National Drought Plan for Sri Lanka

Ministry of Environment
Sri Lanka

September 2020

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Acronyms and Abbreviations

AER	Agro-Ecological Regions
CBDRM	Community Based Disaster Risk Management
CBOs	Community Based Organisations
CCA	Climate Change Adaptation
CC&CRMD	Coast Conservation & Coastal Resource Management Department
CEB	Ceylon Electricity Board CECB
DAD	Department of Agrarian Development
DDMCU	District Disaster Management Coordinating Unit
DDPERP	District Disaster Preparedness & Emergency Response Plan
DesInventar	Sri Lanka Disaster Information System
DMC	Disaster Management Centre
DMCU	Disaster Management Coordinating Unit
DRM	Disaster Risk Management
DRPM	Deputy Residential Project Manager
DRR	Disaster Risk Reduction
EOC	Emergency Operating Centre
EW	Early Warning
FD	Forest Department
FIM	First Inter-Monsoon
GCF	Green Climate Fund
GEF	Global Environmental Facility
GN	*Grama Niladhari*
GOSL	Government of Sri Lanka
ID	Irrigation Department
INGOs	International Non-Governmental Organizations
LA	Local Authority
LUPPD	Land Use Policy Planning Department
MASL	Mahaweli Authority of Sri Lanka
MoA	Ministry of Agriculture
MC	Municipal Council
MD	Department of Meteorology
MDM	Ministry of Disaster Management
MDMHR	Ministry of Disaster Management and Human Rights
MDP	Mahaweli Development Project
M/PC&LG	Ministry of Provincial Councils and Local Governance
NARA	National Aquatic Resources, Research & Development Agency
NBRO	National Building Research Organization
NCDM	National Council for Disaster Management
NDMC	National Disaster Management Centre
NDMCC	National Disaster Management Coordination Committee
NDMP	National Disaster Management Plan
NDP	National Drought Plan

NDRSC	National Disaster Relief Services Centre
NEM	Northeast Monsoon
NEOP	National Emergency Operation Plan
NGOs	Non-Governmental Organisations
NPPD	National Physical Planning Department
NRMC	Natural Resources Management Centre
NWSDB	National Water Supply and Drainage Board
PC	Provincial Council
PDMC	Provincial Disaster Management Committee
PDMCU	Provincial Disaster Management Coordinating Unit
PMC	Project Management Committee
PS	*Pradeshiya Sabha*
RPM	Residential Project Manager
SIM	Second Inter-Monsoon
SLRC	Sri Lanka Red Cross
SOPs	Seasonal Operation Plan
SWM	Southwest Monsoon
UDA	Urban Development Authority
UN	United Nations
UNCCD	United Nations Convention for Combating Desertification
UNCCC	United Nations Framework Convention for Climate Change
UNDP	United Nations Development Programme
WFP	World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization
WMP	Water Management Panel
WMS	Water Management Secretariat
WRB	Water Resources Board

EXECUTIVE SUMMARY

Drought is the most frequent disaster listed out of 21 natural or man-made disasters identified in the Disaster Management Act No. 13, 2005 of the Government of Sri Lanka. Therefore, systematic approach is required to mitigate the impact of drought on the large section of the population who depend primarily on agriculture for their livelihood. The purpose of this National Drought Plan (NDP) is to compile drought related information, identify institutional responsibilities and propose coordinated actions by relevant sectors to mitigate the impact of drought in the country, also taking into the challenges of climate change. The NDP is intended to serve as a working guide for those agencies that have the capabilities and resources to develop effective response and mitigation programs within their areas of jurisdiction. The success of this plan is heavily dependent upon coordination and commitment from all levels of government, private sector, NGOs and the community.

During the formulation of this report, it became difficult to strictly follow the guidelines of the UNCCD since there is no structured, coordinated institutional arrangement to deal with various aspects of drought management, such as vulnerability assessment, prediction, preparedness, communication and dissemination, interventions etc. The responsibilities of relevant institutes are “sectoral and diffused” and, as a result, there are no-proactive programmes to mitigate drought in the country. Most of the drought interventions are ad-hoc and has mainly been reactive in the past. While describing what is currently practiced in the country with regard to drought management, a substantial proportion of this NDP is dedicated for what would be the ideal situation based on various national plans and road maps which consider drought as an important hazard.

As indicated throughout the report, there are number of institutions involved in activities related to drought management. For example, the institutions managing the water resources of this country have a major role to play in this regard. Therefore, sectoral organizations will continue to work along those areas as mandated by respective acts/ordinances. A coordinating mechanism with a clear drought plan, which has a substantial proportion allocated for drought risk reduction or mitigation (proactive planning) compared to currently existing drought relief work (reactive planning) becomes a priority. In view of the non-availability of a NDP at present, this plan could be considered as a very significant initiative for way forward in addressing a very important hazard of the country. However, it is essential to revisit this NDP periodically and keep on improving based on the lessons learnt so that more concrete and effective drought plan for the country would be developed with time.

1. BACKGROUND

Drought is a prolonged dry period in the natural climate cycle that can occur anywhere in the world. It is a slow on-set phenomenon caused by a lack of rainfall. Compounding factors, such as poverty and inappropriate land use, increase vulnerability to drought (WMO, 2020). While drought is considered a normal recurrent feature of the climate it is also considered as a rare and a random event. Although occurrences of droughts are usually not expected in a tropical island's climatic characteristics (De Silva, 2008; Jayamaha, 1975), prolonged periods of dry weather are not uncommon in Sri Lanka. Disasters including floods and droughts contribute to the costs of sustaining national healthcare. On average, the economic costs associated with said events to healthcare has been estimated to be 52.8 million USD yearly, with 78% of the costs originating from droughts (De Alwis and Noy, 2017).

In the most general sense, drought is defined as a deficiency of precipitation over an extended period of time (usually a season or more), resulting in a water shortage. The effects of this deficiency are often called drought impacts. Natural impacts of drought can be made even worse by the demand that humans place on water supply.

All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought, as described below, and impacts cascade from this deficiency. Sequence of drought occurrence and impacts for commonly accepted drought types are given in Figure 1.1 (NDMC, 2020).

Meteorological drought is brought about when there is a prolonged period with less than average precipitation. Meteorological drought usually precedes the other kinds of drought.

Agricultural droughts are droughts that affect crop production. This condition can also arise independently from any change in precipitation levels, soil condition and erosion triggered by poorly planned agriculture which causes a shortfall in water available to the crops. However, in a traditional drought, it is caused by an extended period of below average precipitation.

Hydrological drought is brought about when the water reserves available in sources such as lakes and reservoirs fall below the statistical average. Like an agricultural drought, this can be triggered by more than just a loss of rainfall.

Socioeconomic drought associates the supply and demand of some economic goods. Its occurrence depends on the processes of supply and demand. Socioeconomic drought occurs when the demand for an economic good exceeds the supply as a result of a weather-related shortfall in water supply. The drought may result in significantly reduced hydroelectric power production.

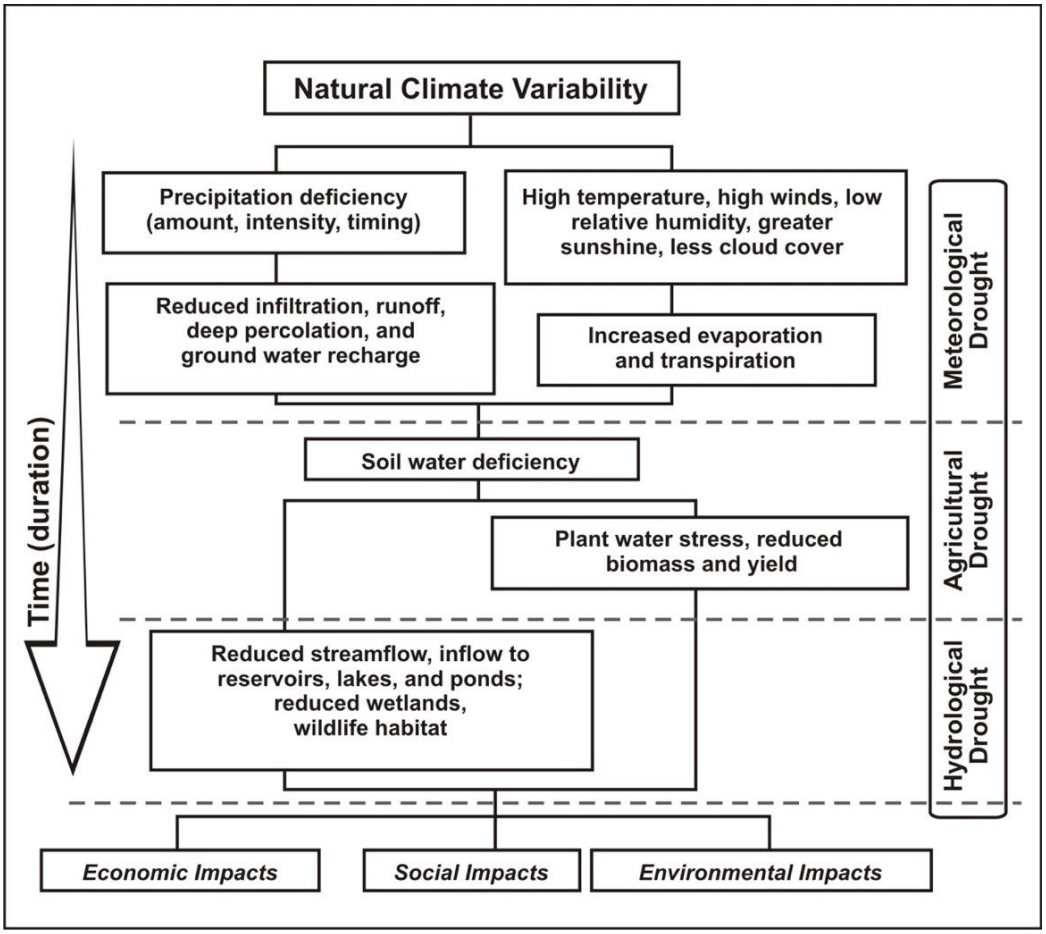

Figure 1.1 Sequence of Drought Occurrence and Impacts for Commonly Accepted Drought Types. All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought and impacts cascade from this deficiency. (Source: NDMC, 2020)

1.1 Purpose

Drought is the most frequent disaster listed out of 21 natural or man-made disasters identified in the Disaster Management Act No. 13, 2005 of the Government of Sri Lanka (GOSL, 2005). Therefore, systematic approach is required to mitigate the impact of drought on large section of the population who depend primarily on agriculture for their livelihood. The purpose of this drought plan is to compile drought related information and propose coordinated actions by relevant sectors to mitigate the impact of drought in the country. The plan is intended to serve as a working guide for those agencies that have the capabilities and resources to develop effective response and mitigation programs within their areas of jurisdiction. The success of this plan is heavily dependent upon coordination and commitment from all levels of government, private sector, NGOs and the community.

1.2 Scope

The National Drought Plan (NDP) includes a description of the country, climate, agro-ecological regions, historical occurrences of drought, risk assessments, identification of impacts related to specific geographical locations. The NDP also emphasizes the identification of pre and post-drought preparedness and mitigation measures for implementation by government agencies, stakeholders, and the general public.

Although, drought is listed as one of 21 hazards under the Disaster Management Act of 2005 (GOSL, 2005), and thereby the Ministry in charge of the subject of Disaster Management has the legal mandate to coordinate, there is no single organization or entity to take charge in drought management. The responsibilities are “diffused” among many organizations. As a result, there are no-proactive programmes to mitigate drought in the country and most of the drought interventions has been mainly reactive. Systematic approach to address drought was initiated by the Disaster Management Centre through the National Hazard Profile where Natural Resource Management Centre (NRMC) of Department. of Agriculture and Meteorology Department developed the “Drought Hazard Profile” for the country. This effort has been further strengthened by number of studies carried out by the NRMC and Meteorology Department including the assessment that include climate predictions.

While describing what is currently practiced in the country with regard to drought management, a substantial proportion is dedicated for what would be the ideal situation based on various national plans, road maps and consultations during a national workshop which consider drought as an important hazard.

2. RELATIONSHIP TO OTHER PLANS AND POLICIES

The Government of Sri Lanka (GOSL) has a number of existing plans and policies aimed to enhance water security, reduce risks associated with natural disasters, conserve natural resources, increase national wealth, and increase the nation's resilience to climate change – all of which are directly relevant to national drought planning and risk reduction. It's important to identify within these plans and policies the parts that will directly or indirectly better prepare for and reduce the risk of drought. This chapter assess the relevant plans and policies for their contribution to drought preparedness and risk reduction.

2.1 Sustainable Development Goals

GOSL has committed to Sustainable Development Goals, including the goals of ending poverty, achieving food security and promoting sustainable agriculture, promoting inclusive growth, reducing inequality and promoting inclusive societies. The development of the rural economy, overcoming inequality of income distribution and supporting agriculture-based livelihoods has been identified as key priorities by the GOSL. The GOSL recognizes that no meaningful reduction in poverty can be achieved in the country without addressing the deleterious impacts of disasters and climate change which include drought. In responding to the challenges, the Government is focused on implementing a number of strategies as outlined in its Nationally Determined Contributions (MMDE, 2016b), National Climate Change Policy (ME, 2012), National Climate Change Adaptation Strategy and Action Plan (MMDE, 2016a), and the Sri Lanka Comprehensive Disaster Management Programme (MDM, 2014). These strategies focus on adaptive measures to avoid/minimize adverse impacts of climate change to the people, their livelihoods and ecosystems and develop the country's capacity to address the impacts of climate change.

2.2 National Climate Change Policy

This Policy guide decisions taken at national and sub-national levels against the threat of climate change (ME, 2012). It presents twenty-five policy statements to cover a number of relevant areas of climate change in Sri Lanka including vulnerability, adaptation, mitigation, sustainable consumption and production, knowledge management and general statements concerning institutional coordination, research and development, technology transfer, legal and regulatory framework, market and non-market based mechanisms and resource mobilization.

2.3 National Adaptation Plan for Climate Change Impacts in Sri Lanka: 2016-25

The National Adaptation Plan for Climate Change Impacts in Sri Lanka (NAP) was prepared in line with the broad set of guidelines set forth by the UNFCCC for the development of national adaptation plan (MMDE, 2016a). The NAP covers adaptation needs at two levels, namely, adaptation needs of key vulnerable sectors and cross-cutting national needs of adaptation. Nine vulnerable sectors were identified in the consultative process, i.e. food security, water, coastal sector, health, human settlements, bio-diversity, tourism and recreation, export development and industry- energy-transportation. Water sector primarily addresses the issues on vulnerability of drought and mitigation. The NAP identifies adaptation options, such as capacity development of water storage facilities (i.e. construction of new reservoirs and rehabilitation of existing reservoirs), promote efficient practices of water management and use, establishment of an efficient climate information and communication system etc. that can fulfil these needs and actions necessary to achieve these adaptation options with responsible agencies and key performance indicators. They together constitute the sectoral action plans for each vulnerable sector.

2.4 Nationally Determined Contribution (NDCs)

GOSL has in its Nationally Determined Contribution (NDCs) to UNFCCC (September 2016) committed to minimizing climate change impacts on food security. The NDCs and National Adaptation Plans focus on the water sector as a crucial crosscutting sector to be addressed and, as such, water management for farming in the Dry Zone, outside of the major irrigation works, is a key priority of the government intervention (MMDE, 2016b).

2.5 National Action Plan for *Haritha Lanka* Programme

The *Haritha Lanka* Programme has identified climate change as the third mission and selected certain strategies/actions relating to both mitigation and adaptation (NCSD, 2009). While the climate change mission in *Haritha Lanka* has given more weight to strategies/actions targeting mitigation, it has adaptation actions in areas of infrastructure vulnerability, land use zoning, rain water harvesting and increase of food security.

2.6 Sri Lanka Comprehensive Disaster Management Programme 2014-2018 (SLCDMP)

The SLCDMP is a policy document, which has a close connection to the National Adaptation Plan (NAP) and the SENDAI Framework. It identifies climate change as a disaster and proposes actions to overcome its' consequences. In addition, other major types of disasters identified by the SLCDMP such as floods, droughts, landslides, high winds/cyclones are also closely associated with extreme weather events. While proposing adaptation actions for extreme events in all sectors, the disaster risk management has been identified separately as a cross–

cutting need of adaptation so that all disaster related actions can be coordinated closely with the existing disaster management agencies such as the Ministry of Disaster Management and the Disaster Management Centre(DMC, 2014).

2.7 National Action Programme for Combating the Land Degradation (NAPCLD):2015-2024

Land degradation enhances the vulnerability to drought. The NAPCLD has highlighted issues such as soil erosion and landslides in up- and mid-country Wet Zone (upper watershed) areas as critical issues together with actions to overcome them (MMDE, 2014). These actions can complement the drought mitigation activities. National Watershed Management Policy (2004) and on Protection and conservation of water sources, their catchments and reservations in Sri Lanka (2014) are also considered as complementary policies to this action programme.

2.8 Land Degradation Neutrality Target Setting Programme (2017-2030)

Land degradation which leads to increased poverty through reduced land productivity and loss of biodiversity is a serious issue in Sri Lanka. Therefore, reversing this trend is important to assure ecosystem services and food security of the nation. Through the Land Degradation Neutrality (LDN) process, the GOSL has committed to achieve LDN targets by 2030 by implementing various measures, such as; a) restore degraded forests, b) establish new forest plantations, c) provide protection status to forests, d) Introduce legislations to avoid land fragmentation, e) strengthen institutional and regulatory mechanisms along with required interventions to restore and manage wetlands and grasslands, f) adopt soil and water conservation measures, in annual and plantation croplands and encourage the adoption of sustainable land management practices through incentives, g) update and operationalize the Soil Conservation Act, control sand mining and to reduce land degradation due to gem mining, h) change the policy of regularizing the encroachment of state lands, i) halt the cultivation of annual crops in steep lands and facilitate the conversion of such lands to perennial crops, j) improve institutional coordination to formulate and implement the National Physical Plan and the Land Use Plan and, k) leverage LDN in to national programmes on climate change adaptation, biodiversity conservation and poverty alleviation (MMDE, 2017b).

2.9 Water Sector Policies

Sri Lanka Water Development Report 2010 (SLWDP) has identified climate change as a major driver of change in the water resources sector. However, information in the report suggests that there is no current policy, plan or programme in the water sector that specifically cover climate change adaptation including drought.

Sri Lanka has tried to address water related issues through sectoral policies of different dimensions. However, there is no exclusive formally approved water policy. The National Policy on Protection and Conservation of Water Sources, their Catchments and Reservations in Sri Lanka of 2014 covers the micro-catchments of rivers and streams, natural and man-made tanks/reservoirs and shallow lakes, and aquifers. The National Rainwater Policy and Strategies of 2005 focuses on rainwater harvesting to meet challenges of supplying adequate water, with relevant amendments made to the by-laws of the National Water Supply and Drainage Board (NWSDB) and the Urban Development Authority (UDA).

The Irrigation Ordinance of 1946 and amended Acts provide legal powers to the Department of Irrigation to manage major irrigation schemes. The Agrarian Development Act of 2000 as amended in 2011 provides the legal authority for the Department of Agrarian Development to manage the majority of the minor irrigation schemes, and the Provincial Councils Act of 1987 provides authority to the provincial councils to manage village tanks, anicuts, etc. The Mahaweli Authority of Sri Lanka Act of 1979 empowers the MASL to optimize agricultural productivity and employment potential and generate and secure economic and agricultural development within the Mahaweli command area.

Sri Lanka faces numerous challenges related to managing water with nearly 40 statutory bodies responsible for water resources. Besides the complex management challenge that the water sector presents, no single agency has stewardship over the country's water resources leading to inefficiency in the use of water resources. However, management of this vital resource is directly related to drought. The chapter on organisation and assignment of responsibilities described in detail the relevance of water resources management in reducing the risk of drought.

2.10 Draft National Agriculture Policy of 2019

This overarching agriculture policy document, still in the draft stage, is part of a strategic response by the Government of Sri Lanka to the evolving priorities and challenges in the global, national and sectoral environments while working towards the national vision of transforming Sri Lanka into a "knowledge-based, export-oriented competitive economy at the centre of the Indian Ocean (MoA, 2019).

To be effective, an overarching agricultural policy provide clarity on the way forward by specifying the focus of strategic policy action in the sector so that these can form the basis for coordinated action by the several public institutions operating in the sector. This policy document identifies 5 core areas for strategic policy action, such as a) increase productivity of farming, ii) energize domestic farm-market linkages and the rural economy, iii) increase export earnings, iv) mainstream gender and youth, and v) Implement effective mechanisms to coordinate, guide and monitor sector development.

2.11 National Policy Framework of the Government of Sri Lanka-2019

The new government has declared the National Policy Framework (NPF), called "**Vistas of Prosperity and Splendour**" with 10 key policies aimed at achieving the fourfold outcome of a productive citizenry, a contented family, a disciplined and just society and a prosperous nation. This 10 key policies consists of, i) Priority to National Security, ii) Friendly, Non-aligned, Foreign Policy, iii) An Administration free from corruption, iv) New Constitution that fulfills the People's wishes, v) Productive Citizenry and a vibrant Human resource, vi) People Centric Economic Development, vii) Technology Based Society, viii) Development of Physical Resources, ix) Sustainable Environmental Management, and x) Disciplined, Law Abiding and values based society.

Under these 10 key policies, sub sectors, sectoral policies, strategies and activities have been identified. There are many strategies which directly address issues related to drought management. Strengthening the flood control systems and drought management capacity, management ecosystems and watersheds, management of water resources in an efficient manner for drinking and agriculture purposes, developing a "National Disaster Database" including disaster affected and potential disaster-prone areas, people, properties, businesses and agricultural lands to provide early warnings and to take preventive measures are some of the examples. It also deals with the safety of vulnerable people such as women and children. One of the activities proposed is to establish a permanent "Care Centre System" to facilitate and minimize the difficulties faced by the people, especially the women and children, who are frequently affected by natural disasters.

3. OVERVIEW OF DROUGHT IN THE COUNTRY

Occurrence of drought in a country is associated with its biophysical and socio-political environment. All these factors are interrelated and vulnerability to drought requires an overall understanding of them and their interactions. The first section of this chapter (3.1) describes the country profile covering most relevant biophysical and socio-political factors which are linked to the occurrence of drought. The second section (3.2 to 3.4) discusses about the mechanism of the occurrence of droughts in the country.

3.1 Country Profile

Location and geophysical characteristics primarily determine the climate of a country. The cultivation seasons depends on the climate characteristics. Soils, geology, land use, socio-economic and administrative arrangements are important in assessing the vulnerability of drought and how to respond to minimize its impact.

3.1.1 Location

Situated from 6^0-10^0 north latitude and from nearly 80^0 to 82^0 east longitude, Sri Lanka has a maximum length of 432 km and width of 224 km with an area of 65,610 km^2. In surface configuration, Sri Lanka comprises of a highland massif situated in the south-centre surrounded by the lowlands. The rivers of Sri Lanka radiates from the central highlands and less than 160 km in length, except the Mahaweli river which is 335 km long.

3.1.2 Climate

There is marked variation in climate due to the central highland region being surrounded by an extensive lowland area. The regional differences in temperature are due to the altitude. There is no temperature variation due to latitude. In the lowlands, the mean annual temperature is 27^0 C and the mean daily range is 6^0 C. In the central highlands with altitudes up to 2400 m a cooler climate is experienced. At Nuwara Eliya which is located at an altitude of 1800 m, the mean annual temperature is 15^0 C and the mean daily range is 10^0 C. The relative humidity varies from 70% during the day to 90% at night. In the seasonally semi arid areas in the northwest and south east, the daily humidity drops to about 60% (The Survey Department, 1988).

The annual rainfall in Sri Lanka varies from 900 mm to 6000 mm as shown in Figure 3.1. The higher values are experienced in the central hill country. The lower values are on the northwestern and southeastern lowlands, as represented by Mannar (967 mm) and Hambanthota (950 mm) respectively.

3.1.3 Factors Affecting Rainfall

There are four important geographical and topographical features in Sri Lanka which considerably influence the rainfall over the island. The first is the fact that Sri Lanka is a small island situated in the warm tropical Indian Ocean. The second is its proximity to the equator. The third is the existence of a large mass of hills at the centre of the island. The fourth is the presence of vast landmass of the Indian subcontinent to the immediate north and northwest of Sri Lanka (Jayamaha, 1975).

The warm air sea surface around the island generally gives tropical maritime air masses over the country. These air masses are usually warm and moist and often unstable. Being close to the equator, the island is favourably placed with respect to the equatorial converge zone. These two factors are conducive to the production of precipitation*. If these two were the only predominant factors, occurrence of drought and dry spell should be a rare feature.*The third factor, namely the central hills, provides orographic trigger action for the production of rain on the windward side. On the other hand, they have a sheltering effect on the opposite side causing a reduction of rainfall along the leeward slopes and beyond. The effect of this sheltering is liable to cause frequent dry spells in the eastern and northern regions of the island during the period of the southwest monsoon from May to September. The effect of neighbouring landmass is to inhibit the input of moisture into airstream passing over it. Airstreams travelling southwards from the subtropical anticyclonic ridge of the northern hemisphere, specially during January have a larger proportion of their trajectories over India and are, therefore, unable to collect much moisture. If this effect predominates, it will lead to dry conditions throughout the entire island during the northeast monsoon of December to February (Jayamaha, 1975).

3.1.4 Climatic Seasons

The Climate of Sri Lanka is dominated by the topographical features as mentioned above and the Southwest and Northeast monsoons' regional scale wind regimes.

The country is influenced by two wind regimes; the Southwest monsoon (May to September) and Northeast monsoon (December to February). The monsoonal rainfall is mainly orographic. The rainfall during the two inter-monsoonal periods, March to April and October – November are mainly convectional. During October-November, the country is also influenced by weather systems that forms in the Southwest Bay of Bengal and the Southeast Arabian sea. The rainfall during October-November is fairly widespread.

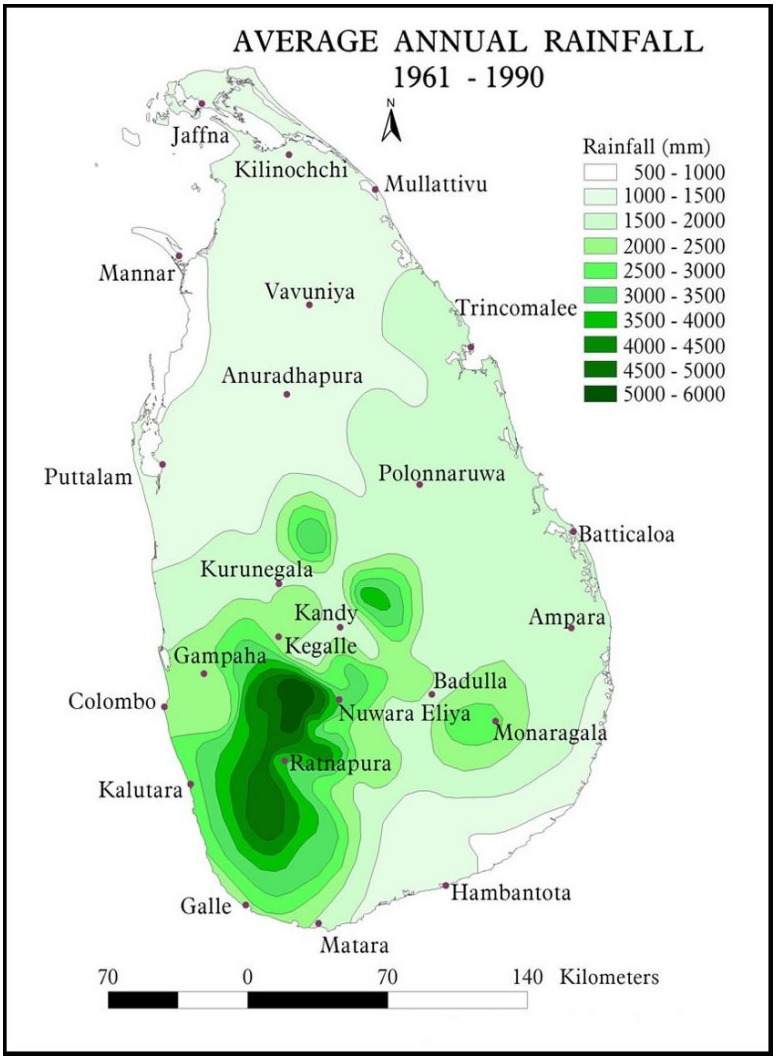

Figure 3.1. Average Annual Rainfall of Sri Lanka

Therefore, the annual climate of Sri Lanka is characterized by 4 climatic seasons as described below (Survey Department, 1988; MMDE, 2014).

First Inter-monsoon Season (March - April)

Warm conditions, with thunderstorm-type rain, particularly during afternoon or evening are the typical weather conditions during this season. The distribution of rainfall during this period shows that the entire South-western sector at the central hills receiving about 250 mm of rainfall, with localized areas on the South-western slopes of the central hills experiencing rainfall in excess of 700 mm. Over most other parts of the island, the amount of rainfall varies between 100 and 250 mm, notably with the exception of the Northern Jaffna Peninsula.

Southwest -monsoon Season (May - September)

Windy weather during this monsoon eases off the warmth that prevailed during the first Inter monsoon season. Southwest monsoon rains are experienced at any times of the day and night, sometimes intermittently mainly in the South-western part of the country. Amount of rainfall during this season varies from about 100 mm to over 3000 mm. The highest rainfall is

received in the mid-elevations of the western slopes of the central highland. Rainfall decreases rapidly from these maximum regions towards the higher elevation. The variation towards the South-western coastal area is less rapid, with the South-western coastal belt experiencing between 1000 mm to 1600 mm of rain during this 5-month long period. Lowest rainfall is recorded in Northern and South-eastern regions.

Second Inter-monsoon Season (October-November)

The rains with thunderstorms, particularly during afternoon or evening, are the typical climate during this season. Unlike in the first Inter-monsoon season, the influence of weather system in the Bay of Bengal is common during the second Inter-monsoon season. Under such conditions, the whole country experiences strong winds with wide spread rain, sometimes leading to floods and landslides. The second Inter-monsoon period of October – November is the period with the most evenly balanced distribution of rainfall over Sri Lanka. Almost the entire island receives in excess of 400 mm of rain during this season, with the South-western slopes receiving higher rainfall in the range 750mm to 1200 mm.

Northeast -monsoon Season (December - February)

The dry and cold wind blowing from the Indian landmass will establish a comparatively cool, but dry weather over many parts making the surrounding pleasant and comfortable weather except for some rather cold morning hours. Cloud-free skies provide days full of sunshine and pleasant and cool night. During this period, the highest rainfall values are recorded in the North-eastern slopes of the central hills and the Eastern slopes of the Knuckles/Rangala range.

3.1.5 Cultivation Seasons

Sri Lanka as an agricultural country has two main cropping seasons associated with rainfall; one from October to December coincides with the initiation of the primary cultivation season recognized as "*Maha"* (October – March) and the April to June rainfall coincides with the secondary cultivation season recognized as "*Yala"*(April – September). Rice being the staple food in Sri Lanka it is the most vital food crop cultivated in the country. The major rice growing areas of the country are located in the Dry Zone and the Intermediate zones and are the most vulnerable to droughts. Thus, high variability of rainfall will have negative impacts on the rain fed paddy cultivation.

3.1.6 Agro-Climatalogical Zones of the Country

Depending on the total annual rainfall, the island has been divided into 3 climatic zones namely Wet Zone, Intermediate zone and the Dry Zone (Figure 3.3). The Wet Zone is the area which receives mean annual rainfall of above 2500mm. The Intermediate zone receives mean annual rainfall of 1750-2500 mm. The mean annual rainfall of the Dry Zone is below 1750 mm. The Dry Zone, is spread over much of the lowland plains. The rainfall is not spread evenly

throughout the year, and there is a long, dry period of about five months. During these dry months, rainfall is less than 50 mm per month.

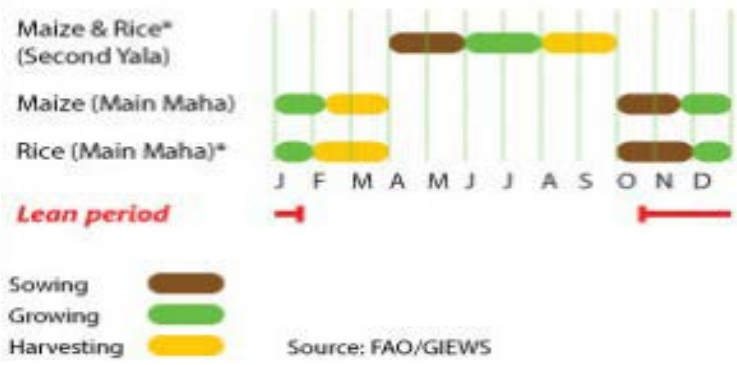

Figure 3.2 Main Cultivation Seasons in Sri Lanka

Based on the three climate zones and three elevations (to represent the temperature) classes namely, up country (>900m), mid country (300-900m) and low country (<300m), 7 agro-climatic zones have been delineated in the country (Department of Agriculture, 1979). They are: Dry Zone Low country (DL), Wet Zone Low country (WL) Intermediate zone Low country (IL), Wet Zone Mid country (WM), Wet Zone Up country (WU), Intermediate zone Mid country(IM) and Intermediate zone Up country(IU). These 7 agro climatic zones have been further delineated into 46 agro-ecological zones based on the rainfall distribution within the year (Figure.3.4). This map is the basis for crop selection and management in different areas and is widely used in development work of the country (Punyawardena et al, 2003).

3.1.7. Geology and Soils

Six main types of groundwater aquifers in Sri Lanka as identified by Panabokke and Perera, (2005), could be summarised in to two types depending on the aquifer characteristics and ground water use. The north western belt including Jaffna peninsula consists of Miocene limestone with high recharge rate whilst the rest of the island (90% of extent) consists of Precambrian hard rocks. As a result, the ground water recharge is very limited in most part of the country.

The nature of major soil groups and their area distribution is given in the National Atlas of Sri Lanka (Survey Department, 1988). In the Dry Zone the predominant soil group is the well drained reddish-brown earths in association with poorly drained humic gley, alluvials and red yellow latosols. In the Dry Zone coastal areas non calcic brown soil with sandy regosols, alkaline and saline soils, and grumosols are distributed in patches. In the Wet Zone red yellow podzolic soils form the major soil group with bog, half bog soils, and sandy regosols along the South west coast. The intermediate zone displays a transition from reddish brown earths to red yellow podsolic soils, with non-calcic brown loam in patches. Each of these major groups

has different textural, structural and clay mineralogy and determines the vulnerability to drought. For example, the non-calcic brown loams tend to have more vulnerability because of its low water holding capacity.

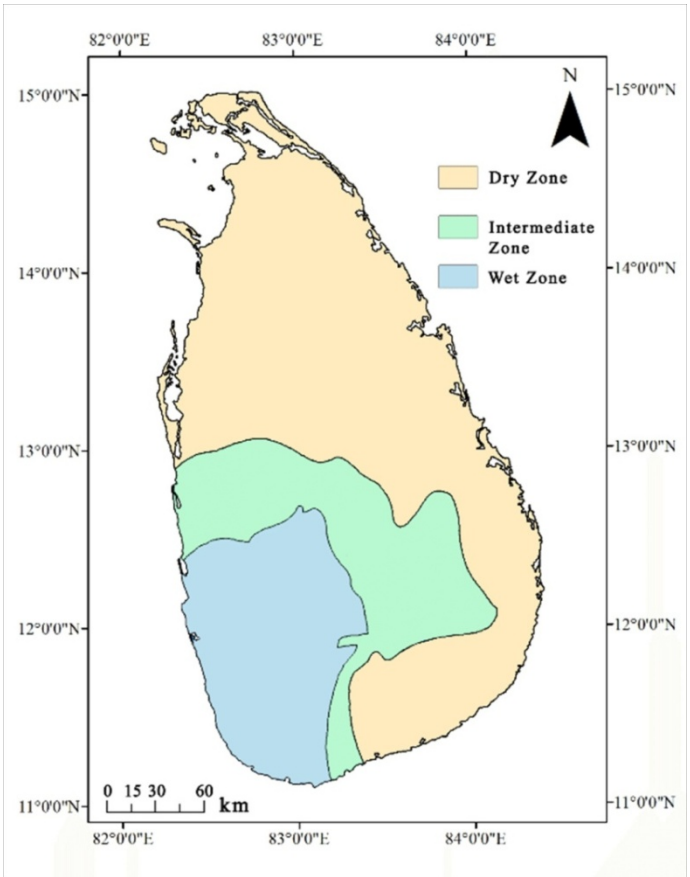

Figure 3.3 Climatic Zones of Sri Lanka (Source: Department of Agriculture)

3.1.8 Land Use

The land use and land cover of Sri Lanka in 2018 is given in Table 3.1 (LUPPD, 2019). There is evidence that sound watershed management practices existed in Sri Lanka before the colonial period, which began in the early 1800s. The central hills, from where all Sri Lanka's major rivers originate, were under natural forest while the valleys were under agricultural production watered by an intricate system of irrigation reservoirs and canals.

The degradation of watershed resources began with the large-scale clearing of the central highlands for plantation crops in the nineteenth century. Rubber plantations became popular around 1900 in the south western lowlands and mid country areas and coconut plantations were established in the coastal areas. Though few regulatory measures were put in place, conversion of forests to other land uses with poor land management practices continued. The large scale land clearing of forests in the Dry Zone by the Government took place after 1930,

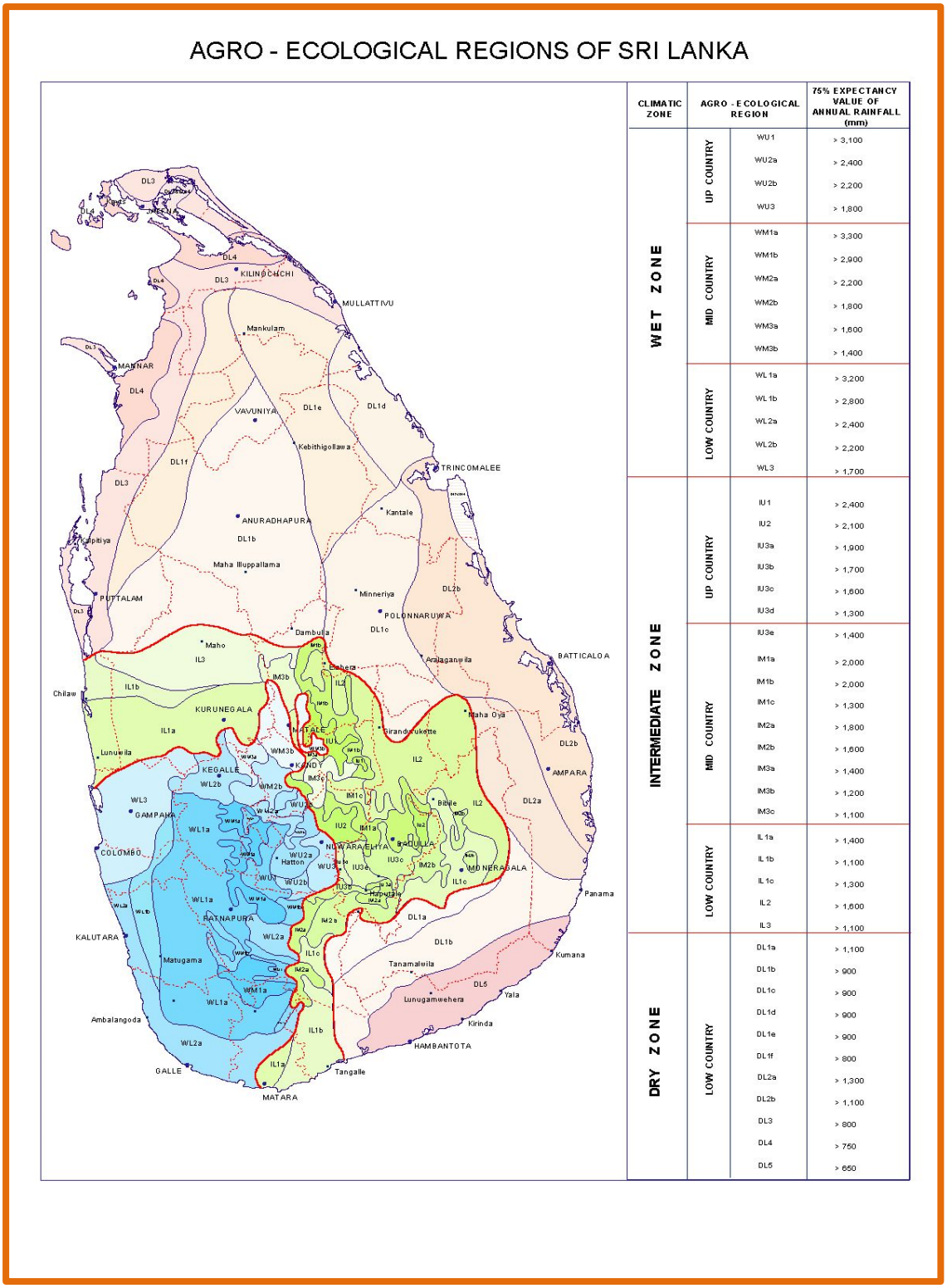

Figure 3.4 Agro-Ecological Map of Sri Lanka (Source: Department of Agriculture)

for development of irrigation settlements. This has accelerated after the implementation of *Mahaweli Ganga* Accelerated Development Programme in 1970s/1980s. It was reported that the deforestation rate from 1956 to 1984 was 42,000 ha/yr (UN REDD Programme, 2017). The population pressure leading to decreased per capita agricultural lands has further aggravated

the problems. As of 2014, the population density was 310 persons per km2 and the land: man ratio of agricultural land in the country remained around 0.14 ha.

Table 3.1 Major Land Use and Land Cover of Sri Lanka (Source: LUPPD, 2019)

Land use Type	Extent (ha)	Percentage (%)
Built Up Land	85,094	1.30
Homesteads/Home Gardens	1,192,925	18.18
Plantation Crops (Tea, Rubber, Coconut)	622,820	9.5
Other Plantations (Palm oil, Cinnamon etc)	157,664	2.39
Paddy	983,550	14.99
Field Crops (Seasonal Crops)	307,311	4.68
Other Cultivation (Banana, Pineapple etc)	27,144	0.66
Abandoned Agricultural Lands	48,660	0.75
Forest Lands	1,916,651	29.22
Scrub	530,006	8.08
Grassland	69,780	1.06
Wetlands	85,443	1.31
Water Bodies	374,553	5.71
Rocks	87,089	1.33
Sandy Areas	19,623	0.30
Bare Lands	52,687	0.80
Total	**6,561,000**	**100**

3.1.9 Biodiversity

Sri Lanka is recognized as a biodiversity hotspot of global importance. Its diverse climate and topographical conditions have given rise to many ecosystems. These ecosystems are the basis for this rich species diversity which is believed to be the highest in Asia in terms of diversity per unit land area. Much of the species are endemic. This is especially relevant for mammals, amphibians, reptiles and flowering plants. The endemic species are distributed in a wide range of ecosystems which can be broadly categorized into forest, grassland, aquatic, coastal, marine and cultivated. The diversity of ecosystems in the country has resulted in a host of habitats, which contain high genetic diversity (MMDE, 2016c).

3.1.10 Forest Resources

As shown in Table 3.1, the latest estimate of forest cover in the country is 29.2 % of the land area. Major area of the forest lands of the country are found in the Dry Zone. The forests in the country have been classified into seven categories namely, Montane, Sub Montane, Lowland, Moist Monsoon, Dry Monsoon, Riverine and Mangrove forest. These forest types make specific ecosystems with very high biodiversity. Encroachment of forests, high demand

for forests for development activities and spread of invasive plant species and frequent fires are the prevalent threats for maintenance of the forest cover of the country (UN REDD Programme, 2017). State owns almost all the forest lands of the country. The Forest Department (FD) and the Department of Wildlife Conservation (DWC) control the majority of the forest lands of the country while State Plantation Corporation (SPC) and Land Reform Commission (LRC) are responsible for about 5%.

3.1.11 Socio-Economic Status

Sri Lanka is an upper-middle-income country with an estimated GDP per capita of USD 4,030 and a total population of 21.7 million people as of 2019. Following 30 years of civil war that ended in 2009, the economy grew at an average of 5.6 percent during the period of 2010-2019, reflecting a peace dividend and a determined policy thrust towards reconstruction and growth.

The Sri Lankan economy is presently transitioning from a rural, agricultural economy towards a more urbanized economy driven by the service sector. At present the share of the service sector in GDP is 62%, followed by the Manufacturing and the Agriculture sectors, which have shares of nearly 30% and the 8% respectively in the country's GDP. The unemployment rate is at 4.4 percent in 2016.

The country has made significant progress in its socio-economic and human development. Social indicators rank among the highest in South Asia and compare favorably with those in middle-income countries. As such, the country has comfortably surpassed most of the Millennium Development Goals (MDG) targets set for 2015 and was ranked 73rd in Human Development Index in 2015. The economic growth has translated into shared prosperity with national poverty headcount ratio declining from 15.3 percent in 2006/07 to 4.1 percent in 2016. Much of the poverty reduction was driven by the reduction in rural poverty. Extreme poverty is rare and concentrated in some geographical pockets. However, a relatively large share of the population subsists on little more than the extreme poverty line.

Sri Lanka is endowed with natural resources that are an important source of income and provide critical input into the country's economic development. Even though the agriculture sector's share of GDP has declined significantly over the last two decades, from about 27% in the 1990's to less than 8% in 2018, around one third of the population remains dependent on agriculture as a major source of income, with 28% of the country's labor force employed in the sector. It also forms the resource base for a number of agro-based industries and agro-services and stimulates economic growth through vertical and horizontal integration with other sectors in the economy (https://www.worldbank.org/en/country/srilanka/overview).

3.1.12 Status on Gender

Women play a major role in the socio-economic fabric of Sri Lanka as they are responsible for bringing the much-needed foreign exchange from three key sectors, i.e. garment industry, export crops (tea) and being employed in the Middle East countries. In addition, they play a dominant role in land and natural resources management. Home gardens, which assures food security for a large section of population is primarily looked after by the women. Some of the activities in crop cultivation are dominated by the women, for example, harvesting and transplanting of paddy crop, plucking in tea plantations etc. They are the most impacted group during drought as they need to ensure that water is available for cooking and sanitation for the family. Because of this, women need to trek long distances to fetch water during the drought period.

The assessment of gender status in Sri Lanka in relation to the rest of the world is given in Table 3.2 (FAO, 2018). In general, Sri Lanka ranks fairly well in terms of gender status. Women have free access to pre-school, primary and secondary education. However, access to education has not led to improvements in gender equality in labour force participation and has not created a situation where women agricultural labourers receive equal pay for equal work. The participation of women in the labour force is low despite the high proportion of women enrolled in universities. Nearly 60 percent of the country's university students are women.

There are large gender disparities in access to and control over resources (e.g. land, water and inputs), access to markets and access to skills training, all of which are critical for agricultural production and livelihoods. Sri Lanka's constitution is non-discriminatory regarding land ownership. However, inequalities in land ownership persist due to gender biases in Sri Lanka's Land Development Ordinance and other customary laws. Only 16 percent of all privately owned land in the country belongs to women. This lack of land ownership limits women's ability to obtain agricultural assets, services and benefits (e.g. subsidies, credit and irrigation water).

3.1.13 Governance and Administration

The country is governed by a mixed system of an elected president and a parliament which elect 225 members of national parliament under proportional system. The country is administratively divided in to nine provinces. The nine provinces are further divided into 25 districts which are subdivided into 315 Divisional Secretariats (DS) divisions and 14009 *Grama Niladari* (GN) divisions. The GN divisions administered by a single government official (GN officer) are the smallest administrative unit of the central government. The GN division is demarcated on the basis of an optimal number of households (estimated at 250 families) that can be managed efficiently at the lowest level of government administration. This

administrative arrangement is very useful to bring relief to the communities when they are in distress. Some key functions and responsibilities of the Central Government have been devolved to the Provinces and a system of Local Government administration comprising of Provincial Councils, Municipal and Urban Councils and *Pradeshiya Sabhas* (at the lowest level). These Councils and *Sabhas* are administered by locally elected council members for a period varying from four to six years. The area under the lowest level of local government or the *Pradeshiya Sabha* is roughly equal to the area under a DS division and sometimes the boundaries are the same for both. Currently, there are 9 Provincial Councils, and 17 Municipal Councils, 42 Urban Councils and 270 *Pradeshiya Sabhas* involved in local governance in Sri Lanka. Map 3.3 shows the boundaries of various administrative units in Sri Lanka.

Table 3.2. Sri Lanka's Position in Global Human Development and Gender Empowerment Indexes. (Source: FAO, 2018)

Index	Value and rank
Human Development Index (HDI) 2016 (UNDP, 2016)	Value: 0.766 Ranking: 73rd out of 168 countries
Gender Development Index (GDI) 2016 (UNDP, 2016)	Value: 0.934 Ranking: Group 3, 'countries with medium equality in HDI achievements between women and men'.
Gender Inequality Index (GII) 2016	Value: 0.386 Rank: 87th out of 159 countries
Global Gender Gap Index (GGGI) 2017	Value: 0.669 Rank: 109th out of 144 countries
Women's Economic Opportunity Index (WEOI) 2012	Value: 47.6 Rank: 84th out of 128 countries

3.2 Mechanisms for the Occurrence of Drought in Sri Lanka

Drought or extreme negative rainfall anomalies are experienced in Sri Lanka under three major meteorological situations. One situation arises when the air stream over the island comes from the Northern hemisphere high pressure system, and travels over the dry mainland of India immediately before reaching Sri Lanka during Northeast monsoon season of December to February. A marked decrease in the formation of weather system (i.e. low-level disturbances, depressions and cyclones) in the Bay of Bengal also gives rise to below normal rainfall during the same months. Such droughts and dry spells can affect most of the island. Rains during mid-March to early May generally occur due to convection under local thermal conditions and the influence of the Inter-Tropical Convergence Zone (ITCZ). However, the activity of the ITCZ during this period is highly variable, and thus it is common to

experience less than normal rainfall in most regions of the country, especially in the Dry Zone. The third situation may occur during the Southwest monsoon months of May to September, when the prevailing air stream of the monsoon is relatively dry due to a deviation in the direction of flow from its usual path. Under such situations, dry conditions are likely to occur in the areas designated wet and intermediate. The period that is least liable to drought conditions is October-December, as this period is the main storm season in Sri Lanka attributed to frequent formation of low-level disturbances and depressions. It is apparent that both the intensity and duration of drought in Sri Lanka increase away from the Southwest towards the north, northeast, northwest and southeast (Punyawardena, 2002).

3.3 Causes of Drought

The causes of drought can be broadly classified in to three classes, namely, a) global factors, b) large scale regional factors and, c) local factors (Basnayake, 1990).

3.3.1 Global Factors

Global factors undoubtedly affect the climate everywhere. For example, the increase of greenhouse gases due mainly to human activities may results in global warming, the decrease in polar ice caps and continental glaciers since the end of last ice age about 18000 ago and the well-known sun-spot cycle. Basnayake (1990) has reported the influence of the sunspot cycle on the rainfall pattern of Sri Lanka.

3.3.2 Large Scale Regional Factors

Large scale regional factors affecting the climate of Sri Lanka have been discussed by several authors (Jayamaha , 1975; De Silva ,1972). Among these factors are;

i) The West Asian high pressure with hot dry continental air mass extending over the Deccan in winter may extend its influence to the North-eastern Dry Zone of Sri Lanka in some years, either directly, resulting in low rainfall.

ii) Inter-annual rainfall variation of Northeast monsoon air streams could be responsible for low *Maha* rains.

iii) Variations in the intensity, frequency, and path of tropical cyclones that play an important role in bringing heavy *Maha* rains in the Dry Zone.

iv) Suppiah (1996) has shown that variation in the Sri Lankan rainfall (i.e. low rainfall in the Southwest and Northwest Monsoon due to appearance of El Nino type ocean-atmospheric circulation in the central eastern Pacific Ocean.

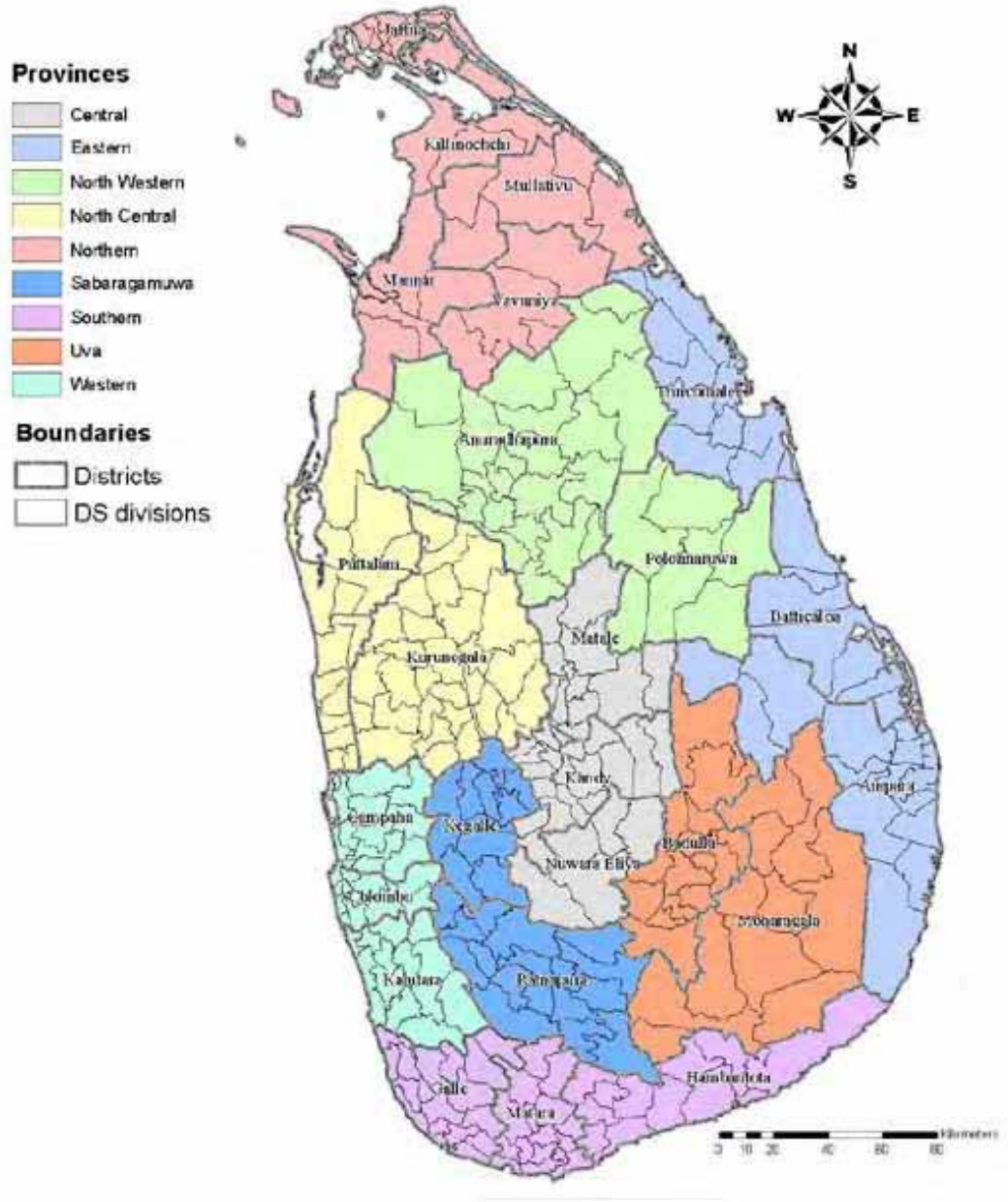

Figure 3.5 Provincial, District and Divisional Secretary Division Boundaries of Sri Lanka **(**Source: Department of Census and Statistics, Sri Lanka)

3.3.3 Local Factors

A connection between extensive deforestation in Sri Lanka during the last two centuries and decrease in rainfall has not been proved. However, reduced water availability and the increased surface runoff have been found (Madduma Bandara, 1977). The increased variability of rainfall in the recent past led to the extreme runoff events (increased floods and low dry weather flow) which further aggravate the occurrence of drought. This kind of local

effect would reinforce global effects discussed earlier to support a trend towards increased droughts in Sri Lanka.

3.4 Historical Occurrence of Drought

The slash and burn agriculture practiced in the Dry Zone of Sri Lanka in the prehistoric period resisted drought by a well-chosen crop combination of mixed cropping such as differing times of maturity, with different tolerances of moisture stress, and frequent moves to new forest lands which ensured continued fertility for crops. The introduction of irrigation-based rice cultivation increased land productivity in the Dry Zone of Sri Lanka. An elaborate system of reservoirs stored not only the rains that fell in the Dry Zone but also the runoff from the Wet Zone that remained under the forest cover serving as further insurance against drought. The slash and burn agriculture system was not discarded but continued to supplement the irrigated lands thus continuing to ensure food security. The historical records such as the *Mahawamsa, Sammohavinodini and Culawamsa* record a succession of drought caused famine, once in every hundred years, except for a gap of 600 years between 600 AD to 1200 AD (Siriweera, 1983).

After the 13th Century, the elaborate irrigation system of the Dry Zone was neglected as a result of political uncertainty and the Dry Zone entered a long period of decline. This decline continued through several centuries of colonialism. During the last century, the Dry Zone has witnessed the restoration of most of the early irrigation systems and the construction of new ones. These together with the introduction of new high yielding varieties have seen a large increase in the land productivity in the Dry Zone. However, the resulting potential increase in social prosperity has been largely nullified by the increase in population in large numbers (Basnayake, 1990). A further problem in the present period has been the deforestation of the hill country of central Sri Lanka which has reduced dry-weather flow of major rivers, thus reducing opportunities for diversion to the Dry Zone.

A detail analysis of drought became possible with the systematic data collection of the Department of Meteorology (DoM) of Sri Lanka. Basnayake (1990) has undertaken a detail analysis of drought using monthly rainfall data of 8 stations representing the Dry Zone from 1879 to 1989. The major season of the Dry Zone is the *Maha* season (Oct-December) or the fourth quarter of the year as shown in Table 3.3.

Thus, on the average the fourth quarter receives 3 times the rainfall of any quarter. Rainfed agriculture, therefore, is clearly dependent on *Maha* rains. Droughts of this rain season would have the greatest effect on the livelihood of subsistence farmer. Therefore, drought appearing in two or more of these months would lead to the total or near loss of the rain fed staple crop. The analysis during this 110-year period (1880 to 1990) has shown that 2 - 3 significant drought occurs per decade in the Dry Zone of Sri Lanka during *Maha* season. The

study further reported that the doughtiness in the Dry Zone of Sri Lanka shows a tendency to increase, both in frequency and intensity (Basnayaka, 1990).

Table 3.3 Average Quarterly Rainfall of the Dry Zone

Quarter	Percentage Rainfall
First Quarter (January to March)	18.0%
SecondQuarter (April to June)	15.6%
ThirdQuarter (July to September)	11.6%
FourthQuarter (October to December)	54.8%

(Source: Basnayaka, 1990)

4. ORGANISATION AND ASSIGNMENT OF RESPONSIBILITIES

There is neither policy nor institution mandated for drought management. However, drought is being included in some of the other policies related to disaster management, climate change etc. The Disaster Management Act No 13 of 2005 (DM Act) provided the basis for the current disaster management approach. The national disaster management policy based on the Act was approved on 28th December 2010.

The Disaster Management Act, No. 13 of 2005 provided the establishment of the National Council for disaster management (NCDM). The Act also made provision to establish the Disaster Management Centre (DMC). One of the important branches of the Ministry of Disaster Management (MDM) includes the National Disaster Relief Centre (NDRC).

There are 21 disasters listed according to the Disaster Management Act, No. 13 of 2005. Drought is listed as the 5thin this list. The DMC of the Ministry of Disaster Management is working towards addressing the issues related to disasters, including drought. For example, the Chapter 3 of the Hazard Profile of Sri Lanka prepared by the DMC with the support of UNDP has studied the drought hazard in the country (DMC, 2012). The Sri Lanka Comprehensive Disaster Management Programme 2014-2018 (MDM, 2014) also describes programmes to mitigate drought.

The National Disaster Relief Centre (NDRC) provides much needed relief to those affected by disasters including drought. It has a Emergency Operation Centre (EOC) which works 24 hours during 7 days a week to coordinate security forces (Army, Navy and Air Force) and police in addition to other relevant organization to support those who are in need. It has a network up to the lowest level of the government, i.e. *Grama Niladari* (GN) Division. The most important task of the NDRC is the distribution of money and other essential items to those who are affected by drought.

4.1 Institutions for Drought Management

The impact of disasters such as floods, cyclones, and landslides have a short time, very visible and requires emergency attention for rescue, relief and resettlement. Therefore, the DMC has already established clear protocols to deal with them. In contrast, drought has a long gestation period. The impacts are felt after few months. Therefore, drought relief in terms of distribution of materials (e.g. food), paying compensation, seed materials etc are the main activities undertaken by the Ministry of Disaster Management through NDRC only at the end of drought if the impacts are very severe. This could be considered as a reactive approach.

However, there are few organizations which proactively attempt to mitigate the impact of drought. The MD and NRMC provide meteorological and agro-meteorological advisories

respectively. The IWMI and UN-WFP also provide climate and food security forecasts for coming season. All these information helps to plan water supply, irrigation and crop cultivation in view of the impending drought thereby reducing the drought impact. There are few other organizations which also play a significant role in managing the drought. The organizations and their mandated tasks in drought management activities are given in Table 4.1.

The impacts of drought are severe on women and children especially in relation to access to water (drinking and sanitation) and food (nutrition). The divisional level child protection officers, the community health workers (who are women and employed by the government for each GN division with a total of about 14,000), the lowest unit of administration, is responsible for looking after nutrition and health aspects of women and children. In addition, there are many NGOs, such as World Vision, CARE, who specifically focus on women and children when they undergo severe hardships. Agency for Technical Corporation and Development, Sri Lanka (ACTED) also provide WASH support for communities to improve the supply of clean drinking water and reduce the distances that women must trek to collect water.

4.2. Managament of Water Resources for Drought Management

The disasters due to drought in Sri Lanka are primarily associated with the scarcity of water due to uneven distribution of rainfall. Therefore, planning, development and management of water resources has been in the forefront in reducing the risks of drought and increasing the resilienceof communities during the recorded history of Sri Lanka. This is exemplified by the fact that highest investment by the Government of Sri Lanka during the last century was made in the water sector. Even at present, almost all the projects to reduce the risk of drought impacts are made in improving the access to water resources. Therefore, it is essential to explain the background on the availability of water resources, how it is sustained and managed as a pre-requisite to prepare a national drought plan.

4.3 Water Resources

Sri Lanka is prosperous in water resources with 103 rivers, more than 20 major wetlands, exceptionally designed minor and major irrigation systems and limited groundwater resource. Since the Dry Zone has less rainfall and a relatively long dry period of about 5 months, water scarcity is a major constraint. In order to address this problem, large number of major/medium

Table 4. 1 Institution in Drought Management Activities

Institution	**Tasks undertaken for drought management**
Disaster Management Centre (DMC)	Develop programmes for drought management and increase awareness through training.
National Disaster Relief Centre (NDRC)	Coordinate drought management interventions and provide relief to drought affected communities.
The National Water Supply and Drainage Board (NWSDB)	Provide drinking water to drought affected communities using bowsers.
Department of Wildlife Conservation	Provide drinking water to drought affected animals in national parks.
Water Resources Board	Identify potential ground water sources in drought prone districts and promote ground water for drinking and irrigation. Responsible for regulation of ground water extraction and use.
Department of Irrigation	Provide irrigation and drinking water from major and medium irrigation schemes and introduce drought mitigation measures such as trans-basin diversions, construction of new tanks and diversion structures.
Mahaweli Authority of Sri Lanka (MASL)	Allocate water for different sectors at the national level in areas under the MASL and provide water for irrigation and drinking purposes.
Department of Agrarian Development	Maintain village tanks to provide water to village communities for drinking/irrigation.
Department of Agriculture	Develop and implement a programme to encourage farmers through an incentive scheme to produce and apply organic manure to rejuvenate the soil, reduce moisture stress and thereby reduce the crop loss; provide micro irrigation facilities; promote research to develop drought tolerant crops.
Local Authorities (District Secretariats and Provincial Councils)	Engauges in drought relief activities (e.g. distribution of relief goods, compensation etc) with relevant organizations, Provide relief to women and children through community health workers at GN level
Farmer Organizations	Formation and managing of user groups to control water resources/tanks
Non-Governmental Organizations (e.g. Sri Lanka Rain Water Harvesting Forum, Community Based Organizations etc)	Promote community/household rainwater harvesting structures for local drinking water security

Agricultural and Agrarian Insurance Board	Expected to help address the risks faced by approximately 1 Mn smallholder farmers during climate catastrophe events via an efficient, affordable crop insurance product
International Water Management Institute (IWMI)	Developed satellite data-based drought monitor and feed the DMC to create 10-day maps

and minor reservoirs has been constructed in the Dry Zone (Figure 4.1). The annual total volume of surface and ground water availability has been assessed at 44,000 MCM and 7,800 MCM respectively (Imbulana et al, 2006). In terms of water demands of the country, 87.34% of freshwater withdrawals are used for agricultural purposes and rest is industrial and municipal water withdrawals. The per capita water availability is about 2500 m^3. Therefore, Sri Lanka can be considered as a country with sufficient amount of available water. However, there is aspatial and temporal variability and the strategies for water resources management should, therefore, focus on reducing this variability. It is estimated that by 2025, under the current scenario, most of the districts in the Dry and Intermediate Zones of Sri Lanka will face severe seasonal or year-round absolute water scarcity.

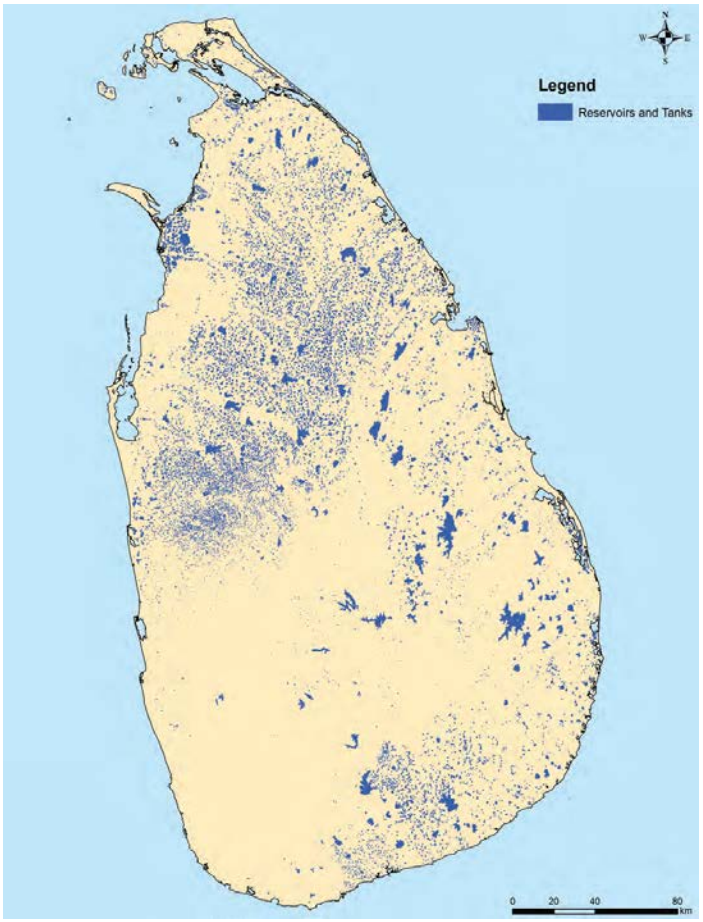

Figure 4.1 Reservoirs of Sri Lanka (Source: DAD, 2011)

Irrigation was essentially developed for paddy cultivation. About 230 man-made major and medium irrigation reservoirs and about 12,000-15,000 minor irrigation reservoirs/village tanks make up the main component of current irrigation sources with a total irrigable area of about 745,000 ha. The cascade system created by interconnection of many tanks is an important feature in the Dry Zone water resources development pattern. The network of village tanks played an important role in supporting many critical livelihood functions in the village life including supply of water needs of humans and livestock, sustenance of the home garden, food and recreation etc. Sri Lanka now cultivates around 1 million ha of paddy land of which around 45% is under major irrigation schemes, 25% under minor irrigation and 30% rainfed. In the same areas, the farmers are engaged in cultivation of other highland food crops such as chilli, onion, vegetables, pulses, tuber crops, maize and other cereals in small extents that amount to a total around 150,000 ha.

Aquaculture initially developed in association with irrigation reservoirs expanded to include a wide range of products. Presently, it comprises fish rearing in the perennial and seasonal reservoirs in the Dry Zone, fish cage culture, shrimp farming, and ornamental fish production using ponds and tanks, etc. The average water area of seasonal small tanks under freshwater fish culture varies from 4.5 ha to 7 ha and requires stocking with fish fingerlings at the beginning of every season.

4.4 Historical Development of Irrigated Infrastructure

The irrigated agriculture was developed as far back as 2500 years ago in the Dry Zone of the country. The historians characterize this early Sri Lankan society as a “hydraulic civilization” (Leach, 1959). The invention of *bisokotuwa* or Valve Pit, the counterpart of the sluice which regulates the flow of water from a modern reservoir tank, has made the construction of large dams possible in 3rd Century AD. River diversion work through the construction of weirs across the longest river in Sri Lanka, Mahaweli was carried out in 495 AD to augment the larger reservoirs build in the Dry Zone. Ever since, constructions of reservoirs and augmentation from river diversions have continued with the thriving civilization in the Dry Zone.

There was a greater socio-economic change after the colonial rule in 1818. Forests in the headwaters of the Wet Zone were cleared for plantation crops and the irrigated agriculture was neglected at least till mid 1880s (De Silva, 2005). Foreign exchange was earned by exporting tea and rice was imported. However, irrigation policy was changed in mid 1880s with an attempt to revive the ancient network of irrigation channels and tanks in the Dry Zone. In this new policy, irrigation was the predominant element, and its objectives were two-fold, namely to increase paddy production of the country and to enable more people to settle on the lands in the drought prone Dry Zone. Its purpose was to reduce unemployment and

lessen the pressure of the population in the Wet Zone which is densely populated. Successive governments after independence have heavily invested on expanding irrigated agriculture in the Dry Zone to achieve self-sufficiency in staple food, rice, as well as other subsidiary crops. A large number of irrigation schemes were either rehabilitated or newly developed after the independence until the biggest ever investment was made in implementing the Mahaweli Development Project (MDP).A master plan to develop the Mahaweli basin, which has the largest potential for both hydropower generation and irrigated agriculture envisaged the development of 350,000 ha of lands in the Dry Zone, including 97,000 ha existing irrigable lands, in Mahaweli and 6 allied basins and install hydropower capacity of about 600 MW. More development work has been undertaken or on going to increase the storage capacity and distribution network in the areas covered by Mahaweli to improve water security is shown in Figure 4.2. The Water Resources Master Plan up to 2030 for the entire country, prepared by the Irrigation Department is given in Figure 4.3. It is expected that the water availability would be increased once these plans are fully implemented.

4.5. Priority of Water Allocation

Irrigated agriculture, hydroelectric power generation and drinking water are the main sectors which uses the Mahaweli water. One of the major constructions of the MDP was the Polgolla barrage and associated tunnel to divert water to the ancient reservoirs in the north central part of the country. A total of 90,000 ha of water-short land received water through this diversion. Three reservoirs, namely Victoria, Randenigala and Rantembe, were constructed across the natural path of the Mahaweli which flows towards east, predominantly for power generation. The installed capacity of power plants of the eastern reservoir cascade is more than 10 times that of the plants along the north central path. Although the use of Mahaweli water for irrigation and hydropower generation are to a large extent compatible, conflicts do arise, particularly over the quantity to be diverted at Polgolla away from the path of maximum generation head. Sending water along the eastern cascade to generate more power is a financially attractive proposition though north central province is more densely populated, consists of large number of ancient irrigated infrastructure and is also politically more powerful. At the stage of drawing the master plan, 1270 MCM was allocated as diversion to the north central province from Polgolla. However, in practice this quantity has been reduced to about 69% during last few years resulting 150% cropping intensity. Allocating water in an equitable and fair manner among large number of tanks in the water-short north central province has also become a problem since demand is always tends to be higher than the supply. Inadequate water at the system level continued to create conflicts among farmers when they try to share water. Therefore, conflicts arise at national level between sectors, such as irrigation and hydropower and local level between farmers in individual irrigation schemes.

4.6 Institutional Arrangements for Water Resources Management

There is a well-established institutional arrangement to manage water resources at the national and the system level. Anticipating conflicts as mentioned above, it became necessary to create a mechanism to manage the water resources of the MDP. It was sensible planning at the initial stage to anticipate issues related to water allocation between sectors and users in view of growing demands in agricultural and industrial development after the completion of MDP. To address this need of water allocation, management and monitoring, the Water Management Panel (WMP) was established in 1985 at the head office of MASL. The WMP is headed by the Director General of MASL and consists of all Heads of Government Agencies concerned with the management and operation of the MDP as shown in Table 4.2. This includes, a) Director General of Irrigation Department, b) Director General of Department of Agriculture c) Chairman of Ceylon Electricity Board, d) General Manager of National Water Supply and Drainage Board, and d) Government Agents/District Secretaries of respective districts within Mahaweli and 6 allied basins. The WMP is assisted in its works by a technically specialized Water Management Secretariat (WMS) constituted within the MASL. The WMS provides information and recommendations to the WMP to assist it in reaching its operational policy decisions. Once the decisions are made, the monitoring of the total programme is directed by the WMS.

The WMS uses a multipurpose, multi-reservoir computer model to plan water allocation. This model uses data on hydrology, crop and irrigation water requirement, energy generation, systems status and diversion capacity of structures and maintenance programme of power plants and other structures. At the beginning of each season WMS prepares a System Operation Plan (SOP) for the cultivation season which gives operation policy, allocation/distribution priorities and programme for the season for Mahaweli and other allied basins (Abeygunawardena and Imbulana, 2005).

Each Mahaweli system has a Residential Project Manager (RPM) who is an administrative head of the system. He is supported principally by two Deputy Residential Project Managers (DRPM), one for irrigation and one for agriculture. Each system is divided to blocks and units and managed by Block Managers and Unit Managers respectively.

In addition to the MASL, which is the major user of water, there are number of other institutions involved in managing water at national and local level as shown in Table 4.2.
These organizations are independent and operate under different ministries. However, all these organizations in one way or another has to be involved in decision making process in water allocation since they all operate within the Mahaweli area identified under the Mahaweli Authority Act No 23 of 1979.

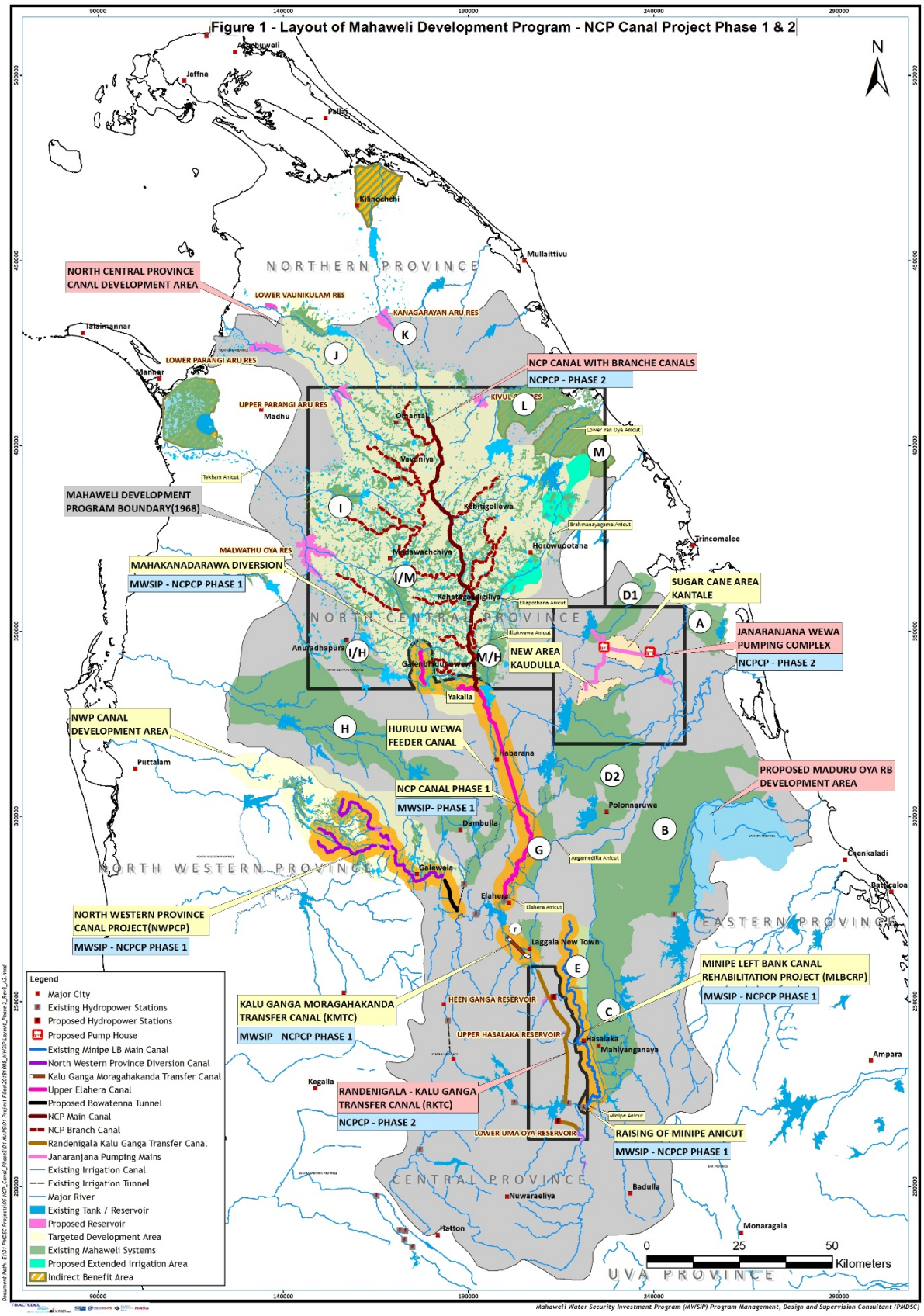

Figure 4.2 Mahaweli Development Programme
(Source: Mahaweli Authority of Sri Lanka)

Figure 4.3 Water Resources Development Master Plan for Sri Lanka - 2030 (Source: Irrigation Department)

4.7 Water Allocation Process

It is important to describe the water distribution system and institutional setup at the project level before explaining the procedure followed in allocation of water. Water stored in a reservoir is released through two main canals, right and left bank canals, from which branch canal originates. Water is delivered to a 1 ha farm plot of each farmer through branch, distributary and field canal. Each farmer receives water through an orifice from the field canal. As mentioned above all the farmers in a system has 1 ha each. This policy of allocating 1 ha land units per farmer has been adopted in all irrigation systems by the GOSL.

Water demand estimates starts from individual farmers in a field canal. The cropping pattern and associated water requirement of each farmer is consolidated at the field canal, distributary canal and system level. The RPM of different Systems of the MDP send this requirement to the WMS. A similar procedure is applied in irrigation systems within the MDP managed by the ID and the bulk water requirement for the system level is provided to the WMS. The Ceylon Electricity Board (CEB) provides information on planed availability and energy and peak power demand over the season. All this information is used by the WMS to prepare the Seasonal Operational Plan (SOP).

Table 4.2 Major Agencies Involved in Water Resources Management and also represented at the Water Management Panel (adopted from Birch and Muthukuda, 2000)

Agency Responsible for Water Resources Management	Major Water Related functions
Mahaweli Authority of Sri Lanka (MASL)	Responsible for water resource allocation among irrigation and hydropower uses. Follow participatory approaches for decision making. Responsible for planning, construction and operation and maintenance of multi-purpose reservoirs, canals headwork and other structures, and for dam safety. Promotion of soil conservation measures and watershed management: monitor sedimentation levels in the reservoirs; provide extension services for irrigated agriculture in command areas. Seasonal allocations are managed to address issues of drought based on real time monitoring and water releases.
Irrigation Department (ID)	Operates the national level hydrology data system. Responsible for planning, construction, operation and maintenance of irrigation, drainage, flood control and drainage infrastructure. Responsible for seasonal planning, seasonal water allocation, rotational water issues during drought period. Implementation of seasonal planning for major and medium irrigation schemes outside areas declared under the MASL Act. Also responsible for flood forecasting and control and implementation drainage and salinity exclusion in irrigation related projects.

	Drought is managed by reducing number of rotations. Introduce solutions to protect the crops during drought period.
Irrigation Management Division (IMD)	Promoting irrigation management through Project Management Committee (PMC) at irrigation system level by means of a co-ordination mechanism with all agencies responsible for irrigated agriculture in major irrigation schemes. Strengthening participatory management of irrigation schemes by promoting formation of farmer organizations and training. Impending drought is managed by "*bethma"* cultivation and crop diversification. These tasks are undertaken by the IMD only in 55 major irrigation schemes whilst the Irrigation Department is responsible for the balance major irrigation schemes.
National Water Supply and Drainage Board (NWSDB)	Responsible for the provision of water supply for domestic an industrial use. Coordinate rural water supply projects with the involvements of CBOs and local authorities. Distribute water using bowsers for drought affected communities.
Ceylon Electricity Board (CEB)	Responsible for hydro-power generation, hydro and thermal mix up; long-term least cost generation planning and development and maintaining hydropower plants and related infrastructure. Shift to thermal power during drought.
Department of Agriculture (DoA)	Involve in research and extension programme on water saving technology on variety of crops, implementation of agricultural policy, promotion of soil conservation and watershed management programmes. Responsible for forecasting drought through agro-meteorological advisories.
District and Divisional Secretaries	District Secretary: Coordination of "Kanna" meetings for irrigation water allocation. Implementation of irrigation ordinance. Coordination of District Coordinating Committee, District agricultural Committee and District Environmental Committee. Divisional Secretary: Coordination of Divisional Environmental Committee and Divisional Coordinating Committee. Involved in distribution of drought relief to communities.

4.8 Platform for Discussion and Decision Making

The SOP prepared by the WMS, taking into consideration of water demand and supply, is discussed at the Pre-Seasonal WMP meeting held with the participation of all concerned agencies and farmer representatives prior to beginning of each season. The approved SOP provides details on projected reservoir releases, energy generation (both hydro and thermal), projected diversions, reservoir behaviour, allocation of water for each irrigation scheme, projected reservoir storage at the end of each month, sluice issues and expected rainfall calculated under average and dry weather conditions, for reservoirs and irrigation schemes connected with Mahaweli development, on monthly basis. Once allocations are made to

different system at the national level, officials along with farmers adjust cultivation plan if there is a shortage of water.

4.9 Issues in Managing Allocated Water During Drought

Though, the preceding sections describe the inclusiveness of all the stakeholders in, a) determining the water requirement, b) take part in decision making (at least legitimizing the decisions taken), and c) get involved in operationalizing the decisions taken, conflicts do arise. Non adherence to the approved SOP by the farmers by cultivating more extents, especially during Yala season, delayed cultivation and over use of water are the common problems. However, these problems are being taken care of a system level through the intervention of farmer organizations since numbers of such violators are minimal. The most common conflicts occur specially during the unexpected drought years when what is delivered at the system level is less than the allocated amount. There are different coping mechanisms adopted by the local population. *Bethma* system has been practiced from ancient times when there is a water shortage where only a portion of the irrigable extent is cultivated (Goonasekere and Gamage, 1999). Change of cropping pattern from high water demanding crops to less water demanding crop is another method. Extending irrigation interval in agreement with fellow farmers and officials is also very common.

During very difficult situations, farmers seek solace in religious activities since the entire community is affected. The religious leader in the village organizes chanting of "*pirith*" or practice "fasting" expecting rain to come. In most instances, rain do come after some time, perhaps, as a natural phenomenon, but the collective action of the community helps them to go through this difficult period together. Rather than encouraging conflicts due to limited resources, sharing the burden together is a common practice that is prevalent in rural Sri Lanka.

4.10 Minor Irrigation Systems (MIS) in Sri Lanka

Tanks with a command area of less than 80 ha are categorized as minor tanks or village tanks. These tanks are man-made lakes or ponds which have been constructed by local people, with indigenous knowledge and skills, from ancient times mostly during the medieval period. The updated village irrigation systems according to the Department of Agrarian Development are about 13,141 (DAD, 2011). MIS was one of the most important elements that govern the stability of settlement in the dry and intermediate zones of Sri Lanka (Somasiri, 1991). Unfortunately, the significant population in the dry and intermediate zones that lives under the MIS represents one of the most vulnerable community groups (Senarathne and Wickramasinghe, 2011).

Ensuring proper maintenance and sustainability of MIS is of vital importance because minor tanks are indispensable for Sri Lankan rice production. It is also worthwhile to note that, *Yala* cultivation almost relies on irrigation water stored in tanks. It is, therefore possible to affirm that proper operation and maintenance of MIS is crucial to ensure the present levels of production, because 1/4 of Sri Lankan paddy lands cultivated and 1/4 of Sri Lanka's paddy production is obtained under MIS. In addition, the water stored in MIS is considered as the only water source available for the village communities and livestock to reduce the risk of drought.

4.10.1 Cascade Systems

Cascade is a "connected series of tanks organized within a micro-catchment of the Dry Zone landscape storing, conveying and utilizing water from an ephemeral rivulet" (Panabokke *et al*., 2002). Each of these cascades forms a distinct small watershed or meso-catchment ranging in extent from 5 to 10 square miles (13-26 km^2). In ancient times, constructed small tank cascade systems was considered as unique irrigation systems with a distinctive gathering of land uses. MIS in a tank cascade are hydrologically interlinked and if the hydrology of one or few tanks is rehabilitated by increasing its storage capacity or increasing the irrigated command area or by diverting water elsewhere, entire hydrology of the cascade is changed.

With the beginning of the twenty first century, a few NGOs first and then the government have focused on cascade-based tank improvement. This interest was the outcome of many research studies conducted from the early 1970s to this day following the attention drawn on micro valley based rural settlement and land use in north central Dry Zone during the early 1770s (Tennakoon, 2017) and later by the IWMI. Having realized the importance of cascade-based development and also identifying its importance to improve the resilience of farming communities of the drought affected Dry Zone, many development projects included cascade development as a primary intervention. The ongoing projects currently going on in Sri Lanka to address drought, described in Annex 1 is aa testimony to this statement**.**

4.11 Groundwater use in Sri Lanka

In the past groundwater has been used on a large scale only in Jaffna peninsula. This is due to the absence of perennial rivers or major water supply schemes to the peninsula and short duration of seasonal rainfall. As the single water source, groundwater fulfils domestic, industrial and agricultural water requirements of the peninsula. In the rest of the country, groundwater from dug wells, usually situated in the back garden, were used for drinking purposes and household chores (Senarath, 1990).

Farmers in Dry Zone mainly depend on seasonal rainfall and irrigation water from reservoirs for cultivation. With the rapid increase of rural farmer population and intensive agriculture practices, the available water resources could not meet the increased water demand from traditional sources. Under these circumstances groundwater as a supplementary source of irrigation came into focus. Scientific surveys in locating groundwater had been practiced in late 1960's in Sri Lanka, though up to late 1970's, the rate of groundwater development was slow. After 1978 there had been a very high rate of development, and by the end of 1980's there were over 12,000 deep bore holes within the country. Since then, the diffusion of groundwater extraction wells has been very rapid in minor irrigation schemes situated in the north central and north western part of the Dry Zone.

With the introduction of large diameter (3-5 m), shallow (about 10 m) wells, called "agro-wells" supported by a subsidy scheme of the Government in 1989, it gained popularity since farmers were able to select crops and time of cultivation with flexibility. According to an estimate, there were about 50,000 agro-wells in the Dry Zone by the end of 2000. A heavy concentration of agro-wells (about 80 %) is found in the northwest Dry Zone. About 65 % of agro-wells are located in minor irrigation schemes.

Small pumps operated by diesel or kerosene engines and electricity is used to abstract water from agro-wells. As a result, farmers have the full control over irrigation. When using agro-wells they can irrigate on on-demand basis (Pathmarajah, 2003). Access to water irrespective of the season, maintenance of crops with supplementary irrigation during *Maha* season, ability to cultivate short duration crops just after *Maha,* maintain crops during *Yala season,* little or low maintenance and no additional infrastructure are the other advantages. An agro-well can irrigate about 0.2 to 0.8ha of land, with 20 % to 80 % increase of yield. The risk of crop failure due to water shortage is minimal. Therefore, an agro-well is considered as an insurance and life time investment for the farmer.

4.12 Conjunctive Use

With the increasing incidence of drought and water scarcity, conjunctive use of water (i.e. using surface water and ground water to meet the crop water demand) is now becoming very popular. In addition, drainage pumping, dead storage pumping is also being practiced. This strategy reduces the risk of drought, especially in irrigation systems, which relied mainly on surface water sources.

4.13 Gender Concerns in Irrigated Agriculture

Gender issues are more common in irrigated agriculture compared to community based water supply for drinking purposes. A study conducted by Saumyarathna et al (2016)**in** *HakwatunaOya* irrigation scheme, in the context of irrigation, has shown that customary laws and traditional social norms have been biased in favour of men. A total of 29% of woman had

the membership of farmer organizations. This is mainly due to the less land ownership of woman. Access to water is directly link to the land. Therefore, women's access to land is crucial to their access to water. According to the traditions, agricultural lands are given to the son and not to the daughter.

Out of total leaders, only 3% of women were in the leadership positions while 97% were men. Woman Farmers were appointed as secretary, treasure and field canal representatives. None of the women held the post of president and water masters. This study indicated five main barriers which restricted woman's accessibility to irrigation water at the field level, such as non-recognition of women as farmers, lack of land ownership, neglected specific gender needs in irrigation, migration of male relatives in the family and less power and voice of the woman. Agriculture in Sri Lanka is a male dominant profession and culturally a woman was given less weight especially with regard to irrigated agriculture. As a result, women are more impacted due to shortage of water compared to men.

4.14 Institutions Responsible for Drought Preparedness and Response

Access to irrigation water (surface or ground water) and drinking water to supplement water received from rainfall determines the status of drought in the country. As explained in the preceding sections, water resources management is a fairly complex process which involves many organizations with varying responsibilities. There are institutional arrangements for these organizations to collaborate in such a manner to ensure that water is managed efficiently and distributed equally among users. Farmer or community-based organizations work very closely with state officials so that joint management of the resource would help to manage drought situation.

Therefore, all these stakeholders have to take the responsibility for drought preparedness and response. There are many platforms (e.g. Water management panel, project management committees, *Kanna* meeting etc) which facilitate discussion among these stakeholders to take proactive measures to response to drought.

5. DROUGHT MONITORING, FORECASTING, AND IMPACT ASSESSMENT

Drought monitoring is done in many countries by analyzing various meteorological and other environmental data such as rainfall, temperature, winds, soil moisture etc. Meteorological, Agricultural, Hydrological and Socio-economic droughts are four categories which depend on monitoring vulnerability of different key sectors. Agricultural and Hydrological droughts are strongly related with meteorological drought whereas socio economic drought depends upon various other factors such as poor infrastructure, political reasons etc. with or without meteorological, agricultural and/or hydrological drought. Therefore, socio economic drought monitoring is not as easy as in case of the other three.

5.1 Drought Monitoring Indices

Because of the objectivity of the definitions adopted for drought, it is difficult to compare its prevalence with its spatial and temporal distribution. Therefore, drought indices are useful indicators only on an absolute scale. They assimilate large sets of data on rainfall, stream flow, and other water supply indicators into a comprehensible picture represented by a single value, which is far more useful than raw data for decision making. Although there are 41 indices available according to the UNCCD Tool Box, five different indices have been used to assess droughts in Sri Lanka. They are briefly described below.

Drought days

The drought day concept has been introduced as drought index based on working out a daily moisture balance taking into account the gains from rains and losses from estimated evapo-transpiration. The number of times the soil moisture is reduced to the limit of permanent wilting point, at which point the productive process of the crop are appreciably decreased, is the indication of drought intensity, expressed as the number of drought days in a month during the critical growth period or during the whole growing season (De Silva, 2008).

Percent normal

The percent normal is a simple calculation well-suited to the needs of a general audience. The percentage of normal precipitation is one of the simplest measurements of rainfall for a location. Analysis using the percent of normal is very effective when used for a single region or a single season.

Standardized Precipitation Index (SPI)

The Standardized Precipitation Index (SPI) is a widely used index to characterize meteorological drought on a range of timescales (NCAR, 2020). On short timescales, the SPI is closely related to soil moisture, while at longer timescales, the SPI can be related to groundwater and reservoir storage. It quantifies observed precipitation as a standardized departure from a selected probability distribution function that models the raw precipitation

data. The raw precipitation data are typically fitted to a gamma or a Pearson Type III distribution, and then transformed to a normal distribution. The SPI values can be interpreted as the number of standard deviations by which the observed anomaly deviates from the long-term mean. This the SPI value varies between +2.0 and −2.0 with extremes outside this range occurring 5% of the time. Positive SPI values indicate a greater than median precipitation while negative values indicate less than median precipitation. The drought intensity based on SPI value is given in table 5.1.

Table 5.1 SPI Values and Drought Intensity

SPI value	Drought Intensity
2.0 and above	Extremely Wet
1.5 to 1.99	Very Wet
1.0 to 1.49	Moderately Wet
-.99 to 0.99	Near Normal
-1.0 to 1.49	Moderately Dry
-1.5 to -1.99	Severely Dry
-2.0 and less	Extremely Dry

Moisture Availability Index (MAI)

MAI is the ratio of the Dependable Rainfall (DRF) to Potential Evapo-transpiration (PET) where dependable rainfall is the amount of rainfall of a particular location at 75 percent probability or expectancy level. It is the rainfall that could be expected to occur at least during 75 years out of 100 years.

MAI = DRF / PET

A value of MAI less than or equal to 0.33 is considered as a very dry condition and not at all suited for rainfed agriculture. Hence, any month having a MAI value of less than or equal to 0.33 could be considered as a dry month (Chithranayana and Punyawardena (2008).

Table 5.2: Drought Severity Classification

No of months with MAI less than or equal to 0.34	Drought Severity
0	wet
1	Slightly wet
2	Mild drought
3	drought
4 or more	Severe drought

NDVI and VCI

The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements, often from a space platform, assessing whether or not the target being observed contains live green vegetation. NDVI is an indicator of the level of photosynthetic activity and reflects whether the vegetation is stressed or not. The Vegetation Condition Index (VCI) compares the current NDVI to the range of values observed in the same period in previous years. VCI can estimate the status of vegetation according to the best and worst vegetation vigour over a particular period in different years that gives a more accurate result as compared to NDVI while monitoring drought at a regional scale (Bajgiran*et al.,* 2008). As suggested by Kogan (1995), when VCI becomes over 50 percent, the pixel was assigned as normal condition of vegetation whereas if the values ranging between 50 to 35 %, those pixels assigned as moderate drought condition and values below 35%, the pixels assigned as severe drought condition. The drought prone areas map for Sri Lanka, given in next chapter was developed based on these indices (Iddawela, et al, 2019).

5.2 Drought Monitoring and Assessment

A study conducted by Manesha et al (2015) tested the applicability of SPI using information from 2001 drought in Hambanthota. Results were verified further by simulation SPI indices for the drought at Hambanthota in 1976. Finally, analysis has conducted for 26 rainfall measuring stations and mapped spatially to find distribution of drought in 2001. It is reported that the 3-month SPI time scale is the most suitable to monitor onset of drought, but 6-month time scale explained the severity and the length of drought period in Sri Lanka. The study also reported that irrespective of what SPI shows, the feeling of drought is different for different places. Soil condition and vegetative conditions, infrastructure, and soil moisture recharging capacity are also important for identifying real drought condition.

Abeysinghe and Rajapaksha (2020) assessed the status of drought in Sri Lanka using the SPI at 3, 6, and 12 months' time scales using monthly rainfall (1970 to 2017) data of 54 weather stations. The result based on SPI identified hydrological years 1975-76, 1982-83, 1986-87, 1988-89, 2000-01, 2001-02, 2013-14, and 2016-17 as drought years for 52, 32, 35, 33, 33, 31, 31, and 31% of tested stations (54), respectively, at annual time scale. Comparison of the SPI at different time scales revealed that more drought events ($SPI \leq -1$) occurred during *Yala* season than *Maha* cropping season.

Many studies suggested that there is a possibility of establishing drought conditions in Sri Lanka during southwest monsoon (May- September) in the El Nino years. To verify this statement, Herath et al (2015) conducted a study in six districts of the Northern Province of Sri Lanka due to drought conditions in 2015 since it was an El Nino year. To identify possible drought conditions in 2015, monthly rainfall data were analyzed using the SPI. Additional information related to this study was gathered from agriculture and irrigation departments to monitor agricultural and hydrological drought. It is reported that, there was no

meteorological, agricultural and hydrological drought, but a possibility for socio economic drought in the above-mentioned areas.

A drought incident is considered as one of the major climatic stresses and will affect the rain fed crop cultivation, reservoir replenishment, the extent of irrigation and also negatively affect the natural environment. Many stakeholders including farmers claim that the availability of water for cultivation has decreased in the recent years possibly due to high incidence of droughts. To test this assumption, a study was conducted by Perera et al (2016) to find whether the occurrence of droughts has increased over the years affecting the water availability of a selected watershed. Daily rainfall data of two stations representing AER of $IL_3$and IL_{1a} of the watershed over a period of 30 years (1981-2010) were used to find the number of non-rainy days, absolute drought events and total number of absolute drought days on annual and seasonal, both on rainfall and cultivation basis. The Coefficient of Variance (CV) of non-rainy days has increased in recent years in the second inter monsoon rainy season and *Yala* cultivation season in IL_3AER.These trends and increased variation would leads to serious implications on the available water that is used for irrigation purposes in addition to rain fed crop cultivation and also the natural environment and its ecosystem.

5.3. National Drought Monitor

Since drought is not a sudden disaster event, developing it can be monitored using several tools – on the ground and remote sensing. Developing dryness may go up to different levels and, therefore, it would be possible to grade those development stages of drought and activate some standing orders, relevant for different stages, so that mitigation activities could be implemented based on certain levels of drought impacts.

IWMI has developed a satellite data-base drought monitor to cover the island, and feed the DMC, with created maps for every ten days. With that, it would be possible to use those definitions of meteorological, hydrological and agricultural drought classifications to declare each drought and activate standing orders. Classification may capture all those aspects and identified them as level 1, 2, 3, etc. Based on regular declaration of areas and levels of 'dryness', the line department representatives in target areas will have standing procedures to follow accordingly. However, more work is needed to make this proposed system fully operational. Arthur C Clarke Centre also has developed a satellite data-base drought monitor to cover the island.

5.4 Proposal for Comprehensive Monitoring and Evaluation

Since there is no coordinated system to monitor drought, a proposal was made in the Road Map towards a Safer Sri Lanka (MDM, 2006). A review of the Road Map at the end of 7 years of implementation revealed that the individual agencies have been implementing specific

projects although there is no national level monitoring system. Therefore, SLCDMP proposes to introduce a monitoring system which will have the following approaches:

- Transforming activity-based national disaster management programme into results-based one.
- Establishing a rigorous tracking system to monitor the interventions and activities of different agencies to ensure their contribution towards DRM.
- Introducing a centralized, web-based platform for effective coordination.
- Facilitating national level decision making process for effective resource allocation.
- Monitoring and Evaluation system will consist of activity and output level indicators that could facilitate in assessing the outcomes. Monitoring of SLCDMP at national level will be done by the National Council for Disaster Management (NCDM) and at the ministry level through the National Disaster Management Coordination Committee (NDMCC).

5.5 Impact of Drought

During the last century the droughts of 1908 and 1911 were the most extensive droughts, affecting more than 20 districts in the "*Yala*" agricultural season while the most extensive drought during the "*Maha*" agricultural season occurred in 1938 and affected 20 districts (Amaradasa-2001). This millennium started with a severe drought in 2001 affecting Dry Zone and intermediate zone. Hambanthota area experienced a prolonged and very severe drought in 2001 and 2002. The total affected families from the drought were more than 800,000 in the year of 2001 (http://www.desinventar.lk/).

Number of organizations which includes, FAO, World Food Programme, World Vision, conducted a study in April 2014 to assess the severity of the 2014 *Maha* season drought, and its impact on food security and livelihoods (MED and MDM, 2014). Their key findings are given below.

- The *Maha*2014 drought seriously damaged agricultural production and is threatening to significantly limit the upcoming *Yala* harvest.
- Three consecutive years of natural disasters has undermined household resilience: populations in affected areas have built up unsustainable levels of debts, have insufficient access to water for irrigation, have limited quality seed supply and are exposed to a continued decline in agricultural income.
- As a consequence, food insecurity has increased dramatically to an estimated 768,000. More than double the caseload in 2012.
- Household food consumption deteriorated sharply: 18 percent of households consumed inadequate diets of low calorie and/or diversity. This used to be around 6 percent. A threefold increase.

- An immediate coordinated relief effort specifically targeting the vulnerable households is recommended to prevent a further collapse in household resilience.

In 2017, Sri Lanka experienced one of its worst droughts in over four decades(MDM and WFP, 2017). This was the culmination of five consecutive years of dry weather during the country's main crop production season. Drought hit the northern Dry Zone especially hard, causing significant reductions in the production of rice, a central pillar of national food security. The drought has affected 20 districts and approximately 1.8 million people. It is reported that water scarcity related to drought risk is considered as the most pressing issue at present and in future (UNDRR, 2019).

The most recent drought in 2019 *Yala* season has affected over half a million people in 105 DS divisions in 18 districts. One of the hardest hit areas is the Puttalam district with some parts not having rain for six months. The rainfall for the whole of the 2018 had been insufficient for cultivated land in the district. Almost 800 irrigation tanks out of the 1380 in the Puttlam district have been depleted due to drought.

According to the DMC, over half a million people in 158,000 families were affected by the drought. The consequences were felt by almost the entire country. About 120,000 people are being supplied drinking water via bowsers and water tanks. The DMC has provided 600 water bowsers to each district severely affected by the drought. Figure 5.1 shows the provinces and the people affected in those provinces due to drought in the *Yala* season in 2019.

5.5.1 Impact of Drought on Women and Children

Women are unfairly affected by vagaries of drought in addition to other disparities that they face in their day to day livelihood activities. As a result, they are less resilient to drought compared to men. There is a substantial difference between women and men in remuneration in casual labour in agriculture. This labour involves temporary work and varies depending on the geographical area, the season and type of crop. It is reported that a casual male worker receives Rs 1 200 per day for agriculture labour work and female worker receive Rs 600 for the same type of work (FAO, 2018). These rates further fluctuate in between seasons, with women receiving even less when rates are low. It is also reported that unpaid family workers represented 16.4 percent of the total employed female population; for men the percentage was just 2.5 (Department of Census and Statistics, 2017c).

One of the studies reported that increasing intensity of drought in Batticaloa and Anuradhapura districts have had multiple negative impacts on children and families, leading to longer-term disastrous consequences (ILO, 2018). Drought conditions appeared to be worse than floods because they lack both irrigation water and water for drinking/domestic consumption. Lack of irrigation water has affected agricultural cultivation, with low yield

leading to a loss of income, in turn, reducing parental support for children's education and diet, creating food insecurity and poor nutrition issues. The lack of safe drinking water and water for domestic consumption, bathing/washing/cooking etc. has led to poor sanitation and health issues for the local communities and their children.

The drought in 2019 impacted 700,000 individuals across the Eastern Province, dramatically limiting access to safe drinking water affecting all spheres of life. It is reported that these conditions put great pressure on families, particularly mothers, who spoke about the emotional burden of leaving their children alone whilst they collected water from wells far from their homes (https://reliefweb.int/report/sri-lanka/supporting-sri-lankan-mothers-and-children-through-prolonged-drought).

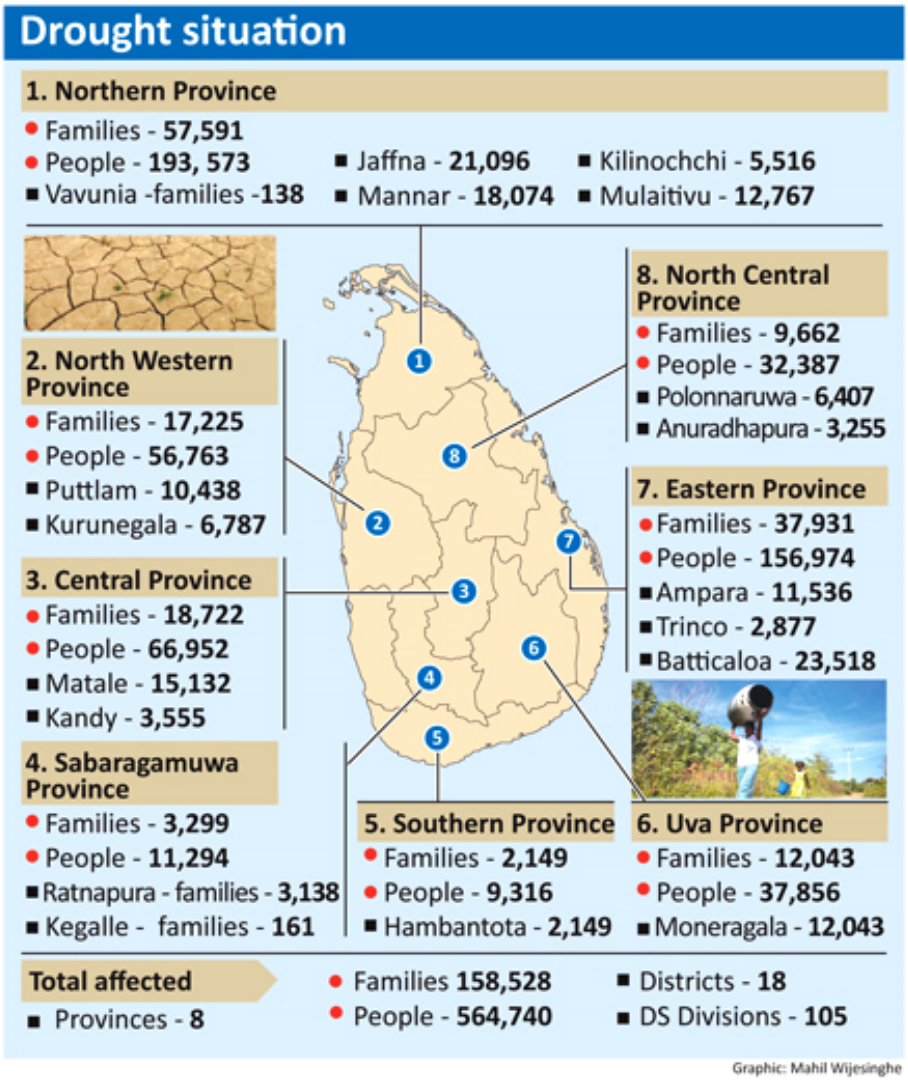

Figure 5.1 Areas and the people affected due to drought in the *Yala* season in 2019 (Source: Sunday Observer, 14th July 2019)

6. DROUGHT RISK AND VULNERABILITY

Vulnerability is defined by IPCC (2007) as "the degree, to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes". It is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. Therefore, the vulnerability of a system depends on internal characteristics (sensitivity and adaptive capacity) of the population and the external factors as climate hazards. Vulnerability is widely used in development and adaptation contexts. Policies, institutions and other types of interventions and initiatives from the government have a notable influence in internal characteristics of the population. Therefore, key vulnerabilities identified by vulnerability assessment can guide policy makers and implementers to identify the geographic areas and groups of people that have to be prioritized and focused. Further, vulnerability assessment facilitates to identify the factors contributing to increase the vulnerability. This helps for better policy decisions and implementations to focus on the real need of the specific group.

6.1 Vulnerability Assessment

According to the framework developed by IPCC (2007), vulnerability is a function of exposure, sensitivity and adaptive capacity.

Vulnerability = f (exposure, sensitivity, adaptive capacity)

Where;

Exposure is the nature and degree to which a system is exposed to significant climatic variations.

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate related stimuli.

Adaptive capacity is the potential or ability of a system, region, or community to adjust to the impacts of climate change.

Except for few localized studies, no studies have been undertaken to comprehensively to assess the drought vulnerability to cover the entire country by taking all three parameters of exposure, sensitivity and adaptive capacity. However, some of the factors which influences exposure and sensitivity are used to assess drought occurrence/hazard. The most comprehensive study to assess drought occurrences in Sri Lanka for cultivation seasons, i.e.*Yala* and *Maha* for all agro-ecological regions was carried out by Chithranayana and Punyawardena (2008).In this study, monthly Moisture Availability Index (MAI)values for each agro-ecological region were calculated using monthly Dependable Rainfall (DRF) values and Potential Evapotranspiration (PET) data for the same locations. The *Yala* season constitutes of six months from March to August while six months from September to February are considered as the *Maha* season. The drought severity classification assumes that stored soil

moisture is adequate to supply the water requirement of crops for three weeks or more and that short drought periods are of lesser importance.

6.2 Spatial Pattern of Drought during *Maha* Season

The second inter-monsoon rains of any year exhibit less spatial and temporal variability and the drought conditions during *Maha* seasons is mainly attributed to the spatial and temporal variability of northeast monsoon rains. All the AERs in the Up-country Wet Zone are free from drought hazards during *Maha* seasons due to the relatively high effectiveness of northeast monsoon rains over those regions (Figure 6.1). Among the six AERs in the Mid country Wet Zone only two regions, namely, WM2b and WM3a are prone to mild drought conditions while the rest are free from drought hazards during *Maha* seasons.

The situation is slightly different in the Low country Wet Zone where two AERs, namely, WL2band WL3 are prone to mild drought conditions while the other three AERs are unlikely to experience drought conditions during *Maha* seasons. As both WL2b andWL3, are located further away from the central hills, the contribution of rains from the northeast monsoon and its associated weather systems in the Bay of Bengal is minimal. Therefore, both January and February are dry months in these regions. Since these two months are at the end of the *Maha* season and exhibit only mild drought conditions, occurrence of severe drought injuries to the crops are unlikely. Meanwhile, regular occurrence of periods of drought in these two regions during January and February favour the tree fruit crop cultivation.

In the case of the Intermediate Zone, all AERs in both the Up country and Mid country Intermediate Zone are generally free from drought hazards during *Maha* seasons. This is mainly due to the relatively high effectiveness of the northeast monsoon rains over these regions as they lie in the eastern flanks of the central highlands. Out of the five AERs of the Low country Intermediate Zone, two AERs, namely, IL2 and IL1c are free from drought hazards during *Maha* seasons. As these two regions lie in the foothills of eastern flanks of central highlands, they receive abundant rainfall from northeast monsoon rains up to February and exhibit no droughts during normal *Maha* seasons. Meanwhile, the other three AERs of the Low country Intermediate Zone, namely, IL1a, IL1b and IL3 which lie in the western half of the island has mild drought conditions during *Maha* seasons due to relatively lower contribution of rains from the northeast monsoon and its associated weather systems in the Bay of Bengal.

In the Dry Zone, all the AERs of the Alfisol region have slightly wet conditions during *Maha* seasons except DL1f region (Figure 6.1). Being farther away from the effective region of the northeast monsoon, theDL1f region is somewhat vulnerable to drought conditions during *Maha* seasons (Mild drought). DL3 adjacent toDL1f, also exhibits similar situation during *Maha* seasons.

Generally, northeast monsoon rains are not so effective in the extreme northern and southern parts of the island and hence, DL4 and DL5 AERs are prone to drought conditions during *Maha* seasons. Meanwhile, the regions under the most effective area of northeast monsoon rains in the Dry Zone, namely, DL2a and DL2b have no threat of drought during *Maha* seasons and are classified as Wet.

6.3 Spatial Pattern of Drought during *Yala* Season

Figure 6.1 shows the spatial pattern of the drought severity during the *Yala* season. Out of15 AERs in the Wet Zone, only WM3b experiences a dry month during the *Yala* season. This region covers a part of the Matale and Kandy districts. As the dry period in this region occurs during the very first month of the season, it is unlikely to affect crop production significantly due to this rainfall deficit. However, if the northeast monsoonal circulation over the island is weak during the previous two months, namely, January and February, a severe shortage in both surface and groundwater may be experienced in this region.

In the case of the Intermediate Zone, the drought proneness is relatively higher compared to the wetter part of the island. Except IL1a AER, all other AERs in the Low country Intermediate Zone are vulnerable to either drought or severe drought conditions during the *Yala* season (Figure 6.1). Being close to the effective region of the southwest monsoon, the IL1a region is likely to experience only mild drought conditions during the *Yala* season. However, if the southwest monsoonal circulation over the island is weak in a particular year, it may lead to intense water deficit conditions even in this region of the Low country Intermediate Zone. Under such situations, paddy cultivation under rain fed or irrigated from minor tanks in this region (i.e., Kurunegala district) is highly vulnerable to water shortage conditions. As the effectiveness of the southwest monsoon fades out over the Intermediate Zone, its vulnerability to drought conditions during the *Yala* season gradually increases. The worst situation in the Intermediate Zone is experienced in the IL3 region where rainfall during March is ineffective and, hence falls under the category of an area prone to severe drought conditions. Meanwhile, the situation in this region is further aggravated due to presence of sandy Non-Calcic Brown (NCB) soils which has a low water holding capacity.

Out of eight AERs in the Mid country Intermediate Zone, only two AERs remained wet during the *Yala* season. As these two AERs namely, IM2a and IM3a are adjacent to the country's wettest AERs such as WM1b, WL2a andWM3b, they exhibit relatively wet conditions. This is mainly attributed to the effect of southwest monsoon rains. All other AERs in the Mid country Intermediate Zone exhibited drought conditions during the *Yala* season except the IM1a region which has a mild drought condition during the *Yala* season. It is mainly attributed to the relatively high rainfall of August and September due to the formation of thunderstorms in the eastern flank of the central highlands when the southwest monsoonal circulation is weak.

Both IU1 and IU2 AERs in the Up-country Intermediate Zone are less likely to experience drought hazards during *Yala* seasons and are classified under the Wet category. Both these AERs receive a substantial amount of rain fall during the southwest monsoon even though they do not fall directly under the most effective area of the southwest monsoon. The rest of the AERs of the Up-country Intermediate Zone, namely, IU3a, IU3b, IU3c, IU3d, and IU3e have either slightly wet or mild drought conditions depending on the contribution of southwest monsoon rains to the respective regions.

All eleven AERs of the Dry Zone of Sri Lanka are prone to severe drought conditions during *Yala* seasons irrespective of their geographical location (Figure 6.1). This is mainly attributed to the relative ineffectiveness of the first intermonsoon rains over the Dry Zone and moisture deprived flow of the southwest monsoons over most parts of the Dry Zone during May to September as a Föhn like wind (*Kachchan*or *YalHulang*).Such winds along with clear sky conditions, which permits enormous amount of solar radiation, result in higher evapotranspiration leading to soil moisture stress in crops. Hence, drought injuries are inevitable in rainfed upland crops during *Yala* seasons unless supplementary irrigation is provided.

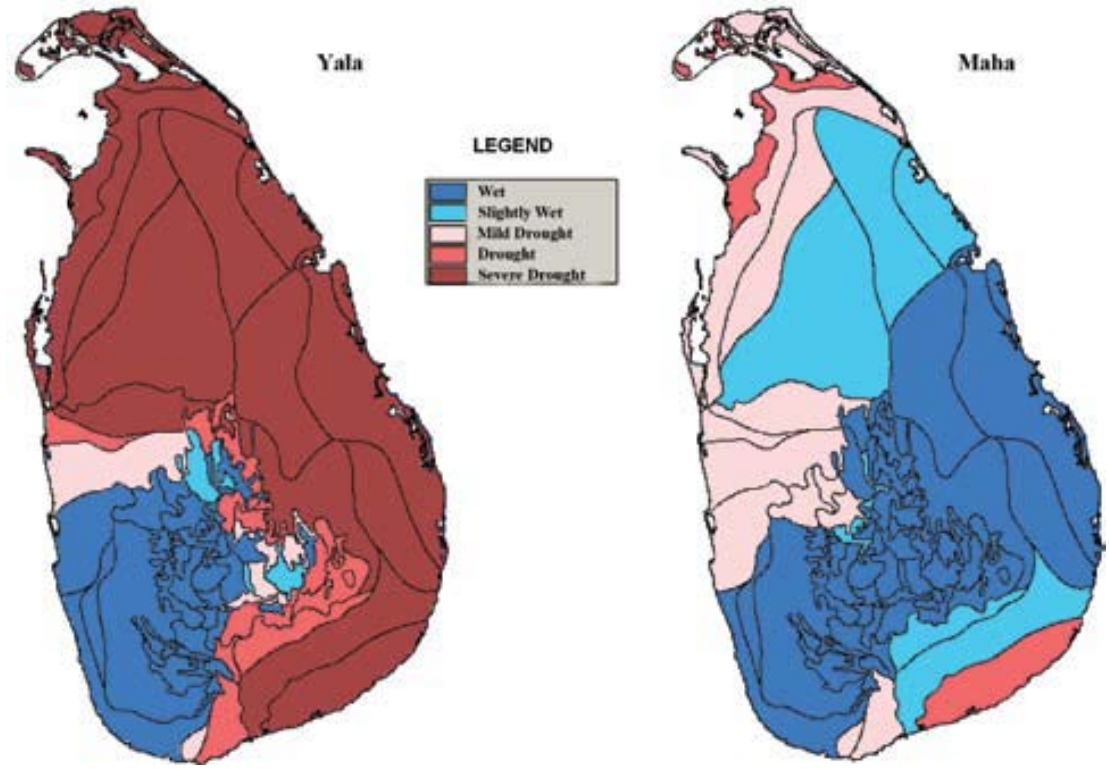

Figure 6.1: Spatial pattern of the drought severity during *Yala* and *Maha* seasons.
(Source: Chithranayana and Punyawardena, 2008)

BOX 1: Summary of the Drought Hazard during Maha and Yala Seasons (adopted from: Chithranayana and Punyawardena, 2008)

Maha Season

- Wet Zone does not exhibit droughts.
- All AERs in the Upcountry and Mid country Intermediate Zone are free from drought hazards. Out of five AERs of the Low country Intermediate Zone, three AERs are vulnerable to drought, exceptIL2 and IL1c.
- Almost all AERs of the Dry Zone are less likely to experience drought conditions except those located in the extreme north-western and south-eastern regions.

Yala Season

- There is a slim chance of drought conditions occurring in the entire Wet Zone.
- All AERsin the Low country Intermediate Zone are vulnerable to drought conditions of varying degrees except the IL1a region.
- Almost all AERs of the Up-country Intermediate Zone are less likely to experience drought conditions.
- All the AERs of the Dry Zone are highly vulnerable to drought conditions.

There are many other studies undertaken to assess the drought hazard of the country. One example is the hazard map of Sri Lanka using 14 indices derived from daily and monthly series of rainfall and potential evaporation data by the DMC (2012). According to the map, Dry Zone has a very high drought hazard whilst the intermediate zone has high drought hazard. The Wet Zone is characterized with very low to moderate drought hazard. These findings tally with the outcome of the study of Chithranayana and Punyawardena (2008).

One of the most recent study is carried out by Iddawela et al (2019,) based on Vegetation Condition Index (VCI) which uses Normalized Vegetation Index (NDVI). They used VCI to assess drought conditions with MODIS 16-day time series satellite data pertaining to 2001 to 2016. After aggregation of 16 years drought occurrence for each month, monthly drought severity maps were prepared for Sri Lanka. The areas where more than 6 years out of 16 years has been categorized as drought prone zones, while areas with 4 or less drought years identified as low drought prone zones and rest of the areas considered as areas with moderate drought conditions. A comparison of monthly drought severity is illustrated in Figure 6.2.

A composite map showing overall drought prone possibility over Sri Lanka were developed by aggregating drought prone areas for each month (Figure 6.3). The results showed that

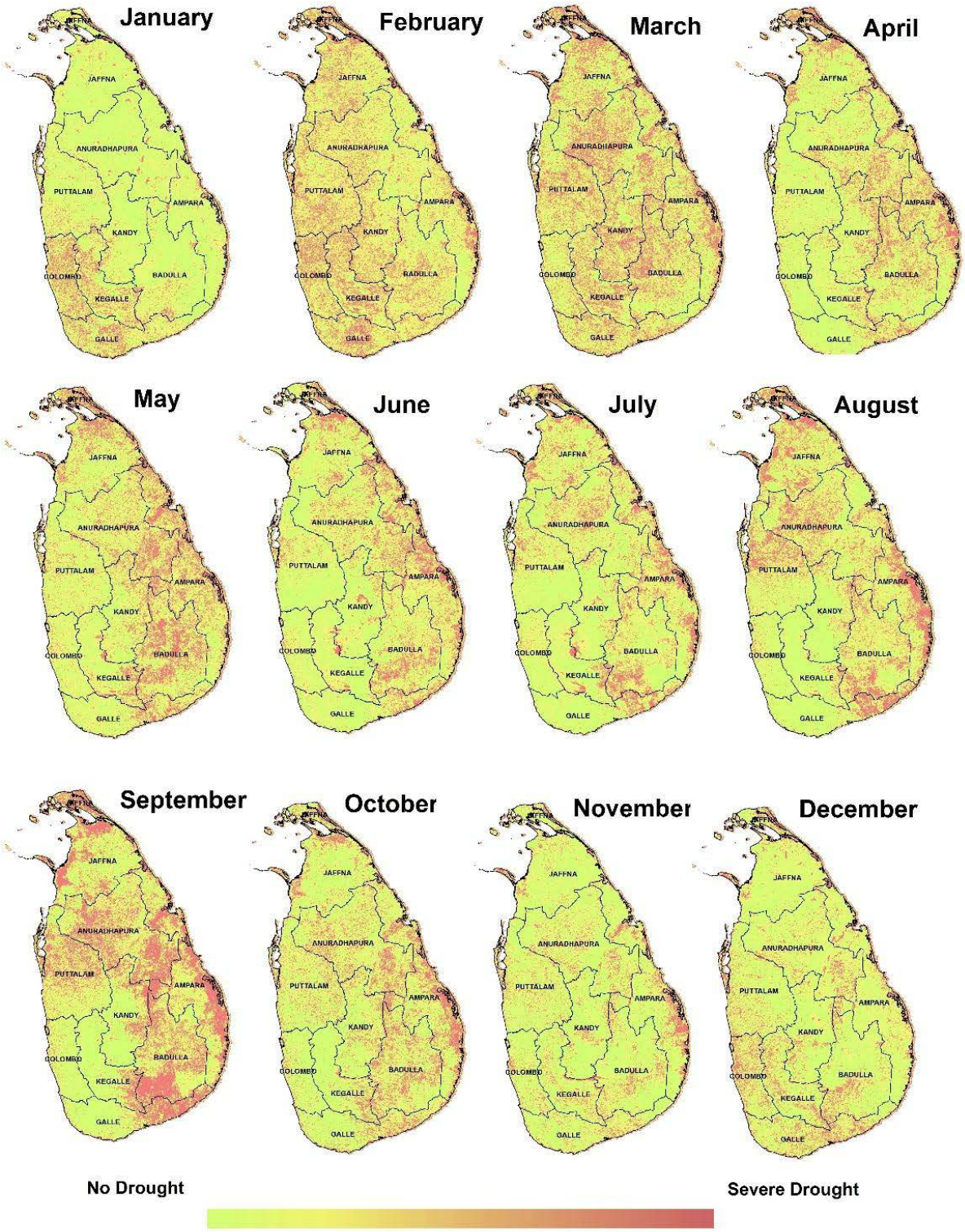

Figure 6.2 Monthly Drought Prone Maps of Sri Lanka
(Source: Iddawela et al, 2019)

drought was lesser in January, except some parts of western and southern provinces. Drought conditions at most of north eastern parts of Dry Zone areas of Sri Lanka could be seen during May to September with a peak drought conditions during August and September at Uva and Easter provinces. Jaffna, Kilinochchi, Batticaloa, and Monaragala districts can be categorized as severe drought prone districts.

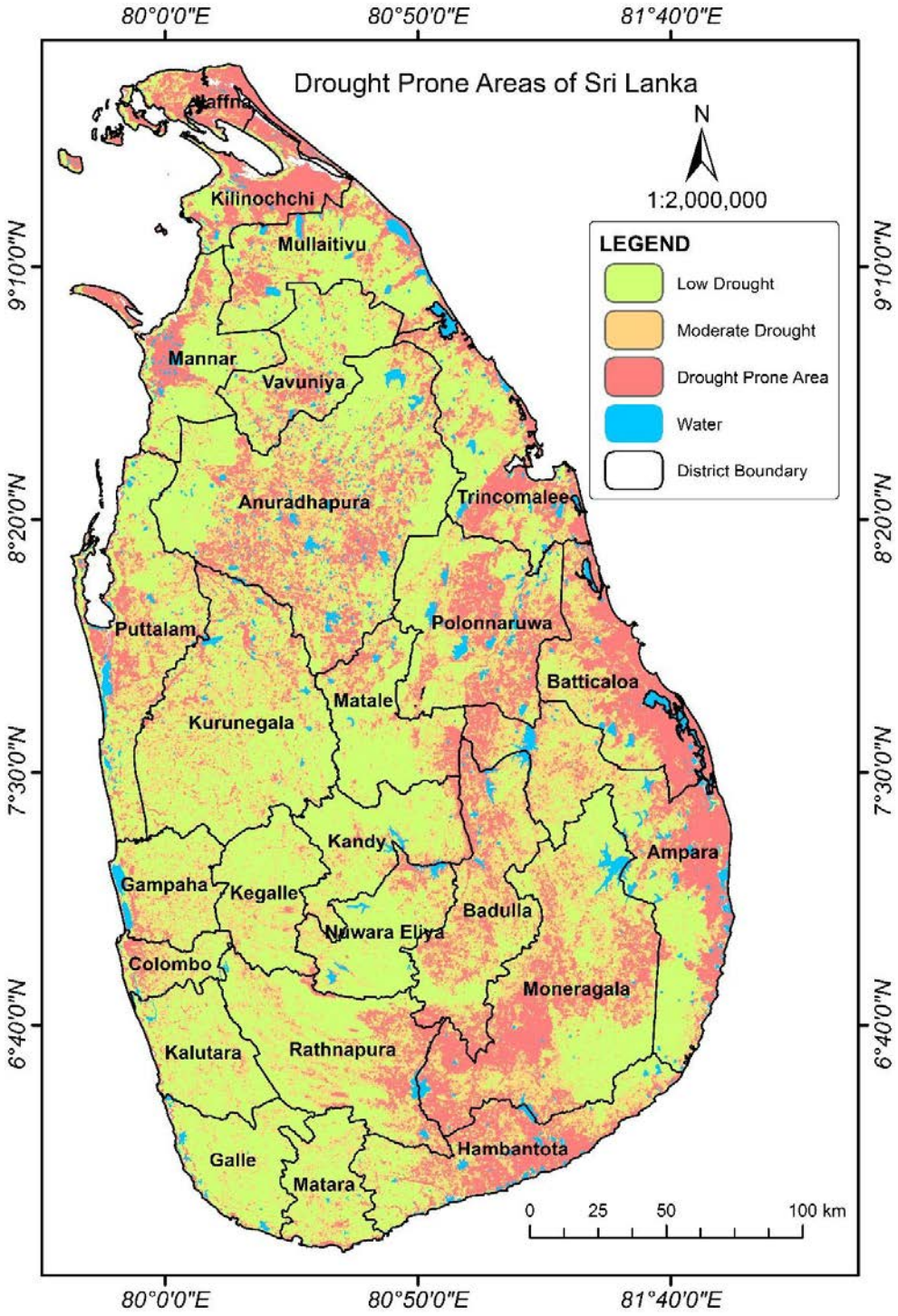

Figure 6.3 Drought Prone Areas of Sri Lanka
(Source: Iddawela et al, 2019)

7. DROUGHT COMMUNICATION AND RESPONSE ACTIONS

The drought communication and response action has not been formally established. However, the process and the line of communication for various other hazards which requires emergency response has been established and is in the process of strengthening. Steps have already being taken to provide disaster hazard information using internet facilities (http://www.desinventar.lk/des_html/disaster_profile/disaster_profile.pdf). How the disaster communication is channelled to the lowest level is described in the National Disaster Management Plan, and is described below. Since drought is also coming under the DMC, it is expected that drought would also be communicated through the same channel in future.

As per the Disaster Management Act, the various mandated technical agencies will be responsible for forecasting and issuing early warning messages on respective hazards to the DMC. The DMC will be the main focal point responsible for coordinating early warning, along with the relevant technical agencies and Technical Committees, its dissemination and for ensuring last mile dissemination. The Emergency Operations Centre (EOC) of the DMC will be in constant coordination with all technical agencies responsible for natural, technological and man-made hazards and in instances of any imminent disaster it will take action to inform the responsible officers for onward communication to the sub-national levels and communities.

7.1 Early Warning Systems

DMC has established an effective early warning system for disasters – natural, technological and man-made - through the EOC of the DMC. Priority will be given for floods, landslides, cyclones, storm/sea surges etc. Methods of obtaining information about impending disaster events and issuing early warnings would vary from one hazard to another due to different characteristics of different hazards.

The broad responsibilities of the DMC with respect to Early Warning would be:

- Strengthening the dissemination capacity of DMC in early warning to vulnerable communities.
- Working out strategy and policy in the given area of activity.
- Initiating awareness on activities related to early warning among the various agencies and public.
- Guiding District Disaster Management Coordinating Unit (DDMCUs) in coordinating and implementing warning dissemination related activities in the Province, district, local agencies, division, GN and community levels.

The specific role of the EOC of the DMC with respect to early warning dissemination would be to;

- Establish coordination with the local technical agencies responsible for forecasting different hazards, which will be in constant communication with regional and international early warning agencies to receive early warning of the respective hazards.
- Establish coordination with all local early warning agencies responsible for other local hazards.
- Establish a reliable communication system (telephones, radio communication etc. from technical agencies to the Head Office and to Provincial / District Control Rooms directly or through Head Office). Ensure redundancy by having alternative communication systems in place in case of breakdowns in the main system.
- Have the system established with media, Military and Police Communication Centre, and ensure dissemination of information through same.
- Create awareness among communities and all concerned including Police and military forces on the communication system in use for early warning dissemination and what immediate actions to be taken, especially on rapid onset of disasters.

Coordinating activities of the EOC of the DMC with respect to receiving early warning and dissemination is illustratively shown in Figure 7.1.

To minimize the losses both to life and property to a maximum possible level through effective communication, DMC carry out communicating using all media. Media coordination is done in 24-hour basis in the DMC by appointing a media spokesperson and a media team. Their task is to;

- Coordinate all local and foreign media and provide early warnings and Information for the general public through electronic and printed media.
- Conduct Press briefings for the Disaster Situations and Special Events in the Disaster Management Centre.
- Prepare Press releases as per the requirement and update the situations accordingly.
- Conduct awareness programs for the Media at nationally and locally.

7.2 Technical Institutions for Forecasting and Early Warning

At present, there are several agencies to handle issues related to different hazards/disasters mentioned above. For most of the disasters, there is a government institution legally mandated to monitor the disasters which fall within their expertise. Some of the key institutions and their responsibilities are given in table 7.1. Water Resources Boards which started to monitor ground water levels in three river basins is expected to issue early warning in future.

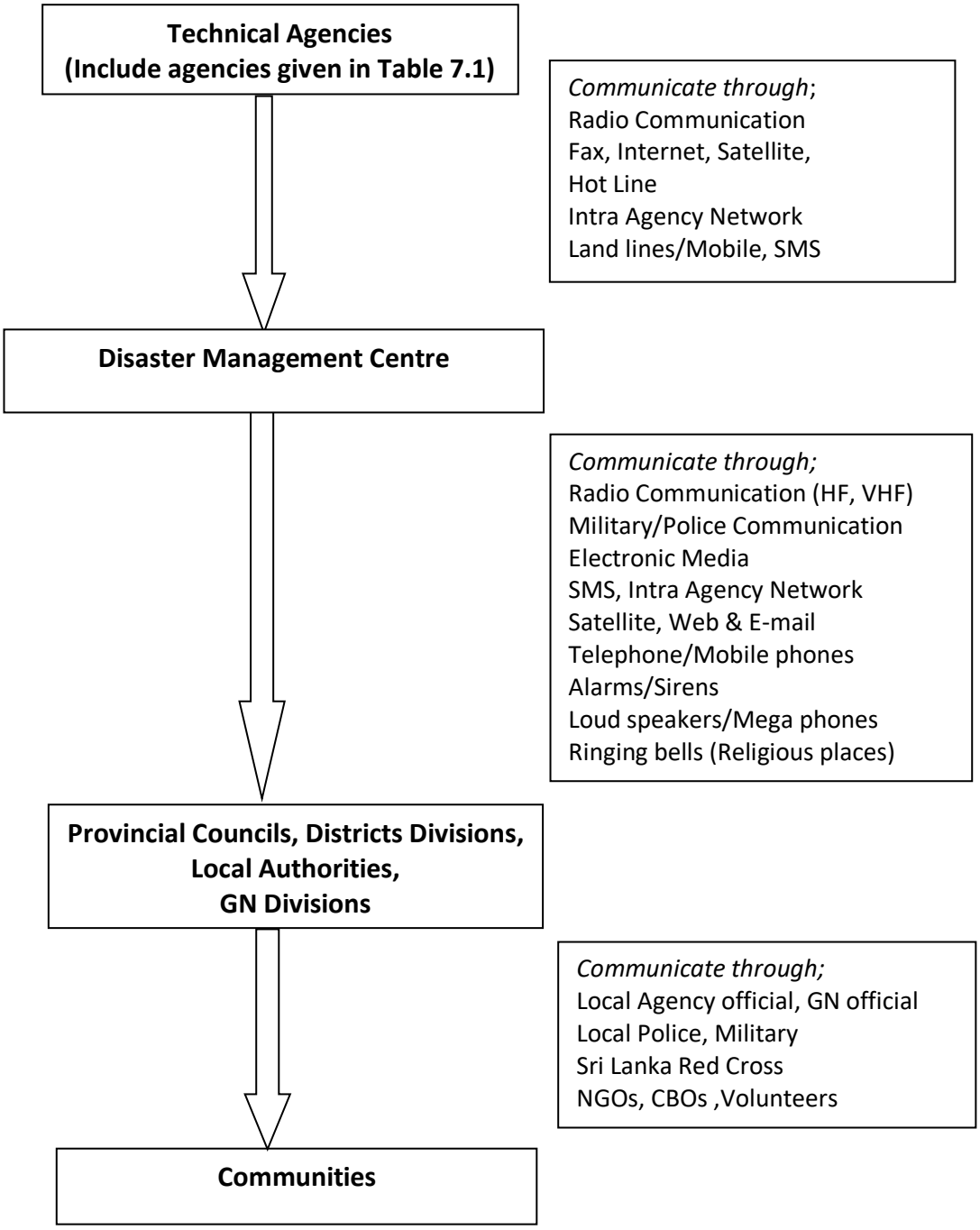

Figure 7.1 Planned System of Dissemination of Early Warning Messages to the Communities (Source: National Disaster Management Plan, 2014)

The project proposals on capacity building and systems improvement with respect to such technical institutions and hazards are given in the National Disaster Management Plan. The procedure adopted by the DMC in this regard is as follows:

- Standard disaster early warning messages and bulletins are being developed by the Mandated Technical Agency on the impending threat indicating the nature of the disaster and the warning level.
- These should reflect the magnitude of the event, the geographical areas likely to be affected, the level of alert and the clear message as to how the community members are expected to act on receiving the message. Communities will be made aware of the exact meaning of the messages and how to act on receiving such messages.
- With these clearly identified the tools for last mile dissemination could be decided upon. For cell broadcasting, SMS messages, Early Warning Towers, short specific messages have been formulated, agreed upon and made ready for use.

Table 7.1Technical Institutions Responsible for Forecasting and Issuing Warning Alerts

Technical Agency	**Responsibility**
Department of Meteorology	Forecast weather related disasters such as drought, strong winds, heavy rains, lightning, tropical cyclones, tsunami etc.
Irrigation Department	Forecast and early warning of Floods and drought.
National Building and Research Organization (NBRO)	monitor landslide prone areas and issue early warning
Natural Resources Management Centre (NRMC) of the Department of Agriculture	Agro-met advisories including Drought
NWSDB	Address water scarcity for drinking purposes, sea water intrusion
Forest Department	Manage forest fires
Mahaweli Authority of Sri Lanka	Manage drought and floods in downstream areas of Mahaweli reservoirs

7.3 Forecasting and Dissemination of Information on Drought

Drought has been identified as a slow onset hazard affecting a large number of people incurring enormous economic losses. The impact of drought could be minimized through advance predictions, thereby supporting decisions related to agriculture, water resource management, etc. Presently climatic and hydro geological data is being collected by a number of agencies including DoM, ID, MASL, CEB, NWSDB, DoA, DAD, WRB, etc. Inputs from all these technical agencies are required to manage drought. For example, DoM convenes the Monsoon Forum to discuss the possible impacts of monsoonal rains in the country. However, there is no formal arrangement for all technical agencies to meet and take a collective decision to issue seasonal forecast on drought. Therefore, interagency forum will be required to share data, technical expertise and generate seasonal forecast advisories. At the sub-

national level, seasonal meetings of farmer organizations and relevant state agencies are convened by the District Secretary to decide on availability of water for cultivation of paddy and other crops. Based on the information provided by the agencies, the District Secretary in consultation with all relevant parties including farmers, outline the water distribution pattern, types of crops and extent of land that could be cultivated. Therefore, it is proposed in the National Disaster Management Plan to restructure and/or strengthen the present "Monsoon Forum" to include other relevant agencies to issue forecast and guidance on both floods and drought. In order to facilitate process of taking informed and timely decisions by the forum, technical capacity of relevant institutions need to be developed.

This includes the following;

- Develop the capacity (physical and human resources) of Department of Meteorology to prepare and issue improved climate forecasts.
- Develop a methodology to issue seasonal climate and weather forecast (weekly or bi-weekly) taking in to consideration meteorological and hydrological data, soil moisture contents, etc. including remotely sensed weather information.
- Restructure/establish an inter-agency forum, led by the MDM, to periodically assess climate outlook, its implications for key socioeconomic sectors, and issue advisories. (Members of the forum: MDM, DoM, DI, MASL, DoA, NWSDB, CEB, DAD, WRB and DMC).

7.3.1 Agro-meteorological Advisories

Drought forecasting become more important for the farming community since it determines their livelihood. This information is useful for them to select the crop/combination of crops, extent to be cultivated and the intensity of cultivation since their investment would be wasted if there is a crop failure.

The Department of Meteorology is responsible for conveying the climatic forecast for the oncoming season to the Natural Resources Management Centre (NRMC) of the Department of Agriculture, which in turn convert such information to agro-meteorology advisories. In preparing this advisory, additional information such as water availability, type of crops with degree of drought sensitivity, length of crop etc. are taken in to account. This advisory is sent to about 5000 registered farmers in the country through Agricultural Instructors. These registered farmers disseminate agro meteorology information to fellow farmers. As at present, this process appears to be the only working mechanism in existence to forecast and disseminate drought to the farming community. The ongoing project on "strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management", described in section 8.2.2 has a major component to improve this process by, a) establishing effective monitoring systems for

drought, floods and water management, b) co-developing and disseminating weather- and climate-based advisories for agricultural and water management through Agricultural Service Centres and Farmer Organizations to farmers and village water managers, and c) developing climate-risk management response measures based on advisories and forecasts for agriculture, water management and flooding in cascade systems.

7.3.2 Climate and Food Security Monitoring Bulletin

International organizations are also involved in providing early warning in relation to drought. For example, IWMI with the UN-WFP prepare Climate and Food Security Monitoring Bulletin for cropping season along with the predictions for forth coming season(https://www.wfp.org/publications/sri-lanka-climate-and-food-security-monitoring-bulletin-maha-primary-harvest-season). The latest one assesses rainfall anomalies, as given in Figure 7.2, and provides information for forth coming cultivation season under six headings such as, a) highlights, b) seasonal observations, c) *Yala* cropping season-2020 and adaptive measures, d) agricultural conditions and food security, e) water needs and *Yala*2020 cultivation, and f) climate forecast and potential future impacts.

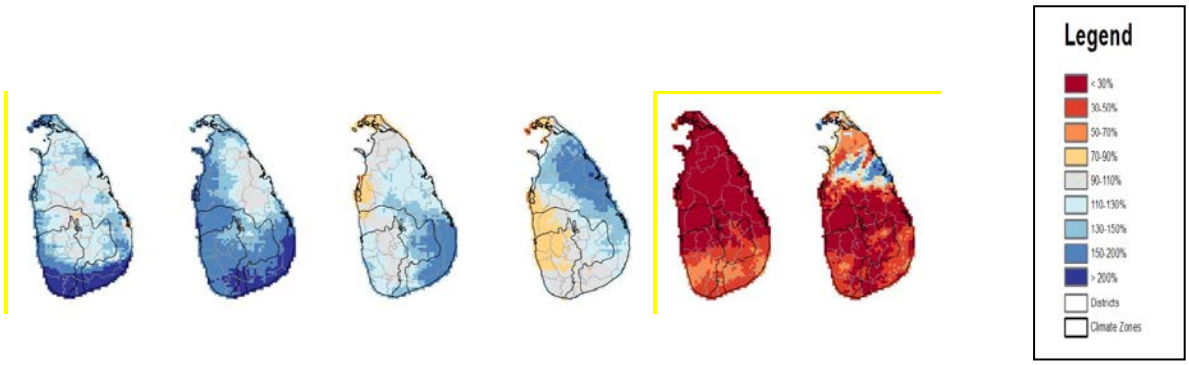

Figure 7.2 *Maha* Season (September 2019- February 2020) Rainfall Anomaly (Deviation from long-term average)
Note: Rainfall Anomaly is based on average rainfall experience in a given month over the average in the past 30 years

This advisory bulletin provides information on the current status of water available in the reservoirs and the likely rainfall during the fourth coming *Yala* season. Based on this information, it provides possible adaptation measures. Information on likely harvest is also useful to device strategies to ensure food security. Since this information is web-based, another mechanism needs to be in place to bring this information to the users, i.e. farmers at the community level as indicated in Figure 7.1.

8. DROUGHT MITIGATION AND PREPAREDNESS

Mitigation can be defined as actions or activities that reduce the overall risk to drought and ultimately reduce the severity of drought impacts. Drought mitigation should be executed prior to the onset of drought conditions. Moreover, mitigation activities should be ongoing and continually funded if the benefits of such efforts are to be fully realized. Unlike emergency or short-term actions to alleviate drought crises, activities such as development of water resources, water conservation, legislative actions, institutional arrangements and public awareness programs are considered as actions with a longer-term emphasis.

8.1 Drought Mitigation

Drought mitigation comprises of broad range of proactive measures. "Risk management," or a proactive approach to drought management, is preferable to the usual reactive or "crisis management" approach. A coordinated drought preparedness program is the key element to reduce drought impacts for individuals, communities, and the environment. If progress is to be made towards improving the ability to manage drought, it will require an integrated approach within and between levels of government, and appropriate involvement of local organizations, the private sector and communities. An effective drought mitigation plan should thoroughly examine and address the needs of each of the drought impact sectors through risk assessment and prioritization of mitigation activities within each impact sector, and plan accordingly. Mitigation is most effective when there are strong commitments for implementing a variety of strategies.

Majority of the suggested interventions for the mitigation of drought is adopted mainly from the Sri Lanka Comprehensive Disaster Management Programme (SLCDMP):2014-2018 which is prepared with a wider consultation of stakeholders. In addition, recommendation made by other national plans given in chapter 2, such as, National Policy Framework of the Government of Sri Lanka (*Vistas of Prosperity and Splendour*), National Adaptation Plan for Climate Change Impacts in Sri Lanka (2016-25), National Action Plan for *Haritha Lanka* Programme, National Action Programme for Combating the Land Degradation of Sri Lanka (NAPCLD), Land Degradation Neutrality Target Setting Programme (2017-2030), Draft National Agriculture Policy of 2019, country papers (De Silva, 2008; Imbulana, 2010), individual research (Rekha Nianthi, 2014; Tennakoon, 2017), consultations with experts and suggestions made at the National Workshop are also used in formulating an exhaustive list of drought risk reduction interventions as listed below.

<u>Strengthening the monitoring of climate change impacts and vulnerability</u>

- Continue to study climate change, especially rainfall variability and its relation to the occurrence of drought and its impacts.

- Initiate studies to assess vulnerability to drought at least at the scale of divisional secretariat level.
- Make use of indices to assess the severity of drought. These indices could later be used for drought response, crop insurance etc.
- Initiate a long-term systematic monitoring programme on climate variability.
- Assess the capacity of existing hydro meteorological information facilities and improve them.
- Implement necessary capacity improvement measures in relevant agencies.
- Bring regulations to facilitate access to climatological and hydrological data from relevant institutions.

Establishment of an efficient climate information and communication system

- Improve the existing system of timely issuing of short-term weather forecasts.
- Strengthen the capacity of the Meteorological Department to issue accurate seasonal forecasting.
- Strengthen early warning systems.
- Strengthen existing agro-meteorology advisory mechanism and formally streamline it with relevant national and local agencies.
- Develop network-based communication systems using mobile phones/internet etc.
- Assess the traditional knowledge of weather forecasting and integrate them for better forecasts of water availability.

Development and management of surface water resources

- Assess the current water storage options in connection to future projections of climate change.
- Develop a road map and investment plan for efficient utilization of existing and future water storage options.
- Rehabilitate cascades and minor tanks.
- Develop strategies for water security of the nation.
- Bring drought management as an agenda item at pre-seasonal meetings during water allocation at the national level by the MASL.

Harness excess water in storage facilities through intra-basin and trans-basin approaches

- Update the national water resources master plan accommodating all stakeholder requirement.
- Develop capacity of water sector agencies.
- Improve the existing hydro meteorological stations for monitoring and forecasting.
- Undertake modelling studies to study various scenarios under varying climate.
- Incorporate climate impact assessment for future water resources development plans.

Enhance the efficient use of ground water resources

- Prepare strategic assessment for ground water utilizations.
- Assess ground water availability, both quantity and quality, at local level.
- Assess, regularize and preserve ground water resources at local level for effective utilization.
- Promote efficient use of groundwater by constructing production wells and boreholes.
- Develop community wells especially for water supply to village communities.
- Regulate the development and use of Agro-Wells (i.e. large diameter shallow wells with an average of about 3 m diameter and 10 m depth that the small farmers used extensively in the Dry Zone exclusively for irrigation).
- Increase ground water recharge by modern techniques.

Promote efficient practices for drinking water supply

- Promote efficient domestic water use practices, such as domestic rain-water harvesting systems and domestic water treatment facilities.
- Incorporate water safety plans.
- Protect headwaters of community water supply schemes.
- Adopt strategies to prevent seawater intrusion into water abstraction intakes of water supply systems.

Improve on-farm water management

- Screen current practices of water management for climate resilience and identify ways to improve them.
- Explore climate resilient indigenous practices of water management and identify ways to integrate them into modern practices.
- Increase the efficiency of use and reduce losses of irrigation water by re-use of drainage (waste) water and use of water saving irrigation applications (sprinkler irrigation, drip irrigation etc).
- Promote the judicious use of surface and ground water (conjunctive use).
- Improve maintenance of existing reservoirs and water distribution network (e.g. Improve the water conveyance efficiency, rehabilitation of village tanks etc).

Promote and strengthen farmer organizations

- Strengthen existing farmer organizations through continuous training and capacity building.
- Encourage common community work (village level) through farmer organizations.
- Facilitate efficient water allocation and distribution within irrigation systems.
- Launch participatory cascade management programmes in village tank catchments.

Promote good farming practices

- Strengthen breeding programmes to develop drought resistant varieties.
- Align planting and farming practices with the forecasted rainfall.
- Use suitable crop varieties (i.e. short duration, drought resistant varieties with less water demand)
- Adopt suitable techniques for cultivation to minimize water use, e.g. grow rice under aerobic conditions to minimize the water use (e.g *Kekulama* or *Manawari* system and System of Rice Intensification (SRI).
- Shared cultivation (*Bethma System)*, i.e. sharing paddy land closer to water outlets when water is limited.
- Change agronomic practices to suit the rainfall regimes and the type of crops (e.g. incorporation of tree crops, Agro forestry, protective agriculture)
- Use of soil and water conservation measures to increase the use of residual moisture and avoid soil erosion under water limited and extreme rainfall situations, respectively.
- Use of new irrigation equipment to enhance productivity and efficiency of irrigation water use.
- Use rain water harvesting techniques to make maximum use of rainwater during drought conditions.
- Promote sustainable cropping system practices for increasing the resilience of field crops, plantations and trees.

Integration of livestock

- Incorporate livestock to enhance land productivity and income, and serves as insurance against drought.
- Use suitable breeds which are tolerant to drought.
- Develop strategies to enhance the availability of food for livestock.

Improvement of watershed management

- Identify and map critical watersheds for intervention.
- Develop and implement watershed management plans for critical upper watersheds.
- Declare critical catchments as reserves.
- Increase the canopy cover in catchment areas of Irrigation, Water supply and Hydropower reservoirs.
- Promote conservation farming methods in reservoir catchments, especially by linking various subsidies (e.g. Fertilizer) to implementation of such activities.
- Establish institutional arrangement for the implementation of national watershed policy.

Public Education, Awareness and Outreach

- Develop educational materials on vulnerability of drought and mitigation actions.
- Promote strategies to communicate such materials via print and electronic media.

Policy and Institutions and legislations

- Making amendments to the existing policies, acts and ordinances and make new regulations, if required, for the purpose.
- Strengthen the capacity of institutions to implement acts and regulations.
- Facilitate policy dialogue with relevant institutes and individuals on drought management.
- Develop capacity of relevant institutions to implement the drought plan and the necessary information management.
- Develop and operationalise a coordinated monitoring system by agencies to evaluate the extent and impact of drought and effectiveness of the responses.
- Prepare comprehensive policy on compensation and subsidies for drought damage and encourage alternative job opportunities and self-employment.
- Promote drought insurance facilities for the agriculture sector.

Land Use Planning

Because drought risk is directly related to land use, the link between land use planning and drought management should be carefully considered in developing land use policies. Among the strategies to formulate National Land Use Policy in Sri Lanka, discussed on 11th February 2020 by the Land Use Policy Planning Department, the following would have a link with the long-term drought management in the country.

- Lands of the country will be classified into broad land use zones for land resources management.
- The reservation of all natural and manmade water courses and sources will be protected with appropriate conservation measures.
- Natural forests with high biological and hydrological values will be conserved while ensuring the natural regeneration of natural forests.
- Areas with high altitudes and with steep slopes will be protected and conserved.
- All human activities which enhance the impacts of natural disasters will be discouraged.
- Land use planning strategies and activities will be promoted to adopt to minimize impacts of climate change.
- Strengthening of land ownership rights will be considered as a means and ways of efficient use of land.
- Land degradation will be considered in land use planning
- Diversification of agricultural land use will be promoted in order to enhance the efficiency of soil, water and fertilizer use.

- Avoid expansion of cultivation into agriculturally marginal and unsuitable lands.
- Protection of wetlands will be ensured by considering it as a prioritized activity in land use planning
- Land use in the coastal areas will be zoned to ensure sustainability of coastal belt.

Food Security and Health Hazards

- Strengthen the food distribution work to drought affected population with a more coordinated manner.
- Develop programmes at the village level with four government officials (i.e. GN Officer, Health Officer, Development Officer and Agricultural Production and Research Officer) so that they could intervene affectively to reduce drought impact in collaboration with relevant government agencies.

Mainstreaming Gender

- Support and strengthen government structures to systematically collect data disaggregated by age, sex, geographic location and drought impact and establish a comprehensive central database.
- Specifically design drought mitigation programmes, based on the above, to minimize the impact of drought on women and children.
- Promote income generating activities among women.
- Devise strategies for improved access to drinking water during drought.
- Make arrangements to provide food and ensure that adequate nutrition is available for women and children during drought.
- Establish and strengthen women organizations to formulate strategies to cope during difficult periods through awareness, alternative livelihood programmes, access to credit, etc.

Community Based Disaster Risk Management

- Provides opportunities to integrate ecosystem-based approaches, climate change, gender, and disability concerns at the community level to promote mitigation of drought.
- Increase government investments at the community level through national programmes.
- Enhance the capacity of communities to incorporate drought risk management elements in the community level planning and target resources.
- Promote the participation of NGOs, such Sri Lanka Red Cross, OXFAM, *Janathakshan*, UNDP, WFP, UNHABITAT and others, for drought mitigation activities.

8.2 Ongoing Projects to Mitigate the Risk of Drought

There are three ongoing projects to address the problems associated with droughts in Sri Lanka which incorporated many suggestions listed above. The first one on Climate Resilience Improvement Project (CRIP) has a very small component, i.e. to develop a flood and drought risk assessment in nine selected river basins in the country (MIWRDM, 2018). However, the other two, namely strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management and Climate-Smart Irrigated Agriculture Project (CSIAP) in Sri Lanka are comprehensive and address various aspects of drought management in the country. The details of these three projects are given in Annex 1. Overall, all these special projects address issues related to drought management in some of the drought prone areas in the country. Based on the lesson learnt, it is required to upscale these interventions to reduce the drought impacts in other areas as well.

9. RECOMMENDATIONS AND IMPLEMENTATION ACTIONS

This drought management plan is intended to serve as a working guide for those agencies that have the capabilities and resources to develop effective response and mitigation programs within their areas of jurisdiction. Drought being a slow onset hazard, the risk reduction on droughts requires multitude of approaches starting with predictions, preparedness, early warnings, crop selection, water resources management, insurance, etc among others as indicated in chapter 8.

9.1 Priority Implementation Actions and Recommendations

There are multiple agencies dealing with water management for different uses ranging from drinking, irrigation, power generation and ecosystem services. These agencies are linked with number of coordinating structures functioning at ministerial, district and village levels primarily on water management and occasionally on drought management. Potential exists to improve the coordination efforts of agencies by introducing an operational integrated drought plan developed in consultation with all stakeholder agencies supported by a coordinating structure with enhanced information management capabilities.

The specific activities undertaken by various stakeholder institutions in relation to drought management, as described in chapter 4: Organisation and assignment of responsibilities was presented at the National Workshop. Though they all are working to mitigate drought impacts on their own, the coordination among them is insufficient. Having endorsed the National Drought Plan, the main stakeholder agencies have agreed to move forward through a better coordinating mechanism as a starting point.

The following activities are required in this regard;

- Facilitate policy dialogues with relevant stakeholder institutes and individuals for an integrated approach for reducing drought impacts.
- Appoint a technical group consisting of members from DoA, ID, MASL, DMC, MDM, DoM, Climate Change Secretariat, MMDE, DAD, WRB, LUPPD etc. and representatives from the NGOs, International Research Institutes (e.g. IWMI), private sector and community to develop a comprehensive action plan for drought mitigation in the country.
- Develop capacity of relevant institutions to implement the drought mitigation plan and necessary information management.
- Continue to develop and implement drought risk reduction strategies, as indicated in chapter 8, by sectoral organizations.
- Mainstream child and women centred drought management programmes.

- Develop drought risk profiles at national level to capture risk and assess damage.
- Develop and operationalize a coordinated monitoring system by agencies to evaluate the extent and impact of drought and effectiveness of the responses.
- Design an index-based insurance scheme for drought damage.
- Introduce required policy and legal enactment to regularize the propose coordinating mechanism for drought management.

9.2 Future Updates and Revisions

As indicated throughout the report, there are large numbers of institutions involved in activities related to drought management. They will continue to work along those lines as mandated by respective ordinances. Therefore, a coordinating mechanism with a clear drought plan, which has a substantial proportion allocated for drought mitigation (proactive planning) compared to currently existing drought relief work (reactive planning) becomes a priority. However, it is important to revisit this national drought plan periodically and keep on improving based on the lessons learnt so that more concrete and effective drought plan for the country would be developed with time.

REFERENCES

Abeygunawardena, M.H. and K.A.U.S.Imbulana. 2005. Inter/Intra basin water transfers and management in Mahaweli systems. In Proceedings of consultation on river basin management. Lanka Jalani, International Irrigation Management Institute, Colombo. 43-58.

Abeysingha, N.S. and U. R. L. N. Rajapaksha. 2020. SPI-Based Spatiotemporal Drought over Sri Lanka. Advances in Meteorology 2020.
https://www.hindawi.com/journals/amete/2020/9753279/(Accessed on 20 March 2020)

Amaradasa, N.A. 2001. Trends and conditions of drought. Department of Meteorology, Colombo, Sri Lanka.

Bajgiran, P.R., A.A. Darvishsefatb, A. Khalilic, and M.F. Makhdoum. 2008. Using AVHRR-based vegetation indices for drought monitoring in the Northwest of Iran J. Arid. Environ. 72: 1086-1096

Basnayake, B.K. 1990. Droughts in the Dry Zone of Sri Lanka. In: Irrigation and Water Resources (Ed: E.R.N.Gunawardena), Proceedings of the Symposium, Postgraduate Institute of Agriculture, Kandy, Sri Lanka. 18-39

Birch, A and P.Muthukuda. 2000. Institutional Development and capacity building for integrated water resources management, Water Resources Council and Secretariat, Colombo, Sri Lanka. 89 p.

Chithranayana, R. D. and B.V.R. Punyawardena. 2008. Adaptation to the vulnerability of paddy cultivation to climate change based on seasonal rainfall characteristics: Journal of the National Science Foundation of Sri Lanka: 36(2):117-123.

DAD. 2011. Handbook of Agro-ecological regions and Watersheds. Department of Agrarian Development. Colombo, Sri Lanka

De Alwis, D. and I. Noy. 2017. The cost of being under the weather: Droughts, floods, and health care costs in Sri Lanka, Wellington: School of Economics and Finance of Victoria University of Wellington .

De Silva, K.S.D. 1972. Droughts. Journal of Ceylon Meteorological Society, 1(2):10-14.
De Silva, K.M. 2005. A history of Sri Lanka. Penguin books. 378-392.

De Silva, R.P. 2008. Understanding Drought- Implications, Strategies and Policies in Sri Lanka. (In: Drought and Integrated Water Resources Management in Asia. Eds: Jasveen Jairath and Vishwa Ballabh). Sage Publication. 125-155.

DMC. 2014. National Disaster Management Plan 2013-2017. The Disaster Management Centre, Ministry of Disaster Management, Colombo, Sri Lanka.

DMC. 2012. Drought. Hazard Profile of Sri Lanka. Disaster Management Centre, Ministry of Disaster Management, Colombo, Sri Lanka.

FAO.2018.Country Gender Assessment of Agriculture and the Rural Sector in Sri Lanka. Colombo.80 pp.

Goonasekere, Kapila and Henry Gamage. 1999. Some indigenous technology knowledge and practices for watershed management in Sri Lanka. Ed: by Prem N Sharma. Asian WATMANET-PWMTA, Participatory watershed management training in Asia (PWMTA) Programme, GCP/RAS/161/NET, FAO(UN), UN House P.O.Box 25, Kathmandu, Nepal. 63 p.
MDMHR (2006). Towards a Safer Sri Lanka, A Road Map for DRM – Volume 2: Project Proposals, Ministry of Disaster Management and Human Rights, Colombo, Sri Lanka.

GOSL. 2005. Sri Lanka Disaster Management Act No. 13 of2005. The Government of Sri Lanka.Colombo, Sri Lanka.

GOSL. 2019. National Policy Framework: Vistas of Prosperity and Splendour. Government of Sri Lanka. Colombo.
http://www.treasury.gov.lk/documents/10181/791429/FinalDovVer02+English.pdf/10e8fd3e-8b8d-452b-bb50-c2b053ea626c (Accessed on 20th July 2020).

Gunawardena, E.R.N. and R.K.Silva. 2014. Legal and Institutional arrangements for equity and access to water resources in Sri Lanka. In: Water Resources Research in Sri Lanka: Symposium Proceedings of the Water Professionals', Geo-Informatics Society of Sri Lanka, pp. 3-19.

Herath, H.M.R.C., K.H.M.S. Premalal, A.L.I. Kaumudie, and D.M.N. Sanjeewani.2015. Analysis of Standard Precipitation Indices to Identify for Drought Condition in 2015. Sri Lanka Journal of Meteorology, Vol.1, 20-31.

http://www.desinventar.lk/des_html/disaster_profile/disaster_profile.pdf

Iddawela, A.U., H.K.Kadupitiya, S.H.S.A. De Silva, B.V.R.Punyawardena, W.M.W.Weerakoon, N.D.K.Dayawansa, H.M.A.H.Uduwerella and D.G.S.D.Gunawardena. 2019. Remote Sensing Vegetation Condition Approach for Mapping Drought Risk in Sri Lanka. Annual Symposium of the Department of Agriculture, Peredeniya, Sri Lanka. 1-16.

ILO (International Labour Organization). (2018). Assessment of the effects of annual drought and floods on child labour (hazardous and non-hazardous) and child welfare in Sri Lanka / International Labour Office, ILO Country Office for Sri Lanka and the Maldives. https://www.ilo.org/wcmsp5/groups/public/---ed_norm/---ipec/documents/publication/wcms_651800.pdf).

Imbulana, K.A.U.S, N.T.S.Wijesekera, and B.R.Neupane. 2006. Sri Lanka Water Development Report 2010. UNESCO and Ministry of Irrigation and Water Resources Manaagament, Colombo, Sri Lanka.

Imbulana, Lalani. 2010.Drought Management in Sri Lanka.SAARC Workshop on Drought Risk management in Asia. Afghanistan Disaster Management Authority, Kabul, Afghanistan. Pp.164-175.

IPCC. 2007. Climate change 2007-Impacts, adaptation and vulnerability. Contribution of the Working Group II to the Fourth Assessment report of the Intergovernmental Panel on Climate Change Summary for Policy Making. New York: Cambridge University Press.

Jayamaha G.S. 1975. An analysis of drought in Sri Lanka. Journal of Sri Lanka Meteorological Society, 42A(2):133-148.

Kogan, F.N. 1995. Application of vegetation index and brightness temperature for drought detection. Advance Space Research, [online] 15(11), pp.91-100. Available at: https://www.sciencedirect.com/science/article/pii/027311779500079T (Accessed on 10 April 2020).

Leach, E.R. (1959). Hydraulic Society of Ceylon: Past and present, Vol. 15.

LUPPD. 1919. Land Use and Land Cover of Sri Lanka. Land Use Policy Planning Department, Colombo, Sri Lanka.

MaddumaBandara, C.M. 1977. Water Resources of South Western Sri Lanka. Asian Regional Meeting of the IHP, Colombo.

Manchanayaka, Palitha and MaddumaBandara, C.M. 1999. Water Resources of Sri Lanka. Natural Resources Series No 4. National Science Foundation, Sri Lanka. pp112.

Manesha, S., SathyaVimukthini , K.H.M.S. Premalal. 2015. Develop Drought Monitoring in Sri Lanka Using Standard Precipitation Index (SPI). Sri Lanka Journal of Meteorology. Vol.1, 64-71.

MDM. 2014. Sri Lanka Comprehensive Disaster Management Programme 2014-2018. Ministry of Disaster Management, Colombo, Sri Lanka.

MDM and WFP. 2017. Sri Lanka: Initial Rapid Assessment on Drought 2016/17.Ministry of Disaster Management, Colombo,Sri Lanka.

MDM. 2019. Hazard Profiles of Sri Lanka. Ministry of Disaster Management, Colombo, Sri Lanka.

MED and MDM. 2014. Drought: Food security and livelihoods affected by erratic weather: Sri Lanka–April 2014. Ministry of Economic Development and the Ministry of Disaster Management of the Government of Sri Lanka, Colombo, Sri Lanka.

MIWRDM. 2018. Climate Resilient Improvement Project: Status Report November 2018. Ministry of Irrigation and Water Resources and Disaster Management. Colombo, Sri Lanka.

MMDE 2012. The National Climate Change Policy of Sri Lanka. Ministry of Environment, Colombo, Sri Lanka.

MMDE. 2014. National Action Programme for Combating the Land Degradation of Sri Lanka:2015-2024. Ministry of Mahaweli Development and Environment. Colombo, Sri Lanka.

MMDE. 2016a. National Adaptation Plan for Climate Change Impacts in Sri Lanka:2016-2025. Climate Change Secretariat, Ministry of Mahaweli Development and Environment. Colombo, Sri Lanka.

MMDE. 2016b. Nationally Determined Contribution. Ministry of Mahaweli Development and Environment. Colombo, Sri Lanka.

MMDE. 2016c. National Biodiversity Strategic Action Plan 2026-2022. Biodiversity Secretariat, Ministry of Mahaweli Development and Environment. Colombo, Sri Lanka.

MMDE. 2017a. National REDD+ Investment Framework and Action Plan, 2017. Sri Lanka UN-REDD Programme, Ministry of Mahaweli Development and Environment. Colombo, Sri Lanka

MMDE.2017c. Land Degradation Neutrality Target Setting Programme (2017-2030). .Ministry of Mahaweli Development and Environment. Colombo, Sri Lanka.

MMDE. 2017d. Project Document on strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management. Ministry of Mahaweli Development and Environment, Colombo, Sri Lanka.

MoA. 2018. Climate-Smart Irrigated Agriculture Project in Sri Lanka. Ministry of Agriculture, Colombo, Sri Lanka.

MoA. 2019. Draft National Agriculture Policy of 2019. Ministry of Agriculture, Colombo. Sri Lanka.

NCAR (National Centre for Atmospheric Research). 2020. Standard Precipitation Index. https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi(Accessed on 19th May 2020).

NCSD. 2009. National Action Plan for Haritha Lanka Programme. National Council for Sustainable Development, The Presidential Secretariat, Colombo, Sri Lanka.

NDMC (National Drought Mitigation Centre, University of Nebraska, USA). 2020. https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx. Accessed on 21/05/2020.

Panabokke, C. R., R. Sakthivadivel R. and A.D.Weerasinghe. 2002. Evolution, present status and issues concerning small tank systems in Sri Lanka, International Water Management Institute Colombo, Sri Lanka.

Panabokke , C. and A.Perera. 2005. Groundwater Resources of Sri Lanka.Water Resources Board.Colombo, Sri Lanka.

Pathmarajah, S. 2003. Use of groundwater for agriculture in Sri Lanka: A synthesis of the past, present and the future. Use of Groundwater for Agriculture in Sri Lanka (pp. 1-9). Agricultural Engineering Society of Sri Lanka, Peradeniya, Sri Lanka.

Perera, A.C.S., B. V. R. Punyawardena,and E. R. N. Gunawardena. 2016. Occurrence of droughts in the HakwatunaOya Watershed of Sri Lanka. In: Water Resources Research in Sri Lanka: Symposium Proceedings of the Water Professionals', Geo-Informatics Society of Sri Lanka.

Punyawardena, B.V.R.2002.Report on Drought Management, Report submitted t the Ministry of Environment and Natural Resources. Colombo. Sri Lanka.

Punyawardena B.V.R., T.M.J.Bandara, M.A.K.Munasinghe, N.J. Banda and S.M.VPushpakumara. 2003. Agro-ecological Regions of Sri Lanka. Natural Resources Management Center, Department of Agriculture, Peradeniya.

Rekha Nianthi, K.W.G. 2014. Farmers' Responses to Drought: Dry Zone of Sri Lanka: (Case Study in Medirigiriya). Case Studies Journal ISSN (2305-509X) – Volume 5, Issue 6, Page 33-39. http://www.casestudournal.com

Saumyarathna, N.G.R., E.R.N. Gunawardena, and N.D.K. Dayawansa. 2016. Water Conflicts among Different Water Users and Uses in the HakwatunaOya Watershed in the DeduruOya Basin, Sri Lanka. Tropical Agricultural Research Vol. 28 (1): 38-49

Suppiah, R. 1996. Spatial and temporal variations in the relationships between the Southern Oscillation phenomenon and the rainfall of Sri Lanka. International Journal of Climatology, 16,1391-1407.

Senarath, D.C.H.1990. Some Management Aspects in the use of Ground Water. In: Irrigation and Water Resources (Ed: E.R.N.Gunawardena). Post Graduate Institute of Agriculture, University of Peradeniya, Sri Lanka.173-177.

Senarathne A. and K.Wickramasinghe. 2011. Commons vs. Commons: Managing Scarce Water Resources in Dry Zone Village Tank Systems in Sri Lanka, Institute of Policy Studies, Colombo, Sri Lanka.

Siriweera, W.I. 1983. Settlement Pattern and Climatic Fluctuation in Sri Lanka. (In: Climate, Water and Agriculture (Eds) M.M.Yoshino), Institute of Geosciences, University of Tsukuba, Ibaraki, Japan. 51-60.

Somasiri S. 1991. Irrigation potential of the minor tanks and their agricultural stability, Land and water management research center, Peradeniya.

Survey Department. 1988. The National Atlas of Sri Lanka. The Government of Sri Lanka, Colombo.

Tennakoon, M.U.A. 2017. Cascade Based Tank Renovation for Climate Resilience Improvement. Ministry of Disaster Management, Colombo, Sri Lanka.

The World Bank. 2020. The World Bank in Sri Lanka. [Online] Available at: https://www.worldbank.org/en/country/srilanka/overview#4[Accessed on 11 April 2020].

UNDP. 2009. Sri Lanka National Report on Disaster Risk, Poverty and Human Development Relationship (Disaster Management Centre). https://www.preventionweb.net/english/hyogo/gar/background-papers/documents/Chap3/Asia-overview/Sri-Lanka-DRAFT-march-09.pdf

UN REDD Programme. 2017. National REDD+ Investment Framework and Action Plan. Sri Lanka UN REDD Programme, Ministry of Mahaweli Development and Environment, Colombo, Sri Lanka.

UNDRR. 2019. Disaster Risk Reduction in Sri Lanka: Status Report 2019. Bangkok, Thailand, United Nations Office for Disaster Risk Reduction (UNDRR), Regional Office for Asia and the Pacific

WMO. 2020.https://public.wmo.int/en/our-mandate/water/drought (Accessed on 10/04/2020)

Annex 1. Ongoing Drought Management Projects

There are three ongoing projects, described below, to address the problems associated with droughts in Sri Lanka. These project titles are;

i) Climate Resilience Improvement Project (CRIP)
ii) Strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management
iii) Climate-Smart Irrigated Agriculture Project (CSIAP) in Sri Lanka.

i) <u>Climate Resilience Improvement Project (CRIP)</u>

The project is implemented for a period of 5 years starting from April 2014 (The total cost is US $ 110 million and funded by the World Bank. The project is implemented under the Ministry of Mahaweli Development and Environment. The main implementing institutions include, i) Irrigation Department, ii) Mahaweli Authority of Sri Lanka, iii) Road Development Authority, iv) National Building Research Organization (NBRO) and, v) Ministry of Irrigation and Water Resources Management.

The proposed Project Development Objective (PDO) is to reduce the vulnerability of exposed people and assets to climate risk and to improve Government's capacity to respond effectively to disasters. The PDO will be achieved through evidence-based investment planning and urgent risk mitigation measures.

The project consists of two main components and two additional components. The first component focuses on analytical activities and long-term development planning, while the second component addresses urgent rehabilitation investments to increase resilience to climate risks. The remaining two components support project implementation and provide flexible funding to recover from a flood event that may occur during project implementation.

Component 1 involves a detail modelling of flood and drought risk in ten major river basins in the country with an estimated budget of US$13 million. These basins were selected based on a combination of probability of occurrence of climate related disaster losses and value of exposed assets at risk to disaster. The purpose of the modelling is to develop comprehensive basin wide investment plans that incorporate the competing risks of both flood and drought. Under this component, government engineers and experts were supported to carry out comprehensive flood and drought modelling and assessment of the underlying causes of flood and drought including rainfall variability and land use changes.

Results of this study clearly shows that impact of the drought is most significant than flood for some river basins. (e.g. Malwatu, Kala, Gal Oya). Selected items are prioritized and feasibility studies are going on at present. In addition to this component, schemes are selected for rehabilitation considering the impacts of drought under CRIP, e.g. Padaviya, HuruluWewa, Muruthewela, Hakwatuna, SenanayaSamudraya, Muthukandiya, Inginimitiya, Kaudulla, Kantale and Allai schemes. CRIP has introduced solutions for drought management such as water saving techniques, improved control and regulatory arrangement, travel time improvements, etc.

ii) Strengthening the resilience of smallholder farmers in the Dry Zone

The project titled "strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management" supports the Government of Sri Lanka to strengthen the resilience of vulnerable smallholder farmers in the country's Dry Zone; particularly women, who are facing increasing risks of rising temperatures, erratic rainfall, and extreme events attributable to climate change(MMDE, 2017). It will address technical, financial and institutional barriers related to achieving integrated water management to improve agriculture-based livelihoods of smallholder farmers in the Dry Zone. GCF resources, in conjunction with government co-financing, will invest about USD 38 million in improving the community irrigation water infrastructure and associated agricultural practices, scaling-up decentralized drinking water systems, and strengthening Early Warnings (EWs) and forecasting for flood-response and water management. The objective of the project is to strengthen the resilience of smallholder farmers, particularly women, in the Dry Zone through improved water management to enhance lives and livelihoods. The expected key Fund Level (GCF) impacts are increased resilience of health and well-being, and food and water security and increased resilience and enhanced livelihoods of the vulnerable smallholder farmers in the Dry Zone of Sri Lanka. The primary measurable benefits include resilient water and agricultural management for 770,500 direct beneficiaries and 1,179,800 indirect beneficiaries who will gain from improved water management, resilient agriculture practices, and provision of climate and weather information.

The project is implemented under the Ministry of Mahaweli Development and Environment. The key implementing organizations include, i) Department of Agrarian Development (DAD), ii) Department of Agriculture (DoA), iii) Department of National Community Water Supply (DNCWS), iv) National Water Supply and Drainage Board (NWSDB), and v) Ministry of Disaster Management (MoD). The project period is July 2017 to June 2024.

The key objective of this Project is to strengthen the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water

management. This will be achieved through three outputs that build upon previous experience and best practice:

Output 1: Upgrading and enhancing resilience of village irrigation systems and scaling up climate-resilient farming practices in three river basins of the Dry Zone: This Output will focus on improved climate-risk informed water management for agricultural production in the selected river basins by upgrading inter-connected cascade systems and associated agricultural practices. Considering the multiple uses of water, the project will invest in added elements (structural and landscaping) to village irrigation cascades to make them more resilient to climate change. Co-financing from the government will also be invested in these upgrades to address non-climatic drivers contributing to deterioration of these systems. Upgrading the village irrigation cascade systems will be delivered using a participatory approach that involves FOs, field officers of agriculture related government institutions, private sector and local NGOs. This Output will support capacity building, training, and knowledge generation for climate-risk management related to integrated water and agricultural management solutions.

The Output will also support targeted women farmers to adopt recommendations made by the Department of Agriculture for drought tolerant crops and climate smart cropping practices for these agro-climatic zones. Women producers will be strengthened as medium scale entrepreneurs through technology transfer, improved extension services, business development training, and market linkages with support from private sector for technology and financing. The climate-smart agricultural packages will also be widely disseminated through the Agrarian Service Centres and extension services of the Provincial Agriculture Departments.

Overall, this Output includes the following key activities:
Activity 1.1 Improve technical capacity and knowledge management targeting Agricultural Services Centres (ASC), local field officials and community organisations for climate-risk informed water management and climate-smart agriculture.
Activity 1.2 Improve resilience of and upgrade village irrigation systems in the identified cascades including restoration of upstream watersheds.
Activity 1.3 Develop and disseminate climate resilient agricultural practices with targeted enterprise development for women.

Output 2: Enhancing climate-resilient, decentralized water management solutions to provide safe year-round drinking water to drought vulnerable communities*:* This Output will deliver drinking water solutions to poor farmer households through a multi-pronged partnership approach to replenish sources, build storage, supply clean and safe drinking water and address root causes of water quality issues. One of the primary co-benefits of the GCF investment (aligned with government investments) in improving access to safe drinking

water is the expected reduction in the disease burden (and current medical costs) in areas where kidney disease is fast spreading. GCF resources and co-financing for rural drinking water supply will, therefore, be used to improve capacity of local officials, CBOs and FOs to incorporate climate-risks in design and management of sustainable rural drinking water solutions (community water supply systems and rainwater harvesting tanks).

Activities carried out in support of this output include:
Activity 2.1 Improve capacity of water supply support staff at district/divisions, selected partner organisations (NGOs) and CBOs to implement and maintain community-based climate change risk informed drinking water related interventions
Activity 2.2 Implement sustainable, climate-resilient drinking water solutions through CBOs and government agencies:

Output 3: Strengthening climate and hydrological observing and forecasting systems to enhance water management and adaptive capacity of smallholder farmers to droughts and floods. Interventions for this output will include providing access to weather/climate related knowledge, such as advice on future seasonal conditions (for agricultural planning) and early warning of storms and flooding for flood and water management including planning of water release from irrigation tanks.

Participatory co-development of tailored advisories (with FOs, farmers, DAD and ID) will ensure that weather and climate information is incorporated into decision making in agricultural and water management in the three river basins. Satellite-based estimates of rainfall generated through this Output will be used to extend advisories to areas not covered by the ground-monitoring network, hence reducing reliance on the network of raingauges. Participatory meetings and inter-agency workgroups will utilize feedback from FOs, farmers and VIS water managers to develop advisories for agriculture and water management. Different media (TV, radio and mobile technologies) will be used for dissemination of warnings to reach all parts of society, particularly women. This Output also addresses capacity barriers at local level to plan for and identify response measures to warnings and advisories. It will develop response plans for agriculture to seasonal forecasts and associated advisories, as well as appropriate water management options. Coordination meetings and SOPs between DoM, DAD, DoA, DMC and ID at the district level will be developed to ensure appropriate coordination takes place.

This output includes the following key activities:
Activity 3.1 Establish effective monitoring systems for drought, floods and water management:
Activity 3.2 Co-develop and disseminate weather- and climate-based advisories for agricultural and water management through ASCs and FOs to farmers and village water managers:

Activity 3.3 Develop climate-risk management response measures based on advisories and forecasts for agriculture, water management and flooding in cascade systems:

iii) Climate-Smart Irrigated Agriculture Project (CSIAP) in Sri Lanka

The Project Development Objective is to improve climate resilience of farming communities and productivity of irrigated agriculture in selected climatically vulnerable Hot-Spot Areas in Sri Lanka (MA, 2018). The 7 selected Hot Spot Areas cover 11 sub-watersheds of 6 river basins of Yan Oya, Mandekal Aru, Kala Oya, Menik Ganga, Per Aru, Kala Oya,in the 7 dry-zone districts of Anuradhapura, Kilinochchi, Kurunegala, Moneragala, Mullaitivu, Puttalam and Trincomalee. This objective will be achieved through increased adaptation of climate-resilient agricultural practices and technologies, improved agricultural productivity, and increased access to markets in targeted smallholder farming communities. The project will be implemented over six years, with three stages planned till 2024. The project design is structured over infrastructure planning, development and management for climate-smart agriculture and climate-smart agricultural techniques and practices. Each of these is briefly described in greater detail below.

Infrastructure for climate smart agriculture

This component attempts to build climate resilience in agriculture production system, through a series of activities aimed at harnessing floodwater for drought mitigation and increasing crop yields during the periods of climatic stress. It is necessary to build supportive irrigation infrastructure to promote more efficient use of surface water for agriculture, complemented with more sustainable use of groundwater, for improving the availability and quality of water at farm level.

Preparation of Climate-Smart Hot-Spot Area Development Plans

This sub-component will support a participatory, inclusive, interactive, and bottom-up development planning process involving irrigated and rain-fed agriculture stakeholders to prepare investment plans at three levels: Hot-Spots (~40,000 ha), mini-watersheds within the Hot Spot Areas (~4,000 ha), including tank cascade systems, stand-alone irrigation systems and rainfed agriculture, and local administrative levels (DS Divisions and GN Divisions). To ensure coordination across all implementing agencies, the planning process will be led by the Provincial Project Management Unit (PPMU) and will incorporate all concerned government agencies, community members, organizations engaged in related development projects, and private sector organizations operating in the area.

Rehabilitation, Modernization and Development of Infrastructure

This sub-component will support (re-) restoration, rehabilitation, modernization, repair and operation and maintenance (O&M) of cascade tanks and individual villages tanks, catchment

clearance and de-silting of supply channels of tanks, lining of water distribution channels in the tank commands and construction of recharge wells in tank beds; (b) drainage and flood control systems agro-wells at the end of field and distribution canals; and (c) small water impounding structures in the upper catchment of the tanks to provide supplementary irrigation for rainfed crops. This sub-component will also support the design, construction/rehabilitation, and O&M of rural roads needed to access minor irrigation infrastructure, farm fields and markets.

Capacity Enhancement and Coordination to Plan and Manage Climate-Smart Infrastructure

This sub-component aims to enhance capacities of key government and non-government actors involved, and to strengthen the institutional framework necessary to support and coordinate the various stakeholders across different agencies, to develop and deliver the **Hot-Spot Area Development** Planning process.

Climate smart agricultural production systems

This component attempts to strengthen the adaptive capacity of small and marginal farmers to adjust and modify their production systems to moderate potential future impacts from climate events. It is also necessary to provide a foundation for "drought-proofing" agriculture in Sri Lanka by scaling up technology transfer and promoting skills development for smallholders and increasing their capacity to adapt to adverse climatic events and reduce impacts on their livelihoods. The objective of this component is to enhance climate resilience through *higher and more stable on-farm productivity growth and farmer incomes* by supplementing the additional irrigation storage and delivery provided in Component 1 with CSA practices, diversification into more climate-resilient and higher value crops, efficient and effective on-farm water management, small-scale market infrastructure investments and the establishment of private sector linkages beyond the farm gate. This component is built on the results of catchment area treatment, rehabilitation, safety of dams, rehabilitation/reconstruction of irrigation schemes, improved availability of water at farm level and improved access road network implemented under Component 1.

Building Individual and Institutional Capacities

This subcomponent will support and finance activities to build institutional capacity to plan, implement, manage, and monitor the project investments in CSA at the provincial, district, and GND levels in all Hot Spot Areas. More specifically, this subcomponent will finance: (i) strengthening farmer community institutions (Farmer Organizations (FOs), and Producer Groups (PGs)); and (ii) strengthening the capacity of GND level officials to deliver targeted climate resilience agricultural services. The in-service training centers of DAD, DOA and ID will be used for training purposes.

Promoting locally-appropriate climate-smart agriculture techniques and practices

This sub component will support the adoption of CSA, covering *production practices* (soil, water, and crop choice & management, etc.) and *post-harvest management* (storage, value addition/processing, packaging, etc.) by enabling farmers to master the practices and management skills required for sustainable production, post-harvest processing, improved quality of produce (taking into account food safety standards) and increase producers' resilience to short- to medium-term climate variability projected for Sri Lanka. The farmers will be provided with the practical skills required for informed decision-making based on accurate problem analysis in their local contexts. A review of best practice of science-based farmer-field demonstrations in the country and region, and ITK from Dry Zone areas of Sri Lanka, would identify proven, locally-adapted climate-resilient practices and technologies.

Strengthening market linkages

Dry Zone farmers currently face low output prices while middlemen collect large margins. To enhance producers' profitability and incentivize the adoption of climate-resilient practices and technologies, selected PGs will be supported in a variety of ways to earn better prices for their produce. Collective marketing will be another facilitated service provided to PGs, so that larger volumes of output can be collected and sold at more distant markets, either directly by PGs or by marketing agents hired by the PG.

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