Climate Technology Centre and Network (CTCN) Technical Assistance
for the Development of an Urban Adaptation Plan for Kurunegala

Climate Change Adaptation Action Plan

For Kurunegala

"Adaptation action plan to address water scarcity and heat stress"

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The Climate Technology Centre & Network (CTCN) has provided Technical Assistance (TA) to Kurunegala Municipal Council (KMC) and Ministry of Mahaweli Development and Environment (MMDE) in Sri Lanka through pro-bono support from Korea Environment Institute (KEI) Korea Adaptation Center for Climate Change (KACCC) and Green Technology Center (GTC) in Republic of Korea.

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1. Executive summary

Kurunegala city has been adversely affected by climate change. Due to the high level of climate change vulnerabilities, the city needs a broader range of feasible climate adaptation measures in terms of integrated planning for climate change adaptation. To overcome this problem, the Ministry of Mahaweli Development and Environment of Sri Lanka and Kurunegala Municipal Council (KMC) requested CTCN Technical Assistance (TA).

In this TA, water scarcity and heat stress are prioritized among diverse climate issues. The process of prioritization is based on discussions regarding the most urgent climate issues with key stakeholders in Sri Lanka. Throughout the multiple stages, an adaptation plan focusing on water scarcity and heat stress has been developed. We hope this adaptation plan will contributes to enhance Kurunegala's resilience to climate change.

To prepare the action plan, a literature review was first conducted. Based on the findings from literature review, climate change risk assessment was performed. The results of risk assessment showed that lack of drinking water is the biggest and the most urgent problem. In addition, experts, non-experts and women recognized lack of water as the most serious problem in Kurunegala to be addressed.

To verify the risk assessment results and to ensure an accurate understanding of the region, we held stakeholder meetings, workshops and a field survey through which the problems of Kurunegala were clearly identified as follows:

- The most crucial problem is decrease in drinking water supply due to drought and extreme heat;
- They experience severe water shortage. Low water efficiency due to high non-revenue water (NRW) aggravates the problem;
- City lakes and groundwater are exposed to bacteria and heavy metal contamination;
- There is a need to find new (additional) water sources;
- They suffer from high level of heat stress; however, there is no responsible organization as well as accurate data and information on it.

Based on the identified problems, we discussed how to tackle these problems in Kurunegala with local stakeholders as well as experts from Korea.

The action plan largely consists of three components including sustainable urban planning, water management and heat management.

- Sustainable urban planning is to improve the city's capacity to store water by transforming the city into water circulation city to get over the city's drought;

- Water management is to increase the effectiveness of water use by reducing the water leakage rate, and secure drinking water by purifying rainwater and groundwater;
- The heat management is to clarify where the responsibility lies to address the heat stress, as well as collect and manage the relevant data and information.

The proposed action plan in this TA has been modified through discussion with and comments from stakeholders. It should be further developed and implemented by local policymakers and stakeholders.

2. Introduction

Kurunegala city is one of the most intensively developed economic and administrative capitals of Sri Lanka located in the North Western Province. Urban systems in Kurunegala city have suffered from high level of climate vulnerabilities, extreme heat conditions, decrease in drinking water supply due to drought, and gradual diminish in urban biodiversity. The city needs a wide range of feasible climate adaptation measures in terms of integrated planning for climate change adaptation. The current measures are limited mainly due to the lack of governance system, financial systems and appropriate urban plans considering climate change adaptation measures.

To tackle these challenges, the Ministry of Mahaweli Development and Environment of Sri Lanka and Kurunegala Municipal Council (KMC) requested CTCN Technical Assistance (TA). In this TA, water scarcity and heat stress are prioritized among diverse climate issues. The process of prioritization is based on discussions regarding the most urgent climate issues with key stakeholders in Sri Lanka. The TA aims at: (i) identifying the current effects of climate change in Kurunegala city, (ii) assessing climate change risk to prioritized issues (water scarcity and heat stress), (iii) proposing an adaptation action plan for addressing water scarcity and heat stress and (iv) building the capacity of city planners and policy makers in order to transform Kurunegala city into a climate-smart city.

Several procedures are needed to set up an action plan. Each country has its own procedures to make an action plan, but they have a similar pattern such as preparation, planning and implementation. In the case of local governments in Korea, action plans were established and managed with seven steps. Details about seven steps are described in the Deliverable 8 (Climate Change Adaptation Planning Manual).

In this TA, the major steps were adopted in developing an action plan for adaptation in Kurunegala city against water scarcity and heat stress, due to limitation of time, budget, data and governance. To establish an action plan, a literature review was performed, and climate change risk assessment was conducted. Based on results of the risk assessment, stakeholder meetings and field surveys were carried out to propose adaptation plans for addressing water scarcity and heat stress.

Through the action proposed in this report, the adaptive capacity and climate resilience of the urban population in Kurunegala against water scarcity and heat stress would be enhanced in the long-term. For this, KMC needs to prepare and conduct the detailed implementation plan as well as develop foundation for the implementation, monitoring and evaluation plan in consideration with proposed actions in this report. It is recommended that proposed action plans in this report need to be incorporated in an adaptation action plan covering different adaptation-related sectors of Kurunegala city.

3. Background

3.1 Area description

Kurunegala is one of the ancient Kingdoms of Sri Lanka lasted for 50 years. Kurunegala District is located in the Northwestern Province of Sri Lanka. Kurunegala City is the capital of Kurunegala District. This city is one of the most intensively developed economic and administrative capitals in the North Western Province of Sri Lanka. It is one of the central cities of Sri Lanka directly connected to a number of major capital cities and towns of the island. The main highways connect it to Colombo, Kandy, Dambulla, Negombo, Anuradhapura and Kegalle.

Covering an administrative area of 11km^2, the Kurunegala City is located topographically in a plain surrounded by the Ethugala where is a large granite rock outcrop. The northern part of the town is slightly higher than the south (Rusaik, 2011).

Figure 3-1) Location of Kurunegala

The local residential population in the municipality is approximately 33,500 and the foot traffic is approximately 200,000. The city is situated at the intermediate climatic zone and experience low-country climatic condition. According to the 2012 census data, the city has a total population of 38,000 with a population density of 53 person/ha in built up areas as of 2017. Kurunegala city is a fast-growing and developing city in the North Western province. Its main economy is service and industry (Government of the Democratic Socialist Republic of Sri Lanka & UN, 2018). The geographic location of Kurunegala City is shown in Figure 3-1. The Kurunegala City is subdivided into 12 Grama Niladhari Divisions for administrative purposes (Figure 3-2).

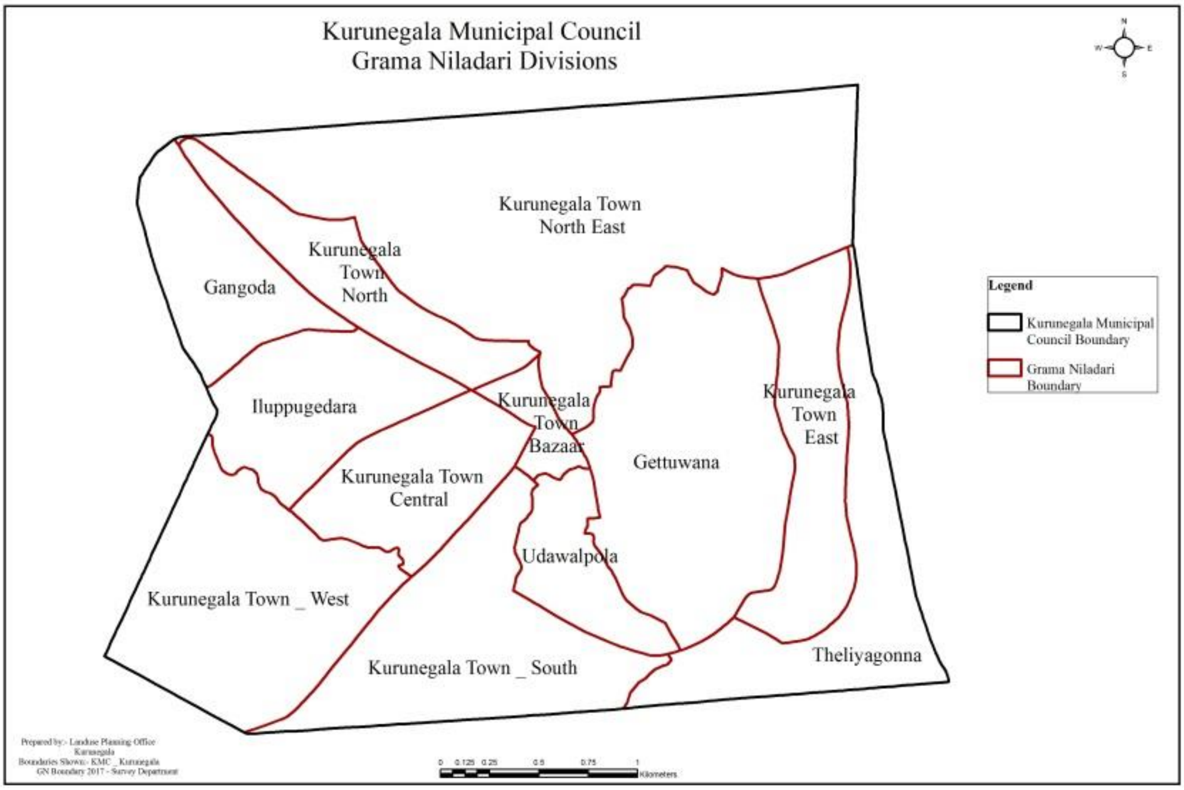
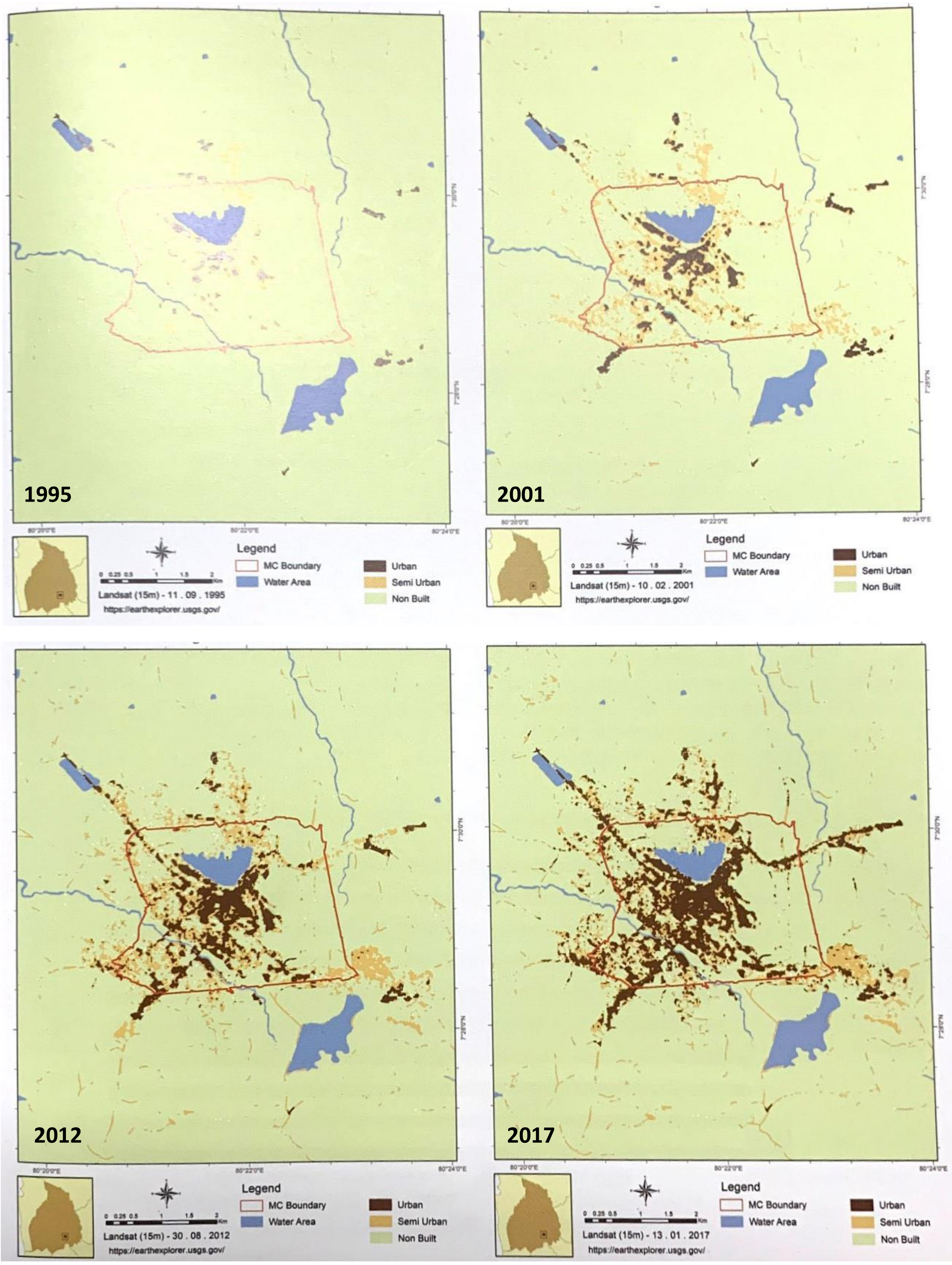


Figure 3-2) The 12 Grama Niladhari Divisions within the Kurunegala city boundary

(a) Urban Expansion

As stated in the report on 'The State of Sri Lankan Cities 2018 (Government of the Democratic Socialist Republic of Sri Lanka, 2018)', Kurunegala is a good example of ribbon development progressing into urban sprawl. As shown in Figure 3-3, the image in the year of 1995 shows a very small urban space, concentrated at the centre of the Municipal Council area. In 2001, semi-urban ribbons are shown radiating out from the centre to the north–west. In 2017, the ribbon expansion has spread along the main roads leading to Puttalam, Colombo, Kandy and Anuradhapura. Ribbon development turning into urban sprawl is shown with the expansion of the city of Kurunegala

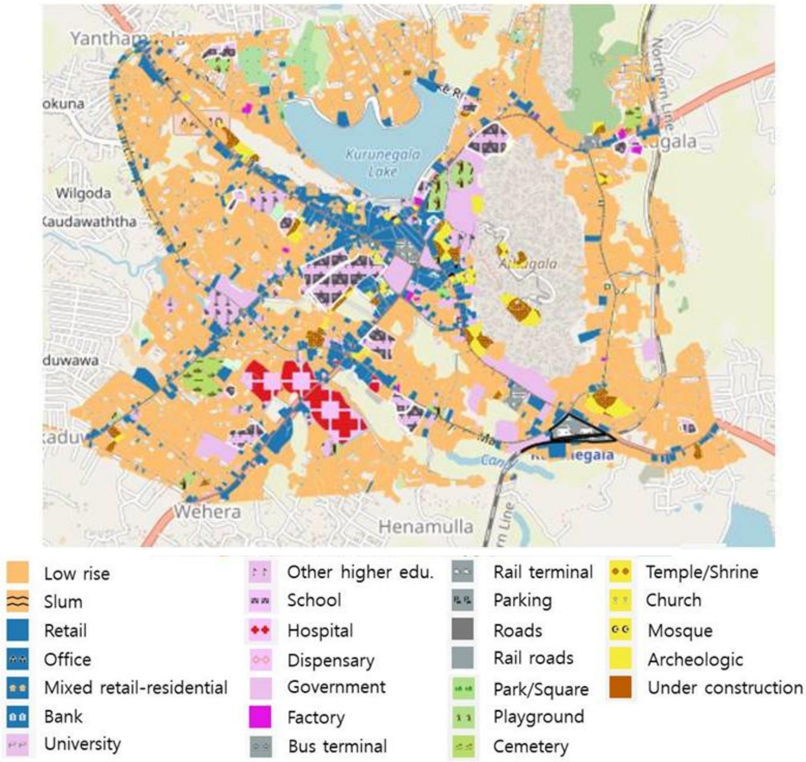


Source: Government of the Democratic Socialist Republic of Sri Lanka (2018)

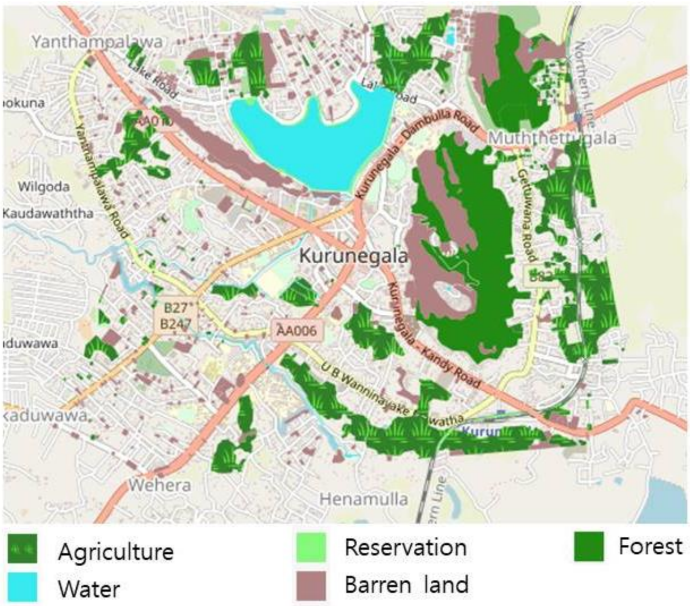
Figure 3-3) Ribbon and sprawl expansion in Kurunegala (1995-2017)

(b) Land Use Patterns

The land use of Kurunegala City comprises of 65% built-up and 35% green space (Figure 3-4). Municipal services cover 13.9% of all land use.



<Built-up areas>



<Non-built-up areas>

Source: Adapted from the Government of the Democratic Socialist Republic of Sri Lanka

Figure 3-4) Built-up and non-built-up areas

3.2 Climate and meteorological patterns

Located in the intermediate zone of Sri Lanka, Kurunegala exhibits a tropical climate (www.climate-data.org). The city's climate which is hot throughout the year is exacerbated by the rocks surrounding the city which retain heat during the day. During the April, the temperature rises up to about 35°C (95°F) leading to reduction of water in reservoirs. Heat stress warnings were issued and the associated guidelines addressing them were provided by the Department of Meteorology and Ministry of Health in April and May this year. During the monsoons from May to August and October to January, there are heavy rains. The average annual rainfall in Kurunegala is approximately 2,000 mm.

According to Table 3-1 and 3-2 on risk exposure, Kurunegala District experienced droughts with a high number of people being affected.

Table 3-1) District climatic zone and risk exposure in 9 provincial capitals

City	Climatic Zone	Exposure
Jaffna	Dry	Drought, flood, cyclone
Anuradhapura	Dry	Drought
Kurunegala	Intermediate	Drought
Trincomalee	Dry	Drought, flood, cyclone,
Kandy	Wet	landslides
Ratnapura	Wet	Flood, landslides, drought
Galle	Wet	Flood, landslide
Badulla	Intermediate	Flood, landslides
Colombo/WRM	Wet	Flood

Source: Government of the Democratic Socialist Republic of Sri Lanka (2018)

Table 3-2) Climate risk exposure in 9 provincial capitals 1974-2017

	Flood		Landslide		Drought		Cyclone	
	Affected	Deaths	Affected	Deaths	Affected	Deaths	Affected	Deaths
Badulla	2,251	–	6,424	41	–	–	–	–
Galle	27,206	–	23	4	–	–	–	–
Ratnapura	113,260	9	6,969	47	4,313	–	–	–
Jaffna	40,268	–	–	–	2,150	–	–	–
Kurunegala	2,774	2	–	–	141,074	–	–	–
Anuradhapura	4,030	–	–	–	19,645	–	–	–
Trincomalee	33,535	–	–	–	18,187	–	75,000	–
Kandy	505	–	2,615	7	–	–	–	–
WRM	3,807,394	223	2,084	36	530,763		9,355	3
TOTAL	**4,031,223**	**234**	**18,115**	**135**	**716,132**	**0**	**84,355**	**3**

Source: Government of the Democratic Socialist Republic of Sri Lanka (2018)

3.3 State of water supply and sewerage

3.3.1 Overview

Water scarcity can be defined as the non-availability of a required amount of water with usable quality at the required time and location for human and environmental use. A more accurate assessment of scarcity therefore focuses on relating available water to the demand for water, rather than to the population. The International Water Management Institute (IWMI) categorized the reason for water scarcity into three types. These are a) absolute or physical scarcity b) economic scarcity and c) institutional/political scarcity. These types reflect the different reasons for waster scarcity to occur (Somaratne & Ariyaratne, 2007).

In ancient times, Sri Lanka used traditional micro watershed management systems which is referred to as the Tank Cascade Systems (TCS) to irrigate the vast dry low-lying plains. Reuse of water through a network of small to large scale tanks is the main principle behind the TCS. The ancient Sri Lanka had unique channel technology. The feeder channels had only one embankment which was constructed long contour lines. Therefore, the channels were able to store a small amount of water. This system reduced the devastating effect of storm water during the rainy season. All components of the TCS are the artificial infrastructures. This system provided water for human consumption as well as supported the existence of local biodiversity, ecosystem services and irrigation (Geekiyanage & Pushpakumara, 2013). Kurunegala situated in the intermediate zone of the island had an ancient cascade system as well. As time went by, the tanks were filled up with soil so that the channels were blocked and then used for other purposes.

As the water resources in the Sri Lankan is precious, it should not be wasted and be conserved. It is thought to achieve merit when water is given free - especially at a time of dire need. When a particular area or district has been hit hard and there is extreme water scarcity during the drought, many volunteers and charities buy bottled water and transport them in trucks. Owners of Bowsers voluntarily provide water to those drought-stricken communities.

The main source of drinking water in Kurunegala City derives from Deduru River and Wendaru Wewa supplemented by the Kurunegala tank during the water shortage periods. The National Water Supply and Drainage Board (NWSDB) and KMC primarily manage the water supply into the city that covers 100% and serve approximately 90% of the population. The remaining 10% of the population utilize groundwater for the domestic use. Most houses use boiled water and cooled well water for drinking water. Common wells and ground wells are available in communities for washing and bathing.

About 78% of Kurunegala town area is drained by two streams, the Wan Ela and the Beu Ela which confluence just before Wilgoda Anicut (weir) and flow on through agricultural land before joining the Maguru Oya (river) at Watawehera estate just outside the western boundary of Kurunegala Municipality (Dissanayake, Clemett, Jayakody, & Amerasinghe, 2007).

Kurunegala city experienced water scarcity during three to four months of the year during the past decade. With the increase in urban population and commodities, the demand for water is sharply soaring up. The water sources are not adequate to meet the increased demand. The KMC is currently working on introducing appropriate interventions to solve the issue of water scarcity.

In August 2018, the Greater Kurunegala Water Supply and Sewerage Project [1] was inaugurated to provide clean water for households, government, private sector offices, schools, hospitals, tourist hotels, and daily floating population of over 70,000. It provides disposal of wastewater for 3,500 domestic and commercial institutions with its well-organized sewerage network. Greater Kurunegala Water Supply and Sewerage Project is thought as a boost to the quality of life and protection of the environment in Kurunegala, and the groundwater and lake water quality will be improved by the wastewater treatment of this project as well.

[1] The project is being implemented in Kurunegala in order to supply the basic water and sanitation needs.

3.3.2 Water supply system

The NWSDB and KMC jointly ensures the supply of safe drinking water to its community. The NWSDB was first established as a Department in 1965 and converted to a Board in 1975. The NWSDB has responsibility for the abstraction and treatment of raw drinking water (NWSDB, 2005). The present water demand of the city is about 8,000m^3 per day. The KMC is the responsible organization for water distribution and revenues collection. Currently, the total length of the water distribution network is approximately 82 km.

The Kurunegala Municipal Area obtains water from the Deduru Oya, Wendaru Wewa as well as from the Kurunegala Wewa during periods of droughts. These are the main water sources for the Kurunegala City. The KMC uses a small reservoir called Tampana originating from a catchment, but where dries up during the drought.

The intake capacity of the NWSDB is 7,200 m^3/day from the Deduru Oya and 1,000 m^3/day from the Wendaru Wewa. This raw water is pumped into the Water Treatment Facility and sold in bulk to the KMC. And then the KMC supplies the pipe borne water to the city.

Gas chlorination is used in the treatment of raw water for drinking. In the case of the Tampana water supply, the water quality is good as it come from a catchment. Therefore, pressure filter and disinfection are only treatment needed to be given. The Kurunegala Wewa has a storage capacity which is equal to 1,750m^3/day. But, this lake is used only in periods of drought. It has a channel linked to the Deduru Oya and can store water for up to 21 days requirement.

It is estimated that the water demand by 2030 will be 19,000m^3/day. Under the Greater Kurunegala Water Supply and Sewerage Project, the present water treatment facility is expected to be upgraded up to the storage capacity of approximately 14,000m^3/day. A feasibility study is being conducted to assess the possibility of developing the Wandurapinu Ella as a Water Supply scheme. The operational and maintenance cost for 1m^3 of water is Rs.52.00. but the bulk selling price to the KMC is Rs. 18.00 per 1m^3 of water. For commercial and construction requests the NWSDB sells water at Rs 70.00 per 1m^3 of water.

There are two Water Treatment Plants in operation (Figure 3-5). The newly constructed Water Storage Tank has been funded (loan) by the Chinese Government. Raw water is pumped here and treated.

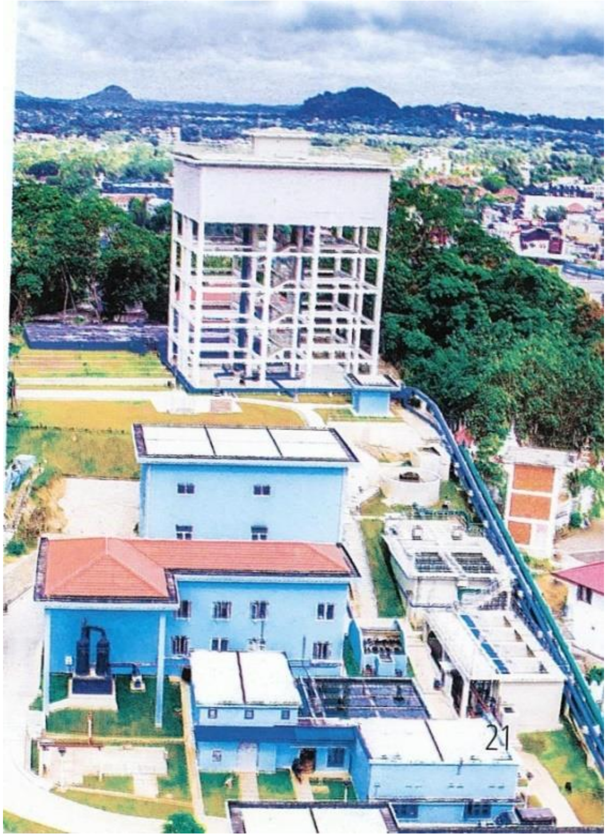


Figure 3-5) Water treatment facility

The present water supply facilities in the KMC area will be expanded up to some extent to the Kurunegala Pradeshiya Sabha areas. 30 Grama Niladhari Divisions will be covered under this project, and total new beneficiaries would be 71,000 people. Furthermore it is intended to provide an uninterrupted water supply (24 hours) to the Kurunegala Teaching Hospital and to the 35,000 residents in the municipal area. It is also intended to facilitate the provision of drinking water to a floating population of approximately 100,000 people daily.

The main components of the Water Supply Project are:

- Construction of a dam across Deduru Oya;
- Improvement of the existing pumping station and construction of a new pumping station;
- Laying of new transmission lines;
- Improvement and development of catchments;
- Improvement of existing water treatment plant with capacity of up to 9,000 m^3/ day;
- Construction of new water treatment plant with capacity of 5,000 m^3 / day;
- Expansion of the water distribution system to three zones;
- Provision of 6,500 new water connections.

3.3.3 Sewage treatment system

The Kurunegala city is one of the municipalities that have a sewerage treatment facility (Figure 3-6) and where institutional and household septic tanks are linked to the main sewerage line.

Figure 3-6) Sewerage treatment facility

The source of funding for the facility installation is from both the Chinese Government loan (USD M77.3) and the Sri Lankan Government funding (Rs. M 3,200). The sewerage system is constructed to cover 43,000 residents in the municipal including Kurunegala Teaching Hospital.

The main components of the Sewerage Project are:

- Construction of sewerage treatment plant (4,500m^3/day) and 5 pumping stations;
- Connection of all environmentally problematic locations in the city to sewerage network;
- Construction of 3,500 household connections;
- Improvement of sewerage network of Kurunegala Teaching Hospital.

The sewerage from existing lines are collected and treated here. After treatment, the residue water is treated and released to the Beu Ela that flows adjacent to the Sewerage plant. Treated water flows into irrigation fields. Compost is made from the remaining sludge which is a form of excellent fertilizer and much in demand from plantations.

The laboratory conducts daily checks on the influent and effluent parameters such as temperature, pH, DO, TSS, NH_3-N and COD, and E coli is also checked regularly. There is no bad odour from the sewerage treatment plant.

The newly built sewerage plant is in operation. The sewerage is treated at 300 m^3 per hour. And a capacity of 1,700 - 2,000 m^3 is treated daily. Currently, there are 3,500 sewerage connections.

3.4 Climate change hazards in Kurunegala city

3.4.1 Heat

Unplanned rapid urban growth causes traffic congestion, overcrowded urban public space with concrete buildings and lack of green space. In Sri Lanka, most of the green space is being replaced by impervious surfaces such as buildings, parking lots, roads and pavements.

The Urban Heat Island (UHI) phenomenon is a major negative impact of rapid urbanization. It was first described in 1818 as a phenomenon that urban areas have a higher atmospheric and surface temperature than their surrounding rural areas. In general, there is a 3-5°C variation observed between urban and rural areas in the daytime. However, during the nighttime, a high 12°C variation can be observed due to the gradual emission of radiant heat from the urban surface. There are two types of UHIs including Surface Urban Heat Island (SUHI) and Atmospheric UHI. Atmospheric UHI is observed based on air temperature, and SUHI is measured based on land surface temperature (Ranagalage et al.,2017).

In a study conducted in the Colombo Metropolitan Area (Ranagalage et al., 2017), it was revealed that there were intensifying SUHI effects during years of 2007-2017. In another study conducted by Ranagalage et al. (2018a), the mountainous region of Central Hills showed an increase from 3.9°C in 1996 to 6.2°C in 2017 along the urban-rural gradient. This implies that most of the existing rural landscape had been increasingly covered by impervious surfaces resulting in a high SUHI in Kandy City.

Rapid changes in urban landscape composition and pattern have been recognized as a main reason for the occurance of SUHI (Estoque et al., 2017; Ranagalage et al., 2017; Ranagalage et al., 2018a). The SUHI can be recognized as a by-product of the unplanned rapid urbanization. The positive impacts of rapid urban development is to bring the socio-economic benefits, and the negative ones of it is to cause the natural environment problem (Estoque & Murayama, 2017; Ranagalage et al., 2018a). There are several negative impacts associated with the rapid increasing UHI, such as degradation of living environments (Estoque et al., 2017; Ranagalage et al., 2017), elevated ground-level ozone, increased mortality rate (Rogan et al., 2013), elevated emissions of air pollutants and greenhouse gases, compromised human health and comfort (EPA, 2008), increased hospitalization of children and elderly people (Ranagalage et al., 2017).

The Figure 3-7 shows the spatial distribution of land and surface temperature (LST) in the Kurunegala area for the years 1996, 2008 and 2018. The mean LST was recoded as 21.9 °C, 23.5 °C, 26.5 °C in 1996, 2008 and 2018, respectively. The mean LST increased by 4.6 °C from 1996 to 2018, showing that the Kurunegala area is becoming vulnerable to occurring UHI phenomena. There is the trend of increasing LST in Western, south-western direction in 2018. There are several main reasons behind these rapid changes in mean LST.

The changes in vegetation cover highly contribute to the increase in mean LST and finally produce UHI phenomenon. Figure 3-8 shows the spatial and temporal changes of normalized difference vegetation index (NDVI) in the Kurunegala area from 1996 to 2018. It indicates that vegetation cover changes in south-eastern, south, south-western, and north-western direction in 2018. The rapid changes that convert natural area into built-up land cause high green cover lost in this area. The similar pattern is shown in Colombo City (Ranagalage et al., 2017; Ranagalage et al., 2018b) and Kandy City (Ranagalage et al., 2018a; Dissanayake et al., 2019).

The normalized difference built-up index (NDBI) maps of Kurunegala in 1996, 2008, and 2018 are shown in Figure 3-9. In 1996 and 2008, areas with high NDBI values were concentrated mostly near the city center along with the road network. However, by 2018, areas with high NDBI values had greatly expanded outside the city center towards the north-western, southern, south-western, and south-eastern parts of the KMC area. The rapid expansion of areas with high NDBI values from 2008 to 2018 was mainly due to the high rate of urban development during this period of time. Increasing built-up areas highly affects the occurrence of UHI phenomenon in the study area. The increasing trend of built-up areas in the Kurunegala city area directly influences changes of mean LST.

Along with the urban-rural gradient of the Kurunegala city, it can be observed that the mean LST had a much higher increase during the years of 2008-2018 than during the years of 1996–2008 (Figure 3-7). This is consistent with the rapid urban development during the years of 2008–2018. The mean NDVI in middle distances has decreased over the years.

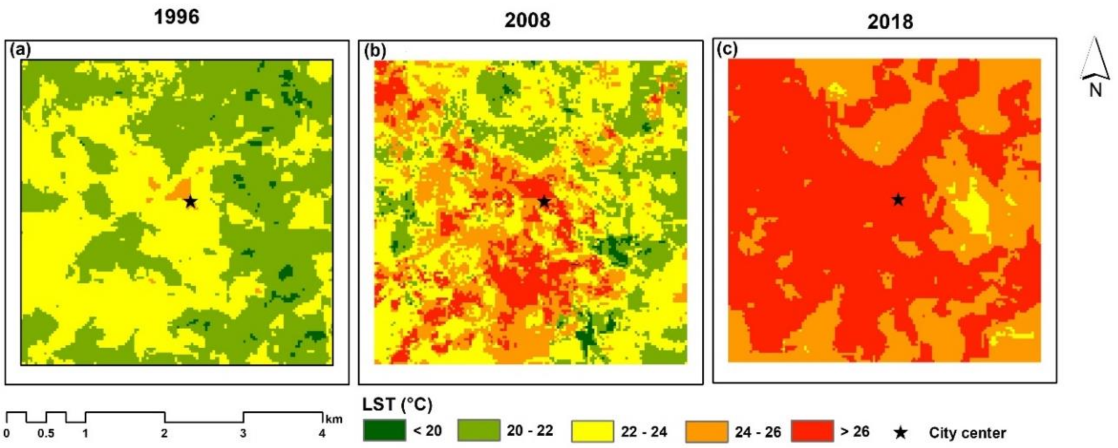


Figure 3-7) Land and surface temperature (LST) maps of Kurunegala in (a) 1996; (b) 2008; and (c) 2018.

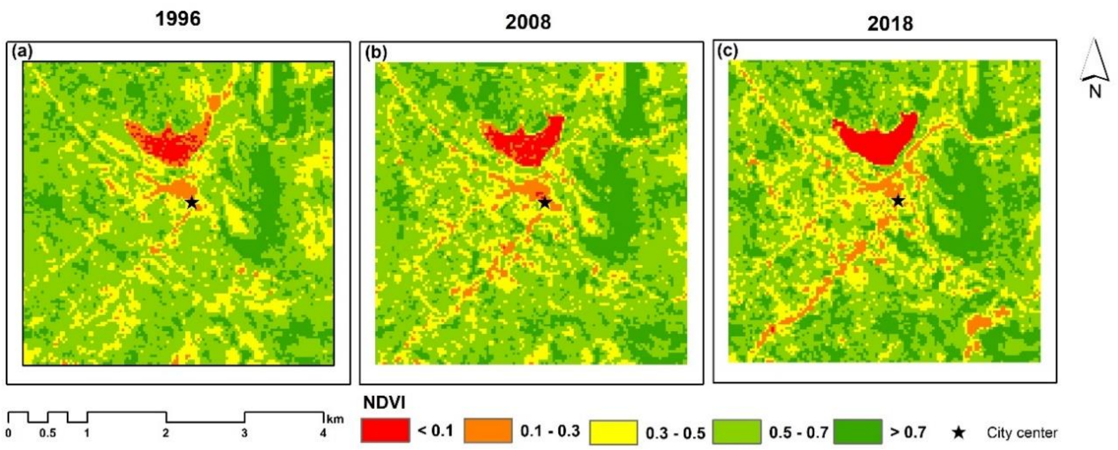


Figure 3-8) Normalized difference vegetation index (NDVI) maps of Kurunegala in (a) 1996; (b) 2008; and (c) 2018.

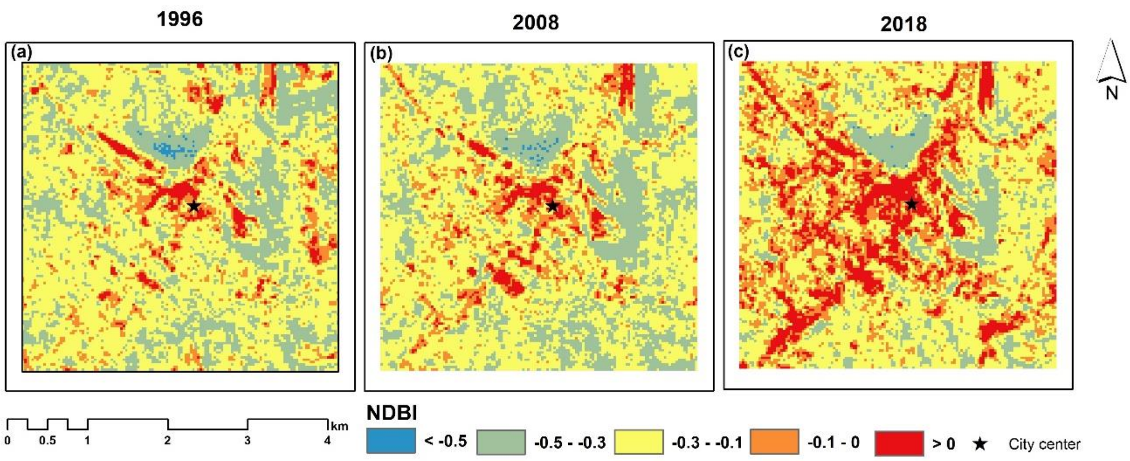


Figure 3-9) Normalized difference built-up index (NDBI) maps of Kurunegala in (a) 1996; (b) 2008; and (c) 2018.

However, in 2018 there were also some slight improvements in the mean NDVI distance between 1.5 km to 1.9 km from the city center. Mean LST has a strong negative significant relationship with mean NDVI in 1996, 2008, and 2018 (Figure 3-10). It shows that NDVI affects to decrease LST in the Kurunegala city area. Due to urban development, more open and vegetated areas have been replaced with impervious surfaces such as buildings, roads, parking lots, pavements, and other constructions. We recognize that the detected temporal variation in the overall mean LST might have been influenced by the absence of green cover and increasing built-up areas. The observed increase in the overall average LST in Kurunegala city from 1996–2018 (i.e., 4.6 °C) might be caused by the rapid urbanization of the area. The significant correlations between LST and NDVI (negative) (Figure 3-10) and between LST and NDBI (positive) (Figure 3-11) along the urban-rural gradient show the pattern of mean LST, NDVI, and NDB. This similar pattern is shown in other cities in Sri Lanka such as Colombo City (Ranagalage et al., 2017; Ranagalage et al., 2018b), Kandy City (Dissanayake et al., 2019) and Nuwara Eliya (Ranagalage et al., 2019).

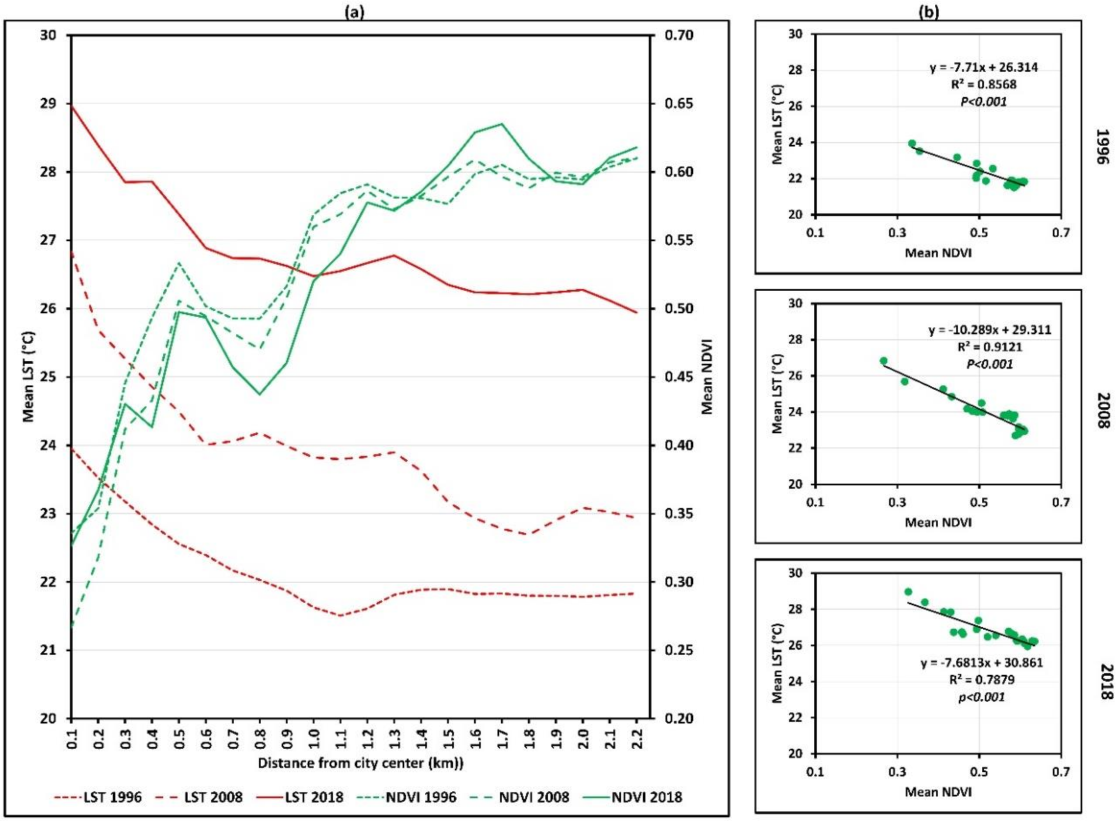


Figure 3-10) (a) Spatial distribution of the mean LST, mean NDVI; (b) scatter plots of the mean LST and mean NDVI in Kurunegala during 1996, 2008, and 2018.

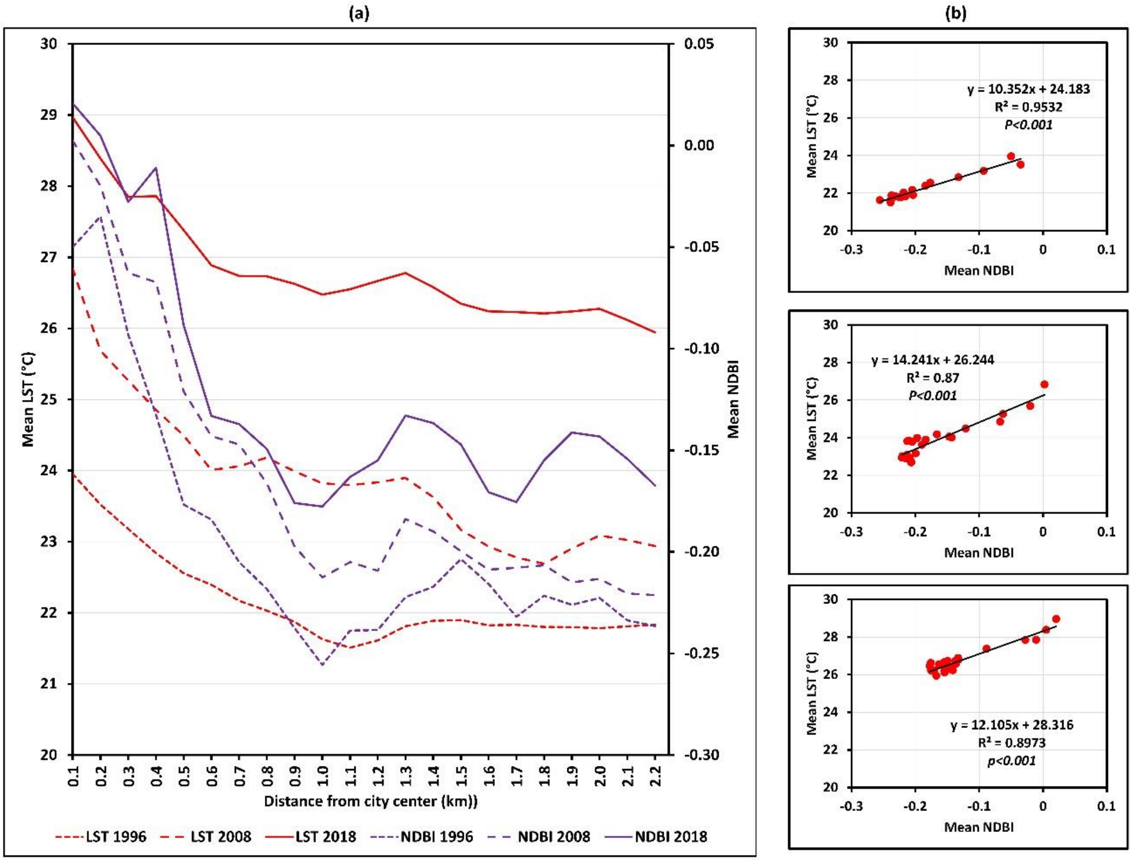


Figure 3-11) (a) Spatial distribution of the mean LST, mean NDBI; (b) scatter plots of the mean LST and mean NDBI in KMC during 1996, 2008, and 2018.

3.4.2 Water-related and vector borne health concerns

Degraded water quality can be an important factor affecting the surge of water borne diseases. After monsoon period, rains plays a crucial role in the spread of diseases due to the higher risk of exposure to polluted waters. Moreover, stagnant water stored into surface depressions can serve as a breeding ground for disease carrying insects (i.e. Mosquitoes, cockroaches, etc.). Due to improper management of wastewater in the city area, the growth of disease-carrying mosquitoes resulted in considerable cases of water-related vector borne diseases such as dengue, filariasis, malaria, and chikungunya.

Dengue is a vector borne disease prevalent with the onset of rains. Any habitat that has the tendency to collect water is a breeding ground for the dengue mosquito. With the drought, there is a necessity to collect water in cans and other vessels due to water cuts. If the water containers are not washed regularly or not monitored, there is a high possibility of dengue mosquito breeding. Currently, there is a slight increase in the incidence of dengue though no mortality has been reported. This is due to the fact that the dengue mosquito lays eggs in the containers used for water storage.

The Public Health Inspectors engage in visiting households twice a month to ensure that the premises are kept clean and free of potential breeding sites for dengue mosquitos. Dengue incidences have been well documented by the KMC (Table 3-3)

Table 3-3) Number of dengue cases reported during 2017-2019

	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Total**
2017	27	27	21	57	170	117	57	48	11	30	38	14	617
2018	12	4	2	0	2	1	8	2	0	0	0	0	31
2019	3	5	0	1	0	1	2	-	-	-	-	-	12*

* Sum of the number of dengue cases between January and July 2019

4. Methodology for developing climate change adaptation action plan for Kurunegala

To establish an action plan, the climate change risk assessment was carried out. In order to identify the current status and verify the results of the risk assessment in practice, we conducted a field survey and stakeholder meetings. The detailed process of adaptation action planning is described in the Deliverable 8 (Climate Change Adaptation Planning Manual). In brief, the action plan was prepared through stakeholder meetings, field survey and workshops based on the results of risk assessment.

4.1 Climate change risk assessment of Kurunegala

Climate change risk assessments are conducted to figure out what are current and projected risk factors that impact a community. Climate change risk assessment is a key element of climate change adaptation policy development. It informs policy decision-makers of the potential risk of climate change and provides a means to evaluate the impacts along with evidences to compare different options of strategies and policies.

Through the TA, KMC wanted to do risk assessment using both indicator-based (quantitative assessment) and survey-based (qualitative assessment) approaches. But it was difficult to collect enough data to figure out the impact of climate change in Kurunegala. Therefore, only survey-based approach was implemented for risk assessment in this TA whereas it was carried out to collect assessable data for indicator-based approach.

The risk assessment was designed to provide foundation for climate change adaptation action plan of Kurunegala. In this report, only a brief summary of the risk assessment was presented, and details on its methodology and results were included in the Deliverable 3 (Report on the result of climate change risk and vulnerability assessment) and the Deliverable 4 (Climate change risk assessment guidelines) of the TA.

As mentioned, the target area for risk assessment was Kurunegala city. The qualitative risk assessment (survey-based approach) was conducted as to water scarcity and heat stress in the city. In order to identify the most serious risk regarding water scarcity and heat stress, detailed 7 indicators were set up based on consultation with KEI and KMC. For each indicator, concrete risk factors that cause the impact of water scarcity and/or heat stress were provided. In consultation with KMC, 57 risk factors were finally selected and grouped into 7 indicators as below:

- Drinking water resources risk/vulnerability to drought (DWR);
- Water management risk/vulnerability (WM);
- Water quality and aquatic ecosystem risk/vulnerability (WQAE);
- Water resources risk/vulnerability (WR);
- Sanitation risk/vulnerability of drought and flood (SDF);
- Health risk/vulnerability to flood (HF);
- Health and infrastructure risk/vulnerability to heat stress (HIH).

The water and/or heat experts were requested to respond about the possibility of occurrence and the impact of each risk factor by using 5-point Likert scale. By multiplying average possibility of occurrence and average impact together, scores for risk factors and indicators could be obtained. The obtained scores for indicators are presented in Table 4-1 and Figure 4-1.

Water and/or heat experts in KMC consider 'Drinking water resources risk/vulnerability to drought' as an indicator with the highest risk, followed by 'Water resource risk/vulnerability'. Given the fact that both indicators are related to water resources, it is clear that the water resources is an impending issue that urgently needs to be addressed in Kurunegala city.

Table 4-1) Results of qualitative risk assessment in Kurunegala city

Code	Indicator	No. of risk factors	Avg. possibility of occurrence	Avg. Impact	Score	Rank
	Total	57	2.99	2.97	8.88	-
DWR	Drinking water resources risk/vulnerability to drought	3	3.86	4.14	15.98	1
WR	Water resources risk/vulnerability	11	3.34	3.36	11.22	2
HIH	Health and infrastructure risk/vulnerability to heat stress	11	3.14	3.11	9.77	3
SDF	Sanitation risk/vulnerability of drought and flood	3	3.1	2.91	9.02	4
WM	Water management risk/vulnerability	11	2.71	2.74	7.43	5
HF	Health risk/vulnerability to flood	7	2.51	2.6	6.53	6
WQAE	Water quality and aquatic ecosystem risk/vulnerability	11	2.37	2.34	5.55	7

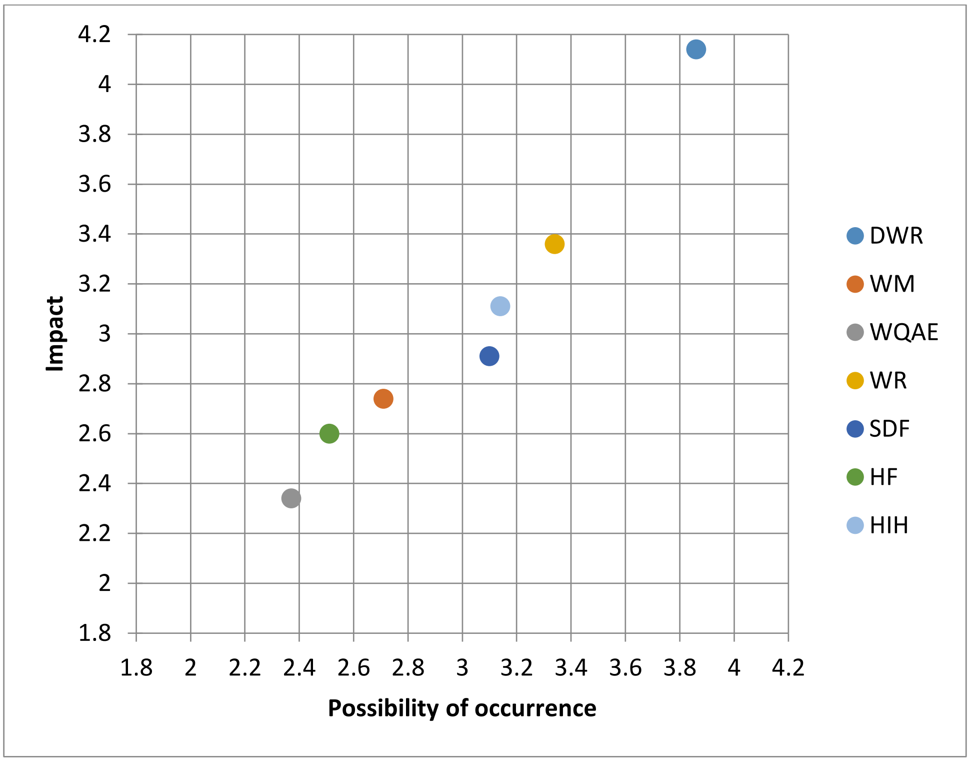


Figure 4-1) Results of qualitative risk assessment in Kurunegala city

We tried to figure out what is the first risk factor for each indicator. It aimed to identify the most prioritized risk factor for each indicator, which needs to take into account in preparing adaptation measures in Kurunegala city. The first risk factor for each indicator is shown in the Table 4-2.

Table 4-2) First risk factor for each indicator in Kurunegala city

Code	Indicator	First risk factor
DWR	Drinking water resources risk/vulnerability to drought	Lack of drinking water resources due to drought
WM	Water management risk/vulnerability	Drying streams and water bodies (natural and artificial) due to drought
WQAE	Water quality and aquatic ecosystem risk/vulnerability	Water quality deterioration due to temperature increase
WR	Water resources risk/vulnerability	Lack of water for building maintenance and management
SDF	Sanitation risk/vulnerability of drought and flood	Increase of water borne/ vector borne diseases

HF	Health risk/vulnerability to flood	Increase of water borne diseases through water and food
HIH	Health and infrastructure risk/vulnerability to heat stress	Reduced function of green space and increased loss of green cover due to heat stress

We reviewed 'Top 10 risk factors' as to water scarcity and heat stress in Kurunegala city. As shown in Table 4-3 and Figure 4-2, 'Lack of drinking water resources due to drought' is identified as the highest risk factor, followed by 'Lack of water for building maintenance and management' and 'Drying streams and water bodies (natural and artificial) due to drought'. According to the results of qualitative risk assessment, lack of water due to drought is the biggest and most urgent problem in Kurunegala city.

Table 4-3) Top 10 risk factors in Kurunegala city

Code	Risk factor	Avg. possibility of occurrence	Avg. Impact	Score	Rank
DWR01	Lack of drinking water resources due to drought	3.86	4.14	15.98	1
WR01	Lack of water for building maintenance and management	4.03	3.91	15.76	2
WM08	Drying streams and water bodies (natural and artificial) due to drought	3.94	3.83	15.09	3
WR07	Decrease of national water supply capacity due to rainfall pattern change	3.89	3.74	14.55	4
HIH02	Reduced function of green space and increased loss of green cover due to heat stress	3.86	3.71	14.32	5
WR10	Increased gap of water supply among regions due to drought	3.76	3.79	14.25	6
WR05	Increase of water demand due to increase of crop evapotranspiration	3.83	3.66	14.02	7
WR06	Increase of water demand for livestock and animal husbandry due to drought	3.56	3.47	12.35	8
WR09	Un-controlled use of groundwater due to lack of water	3.6	3.43	12.35	9
WM11	Increased frequency of drought due to persistent non-precipitation days	3.6	3.4	12.24	10

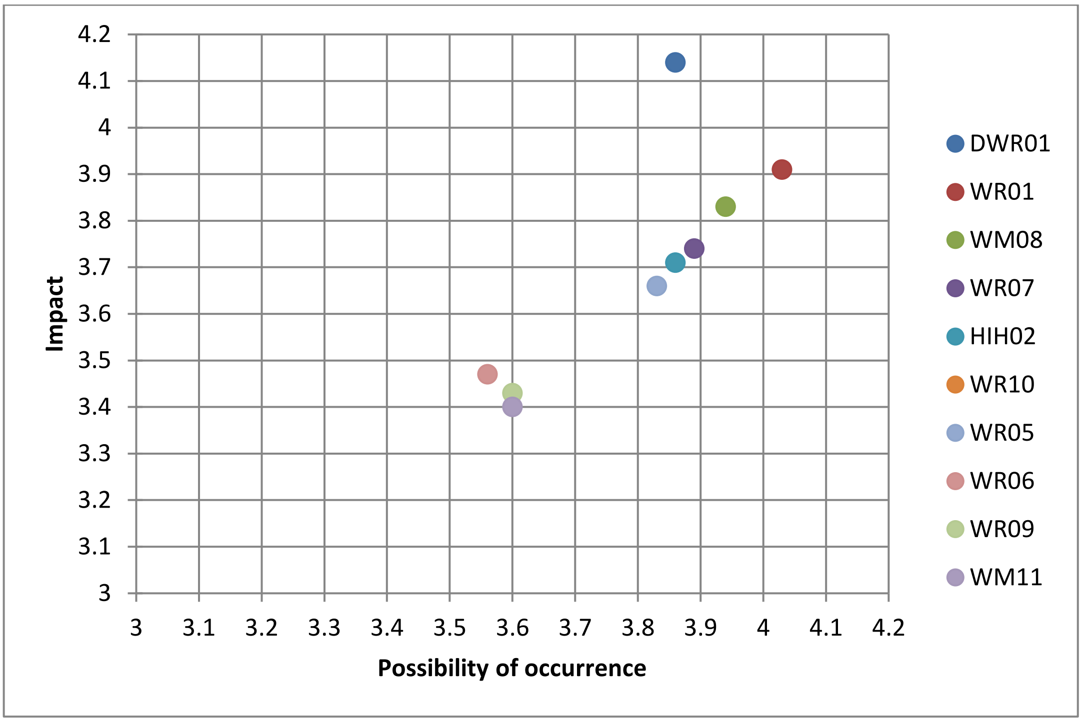


Figure 4-2) Top 10 risk factors in Kurunegala city

4.2 Climate change awareness survey

The purpose of this survey was to identify key issues related to water scarcity and heat stress that are felt by local residents and related experts in Kurunegala city, especially women.

The main questions asked to local residents and related experts were as below:

- Rank the top 3 climate change risks affecting you;
- Rank the top 3 climate change actions that need to be prioritized.

Results of the survey are presented in Figure 4-3 and 4-4. 'Lack of drinking water' is considered as the most significant risk of water scarcity whereas 'Increasing risk of tropical diseases' is identified as the most significant risk of heat stress. Almost half of survey participants consider 'Supplying drinking water' and 'Greening the city' as key actions to reduce water scarcity and heat stress in Kurunegala city respectively.

Figure 4-3) Rank the top 3 climate change risks affecting you (Other experts).

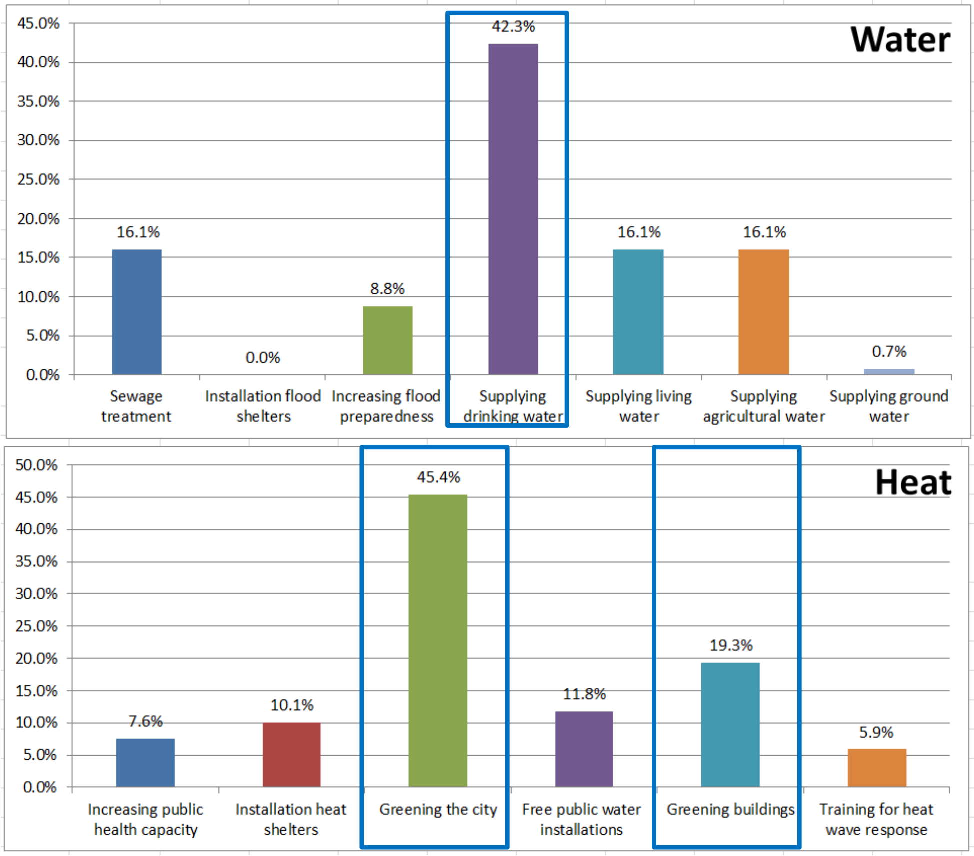


Figure 4-4) Rank the top 3 climate change actions that need to be prioritized (Other experts)

We also focused on the gender issues and tried to figure out what women are thinking about climate change and identify their damage associated with the climate change.

One of the questions was ‘How severe do you think the climate change impacts are in Kurunegala city?’ Almost half of respondents, 47.5 percent, thought climate change impact is ‘Very high’ risk and 25 percent agreed that it is ‘High’ risk (Figure 4-5). The results show that women in Kurunegala city feel the effects of climate change and require appropriate action immediately.

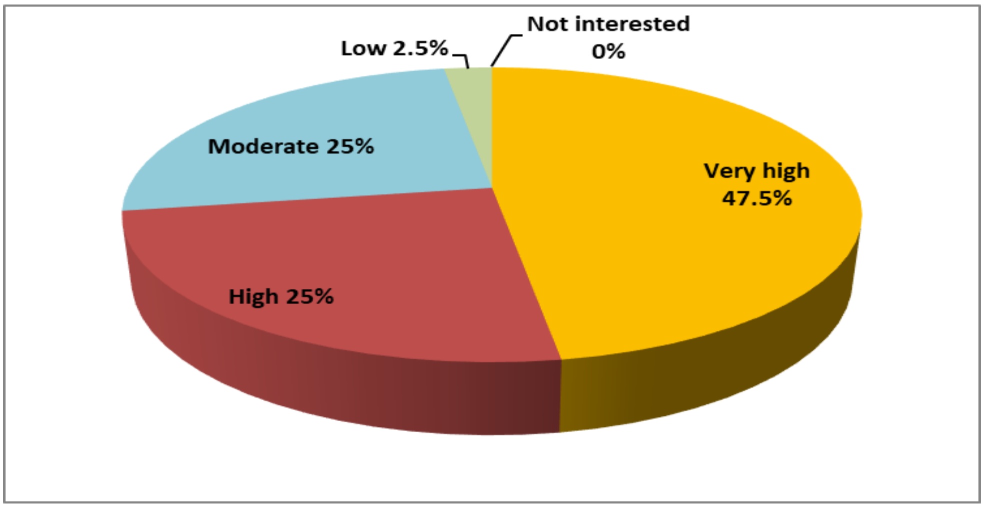


Figure 4-5) How severe do you think the climate change impacts are in Kurunegala? (Gender)

Women selected ‘Lack of drinking water’ and ‘Withered agricultural crop’ as the most serious risk of water scarcity and heat stress respectively (Figure 4-6). They strongly needed ‘Supplying drinking water’ and ‘Greening the city’ as key actions to reduce risk of water scarcity and heat stress in Kurunegala city (Figure 4-7).

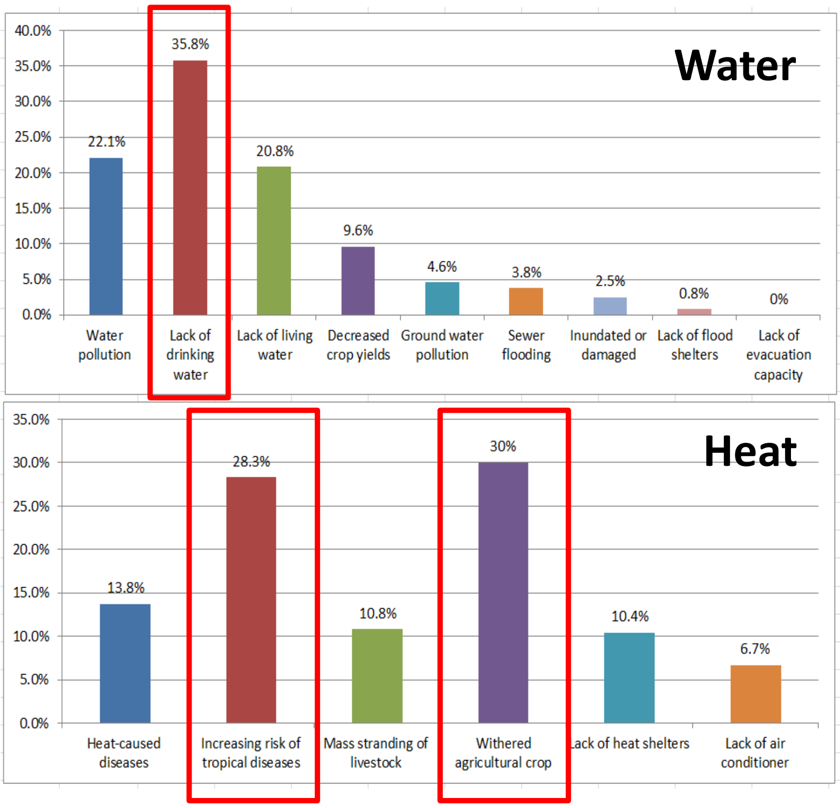


Figure 4-6) Rank the top 3 climate change risks affecting you (Gender)

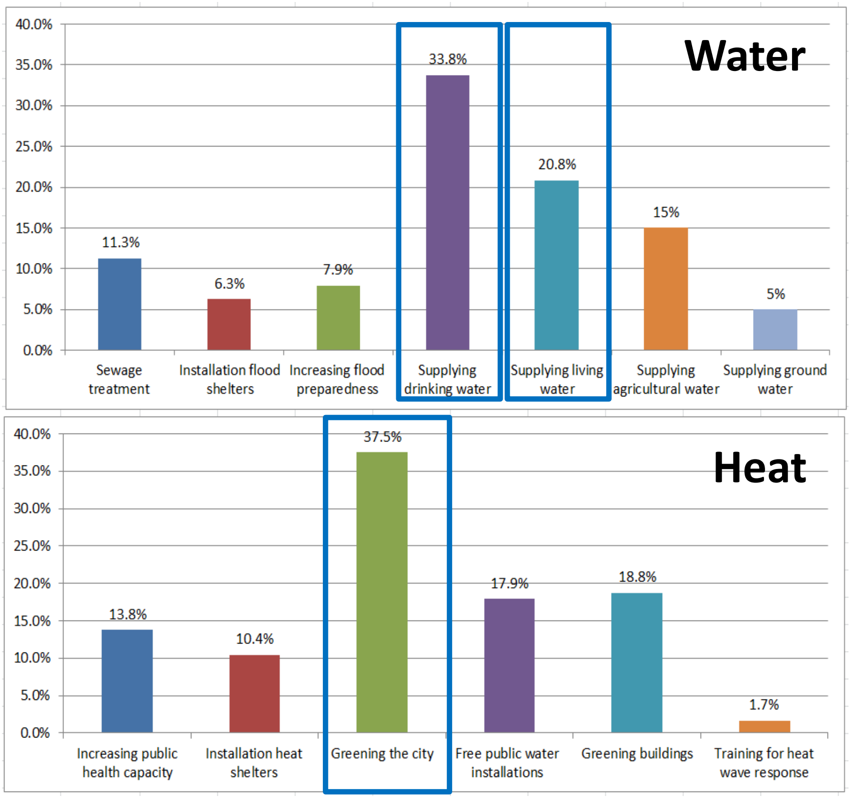


Figure 4-7) Rank the top 3 climate change actions that need to be prioritized (Gender)

According to the results, it is identified that supplying drinking water and greening the city need to be prioritized above all other needs in the issues of water scarcity and heat stress. These opinions on climate change risks and actions were reflected on climate change adaptation action plan for Kurunegala to be discussed in the following section.

4.3 Verification of climate change risk

Consultant workshop, stakeholder meeting, field study and training workshop were conducted to verify the risks and establish adaptation measures based on the climate change risk assessment. Different stakeholders engaged in the meeting and workshops so that we could incorporate opinions from a wide range of stakeholders such as water and heat experts, technical experts, policymakers as well as relevant authorities.

4.3.1 Consultant workshop

At the consultant workshop in July 2019, the most urgent risk issues were set based on the risk assessment results, and their solutions were discussed with stakeholders (Figure 4-8). The summary of the discussions is shown in Table 4-4.

Table 4-4) Results of the group discussions

	Group 1	Group 2
Risk factor	Lack of drinking water resources due to drought	Lack of drinking water resources due to drought
Solution	(a) Reduction of non-revenue water (b) Water recycling methodology (c) New water scheme	(a) Development of Wendaru Wewa (b) Two lines of water supply (drinking water, gray water) (c) Repairing of leaking pipelines
Risk factor	Drying streams and water bodies (natural and artificial) due to drought	Lack of water for building maintenance and management
Solution	(a) Increasing the green coverage	(a) Water reuse for building maintenance (b) Water recycling for plantation and agriculture (c) Rainwater storage system

Figure 4-8) Consultant workshop in July 2019

Gender issues were also discussed to identify the current status of gender inequality associated with climate change and to come up with measures. However, there was not much response about gender issue. The participants stated that in the cultural context of Sri Lanka, families are the social unit. They must have often extended families living with them. In the Kurunegala urban area, there are tap lines. Water is stored in small plastic tanks for use during water cuts, and the Municipality provides treated water from bowsers to households during the drought. In peri-urban areas there are wells in households for drinking water and common wells for bathing purposes. Money is not charged for using these facilities. Water obtained from wells is boiled in wood stoves before drinking. Generally, the entire family including the males assists to collect and bring in water from the bowsers in the city area.

4.3.2 Stakeholder meetings

(a) National Water Supply and Drainage Board (NWSDB) - Regional Support Centre

The team had a discussion with Ms. Thanuja Premaratne, Manager (O&M) of the NWSDB, on 18 July 2019 (Figure 4-9). The major challenges faced by the NWSDB and the KMC are the lack of reliable sources of water, high amount of NRW percentage, contamination of natural water resources by human and industrial waste and the inadequate resource availability for the operation and maintenance services. The NRW is approximately 45% which is well above the national average. The primary reason for NRW is the frequent leakage of the aged distribution pipe network and defective domestic meters.

The operational and maintenance cost for $1m^3$ of water is Rs.52.00. But the bulk selling price to the KMC is Rs. 18.00 per $1m^3$ of water. For commercial and construction requests the NWSDB sells water at Rs 70.00 per $1m^3$ of water.

Figure 4-9) Meeting with NWSDB at the head office

(b) Greater Kurunegala Water Supply and Sewerage Project

The team had a discussion with Mr. Kolitha Atapattu, O.I.C Sewerage Treatment Plant and email communication with Eng.I.R. Gamage (Head of the Plant). According to '*Identification report of Kurunegala water supply system by Greater Kurunegala Water Supply & Sewerage Project'*, efficiency of the existing water supply system in Kurunegala city is very low. The approximate NRW percentages between 2014 and 2016 are indicated in Figure 4-10.

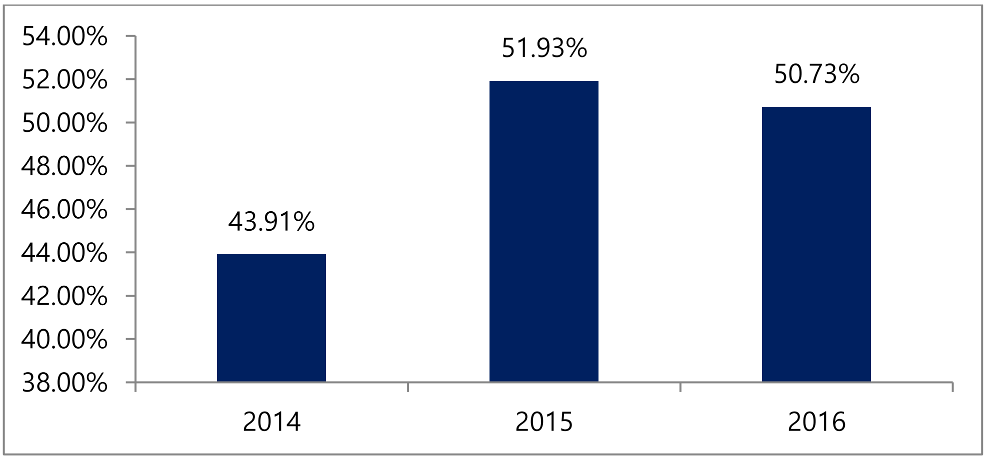


Figure 4-10) NRW percentages (2014 – 2016)

According to the results of tentative NRW study in KMC network, it is identified that the NRW percentage is about 45%. This value indicates the lack of effectiveness and efficiency of the water distribution in the city. This figure is considerably high compared to island's average of 32%. Compared to other water schemes of Kurunegala with an average NRW of 13%, this figure is very high. There are many factors that can influence on the increase in NRW value of the network. As shown in Figure 4-11, some of the reasons are:

- Leakages in the transmission and distribution systems and in the service reservoirs;
- Illegal water consumption;
- Production and consumer metering errors;
- Administrative errors (Estimated meter readings, errors in estimation, etc).

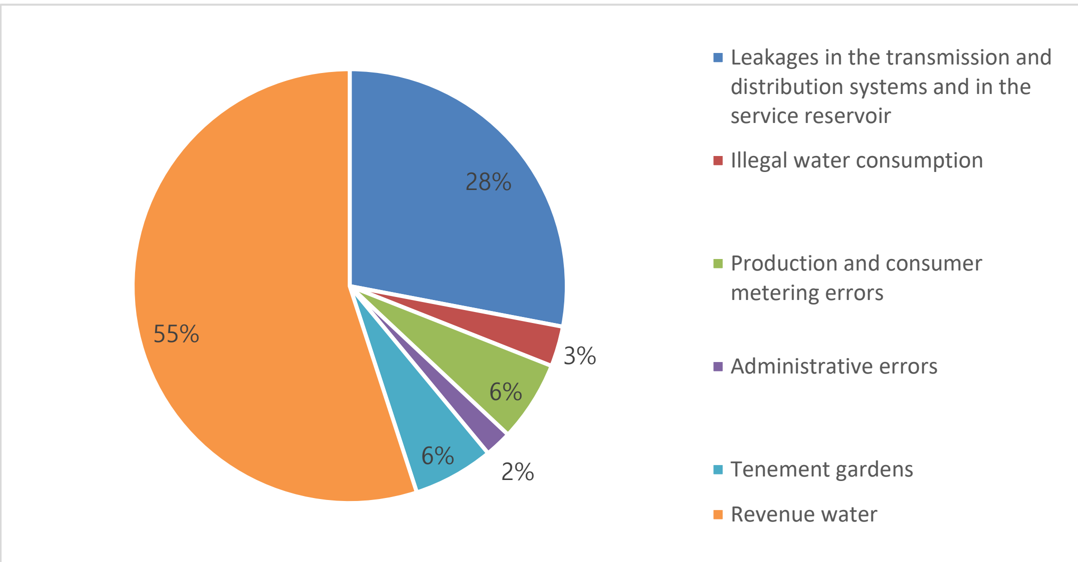


Figure 4-11) NRW Breakdown (Greater Kurunegala Water Supply & Sewerage Project, n.d.)

As the amount of NRW in Kurunegala is significant, it is essential to take proper actions.

(c) Meeting with stakeholders in Kurunegala Municipal Council

The team had a meeting with the following stakeholders in KMC (Figure 4-12):

- Assistant Commissioner (Mr. D.P.S Kumara);
- Engineer (Eng. D.R.W.W. Kaluarachchi);
- Dengue Unit personnel (Ms. Menaka Herath and Mr. Gayan Chathuranga) and
- Senior Public Health Inspector (Mr. W.A.G. Upatissa).

April is one of the hottest months of the year in Kurunegala. The temperature rose to 42°C within the city in April-May this year. Kurunegala city has been experiencing a drought for the past three months. The catchment area of Tampane has totally dried up. Deduru Oya water levels have declined. The Kurunegala Wewa is being used to provide water for the city. This water is treated and sent to areas by engaging bowsers.

Some of the wells within the city have also dried up. People in the peri -urban areas use the common well for bathing and washing purposes and use the household well for drinking water purposes. Most of the wells are contaminated by runoff both from fertilizer and sewerage pits. Most of the groundwater wells have also dried up, and the Municipality does not encourage the digging of groundwater wells. There are daily water cuts. People fill their plastic tanks with water as storage. Currently, there is a slight increase in the incidence of dengue although no mortality has been reported. This is due to the fact that the dengue mosquito lays eggs in the containers used for water storage.

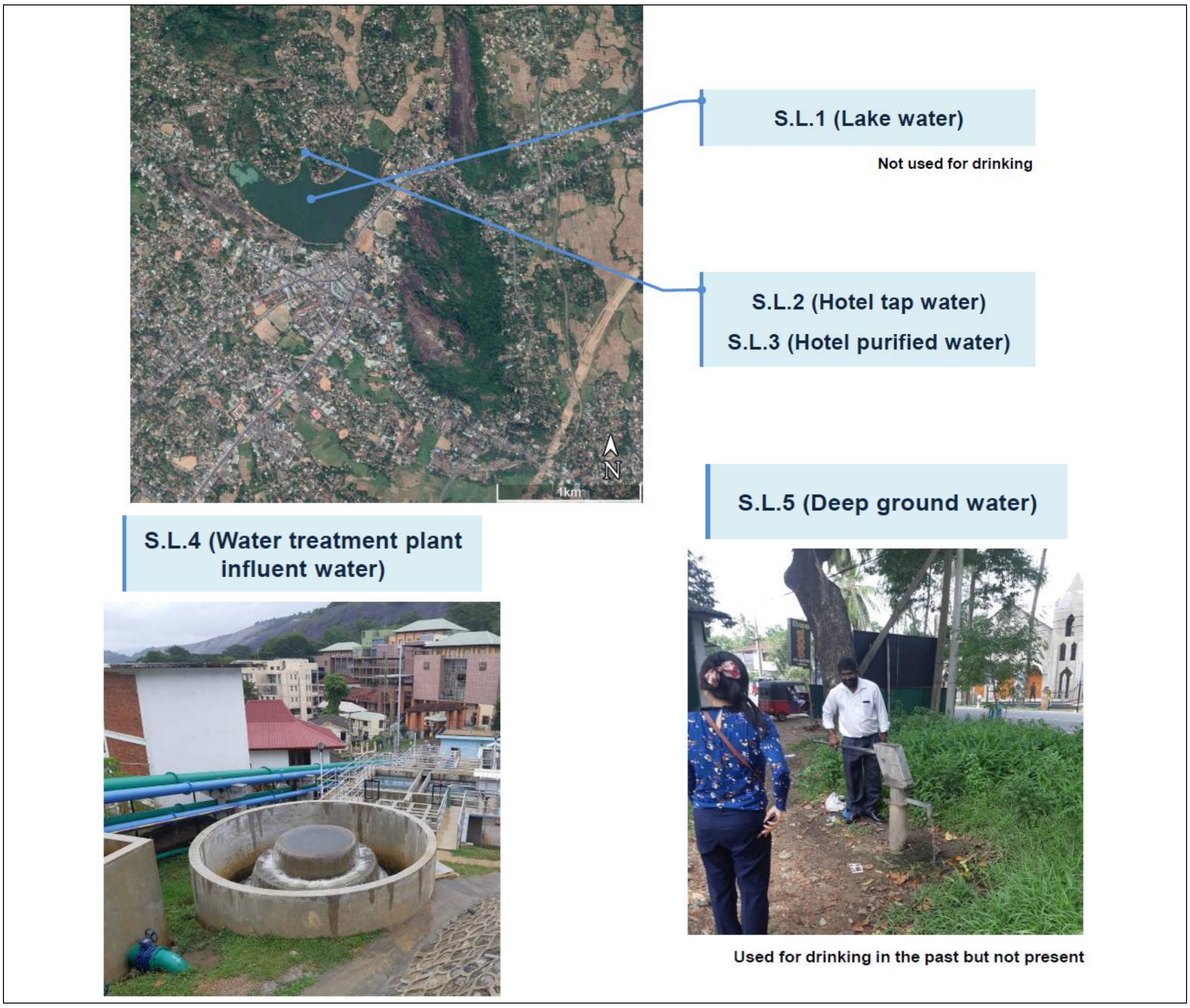
Figure 4-12) Meeting with stakeholders in KMC

Unlike other Municipal Councils, the KMC buys water in bulk from the NWSDB and distributes it into the residents. The KMC has fixed 8,273 water meters, including 5,671 for houses, 1,898 for the commercials, 266 for outside houses (outside the Municipal town area) and 31 for outside commercial tap connections. Considerably less is charged for water units in comparison with electricity units. There is a proposal for the next budget to provide tap connections to 16,000 households, but there are financial constraints.

There is an App. for smart phones. This is a complaint line, where the public can inform if there are any leaks or burst pipes. The pipe system is very old and needs to be replaced. There are many noted leakages form the pipe system (NRW). A procedure is being set up to check for water pipe leaks, but this is a very expensive procedure, and there are financial constraints.

4.3.3 Field study

During the consultant workshop in July, we sampled several locations within the city of Kurunegala. The sampling locations are indicated in Figure 4-13. We inspected the water quality and its results are presented in Table 4-5.



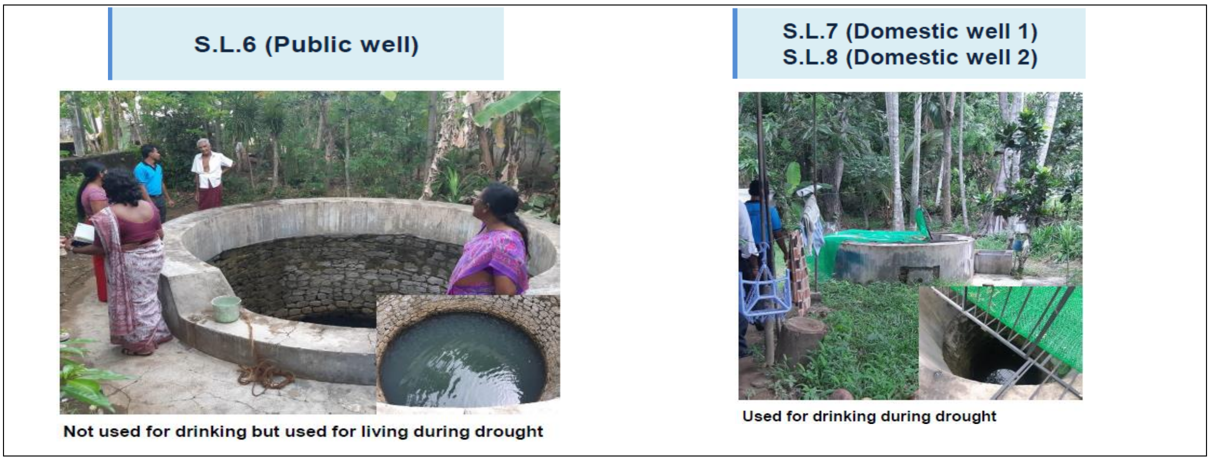


Figure 4-13) Sampling locations

Table 4-5) Results of water quality test

		Temp. (℃)	pH	Conductivity (SPC)	DO (mg/L)	Turbidity (NTU)	Total bacteria (CFU/mL)	Coliform (CFU/mL)	As (ug/L)	Cd (ug/L)	Cu (ug/L)	Pb (ug/L)
S.L.1	Lake	29.0	8.18	225	4.39	30.60	1880	4	0.2	0.0	2.0	0.5
S.L.2	Hotel tap	-	-	-	-	-	76	0	0.1	0.0	1.3	0.3
S.L.3	Hotel purified	-	-	-	-	-	66	7	0.0	0.0	0.1	0.0
S.L.4	WTP influent	-	-	-	-	-	172	1	0.3	0.0	2.0	0.2
S.L.5	Deep ground water	-	-	-	-	-	-	-	0.1	0.0	118.3	3.7
S.L.6	Public well	27.8	7.15	616	4.64	4.01	122	0	0.1	0.0	1.0	0.1
S.L.7	Domestic well 1	26.8	7.00	877	1.33	0.46	39	0	0.2	0.0	0.9	0.1
S.L.8	Domestic well 2	-	-	-	-	-	23	0	0.1	0.0	3.8	0.2

The sample from Lake (S.L.1) has the largest amount of bacteria, and Public well (S.L.6) also has amount of bacteria. Specially, Deep groundwater (S.L.5) has high concentration of heavy metals. It contains 118.3ug/L of copper and 3.7ug/L of lead. Although the results were obtained from a single sample, there are concerns about bacteria and heavy metal contamination in the use of groundwater.

4.3.4 Training workshop

Based on the findings from the consultant workshop, the stakeholder meetings, the field visit and survey, Dr. Hanna Cho explained the draft of the action plan at the training workshop in September 2019 and received feedback from the stakeholders (Figure 4-14).

Regarding the draft action plan, we had discussions with stakeholders. For each component of the action plan, relevant stakeholders provided feedback. Further details were interpreted from English into Sinhalese by Ms. Hasula Wickremasinghe if requested, in order to make sure of clear understanding of the contents. The discussions were meaningful and effective as comments from decision-making level as well as technical level were gathered at the same time. The discussions are summarized as follows:

- If it is possible to implement each component of action plan or not;
- If relevant measures are underway;
- Some stakeholders raised questions, and Dr. Hanna Cho and Mr. Nash Jett Reyes answered;
- Some stakeholders expressed their concerns about why it might not fit the situation of Kurunegala or what obstacles there are to be addressed;
- What should be done to facilitate the implementation of the action plan.

To sum up, most of the components suggested by KEI received positive feedback. This could be attributed to the thorough field survey in previous visits. The feedback from the stakeholders were reflected on the final draft of the action plan.

Figure 4-14) Training workshop in September 2019

4.4 Implication

As a result of risk assessment of climate change and the discussion at the meetings and workshops with various stakeholders, securing of drinking water during drought period was identified as the most urgent issue in Kurunegala city.

In the year 2019, the drought period was from June to August. But, there was a rise in ambient temperature since April. Last year the dry period was only for two months. It seems that the duration of dry weather extends each year.

The principal issue in water scarcity is that there is no reliable water source. Deduru Oya which had been utilized all these years provides irrigation (paddy) schemes as well. The Irrigation department has built a weir in Deduru Oya in order to provide water for agricultural purposes. During the dry periods, the KMC, NWSDB and other related institutes have monthly discussions with the District Secretariat in order to assess the situation of the drought and availability and distribution capacity of water sources. It is necessary to come up with measures to deal with water shortage during dry period.

The other serious issue in water scarcity is high amount of NRW percentage. The NRW on a three-year average (2014-2016) is approximately 50% in Kurunegala. The primary reason for NRW is due to the frequent leakage of the aged distribution pipe network and defective domestic meters. There is no digitized system for data collection and data storage at the KMC. It is necessary to formally design database system for continuous data collection and dissemination of information. It is needed to digitize the number of bulk waters bought from the NWSDB and categorize how the water units have been utilized (household, commercial, etc.). It is necessary to map the distribution of wells (e.g., groundwater wells, common bathing wells, etc.) and monitor whether they are in use or not during drought period. Based on the data through the digitized system, it is required to determine which area has leakage and to perform pipe network maintenance for the area.

Despite the fact that there are constant complaints of heat stress it has not been documented. There are no factual reports connecting heat stress to health problems. There has been a slight increase in the incidence of dengue in September although no mortality has been reported.

The problem is there are several organizations related to heat stress, but their responsibilities are unclear. It is necessary to define the impact and damage status of the heat stress and to design database system for continuous data collection and dissemination of information to manage heat stress. Based on the database system, it is imperative to manage the problem and establish action plans for reducing the impact.

5. Climate change adaptation action plan for Kurunegala

5.1 Objectives of action plan

Based on the results of risk assessment and discussions with stakeholders, critical problems in Kurunegala have been identified. An adaptation action plan was developed to provide solutions to the issues. Summary of problem identification and direction of the action plan is presented in Table 5-1.

Table 5-1) Summary of problem identification and direction of Action Plan

Sector	Problem identification	Direction of Action Plan
Water scarcity	> Water shortage is becoming serious during drought period. > Water resources need to be secured. > High amount of NRW > Lack of management of water resources (There is no data on how much bulk water inflows and how the water units have been utilized in Kurunegala area)	> Need short-term measures to respond to water shortages – rainwater utilization > Measures to secure water resources to prepare for a drought – water circulated city e.g: Management of drinking water wells and groundwater sources (If it is possible to link all the household, commercial, government institutions into sewerage system, contamination of groundwater will be less.) > Effective use of existing water resources – reduced NRW rate
Heat stress	> No responsible organization to manage heat stress > There is no information or data relevant to heat stress.	> Need responsible organization for heat stress e.g: Health Department and KMC > Data establishment for identifying and managing the impact of the heat stress > Measures to reduce heat stress

The action plan consists of three objectives: (a) Sustainable urban planning, (b) Water supply management, and (c) Heat management (Figure 5-1). Detailed descriptions of these components are presented in Appendix A - C.

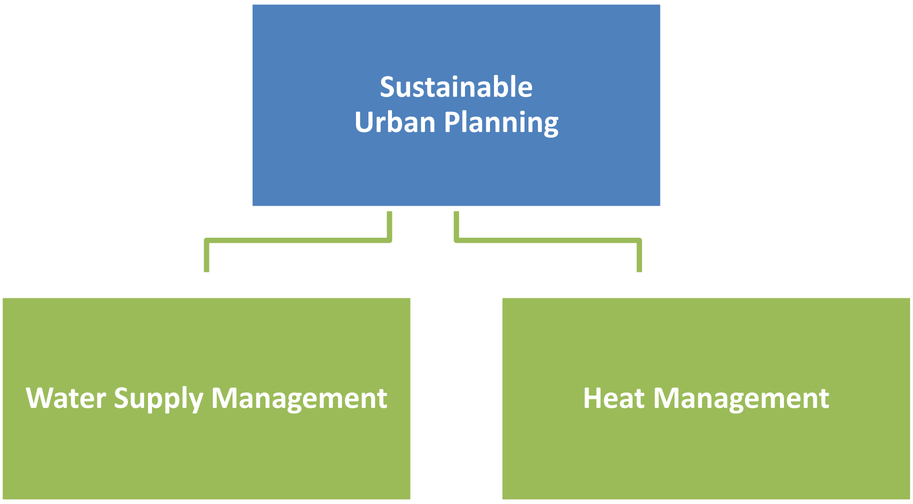


Figure 5-1) Action plan structure

5.2 Action plan

The adaptation activities in each component are presented. Concerns, remarks, time and budget estimates are provided so that they can be referred to in the preparation and implementation phase.

5.2.1 Sustainable urban planning

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Sustainable urban planning							
1	Installation of rain barrels on government compounds or offices	Stored quantity not adequate to supply for entire staff Require large area for storage	Barrels for water storage should be covered properly to prevent mosquito breeding.	600L container: USD 420 Underground storage tank: USD 1,260/ton	V		
2	Use of household roof runoff or water reuse or groundwater recharge	The local government discouraged the use of roof gutters. Stagnant water at the roof gutters can serve as breeding grounds for dengue-carrying mosquitoes. Leaves from trees usually clog roof gutters.	Roof gutters should be sloped properly to entirely drain rainwater and prevent mosquito breeding. Regular maintenance should be conducted to ensure that the gutters are not harbouring insects and free from clogging.	-	V		Budget would differ based on type of house and area
3	Conversion of conventional roofs to green roofs	Watering of green roof during drought period	May have a source of recycled water for this	Consists of waterproof membrane, barrier layer, grainage layer, vegetation base, and plants: USD 230/m^2	V		
4	Use of permeable pavements and installation of tree-box filters on sidewalks	The potential of using limestone blocks as an alternative to permeable pavements/blocks should be tested on a small-scale project.	Permeable blocks will have to be set with filterable troughs for storm water drainage for excess water	Permeable concrete: USD 210/m^2 Permeable block: USD 250/m^2		V	

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Sustainable urban planning							
5	Replacing concrete center islands on main roads by bioretention systems	Since the main roads were already established, it may be difficult to incorporate these systems in the current network	Could be incorporated into newly built roads and into government and institutional landscapes	Storage system utilizing soil media and plant: USD 500/m^2		V	
6	Utilization of horizontal subsurface flow constructed wetlands (HSSF CW) for wastewater treatment	Some areas have high groundwater table whereas other regions were underlain by hard rock formations. Local ordinances or policies should be reviewed to check the possibility of using the treated effluent for groundwater recharge.	The local government is currently implementing a similar project. Instead of using HSSF CWs, public toilets were discharged on leaching fields. The wastewater discharged on leaching fields will eventually reach the groundwater table. Compared with the treated effluent using HSSF CWs, leaching fields have higher potential of contaminating groundwater.	-		V	

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Sustainable urban planning							
7	Database establishment (GN wise data collection)	Data gaps need to be identified. Database has to be designed. Data needs to be collected at household level as well as institution and business level by trained data collectors. Such data needs to be transferred into database. Staff needs to be trained for analysis and reporting.	Additional staff needs to be recruited. MRV of data needs to be done. Require computers with high RAM	USD 60,000		V	
8	Integrating data collection with other related institutes and establishing a system	Existing data collection formats need to be changed.	Each institution should be given the data requirement. Databases created accordingly The data needs to be transferred into a central place.	USD 50,000		V	
9	Mapping of KMC boundaries and GNs (by LUPPD) using 1:2000 scale	This software is expensive. Staff needs to be trained to use the software.		-		V	

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Sustainable urban planning							
10	Incorporating land-use into maps	Staff needs to be trained to use this. Need ground truthing to be done.		-		V	
11	Vulnerability assessment of 12GNs	Specific data is not available. Time consuming Require to purchase meteorological data	Due to small land area, vulnerability assessment may not be accurate.	USD 100,000	V		
12	Building a new sewerage treatment plant on new land	Land has been set aside for this purpose. Lack of finances.	Needs to be able to treat sewerage from all households and institutions Predicting population increase and incorporating economic development	-		V	
13	Expansion of laboratory of water treatment facility	Require new equipment. Area for working needs to be expanded.	New technology needs to be used. Trained maintenance personnel are needed.	USD 5M	V		
14	Transforming drainage canals in schools and government buildings into infiltration trenches	Possibility needs to be checked. Need to assess whether this is adequate during heavy rains.	Access to quantity of material is questionable	-		V	

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Sustainable urban planning							
15	Application of adaptation systems in government offices as pilots	Attitudinal change Empty areas are always utilized for buildings.	Policy to keep at least 20% of area without concreting or without buildings	-		V	

5.2.2 Water supply management

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Water supply management							
1	NRW Reduction plan	The scale of the problem is defined, and the location of areas with the highest levels of NRW can be identified. Installing or replacing the additional meters is required. It should be tested on a small-scale project.	New waterlines need to replace the old. Faulty meters have to be replaced. NRW has to be calculated accurately. Pilot program for NRW in the urban area with a high level of NRW: - Pipeline Length: 10 km - NRW: from 50% to 80%	Leak detection & analysis: USD 3M Meter installation and/or replacement: USD 4M Smart water management (ICT monitoring & GIS): USD 4M Change and repair the pipe: USD 9M ~ - Staff Costs: USD 2M - Office and Administration: USD 1M - Travel and Accommodation: USD 1M - External Expertise and Service: USD 2M - Equipment: USD 4M - Infrastructure and Works: USD 10M		V	

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Water supply management							
2	Water storage system with Gravity-driven (GD) and Nano Membrane system - Small GDM in house - Large GDM in public building - Nano Membrane system in near groundwater well	The current Reverse Osmosis (RO) process eliminates minerals in water. The GD and Nano system will not remove minerals.	A GDM system is strong against water borne disease. Nano Membrane system is powerful to remove almost all contaminants and heavy metals. Installation of system in peri-urban area and the place where groundwater is used is a priority.	One small-scale GDM: USD 100 ~ 200 One large-scale GDM system: USD 2,000 One Nano Membrane system: USD 3,200	V		
3	Development of Wendaru Wewa	Due to lack of maintenance Wendaru Wewa is not utilized with full capacity.	Budget and priority review are required.	-		V	
4	New water scheme	Feasibility study is required to identify new sources of water. Most streams at Kurunegala are seasonal.	Budget and priority review are required.	-		V	
5	Two lines of water supply (drinking water & gray water)	Two lines need to be laid when new pipes are being laid. Treated water from sewerage plant and water treatment plant can be utilized here.	Budget and priority review are required.	-		V	

5.2.3 Heat management

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Heat management							
1	Preparing a management organization	There are several organizations involved, but their responsibilities are unclear.	Coordination of committee with relative organizations	-	V		
2	Collecting, analyzing, and monitoring basic data	UHI assessments need to be made at GN level. Identification of causes that increase surface temperature Maintenance of database by central point (e.g. KMC) Nighttime data needs to be collected by Met. Dept.	Data on the age group, sex and occupation of people who die of heat wave is needed. Data on whether the deaths occur indoor or outdoor and the economic status of people who die of heat wave is needed. Need to recruit new staff	-	V		
3	Identification of heatwave illness and recordings of casualties	Awareness creation for medical centres and schools on how to identify heat stress and related symptoms Documentation needs to take place in medical clinics, etc.	Recorded maximum temperature on the particular time periods and place Recording medical check-up report with causes.	USD 20,000.00	V		

	Adaptation Activity	Issue/Concern	Remarks	Budget Estimate	Short-term	Mid-/Long-term	Comments
Heat management							
4	Installation of green & shade curtain	How to water it during scarce water availability	The green curtain blocks solar and radiant heat in summer, preventing the rise of indoor temperature and reducing energy consumption due to the cooling effect on surrounding air caused by plant production.	Panel type: USD 500-900/m^2 Mesh type (using vines): USD 50-150/m^2	V		

Note: Budget estimation for each adaptation activity is based on unit price. The total budget for adaptation activities would vary depend on the scope and area of concerns.

5.3 Suggested potential pilot project

As for demonstration of adaptation measures, potential pilot projects which could be implemented in the city hall building are presented in Table 5-2.

Table 5-2) Potential pilot project elements

Current structure	Potential improvement	Remarks
 Conventional roof and drain	 Connect roof drains to rain barrels	> For roofs with considerable large surface area, connecting roof drains to rain barrels for rainwater harvesting purposes can maximize the use of available water sources in the city.
 Conventional drain	 Rain garden	> Rain gardens can help promote groundwater recharge by means of its high infiltration capacity. It can also improve the aesthetic value of a landscape
 Conventional drainage canal	 HSSF constructed wetland	> Constructing HSSF wetlands in place of conventional drainage canals can reduce the amount of pollutants being discharged into natural streams. Since the canal is open, and stagnant water is present, it can pose a risk of harbouring disease-carrying insects. HSSF wetlands can help reduce the risk of insect breeding while helping to improve water quality.

Current structure	Potential improvement	Remarks
 Conventional planter boxes	 Tree-box filter	> Redesigning conventional planter boxes to tree-box filters is effective means of stormwater management and runoff treatment. The runoff must be redirected to the facility in order to ensure that the system serves its intended purpose.
-	 Green curtain	> Green curtain blocks solar and radiant heat in summer and prevents the rise of indoor temperature.
-	 Nano membrane system	> Nano Membrane system can remove dissolved contaminants, such as heavy metals and toxic Ions as well as remove relatively large contaminants, such as pathogens and colloids/particles.

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