a Resources for the Construction Industry 2006
	Water Hyacinth Ordinance No 09 of 1909
	The State Lands Ordinance
Multilateral environment agreements (MEA)	United Nations Framework Convention on Climate Change (UNFCCC)
	Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean
	United Nations Convention on the Law of the Sea (UNCLOS)
	Stockholm Convention on Persistent Organic Pollutants (POPs)
	The Rotterdam convention
	Basel Convention
	International Convention for the Prevention of Pollution from Ships (MARPOL-1973) and Protocol 1978
	United Nations Convention on the law of seas (UNCLOS)

7 ISSUES RELATED TO THE SRI LANKAN WATER SECTOR

There are plenty of factors affected by the issues in the Sri Lankan water sector. Depletion and degradation of water resources, inappropriate human activities, urbanization, industrialization, population growth, and lack of rules and regulation are contributing factors to the water crisis. These arecritical issues that need to be paid more attention to create a sustainable Sri Lankan water sector.

7.1Deforestation

Forest degradation is one of the significant prevalent situations in Sri Lanka. Many researchers mentioned that Sri Lanka lost 60% of its forest cover, from 80% in the late 1800s to 25% in the early 2000s [18]. Forest coverage is going down rapidly. Currently, Sri Lanka is facing a lot of environmental concerns. Recently, Sinharaja deforestation has stirred up massive discourse cases. Sinharaja is a world heritage and a top tropical rainforest in the world. It's not only the headwater of a few Sri Lankan's main rivers, such as *Nilvala* and *Ginganga*, but also from a biodiversity point of view. It's unique over plenty of vegetation, flora, and fauna, and endemic wildlife. Many researchers have proven that Sinharaja can store tons of atmospheric carbon, thus improving our atmospheric air quality. However, the area is under threat due to illegal encroachment, mining, logging, and even road construction, thus resulting in habitat degradation [19]. Due to these various activities and developments, the area is currently at risk of losing its valuable status which was achieved in early 1988 from the UNESCO world heritage site. Sinharaja and Nakiyadeniya, Kanneliya,is some other rainforests that can be found in Sri Lanka.

Forests are anessential element in the water cycle because they add water to the atmosphere through transpiration, regulate the water flow through filtering pollutants, reduce solar erosion, improve soil properties, and reduce GHG emissions. Furthermore, adequately managed forests can mitigate adverse effects from extreme weather conditions, floods, droughts and keep the regional water balance. Moreover,

illegal logging and small-scale tree removal also enhancing soil erosion impacts [20]. Forest contributes to secure the available freshwater resources. That's why it is essential to control our deforestation rate.Deforestation would lead to reducing tree transpiration rates, thus causes to decrease in the amount of rainfall in particular areas. This will be the crucial factor for creating droughts seasons. Trees and plants are responsible for extracting groundwater from soil and released back to the environment, and thus if deforestation will continue, there will be no environment for the future generation. [21].

If we take another example as the Knuckles mountain range, it is also a unique ecosystem found in Sri Lanka. UNESCO also declared Knuckles as a world heritage. However, unfortunately, many of us neglect it. Illegal '*wallapatta*', cardamom cultivation, deer hunting for meat, illegal gem mining, and illegal encroachment are regular threatening activities in Knuckles forests these days.Knucklesareessential to us concerning water catchments, endemic biodiversity, and many other aspects. When considering the water flow which finally feeds the Mahaweli river, approximately one-third of that water flow is originated from the Knuckles range [22]. Thus it has become an enormously valuable resource since drinking water becomes a more rare thing in the future. When considering Sri Lankan agriculture, it mostly depends on water. Several irrigation projects started recently by considering the '*Kalu*' river and '*Moragahakanda*' reservoir. Most of the water which goes into these two projects originated from the Knuckles mountain range. Therefore conserving these heritages are ultimately beneficial for sustainable water management.

7.2 Agrochemicals and fertilizer usage

Fertilizers are the most critical resource for agriculture. Therefore, utilizing sustainable fertilizer and pesticide practices, soil management, irrigation systems are much essential. When fertilizers are applied at high rates, they may leach into groundwater or surface water runoff into waterways. This would lead to an increase in water pollution. Other than that, excess nutrients may enter water bodies through soil erosion. Hence, this will contribute to making an uncontrollable disaster [23].

For example, Nuwaraeliya is famous mainly for exotic vegetables (beet, leaks, potato) cultivation and tea plantations. Farmers mainly using agrochemicals, pesticides, nutrients in large quantities. Due to agricultural runoff, these pollutants are ends up in water sources which become the most serious concerning the matter.

Access to surface water is much more difficult in dry zone areas (Anuradhapura, Polonnaruwa, etc). Therefore, most people rely on groundwater sources for their daily needs. Nevertheless, in areas like Anuradhapura, pesticides, agrochemical, chemical fertilizer usage is a common practice for their agriculture. Groundwater contamination resulted from those issues; thus, most people affect some water bone diseases like chronic kidney disease of unknown etiology(CKDu), dental fluorosis, etc [24]. Many researchers reveal that the number of kidney patients rises primarily because of the usage of unclean drinking water. Therefore, sustainable agricultural practices are an essential requirement.

7.3 Sand and Gem mining

Sand is in high demand in the construction sector, and today a billion tonnes of sand are required for the Sri Lankan building and construction sector. Sand is lifted from river beds, beaches and dredged from sea beds. River sand is preferred for construction because it requires less processing and has better quality than other sources. Excessive mining, as in fig. 3 can alter the river bed, force the river to change course, eroding river banks, and leads to flooding. It also destroys the habitat of aquatic animals and also affecting under groundwater tables.

Fig. 3. Sand Mining [25]

In the Rathnapura district, gem and sand mining is one of the major occupations for many people [25]. We can see plenty of illegal sand mining locations near the '*Kalu Ganga*' catchment area. This leads to increased water turbidity levels, dropping of the water table, landslides at up steam, and water treatment plants near the catchment areas are also experienced many operational issues when the turbidity level shows a considerable increasein the anticipated value. Another significant impact is that the seawater intrusion into surface water. This causes high conductivity and chloride levels in the water. Thus it is much difficult to treat and get it up to SLS drinking water standard.

7.4Unsustainable urban wastewater management

Inappropriate household waste management, industrial discharge mostly leads to water pollution. For example, Bolgoda wetland is a beautiful water catchment area. Due to irregular development plans, and inappropriate human activities, this catchment has largely deteriorated, as in Fig. 4. According to the Global nature fund, Bolgoda and Madampe lakes are proclaimed as the 'Threatened Lakes of the Year 2018'. Inappropriate discharge of industrial chemicals, wastewater from hotels, sawmills causes the degradation of these wetlands and mangrove swamps in the area [26]. This pollution has directly affected nearby drinking water sources, and sometimes it creates eutrophication and led to the growth of the 'Diya Habala', which is affected to the lake's fauna and flora.

Fig. 4. Bolgoda Wetland Pollution [26]

In the upcountry, Nuwaraeliya has been facing a different situation altogether. Nuwaraeliya receives water directly from water sources within the '*Piduruthalagala*' forest reserve. However, the water distributed in

the area has been contaminated with sewage, and specific industries released their sewage water, including fecal matter, directly to water canals because of the lack of a proper sewage system. Sometimes poor conditions of the underground piping system are also a significant factor in sewage contamination[27].

Another example is the Kelani river water pollution issue. It is one of the largest rivers in Sri Lanka, providing 80% water for Western provinces. There are more than 7000 industries locate near the Kelani river. So now the riverbank is deteriorating rapidly due to inappropriate constructions, solid, sewage, wastewater discharge, and illegal house construction along the riverside. Due to the lack of waste management practices, these issues damage the ecosystem [28]. Because of the poor quality of water sources, bottled water has taken much of the space in the water sector. However, it does not have a quality control mechanism. Therefore, it is essential to have a sustainable methodology to develop the water sector and conserve the natural resources from water pollution.

8 Global Water Management and its Applicability for Sri Lanka

The world community has given a variety of guidelines, principles, and goals for global water management. Agenda 21 and the Dublin principles in 1992 have defined water as an economic, social good, and finite resource. Scientists observed that unsustainable water extraction, changes in land use and land management practices, deforestation, destruction of valuable wetlands lead to degrading water quantity and quality. Therefore under these guidelines, freshwater was identified as an essential element for life and conserving, reusing, and sustaining the water sector became necessary.

Sustainable development goals (SDGs) were named at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. Every country on earth agreed to these 17 SDGs and 169 targets to address the global water crisis and other significant challenges. Each goal is having specific targets to achieve for a sustainable world. Under this concept, several actions were planned to be achieved by 2030: eradicating hunger, poverty, ensuring basic needs and equity for all, managing natural resources, taking action against climate change, reducing the loss of biodiversity, etc. Goal 6, goal 12, goal 13, goal 14, as in Fig. 5 can be identified as the key goals of sustaining our water sector [29].

Fig. 5. SDG goals 6,12,13,14 [29]

Goal 6 ensures access to water and sanitation for all. There are six targets related to goal 6, which mainly focus on protecting and restoring water-related ecosystems. There are many sub-components of goal sixand water quality, water efficiency, integrated water resource management, etc. In Sri Lanka, there are so many environment-related issues, including deforestation, habitat loss, catchment degradation, etc. Hence, the new valuing methodologies modeling new systems, practices, and approaches have to consider to arrive at a more realistic valuation of water resources. Under goal six targets, Sri Lanka is currently improving water supply infrastructures, piped water systems, tube wells, and protected dug wells to supply adequate water as per the requirement of urban, semi-urban, and rural populations.

Furthermore, the government also makes plans to increase pipe bone water coverage [30]. Sri Lankans face many issues due to insufficient development of the water sector, including lack of sanitation & hygiene facilities, inadequate school toilets & menstrual hygiene facilities, lack of disabling or elder-friendly toilets in public places, etc. Usually, these are the key reasons people use less water for most daily needs.

Goal 12 ensures sustainable resource consumption and production for all. Degradation of water resources and ecosystem, inappropriate industrial production discharges, unsustainable resource usages, overexploitation acting in such a way as to harm people again like water pollution, eutrophication, the building of garbage mountains, the collapse of the dumps and a large number of peoples lost their lives, etc. The Meethotamulla garbage dump disaster is the best example of this unsustainable consumption and production. Policy formulation practices like National Policy on sustainable consumption and production, green public procurement policy, national policy and strategy on cleaner production, national green reporting system & energy star rating system and energy audit systems development, the establishment of sustainable energy authority & national cleaner production center are some of the key solutions to achieve goal 12 targets in Sri Lanka [30].

Goal 13 ensures a sustainable climate action plan for all over the country. Sri Lanka is recognized as a disaster hotspot by UNISDR due to natural disaster patterns and climate change impacts over the years. Under goal 13 targets, Sri Lanka takes priorities and actions for climate change and reduces disaster risks. Plans were implemented for a high standard mechanism for early warning systems on natural disasters, extreme weather events, evacuations, and actions to prevent losses and damages, etc. Environmental organizations (Disaster Management Centre, Department of Agriculture, Department of Meteorology, Department of Irrigation, Department of Agrarian Development) were established to implement a sustainable climate action plan [30].

Goal 14 ensures sustainable use of oceans, seas, and marine resources. Ocean resources of Sri Lanka mostly fall within the Bay of Bengal Large Marine Ecosystem, which has been considered as one of the most productive ecosystems in the world oceans. Sri Lankan coastal and marine resource provides thousands of ecosystem services including fisheries and minerals. However,Sri Lanka was still recorded as one of the largest plastic polluters and threatened marine areas. To conserve life below water, Sri Lanka following specifics legal framework structures include the Fauna and Flora Protection Ordinance of 1937, Marine Pollution Prevention Act of 1981, Coast Conservation Act of 1981, Fisheries and Aquatic Resources Act of 1996, National Environmental Act no 47 of 1980. Apart from that, there are international conventions treaties ratified to conserve ocean resource, such as the UN Law of the Sea Convention (ratified 1995), International Convention for the Prevention of Pollution from Ships-MARPOL (Annex I - VI), International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC) 1990, International Convention on Civil Liability for Bunker Oil Pollution Damage 2001, International Convention on the Control of Harmful Anti-fouling Systems on Ships, Ballast water Management Convention implemented in 2017, United Nations Fish stock agreement, United Nations Convention Biological Diversity, BASEL Convention, etc [31].

9 FUTURE SUGE\GESTIONS AND RECOMMENDATION

Many solutions and steps can be taken to promote a sustainable Sri Lankan water sector.

9.1 Sustainable Agriculture System

A sustainable agriculture system is much more essential in the water sector because of the highest available freshwater withdrawals for our agricultural needs. The improvement of the irrigation systems by enhancing

the usage of modern drip irrigation systems, as in Fig. 6, is a solution to avoid agricultural water wastages. It is a very efficient system as it is used a significantly less amount of water and delivers water and nutrients directly to the plant's roots [32]. Thus, it produces a higher yield while conserving our water resources and minimizing the water evaporation rates.

Fig. 6. Drip Irrigation System [32]

Moreover, agrochemical and fertilizer usage become one of the significant issues for water pollution, as discussed in the previous section. Therefore, instead of using chemical fertilizers, people can encourage farmers to use organic fertilizer for their plantations. Preparing their organic compost is one of the significant advantages of avoiding pollution from agricultural runoff and further utilizing the agricultural waste to produce organic fertilizer is ultimately reducing the waste handling problems [33].

Another method is promoting traditional indigenous crops proven to be more drought-resistant and needs fewer water inputs. Throughout the country, especially in Anuradhapura, Moneragala, Ampara, Puttalam, Vavuniya, Kurunegala, and Hambantota, most people experienced water shortage issues. Therefore farmers can grow wood, apple, mango, satinwoods (‘*Burutha*’), teak (‘*Thekka*’), neem (‘*Kohomba*’), which require less amount of water for the growing season.

Farmers can allocate their paddyland for non-rice crops when they have lower rice yields. For example, people can encourage farmers to use hybrid seeds which are resistant to pests, disease, and drought and provide high-quality yield throughout the year. Red lady F1 papaya, tomato, pumpkin seeds are the most usable hybrid seeds in today’s Sri Lankan market [34]. Apart from that, proper manure, fertilizer practices also contribute to avoiding pollution from agriculture runoff [35].

9.2 Harvesting Rainwater

Our ancestors have considered harvesting rainwater is an important task. Rainwater harvesting means collecting rainwater in rainy seasons and using them in other seasons. Due to climate change issues, most parts of the country experienced excessive rainfall in the rain season and the drought season, and it has now turned excessively long. Therefore harvesting rainwater is very much beneficial, especially for women, to fulfill their daily needs. This is a sustainable method that plays a vital role in agriculture, urban and rural areas for the people who do not have enough water for usage. Roof catchments, ground catchments (artificial), rock catchments (natural) are some of the methods to collect rainwater. Thus, one solution is to promote rainwater collection systems as in Fig. 7 for each household to utilize every drop from rain and. Not only that, but also this concept can use even for apartments in urban areas as well.

Fig. 7. Rainwater collection systems [36]

9.3 Sustainable wastewater management techniques

There should need to have an effective policy response in the wastewater management process. The key legislation for wastewater management is the National Environment Act (NEA) no 47 of 1980, amended in 1988 and 2000. Under this Act, specific wastewater discharge limitations are listed based on the discharge type and the industry type. Therefore, it is required to give particular attention to protect and safeguard these policies.

Onsite eco-friendly wastewater system method can be introduced for households, industries, and commercial places to utilize their toilet waste, kitchen waste, and bathroom wastewater. Wastewater from the building can be collected to a settling tank and allow all solid parts to settle as sludge. With time, microorganisms will decompose the sludge, and the liquid part of the wastewater flows to another tank. Then water can be pumped to a small wetland area where plants and microorganisms will reducing pollutant level, and odorous gases and some part of water will be lost through transpiration, evaporation. From wetland cells, water effluent can be collected to another tank or processed through to the drip irrigation system mentioned previously. Different types of invasive plant species like '*Phragmites', 'Eichhornia crassipes'* and '*Typha'* can be used to construct wetlands [37]. For industries, implementation wastewater treatment plant or resource extraction plant will be the best solution. However, it is a highly cost-effective method. Therefore the previously mentioned wetland treatment concept can be used to utilize the wastewater, and then treated water can be pump again for industrial purposes.Nevertheless, here, it is essential to consider the type of wastewater before constructing any wetlands. Table. 3 illustrates some of the common wetland plants for various wastewater.

Table. 3. Different wetland construction plant for different wastewater types

Wastewater type	**Suitable wetlands plants**	
Steel industry wastewater	*Phragmites australis* *Typha Angustifolia*	[38]
Textile wastewater	*Eichhornia crassipes (water hyacinth)*	[37]
Diary wastewater	*Eleocharis dulcis* *Frimbistilisdichotoma* *Scirpusgrossus*	[37]
Municipal wastewater	*Limnocharis flava* *Pistia stratiotes*	[39]
Domestic wastewater	*Canna generalis* *Heliconia Psíttacorum* *Polianthus tuberosa L.* *Iris pseudacorus*	[40]

	Zantedeschia aethiopica.	
Slaughterhouse wastewater	*Typha latifolia*	[41]
Salinity wastewater	*Arundo donax*along with*Sarcocorniafruticosa*	[42]

Apart from that, implementing a downflow hanging sponge system for trickling filters will also be another low-cost wastewater treatment technique, especially for the industries engaging in aerobic wastewater treatments[43]. Furthermore, the oxygen transfer dynamics and nitrification in a novel rotational sponge reactor to remove nitrogen from wastewater is another solution [44].

Sewage treatment is another solution to reduce water shortages. At least there should need to have 2 or 3 sewage treatment plants in each district. With the supply of sewage water into a centralized system, treated water can be used again for usable work. Not only that but optimizing the rotational speed and hydraulic retention time of a rotational sponge reactor for sewage treatment is another chance to get rid of the sewage treatment problems [45].

9.4 Reducing dependency on chemical-based water treatment

Almost every water treatment plant operation is primarily based on chemicals, large machinery, high-cost infrastructures, etc. It takes many years to develop such types of plants in developing countries like Sri Lanka. It requires a high-skilled technical labour force, funds, etc. On the other hand, chemicals used for the water treatment process, such as aluminum sulfate creating large sludge production and disposal issues. Moreover, excess chemical usage may cause to corrode the distribution pipelines, long-term chemically treated water usage may create some health issues, etc. [46].

Therefore, instead of using chemicals and high-cost infrastructures, people can encourage to development of low-cost water treatment plants from region to region. Many researchers investigated the performance of various natural materials on water treatment. '*Moringa oleifera*', coconut shell charcoal, sand, gravel, bone charcoal are some materials that are adapted to cope with the Sri Lankan culture[47] [48]. This will enhance the groundwater/surface water usage, and it will be the best golden solution to treat poor quality rural groundwater/surface water for future use.

9.5 Ecosystem conservation

Water supplies in our country mainly depend on healthy ecosystems such as wetlands, mountains, forests, and grasslands that recharge, store, and sustain reliable water sources all year. Therefore, government and private sectors should need to protect, restore, and manage biodiversity, rehabilitate wetlands and new wetlands construction, reforestation, ban deforestation and dumping wastes/ garbage everywhere, restrict illegal sand mining and other damaging activities in sensitive areas, etc.

For example, alternative resources should be needed to replace sand as stable building material when restricting sand mining processes. Many researchers reveal that fly-ash, quarry dust or limestone, copper slag can be used in concrete instead of sand[49] [50]. Likewise, ecosystems, water sources can be secured by finding additional alternative solutions.

9.6Government and Community commitment

There are important milestones regarding the water sector, and it will not be easy to achieve without government, private sectors, communities, etc. Over the years, governments, international donors, private sectors are engaging with community base water projects to provide sustainable water and sanitation services in rural villages. However, most of these projects were often unsuccessful because of their people's lack of knowledge and participation.When developing such projects, first attention should mainly focus on

the communities' opinions, and relevant authorities should take responsibility for their hands. It is essential to realize that rural water schemes will be more successful if people can act as facilitators and our role needs to assist the community. In that way, community projects will be more sustainable than the actual level.

The responsibility of conserving water is to hand on communities and needs to have high government commitment. The influential environmental laws and regulations of the country are more than enough to protect this environment. However, those regulations had become more irrelevant when people paid bribes to higher authorities to cover up their illegal actions on the environment. Government, public sector corruption is already getting worse condition in the country. Most people are getting to persecute by higher authorities when they raise their voice against these illegal environments polluting cases. That's the worst condition in Sri Lanka right now. Therefore, the central government, which operates on higher levels, its relevant ministries, and the relevant ministry of the provincial councils, should create a sustainable legal framework for workers under their institutions not to take bribes. Government should need to provide the necessary fundings, and they should provide a correct vision to their workers, public regarding the conservation of water and its resources. However, not only the government but civil society organizations, community organizations, and also NGOs who genuinely campaign for these issues should come forward together to implement necessary procedures.

10 Conclusion

Water changes our lives, so it has become a powerful solution to any arising problems in communities. People can meet the challenges and improve their lives if they have clean water. Overexploitation, unequal social relationships, catchment degradation, sand mining are important reasons for the unsustainable water sector in Sri Lanka. Therefore, Sri Lankans can move towards a sustainable level through various simple processes, including reducing the leakages from old pipe network systems by installing new systems or by preparing old ones, constructing communal wells to access groundwater with collaboration. Government and private sector participation, educate people about basic water conservation methods like stop letting water go to waste while having a shower, brushing and in any other daily activities, watering the garden after sunset and watering only when needed, etc. Apart from that, developing plans across the industrial sectors, domestic, commercial sectors together by protecting the water resources will ensure that we have a sustainable future.

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