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The Impact of Climate change on Water Resources in Northern Sri Lanka: Stakeholder Perspectives

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ABSTRACT

Climate change is a global phenomenon affecting the entire planet, including Sri Lanka. The Northern Province of Sri Lanka is particularly vulnerable to the impacts of climate change, especially regarding water resources. Public awareness of climate change and its impact on water resources is crucial for sustainable water management practices in the study area. In this context, this study attempted to analyze public perception of the climate change impact on the water resources of Northern Sri Lanka. There are different groups of water users in the study area. They were stratified as agriculture water users, industrial water users, fishing water users and domestic and drinking water users. Accordingly, a questionnaire survey was conducted using a stratified sampling method to identify consumer perceptions, and the collected data were analyzed using the SPSS tool. 87% of the consumers believe that climate change has a significant impact on water resources, and 50% of the people expressed vulnerability of the agriculture sector to the climate change impact on water resources. Water scarcity during the yala season became a crucial threat to paddy cultivation in the study area. Other kind of water users such as industrial water users, fishing water users and drinking and domestic water users face difficulties in obtaining water resources for their needs during the SWMS and FIMS. Furthermore, drinking and domestic water users mentioned that they face water quality issues especially during July, August and September. During the southwest monsoon season, water users face difficulties in obtaining water for their domestic needs due to water scarcity. Majority of the water users know about climate change, but many of them don't know how climate change affects their water sources. Water suppliers should implement special projects regarding climate change impacts on water resources in the study area. This will lead the water users to use water efficiently and protect the water sources sustainably.

1. Introduction

The distinction between climate and weather is imperative, although these two occurrences maintain a close association. Weather pertains to short-term conditions that possess the ability to swiftly alter, whereas climate establishes the enduring essence of a specific location, delineating whether it possesses a temperate or tropical disposition. The correlation between weather and climate assumes paramount importance, for weather is subservient to the supremacy of climate(United Nations Office for Disaster Risk Reduction (UNDRR), 2021).

Climate governs the temperatures, diversity of weather patterns, winter characteristics, cumulative precipitation, and even the distinctive qualities of meteorological phenomena such as the intensity of tempests. It is due to this intricate interconnection that we now confront both elevated temperatures and an augmented frequency of weather extremes and calamities as an outcome of climate modification. Typically, the assessment of climate change necessitates the utilization of a minimum three-decade average(Fonseca et al., 2023). Climate change has become one of the most crucial issues in the world. In this century, human society has witnessed a significant alteration in the natural patterns, which has resulted in a profound disturbance to the ecosystems (Yazdandoost et al., 2021). Various countries around the world exhibit different phenomena of climate change with severity and high frequency in their corresponding regions(IPCC, 2023). The pivotal problem is that the global temperature shift has aggravated the impact of the natural disasters and reduced the economy's stability in those nations. The causes of climate change are complex and may include industrial activities, agricultural practices, deforestation, and pollution, among others. The consequences of these changes have affected every region of the world, and the most vulnerable groups, such as low-income communities, are often the most severely impacted(Kumar Guntu & Agarwal, 2020).

Many countries around the world are facing the challenge of climate change, which is affecting their primary economies such as agriculture or overall living standards. Climate change and its impact on water resources are among the critical issues that the world is currently facing in the 21st century. It is important to raise public awareness on the issue of climate change on water resources, as it will transform how we consume, use, manage and develop water resources(Grover et al., 2022). The effects of climate change on water resources are wide-ranging, and they have a profound impact on the environment, economy, and human health. One of the main impacts of climate change on water resources is increased drought and flooding(Mo et al., 2017). The changing weather patterns result in decreased precipitation and increased evaporation, which exacerbates drought conditions. On the other hand, when rain finally falls, the ground, being unable to absorb all the moisture, causes flooding, and the runoff carries pollutants into rivers, lakes, and other bodies of water(Li et al., 2021). The public must understand the effects of climate change on water resources, as clean water is essential for human survival and to maintain our ecosystems. By increasing public awareness, individuals can make informed decisions regarding water consumption, water-saving strategies, and the like(Sholihah et al., 2020).

Sri Lanka is among the nations that are facing the brunt of this phenomenon, with its geography and environmental makeup suffering from the effects of extreme weather events(De Silva & Kawasaki, 2018). The country's weather patterns are characterized by erratic and intense changes as well as an increased frequency of extreme events(Hewawasam & Matsui, 2022). These changes have led to numerous challenges for Sri Lanka, from agricultural and economic instability to overall social and

environmental distress(Lacombe et al., 2019). Increased frequency of extreme weather conditions, a rise in temperature, heightened precipitation, reduced number of rainy days, elevated humidity and altering atmospheric pressures are all affecting agriculture and water management in the Northern region of Sri Lanka (Piratheeparajah, 2016). The increased occurrence of drought months, erratic rainfall, and flooding events, along with the increased incidents of land degradation and water pollution over the years make this a crucial issue (Alahacoon & Edirisinghe, 2021a). Water resources also exhibit significant variation due to the changing climate, particularly significant inland. The ground elevation and subsurface saturation determine the amount of water affecting the surrounding topography, leading to an overwhelming impact.

The Northern region of Sri Lanka is highly susceptible to the effects of climate change. The annual mean temperature in the Northern Province has risen by 0.84°C between 1992 and 2022, accompanied by a 10 mm increase in rainfall (Nagamuthu, 2022). Notably, the central and western areas of the study region experience more substantial temperature increases compared to the eastern part. Additionally, the number of rainy days has declined by 22 days in the current climatic period compared to the previous period. Variations in both rainfall and temperature patterns are observed throughout the Northern Province. The contribution of the North East monsoon to the overall annual precipitation in the Northern Province of Sri Lanka has diminished. Even the future projections, as determined by various shared socio-economic pathway scenarios (SSPs), indicate an escalating trend in both rainfall and temperature based on multi-model ensembles. Furthermore, several studies have emphasized that water resources pose a significant concern in the face of climate change across Sri Lanka(Nagamuthu et al., 2021).

The awareness regarding climate change has led to recognition of the countries awarded for their remarkable efforts in combating it(Fonseca et al., 2023). Every citizen is expected to know the various factors responsible for this phenomenon, its implications, and the measures to mitigate it (Somasundaram et al., 2020). Sri Lanka has witnessed an increase in awareness of climate change due to the efforts of various individuals of different ideologies, who have taken up various initiatives in different parts of the country. The government of Sri Lanka has taken numerous steps to combat climate change by different initiatives related to human, society and country. Moreover, public awareness can be a catalyst for policy change (Thennakone, 2018). It can put pressure on governments to enact policies that mitigate climate change's devastating effects on water resources. Policies such as incentivizing the conservation of water, investing in research on sustainable water management practices, and regulating industrial water pollution are just some examples. Informed public opinion and advocacy can actively influence policy, both locally and globally.

The study area is experiencing severe water scarcity, particularly in the western part. The severity of the water scarcity is increasing each year, and climate change is exacerbating the problem. Water users in the area are vulnerable to inadequate and poor-quality water during the summer months. Studies indicate that all types of water resources in the study area are under threat due to climate change. There have been limited efforts to raise awareness about climate change, and this study aims to assess the knowledge of water users in the study area regarding climate change and its impact on water resources. After three decades of internal conflict, diverse forms of development initiatives have been spawned in Northern Sri Lanka. However, the ramifications of climate change on the region's water resources pose an insurmountable impediment to sustainable progress. Against this backdrop, the endeavour is underway to assess the

extent of public cognizance regarding the effects of climate change on water resources within the Northern Province of Sri Lanka. The findings of this effort could assist policymakers in charting a course toward augmented awareness concerning the impact of climate change on the water resources of the Northern Province in the future.

1.1 Study Area

The study area being considered is the Northern Province, situated in the northmost part of the country and adjoining the southern region of India. In terms of administration, it is divided into five districts, comprising a total of 34 divisional secretariat divisions within Northern Sri Lanka (refer to Figure 1 for the same). While the Palk Strait forms the northern borders, the Bay of Bengal is situated to the east and the Arabic Sea to the west. On the southern front, it is bounded by the North Central Province. The study area, with an average annual rainfall of 1240mm, is accompanied by a yearly mean temperature of 29 °C (refer to Figure 2).

The Northern region boasts of 24 rivers, categorized as seasonal rivers, across which 54 Major/Medium Irrigation schemes are located (refer to Figures 3). These schemes are retained by IDNP and consist of nine significant tanks to jointly provide irrigation water to 70,197 acres of farmland, rendering immense benefits to 28,459 farming families. The Valukkaiaru drainage scheme, accounting for 2,000 acres, and 54 Salt Water Exclusion schemes, providing saltwater exclusion facilities to 16,508 acres, along with the Jaffna Lagoon scheme, inclusively comprising the Elephant Pass Lagoon scheme, Upparu Lagoon scheme, and Vadamarachchi Lagoon scheme, are all monitored by IDNP.

The northern province is also home to nine major/medium irrigation schemes and five substantial reservoirs (held by the esteemed Central Irrigation Department) catering to the irrigation water needs of a vast expanse spanning 45,551 acres of farmland. Further, the Agrarian Development Department supervises no less than 2,744 minor irrigation schemes to supply irrigation water to 77,874 acres. According to the Northern Provincial council report (2022), more than 987654 people are living in the Northern Province and more than 68% of the people are directly or indirectly connected with the agricultural activity. The Jaffna district has the highest population density and the Mullaitivu has the lowest population density in the Northern Province. This has remarkably improved the lives of over 89,336 agriculture-oriented families in the region. Lastly, it must be noted that the aquifers, dispersed amidst the Jaffna Peninsula's inner limestone layers alongside a portion of the Mannar district, represent remarkable water sources that furnish essential drinking and agricultural water requirements of the province.

2. Materials and Methods

The primary goal of the study is to discern the public's perception of the effects of climate change on the water resources of Northern Sri Lanka. As such, this study predominantly relies on primary data, particularly the outcomes of the questionnaire survey. The entirety of the data utilized in this study is sourced from the said survey. The questionnaire method played a vital role in this study to collect the essential data and information related to climate change and surface water resources of the northern region of Sri Lanka.

2.1 Questionnaire Sample-size Determination

The number of questionnaire determination was the challenging matter in this study because the population number of the study area is very vast, and according to the Northern Provincial Council Report (2022), more than 1088537 people live in the study area. However, only about 120,000 people use these surface water bodies for their

needs. These 120,000 people were the sample population for this study. The population composition is different in each district.

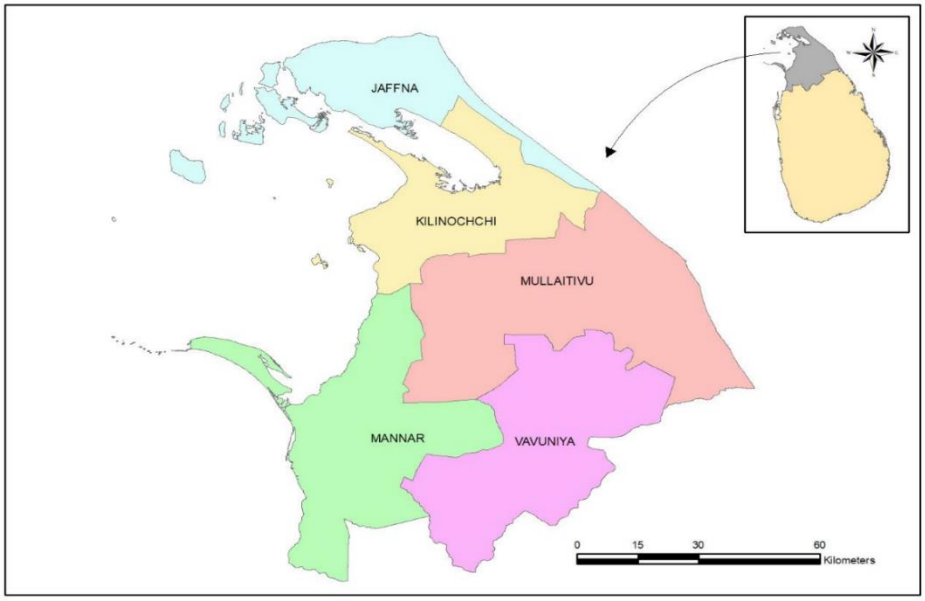

Figure 1. The study area

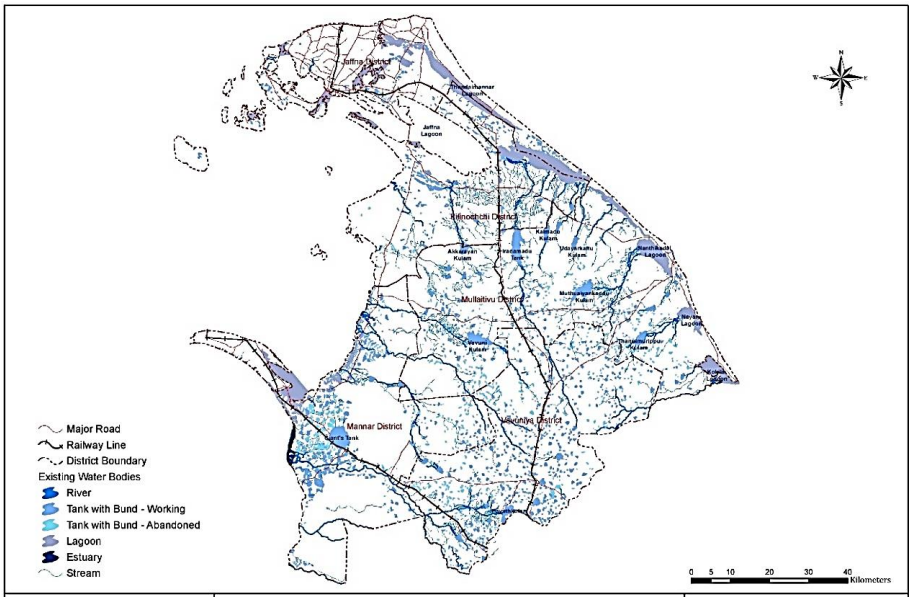

Figure 2. Surface water network of the Northern region of Sri Lanka. This network includes river basins, reservoirs, ponds, and lagoons (Lagoons are with salt water) (Department of Irrigation of Northern Province of Sri Lanka, 2022).

Due to the massive population of the study area, the sample size for distributing the questionnaire for this study was determined based on the Krejciec and Morgan (1970)

method. The following equation was used to determine the sample size.

$$S=X^2 NP(1-P) \pm d^2 (N—])+X^2 P(1—P) \quad (1)$$

where

- s = required sample size.
- X^2 = the table value of chi-square for 1 degree of freedom at the prefered significance level *(0.05* = 3.841).
- N = the sample population size.
- P = the population amount (assumed to be 0.50 since this could provide the maximum sample size).
- d = the degree of accuracy expressed as a proportion (0.05).

According to the Krejeice and Morgan method, sampling differs for each population sample size. According to the Krejeice and Morgan method (1970), 384 (400) were included in the questionnaire survey based on the study area's total population.

The stratified sampling method is applied as the sample selection method in this study. The stratified sampling method is a probability sampling method used widely in many kinds of research worldwide (Kruger, 2012). The first stratum was allocated for the different water users in this study. There are four strata used in this study as shown below;

1. Stratum one (01) is for the drinking and domestic water users
2. Stratum two (02) is for the agricultural water user
3. Stratum three (03) is for the users for the fishing activities
4. Stratum four (04) is for the industrial water user.

Within the strata, the samples were selected using the following formula

SSS= SES/ PS X LS (2)
SSS= Sample size of the strata
SES= Size of the entire sample
PS= Population size
LS= Layer size

According to this formula, samples in every stratum were computed, and the sample size was determined.

For water users for the agriculture purposes - 400/120000x 70000= **233**

For Drinking and Domestic water users - 400/120000 x 30000= **100**

For users for the fisheries purposes -400/ 120000 x 10000 = 33 + 1= **34**

For industrial water users - 400/ 120000 x 10000 = **33** Total sample size = **400**

After defining the strata to distribute the questionnaire, the convenient sampling method was employed to distribute the questionnaire. The respondents for the questionnaire were selected within every stratum based on the convenience sampling method covering all river basins and all significant reservoirs of the study area.

This study used the convenience sampling method as the sub-section of sample selection. Convenience sampling is one of the scientific sample selection methods widely used by various researchers for various purposes. Convenience sampling is a method of collecting samples by taking samples that are conveniently located around a location. According to the sample size determined, earlier samples were selected from each stratum in this study (Figure 4)

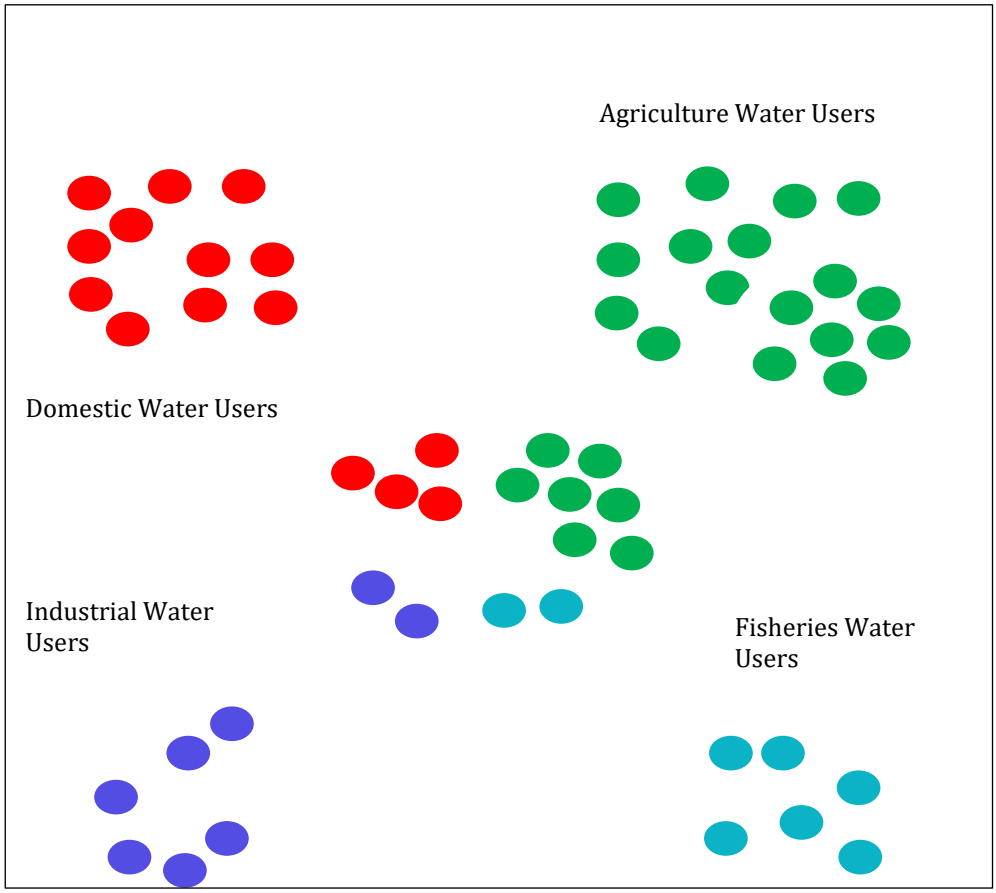

Figure 3. Stratified convenience sampling method of this study

The following areas (Table 1) were considered to select the samples to distribute the questionnaire in this study. Even though all four hundred questionnaires were distributed based on the strata, 100 questionnaires were distributed to each stratum population based on a convenience sampling method with two assistants' help.

Some of the respondents did not return the questionnaire. However, 390 questionnaires were collected from the respondents.

2.2 Analysis Method

All collected questionnaires were entered into the Statistical Package for Social Science (SPSS) software. SPSS is a widely used statistical software for data analysis in social sciences research. The software interface is intended to be approachable and straightforward for users possessing minimal or no programming expertise, rendering it a valuable resource for researchers and analysts who must carry out statistical analysis on their data.

The utilization of SPSS for data analysis significantly reduces the amount of time expended compared to other statistical tools. This feature facilitates facile data entry and the conduct of in-depth analysis within stipulated timelines.

Consequently, the SPSS report effectively serves as a critical tool for evaluating results

and analysing research topics optimally. Notably, the tool's utility spans both quantitative and qualitative data types, with diverse graphical representations- charts, tabulations, and graphs -viz., proving invaluable for understanding trends and envisioning relationships between different variables.

Table 1: Samples collected locations

No.	Sample Location	No.	Sample Location
1	Thirunelvely	26	Muththaiyankaddu(Right)
2	Kopay	27	Kanukkerny
3	Karaveddy	28	Mullaitivu
4	Chunnakam	29	Mankulam
5	Kodikamam	30	Puthukkudiyiruppu
6	Punkuduthivu	31	Nedunkerny
7	Velanai	32	Kanakarayankulam
8	Uduppiddi	33	Omanthai
9	Sandilippai	34	Thandikkulam
10	Alaveddi	35	Pavtkulam
11	Akkarayankulam	36	Puliyankulam
12	Uruththirapuram	37	Thavasikulam
13	Murasumoddai	38	Vavuniya Town
14	Kandavalai	39	Cheddikulam
15	Tharmapuram	40	Nelukkulam
16	Vaddakachchi	41	Iluppaikkadavai
17	Thiruvaiyaru	42	Murunkan
18	Paranthan	43	Andankulam
19	Poonarin	44	Madhu
20	Skanthapuram	45	Nanaddan
21	Thunukkai	46	Uyilankulam
22	Pandiyankulam	47	Mannar
23	Oddusuddan	48	Thevanpiddi
24	Udaiyarkaddu	49	Peaslai
25	Muththaiyankaddu(Left)	50	Musali

3. Results and Discussion

The study yielded a diverse range of findings regarding consumer attitudes towards the influence of climate change on water resources. Public sentiment pertaining to the impact of climate change on water resources manifested itself in divergent ways, depending on the respective water consumers. The general populace within the study area exhibited a thorough understanding of climate change and its repercussions on water resources. Views encompassing multidimensional aspects of the impact were expressed by the same populace. The results of the study showed the ramifications of climate change on water resources in the Northern region of Sri Lanka.

3.1 The level of knowledge on climate change and its impact on water resources among the water users

The majority of the people in the study area have a basic knowledge of climate change, but they lack understanding of its impact on water resources. Only a small percentage of people have enough knowledge on this topic. The knowledge of climate change-impact on water resources in Northern Sri Lanka varies across different perspectives.

3.2 Impact of Climate change on water resources

Climate change poses a serious threat to Sri Lanka, especially for the Northern region of Sri Lanka. Climate change is the primary cause of many effects in the study area's physical, economic, and social components. In this way, this study attempts to find the impact of climate change on the study area's surface water resources. In the Northern region of Sri Lanka, most people use surface water for agriculture purposes. Next to agriculture, many people use surface water for drinking and domestic purposes. Many people use the surface water for fisheries and industrial activities in the Northern region of Sri Lanka. The following table indicates the different usages of surface water in the study area.

As per the analysis, more than 87% of the people of the study area said that their surface water resources are severely affected by climate change; only 4% of the people of the study area said that climate change is not the primary cause for the surface water problem, and 07% of the people pointed out that they do not know what the immediate threat to their surface water resources is. Therefore, primary and secondary data were used to study the climate change impact on the Northern region of Sri Lanka.

The Northern region's water resources also face difficulties in managing water resources due to climate change. According to the people's concerns of the Northern part, more than 60% of the people conclude that climate change is a potential threat to the water resources of the Northern region. Further, more than 50% of the people believe that climate change impacts water resources much, mostly affecting the agriculture sector because it depends on the surface water resources of the Northern region (Figure 6). Next to the agriculture sector, the fisheries sector, industrial sector and manufacturing sectors are affected.

Furthermore, the farmers of the Northern region expressed the view that the water problem is the main and the biggest threat to the agriculture sector in the Northern Province of Sri Lanka. More than 45% of the farmers believe that the water problem is the main constraint to their agriculture activities from seeding to marketing due to water scarcity and, in some cases, due to water surplus in the Northern region of Sri Lanka. On the other hand, inadequate market facilities and a shortage of capital contribute less to the water problem for their sustained and constant agricultural activities in the study area (Figure 7).

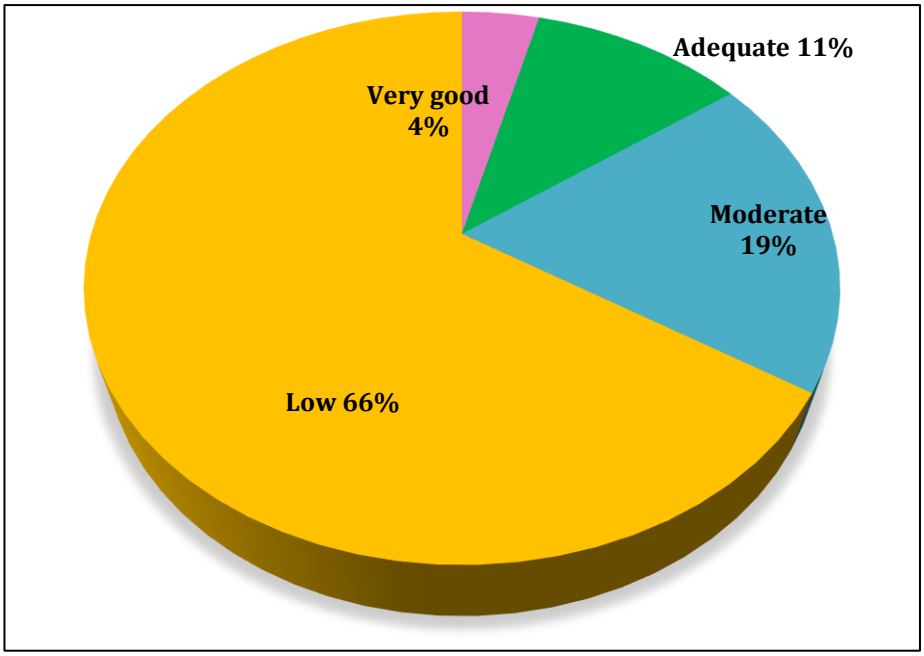

Figure 4. Knowledge level of water users on Climate change

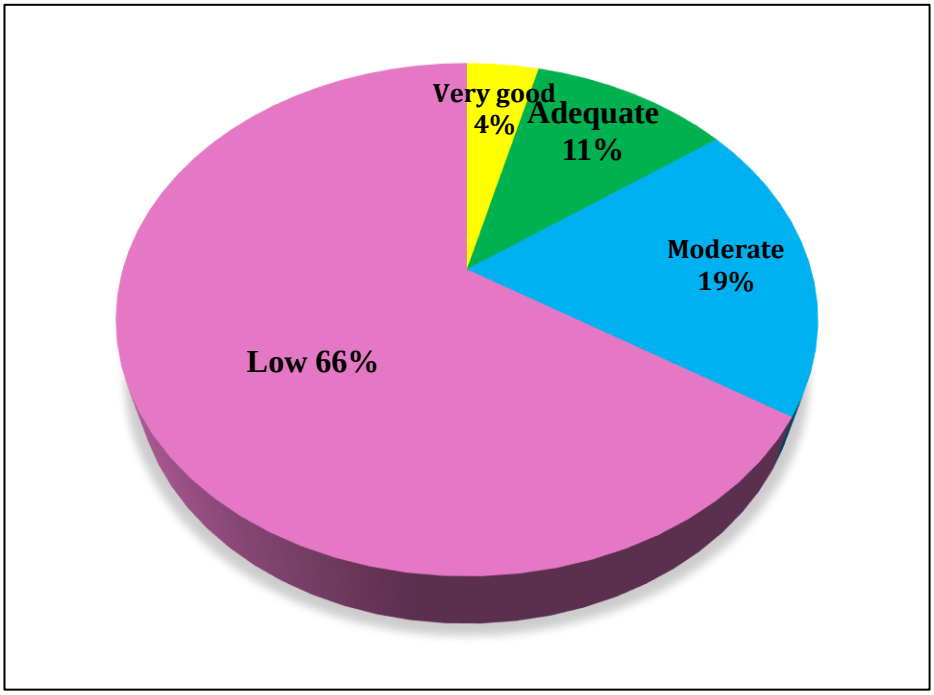

Figure 5. Awareness of water users on climate change-impact on water resources

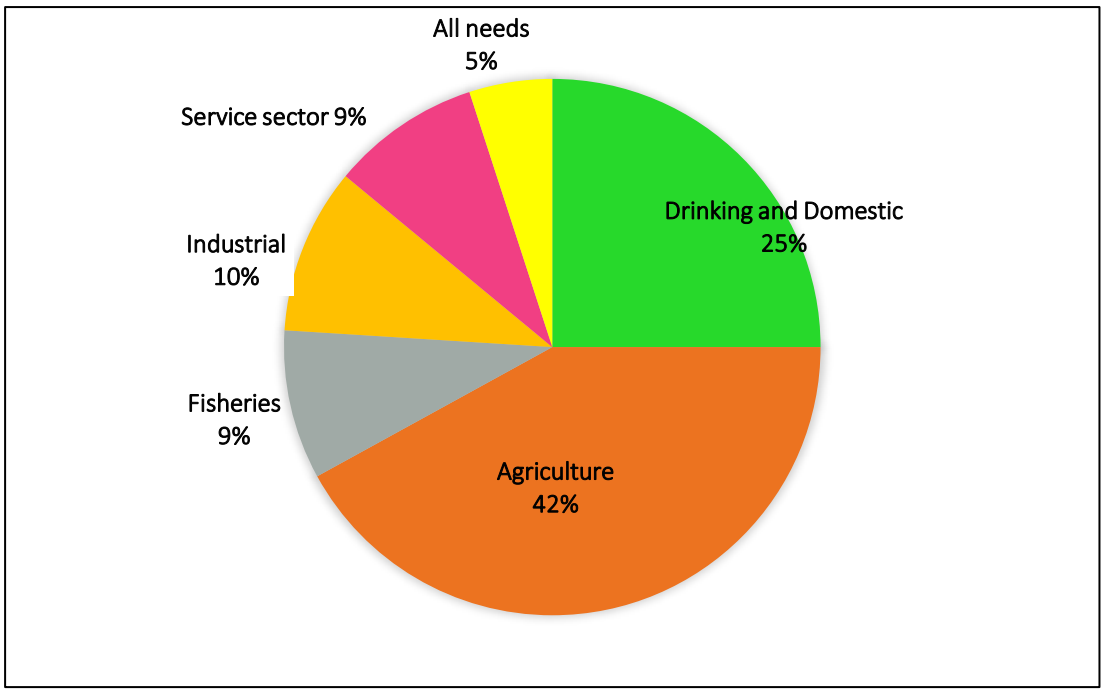

Figure 6. Different surface water uses and their percentage in the Northern region of Sri Lanka

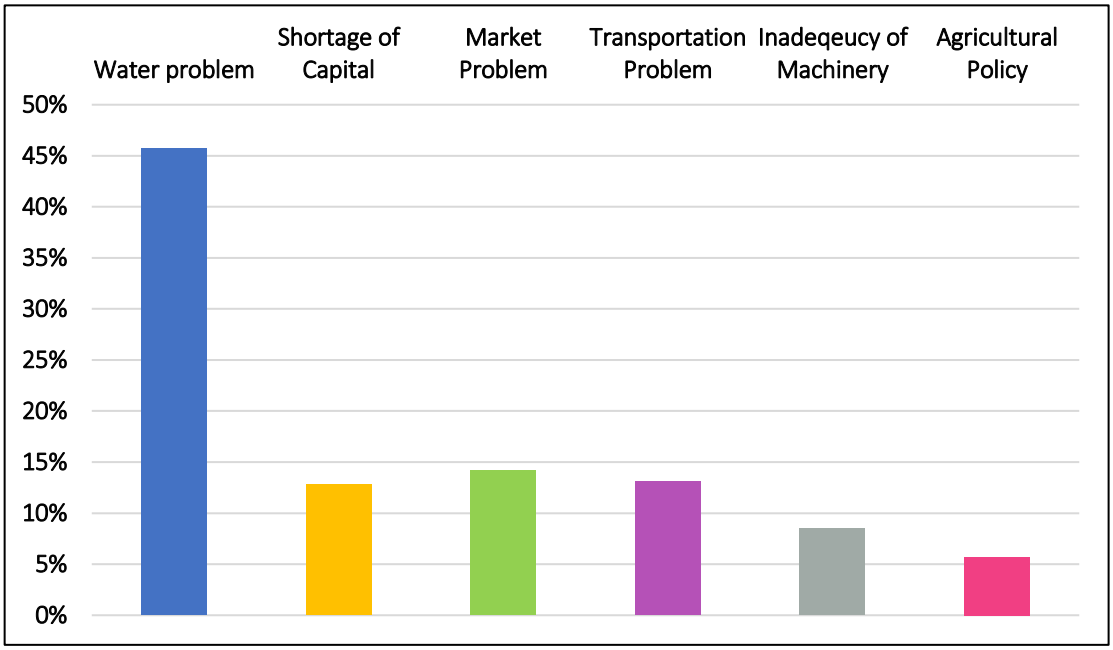

Figure 7. Types of threats to the agricultural activities of the Northern region of Sri Lanka.

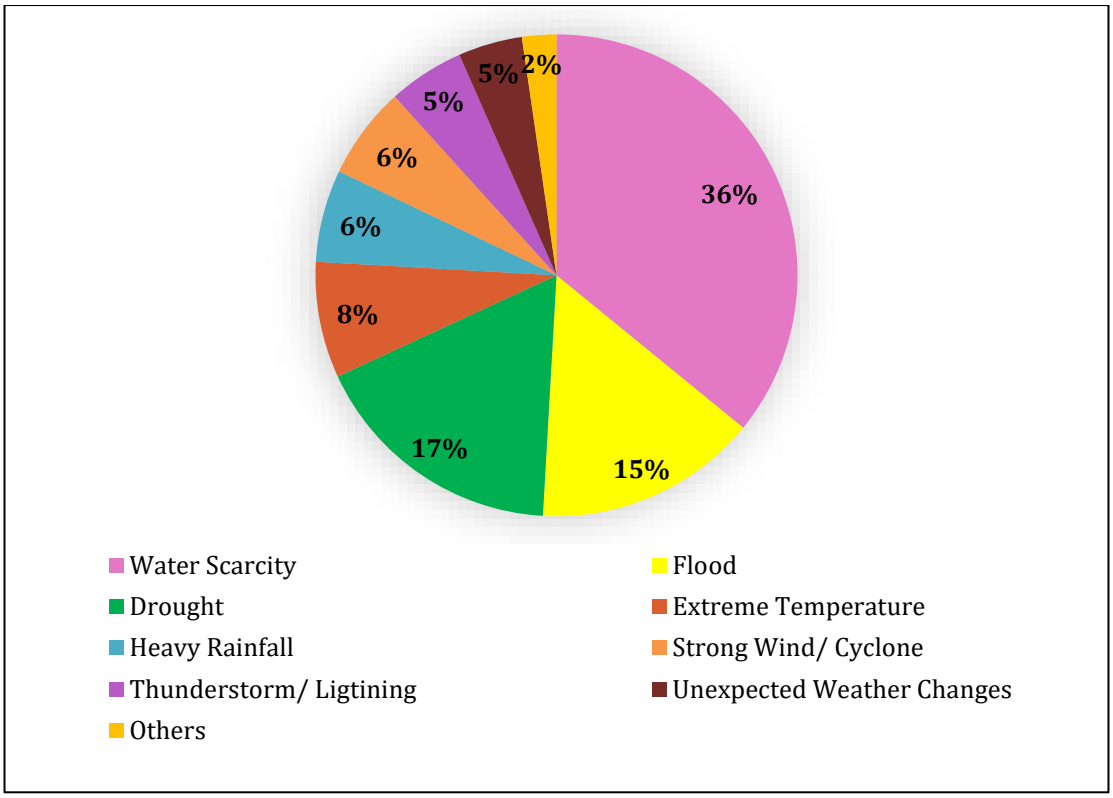

Figure 8. Various kinds of climate change impacts in the Northern region of Sri Lanka

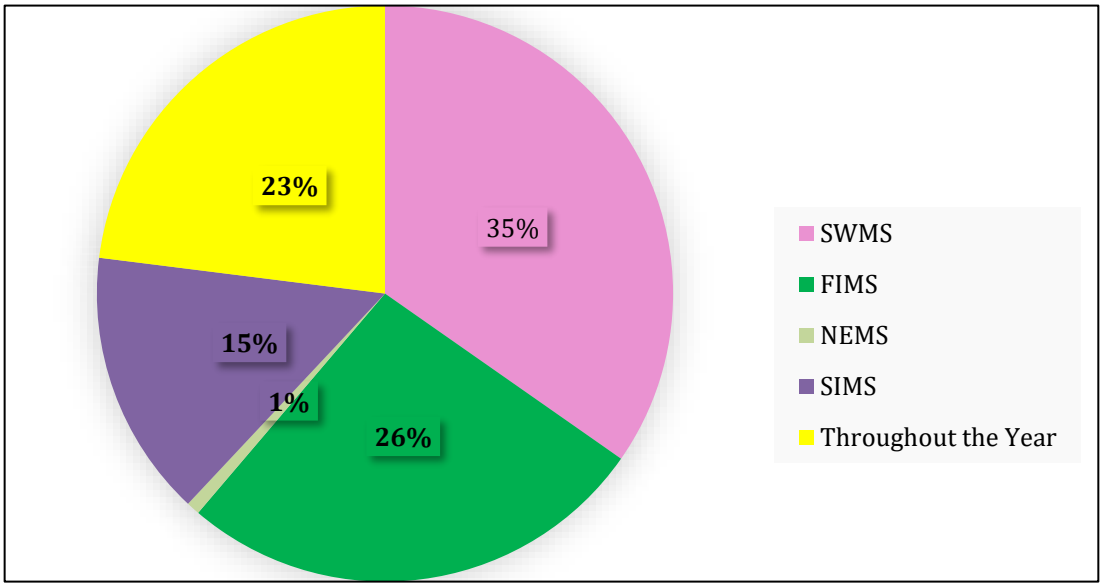

Figure 9. Water scarcity seasons in the Northern region of Sri Lanka

3.3 Climate change and water scarcity

Climate change has a considerable threat to water scarcity in the Northern region of Sri Lanka, and 35.9% of the people said that water scarcity is the main cause of climate change in the study area (Figure 8). More than 45.4% of the people said that they had been affected by the unexpected but continuous water scarcity or drought due to non-availability of water in their water reservoirs, and 19% of the people said that they have been partially affected by the water scarcity problem. As per the questionnaire analysis, more than 38% of the respondents replied that climate change impacts and induces water scarcity among all physical impacts in the study area.

The farmers mentioned that they were severely affected by the water scarcity problem in the Northern region of Sri Lanka. 81% of the study area farmers said that their agricultural activities are affected by water scarcity, especially Yala season paddy cultivation. Further, farmers of Thunukkai, Mallavi, Mankulam, Oddusudan, Murungan, Nanaddan, Pavtkulam, Akkarayankulam, Nagapaduvan, Vidaththaltheevu, Nedunkerny Muththaiyankaddu, Udaiyarkaddu, Omanthai, Cheddikulam, and Poonakari stated that their paddy crops are affected due to water scarcity problem in the river basins and reservoirs during March, April and May due to climate change.

Most of the study area respondents pointed out that they have faced severe water scarcity problems during recent years in the SWMS and FIMS due to climate change and face difficulties getting drinking water in these seasons (Figure 9).

According to the questionnaire analysis, surface water faces the most critical threat due to climate change; especially, agricultural people mentioned that they were severely affected by climate change because their water irrigation system was frequently influenced by climate change. More than 67% of the farmers said that they had been affected by climate change on the irrigation from the water reservoirs. Within the climate change factors, 35.93% are of the view that the extreme temperature affects their surface water resources, and next to that, higher evaporation affects (18.75%) their surface water resources (Figure 10).

There are many reasons for the severe water scarcity problem during the SWMS due to climate change, such as higher evaporation, extreme drought, and extreme weather, absence of rainfall, extreme wind, mismanagement of water, the flawed drainage system, and spillage of water. However, many people mentioned that the high evaporation and the absence of rainfall are the dominating factors for the water scarcity problem in the Northern region of Sri Lanka. Figure 11 illustrates the reasons for the water scarcity problem in percentage.

According to the farmers of the Northern Province of Sri Lanka, they have to face the water scarcity problem during the Yala season, which starts in March and ends in September, under the first inter-monsoon season and southwest monsoon season (Figure 12). 58% of the farmers experienced severe water scarcity during the Yala cultivation season, and 16% of the people pointed out that they face the water scarcity problem in all seasons, thus cultivating based on a rain-fed agriculture system.

There is an increasing pattern in the water scarcity area every year, and the extent of water scarcity is dramatically increasing every decade. From 1970 through 1990, only 29% of the area of the Northern region faced the water scarcity problem, and it increased to 43% in 2000-2010, and further, it has risen to 63% in the period from 2010 to 2018. According to the current increase in maximum rainfall and evaporation rate, it is expected that water scarcity will increase to 89% from 2020 to 2030. From 1970 to date,

the severity of water scarcity has been rising in the study area every year. During the 1970s, seasonally, the study area faced water scarcity. The inhabitants could access their water needs only within their village-limits because a few dug-wells were without water, and some deep dug-wells had adequate water for the people. However, during the 1980s, the water level of some wells declined further, and people had to move to other places to get water for their needs. During the 1999s, water level of more than 45% of the wells declined during the early part of the first inter-monsoon season. During the 2000s, water scarcity spread widely, and there was an increase in the severity of the water scarcity, and the people started to pay money for their water needs. Later in the 2010s, there was an increase in the communal violence due to water conflict. From 1990 to 2000, only 05 cases were reported to the police station. From 2000 to 2010, only 09 cases were reported in the police (Previously ruled by the Liberation Tigers of Tamil Eelam (LTTE) and police services belonged to them). However, from 2010 to 2019, it increased to 18 cases, and it is becoming some villages' conflicts, resulting in other social and cultural consequences.

Seasonally, there are many variations in the water scarcity problem in the study area. Southwest Monsoon Season is the critical season for this area, and people of this area spend more than two hours of the day getting drinking water and more than one hour getting water for their domestic purposes. Also, they are paying more than 120 Sri Lankan Rupees (SLRs) out of their day-to-day earning (average 750SLRs) per day to get freshwater. Even in June, July, and August, people face difficulties getting fresh water even within eight kilometers of the area. The water scarcity problem in the study area starts in the latter part of the first inter-monsoon season, especially in April. During the North-East monsoon season, there is no water scarcity problem due to the intensity of the rainfall and the full water level of the tanks. During this period, people of this area cultivate paddy using this water, and they do not need to buy water.

As per the monthly analysis of the water scarcity problem, there is no water scarcity problem in October, November, December, and January because the groundwater level of these months is high; also, some of the surface water bodies (minor scales) hold water due to the intense rainfall of the northeast monsoon season. However, from February onward, people face the water scarcity problem in the Northern region. The water scarcity problem peaks in May, June, July, August, and September.

The early water scarcity problem does not cause any severe problem in the study area. However, it is becoming an urgent issue after the increase in competition and communal riots for water usage. Also, it is becoming a caste-based problem causing community unrest, and dividing the communities and villages. There are two major religious groups of people in the study area, Hindus and Christians, and some issues on water conflict lead to a spiritual problem. More than 43 cases have been filed in the police stations for the water conflict in the study area. Still, there are eleven civil cases filed in this regard.

Water scarcity problems pose many difficulties to the people. According to Samurdhi, 2019), more than 57% of the people are under the poverty line in the Northern region. They have problems related to water charges and reporting to their labor work on time. Because, if any family has children, the family head has to spend his time getting the water, which will affect their job. Due to the severe internal war, the study area has several women-headed families (As per the Northern Provincial Council report, 19342). They face problems getting water, and most people (more than 87%) use their bicycles to get the water. In some areas, people have to go more than 2km to get water, and the helpless people (women-

headed families) are concerned about the protection of their children as they move to other places to get water. There is a queue at the water collecting center (wells or tanks) and due to the urgency of the people, (to report to work) sometimes conflicts arise among water users. When such conflicts affect the families, communities, and villages, there is social unrest.

Money is the biggest problem for people in the study area to get water. More than 50% of the people are under the poverty line; they face difficulties in buying water. The National Water Supply and Drainage Board, Predeshiya saba, and some non-government organizations provide drinking water to the people by using their moving water-tankers. Yet, the people have to pay. This compels the people to limit one of their essential needs. In some areas, school children collect water for their home needs, and as a result, they get late to school.

3.4 Climate change and Water supply in the Northern region of Sri Lanka

Climate change has an impact on the water supply of the study area. Water supply pattern changes and the supply is interrupted due to frequent drought and flood occurrences. Drought has impacted the availability of water and therefore, the relevant authorities (Department of irrigation and the National water supply and drainage board) are unable to supply water for agriculture or drinking purposes. Water supply is also interrupted during the floods when the water supply systems collapse. In the study area, more than 50.9% of people mentioned that they are affected by the reduced quantity of water supply, 20.3% of the people viewed that they are affected by the reduction of water supply time, and 16.8% of the people stated that they were affected by the change of time (Figure 13). More than 67% of the people stated that they were affected by the interrupted water supply, especially during the Yala season. However, the Northern region's water managers explained that they faced difficulties in supplying adequate water for the farmers because of the water scarcity in the reservoirs due to the absence of rain or low rainfall in February, March, and April. The study area's water governing authorities expressed difficulties managing the water demand, especially during water scarcity. They have requested water supply during the water scarcity period, especially in the SWMS and FIMS. Still, the water is not adequate in the reservoirs, and they have faced difficulties in prioritizing the requirement due to political pressures.

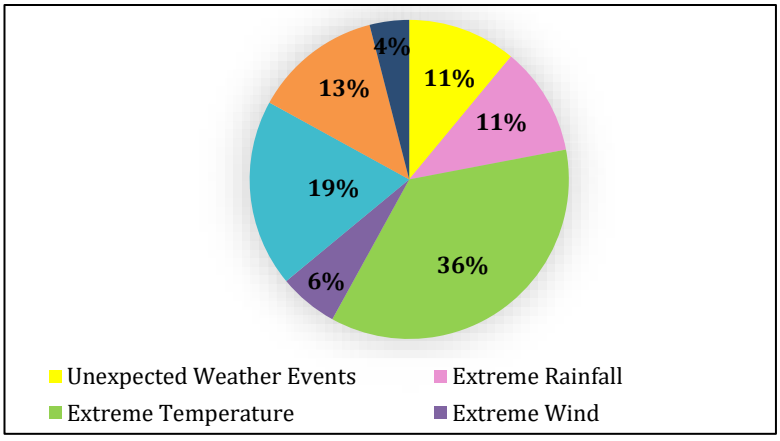

Figure 10. Threats to the surface water resources in the Northern Sri Lanka

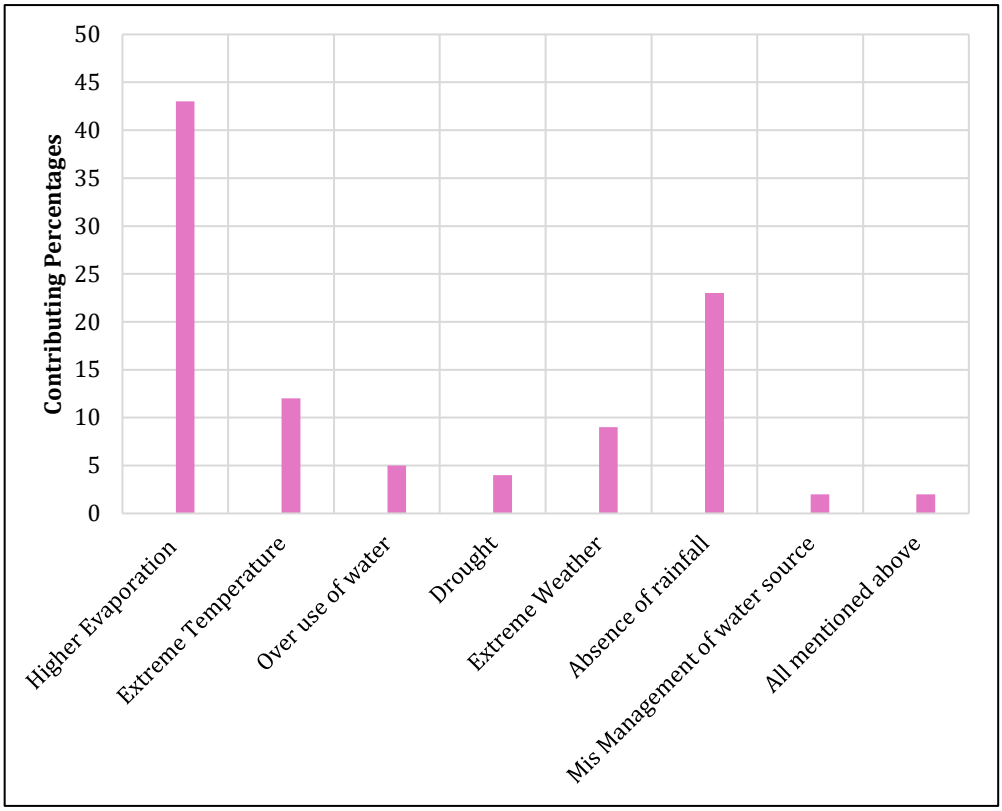

Figure 11. Reasons for the water scarcity problem during SWMS in the study area.

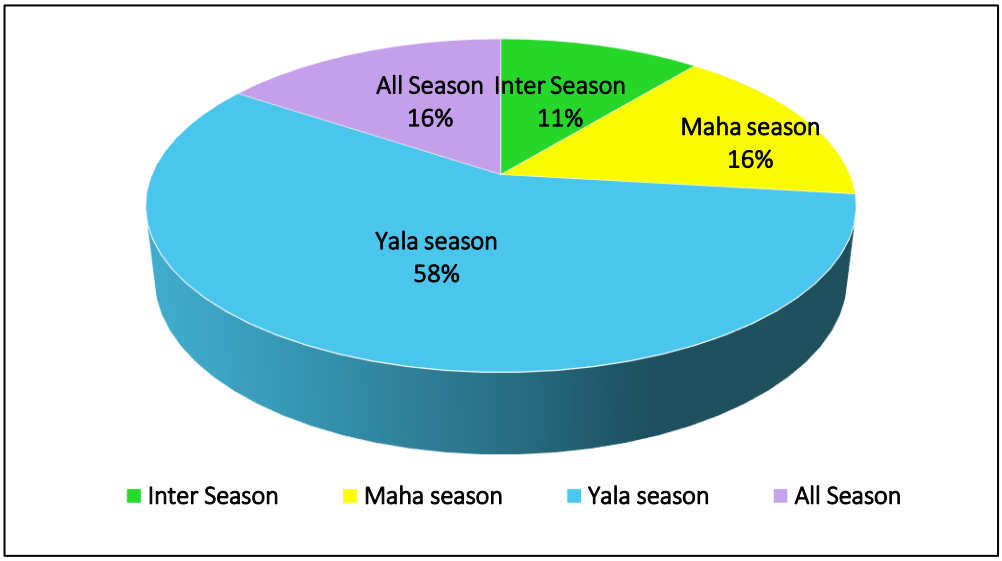

Figure 12. Water scarcity crop seasons in the Northern region of Sri Lanka

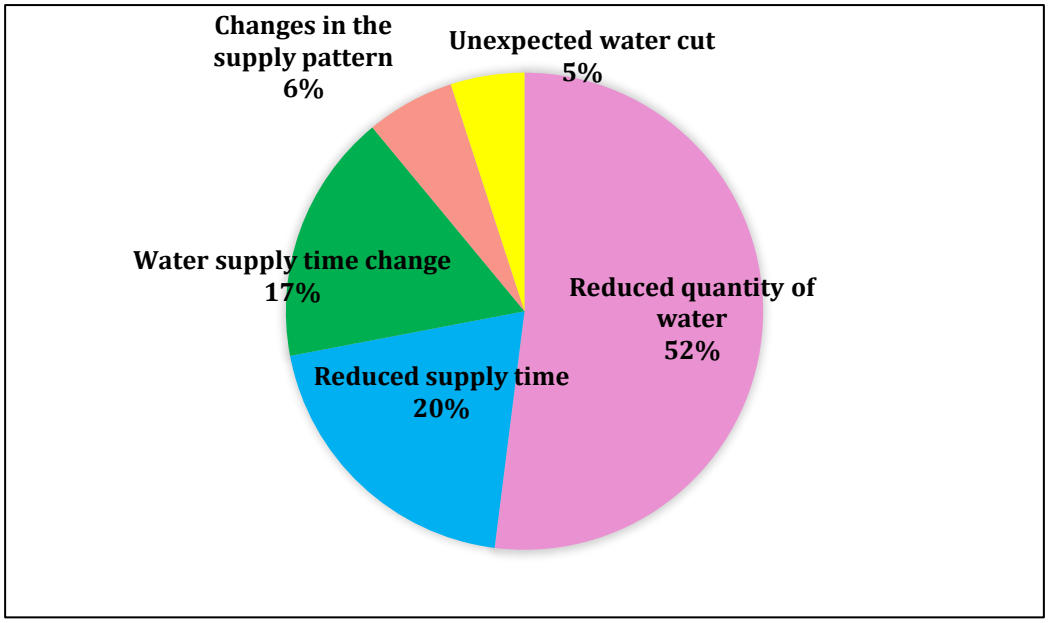

Figure 13. Climate change impact on the water supply of the Northern region of Sri Lanka

Drinking and domestic water users from the supply line also mentioned that they were severely affected during the FIMS & SWMS due to the water cut and reduced supply. In addition, the National Water Supply and Drainage Board (NWSDB), the responsible organization in Sri Lanka to supply domestic and drinking water to the public, expressed their view that they faced difficulties getting adequate water for drinking and domestic purposes.

More than 77% of the people said that during the early period (before 2000), the water scarcity problem was not a severe problem in the study area. However, now it is becoming a very severe problem. During the water scarcity period, they get no water supply or receive a significantly less water supply. Further, they have to move to other places to get water for drinking and domestic purposes. 24% of the people mentioned that they used to go 3km distance to get their water needs, 35% of the people said that they are getting their water within 02km distance, and 41% of the people are getting water for their needs within 01 km distance.

3.5 Climate change and Increasing Drought Severity during the SWMS

According to the questionnaire survey, drought is the prime and severe physical impact of climate change in the study area. More than 28% of the questionnaire respondents expressed their view that drought is the major issue in the study area due to climate change (Figure 14). The following figure illustrates the different types of physical impact due to climate change in the recent decade in the study area.

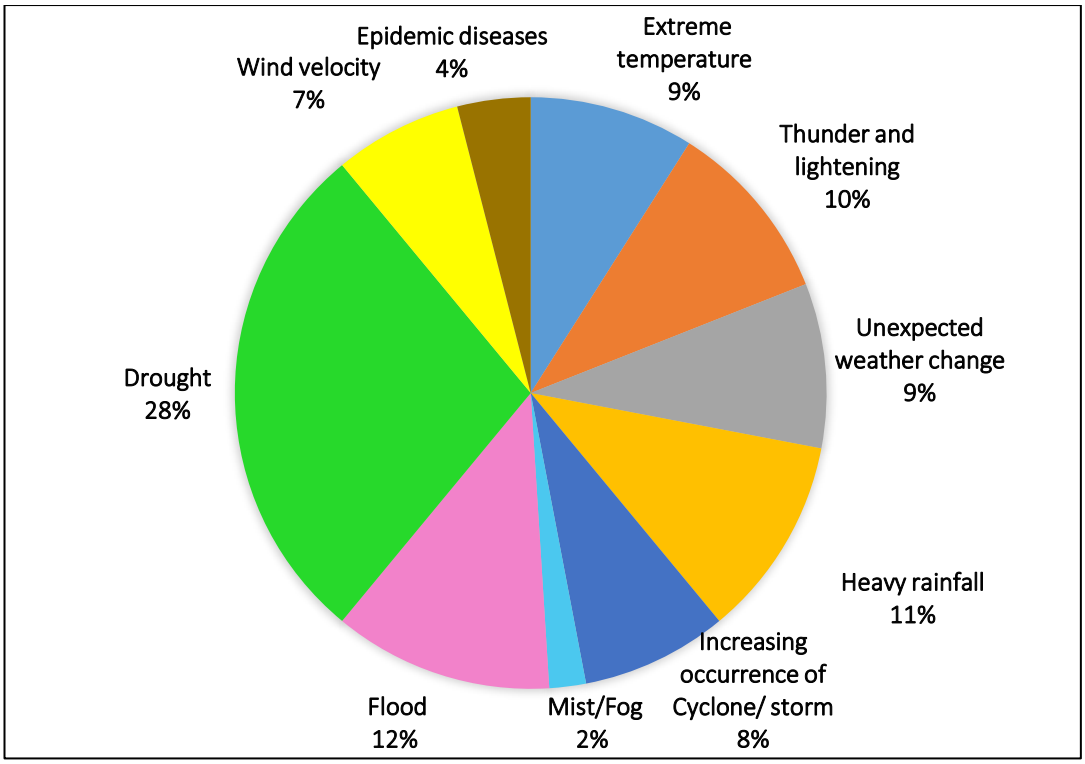

Figure 14. Physical impacts of climate change in the Northern region of Sri Lanka

During the SWMS, there is an increasing water scarcity pattern or drought problem in the study area. An increasing drought pattern is identified in the study area due to climate change. Among all the Northern Region seasons, a higher number of drought events have been observed during the SWMS and FIMS. Due to the low or no rainfall during these periods, water scarcity or drought creates much vulnerability in the Island areas, Manthai West, Nanaddan, Musali, and Manthai East areas. Drought creates many challenges for the farmers of the study area during the SWMS, and many crop losses have been recorded lasting for over more than four months. During this period, the cash crops and vegetable cultivation were severely affected by drought or dry spells in the study area.

In the study area, people consider that increasing drought is the leading cause for the increasing severity of water scarcity. Also, people mentioned that the extreme temperature and the higher rate of evaporation are the main factors for the water scarcity problem. The following diagram indicates various causes of the increasing water scarcity problem in the study area.

Climate change is a critical phenomenon that poses significant threats to our planet. However, there are varying opinions on how the public perceives climate change. On one hand, some people argue that the majority of the public now accepts that climate change is real, human-caused, and that urgent action is necessary to mitigate its effects(Cho, 2020). On the other hand, some people argue that there is a significant section of the public that does not believe in climate change or the urgency of taking action.

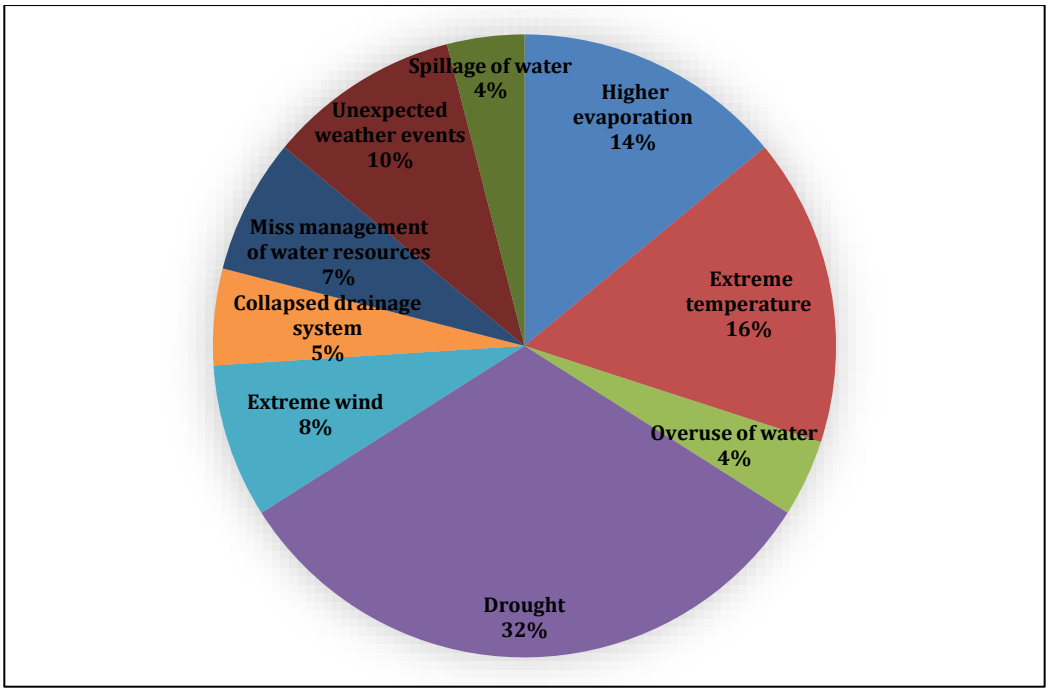

Figure 15. Causes of water scarcity in the study area.

Proponents of the first argument insist that surveys have shown that a vast majority, around 97% of climate scientists who research and study the issue, agree that climate change is caused by humans. Additionally, more people are now taking part in environmentally friendly practices, such as recycling, reducing single-use plastics, and supporting green initiatives(IPCC, 2022). They also highlight the formation of climate action groups worldwide and individual activism that has pushed governments to prioritize climate change in policy-making, all of which suggest that the public's awareness and acceptance of climate change has increased.

Those who disagree with this view contend that the public's lack of understanding and awareness of climate change remains a significant issue. They argue that nearly 25% of the farmers of the study area do not believe in climate change, according to the survey. Additionally, approximately the same percentage of the population views climate change as not an urgent threat. They contend that the public's skepticism towards climate change is often due to political polarization, misinformation, and limited exposure to climate change issues in mainstream media(Rahimi, 2020).

The water risks from climate change vary significantly based on the region and availability of resources. However, it is undeniable that some of the water management practices from past centuries, such as over-extraction of groundwater reserves, have led to unsustainable water use in many areas globally. Thus, adjusted management practices are essential to address both historic overuse and future demands, especially in areas susceptible to climate impacts(Mohsin et al., 2022).

Water availability in the reservoir will influence the high evaporation rate, while higher runoff will impact the water availability and reservoir. Majority of the farmers mentioned that the demand for

water has increased due to unforeseen dry weather conditions in the SWMS, resulting in authorities struggling to meet the demand. Furthermore, the water usage has increased in the study area due to enhanced awareness regarding water usage, leading to many individuals using their land for organic farming. More than 80% of the paddy cultivators pointed out that, high water demand usage has also risen, leaving the supply reservoir empty. Several authors have attested to these same outcomes in their studies (Dananjaya et al., 2022; Shelton & Lin, 2019; Shanthi De Silva, 2016). As a result of water scarcity or shortage, farmers in the study area face difficulties during the Yala season, struggling to harvest paddy. The water authorities also report difficulties managing the water supply owing to the high demand for water due to climate change (Azevedo de Melo et al., 2021; De Costa, 2010)

According to water users of the Northern region, the Northern region experiences microclimatic variations, and the area's natural setting decides the variations in natural hazards occurring spatially and temporally. For instance, drought may manifest in the first inter-monsoon season, extending to the southwest monsoon season in some years. Lack of rainfall caused this incident as per recent studies (Withanachchi et al., 2014). Additionally, some previous studies indicate that the Northern, North Central, and Northwestern parts of Sri Lanka endure over seven months of the driest months in a year during the southwest monsoon season recorded the southwest monsoon season as the dry spell, especially July, August, and September, with these months having the highest average temperature of 35 °C(Siriwardana et al., 2018; Herath & Jayawardena, 2018; Alahacoon & Edirisinghe, (2021) .

Water users of the Northern Province mentioned that, since recently, water scarcity has become a more critical issue in the study area. The rapid increase in temperature, evaporation, dwindling rainy days, and changes in rainfall pattern seasonality are the primary reasons for the severity of the water scarcity problem in the Northern region of Sri Lanka. This problem is not unique to this region, but rather becoming an increasingly significant issue for the whole country due to global climate change. Several studies reveal that an extended period without rainfall is the leading cause of the water scarcity problem in many parts of the country. However, when looking at the total amount of rainfall in the study area, the drought or water scarcity problem during the SWMS is due to water administrators' mismanagement since no new reservoirs have been built since 1970s.

4. Conclusion and Recommendation

This study has some recommendations towards mitigating the climate change impact on the Northern region of Sri Lanka's surface water resources.

According to the survey, more than 56% of the surface water users recommend that awareness about climate change is essential to mitigate the climate change impacts on the Northern region of Sri Lanka's surface water resources. Further, 9.4% of the water users recommend that the rainwater harvesting system is the second option to mitigate the impact of climate change on the water resources of the Northern Sri Lanka. Therefore, awareness related to climate is necessary for the study area. People should know about climate change, rainfall periods, average amount, average temperature, highest temperature months, low-temperature months, wind direction, wind velocity, atmospheric humidity, atmospheric pressure, extreme weather, surface water levels, availability, changes in the evaporation, and changes in the runoff and water scarcity effects. Especially farmers should know about the climate change and its impact. All types of people should have this awareness. Printed and Electronic media can

be used to create sufficient awareness among the people to mitigate climate change.

Climate change is already impacting the water resources in the Northern Province. Increased temperatures, erratic rainfall patterns, and extreme weather events are causing flooding, drought, and changes in river flow. These impacts could have severe consequences for farming, fishing, and other water-based livelihoods, as well as the health of communities that rely on safe and reliable access to water.

Implementing strategies to mitigate climate change impact on water resources in the Northern Province is essential to ensure long-term sustainability. This includes investing in water conservation measures, such as rainwater harvesting systems and improved water management practices. It also involves strengthening the capacity of communities to adapt to changing water resource conditions. Mitigating the impact of climate change on water resources in the Northern Province is also essential for maintaining ecological integrity. Water ecosystems provide habitat for fish, birds, and other wildlife, and help regulate climate and air quality.

Climate change has much impact on many socio-economic sectors of the Northern region of Sri Lanka. Water users of the Northern Sri Lanka have adequate knowledge on the climate change but they are not aware about the climate change impact on the water resources. They said that their agricultural activities are affected due to water scarcity during the Yala season, and during the SWMS, domestic water users do not receive adequate water for their domestic usage. Surface water is a vital natural resource for the Northern region of Sri Lanka. Therefore, any threat to the surface water in any form affects not only the human beings, but also the other living organisms. In this context, climate change mitigation measures or climate change adaptation strategies towards protecting the study area's surface water resources is an essential and primary concern of all stakeholders in the sustainability of the Northern region of Sri Lanka.

4. References

Alahacoon, N., & Edirisinghe, M. (2021a). *Satellite-Based Meteorological and Agricultural Drought Monitoring for Agricultural Sustainability in Sri Lanka*.

Alahacoon, N., & Edirisinghe, M. (2021b). *Spatial Variability of Rainfall Trends in Sri Lanka from 1989 to 2019 as an Indication of Climate Change*.

Azevedo de Melo, N., Minuzzi Delevati, D., Ben da Costa, A., & Lobo, E. A. (2021). The use of phytosociology to evaluate the efficiency of headwater preservation areas in the Andreas Stream Hydrographic Basin, RS, Brazil. *Ecological Indicators*, *129*, 107904. https://doi.org/10.1016/j.ecolind.2021.107904

Cho, H. (2020). Climate change risk assessment for kurunegala, sri lanka: Water and heat waves. *Climate*, *8*(12), 1–20. https://doi.org/10.3390/cli8120140

Dananjaya, P. K. V. S., Shantha, A. A., & Patabendi, K. P. L. N. (2022). Impact of Climate Change and Variability on Paddy cultivation in Sri Lanka. *Research Square*, 1–13. https://doi.org/10.21203/rs.3.rs-2149945/v1

De Costa, W. A. J. M. (2010). Adaptation of agricultural crop production to climate change: A policy framework for Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, *38*(2), 79–89. https://doi.org/10.4038/jnsfsr.v38i2.2032

De Silva, M. M. G. T., & Kawasaki, A. (2018). Socioeconomic Vulnerability to Disaster Risk: A Case Study of Flood and Drought

Impact in a Rural Sri Lankan Community. *Ecological Economics*, *152*(November 2017), 131–140. https://doi.org/10.1016/j.ecolecon.2018.05.010

Fonseca, C., Wood, L. E., Andriamahefazafy, M., Casal, G., Chaigneau, T., Cornet, C. C., Degia, A. K., Failler, P., Ferraro, G., Furlan, E., Hawkins, J., de Juan, S., Krause, T., McCarthy, T., Pérez, G., Roberts, C., Trégarot, E., & O'Leary, B. C. (2023). Survey data of public awareness on climate change and the value of marine and coastal ecosystems. *Data in Brief*, *47*. https://doi.org/10.1016/j.dib.2023.108924

Grover, S., Tayal, S., Sharma, R., & Beldring, S. (2022). Effect of changes in climate variables on hydrological regime of Chenab basin, western Himalaya. *Journal of Water and Climate Change*, *13*(1), 357–371. https://doi.org/10.2166/wcc.2021.003

Herath, H. M. R. C., & Jayawardena, I. M. S. P. (2018). Comparison of NEX NASA Statistical Downscaling Data and CORDEX Dynamical Downscaling Data For Sri Lanka. *Sri Lanka Journal of Meteorology*, *3*(September).

Hewawasam, V., & Matsui, K. (2022). Traditional Water Governance Practices for Flood Mitigation in Ancient Sri Lanka. *Climate*, *10*(5), 1–13. https://doi.org/10.3390/cli10050069

IPCC. (2022). Climate Change 2022, Mitigation of Climate Change Summary for Policymakers (SPM). In *Cambridge University Press* (Issue 1). https://www.ipcc.ch/report/ar6/wg2/

IPCC. (2023). Summary for policymakers. In: Climate Change 2023: Synthesis Report. A report of the Intergovernmental Plane on Climate Change. *Journal of Crystal Growth*, *2*, 36.

Kruger, R. A. (2012). *Designing and conducting focus group Interviews*.

Kumar Guntu, R., & Agarwal, A. (2020). Investigation of Precipitation Variability and Extremes Using Information Theory. In *Sciforum Electronic Conference Series* (Vol. 3).

Lacombe, G., Chinnasamy, P., & Nicol, A. (2019). Review of climate change science, knowledge and impacts on water resources in South Asia. Background Paper 1. In *Inernational Water Management Institute*. https://doi.org/10.5337/2019.202

Li, L., Li, G., Cui, L., He, L., & Chen, Y. (2021). Method for modelling ecological competition based on Pareto optimality: A case study of coastal wetlands in Jiangsu Province, China. *Ecological Indicators*, *129*, 107946. https://doi.org/10.1016/j.ecolind.2021.107946

Mo, X. G., Hu, S., Lin, Z. H., Liu, S. X., & Xia, J. (2017). Impacts of climate change on agricultural water resources and adaptation on the North China Plain. *Advances in Climate Change Research*, *8*(2), 93–98. https://doi.org/10.1016/j.accre.2017.05.007

Mohsin, A., Shehzad, A., Bilal, F., Imran, F., Akhtar, S., & Fatima, S. A. (2022). Assessment of Awareness on Climate Change among Public and Private Universities of Lahore. *Indonesian Journal of Innovation and Applied Sciences (IJIAS)*, *2*(1), 80–87. https://doi.org/10.47540/ijias.v2i1.439

Nagamuthu, P. (2022). Analysis of observed temperature changes in the Northern region of Sri Lanka based on climate

change perspective. *Journal of Asian Geography*, *1*(1), 48–58.

Nagamuthu, P., Chan, N. W., & Tan, L. (2021). *Trend Analysis of Rainfall in the Northern Region of Sri Lanka from 1970 to 2019*. 85–107.

Piratheeparajah, N. (2016). Temporal and Spatial variation of the Atmospheric Temperature of the Northern province of Sri Lanka. *The International Journal Environmental Science*, *5*(5), 63–67.

Rahimi, M. (2020). Public awareness: What climate change scientists should consider. *Sustainability (Switzerland)*, *12*(20), 1–4. https://doi.org/10.3390/su12208369

Shanthi De Silva. (2016). *Impacts of Climate Change on Water Resources in Sri Lanka Impacts of Climate Change on Water Resources in Sri Lanka*. *July*.

Shelton, S., & Lin, Z. (2019). Streamflow Variability in Mahaweli River Basin of Sri Lanka during 1990–2014 and Its Possible Mechanisms. *Water*, *11*(12), 2485. https://doi.org/10.3390/w11122485

Sholihah, Q., Kuncoro, W., Wahyuni, S., Puni Suwandi, S., & Dwi Feditasari, E. (2020). The analysis of the causes of flood disasters and their impacts in the perspective of environmental law. *IOP Conference Series: Earth and Environmental Science*, *437*(1). https://doi.org/10.1088/1755-1315/437/1/012056

Siriwardana, C. S. A., Jayasiri, G. P., & Hettiarachchi, S. S. L. (2018). Investigation of efficiency and effectiveness of the existing disaster management frameworks in Sri Lanka. *Procedia Engineering*, *212*(2017), 1091–1098. https://doi.org/10.1016/j.proeng.2018.01.141

Somasundaram, D., Zhang, F., Ediriweera, S., Wang, S., Li, J., & Zhang, B. (2020). Spatial and temporal changes in surface water area of sri lanka over a 30-year period. *Remote Sensing*, *12*(22), 1–23. https://doi.org/10.3390/rs12223701

Thennakone, V. (2018). Impact of Climate change on the water flow of the Kalu Ganga river in Sri Lanka. *International Journal of Hydraulic Engineering*, *3*(4), 38–51.

United Nations Office for Disaster Risk Reduction (UNDRR). (2021). Special Report on Drought 2021. In *Report:* https://www.undrr.org/contact-us

Withanachchi, S., S., Köpke, S., Withanachchi, R., C., Pathiranage, R., & Ploeger, A. (2014). Water resource management in dry zonal paddy cultivation in mahaweli river basin, Sri Lanka: An analysis of spatial and temporal climate change impacts and traditional knowledge. *Climate*, *2*(4), 329–354. https://doi.org/10.3390/cli2040329

Yazdandoost, F., Moradian, S., Izadi, A., & Aghakouchak, A. (2021). Evaluation of CMIP6 precipitation simulations across different climatic zones: Uncertainty and model intercomparison. *Atmospheric Research*, *250*(September), 105369. https://doi.org/10.1016/j.atmosres.2020.105369