



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

Climate Change Risk Assessment Guidelines

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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. Introduction

In 2018, Climate Technology Centre and Network (CTCN) initiated a Technical Assistance (TA) entitled “Development of an urban adaptation plan for Kurunegala” in response to a request from Municipal Council of Kurunegala through the Ministry of Mahaweli Development and Environment of Democratic Socialist Republic of Sri Lanka. Republic of Korea NDE (Ministry of science and ICT) decided to accept and support the TA as Pro bono. It was assigned to Korea Adaptation Center for Climate Change (KACCC) as the key implementer, which is a sub-division of the Korea Environment Institute (KEI)

The primary roles of the TA are as follows : i) identifying the current effects of climate change in Kurunegala City; ii) assessing climate change vulnerability and risk to prioritize issues (heat wave and water management); iii) proposing an adaptation action plan to address heat wave and water management and; iv) building the capacity of city planners and policy makers to transform Kurunegala City into a climate-smart city.

This report guides how to assess climate change vulnerability and risk to prioritize the issues in Kurunegala city, especially for heat wave and water management.

Risk assessments are applied to reduce future uncertainties when climate change issues are discussed among decision makers. Climate change risk assessment provides an opportunity to have a systematic and comprehensive perspective for the climate change risks. By conducting the risk assessment, adaptation policies can be prioritized as well as appropriate adaptation measures can be provided for the efficient management.

2. Literature Review

2.1 Background

There is a growing recognition that today’s policy choices are highly sensitive to uncertainties and risk associated with the climate system and the actions of decision makers. Therefore, the choice of climate policies can be considered as an exercise for the risk management (Kunreuther et al., 2013a).¹

In this chapter, we would like to enhance our understanding of risk assessment by reviewing the concept of risk and the leading international examples to manage it.

¹ https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter2.pdf

2.2 Concept of Climate Change Risk Assessment

2.2.1 IPCC

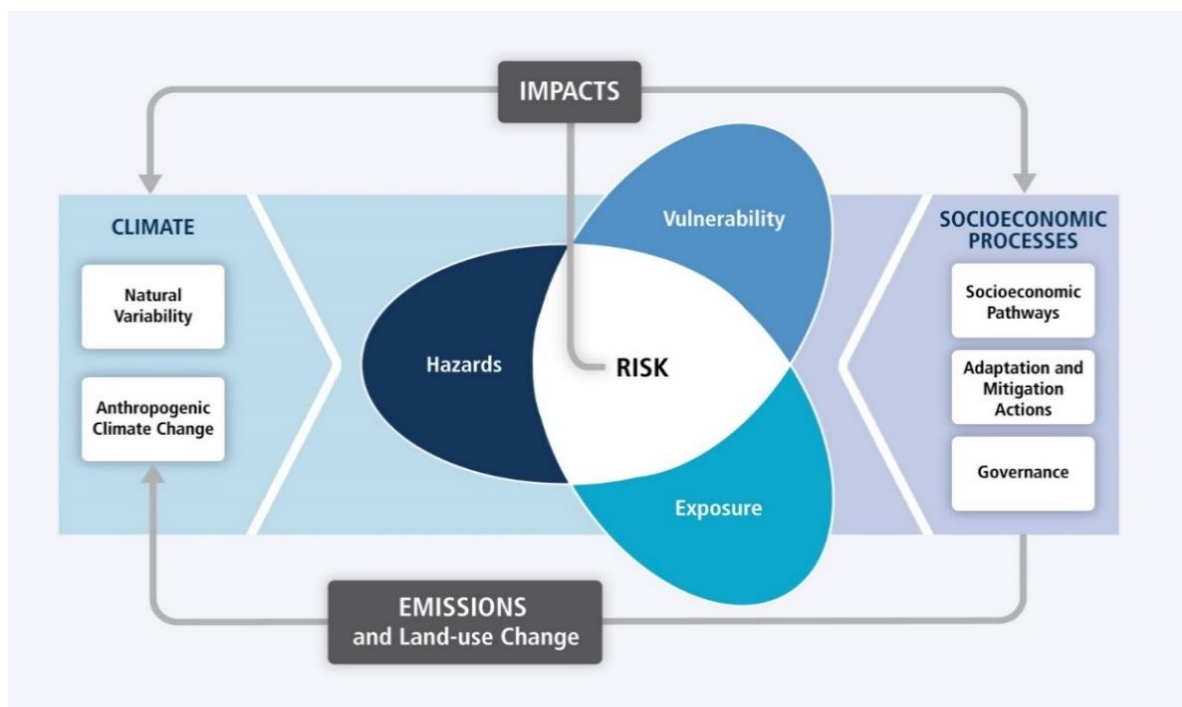


Figure 2-1) IPCC's risk

- **Risk:** According to the Fifth Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC)², risk refers to the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. The risk assessment is different by nations.
- **Hazard (Climate signal / direct physical impact):** In the IPCC report, the term hazard usually refers to climate-related physical events or trends or their physical impacts. To be specific, it includes the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impact, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.

² The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change

- **Exposure:** The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
- **Vulnerability:** The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
- **Impacts (Consequences, Outcomes):** Effects on natural and human systems. In the IPCC report, the term refers to the effects on natural and human systems of extreme weather and climate events and of climate change, also referred to as consequences and outcomes.

Box. 1-1

- **Capacity:** ‘Ability of societies and communities to prepare for and respond to current and future climate impacts’
- **Coping Capacity:** ‘The ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term’
- **Adaptive Capacity:** ‘The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences’ (e.g. knowledge to introduce new farming methods)

Table 2-1) Comparison between AR4 and AR5

	Example	AR4	AR5
External climate signal	Lack of precipitation	Exposure	Hazard
Direct physical impact	Drought	Potential impact	Hazard
Internal attributes sensitivity	Crop type	Sensitivity	Vulnerability (Sensitivity)
Internal attributes capacity	Knowledge on water management	Adoptive capacity	Vulnerability (Capacity)
Presence and relevance of exposed elements	Relevance of small-holder farming in the region	Implicitly included in sensitivity	Exposure
Final outcomes	Water scarcity for smallholder farmers	Vulnerability	Risk

2.2.2 UNISDR

2.2.2.1 Description of Indicators

The description of indicators adopted in the guideline are based on the open-ended Intergovernmental Expert Working Group (OIEWG) report to the General Assembly on Indicators and Terminology, 2016.

- **Disaster risk:** The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socioeconomic development, disaster risks can be assessed and mapped in broad terms at least. It is important to consider the social and economic contexts in which disaster risks occur and that people do not necessarily share the same perceptions of risk and their underlying risk factors.
- **Acceptable risk**, or tolerable risk is therefore an important sub-term; the extent to which a disaster risk is deemed acceptable or tolerable depends on existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or “accepted practice” which are based on known probabilities of hazards and other factors.
- **Hazard:** A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards may be natural, anthropogenic or socio-natural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Human-induced hazards are induced entirely or predominantly by human activities and choices. This term does not include the occurrence or risk of armed conflicts and other situations of social instability or tension which are subject to international humanitarian law and national legislation. Several hazards are socio-natural, in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change.
- Hazards may be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity or magnitude, frequency and probability. Biological hazards are also defined by their infectiousness or toxicity, or other

characteristics of the pathogen such as dose-response, incubation period, case fatality rate and estimation of the pathogen for transmission.

- **Multi-hazard** means (1) the selection of multiple major hazards that the country faces, and (2) the specific contexts where hazardous events may occur simultaneously, in a cascading manner or cumulatively over time, and considering the potential interrelated effects. Hazards include biological, environmental, geological, hydro-meteorological and technological processes and phenomena as mentioned in the Sendai Framework for Disaster Risk Reduction 2015-2030.
- **Exposure:** The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. Measures of exposure can include the number of people or types of assets in an area. These can be combined with the vulnerability and capacity of the exposed elements to any particular risk to estimate the quantitative risks associated with that hazard in the area of interest.
- **Vulnerability:** The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

Box. 1-2

- **Residual Risk:** the disaster risk that remains even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. The presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach.
- **National Disaster Risk:** intensive and extensive disaster risks that either have a potential (cumulative) impact that is significant and relevant for the nation as a whole and/or require national disaster risk management (DRM) coordination. Annotation: the boundaries of National Disaster Risk depend on the purpose and scoping of a national disaster risk assessment (NDRA) process. This has to be defined in each country, taking into account existing governance and DRM policies. National Disaster Risks at least include all risks that cannot be sufficiently managed at sub-national level.
- **Extensive Disaster Risk:** the risk associated with low-severity, high-frequency events, mainly but not exclusively associated with highly localized hazards.
- **Intensive Disaster Risk:** the risk associated with high-severity, mid to low-frequency events, mainly associated with major hazards.

2.2.2.2 Background

In 2016, UNISDR commissioned the development of guidelines on national disaster risk assessment (NDRA) as part of a series of thematic guidelines under its “Words into Action” initiative to support national implementation of the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030. The guidelines are the result of the collaboration between over 100 leading experts from national authorities, international organizations, nongovernmental organizations, academia, think tanks and private-sector entities. They focused on Sendai Framework’s first Priority for Action. Understanding disaster risk, which is the basis for all measures on disaster risk reduction, is closely linked to the other three Priorities for Action.

The guidelines use the classic disaster risk concept, which describes the risk in terms of likelihood and impact. This concept is based on the interaction between hazard, exposure, vulnerabilities and capacities. Although the Guidelines focus on national disaster risk assessment, many of the concepts they contain are relevant and applicable to sub-national and sector-specific assessments.

Disaster risk assessment under these guidelines aims at having holistic assessments that provide an understanding of the many different dimensions of disaster risk (hazards, exposures, vulnerabilities, capacities). The assessments can include diverse types of direct and indirect impacts of disaster – physical, social, economic, environmental and institutional. They can also provide information on the underlying drivers of risk – climate change, poverty, inequality, weak governance and unchecked urban expansion.

Box. 1-3

- **Disaster Risk Assessment:** A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend. Disaster risk assessments include: the identification of hazards; a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios.⁴

⁴ In these Guidelines, assessment of coping capacity, underlying drivers of risk, direct and indirect impact are part of understanding disaster risk

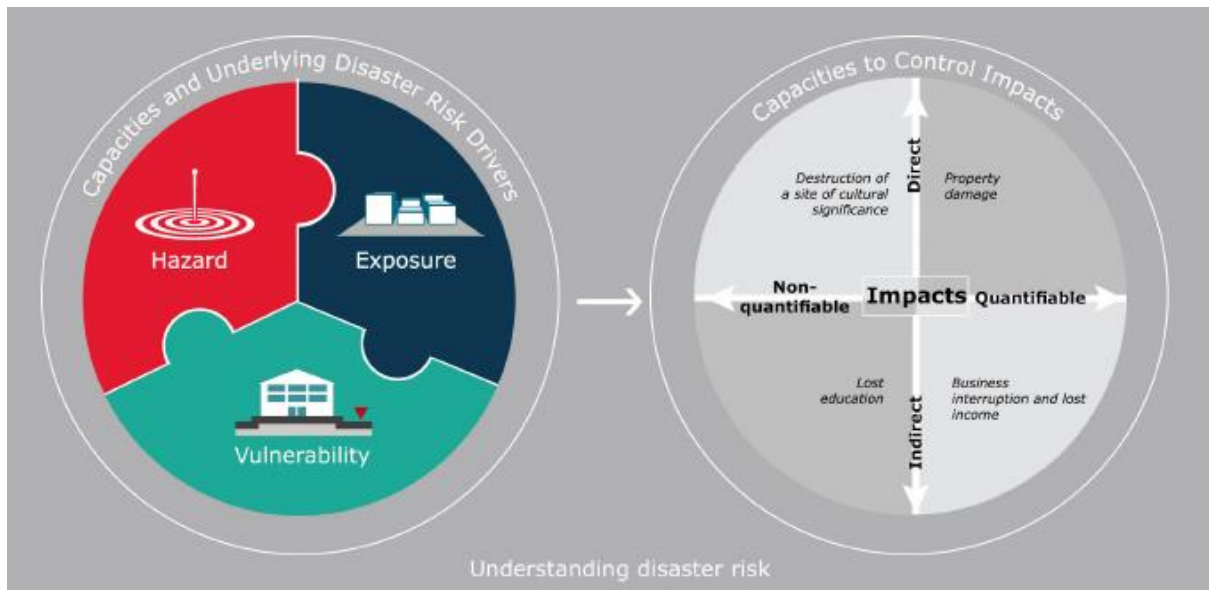


Figure 2-2) Dimensions of risk

2.2.2.3 Reasons for Indicators/Proxy Variables Selection

The reason for the indicator selection is mainly due to the focus of the guideline on Sendai Framework's first Priority for Action - *Understanding Disaster Risk*. It stated that policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment.

2.3 Case Study of Climate Change Risk Assessment

2.3.1 Atlanta, USA

2.3.1.1 Overview

- Year: 2010
- Equation: $Risk = Consequence * Probability$

2.3.1.2 Description of Indicators

The below descriptions of the indicators used for the assessment are based on the ICLEI's guidebook.⁵

⁵ Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments, 2007

- **Consequence of an Impact:** What are the known or estimated consequences (economic, ecological, social, cultural and legal) of a particular climate change impact? The estimations can be qualitative (high, medium, low) or quantitative (by attaching monetary value). Assessment of the consequence should be also a factor in the estimated scale of the impact such as the size of the population or land area affected by a projected climate change impact.
- **Probability of an Impact:** How likely is it that a projected impact will occur? Probability can be assessed qualitatively (high, medium, low) in cases where resources and information are limited and quantitatively using technical analytical techniques.

2.3.1.3 Background

Morsch (2010) provides a climate change adaptation guidance to local decision makers by identifying vulnerable planning areas in the city and assessing the risks of expected climate impacts. The analyses results determined the priority objectives for adaptation planning. Twenty-four planning areas⁶ in the nine sectors were assessed to determine their vulnerability and risk associated with the climate change. The results were also able to determine the priority planning areas for the city’s adaptation focus. In the report, a framework for subsequent adaptation planning phases were provided.

Table 2-2) 9 sectors and associated planning areas assessed

Sector	Planning Areas Assessed
Health	Air Quality; Outbreak Prevention
Water Resources	Water Quality; Water Supply
Energy	Energy Production; Energy Demand; Energy Assurance
Building Infrastructure	Stormwater Management; Building and Energy Code; Building Maintenance
Ecology	Urban Forest Management; Greenspace; Pest and Invasive Species Management
Transportation	Public Transit; Paratransit Service; Road and Bridge Maintenance; Air Transport
Public Safety	Police Services; Fire Safety; Disaster Response
Land Use and Development	Affordable Housing; Urban Planning
Materials	Residential Waste Collection

⁶ **Planning Areas:** areas which community or government determine to be the most important given their vulnerabilities to climate change and associated risks.

2.3.1.4 Risk Assessment Process

Risk assessment undertaken in this report followed the model outlined in the guidebook developed by Center for Science in the Earth System and King County. Risk assessments were conducted by estimating the consequences of climate change impact on each of the planning areas and considering the probability of an impact to occur (Risk = Consequence + Probability). In this report, probability of impact was determined by the level of certainty for the climate change based on the scientific literatures. The degree of impact was estimated through a consideration of the size of the affected population and roughly quantified point system that is shown below;

Table 2-3) Risk assessment scoring table

	1 point	2 points	3 points
A) Citizens Affected	Few	Half Atlanta Population	Entire Atlanta Population
B) Life threatening	No	Uncertain	Yes
C) Cost	Low (up to several \$ Million)	Medium (~several \$ Million - \$50 Million)	High (~\$50 Million +)
D) Probability	Uncertain	Likely (>66%)	Very Likely (>90%)

Table 2-4) Risk assessment scoring system

RISK ASSESSMENT		
DEGREE OF IMPACT OF CHANGE ON SYSTEM	PROBABILITY OF IMPACT	ESTIMATED RISK LEVEL
A + B + C	D	A + B + C + D

For example, the risk level of water quality to climate change was found to be high as per the table below.

Table 2-5) Water quality risk assessment

WATER QUALITY RISK ASSESSMENT		
DEGREE OF IMPACT OF CHANGE ON SYSTEM	PROBABILITY OF IMPACT	ESTIMATED RISK LEVEL
Citizens Affected: All (3) Life-threatening: Uncertain (2) Costs: High (3)	Very Likely (3)	11 Points: High

- A planning area with **10-12** risk points was deemed high risk.
- A planning area with **7-9** risk points was deemed medium risk
- A planning area with **4-6** risk points was deemed low risk

2.3.2 Melbourne, Australia

2.3.2.1 Overview

- Year: 2009
- Equation: *Risk = Consequence + Likelihood*

2.3.2.2 Risk Assessment Process

The risks were assessed with three different points categorized by time length. These are short term (in the next two to three years), medium term (by 2030) and long term (by 2070). It is helpful to analyse any potential changes to the level of risk to the municipality over time.

The City of Melbourne (2009) uses a '5+5' combined risk rating index (consequence + likelihood). For the effective risk management, it is recommended that these combined risk rating is plotted against the control effectiveness at five scale.

The risk matrix below is used to plot the risk according to their risk rating and control effectiveness. The risk management priority is then determined in line with the matrix quadrant they located in it.

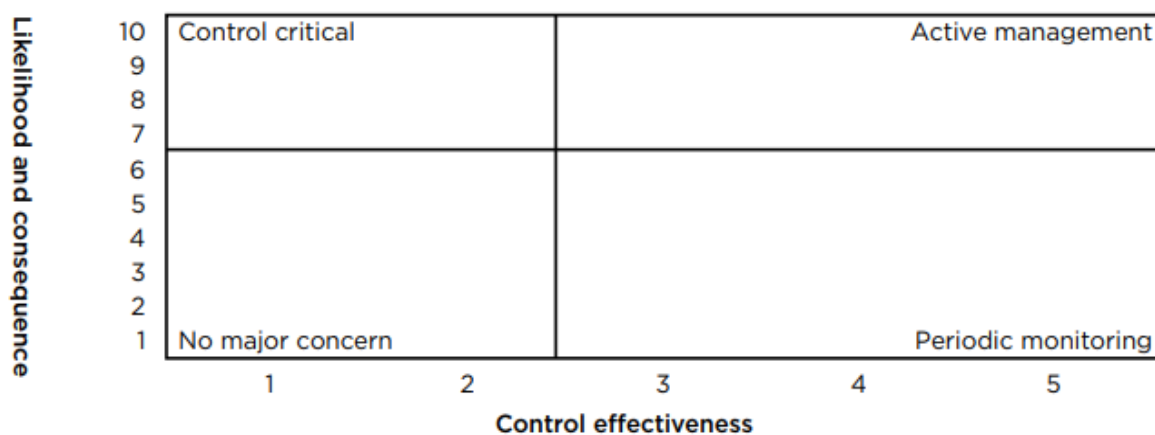


Figure 2-3) The risk matrix

Risks in the quadrants are described as below:

- **No major concern** – (Combined risk rating of 6 or less and control measure rating of 1 to 2) risks in this quadrant are generally of no concern and management consists of periodic re-evaluation, including underpinning assumptions, to ensure conditions are the same.

- **Periodic monitoring** – (Combined risk rating of 6 or less and control measure rating of 3 to 5) risks in this quadrant are generally unable to have control measures that can suitably minimise the risk, and are therefore monitored accordingly to ensure organisational awareness and preparedness.
- **Control critical** - (Combined risk rating of 7 to 10 and control measure rating of 1 to 2) risks in this quadrant are considered of enough likelihood and consequence to be a concern however have a control measure that is considered effective and vital to their appropriate mitigation.
- **Active management** - (Combined risk rating of 7 to 10 and control measure rating of 3 to 5) risks in this quadrant should be of the highest priority to all concerned. These risks are of sufficient likelihood and consequence to be above the risk threshold and have unacceptable level of control.

2.3.2.3 Control Effectiveness

Risks were assigned with 5 scale rating for the known control measures currently in place to monitor or mitigate their occurrence. 1 is considered well controlled and 5 is considered uncontrolled. Critical risks with control measures rated 1 or 2 were considered ‘control critical’ and require strong management, ongoing monitoring and auditing of the control measure. Critical risks with control measures of 3 or higher are considered to be in ‘active management’ and require priority assessment and active response.

Table 2-6) City of Melbourne risk likelihood ratings

Likelihood	Number	Description
Almost Certain	5	The event is expected to occur in most circumstances
Likely	4	The event will probably occur in most circumstances
Possible	3	The event should occur at some time
Unlikely	2	The event could occur at some time
Rare	1	The event may occur only in exceptional circumstances

Table 2-7) City of Melbourne risk consequence ratings (1)

Consequence Category		Business Continuity	Environmental	Financial and Economic	People and OHS
Catastrophic	5	The continuing failure of the City of Melbourne or major service providers to deliver essential services. The removal of key revenue generation.	Catastrophic and irreversible environmental damage attributed by the courts to the negligent or incompetent actions of the City of Melbourne.	Above \$20,000,000 (calculated as approximately 10% of the City of Melbourne's annual revenue before tax)	Multiple fatalities (more than five persons) and significant irreversible disabilities.
Major	4	Widespread failure to deliver several major strategic objectives and service plans. Long-term failure of major service provider causing lengthy service interruption.	Long-term and widespread environmental damage taking greater than 5 years to recover and requiring significant restorative work.	\$2,000,000 to \$20,000,000	Single or multiple fatalities and multiple irreversible disabilities.
Moderate	3	Failure to deliver minor strategic objectives and service plans. Temporary and recoverable failure of service provider causing intermittent service interruption for a week.	Significant environmental damage taking several years to recover and requiring moderate restoration work.	\$200,000 to \$2,000,000	Multiple irreversible disabilities and/or critical long-term injuries.
Minor	2	Temporary and recoverable failure of service provider causing intermittent service interruption for several days.	Minor environmental damage such as remote temporary pollution.	\$20,000 to \$200,000	Single or multiple disabilities requiring short to mid term hospitalisation/ medical aid.
Negligible	1	Negligible impact on business processes, brief service interruption for several hours to a day.	Brief, non hazardous, transient pollution or damage.	Up to \$20,000	Injuries requiring minimal temporary first aid.

Table 2-8) City of Melbourne risk consequence ratings (2)

Consequence Category	Reputation	Infrastructure and Assets	Political	Liability	
Catastrophic	5	Loss of support of the State Government with scathing criticism and removal of the Council. International media exposure.	Long-term loss of Town Hall, CH1, CH2 or CBB, including damage to the City of Melbourne assets such as IT infrastructure etc.	Loss of power and influence restricting decision making and capabilities. Dismissal of the Council by State Government.	Regulatory or contract breaches causing very serious litigation, including major class action. Significant prosecution / fines for the City of Melbourne and individuals.
Major	4	Public and National media concern / exposure with adverse attention and long-term loss of support from the City of Melbourne residents.	Short to mid term loss of Town Hall, CH1, CH2, or CBB. Damage to the City of Melbourne assets.	Major adverse impact and intervention by Commonwealth and State Government.	Major regulatory or contract breaches and litigation. Liability implications and fines for Directors/Managers.
Moderate	3	Significant statewide concern / exposure and short to mid term loss of support from the City of Melbourne residents.	Damage to one part of a major facility or many parts / all of a small facility.	Moderate adverse impact and intervention by State Government.	Regulatory or contract breaches causing investigation / report to authority and prosecution and moderate fines.
Minor	2	Minor local community concern manageable through good public relations.	Damage to internal assets, system etc. Isolated to a part of a facility.	Minor adverse impact and intervention by Local Government Authorities and Municipal Association of Victoria.	Minor regulatory or contract breaches causing likely prosecution and minor fines.
Negligible	1	Transient matter, such as customer complaint, resolved in day-to-day management.	Minor property damage such as storm, criminal, accidental, no internal asset damage.	Negligible impact from one Local Government Authority.	Negligible regulatory breaches that are detected early and rectified. Insignificant legal issues and non compliance.

2.3.3 Vancouver, Canada

2.3.3.1 Overview

- **Year:** 2012
- **Equation:** *Risk = Likelihood * Consequence*

2.3.3.2 Description of Indicators

- **Risk:** a function of the likelihood and consequence of an impact.
- **Likelihood:** the probability of the projected impact occurring.

- **Consequence:** the known or estimated effects (economic, ecological, social or legal) of a particular impact.

2.3.3.3 Risk Assessment Process

- **Likelihood:** The first step is to determine the likelihood. The City of Vancouver (2012) characterized the impact as a single event (windstorm) or a recurring event (increasing annual rainfall). A likelihood rating from 1 to 5 was then assigned where 1 is “rare” and 5 is “almost certain”.
- **Consequence:** The second step of a risk assessment is to evaluate the consequence of an impact. Using a relatively common risk assessment matrix, Vancouver looked at how the impacts would affect five areas: public safety, local economy and growth, community and lifestyle, environment and sustainability, and public administration. Matrix ratings ranging from 1(negligible) to 5(catastrophic). The sum of all the consequence values was then totalled to give the overall impact and consequence rating.

The consequence and likelihood are then multiplied to obtain a risk rating on the following scale. According to the risk results, all impacts are within the low to medium range, with the majority being medium-low and medium risks. No high risk impacts were identified given the rating matrix



Figure 2-4) Risk assessment ranking scale

Impact Statement	Consequence Rating					Consequence Total /25	Likelihood Rating /5	Risk Score /125
	Public Safety	Local Economy and Growth	Community and Lifestyle	Environment and Sustainability	Public Administration			
Water supply shortages felt in late summer due to a decreased spring snow pack and higher summer temps influencing greater draw downs and evaporation could result in increased costs for water and imperative conservation measures	1	2	3	2	2	15	3	45
Increased health and safety risks to vulnerable populations during extreme heat events	4	1	1	1	1	8	4	32
Increased surface water flooding from ponding of rainfall in low lying areas or heavy rainfall overcoming the capacity of drainage system	2	2	2	2	2	10	5	50
Increase in number of combined sewer overflows	2	2	2	3	2	11	4	44

Figure 2-5) Example of risk assessment

2.3.4 Kenya

2.3.4.1 Overview

- **Year:** 2012
- **Equation:** *Risk = Likelihood * Consequence*

2.3.4.2 Background

The effects of climate change on Kenya’s social, environmental and economic systems were reviewed by LTS International & Acclimatise (2012). In the report, risks and opportunities were identified from a desk-based review using peer-reviewed and grey literature together with national communications, technology needs assessment report, and other relevant national planning documents.

2.3.4.3 Risk Assessment Process

Risk is defined as the “combination of the probability (likelihood) of an event and its consequences” ($Risk = Likelihood * Consequence$)

Risks were rated with the assumption that no additional adaptation measures are in place to address climate change. This allows for the government to consider how significant the risks of climate change could be if no action is taken on adaptation.

2.3.4.4 Likelihood

The rating method considered the probability of the climate-related impact occurring out to the 2050s as outlined in the table below. The 2050s was chosen as a reference point because the vast majority of reviewed literatures including climate projections and impact models selected this year.

A	B	C	D	E
Extremely unlikely	Unlikely	About as likely as not	Likely	Extremely likely
Event not expected to occur, but possible (<5% probability of occurrence per year in 2050s)	Event unlikely to occur, but not negligible (5-33% probability of occurrence per year in 2050s)	Event less likely than not, but still appreciable chance of occurring (33-66% probability of occurrence per year in 2050s)	Event more likely to occur than not (66-95% probability of occurrence per year in 2050s)	Event highly likely to occur (>95% probability of occurrence per year in 2050s)

Figure 2-6) Likelihood scoring criteria

2.3.4.5 Consequence

The rating method was based on a qualitative assessment of the severity of consequence of the climate-related impact. Consequence criteria were developed for six-grouped themes anticipated to experience the greatest impacts caused by climate change (See table below). Where possible, the criteria draw upon internationally recognised scales, such as the USAID Famine Early Warning Systems Network (FEWNET)⁷. In the case where a reference system was unavailable, the authors can use their expert judgement and experience to devise a risk assessment system that fit into the local context. If the several sub-components were specified, each individual bullet-point did not need to be applicable for a risk to be assigned that score.

2.3.4.6 Economic quantification

These monetary estimates include both historical analogues (i.e. based on past climate-related events, such as El Niño and La Nina- induced flood and drought in 1997-1998 and 1999-2000, respectively) and future annual projections. In combination with government-provided estimates, the monetary values outlined in the risk assessment report were mainly based on two major economic assessments, which are multi-sectoral and country-wide

Table 2-9) Consequence criteria (World Bank, 2006; SEI, 2009).

Consequence severity	Economic Pillar / Agriculture, Livestock and Fishing	Economic Pillar / Manufacturing / Wholesale, Retail and International Trade / Tourism	Social Pillar / Environment, Water and Sanitation	Social pillar / Health / Population, Urbanisation & Housing / Gender, Vulnerable Groups & Youth / Education & Training	Foundations for national transformation / Infrastructure	Foundations for national transformation / Security, Peace Building and Conflict Resolution
1	<ul style="list-style-type: none"> • Slight losses of annual production and/or livestock covered by normal contingency allocations. • Livelihood: Non-stressed. • Phase 1: No Acute Food Insecurity. 	<ul style="list-style-type: none"> • Slight losses covered by normal contingency budgets and or slight disruption to business continuity. • Slight loss in competitiveness and reduction in trade. 	Slight impact: Temporary with recovery in less than one season	<ul style="list-style-type: none"> • Slight increase in the number of reported cases of illness and disease. • Unchanged mortality rates. • No consequences for educational development. 	Slight damage: Repairable with no disruption to operations / performance	Slight impact: Low-level and short-term social instability. No intervention required by local government.
2	<ul style="list-style-type: none"> • Minor losses of between 2% and 10% of annual production and/or livestock. • Livelihood: Stressed. 	<ul style="list-style-type: none"> • Minor losses of between 2% and 10% of annual profits and/or minor disruption to business continuity. 	Minor impact: Short term with recovery in less than 5 years	<ul style="list-style-type: none"> • Minor increase in the number of reported cases of illness and disease. • Unchanged mortality rates. 	Minor damage: Repairable with disruption to up to 2% to 10% of operational capacity / performance	Minor impact: Minor medium-term social instability on small number of people. Intervention

⁷ <http://www.fews.net/ml/en/info/pages/scale.aspx>

	<ul style="list-style-type: none"> Phase 2: Stressed Food Insecurity. 	<ul style="list-style-type: none"> Minor loss in competitiveness and reduction in trade. 		<ul style="list-style-type: none"> Minor consequences to educational development. 		required by local government.
3	<ul style="list-style-type: none"> Moderate losses of between 10% and 25% of annual production and/or livestock. Livelihood: Accelerated depletion. Phase 3: Crisis Food Insecurity. 	<ul style="list-style-type: none"> Moderate losses of between 10% and 25% of annual profits and/or moderate disruption to business continuity. Moderate loss in competitiveness and reduction in trade. 	Moderate impact: Medium term with recovery in between 5 and 10 years	<ul style="list-style-type: none"> Moderate increase in the number of reported cases of illness and disease. Marginal increase and unstable mortality rates. Moderate consequences for educational development. 	Moderate damage: Repairable with disruption to between 10% and 25% of operational capacity / performance	Moderate impact: Moderate medium-term social instability or frequent social issues. Intervention required by local government.
4	<ul style="list-style-type: none"> Major losses of between 25% and 50% of annual production and/or livestock. Livelihood: Irreversible depletion. Phase 4: Emergency Food Insecurity. 	<ul style="list-style-type: none"> Major losses of between 25% and 50% of annual profits and/or major disruption to business continuity. Major loss in competitiveness and reduction in trade. 	Major impact: Long term with recovery in more than 10 years	<ul style="list-style-type: none"> Major increase in the number of reported cases of illness and disease. Significant increase in mortality rates. Major consequences for educational development. 	Major damage: Repairable with disruption to more than 25% and 50% of operational capacity / performance	Major impact: Extensive long-term social instability and migration. Intervention required by government and NGO's.
5	<ul style="list-style-type: none"> Catastrophic losses of more than 50% of 	<ul style="list-style-type: none"> Catastrophic losses of more than 50% of 	Catastrophic impact: Irreversible,	<ul style="list-style-type: none"> Catastrophic increase in the number of 	Catastrophic damage: Complete or near complete	Catastrophic impact: breakdown of

	<ul style="list-style-type: none"> annual production and/or livestock. Livelihood: Near complete collapse. Phase 5: Catastrophe Food Insecurity 	<ul style="list-style-type: none"> annual profits and/or permanent disruption to business continuity. Massive loss in competitiveness and reduction in trade. 	permanent loss	<ul style="list-style-type: none"> reported cases of illness and disease. Catastrophic increase in mortality rates. Massive consequences for educational development. 	failure. More than 50% of operations compromised.	social order, resulting in conflicts and cross-border migration. Armed intervention by national and international forces.
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2.3.4.7 Ranking

Once individual risks were rated based on their likelihood of occurrence and severity of consequence, the complete aggregated list and individual thematic lists were then ranked with very high likelihood and critical impact at the top of the list as shown below.

CONSEQUENCE SEVERITY	LIKELIHOOD				
	A	B	C	D	E
	Extremely unlikely	Unlikely	About as likely as not	Likely	Extremely likely
	Event not expected to occur, but possible (<5% probability of occurrence per year in 2050s)	Event unlikely to occur, but not negligible (5-33% probability of occurrence per year in 2050s)	Event less likely than not, but still appreciable chance of occurring (33-66% probability of occurrence per year in 2050s)	Event more likely to occur than not (66-95% probability of occurrence per year in 2050s)	Event highly likely to occur (>95% probability of occurrence per year in 2050s)
1					
2					
3					
4					
5					

Figure 2-7) Likelihood of occurrence and severity of consequence

Low	Medium	High	Serious
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Figure 2-8) Magnitude of risk

2.3.5 Republic of Korea

2.3.5.1 Overview

- **Year:** 2007, Based on AR4
- **Area:** Heat wave
- **Equation:** $Vulnerability\ Index = \alpha * Climate\ Exposure\ Index + \beta * Sensitivity\ Index - \gamma * Adaptive\ Capacity\ Index$ (α, β, γ : weighting factor)

2.3.5.2 Description of Indicators

- **Climate Exposure:** It refers to climate stimuli that affect systems. The climate exposure proxy variables were extracted from RCP 4.5 and 8.5 scenarios that were

refined based on the HadGEM2 model and the climate projection model from the UK Met Office including future climate change projections such as mean temperature. Climate exposure proxy variables are indices associated with actual and effective temperatures of heat waves including the duration and annual average value of daily maximum temperature.

- **Sensitivity:** It indicates a system that responds sensitively to climate stimuli. Proxies for sensitivity includes health, age, population, and regional productivity. Sensitivity proxy variables are indices associated with vulnerable populations of those sensitive to heat waves such as people aged 14 or younger, and those aged 65 or older. The number of deaths caused by heatstroke and sunstroke were included as sensitivity proxy variables as these variables reflect the direct effects of a heat wave.
- **Adaptive Capacity:** It is the ability of a system to adjust to climate stimuli. Its proxy variables include indices associated with healthcare systems and socioeconomic factors. Adaptive capacity proxy variables included gross regional domestic product (GRDP), financial independence, and the number of emergency medical centers.
- **Weighting factor:** weighting factors were determined using both the principle component analysis (PCA) and analytic hierarchy process (AHP) based on previous studies conducted by the Korea Environmental Institute (KEI) and the National Institute of Environmental Research (NIER). These studies include Development and application of a methodology for climate change vulnerability assessment-Sea level rise impact on a coastal city; Development and Application of a Climate Change Vulnerability Index and; Climate Change Vulnerability Maps for Local Climate Change Adaptation Planning.

2.3.5.3 Background

Vulnerability Assessment Tool to build Climate Change Adaptation Plan (VESTAP) can be used to evaluate Korea's vulnerability to major climate impacts (Oh et al, 2017). VESTAP is based on RCP 4.5/8.5 scenarios and can provide evaluation results in 10-year intervals from the 2010s to 2040s. VESTAP, constructed using a GIS system, was based on 7 categories and 32 vulnerability conditions. A case study focusing on health vulnerability assessment associated with heat waves was carried out and the results were analysed in the level of administrative district. Climate change vulnerability was assessed based on the methods defined in the IPCC's Fourth Assessment Report (AR4) that explain a residual impact of climate change after adaptation.

2.3.5.4 Reasons for Indicators/Proxy Variables Selection

After reviewing the several reports and articles as well as conducting expert review through 3 levels of expert questionnaire for AHP analysis method, it seems that they adequately encompass the climate exposure, sensitivity, and adaptive capacity of Korea

2.3.6 Copenhagen, Denmark

2.3.6.1 Overview

- Year: 2011
- Equation: $Risk = Probability * Costs\ of\ event$

2.3.6.2 Risk Assessment

Risk can be understood as a meaning of the probability of an event happening times the costs of the event. ($Risk = Probability * Costs\ of\ event$)

Table 2-10) The risk matrix

	COST	Low	Medium	High
PROBABILITY				
Likely		Risk can be tolerated	Risk can be tolerated	Moderate risk
Likely		Risk can be tolerated	Moderate risk	Risk cannot be tolerated
Very likely		Moderate risk	Risk cannot be tolerated	Risk cannot be tolerated

For the calculation of risk used to prioritise the actions, it should be normalised so that different threats can be compared. This can be done by calculating the combined public risk on a ten-year basis over a hundred-year period. This is compared with a simple assessment criterion divided into levels as shown in the table below.

Table 2-11) Ten year risk in DDK million

Ten-year risk in DDK million	0 - 500	501 - 1500	> 1500
Assessment criterion	Low risk	Medium risk	High risk

2.4 Risk & Vulnerability Assessment Methodologies and Approach

The tools and methodologies of the risk and vulnerability assessment are well presented by some institutions. Examples of the toolboxes and collections of methods can be found in Annex A.

2.5 Gender Inclusive Climate Change Adaptation

Overview of the key concepts of gender

According to the NEST (2011), the term of 'gender' describes the socially constructed roles and responsibilities of men, women, boys and girls, whose role may vary over time and by location.¹⁰ 'Gender roles' refers to different learned behaviour that are expected from women and men. The concept of gender is important as it can reveal how women's and men's roles are determined by social values and therefore can be flexible depending on the situation they are in.

Climate change

Climate change could have the potential and extensive impacts. For example, changing rainfall patterns occurred by climate change can lead to food insecurity and loss of livelihoods as well as cause out-migration by men seeking other forms of income. This migration could increase the burden of women left with their children in the villages. But women in developing countries have an essential role to play in the natural resource management and have special knowledge of linkages in fragile ecosystems. Therefore, the gender involves the issue of how the different sex shapes vulnerability and adaptation to climate change impacts.

Gender inclusive climate change adaptation

Climate change and gender inequality are inextricably linked in that they both create obstacles to achieve poverty reduction and development goals (Aguilar, 2008).¹¹ Both climate change and gender inequality aggravate the impacts of climate change. Moreover, women's vulnerability to climate change is getting worse by a lack of necessary policies and regulations to address it. Therefore, the attempts to ensure gender equality can help to reduce the impact of climate change.

Approaches and policy development to address climate change have primarily focused on technical and scientific measures. Therefore, those efforts less consider the ways in which political decisions and economic environments influence the response of women and men, or the social implications on the lives of women and men.

Tools to ensure gender integration in climate change projects

The collection of primary data presents the best opportunities for gender-based research. Methods of primary data collection include:

¹⁰ NEST (2011), Gender and Climate Change Adaptation: Tools for Community-level Action in Nigeria, Nigerian Environmental Study/Action Team (NEST), Building Nigeria's Response to Climate Change (BNRCC) Project

¹¹ Aguilar, L. (2008). Gender perspectives on climate change, 52nd Session of the Commission on the Status of Women. New York, 25 February - 7 March 2008. Available at: http://www.gdonline.org/resources/Aguilar_CSWgender-climatechange.pdf

1. Administration of questionnaires;
2. Interviews with key knowledge holders;
3. Holding focus group discussions;
4. Participant and non-participant observation;
5. Other participatory techniques.

The aims of the gender assessment are to reinforce the linkages between community knowledge & practice and research & science to provide the necessary background for setting the municipal policies on climate change adaptation.

3. Indicator-based Approach Assessment

3.1 Background and Purpose

Climate change risk is a comprehensive concept of hazard, exposure and vulnerability, which is hard to be quantified in practice. Studies were conducted to quantify the risk of climate change which can be interpreted as a qualitative concept. The indicator-based risk methodology using variables was presented. Variables can be a tool that enables the visibility of a qualitative phenomenon with measurable information. This information reflects the concept of risk. Variables of the risk concept can be presented as a quantifiable indicator. The purpose of the indicator-based risk assessment is to identify the most vulnerable areas and problems by conducting quantitative data analysis.

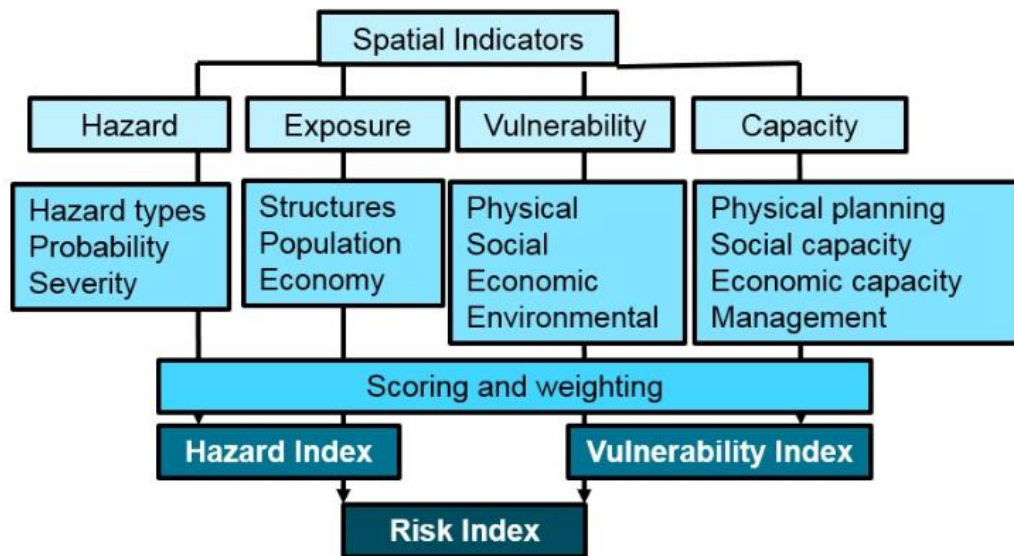


Figure 3-1) Indicator-based approach

3.2 Assessment Process

- **Step 1: Set objective and scope of risk assessment**

As the first step, the main and minor objectives of the risk assessment need to be provided and the scope of the risk assessment should be defined.

In this technical assistance, the target area for risk assessment is Kurunegala. The water management and heat stress are the major topics that will be evaluated.

- **Step 2: Selection of conceptual framework**

In the second step, it is necessary to select of the most representative conceptual framework from all the available risk assessment models.

The factors of hazard, exposure, and vulnerability increase the level of risk while the one of adaptive capacity reduce it. Therefore, this concept should be presented in conceptual framework. There are a list of models and frameworks applied for risk assessment. The users need to decide the most appropriate ones that fits their interests and the subject of concerns.

Davidson/Bollin Disaster Risk Model (Davidson, 1997; Bollin et al.,2003)

$$\text{Risk} = \text{Hazard} + \text{Exposure} + \text{Vulnerability} - \text{Coping Capacity}$$

UNISDR Model

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}$$

IPCC Model

$$\text{Vulnerability} = (\text{Exposure} \times \text{Sensitivity}) / \text{Capacity}$$

Rana & Routray Model (Rana & Routray, 2016)

$$\text{Risk} = (\text{Hazard} \times \text{Exposure} \times \text{Sensitivity}) / \text{Capacity}$$

Risk Assessment Framework (KEI)

According to the risk assessment framework of the IPCC AR5 (2014) and UNISDR (2017), the framework can be revised as below. This framework is updated based on the risk assessment in Copenhagen (2011) and Vancouver (2012).

$$\text{Risk} = \frac{\text{Hazard} \times \text{Exposure} \times \text{Vulnerability}}{\text{Capacity}} = \text{Hazard} \times \frac{\text{Impact} *}{\text{Capacity}}$$

* $\text{Impact} = \text{Exposure} \times \text{Vulnerability}$

(Constraint: $w_H = w_V = w_E$)

- **Step 3: Review of available data and selection of indicators**

Reliability of the risk calculation highly depends on information availability. Appropriate indicators should be selected systematically by reviewing past literatures as well as having experts discussion and consultation.

In this technical assistance, considering local context of risk and geographical characteristics, the possible indicators of risk assessment are selected by Kurunegala Municipal Council (KMC). Then, the selected indicators are reviewed by risk assessment experts in Korean Environment Institute (KEI). A final list of indicator for quantitative analysis of risk assessment in Kurunegala is as below:

1. Drinking water resources risk/vulnerability to drought
2. Water management risk/vulnerability
3. Water quality and aquatic ecosystem risk/vulnerability
4. Water resources risk/vulnerability
5. Sanitation risk/vulnerability of drought and flood
6. Health risk/vulnerability to flood
7. Health and infrastructure risk/vulnerability to heat stress

A list of indicators and associated factors are included in the Annex B of this report.

Table 3-1) Quantifiable factors for ‘Drinking water resources risk/vulnerability to drought’ indicator

Hazard	Consecutive dry days
	Occurrence of extreme rainfall anomalies - Stranded Precipitation Index (SPI)
	Change in maximum temperature
	Monthly Average Evaporation
Exposure	Population Density
	Tax Units
	Population receiving government assistances
	Livestock population
Vulnerability	Number of female lead house holds
	Tax units which haven't secondary water sources
	Monthly water usage
	Number of house-hold who are getting medicine through regular clinic
Capacity	Water supply ratio
	Bowser water supply
	Access to information
	Number of water bottles used(purchased) per day
	Availability of secondary water source
	Tax amount
	Number of hospitals, day care, schools

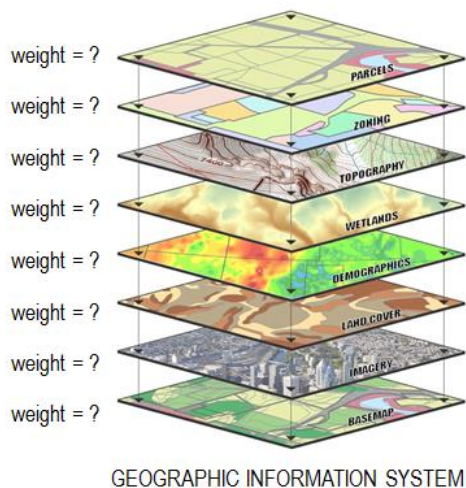
- **Step 4: Data collection & Standardization**

After completing the selection of indicators, input data must be collected, collated, converted (into shapefile or raster file), resampled and standardized. If the data is unavailable, it is required to go back to the step 3 to find out alternative indicators.

Since the data were collected in various ways, formats and quantitative measures, pre-processing is necessary to standardize the collected data. In MCDM, standardization is needed to obtain a same scale since the indicators have different units of quantitative measurements. There are several standardization methods such as fuzzy logic concept, vector normalization, and logarithmic normalization. However, in this research, the z-score standardization technique was used due to its simplicity and reliability.

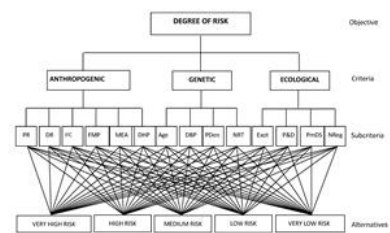
Most of the collected data were facts and values from reports of government agencies and questionnaire. These administrative data were converted into a shapefile format. Then, the shapefile was transformed into a 10m grid raster. Other necessary pre-processing steps such as resampling (used to ensure the consistency in grid sizes) and extraction (used to change the extent of work) were used whenever necessary.

In this technical assistance, the data was collected based on the Ward/Grama Niladhari Division (GND) divisions in the Kurunegala Municipal Council Area-(12 GND). Several necessary data were unavailable. Hence, multiple alternative indicators that can replace them were considered.



AHP

ANALYTICAL HIERARCHY PROCESS



AHP has the advantage of permitting hierarchical structure of the criteria, which provides users with a better focus on specific criteria and sub-criteria when allocating weights

Figure 3-2) GIS & AHP

- **Step 5: Risk calculation and assessment**

In the calculation, weighting should be set for each indicator. Several multicriteria decision methods are available to calculate the weights for each criterion. Among a number of weighting methods, AHP is a most widely used method for the risk assessment.

AHP is experts' evaluation via survey, and it includes construction of pairwise matrix, determination of experts' individual consistency ratio, integration of experts' opinion (Geometric Mean) and calculation of weight coefficients.

3.3 Gender Inclusive Analysis

To mainstream gender issue into climate change adaptation policy, it should be included in quantitative analysis for risk assessment.

In this technical assistance, gender-related issues are assessed by including associated indicators in the 'vulnerability' (see Annex B) as we consider this issue seriously.

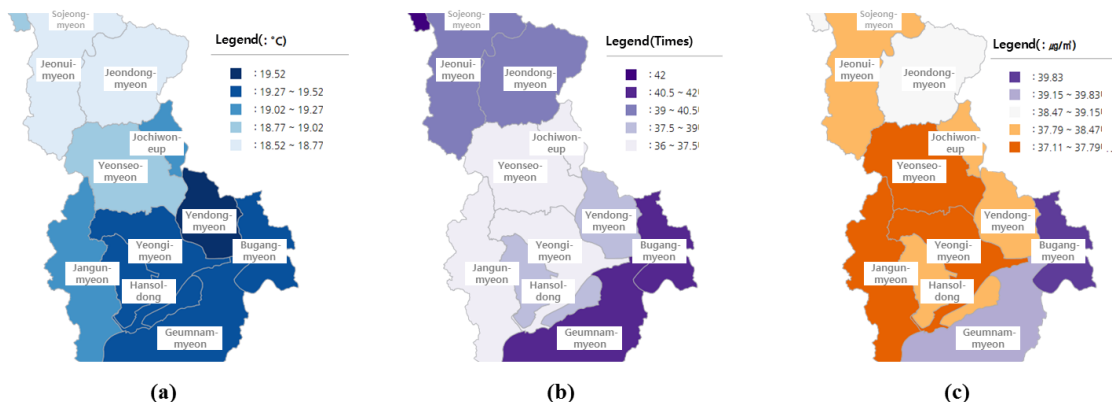
3.4 Expected Result

The outcome of the quantitative analysis are produced using GIS. Such results will be used as a baseline evidence for the climate change adaptation plan in the city of Kurunegala.

Example of GIS analysis result

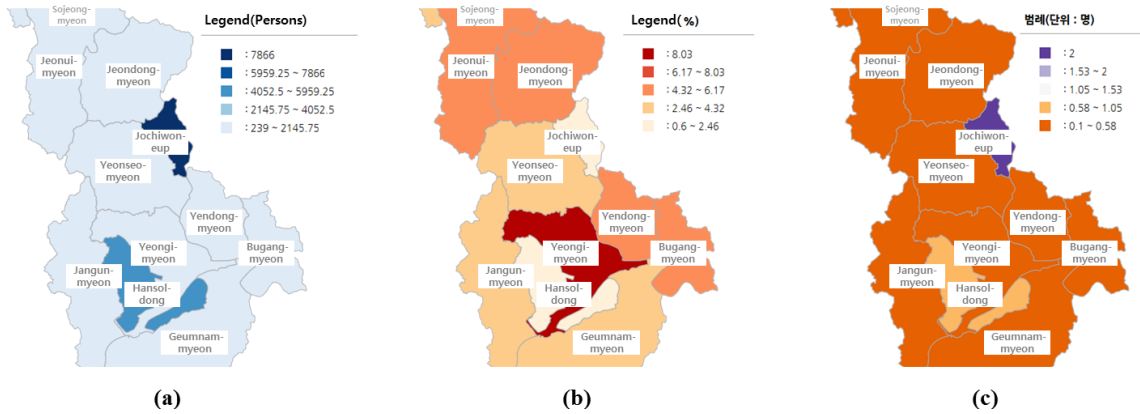
* This case is health vulnerability assessment based on AR4 in Sejong Metropolitan Autonomous City.

Climatic exposure impacts



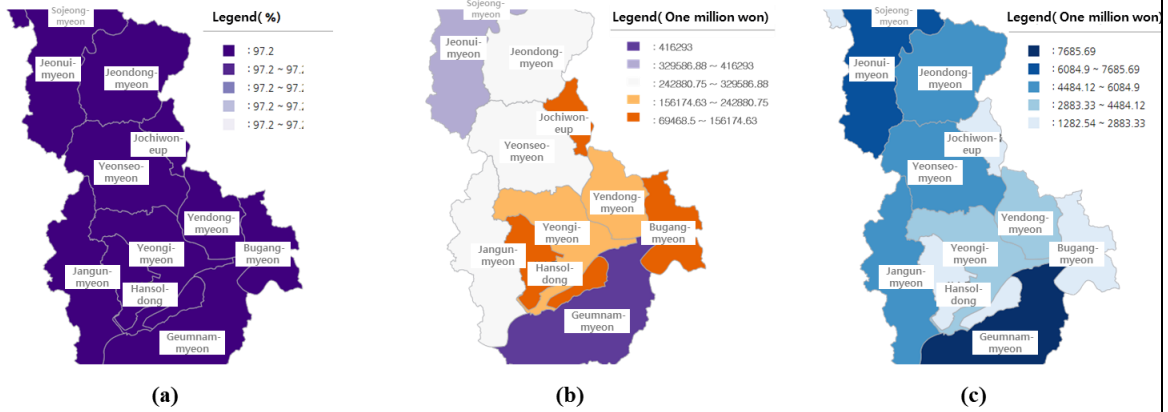
(a) Annual average of daily maximum temperature, (b) Number of times that fine dust concentration is 100ug/ m³ or more days, (c) Annual average concentration of fine dust

Sensitivity impacts



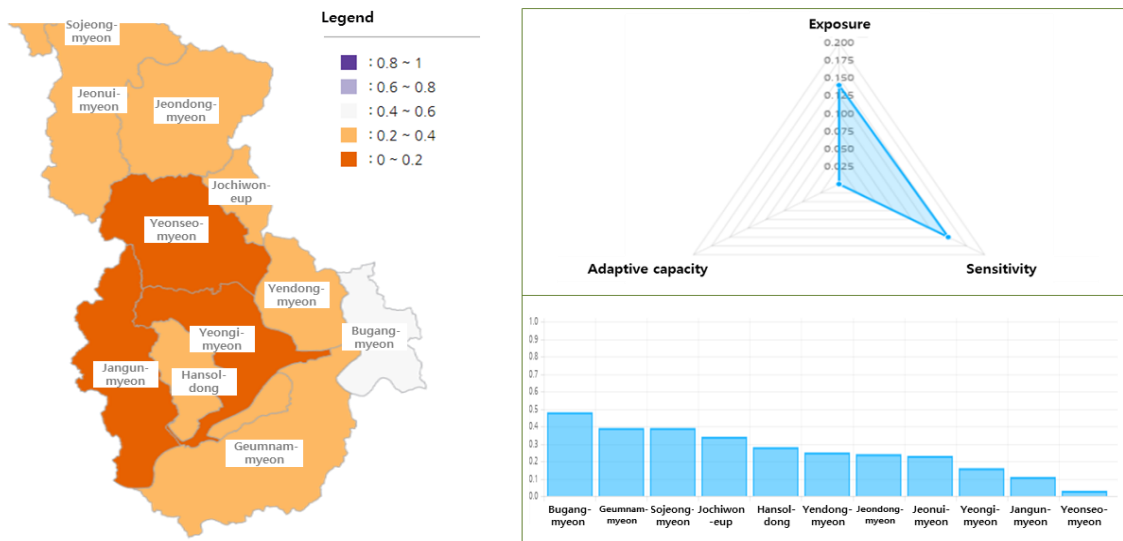
(a) Population under 14 years old, (b) Elderly people living alone (aged 65 and over) Rate, (c) Number of patients hospitalized respiratory disease

Adaptive capacity impacts



(a) Health Insurance Coverage population ratio, (b) Regional GDP, (c) GRDP Healthcare and Social Services

Health vulnerability assessment result



Final vulnerability assessment result can be produced by overlapping of each impact factor maps.

4. Survey-based Approach Assessment

4.1 Background and Purpose

The purpose of the survey-based approach assessment is to prioritize risk factors. It is based on expert's intuition and present the current problems on water scarcity and heat stress in Kurunegala. A major advantage of the qualitative analysis is to collect data from experts, which cannot be identified using statistical method.



Figure 4-1) Risk management international standard

4.2 Assessment Process

- **Step 1: Establish the context**

In this technical assistance, the target area for risk assessment is Kurunegala. The water management and heat stress are the major topics that will be evaluated based on the stakeholder's feedback and field observations.

- **Step 2: Identify the risks**

Before identifying the most serious risk factor associated with water management and heat stress, a risk indicator (a group of risk factors) should be set up. The KEI introduced a list of the indicators used in the Republic of Korea for the risk assessment. Risk indicators were listed as below:

1. Water resources risk/vulnerability
2. Water management risk/vulnerability

3. Water quality and aquatic ecosystem risk/vulnerability
4. Health and infrastructure risk/vulnerability to heat wave
5. Health risk/vulnerability to flood

As local context is a vital element in assessing climate change risk and vulnerability, KMC reviewed indicators used in the Republic of Korea. Based on comments from water and health experts in Kurunegala, KMC amended indicators for risk assessment in Kurunegala as below:

1. Drinking water resources risk/vulnerability to drought
2. Water management risk/vulnerability
3. Water quality and aquatic ecosystem risk/vulnerability
4. Water resources risk/vulnerability
5. Sanitation risk/vulnerability of drought and flood
6. Health risk/vulnerability to flood
7. Health and infrastructure risk/vulnerability to heat stress

○ **Step 3: Analyse the risks**

Risk factors for each indicator should be identified and analyzed to determine the most urgent priority of climate change risk in Kurunegala. To prioritize risk factors in each indicator, experiences from the Republic of Korea are considered, and the following steps were conducted.

Firstly, the KEI collected risk factors in the area of water management and heat wave at national and municipal levels of Republic of Korea. The municipal risk factors were collected from 6 municipal governments¹² whereas the provincial risk factors from 5 Provinces¹³ in the Republic of Korea. The 84 risk factors for 7 indicators were selected based on a case study from the Republic of Korea. KMC reviewed the list of risk factors and revised them in consideration with their environmental situation, determining 57 risk factors for qualitative analysis of risk assessment in Kurunegala (see Annex C).

○ **Step 4: Evaluate the risks**

In this step, the risk factors were prioritized, and the most urgent and serious risks caused by climate change in Kurunegala were identified. A survey was conducted to evaluate the priority of the risk factors in each indicator.

Drafting survey and conducting experts' review

¹² Busan Metropolitan City, Daegu Metropolitan City, Incheon Metropolitan City, Daejeon Metropolitan City, Gwangju Metropolitan City, and Ulsan Metropolitan City

¹³ Gangwon Province, South Chungcheong Province, South Cheolla Province, South Gyeongsang Province, and North Gyeongsang Province

The draft questionnaires of the survey was prepared by the KEI using the selected 57 risk factors that were reviewed by KMC. The questionnaire is made based on Five Likert scale. The questions are related to the possibility of occurrence and impact on water scarcity and heat stress. The highest score of 5 means 'very severe' and the lowest score of 1 means 'very low'.

Conducting the survey

This survey aims to find the priority of risk factors and the current problems on water scarcity and heat stress caused by climate change. The survey was carried out at expert workshop that was held on 17th July 2019. 35 climate change adaptation experts in the KMC participated in the survey. Through the survey, KMC experts evaluated the possibility of occurrence (percentage) and impact (scale) of each sector risk item in Kurunegala within the next 5 years.

Analysis and result

After the survey is conducted by 35 experts in water and heat sector, the result of survey were sent from KMC to KEI. The survey results were digitally recorded using the excel sheet, and data analysis was performed for climate change risk assessment.

Risk is the combination of the likelihood (probability of occurrence) and the consequences of an adverse event (e.g. climate hazard). It is interrelated with 'Vulnerability', 'Exposure' and 'Hazards', being calculated as the following formula. -

Percentage of its possibility of occurrence x Impact

Table 4-1) Raw survey data sent by KMC

Category Code	Respondent Information			Drinking water resources risk/vulnerability					
	Name	Title, Organization	Professional field	DWR01	DWR01	DWR02	DWR02	DWR03	DWR03
				Possibilit	Impact	Possibilit	Impact	Possibilit	Impact
1	D.R.W.Kaluaracchi	Municipal Engineer, KMC	Water	2	5	1	5	1	1
2	H.N.B.Abeywardhana	Director, Dept of Local Govt	Water & Heat	5	4	4	4	3	3
3	L.S.Kahandagamage	Got. Surveyer, Survey Dept	Water & Heat	5	5	1	1	1	1
4	W.A.Wijayananda	Operation Leader, MMC	Water	3	3	2	2	3	3
5	E.M.P.K.Ekanayake	UDA	Water	3	3	3	2	2	2
6	R.M.S.Ratnayake	Medical Officer, KMC	Water & Heat	5	4	5	4	5	4
7	Chintha Vithana	Director, District Secretariat	Water & Heat	3	5	4	4	3	4
8	Dhammika Kurera	Development Officer, KMC	Water	2	2	2	2	3	3
9	E.M.I.K.Ekanayake	Senior Engineer, Water Supply & Drainage Bd	Water	4	4	3	2	2	2
10	A.C.Vidanapathirana	Director, ISB	Water & Heat	5	5	1	1	2	1
11	Madhusa Jayakody	Consultant, ISB	Water & Heat	5	5	5	5	5	5
12	S.Ratnayake	Asst.Director, Ministry of Environment	Water & Heat	5	5	4	5	2	2
13	Kumudini Vidyalankara	Asst.Director, Ministry of Environment	Water	5	5	1	1	1	1
14	Dakshini Perera	Asst.Director, Ministry of Environment	Water	3	3	2	2	3	3
15	Darshika Pathiratna	DO, Ministry of Environment	Water & Heat	4	4	3	2	2	2
16	Menaka	DO, Health Unit, KMC	Water & Heat	3	5	4	4	3	4
17	Gayana Chathuranga	DO, Health Unit, KMC	Water & Heat	3	5	4	4	3	4
18	Susantha Udagedara	Technical Coordinator, Vulnerability, TNC	Water & Heat	3	3	4	4	1	1
19	Nandana Senaratne	Air Quality Control & National Ozone Unit, M	Water & Heat	4	4	3	2	3	3
20	W.A.M.K.Chandrasena	Planning Officer, UDA	Water & Heat	3	3	3	3	2	2
21	A.D.Ranjith Jayakody	Health Supervisor, KMC	Water & Heat	5	5	3	2	1	1
22	H.N.M.C.Herath	Land Use Planning Offier, LUPPD	Water & Heat	3	3	2	2	3	3
23	D.P.S.Kumara	Disaster Management Centre	Water & Heat	3	3	3	3	1	1
24	Bandula Warnakulasori	Disaster Relief Officer	Water & Heat	4	4	3	3	3	3
25	R.D.D.Rajakaksha	Public Health Inspector,KMC	Water & Heat	2	5	1	5	1	1
26	K.L.R.Somaweera	Administrative Grama Niladhari	Water & Heat	3	3	2	2	2	2
27	W.R.Samaranayake	Asst. Director, District Land Use Planning Offi	Water	5	5	4	5	2	2
28	D.Kumara	CEA	Water & Heat	5	5	3	2	2	2
29	Gamage	Greate Kurunegala Water Supply &Sewerage P	Water	4	4	2	2	2	2
30	Pathum Lakmal	Greate Kurunegala Water Supply &Sewerage P	Water	5	5	1	1	2	1
31	Thanuja Premaratne	National Water Supply & Drainage Board	Water	4	4	3	2	2	2
32	Kumara	Asst. Commisioner, KMC	Water & Heat	5	5	1	1	2	1
33	Nalaka Arjuna	Municipal Engineer, KMC	Water & Heat	4	4	3	2	3	3
34		Provincial Ministry	Water	5	5	3	3	3	3
35	Eng. Kumudini Dheera	Dept. Irrigation	Water	3	3	2	2	4	4

Table 4-2) Data calculation

Indicator		Avg. possibility of occurrence (%)	Avg. Impact	Score	Rank
Total		2.99	2.97	8.88	-
Drinking water resources risk/vulnerability	DWR	3.86	4.14	15.98	1
Water management resources risk/vulnerability	WM	2.71	2.74	7.43	5
Water quality and aquatic ecosystem risk/vulnerability	WQAE	2.37	2.34	5.55	7
Water resources risk/vulnerability	WR	3.34	3.36	11.22	2
Sanitation risk/vulnerability of drought and flood	SDF	3.1	2.91	9.02	4
Health risk/vulnerability to flood	HF	2.51	2.6	6.53	6
Health and infrastructure risk/vulnerability to heat stress	HIH	3.14	3.11	9.77	3

Score was calculated by using formula mentioned above, then factors were ranked depending on their score.

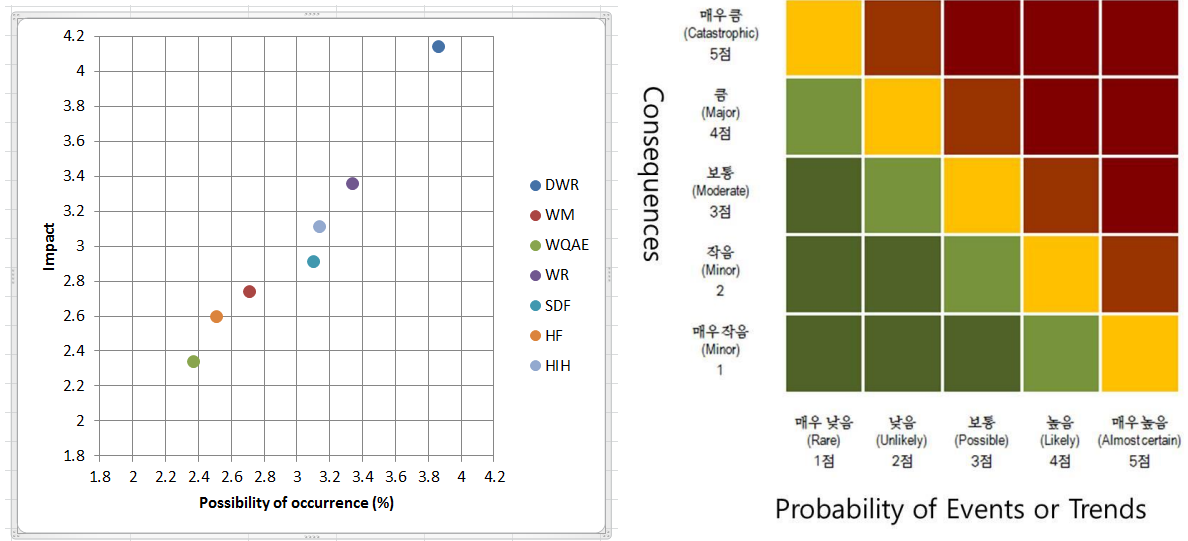


Figure 4-2) Result

Results of the data analysis are shown in a matrix below. Each coloured area is interpreted as;

- Red area: risk cannot be tolerated
- Yellow area: moderate risk
- Green area: risk can be tolerated

The matrix could be understood by two ways as a comparative analysis: 1) impact without capacity and 2) impact with capacity. The impact without capacity means initial risk, and the impact with capacity refers to final risk. The matrix could be used for preparing a climate change adaptation plan.

○ **Step 5: Treat the risks**

Based on the results, measures to reduce risks in the Red area should be established first. The measures of adaptation should be selected according to the economic and cultural characteristics of the region. It is necessary to develop a plan that can reduce the impact of serious risk by establishing short, medium and long-term strategies depending on the level of risk. In developing the plan, policy-makers should collect and consider opinions from residents, experts and stakeholders. Based on this, the final action plan should be made.

4.3 Gender Inclusive Analysis

To mainstream gender issue into climate change adaptation policy, it should be considered in the qualitative analysis.

To focus on gender issue, we set it up as a key agenda at consultant workshop. The survey was also conducted for the women vulnerable to climate change to figure out their opinions on the climate change damage and impact.

4.4 Expected Result

It is expected to provide the priority of risk factors and associated problems of Kurunegala city. Results from qualitative analysis could be used as a baseline evidence for the climate change adaptation plan for the city.

In this technical assistance, results of qualitative analysis were presented at the workshop held on July 2019.

5. Discussion and Result

For the successful analysis of the climate change risk and vulnerability of the city, it is important to develop indicators and survey questions in consideration with local condition and environment. In this technical assistance, possible indicators and risk factors were taken from risk assessment experience from the Republic of Korea. However, they were reviewed and amended based on consultation with local experts in Kurunegala. In quantitative analysis, it was required to find alternative indicators in the case where the data is inaccessible and unavailable.

Adaptation action plan for Kurunegala needs to be developed based on result of risk assessment. With quantitative risk assessment, Kurunegala can identify and prioritize risk factors in vulnerable areas. Based on qualitative assessment, KMC can find risk factors that are organized by experts in Kurunegala and should be prioritized for action plan.

6. References

- Aguilar, L. (2008). Gender perspectives on climate change, 52nd Session of the Commission on the Status of Women. New York, 25 February - 7 March 2008. Available at: http://www.gdnonline.org/resources/Aguilar_CSWgender-climatechange.pdf
- Bollin, C., Cárdenas, C., Hahn, H., & Vatsa, K. (2003). Disaster risk management by communities and local governments. Washington D.C. <http://publications.iadb.org/handle/11319/4642>
- City of Copenhagen (2011) Copenhagen Climate Adaptation Plan. [COWI, DELOITTE, RAMBØLL, DMI, KU-LIFE, DHI AND GRAS (eds.)]. City of Copenhagen, Denmark
- City of Melbourne, Climate Change Adaptation Strategy, 2009. Retrieved from <https://www.melbourne.vic.gov.au/SiteCollectionDocuments/climate-change-adaptation-strategy.pdf>
- City of Vancouver (2012), Climate Change Adaptation Strategy. Vancouver, Canada. <https://vancouver.ca/files/cov/Vancouver-Climate-Change-Adaptation-Strategy-2012-11-07.pdf>
- Davidson, R., & Shah, H. (1997). An urban earthquake disaster risk index. John A. Blume Earthquake Engineering Center, Stanford University. https://stacks.stanford.edu/file/druid:zy159jm6182/TR121_Davidson.pdf
- IPCC (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.
- Kenya Adaptation Technical Analysis Report: (Risk Assessment Report), 2012. Retrieved from <http://www.kccap.info/phocadownload/final/SC3/TR1%20NCCAP%20Risk%20Assessment%20Report.pdf>
- Morsch, A. (2010). A Climate Change Vulnerability and Risk Assessment for the City of Atlanta, Georgia (Master's Thesis). Duke University, Durham, USA. Retrieved from <https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/2157/Masters%20Project%20by%20Amy%20Morsch.pdf?sequence=1>
- NEST(2011), Gender and Climate Change Adaptation: Tools for Community-level Action in Nigeria. Ibadan, Nigeria. <https://genderinsite.net/sites/default/files/BNRCC-Gender-Toolkit.pdf>
- Oh, K. Y., Lee, M. J., & Jeon, S. W. (2017). Development of the Korean climate change vulnerability assessment tool (VESTAP)—Centered on health vulnerability to heat waves. *Sustainability*, 9(7), 1103.

Rana, I. A & Routray, J.K. (2016). Actual vis-à-vis perceived risk of flood prone urban communities of Pakistan. International Journal of Disaster Risk Reduction.

Stockholm Environment Institute (SEI) (2009), Economics of Climate Change Kenya. <https://mediamanager.sei.org/documents/Publications/SEI-ProjectReport-Downing-EconomicsOfClimateChangeKenya-2009.pdf>.

UNISDR, 2017. National Disaster Risk Assessment - Governance System, Methodologies, and Use of Results, the United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

World Bank (2006), Climate Variability and Water Resources Degradation in Kenya- Improving Water Resources Development and Management. The World Bank. Washington D.C., United States.

<http://documents.worldbank.org/curated/en/990211468283546915/pdf/348540KE0Clima101OFFICIAL0USE0ONLY1.pdf>

LTS International and Acclimatise (2012), Adaptation Technical Analysis Report, prepared for Kenya's National Climate Change Action Plan

Annex A. Examples of Toolboxes and Collections of Methods

Prominent examples of toolboxes and collections of methods to evaluate impacts, vulnerability and adaptation to climate change include the following:

- The United Nations Framework Convention on Climate Change (UNFCCC) Compendium (UNFCCC, 2009) and ongoing follow-up work under the Nairobi work programme (UNFCCC, 2011) are offered in a web-based resource that provides key information on available frameworks, methods and tools to evaluate impacts of, and vulnerability and adaptation to climate change.
- The UNFCCC Resource Guide for Preparing the National Communications of Non-Annex I Parties – Module 2: Vulnerability and Adaptation to Climate Change (UNFCCC, 2008b) is a resource guide that provides an overview of the main methods, tools and data used by Non-Annex I Parties to the UNFCCC to assess vulnerability and adaptation to climate change. It emphasises methods that are readily accessible and applicable.
- The Toolkit for Vulnerability and Adaptation Training by the Stockholm Environment Institute (Downing & Ziervogel, 2004) contains a selection of methods and tools for assessing vulnerability and the potential benefits of adaptation options. Most of the methods and tools can be classified as ‘bottom-up’.
- The National Communications and Support Programme (NCSP) of the United Nations Development Programme (UNDP, 2012) maintains a collection of guidance documents and general methodologies.
- The BASIC project (Building and Strengthening Institutional Capacities on Climate Change) provides a set of methods that are specifically applicable to the Indian context (www.basic-project.net).
- Participatory Scenario Development Approaches for Identifying Pro-Poor Adaptation Options by the World Bank (Bizikova, et al., 2010) is a manual that presents readers with a generally applicable and detailed methodology for carrying out workshops to develop participatory scenarios.
- Gender and Climate Change Research in Agriculture and Food Security for Rural Development by the Food and Agriculture Organization (FAO, 2011) is a training guide that teaches the reader how to investigate the gender dimensions of vulnerability and adaptation to climate change in the fields of agriculture and food security. These collections provide useful and extensive overviews of the existing approaches. However, they provide little practical help for choosing the right approach for assessing vulnerability in a given context (Hinkel & Bisaro, 2013). Apart from these general collections of possible tools and methods, several guidebooks for climate change vulnerability assessments have been developed. These guidebooks advise their readers on how to combine a set of different methods and tools to carry out a

vulnerability assessment. Most of these guidebooks and instructions can be identified as either applying mostly bottom-up approaches or predominantly top-down approaches.

- CRiSTAL – Community-based Risk Screening Tool – Adaptation and Livelihoods
CRiSTAL is a project-planning tool that helps project planners and managers to integrate risk reduction and climate change adaptation into livelihoods projects (www.iisd.org/cristaltool).
- CARE Climate Vulnerability and Capacity Analysis Handbook (CARE, 2009). This practical handbook presents a participatory methodology to assess climate change vulnerability at the community level. It emphasises that not all social groups are equally vulnerable.
- Framework for Community-based Climate Vulnerability and Capacity Assessment in Mountain Areas (ICIMOD, 2011). This publication presents an analytical framework and a participatory methodology for assessing climate change vulnerability in mountain communities.
- Participatory Capacity and Vulnerability Analysis – Finding the Link Between Disasters and Development (Oxfam, 2002). This handbook focuses on vulnerability to disasters rather than long-term climate change. However, it is a useful resource for carrying out participatory vulnerability assessments in rural and urban communities.
- CEDRA – Climate change and Environmental Degradation Risk and adaptation Assessment (Tearfund, 2012). This publication explicitly combines assessments of risks from both climate change and environmental degradation. Top-down • Scanning the Conservation Horizon – A Guide to Climate Change Vulnerability Assessment (Glick, et al., 2011). This guide focuses on assessing the ecological impacts of climate change.
- Review of climate change adaptation methods and tools (Schipper, et al., 2010). This review of adaptation methods and tools examines approaches that have been developed and applied around the world, with a particular emphasis on Asia.
- Preparing for Climate Change – A Guidebook for Local, Regional, and State Governments (Snover, et al., 2007). Chapter 8 of this guidebook presents a general framework for sectorial top-down vulnerability assessments. It includes examples of assessments in three sectors (hydrology and water resources, infrastructure, and transportation).
- Impacts, Vulnerabilities and Adaptation in Developing Countries (UNFCCC, 2007). This publication provides background information on the vulnerabilities and adaptation in developing countries, as well a general framework for carrying out vulnerability assessments at the national level. However, it provides little practical guidance on how to carry out these assessments.

- Handbook on Vulnerability and Adaptation Assessment (UNFCCC, 2008a). This handbook is intended to help Non-Annex I Parties to the UNFCCC (mostly developing countries) prepare the sections of their Second National Communications on Vulnerability and Adaptation. It gives detailed instructions on developing socio-economic and climate change scenarios, and on carrying out top-down vulnerability assessments in individual sectors (coastal resources, water resources, agriculture, and human health).

(Source by *A Framework for Climate Change Vulnerability Assessments* (GIZ, 2014))

Annex B. List of Indicators for Indicator-based Approach Assessment

(1) Drinking water resources risk/vulnerability to drought

Category		Factor	Data Source
Risk (AR-5)	Hazard	Consecutive dry days	Department of Meteorology, Colombo
		Occurrence of extreme rainfall anomalies - Stranded Precipitation Index (SPI)	Department of Meteorology, Colombo
		Change in maximum temperature	Department of Meteorology, Colombo
		Monthly Average Evaporation	Department of Meteorology, Colombo
	Exposure	Population Density	Through Grama Niladhari and Questionnaire survey
		Tax Units	Kurunegala Municipal Council
		Population receiving government assistances	Through Grama Niladhari and Questionnaire survey
		Livestock population	Questionnaire survey
	Vulnerability	Number of female lead house holds	Through Grama Niladhari and Questionnaire survey
		Tax units which haven't secondary water sources	Questionnaire survey
		Monthly water usage	Questionnaire survey
		Number of house-hold who are getting medicine through regular clinic	Questionnaire survey
	Capacity	Water supply ratio	Kurunegala Municipal Council
		Bowser water supply	Kurunegala Municipal Council
		Access to information	Questionnaire survey
		Number of water bottles used(purchased) per day	Questionnaire survey
Availability of secondary water source		Questionnaire survey	
Tax amount		Kurunegala Municipal Council	
Number of hospitals, day care, schools		Through Grama Niladhari and Questionnaire survey	

(2) Drinking water resources risk/vulnerability to drought (as an example)

Category	Factor	Data/Variable	Rationale	Data Source	Functional Relationship (+or -)
Hazard	Consecutive dry days	Maximum number of consecutive days when precipitation is less than 1mm-1990 - 2015-time series.	An increase in this indicator suggests an increase in the duration of droughts. Reservoirs and ground water levels drop and caused decreasing water supply.	Department of Meteorology, Colombo	+
	Occurrence of extreme rainfall anomalies - Stranded precipitation Index (SPI)	Depending on the drought impact in question, SPI values for 3 months or less might be useful for basic drought monitoring, values for 6 months or less for monitoring agricultural impacts and values for 12 months or longer for hydrological impacts-1990 - 2015-time series.	Longer the SPI may contribute to metrological drought. This contributed to maximum length of drought period.	Department of Meteorology, Colombo	+
	Change in maximum temperature	Average Number of days of which exceeds the day time temperature of 34°C-1990 - 2015-time series .	Loss of water in surface waters due to rapid evaporation. Increasing magnitude of the offset increases the vulnerability/risk.	Department of Meteorology, Colombo	+
	Monthly Average Evaporation	Monthly average evaporation-1990 - 2015-time series in dray period	Higher the surface area exposed higher the risk of evaporation during droughts.	Department of Meteorology, Colombo	+

Exposure	Population Density	Most reason population density (number of peoples/km ²)	Higher the population density (number of peoples/km ²) will highly demand for the water.	Through Grama Niladhari and Questionnaire survey	+
	Tax units	Total number of tax unit for /km ²	Higher the number of tax unit for /km ² will impacted to drought	Kurunegala Municipal Council	+
	Population receiving Government assistances	Percentage (%) of population receiving Government assistances, subsidies etc.	Better identification of real vulnerable groups based on more comprehensive factors (political rigidity, population growth, poverty, culture, dependency, geographic isolation and activities etc.). Increased poverty, there is a move towards high risk/vulnerability to water during the drought period .	Through Grama Niladhari and Questionnaire survey	+
	Livestock Population	Total number of livestock (checken+cow+pig)population in each GND	Higher the livestock number may have impacted due to drought.	Questionnaire survey	+
Sensitivity	Number of female lead house holds	Number of female lead house holds	Higher the number of female led household the risk due to (access to water) drought hazards is higher as limited access to sources outside their premises	Through Grama Niladhari and Questionnaire survey	+

	Tax units which haven't secondary water sources	Total number of tax units does not have secondary water sources	Tax units which haven't secondary water sources lead to higher vulnerable during the drought period	Questionnaire survey	+
	Monthly water usage	Monthly average water usage	Monthly average water usage	Questionnaire survey	-
Capacity	Water Supply ratio	Water Supply ratio (%)	Higher the water supply ratio will reduced the water scarcity	Kurunegala Municipal Council	-
	Bowser water supply	Water supply through bowsers during the drought period	Amount of water supply through bowsers during the drought period will reduce the water stress	Kurunegala Municipal Council	-
	Access to information	Number of families/ persons with modern communication facilities	Increase access to information facilitates affected families to be better prepared	Questionnaire survey	-
	Number of water bottles used (purchased) per day	Affordability and effectiveness of delivery system	Indicator to assess water stress	Questionnaire survey	-
	Availability of secondary water source	Total number of unit which are available with the secondary water source	Higher the number of availability of secondary water sources may reduce the water scarcity during the drought	Questionnaire survey	-
	Number of house hold who are getting medicine	Total number of people who are getting medicine through regular clinic	Higher the number of people who are getting medicine through regular clinic may highly vulnerable to drought	Questionnaire survey	+

	through regular clinic				
	Number of hospitals, day care, schools	Maximum capacity of hospitals, day care, schools	Higher the number of proportion of, hospitals, day care, schools lead to higher risk/vulnerability	Through Grama Niladhari	+
	Tax amount	Total number of tax revenue in each word (alternative indicator for GRDP)	Higher the number of tax revenue in each word may lesser vulnerable	Kurunegala Municipal Council	-

* Prepared by KMC

(3) Water management risk/vulnerability

Category		Factor	Data Source
Risk (AR-5)	Hazard	Occurrence of extreme rainfall anomalies	Department of Meteorology, Colombo
		Consecutive wet days	Department of Meteorology, Colombo
		Consecutive dry days (days)	
		Number of flood events - 1986 to 2017 (1986 -2000, 20%; 2001 - 2017, 80%)	Disaster Management Center- Disinventa database
	Exposure	Population Density	Through Grama Niladhari and Questionnaire survey
		Water supply	Kurunegala Municipal Council and Water board
		Livestock Population	Questionnaire survey
		Population receiving Government assistances	Through Grama Niladhari and Questionnaire survey
		% of area of lowland area	LUPPD
	Vulnerability	Number of female lead house holds	Through Grama Niladhari and Questionnaire survey
		Availability of secondary water sources (well water)	Questionnaire survey
		Industrial water use(thousand m3/y)	
		Agricultural water use(thousand m3/y)	
		Living water use(thousand m3/y)	
	Capacity	Access to information	Questionnaire survey
		Number of water bottles used (purchased) per day	Questionnaire survey
		Availability of secondary water source	Questionnaire survey
		Water purification cost	Questionnaire survey
		Tax amount	Kurunegala Municipal Council
		Water supply ratio(%)	
Reservoir capacity for water supply per unit of area(thousand m3)			
Number of hospitals, day care, schools		Through Grama Niladhari	
Inland drainage facilities	Water board		

(4) Water quality and aquatic ecosystem risk/vulnerability

Category		Factor	Data Source
Risk (AR-5)	Hazard	Occurrence of extreme rainfall anomalies	Department of Meteorology, Colombo
		Consecutive wet days	Department of Meteorology, Colombo
		Consecutive dry days	Department of Meteorology, Colombo
		Occurrence of extreme rainfall anomalies - Stranded precipitation Index (SPI)	Department of Meteorology, Colombo
	Exposure	% of area of lowland area	LUPPD
		Aquatic Fauna and Flora recorded	Biodiversity Secretariat
		Land Management ratio	LUPPD
		Different type of aquatic eco systems	
	Vulnerability	Area of special ecosystems	Through Grama Niladhari and Questionnaire survey
		Cover of savage connection	Water Board
		Threaten aquatic Species	Biodiversity Secretariat
		Monthly water usage	Questionnaire survey
		Livestock Population	Questionnaire survey
		Number of house hold who are getting medicine through regular clinic	Questionnaire survey
	Capacity	Water Supply ratio	Kurunegala Municipal Council
		Bowser water supply	Kurunegala Municipal Council
		Access to information	Questionnaire survey
		Number of water bottles used (purchased) per day	Questionnaire survey
		Availability of secondary water source	Questionnaire survey
		Water purification cost	Questionnaire survey
Number of hospitals, day care, schools		Through Grama Niladhari	
Tax amount		Kurunegala Municipal Council	
Average number of sanitation facilities		PHI	
Sealed shops due to poor sanitation		Questionnaire survey	

(5) Water resources risk/vulnerability

Category	Factor	Data Source	
Risk (AR-5)	Hazard	Consecutive dry days	Department of Meteorology, Colombo
		Occurrence of extreme rainfall anomalies - Stranded precipitation Index (SPI)	Department of Meteorology, Colombo
		Change in maximum temperature	Department of Meteorology, Colombo
		Monthly Average Evaporation	Department of Meteorology, Colombo
	Exposure	Population Density	Through Grama Niladhari and Questionnaire survey
		Tax units	Kurunegala Municipal Council
		Population receiving Government assistances	Through Grama Niladhari and Questionnaire survey
		Livestock Population	Questionnaire survey
	Vulnerability	Number of female lead house holds	Through Grama Niladhari and Questionnaire survey
		Tax units which haven't secondary water sources	Questionnaire survey
		Monthly water usage	Questionnaire survey
		Cost of flood damage for recent 3 years (USD or LKR)	
		Number of casualties by floods for recent 3 years (number of people)	
		Average slope (degree)	
		River levee (bank) area ratio (%)	
	Number of house hold who are getting medicine through regular clinic	Questionnaire survey	
	Capacity	Water Supply ratio	Kurunegala Municipal Council
		Bowser water supply	Kurunegala Municipal Council
		Access to information	Questionnaire survey
		Number of water bottles used (purchased) per day	Questionnaire survey
Availability of secondary water source		Questionnaire survey	
Number of hospitals, day care, schools		Through Grama Niladhari	
Tax amount		Kurunegala Municipal Council	
Reservoir capacity (Thousand ton)			

(6) Sanitation risk/vulnerability of drought and flood

Category		Factor	Data Source
Risk (AR-5)	Hazard	Consecutive dry days	Department of Meteorology, Colombo
		Stranded precipitation Index (SPI)	Department of Meteorology, Colombo
		Occurrence of extreme rainfall anomalies	Department of Meteorology, Colombo
		Consecutive wet days	Department of Meteorology, Colombo
		Number of flood events - 1986 to 2017 (1986-2000, 20%; 2001-2017, 80%)	
	Exposure	Population Density	Through Grama Niladhari and Questionnaire survey
		Tax units	Kurunegala Municipal Council
		Population receiving Government assistances	Through Grama Niladhari and Questionnaire survey
		Average number of sanitation facilities	PHI
	Vulnerability	Number of female lead house holds	Through Grama Niladhari and Questionnaire survey
		Dependency ratio - income	Questionnaire survey
		Number of house hold who are getting medicine through regular clinic	Questionnaire survey
		Number of schools and welfare facilities for the aged	
	Capacity	Water Supply ratio	Kurunegala Municipal Council
		Sealed shops due to poor sanitation	Questionnaire survey
		Cover of savage connection	Water Board
		Access to information	Questionnaire survey
		Number of hospitals	
Number of public official for sanitation			

(7) Health risk/vulnerability to flood

Category		Factor	Data Source
Risk (AR-5)	Hazard	Occurrence of extreme rainfall anomalies	Department of Meteorology, Colombo
		Consecutive wet days	Department of Meteorology, Colombo
		Number of flood events - 1986 to 2017 (1986 -2000, 20%; 2001 -2017, 80%)	Disaster Management Center- Disinventa database
		Population Density	Through Grama Niladhari and Questionnaire survey
	Exposure	Population aged 14 or younger	Through Grama Niladhari and Questionnaire survey
		Population aged 65 or older	Through Grama Niladhari and Questionnaire survey
		Population receiving Government assistances	Through Grama Niladhari and Questionnaire survey
		Recorded water bone diseases	PHI
		% of area of lowland area	LUPPD
		Livestock Population	Questionnaire survey
	Vulnerability	Number of female lead house holds	Through Grama Niladhari and Questionnaire survey
		Number of house hold who are getting medicine through regular clinic	Questionnaire survey
		Number of schools and welfare facilities for the aged	
	Capacity	Access to information	Questionnaire survey
		Tax amount	Kurunegala Municipal Council
		% of rain water collection (including detention facilities)	Questionnaire survey
		Educational level	Questionnaire survey
% of health insured population (%)			
Number of hospitals			
Number of public official for sanitation			

(8) Health and infrastructure risk/vulnerability to heat stress

Category		Factor	Data Source
Risk (AR-5)	Hazard	Consecutive dry days	Department of Meteorology, Colombo
		Occurrence of extreme rainfall anomalies - Stranded precipitation Index (SPI)	Department of Meteorology, Colombo
		Change in maximum temperature	Department of Meteorology, Colombo
		Monthly Average Evaporation	Department of Meteorology, Colombo
		Temperature Humidity Impact	Department of Meteorology, Colombo
		Urban Heat Island	UHI study
	Exposure	Population Density	Through Grama Niladhari and Questionnaire survey
		School, daycare centers and Kindergarten	Through Grama Niladhari and Questionnaire survey
		Population aged 14 or younger	Through Grama Niladhari and Questionnaire survey
		Population aged 65 or older	Through Grama Niladhari and Questionnaire survey
		Population receiving Government assistances	Through Grama Niladhari and Questionnaire survey
		Livestock Population	Questionnaire survey
	Vulnerability	Road and Rail road	Questionnaire survey
		Number of female lead house holds	Through Grama Niladhari and Questionnaire survey
		Tax units which haven't fans or AC	Questionnaire survey
		Number of house hold who are getting medicine through regular clinic	Questionnaire survey
		Urbanization rate	
	Capacity	Population receiving Government assistances	Through Grama Niladhari and Questionnaire survey
		Water Supply ratio	Kurunegala Municipal Council
		Availability of Fans and, AC	Questionnaire survey
Access to information		Questionnaire survey	
Health Insurance		Questionnaire survey	
Tax amount		Kurunegala Municipal Council	
Educational level		Questionnaire survey	
Forest cover (green area)		LUPPD data	
Number of shelters and cooling centre			
Number of hospitals			
Number of public official for sanitation			

Annex C. Risk Factors of Each Indicator for Survey-based Approach Assessment

■ Drinking water resources risk/vulnerability to drought

: Risk or vulnerability on sources of useful or potentially useful portable water.

Code	Cause	Risk Factor
DWR01	Drought	Lack of drinking water resources due to drought
DWR02	Flood	Disruption of drinking water facilities
DWR03	Flood	Hindrance to water treatment efforts

■ Water management risk/vulnerability

: Risk or vulnerability on water management that is the control and movement of water resources to minimize damage to life and property and to maximize efficient beneficial use

Code	Cause	Risk Factor
WM01	Flood	Disruption and functional degradation of river facility (i.e. embankment, bridge, etc.)
WM02	Flood	Influence on the operation of waterworks facilities (i.e. less access to operational mechanism)
WM03	Flood	Economic loss due to impact from interruption of transportation and industry related with rivers and canals
WM04	Flood	Increase of damaged irrigation facilities due to flood
WM05	Flood	Increase of property assets loss due to increased frequency of flood
WM06	Flood	Damage to drainage facilities (i.e. storm sewer system, etc.) due to increase in urban sediment drainage and high volume of water
WM07	Drought/ Flood	Increased cost risk due to lack of industrial water and water treatment due to water quality deterioration
WM08	Drought	Drying streams and water bodies (natural and artificial) due to drought
WM09	Flood	Decrease of safety and increase of destruction risk of water supply and repair facilities
WM10	Flood	Change in flooding occurrence and floodplains due to flood
WM11	Drought	Increased frequency of drought due to persistent non-precipitation days

■ Water quality and aquatic ecosystem risk/vulnerability

: Risk or vulnerability on water quality that the condition or health of waterways, like rivers, wetlands.

Code	Cause	Risk Factor
WQAE01	Drought	Water quality deterioration due to pathogenic bacteria by temperature rising
WQAE02	Storm	Increase of water pollution risks due to excessive inflow of land pollution source (i.e. living sewage, industrial wastewater, etc.) by heavy rain
WQAE03	Drought, Flood	Fluctuations in water ecology according to rainfall pattern change
WQAE04	Drought, Flood	Water quality deterioration due to rainfall pattern change
WQAE05	Ambient Temperature	Increase of algal blooms and deterioration of aquatic ecosystem due to average water temperature rising
WQAE06	Avg. water temp. rising	Increase of diseases and new pathogenic microorganisms occurrence due to water temperature rising
WQAE07	Avg. water temp. rising	Acceleration of extinction of endangered species and endemic species by climate change
WQAE08	Storm	Effluence increase due to fertilizer, pesticides and animal wastes according to rainfall intensification
WQAE09	Temp. rising	Increase of abnormal reproduction of alien invasive species
WQAE10	Avg. water temp. rising	Fluctuations in species composition and spawning season of fish
WQAE11	Avg. water temp. rising	Fluctuations in species composition and spawning season of mollusca and crustaceans

* Avg. = Average, Temp. = Temperature

■ Water resources risk/vulnerability

: Risk or vulnerability on resource of water that is useful or potentially useful, for agricultural, industrial, household, recreational and environmental activities. .

Code	Cause	Risk Factor
WR01	Heat stress, drought	Lack of water for building maintenance and management
WR02	Avg. water temp. rising	Change in habitat of aquatic flora and fauna
WR03	Avg. water temp. rising	Loss of fishery according to increase of harmful organisms (i.e. red tide, jellyfish, etc.) due to average water temperature rising
WR04	Avg. water temp. rising	Fluctuations in spawning habitat and season of fish and molluscs and crustaceans due to water temperature rising
WR05	Drought	Increase of water demand due to increase of crop evapotranspiration
WR06	Drought	Increase of water demand for livestock and animal husbandry due to drought
WR07	Drought	Decrease of national water supply capacity due to rainfall pattern change
WR08	Drought	Lack of water for SME industries due to drought
WR09	Drought	Un-controlled use of groundwater due to lack of water
WR10	Drought	Increased gap of water supply among regions due to drought
WR11	Drought	Change in groundwater level due to increase of groundwater use

* Avg. = Average, Temp. = Temperature

■ Sanitation risk/vulnerability of drought and flood

: Risk or vulnerability on sanitation that is the process of keeping places clean and healthy, especially by providing a sewage system and a clean water supply, due to drought and flood.

Code	Cause	Risk Factor
SDF01	Drought, flood	Increase of waterborne diseases
SDF02	Flood	Overflow of toilet
SDF03	Drought	Lack of water for toilet usage

■ Health risk/vulnerability to flood

: Risk or vulnerability on health that is impacted by flood

Code	Cause	Risk Factor
HF01	Flood	Increase of mortality rate due to disaster
HF02	Flood	Increase of injury rate due to disaster
HF03	Flood	Lack of Focused management on health vulnerable groups (i.e. infants and the elderly)
HF04	Flood	Increase of medical demand and lack of medical supply due to disaster
HF05	Flood	Increase of waterborne diseases (i.e. typhoid, cholera, bacterial heterogeneity, etc.) through water and food
HF06	Flood	Increase of health problems (i.e. falls, trauma, etc.) due to safety accidents with flood
HF07	Flood	Increase of vector borne diseases

■ Health and infrastructure risk/vulnerability to heat stress

: Risk or vulnerability on health and infrastructure that is impacted by heat stress and drought.

Code	Cause	Risk Factor
HIH01	Avg. water temp. rising, drought	Increased intensification of the Urban Heat Island (UHI) phenomenon
HIH02	Heat stress	Reduced function of green space and increased loss of green cover due to heat stress
HIH03	Avg. water temp. rising	Increase of waterborne diseases such as diarrhea caused by drought
HIH04	Avg. water temp. rising	Increase of morbidity and infectious diseases (i.e. infectious diseases, etc.) due to average temperature rising
HIH05	Heat stress	Increase of mortality due to heat wave
HIH06	Heat stress	Increase of cardiovascular diseases due to heat wave
HIH07	Heat stress	Increase of impacts on vulnerable groups due to intensification of Urban Heat Island (UHI) phenomenon caused by heat stress
HIH08	Heat stress	Decrease of labor productivity and labor time due to heat stress
HIH09	Heat stress	Increase of demand for consumer goods suitable for heat stress
HIH10	Heat stress	Increase of medical demand due to heat stress
HIH11	Heat stress	Increase of limited outdoor activities tourisms due to heat stress

* Avg. = Average, Temp. = Temperatu