CLIMATE SMART DISASTER RISK REDUCTION INTERVENTIONS IN AGRICULTURE SECTOR – FLOOD HAZARD

A Practitioner's Guidebook

2019

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Executive Summary

Climate Change is inevitable and the agriculture and water sectors are the most vulnerable. Recent studies have shown that due to climate change, the world is moving towards scenarios of either too much, or too little, water. Agriculture is an open system and provides livelihoods for 60% of the world's population. More than 2.2 billion people depend on agriculture for their livelihoods in Asia. Thus, climate induced natural hazards, especially floods, are likely to affect the sector as well as the livelihoods of the dependent population considerably.

Due to the distinct climatic variability across the Asian continent and its geophysical setting, the majority of countries on the Asian continent are subject to natural disasters. The frequency of these extreme events, especially the hydro-meteorological events, has shown an increasing trend. The present study explores the consequences of these extreme events in three countries of the Asian region, namely: Thailand, Nepal and Sri Lanka which have distinct geographical settings. These three countries are subject to frequent natural disasters, especially floods and droughts, due to their respective geographical exposure and climatic regime, which in turn, result in disastrous consequences of varying degrees, affecting the agricultural sector of the respective countries.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has revealed that warming of the climate is unequivocal, and that rapid climate change over the past 50 years is anthropogenic-driven. Climate change has already affected both South and Southeast Asia with rising temperatures, decreasing rainfall, rising sea levels and increasing frequency and intensity of extreme events.

One of the major shortfalls of conventional disaster management strategies is a lack of adequate blends of climatic information on the nature of future climate risks and post-disaster reconstruction processes or modalities which eventually lead to an increased risk of disaster rather than a decrease. The present initiative, funded by the Asia Pacific Network for Global Change Research, Japan, looks into an entire gamut of flood mitigation interventions in the agricultural sector in the three countries of intervention starting from floodplain management, land treatment, flood modification measures and agronomic practices to Integrated Water Resource Management. One of the unique recommendations is a climate inclusive, flood early warning system in these countries which is generally lacking. We are aware that low-income countries and small islands and their rural communities (whose main livelihood is agriculture in the flood-plain and low-lying areas) are the most endangered communities by flood hazards. Environmental degradation and socio-economic factors like poverty and urban population growth, contribute additionality to the vulnerability by flood hazards of the communities in these three countries where a Flood Early Warning System could make a paradigm shift in community resilience regarding flood hazard.

This Practitioners Guide Book is for the use of local Government Employees engaged in mainstreaming Climate Smart Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) practices for development planning at local government level in the Asian Region. This Practitioners Guide Book focuses on three Asian countries, Thailand, Sri Lanka and Nepal. We sincerely hope that the Practitioner's Guidebook on Climate Smart Disaster Risk Reduction Interventions in the Agriculture Sector, with special reference to flood hazards, will contribute to the various DRR initiatives in these three countries and in Asia as a whole.

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CHAPTER 1 GENERAL INTRODUCTION TO THE GEOGRAPHY AND CLIMATE OF ASIA

1.1. Asia a Glimpse

- The largest and most populous continent (Figure 1 and Figure 2).
- Home to a diverse socio-economic and cultural environment.
- Considerable proportion of the population lack knowledge, competence and access to essential infrastructure to move forward for facing emerging climate-related disasters.

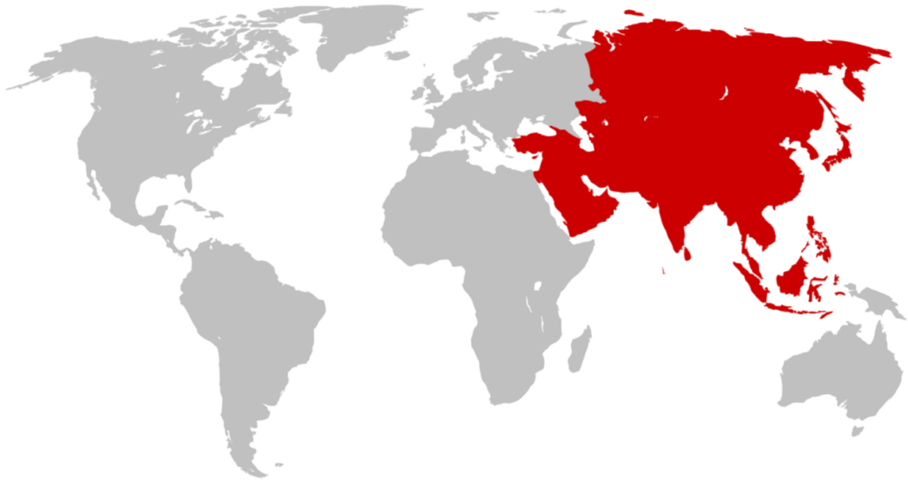


Figure 1 Extent of Asia (Source: https://www.freepik.com)

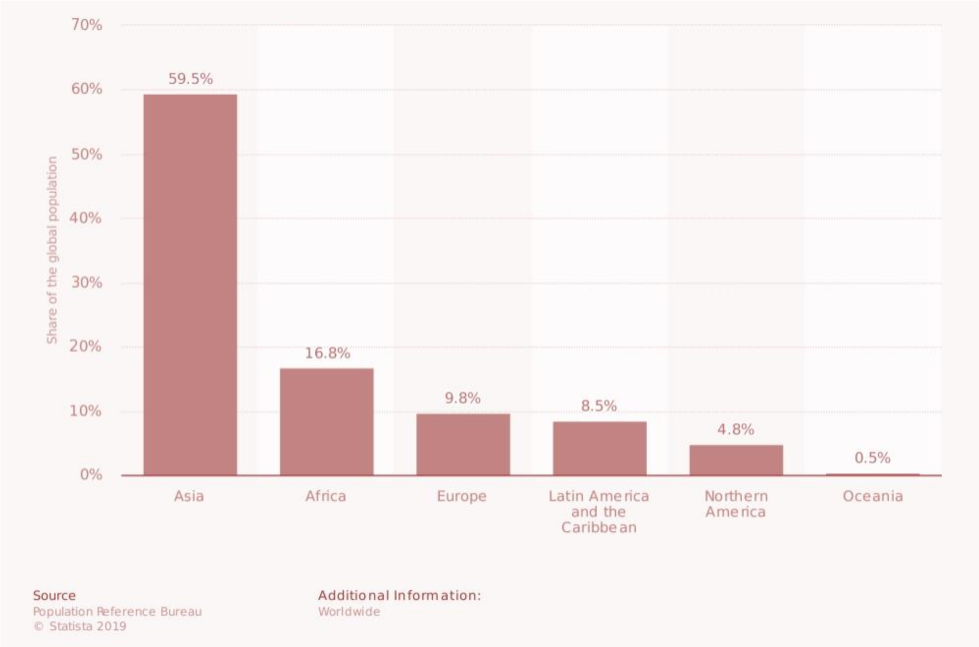


Figure 2 Distribution of Global Population by Continent in 2018

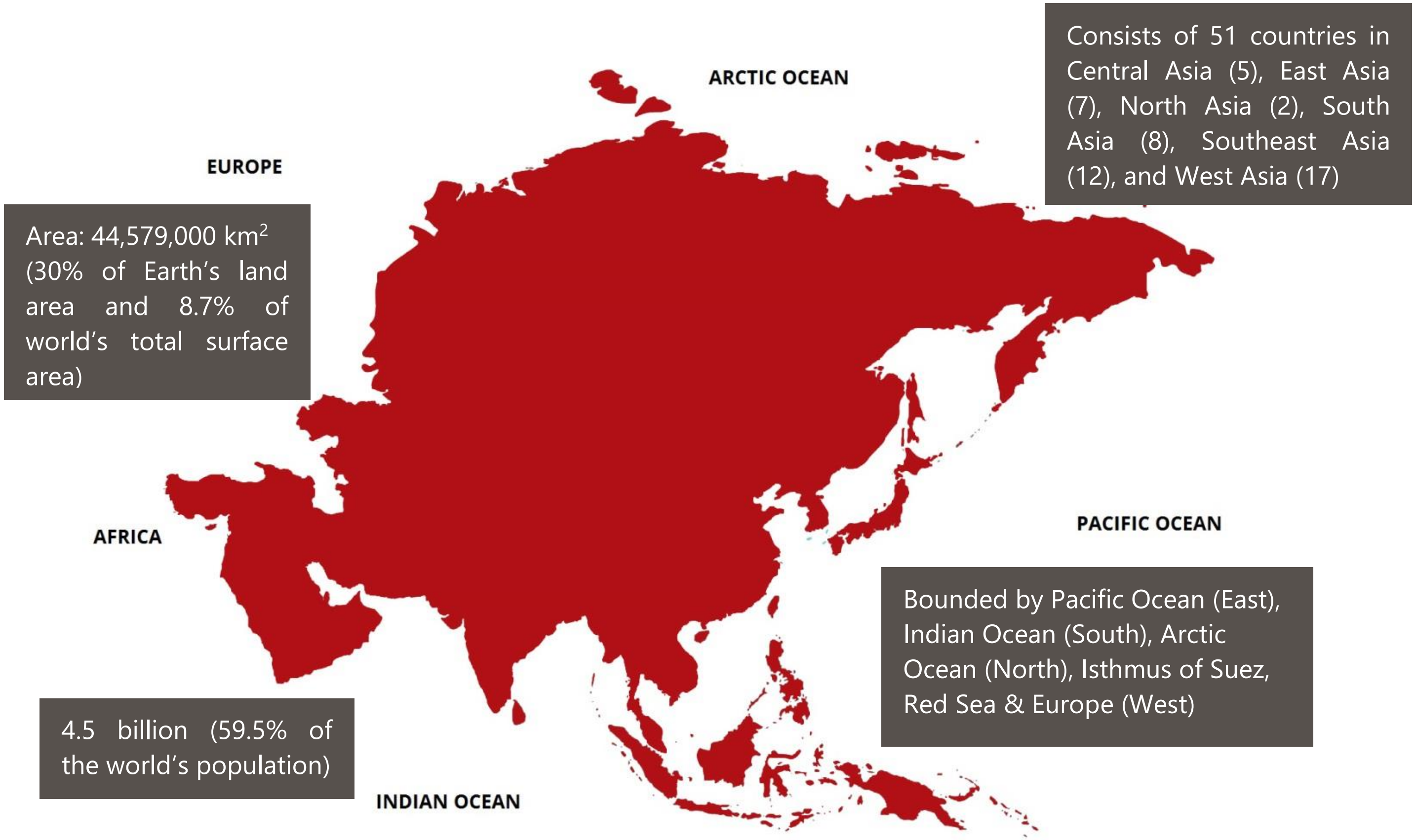
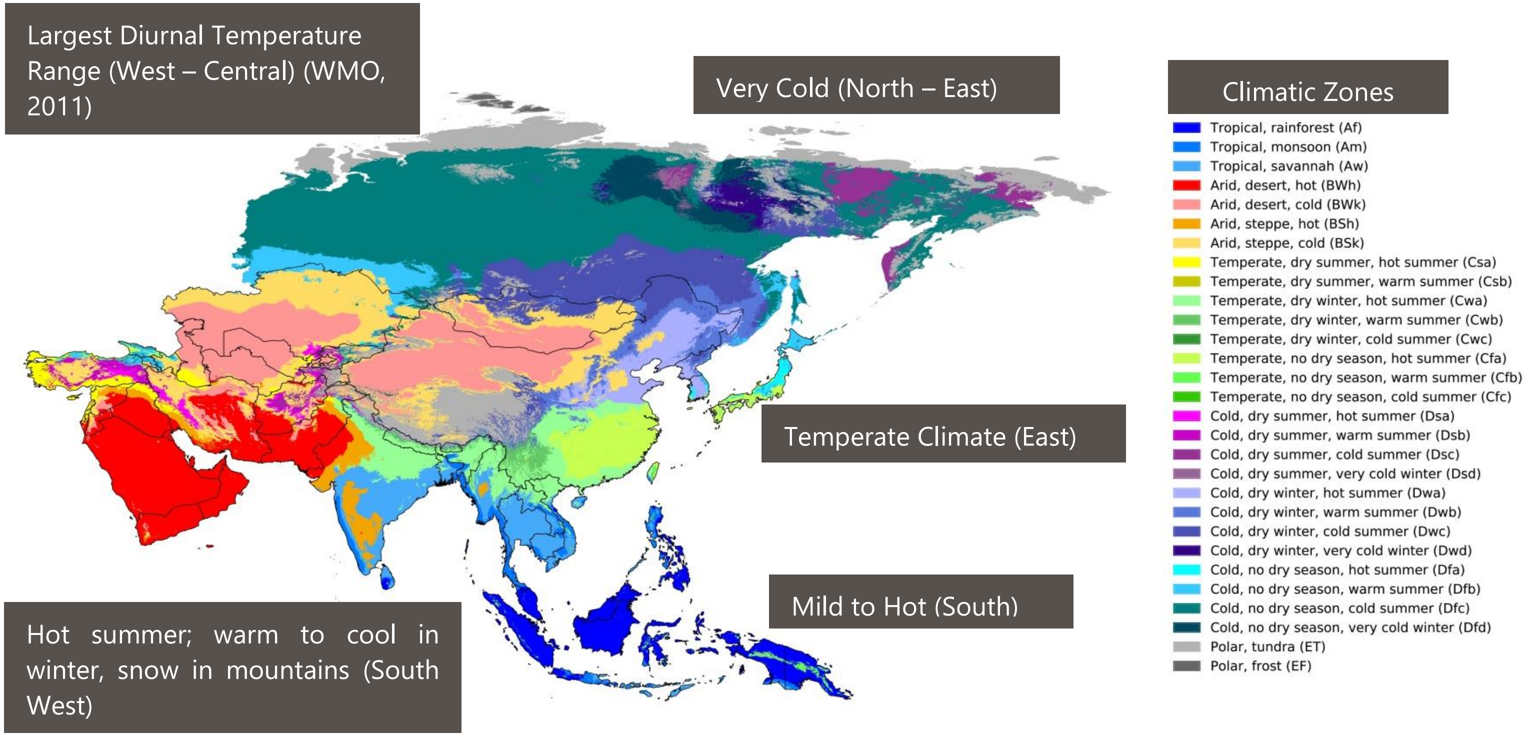


Figure 3 Physical and Social Statistics of Asia (Source: https://www.freepik.com)

Figure 4 Countries in Asia - Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei, Burma, Cambodia, China, East-Timor, Georgia, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Laos, Lebanon, Malaysia, Mongolia, Nepal, North Korea, Oman, Pakistan, Papua New Guinea, Philippines, Qatar, Russia, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syria, Taiwan, Tajikistan, Thailand, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Vietnam, Yemen (Source: https://www.mapsofworld.com/ asia-political-map.htm)

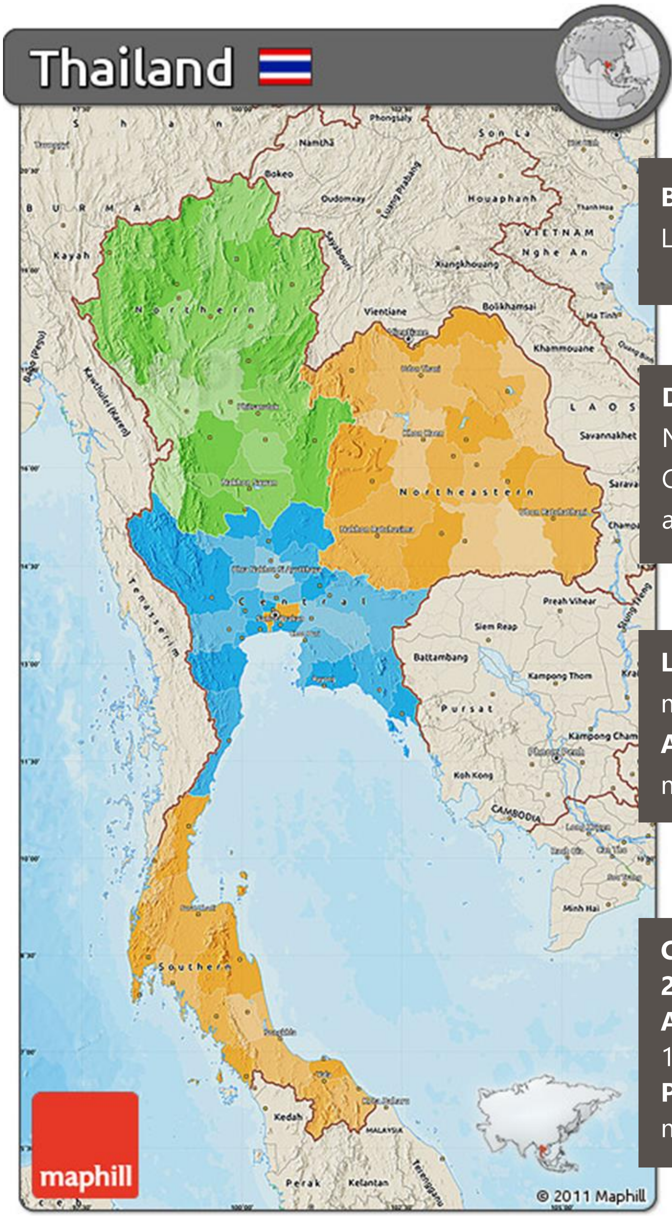


Source: Beck et al.: Present and future Köppen-Geiger climate classification maps at 1-km resolution, Scientific Data 5:180214, doi:10.1038/sdata.2018.214 (2018)

Figure 5 Climate Classification of Asia (1980-2016) - Mountain barriers and inland depressions give Asia a unique array of climatic zones

CHAPTER 2 GENERAL INTRODUCTION TO THE GEOGRAPHY AND CLIMATE OF THAILAND, NEPAL AND SRI LANKA

2.1. Geography & Climate of Thailand



Border With: Myanmar, Laos, Cambodia, Malaysia

Divided into 6 regions: Northern, North Eastern, Central, Eastern, Southern and Western

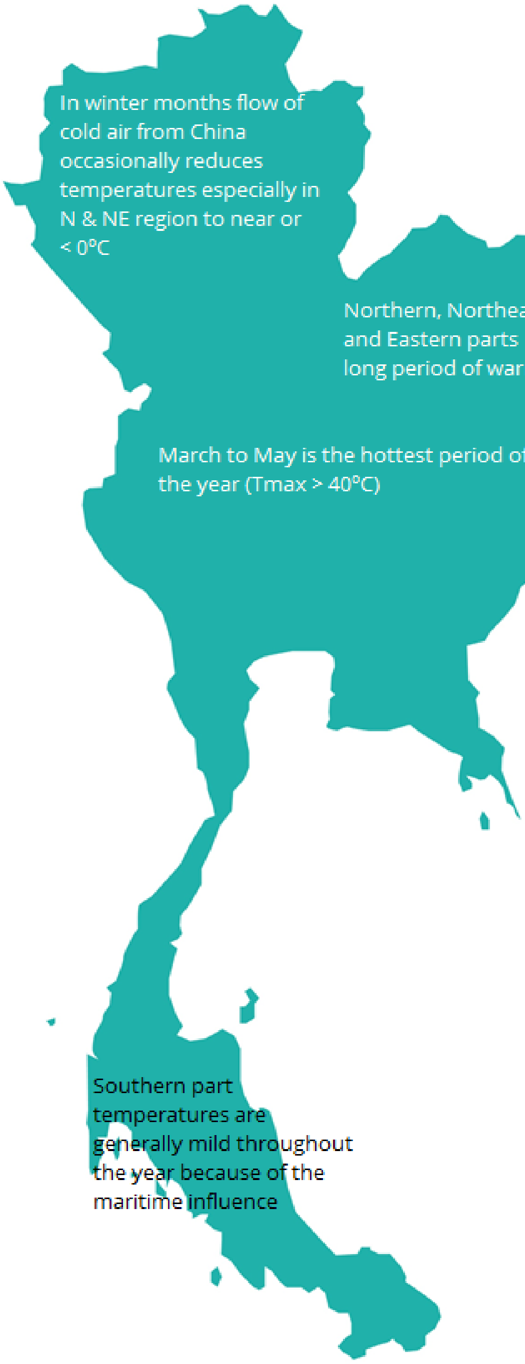
Land Coverage: 51.4 million ha
Agriculture: 21.07 million ha (41% of total

Cultivated Extent (FAO, 2011a): 18.9 million ha
Annual Crops (Rice): 15.3 million ha
Permanent Crops: 3.7 million ha

Characteristics of different physiographic regions of Thailand

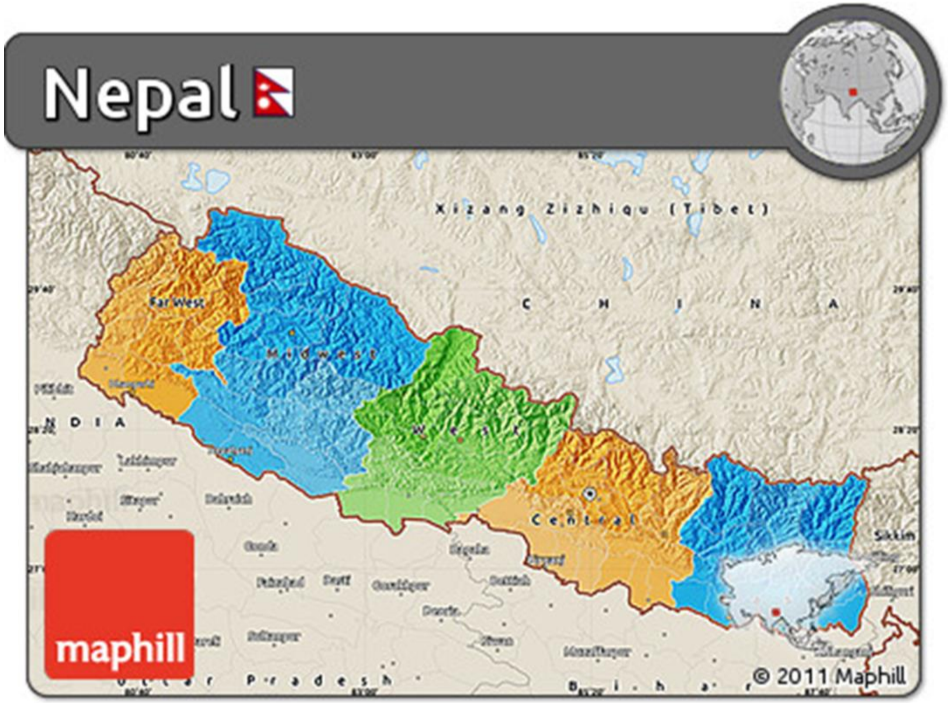
Region	Physiographic Characteristics
Northern	• Hilly and mountainous incised into river valleys and upland areas • Most rivers, including the Nan, Ping, Wang, and Yom, unite in the lowlands of the lower part of the northern region and the upper part of the central region
Northeast	• High level plain called Northeast plateau • Northwest and southeast oriented Phu Phan ridge in the north eastern region separates this part into two basins • One large high level plain in the west; the other is smaller and sloping towards the east
Central	• Large stretch of flat land (flood plain of the river) • Ping, Wang, Yom and Nan Rivers originating in the Northern region join to form the Chao Phraya River at Nakhon Sawan province • Bangkok city is located in this region • The area is subjected to frequent flooding
Eastern	• Facing the Gulf of Thailand to the south • Consists of plains and valleys, there are small hills towards the northern, central and eastern parts of the region
Southern	• This is a peninsula between the Andaman Sea towards the west and South China Sea towards the east. • The long ridge of western mountains in the Northern and Central region extends to this region. • The Phuket ridge along the west coast, and Nakhon Si Thammarat ridge in the lower part of the central region, form the backbone of the Southern region separating it into two regions: Southern Thailand east coast and southern Thailand west coast
Western	• Mountainous area with steep river valleys • There are less-disturbed forest areas • Water and minerals are important natural resources • There are several major dams • Mining is an important industry

Climate of Thailand (TMD, 2015)



Rainfall	
Pre Monsoon	This is the transitional period from the northeast to southwest monsoons. Weather is warmer and the hottest month is April
SW Monsoon	Rain caused by: • Moist air from the Indian Ocean • Inter Tropical Convergence Zone (ITCZ) • Tropical cyclones Wettest period is August to September

2.2. Geography & Climate of Nepal



Border With: India, China

Divided into 3 regions (FAO, 2011b): High Himalayas in the North (24%), Hills and mountain slopes in the central region including Siwalik elevation 700-300m (56%) and the southern plains or Terai with elevation < 300 m (20%)

Location: Part of Ganges basin with 15 mountain peaks >7,000 m (Mount Everest 8,848 m) with rugged topography and 12 climatic regions

Land Coverage: 14.7 million ha
Agriculture: 4.00 million ha

Cultivated Extent: 2.52 million ha
Annual Crops (Rice): 2.4 million ha
Permanent Crops: 0.12 million ha
(FAO, 2011b)

Climate of Nepal

Temperature

The spatial variation of mean annual temperature is influenced by the physiographic setting.

The temperature decreases from the southern lowlands (*Terai*) to the high altitude Himalayan region.

Extreme Temperature recorded in 1987

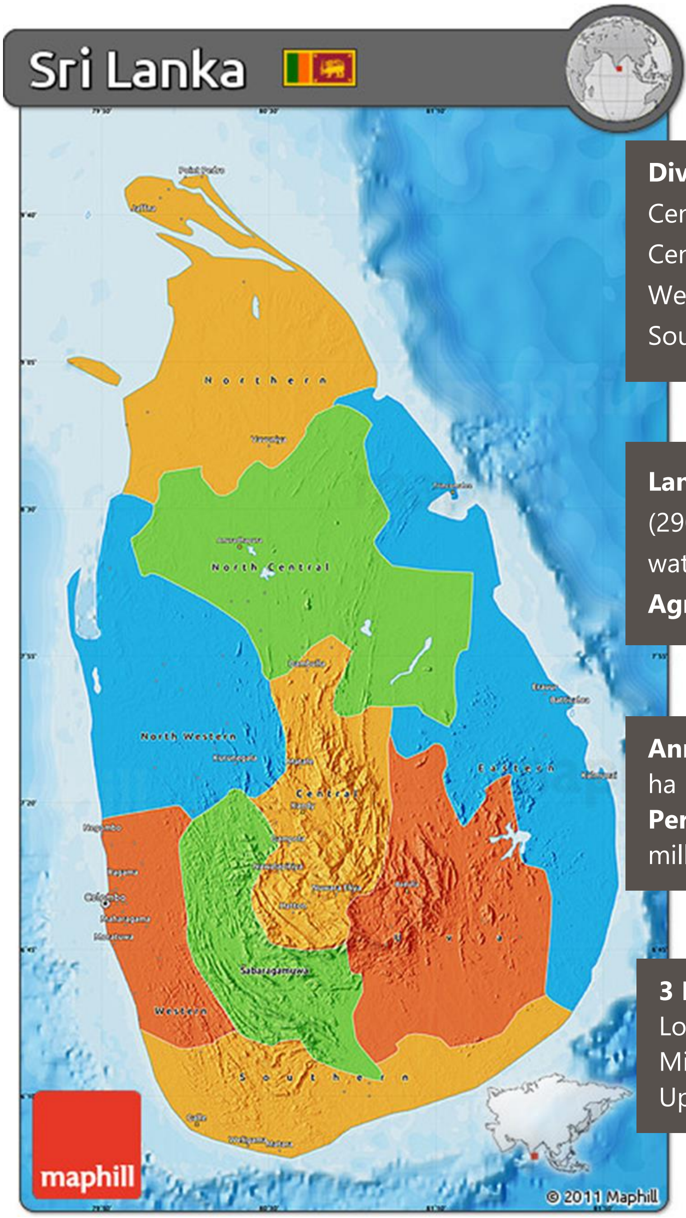
Rainfall

Precipitation falls as snow at elevations >5,100 m in summer and > 3,000 m in winter.

Southwest monsoon (June to September) brings >75% of the total rainfall and <25% in winter (December to February).

- Single Crop in Himalayan and Mountainous Region up to 2300 m (mainly rice).
- Double / Triple Crop in *Terai* subject to water availability up to 800 m.

2.3. Geography & Climate of Sri Lanka



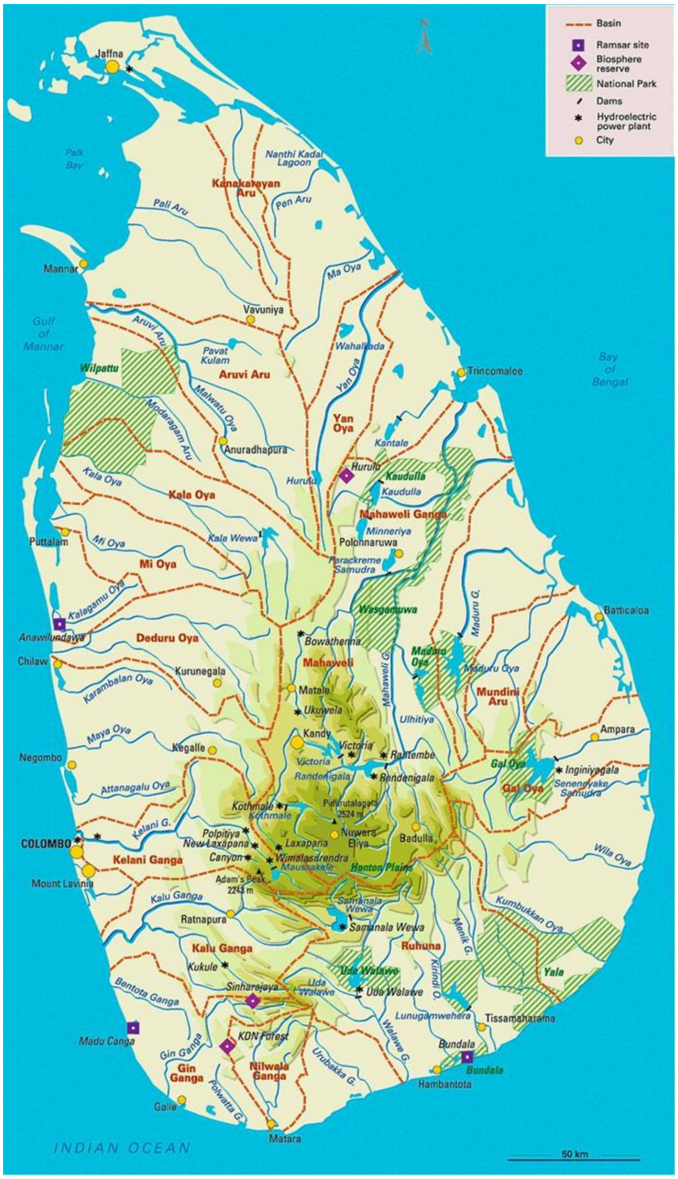
Divided into 9 provinces: Central, Eastern, North Central, Northern, North Western, Sabaragamuwa, Southern, Uva and Western.

Land Coverage: 65610 km^2 (2905 km^2 inland waterbodies)
Agriculture: 2.17 milion ha

Annual Crops: 1.20 million ha
Permanent Crops: 0.97 million ha

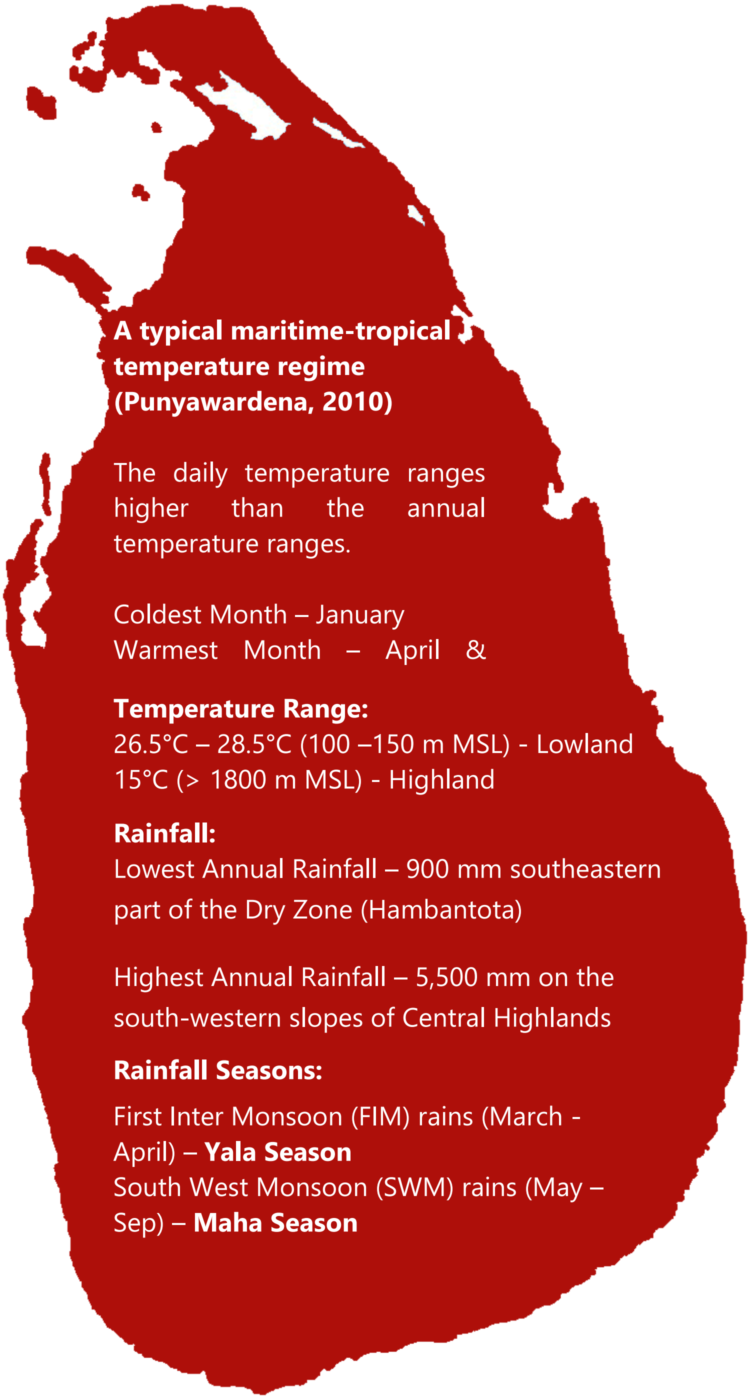
3 Elevation Zones:
Low country < 300m
Mid country 300-900m
Up country > 900m

Major Rivers of Sri Lanka



All rivers originate from the Central Highlands spreading in a cart-wheel fashion from the centre towards the coast. Most of the island's surface consists of plains located between 30 and 200 m above mean sea level (MSL). The coastal belts around the country extend up to about 30 m above MSL (https://tl.maps-sri-lanka.com).

Climate of Sri Lanka



A typical maritime-tropical temperature regime (Punyawardena, 2010)

The daily temperature ranges higher than the annual temperature ranges.

Coldest Month – January
Warmest Month – April &

Temperature Range:
26.5°C – 28.5°C (100 –150 m MSL) - Lowland
15°C (> 1800 m MSL) - Highland

Rainfall:
Lowest Annual Rainfall – 900 mm southeastern part of the Dry Zone (Hambantota)

Highest Annual Rainfall – 5,500 mm on the south-western slopes of Central Highlands

Rainfall Seasons:

First Inter Monsoon (FIM) rains (March - April) – **Yala Season**
South West Monsoon (SWM) rains (May – Sep) – **Maha Season**

Monsoonal, convectional and formation of “Weather Systems” in the Bay of Bengal account for a major share of the annual rainfall in Sri Lanka.

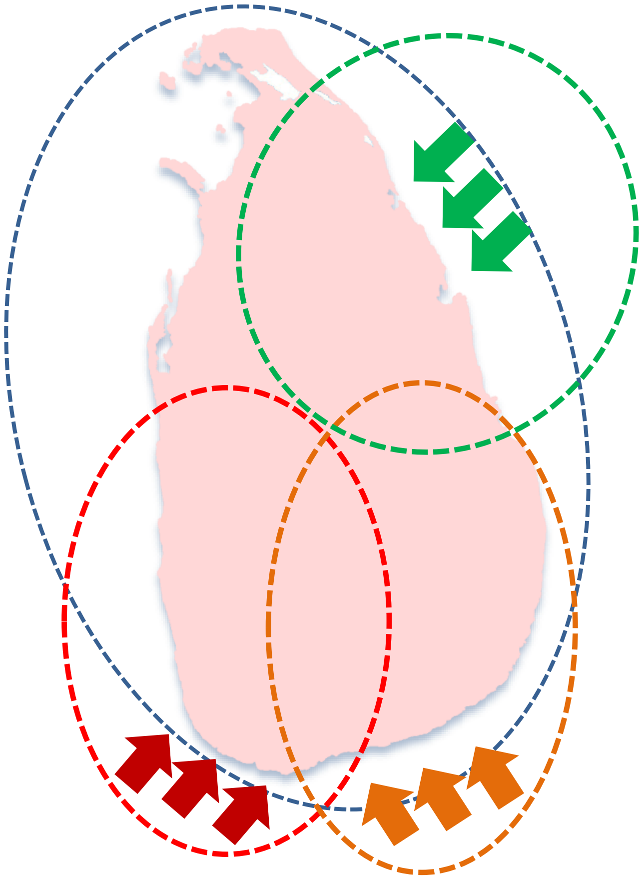


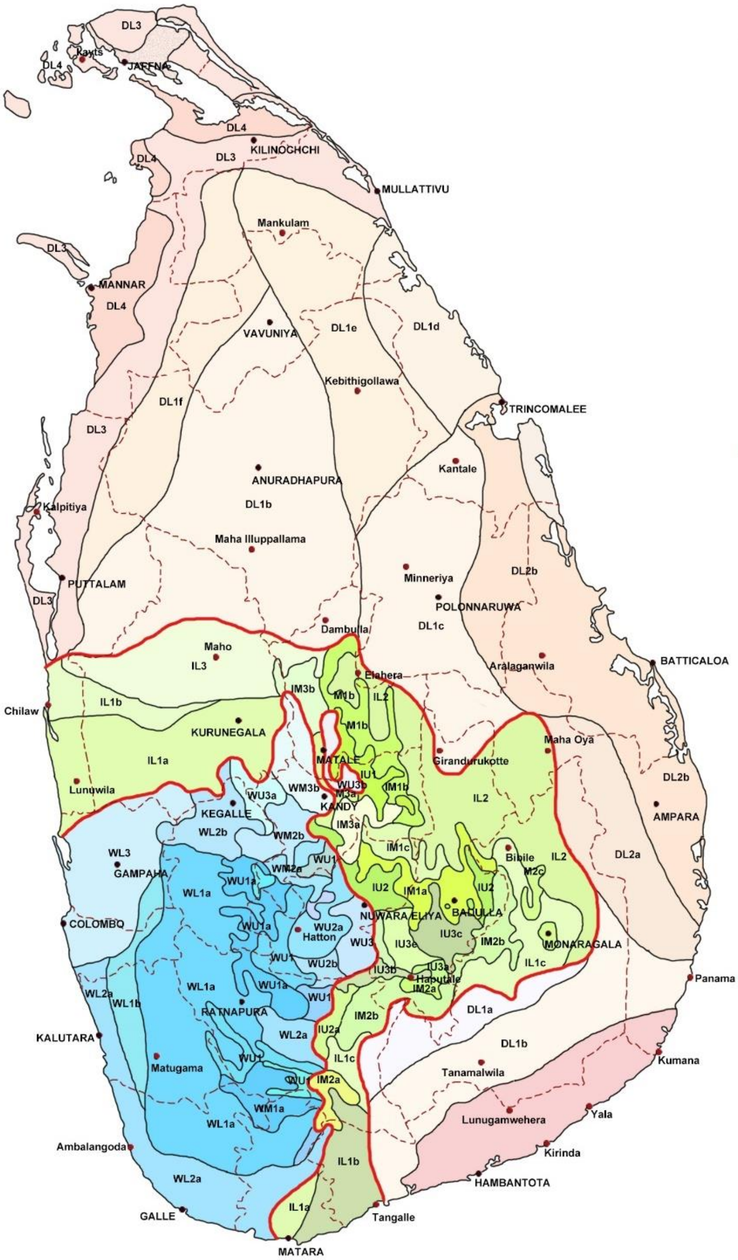
Figure 6 Weather system influencing climate of Sri Lanka

North-East Monsoon – December to February

First Intermonsoon – March to April

South – West Monsoon – May to September

Second Intermonsoon – October to November



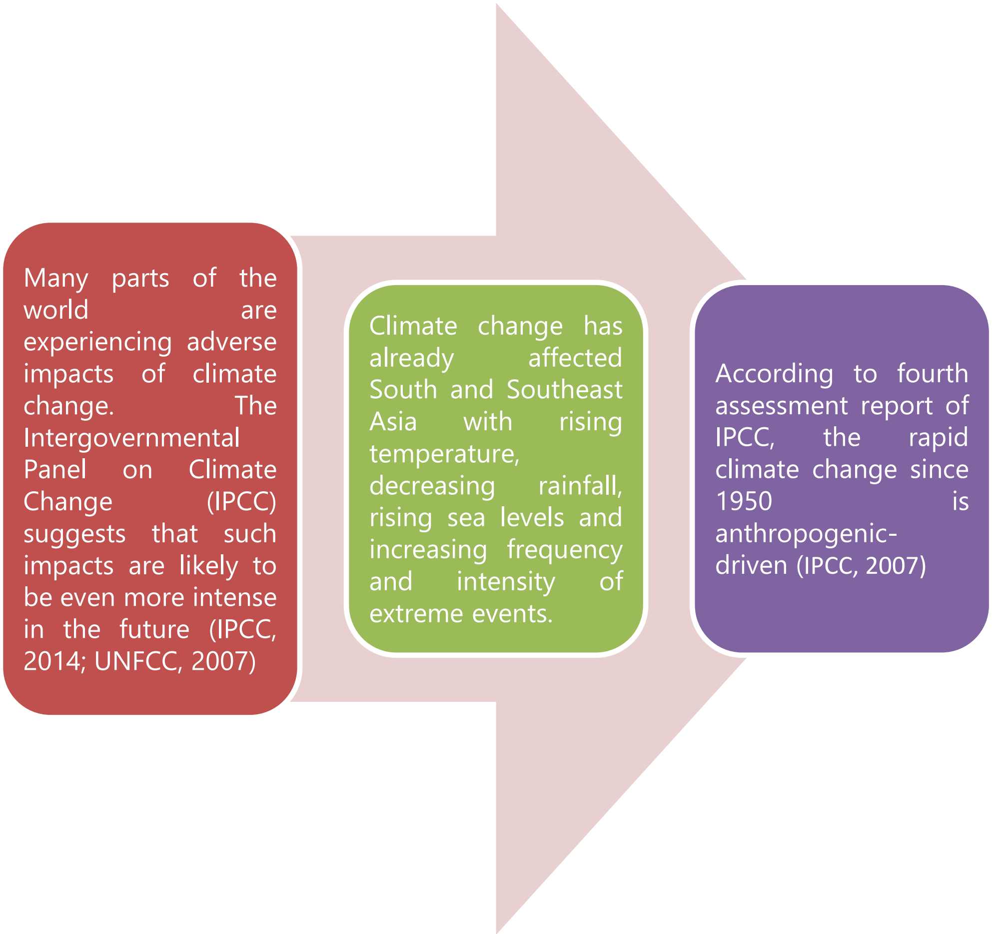
CLIMATIC ZONE	AGRO-ECOLOGICAL REGION		75% EXPECTANCY VALUE OF ANNUAL RAINFALL (MM)
WET ZONE	UP COUNTRY	WU 1	> 3,100
		WU2a	> 2,400
		WU2b	> 2,200
		WU3	> 1,800
	MID COUNTRY	WM1a	> 3,300
		WM1b	> 2,900
		WM2a	> 2,200
		WM2b	> 1,800
		WM3a	> 1,600
		WM3b	> 1,400
	LOW COUNTRY	WL1a	> 3,200
		WL1b	> 2,800
		WL2a	> 2,400
		WL2b	> 2,200
		WL3	> 1,700
INTERMEDIATE ZONE	UP COUNTRY	IU1	> 2,400
		IU2	> 2,100
		IU3a	> 1,900
		IU3b	> 1,700
		IU3c	> 1,600
		IU3d	> 1,300
		IU3e	> 1,400
	MID COUNTRY	IM1a	> 2,000
		IM1b	> 2,000
		IM1c	> 1,300
		IM2a	> 1,800
		IM2b	> 1,600
		IM3a	> 1,400
		IM3b	> 1,200
		IM3c	> 1,100
	LOW COUNTRY	IL1a	> 1,400
		IL1b	> 1,100
		IL1c	> 1,300
		IL2	> 1,600
		IL3	> 1,100
DRY ZONE	LOW COUNTRY	DL1a	> 1,100
		DL1b	> 900
		DL1c	> 900
		DL1d	> 900
		DL1e	> 900
		DL1f	> 800
		DL2a	> 1,300
		DL2b	> 1,100
		DL3	> 800
		DL4	> 750
		DL5	> 650

Figure 7 Agro-Ecological Zones of Sri Lanka (Source: Punyawardena, 2007)

Zone	Features
Wet	South-western region includes south-western slopes of the central hills. Average annual rainfall > 2,500mm without pronounced dry periods.
Dry	Plains in the northern, north central, south-eastern and eastern parts of the country. Mean annual rainfall of less than 1,750mm with a distinct dry season from May to September.
Intermediate	That surrounds the Central Highlands except in the south-west). Receives mean annual rainfall between 1,750 to 2,500 mm with a short and less prominent dry season from May to September.
Arid	Plains in the northwest and southeast parts of the country.

CHAPTER 3 SALIENT FEATURES OF CLIMATE CHANGE IN ASIA WITH SPECIAL REFERENCE TO THAILAND, NEPAL AND SRI LANKA

3.1. Climate Change in Asia



Parameters	Changes Observed (IPCC, 2014)
Mean annual temperature	Increased over the past century in world
Number of cold days and nights	Decreased
Global average temperature	Increased snow and ice melting and associated changes in wind patterns and cyclone activity.
Number of warm days and nights	Increased
Heat wave frequency	Increased
Warming trend	Increased >2°C per 50 years in northern Asia Increased in cold season between November and March

Temperature in Asia (Salient Feature) (IPCC, 2014)

Mid-latitude (semi-arid are) of Asia	Warming trend has been strong (1901 – 2009) with an increase of 2.4°C.
East and South Asia	Annual mean temperature has increased during the 20^{th} century.
West Asia	Upward temperature trends are notable and robust in recent decades.
South-east Asia	Temperature is increasing at a rate of 0.14°C to 0.20°C per decade since the 1960s, coupled with a rising number of hot days and warm nights, and a decline in cooler weather.

Observed Rainfall in Asia (Salient Feature) (IPCC, 2014)

Precipitation trends	Both increasing and decreasing trends - observed in different parts and seasons of Asia.
Northern Asia	There is an increasing trends of heavy precipitation events.
Central Asia	No spatially coherent trends observed.
East Asian summer and winter monsoon circulations	Experienced an inter-decadal scale weakening after 1970s, leading to deficient mean precipitation.
West Asia	A weak but non-significant downward trend in mean precipitation was observed in recent decades, although with an increase in intense weather events.
South Asia	Seasonal mean rainfall shows inter-decadal variability, noticeably a declining trend with more frequent deficit. (Example, over India, the increase in the number of monsoon break days and the decline in the number of monsoon depressions are consistent with the overall decrease in seasonal mean rainfall. But an increase in extreme rainfall events occurred at the expense of weaker rainfall events over the central Indian region and in many other areas).
South Asia	Frequency of heavy precipitation events is increasing, light rain events are decreasing.
Southeast Asia,	Annual total wet-day rainfall has increased by 22 mm per decade, while rainfall from extreme rain days has increased by 10 mm per decade, but climate variability and trends differ vastly across the region and between seasons.
Southeast Asia,	Between 1955 and 2005 the ratio of rainfall in the wet to the dry seasons increased. While an increasing frequency of extreme events has been reported in the northern parts of Southeast Asia, decreasing trends in such events are reported in Myanmar.

Peninsular Malaya	During the southwest monsoon season, total rainfall and the frequency of wet days decreased, but rainfall intensity increased in much of the region. On the other hand, during the northeast monsoon, total rainfall, the frequency of extreme rainfall events, and rainfall intensity all increased over the peninsula.

3.2. Projected Climate Change in Asia (Salient Feature)

1.5°C rise in global temperatures is precarious
2°C rise is catastrophic

Statement	Justification *(This assessment holds for all land areas of Asia by the mid- and late 21st century)*
Warming is very likely in the 21st century in Asia (Christensen et al., 2007)	*Ensemble-mean changes in mean annual temperature exceed 2°C above the late-20th-century baseline over most land areas by the mid-21st century under RCP8.5, and range from greater than 3°C over South and Southeast Asia to greater than 6°C at high latitudes by the late-21st century. However, the ensemble-mean changes are less than 2°C above the late-20th-century baseline in both the mid-and late 21st century under RCP2.6, with the exception of changes between 2°C and 3°C at the highest latitudes.*
Projections of future annual precipitation change are qualitatively similar to those assessed in the AR4 (Christensen et al., 2007)	*Precipitation increases are very likely at higher latitudes by the mid-21st century under the RCP8.5 scenario, and over eastern and southern areas by the late 21st century. Under the RCP2.6 scenario, increases are likely at high latitudes by the mid-21st century, while it is likely that changes at low latitudes will not substantially exceed natural variability* (IPCC, 2014).

Future increases in precipitation extremes related to the monsoon are very likely in East, South, and Southeast Asia (IPCC, 2014).	*More than 85% of CMIP5 (Coupled Model Inter-comparison Project Phase 5) models show an increase in mean precipitation in the East Asian summer monsoons, while more than 95% of models project an increase in heavy precipitation. All models and all scenarios project an increase in both the mean and extreme precipitation in the Indian summer monsoon.*

3.3. Climate Change in Thailand (Salient Feature)

Statement	Justification
Daily temperature is changing	There are remarkable changes over 1970-2006.
Increasing trends in temperature indices	Increasing trends in both maximum and minimum temperatures which are consistent with general warming trends observed at global and regional time scales.
Increase in daily maximum, mean and minimum temperatures	Linear trend analyses in annual time series of daily maximum, mean and minimum temperatures have revealed that annual means of these three variables will exhibit widespread increases in ranges of 0.12°C-0.59°C, 0.10°C-0.40°C and 0.11°C-0.55°C/decade, respectively (Limsakul et al., 2011).
Increasing warm days and nights	The annual series of warm days and nights analysed through the TX90p and TN90p (daily maximum or daily minimum temperature above its 90th percentile) significantly increased by 3.4 days/decade and 3.5 days/decade, respectively (Limsakul et al., 2011).
Severe droughts to severe floods	During the past decade, rainfall in Thailand has fluctuated from severe droughts to severe floods, leaving residential and agricultural areas reeling. Flood events average 11 events a year. The number of deaths average 150/year, but more than 400 deaths in 2011. Both drought and flood events are more frequently spread over the last 20 years (Bhatikul, 2012).
Droughts and floods events are more frequently spread over the past 20 years	The annual rainfall records of Thailand for the period 1951-2005 have revealed decreasing trends of average annual rainfall (Archevarahuprok, 2008). A recent study based on quality-controlled daily rainfall data to ascertain long-term trends and variability of total and extreme

	rainfall indices of Thailand during 1955–2014 revealed that while extreme rainfall events have been less frequent across most of parts of Thailand, they have become more intense. Moreover, the indices measuring the magnitude of intense rainfall events indicate a trend towards wetter conditions, with heavy rainfall contributing a greater fraction to annual totals. One consequence of this change is the increased frequency and severity of flash floods as recently evidenced in many parts of Thailand (Limsakul and Singhruck, 2016).
Thailand is becoming warmer	Climate change tends to be slightly warmer at the turn of the century, but hot areas will be much widespread (Chinvanno, 2013). Hot periods of the year will be much warmer and longer, while summer time will expand into winter. Higher rainfall regimes will experience increasing intensity as the length of the rainy season tends to be more or less the same with higher risk of floods in years to come.

3.4. Climate Change in Nepal (Salient Feature)

Statement	Justification
Depicted with a positive trend of 0°C to 0.5°C per decade (DHM, 2017)	This is based on a temperature trend analysis of the data of 80 stations for the period 1981-1998, Nepal (the exception is small pockets in the eastern region and far western Terai).
The overall temperature in the country found to be rising at the rate of 0.41ºC per decade	These observations are based on 30-years' time series of data prior to 2010 which used 110 stations for surface air temperature and 309 stations for precipitations. These stations are generally well distributed in lower altitude regions of the country; however, at higher altitude regions the numbers of stations are fewer. Hence the results limit understanding of the climate in Nepal.
The IPCC's 2007 Fourth Assessment Report designated this region a "white spot"	This is because of the limited number of scientific studies conducted in this region, including Nepal due to lack of reliable and consistent historical time series of climatic data.
Overall trend	In Nepal annual mean maximum temperature is 23.6 °C and that of minimum is 11.6°C. From the distribution of the annual mean temperature trend, it has been evident that except for small isolated pockets, an increasing trend up to 0.55° C per decade in most parts of Nepal.
Highest precipitation	> 5000 mm is centered over the southern flank of Annapurna range and the driest part with about 500 mm on the lee side of the same. This shows the importance of topography on spatial variations of precipitation distribution in Nepal. In addition, eastern high altitude regions have two pockets of about 3,000 mm annual precipitation. The rest of the

	country have precipitation distribution of approximately 1,000-2,000 mm per annum, which increases towards northern mountains, except over the western part of the country where it decreases towards the north. Meanwhile, all-Nepal average annual precipitation is 1,683 mm of which 1,330 mm falls during summer monsoon.
Increasing trends of extreme precipitation events	Study done with these historical precipitation time series have shown that monthly maximum on 1-day precipitation amount, annual number of days when precipitation of 50 mm or more falls, extremely wet days (annual total precipitation when rainfall exceeds 99th percentile) all exhibit increasing trends in many stations particularly in the west and decreasing trends in some mountainous locations. However, the annual total precipitation in wet days (days with 1 mm or more precipitation) does not exhibit increasing trends. In addition, increasing trends in consecutive dry days (maximum number of consecutive days with rainfall less than 1 mm) and decreasing trends in consecutive wet days (maximum number of consecutive days with rainfall equal or more than 1 mm) over most of the stations are good indicators of increasing extreme precipitation events in Nepal.
Mean temperature could rise by 0.9°C – 1.1°C in the medium-term period and 1.3°C – 1.8°C in the long-term period (MoFE, 2019).	Future scenarios have been prepared for precipitation and temperature considering the years 2016 – 2045 as the medium-term period and 2036 – 2065 as the long-term period – corresponding to the 2030s and 2050s respectively – with respect to the reference period (1981-2010). The temperature is projected to increase for all the seasons. The highest rates of mean temperature increase are expected for the post-monsoon season (1.3°C – 1.4°C in the medium-term period, and 1.8°C – 2.4°C in the long-term period) and the winter season (1.0°C – 1.2°C in the medium-term period, and 1.5°C – 2.0°C in the long-term period).
Precipitation is projected to increase	Precipitation is projected to increase in all seasons, except the pre-monsoon season, which is likely to see a decrease

in all seasons except Pre monsoon (MoFE, 2019).	of 4–5% in the medium-term period. The post-monsoon season might have the highest increase in precipitation with respect to the reference period, possibly going up by 6–19% in the medium-term and 19–20% in the long-term.

This recent projection suggests that in general, the climate in entire Nepal will be significantly warmer and wetter in the future, except for a decrease in precipitation during the pre-monsoon season. At the same time climate extremes related to temperature and precipitation suggest that more extreme events are likely in the future. All these scenarios suggest that different developmental sectors relating to water resources, in particular, will be significantly affected and so a better understanding of these changes will help to design better adaptation strategies, and implement them in a more sustainable manner.

3.5. Climate Change in Sri Lanka (Salient Feature)

Statement	Justifications
There is a warming trend of the temperature regime in Sri Lanka	Sri Lanka possesses an established series of historical climatic data, especially rainfall and temperature starting from 1860s. Recent analysis of these data has shown that country's average temperature is significantly increasing at a rate of 0.01°C to 0.03°C per year (Fernando and Chandrapala, 1995; Nissanka et al., 2011) with an increased occurrence of more warm days & nights (Premalal and Punyawardena, 2013)
The increase is more pronounced in night time minimum temperature than that of the daytime maximum temperature (Marambe et al., 2012).	Data indicates that increases in night-time minimum air temperature contribute more to average increases in annual temperature than that of daytime maximum air temperatures (Basnayake, 2007).
Number of days with Cold Day-times and Cold Night-times significantly decreasing in most places of the country.	A significantly increasing trend observed with number of days with warm day-times and warm night-times (Premalal and Punyawardena, 2013)
No discernible significant trends in seasonal and annual rainfall, except a few locations among over 400 rain gauging stations of the country (Nissanka et al., 2011, Marambe et al., 2012).	The same is true in terms of variability of cumulative annual and seasonal rainfall during the same period. Nevertheless, it has been observed that variability of seasonal rainfall during the most recent decade (2001 – 2010) has increased compared to the previous decade (1991 – 2000) in most of the island, across all three climatic zones, with the occurrence of more frequent drought and flood conditions

Occurrence of extreme positive rainfall anomalies in the Dry zone and Central Hills	Occurrence of extreme positive rainfall anomalies in the Dry zone and Central Hills of the country have shown that contrary to common belief, there is no significant increase of heavy and very heavy rainfall events in the region, but with an apparent increase of such events during the period of 2006-2010 has been evident in the Central hills (Abeysekara et al., 2015) and the Dry zone (Premalal and Punyawardena, 2013).
Positive South West Monsoon rainfall anomaly	Climate change projections indicate southwest monsoon rainfall anomaly is positive and increasing in both moderate and high emission scenarios, with an increasing anomaly which is significant in the wet zone.
Northeast monsoon and First Inter monsoon rainfall anomaly is negative for short-term, medium-term and long-term projections and the negative trend is observed under both moderate and high emission scenarios	The northeast monsoon rainfall anomaly is slightly positive in short-term projections, 2020-2040, and negative thereafter for medium-term and long-term projections under high emission scenarios. A negative trend is observed for a high emission scenario. A decreasing anomaly is significant over the Dry Zone. The First Inter Monsoon rainfall anomaly is negative in 2020-2040, slightly negative in 2040-2060 and positive in 2070-90 except for north-eastern parts under moderate emission scenarios. The First Inter Monsoon rainfall anomaly is negative in all three time frames with no significant trend under high emission scenarios
The Second Inter Monsoon rainfall anomaly is negative in north-eastern parts and positive in southwestern parts in 2020-2040.	The Second Inter Monsoon rainfall anomaly is positive and increasing under high scenarios with a significant increase of positive rainfall anomaly over the southwestern and south-eastern parts
Multi Model Ensemble prediction indicates an increase in maximum and minimum temperatures for all three time periods in 2020-2040, 2040-2060 and 2070-2090, for both	For moderate emission scenarios, the Multi Model Ensemble prediction indicates that an increase of minimum and maximum temperature of 0.7°C–1.2°C, 1.0°C-1.6°C and 1.5°C-2.3°C can be expected during 2020-2040, 2040-2060 and 2070-2090 respectively. For high emission scenarios, the Multi Model

moderate emission and high emission scenarios	Ensemble prediction indicates that an increase in minimum temperature of 1.1°C – 1.5°C, 1.6°C - 2.5°C, and 2.4°C - 3.5°C and an increase in maximum temperature of 1.0°C – 1.5°C, 1.4°C - 2.3°C and 2.2°C - 3.2°C can be expected in the time periods of 2020-2040, 2040-2060 and 2070-2090 respectively.
Sri Lanka to have more warm days and nights and fewer cold days and nights by 2080 (Cruz et al., 2007)	Multi-model ensemble projections (composite products of six global climate models) has revealed that Sri Lanka's temperature will continue to rise in years to come (by 2080) with more warm days and nights and fewer cold days and nights (DoM, GoSL).
Cumulative seasonal rainfall of the First Inter Monsoon (FIM) will decrease while cumulative rainfall in the South West Monsoon (SWM) rainfall will increase	The increased cumulative rainfall in the South West Monsoon (SWM) rainfall will result in the wetter parts of the country becoming even wetter from March to August, when both the FIM and SWM are most active, leading to frequent and intense flood hazards
Rainfall of the Second Inter Monsoon (SIM) season will increase across all parts of the country while the North East Monsoon (NEM) will become drier in semi-arid areas (DoM, GoSL)	Prevalence of drought conditions during *Maha* seasons in the Dry zone of Sri Lanka will likely to be a common feature in future, a serious situation to think of in terms of national food security of the country as the Dry zone is the national Food-basket of the country (DoM, GoSL).

**All projections relative to 1975-2005 base data*

CHAPTER 4 CLIMATE RELATED NATURAL HAZARDS IN THE ASIA WITH SPECIAL REFERENCE TO FLOOD HAZARD

4.1. What are Natural Hazards?

Natural hazards are defined by UNDRR as natural processes or phenomena that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Figure 8 Flood in Sri Lanka in May 2017 (Source: goldfmnews.lk & herunews.lk)

4.2. Climate Change and Natural Hazards

Global warming refers to the long-term warming of the planet since the early 20th century, and most notably since the late 1970s, due to the increase in fossil fuel emissions since the Industrial Revolution. Climate change refers to a broad range of global phenomena created predominantly by burning fossil fuels, which add heat trapping gases to Earth's atmosphere. It has been projected that global warming is expected to make the climate warmer, wetter and more extreme. Hence, it can be expected that such changes in climate regime will increase the severity and frequency of climate induced natural disasters like floods, droughts, cyclones, storm surges, heat and cold waves, landslides and lightning strikes.

Figure 9 Climate Change & Global Warming (Source: climate.nasa.gov/resources/global-warming/)

Due to Global warming and resulting climate change **Floods in Asia are likely to be very common.** Floods, severe storms, droughts and other climate-related extremes are responsible for over 90% of global disasters and affect the most people. According to the United Nations' Global Humanitarian Overview Report – 2019, in the period between 2014 and 2017, 870 million people from 160 countries of the world, either lost their lives, their livelihoods or were displaced from their homes because of disasters caused by natural hazards.

Figure 10 Chao Phraya river inundating large area near Bangkok in Thailand in 2011 (Source: Daniel Julie, http://Thailand/Thai floods/)

Figure 11 Flash flood damage to roads during 2013 floods in Nepal (Source: wikimedia.org)

Figure 12 Rescue during floods in Sri Lanka 2009 (Source: https://www.flickr.com/people/tro-kilinochchi/)

4.3. Climate Induced Natural Hazards in Asia (Cause and Effect)

Countries in Asia-Pacific region experience more climate induced natural disasters than any other region in the world

World wide damage in 2009 estimated at 47 billion USD has increased to 340 billion USD in 2017

Between 2014 and 2017 Asia Pacific region experienced 217 storms and 236 cased of flooding affecting 650 million and 33000 deaths (UNOCHA, 2019)

Many Asian countries share common characteristics of growing population and considerable poverty

Rapid industrialization in Asian countries is driving high concentrations of people to live in poorly constructed, crowded cities

The Asian region also suffers from high rates of environmental degradation

Lack of awareness to cope with climate change disasters and lack of early warning to act

The deadliest ever tropical cyclones to hit Bangladesh is the Chittagong region of south-eastern Bangladesh in April 1991 which killed over 135,000 people and left an estimated 10 million homeless. Poor communications and lack of preparedness meant that villagers received no warning of the coming storm (UN Global Humanitarian Overview Report, 2019)

4.4. Reasons for high exposure and vulnerability to natural hazards

Villages and farms near coastal regions often lack resources to build adequate sea defense structures leaving them exposed to monsoon rains and storms.

Rapid urbanization without inadequate planning make densely populated urban areas more vulnerable to floods and storm surges, particularly near coastal regions and large rivers

Places where logging and land clearances for farming activities in catchment areas have caused dramatic loss of tree cover, depletion of natural protection has increased the risk of landslides and flash floods

Deep-rooted poverty make communities more vulnerableless due to less coping capacity being exacerbated by political and economic instability prevailing in many Asian countries.

Benefit of Floods

Floods though considered as a hazard but it is not devoid of any beneficial aspects.	Floods replenish groundwater aquifers and sustain groundwater supplies. Floods help to maintain wetland systems which play a vital role in ecology, providing habitats for a rich bio-diversity. Floods lead to increased fertility of the floodplains by regularly depositing rich silt on the riparian lands. Without the build-up of these alluvial deposits, riparian cultivators would have to spend significant amounts on chemical fertilizers for their lands to maintain the fertility (such as in Thailand, Bangladesh, Myanmar, Vietnam).

THE TRUTH - Lack of Awareness to Cope with Climate Change Disasters

4.5. Floods in Thailand

Thailand is a flood-prone country. The monsoon is the main contributor of rainfall in Thailand but other weather systems can also increase rainfall during the monsoon months. Tropical cyclones, for example, can generate copious amounts of rainfall long after strong winds have diminished. Although Thailand is rarely impacted by typhoon winds, the remnants of storms crossing Vietnam, Cambodia and Laos from the east generate heavy precipitation in Thailand on a near-annual basis (Anon, 2016).

Figure 13 Satellite sensor data showing the flood inundation during 2011 floods in Ayutthaya and Pathum Thani Provinces, Thailand in October (right), compared to before the flooding in July (left) (Source: NASA EO-1 team)

Cause of Flood in Thailand	
Copious amount of monsoonal rains	**The impact of floods in Thailand is the result of both natural and anthropogenic factors.** The first factor is the copious amount of monsoonal rains which will often be augmented by approaching storms from the east.
The nature of the terrain	The second is the terrain of the region. Due to the gentle slope of the downstream parts of the Nan and Yom Rivers (the tributaries of the Chao Phraya River system) a high volume of discharge flows into the lower part of the watershed from the narrow, upstream section of the river system. In addition, the Chao Phraya River has a modest bank full capacity, particularly in the downstream section, which results in it being flood-prone.
Land use pattern of down stream	The third factor is the landuse/landcover downstream of the Chao Phraya River including Bangkok metro area which is located on the former floodplains of the river. The natural drainage and wetlands have been replaced with urban structures. The same applies for the surrounding, mega industrial parks, located out of the Bangkok metropolitan area as well (Engkagul, 1993).
Over extraction of ground water	In addition, land subsidence in Bangkok, due to over extraction of ground water for industries, might have also worsened flood damage, given that the elevation of Bangkok is 0.5 m to 1.5 m above MSL (ADB, 1994).
Lack of reliable climate forecast system	Another factor is the lack of reliable seasonal weather forecasts with a reasonable lead time. If such forecasts were available, an optimum reservoir operation strategy could be drawn up to meet two competing objectives that confound reservoir operations, namely, storing water for use during the dry season and minimizing flooding during the wet season (Lebel et al., 2011).
High tidal tides	The high tides from the sea and low efficiency of the drainage systems are also contributing factors. As the population and number of exposed properties will continue to grow in Thailand, losses from this peril will continue to rise, especially under a changing and variable climate, since floods will be more frequent and intense in this region in future.

4.6. Floods in Nepal

Floods significantly impact Nepal in terms of the number of affected people and frequency of events. For example, data on the number of people affected by various types of natural disaster that occurred in Nepal during the period 1971-2006, reveal that 68.3% of the total affected people were impacted by floods Nepal is ranked the 30th country in the world in respect of relative vulnerability to floods, according to a study conducted by the UNDP. There are more than 6,000 rivers and streams in Nepal. Most of them flow from north to south, generally, with a high velocity due to the high gradient. The glacier lakes in Nepal can also burst any time leading to catastrophic floods resulting loss of life and physical properties.

Figure 14 Glacier Lake in Nepal (Source: http://www.icimod.org/dvds/201104_GLOF/)

Cause of Flood in Nepal	
Most of the large rivers are snow-fed and originate from the Himalayan glaciers which are covered by perpetual snow	Hence, the melting snow maintains a considerable base flow which swells very quickly with a very high intensity of rainfall during the monsoon season causing floods.
The monsoonal rainfall which falls mostly during June and September every year, contributes to about 80% of the annual rainfall	Extreme floods occur during this period, mostly due to concentrated spells of heavy rainfall
The filling of natural wetlands, the rapid urbanization across the countryside and many other human interventions/land use changes, have reduced infiltration and subsequent percolation, leading to more stagnating water	This results in higher floods, even with a minor positive anomaly of rainfall.
In the Himalayan region glacier lakes are common. These lakes contain huge volume of water and remain in unstable condition **As a result, these lakes can burst any time and catastrophic floods can occur any time resulting in loss of life and physical properties.**	There are a total of 159 glacial lakes in Koshi basin and 229 in Tibetan Arun basin. Among them 24 glacier lakes that are potentially dangerous. Lakes in Upper Barun, Lower Barun, Chamlangtsho, Tsho Rolpa, Sabou, Dudh Kunda, Majang, Inja, Thulari.

4.7. Floods in Sri Lanka

In Sri Lanka floods are common than any other natural hazards. There are three types of floods mainly affect Sri Lanka (Meegastenna, n.d.):

- Riverine floods
- Urban floods
- Reservoir induced floods

Figure 15 Floods in Aranayake, Kegalle District, Sri Lanka in 2016 (http://geoedge.lk/cfr/sri-lanka-floods-and-landslides/)

Classification of Floods in Sri Lanka

Flood Type	Characteristics
Riverine floods	This is an alternative term to identify river floods. When any river/stream reaches its carrying capacity/flood stage, the swollen flow overflows the banks of the river/stream and inundates low-lying areas and levees on either side.
Urban floods	types of flood occur in a relatively short space of time and can inundate an area with several feet of water due to intense rains, inadequate drainage provision, the blockage of drains with debris and irrational land use such as the filling of wetlands and blocking of natural drainage

Reservoir induced floods	types of flood occur downstream of a reservoir due to spillage during intense or prolonged rains or the breaching of dams due to extensive rainfall in the upper catchment

Major floods of Sri Lanka are associated with two monsoon season:

- South west monsoon season (May to September) in the south western part of the country, especially the Sabaragamuwa provinces, also termed the 'Wet Zone' of the country
- North east monsoon season (December to February) in eastern, northern and north-central provinces of the country; the 'Dry Zone' of the country.

Figure 16 Crop damage due to over flowing river in Sri Lanka during 2011 Floods (Source: Daily News Tuesday 15 Feb 2011)

Cause of Flood in Sri Lanka	
Period from October to December is considered as the "stormy months" of Sri Lanka	This is due to the frequent formation of weather systems in the Bay of Bengal on account of the position of the Inter Tropical Convergence Zone (ITCZ) on, or near to, Sri Lanka. Heavy rainfall receipt from these weather systems can cause floods in any part of Sri Lanka depending on the relative position of the weather system in the Bay of Bengal.
Heavy down pours and associated floods in most parts of the island especially in the eastern region occurs at the latter few weeks of the year or in January once or twice per season	This is when usual north east monsoonal blow change its trajectory over the Bay of Bengal from north-east to northerly direction (due to easterly waves coming all the way from the Pacific Ocean and eastern Indian Ocean)
Localized high intense thunder storms even exceeding 100 mm/h rainfall intensity leading to flash floods or urban floods	These types of thunder storms occur during April in a given year when the country is experiencing intense convectional activity due to the sun's directly overhead position on the island

CHAPTER 5 DAMAGE & LOSS DUE TO CLIMATE INDUCED DISASTER IN AGRICULTURE SECTOR IN THAILAND, NEPAL AND SRI LANKA

THE HOLISTIC PROCESS OF PARADIGM SHIFT IN CLIMATE RELATED DISASTER RISK REDUCTION IS SPELLED AS 'CLIMATE SMART DISASTER RISK MANAGEMENT (CSDRM)'

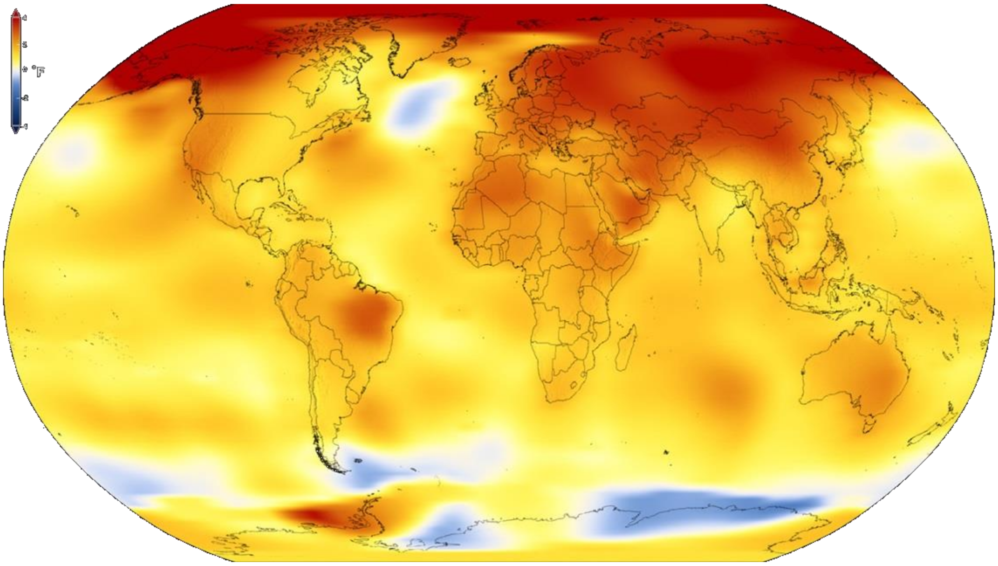


Figure 17 Earth's Average Global Temperature from 2013 to 2017, as compared to a baseline average from 1951 to 1980 (Source: NASA, NOAA)

The effect of global warming will be worse in least-developed and developing countries. This is mainly due to the low coping capacity and lack of awareness and preparedness to face the effects of global warming and subsequent change in climate.

Agrarian communities in monsoonal, tropical, sub-tropical and coastal regions of the Asia are now facing extreme weather conditions resulting in greater uncertainties in crop cultivation; the dry areas are further drying up while the flood prone areas are being subjected to intense flooding; leading to undeniable impact on the agriculture sector. Thus the policy makers are required to design and implement science-based strategies to manage and mitigate effects of global warming related disasters and the capacity of the community are required to be enhanced on the risks from the extreme events to enable better adaptation.

5.1. Disaster Management Strategies

Figure 18 A holistic approach to Disaster Management Cycle (http://emtv.com.pg)

Issues	Effect
Lack of adequate climate information on the nature of future climate risks and post-disaster reconstruction process (Michell, 2010)	Lead to increase in risk than minimizing risk
A strong necessity exists for climate predictions and projections to provide opportunities to increase the lead times of early warnings	Seasonal climate outlooks help policymakers to predict and manage – excessive flood or drought with predicted rainfall information and thereby minimizing the risk associated with it
Short-term disaster reactive responses give only vital need of the day to day living and hope for people living through disasters	Necessity for sustainable solution

The climate forecasts through seasonal to decadal time scale help make informed decisions on long term investments and strategic planning	
1	Riparian zone management (Inter-phase between land and water channel).
2	Development of new building codes and the retrofitting of infrastructure like levees to withstand more frequent and severe flood hazards.
3	A long-term solution embedded to development planning gives a hope for potential vulnerable people and sustainable solutions in reducing the vulnerability to reduce exposure to such climate related risks.

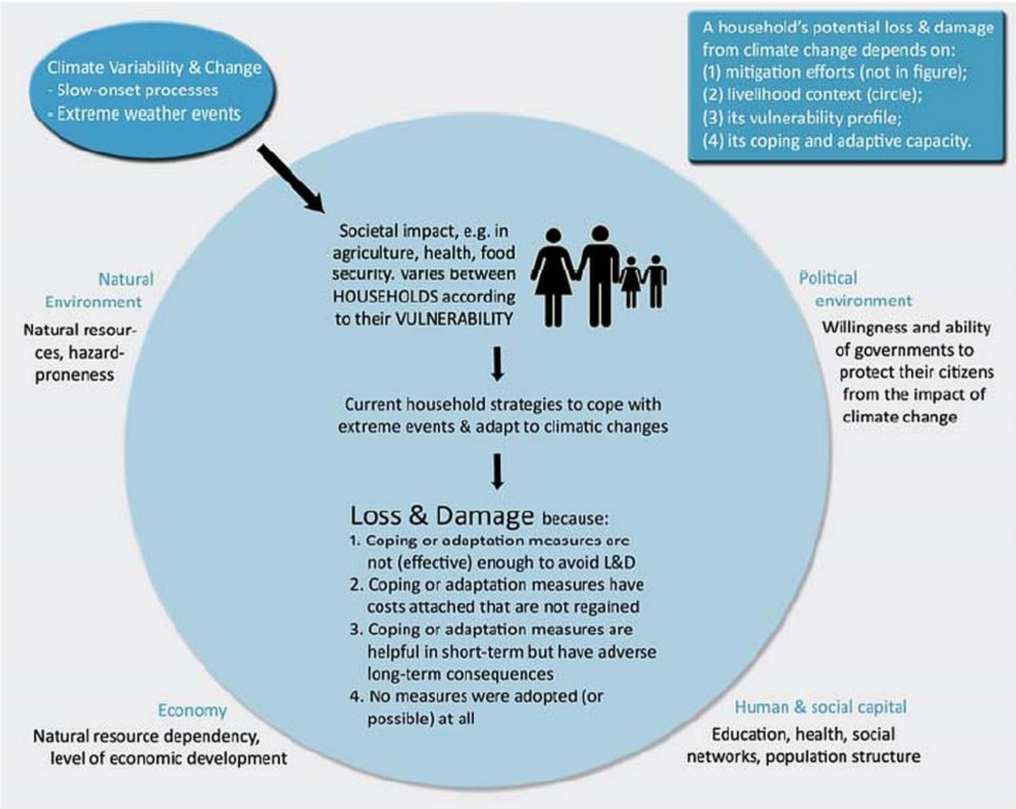


Figure 19 Climate related disaster and its effect (Source ADRC)

5.2. Climate Related Disasters and Agriculture

1. A noticeable rise in climate related disasters (droughts, floods and storms) were reported worldwide from 1980 to 2014, with considerable economic losses (FAO, 2016).

2. These climate-related disasters are significant to Asian region where agriculture is the main livelihood option and dependent on the prevailing weather conditions and are highly sensitive to rainfall extremes, both droughts and floods.

3. Climate related disasters to agriculture vary (degree and scale) on the geographical position of respective countries across world's climatic zones.

4. Crops tend to be the most affected by floods and storms; livestock is overwhelmingly affected by droughts; the fisheries and aquaculture sector is mostly affected by storms including hurricanes and cyclones while most of the economic impacts to forestry sector is caused by storms, excluding wild fires with no significant impact from droughts.

The tables below shows the annual occurrence of climate related disasters and associated economic damage (Adapted from FAO, 2016)

Annual Occurrence of Climate induced Disasters		
1980 – 1990	→	**2004 – 2014**
149		332
Annual Economic Damage due to Climate induced Disasters		
USD 14 billion	→	USD 100 billion
% share of damage and loss to agriculture sector due to Climate induced Disasters		

2003		2013
17	→	31

Sector	Effect on Agriculture Sector
Crops	Floods (59.1%) / Drought (14.9%) / Storms (26%)
Forestry	Storms (94.7%) / Floods (5.3%)
Livestock	Drought (87.6%) / Floods (8.6%) / Storms (3.8%)
Fisheries	Floods (31.3%) / Storms (59%) / Drought (9.8%)

Negative impacts beyond physical damage to agriculture sector due to climate induced disasters	
1	Disrupt agricultural production and productivity
2	Negative cascading effects along the value chain
3	Reduction in industrial output in sectors that depend on agriculture
4	In medium and large scale disasters, high production losses can have negative consequences for the balance of payment of the country
5	Reduction in sectoral and national economic growth
6	Disasters weaken the efforts of governments and international donors to eradicate hunger and food insecurity and poverty and also undermine in achieving sustainable development goals of the United Nations by the year 2030

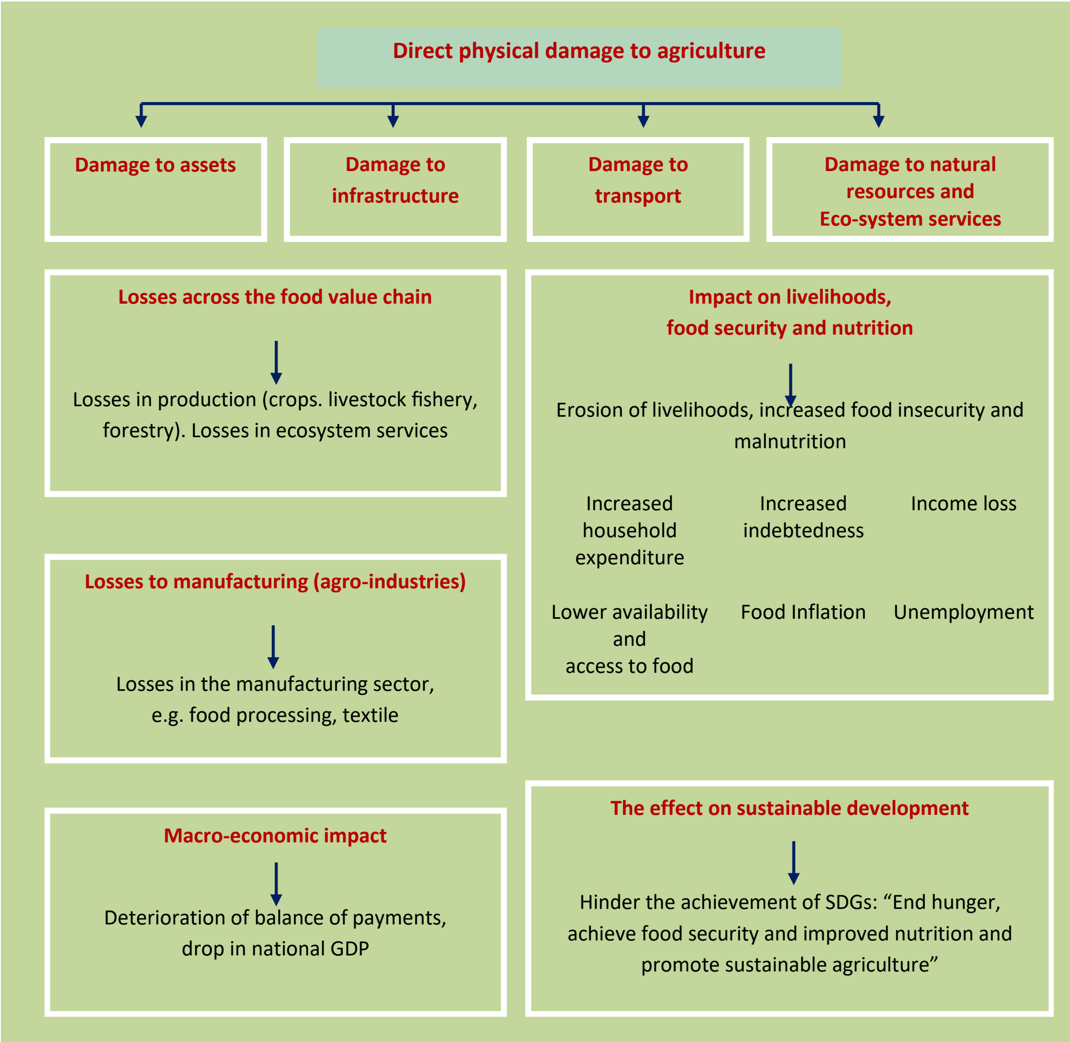


Figure 20 Direct and indirect impacts and consequences of natural disasters on the agriculture sector (Adapted from FAO, 2016)

Climate induced disasters – Thailand

Frequent climate induced natural disasters in Thailand are floods and / or droughts. Bangkok, the capital of Thailand (called as 'Wet city') is exposed to prolonged inundation due to overflowing of the Chao Praya River, usually during heavy monsoon seasons or stormy weather conditions. The table below shows some of the worst climate induced disasters affecting the country.

Disaster	Frequency	Period	Affected parties /sectors
Floods	Frequent	Monsoon June – Sept	Properties, Livelihood, Agriculture
Drought		March - April	Agriculture, industrial and service sectors / heavy deforestation in catchment
Tropical storms	4 / year	June – November	Southern region is more vulnerable
Tropical storms	2011	July	815 deaths 13.6 million affected 45 billion USD loss 20,000 ha of farm land affected Bangkok city inundated (Anon, 2016a)

Climate induced disasters – Nepal

Salient points of climate induced disasters in Nepal are given in Table below

Status climate related disasters	4th country in terms of relative vulnerability to climate change One of the most disaster-prone countries in the world
Damages 1990 - 2017	Accounted for 25% of deaths 84% population adversely affected Causing economic losses of 76%
Natural Hazards	Floods, Landslides, Windstorms, Hailstorms, Fires, Earthquakes And Glacial Lake Outburst Floods (GLOFs).
Landslides and floods	Most destructive types of disasters. Common during the monsoon season, (June – September), when 80% of the annual precipitation falls, coinciding with snowmelt in the mountains (MoHA 2015).
Glacial Lakes Outburst Floods	Increased glacial melt in Nepal during the monsoon period contribute to Glacial Lakes Outburst Floods (GLOFs) resulting in catastrophic floods in the downstream. Out of 2,315 glacial lakes about 15 of them are found substantially dangerous in Nepal with potential GLOFs (DRRP, 2019).
Drought	Dry-spells have become more frequent, longer, intense and severe during recent past. Caused by uneven and irregular monsoon rainfall in the summer. Usually occur between

November and May. Some parts of Terai, mid-land and Trans-Himalayan belts of Nepal are prone to drought.

Thus, it is clear from these numbers that proactive Disaster Risk Reduction (DRR) strategies and policies are important and must receive high priority in national level policy making. The agricultural sector of the country is predominantly made up of small holder farms which are mainly rain fed. Historically, the agricultural sector has been heavily affected by floods and erratic rainfall, although there have also been droughts in recent years under a changing and variable climate regime (MoSTE, 2014).

Climate induced disasters – Sri Lanka

Salient points about climate induced disasters in Sri Lanka

Disasters	Losses
Climate related natural disasters and associated losses from damage to housing, infrastructure, agriculture, and expenditure on relief	USD 327 million
The annual losses Floods Cyclones Or High Winds Landslides Droughts	USD 2.1 billion USD 2.5 billion USD 1.1.billion. USD 0.9 billion *This is equivalent to 0.4 percent of GDP or 2.1% of government expenditure*
May 2016 Floods and landslides	USD 572 million

1. Out of 21 natural and human induced disasters which pose serious threats to the island nation, flood, droughts and landslides are considered the most significant as they can affect the country's population, the livelihood of the people, the infrastructure and environment (Punyawardena and De Silva, 2012).
2. Besides riverine floods, flash floods and urban floods, flood occurrence due to reservoir operations and floods caused by dam breaching are of special

importance to Sri Lanka. In Sri Lanka, areas vulnerable to floods share some common characteristics. They tend to be in high rainfall receiving areas, low in elevation and close to stream or sea. However, the presence of any, or all, of these characteristics does not make an area necessarily flood-prone. Similarly, their absence does not guarantee that an area is free from the occurrence of flood (Punyawardena and De Silva, 2012).

3. Even though Sri Lanka has a tropical monsoon climate according to the world's climatic nomenclature, with a high rainfall regime ranging from 900 to over 5,500 mm annually, drought is still a common feature of the Sri Lankan landscape.

4. Drought or extreme negative rainfall anomalies are experienced in Sri Lanka in three major meteorological situations. One situation arises when the air stream over the island comes from a northern hemisphere high pressure system and travels over the dry mainland of India immediately before reaching Sri Lanka during the northeast monsoon season, December to February.

5. A marked decrease in formation of weather systems (low-level disturbances, depressions and cyclones) in the Bay of Bengal also creates below normal rainfall during October to January. Such droughts and dry spells can affect most regions 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).

6. However, activity of the ITCZ during this period is highly variable and thus, it is common to experience below 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 deviation in the flow direction from its usual path. Under such situations, dry conditions are likely to occur in agro-ecological regions that lie across even Wet and Intermediate Zones. Thus, it is apparent that almost all locations of the island carry the potential threat of drought occurrence (Chitranayana and Punyawardena, 2008).

Landslides due to increased rainfall events in the island

Figure 21 Landslide due to heavy rainfall in Koslanda, Badulla District, Sri Lanka in 2014 (Source: Vikalpa)

Many of the natural hill slopes that have stood safe for centuries are now frequently subject to landslides. This is mainly due to anthropogenic activities and irrational land use practices on vulnerable hill slopes. The situation will be further aggravated as the frequency of intense rainfall will be more likely under a changing and variable climate regime. Nearly 13,00 km^2, (20% of the total extent of the island) covering 10 administrative districts (out of 25) such as Badulla, Nuwara Eliya, Matara, Kandy, Kegalle, Ratnapura, Kalutara, Galle, Matara and Hambantota, are considered as highly vulnerable to landslides (Bandara et al., 2012).

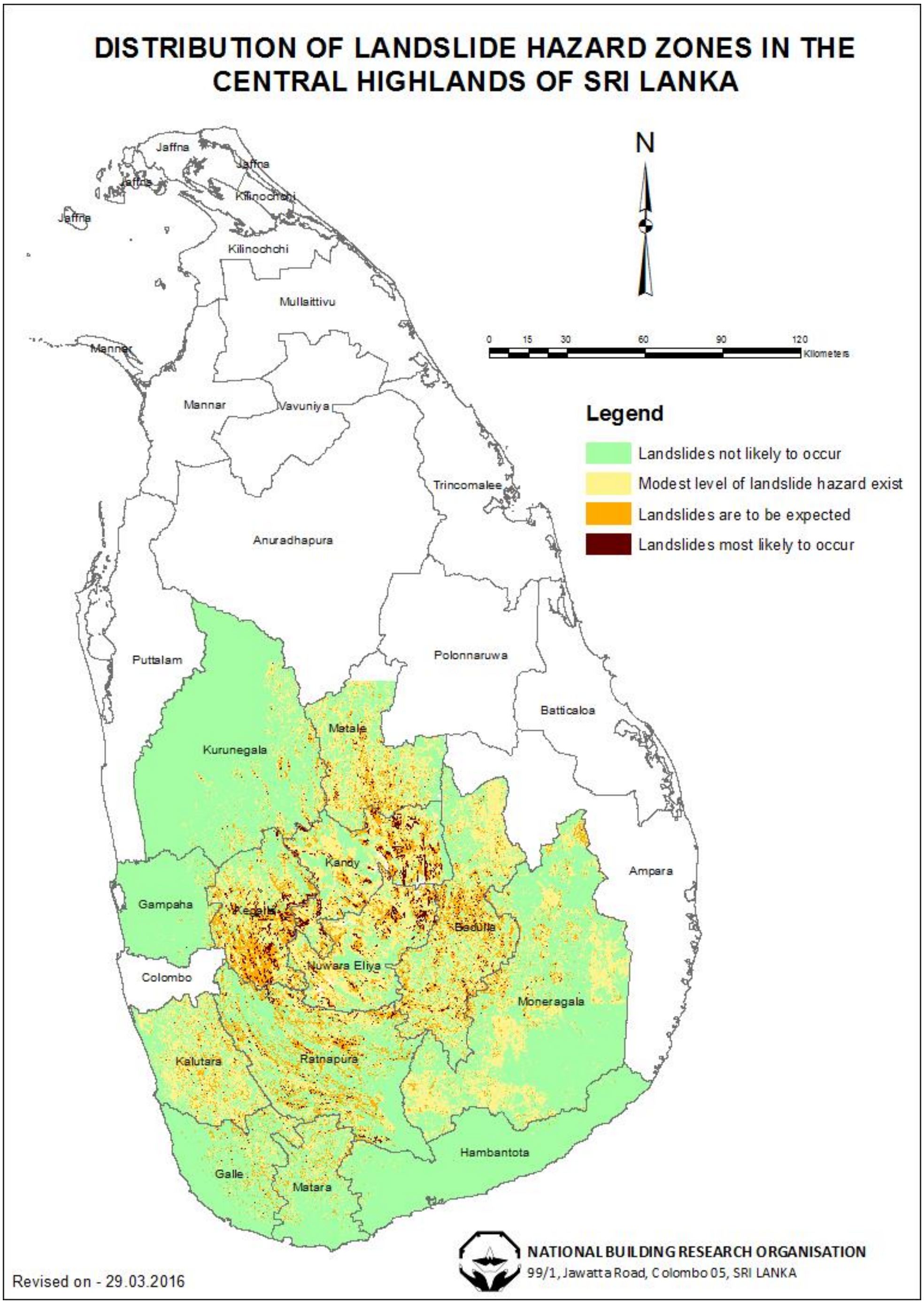


Figure 22 Landslide hazard zonation map of Sri Lanka (1:50000 scale) (Source: www.nbro.gov.lk)

CHAPTER 6 CLIMATE SMART DISASTER RISK REDUCTION INTERVENTIONS IN AGRICULTURE SECTOR IN THAILAND, NEPAL AND SRI LANKA

6.1. Overview

Since ancient times, human civilizations have prospered on the floodplains of large rivers, taking advantage of the benefits of floods, which are much more than just a hazard. This remains true to the present day: Bangkok in Thailand along the Chao Praya river, Colombo in Sri Lanka on the bank of the Kelani river and Kathmandu in Nepal on the banks of the Bagmati river.

Housing is often located in flood prone areas, together with economic activities. These zones often represent a major source of income, livelihood and housing for thousands of communities, while floods play a key role in these processes (WMO and GWP, 2006).

A changing climate is expected to lead to changes in the frequency, intensity, spatial extent, duration and timing of weather and climate extremes especially in rainfall and temperature regimes of respective countries.

Due to climate change these impacts are more severe and are seen as additional and hard stresses on countries currently facing the problems of already losing sustainability. Meanwhile, the three countries under review are especially vulnerable to climate related disasters as they have a comparatively higher degree of exposure to such hazards in aforesaid sections of this report.

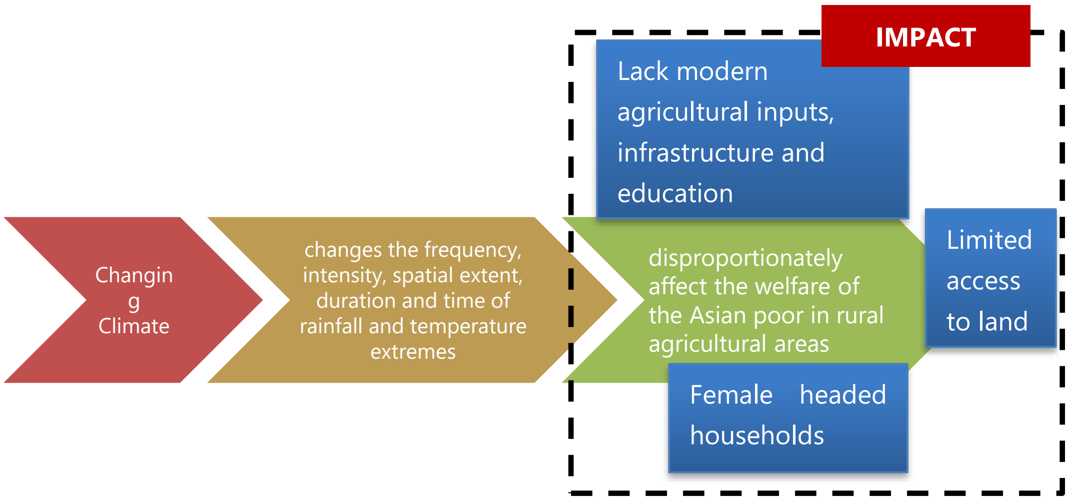


Figure 23 Sustainable Development: Linking economy, society, and environment (Source: van den Berg 2018)

As a counter action for threats posed by climate change on global food security, and sustainable development, the Food and Agriculture Organization (FAO) of the UN came up with a concept of Climate Smart Agriculture (CSA) that integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges and is as such composed of three main pillars or goals.

Food security and increased sustainable agricultural production

- Sustainably increasing agricultural productivity to support equitable increases in incomes, food security and development

Adapting and building resilience to climate change from the farm to national levels

- Adaptation to climate change

Reducing and/or removing greenhouse gases emissions (GHG), where possible

- Climate change mitigation

Until early 1900s, the main flood mitigation practice was construction of levees only followed by reservoir constructions in large river basins. The concept of Non-Structural Measures (NSMs) was first used in the context of flood control in late 1970s as a means to reduce the ever-increasing damage by floods, without unduly expanding the costly infrastructure. In that sense, NSMs were perceived more as complementary additions to the essentially structural solutions to flood hazard in order to reduce costs and enhance efficiency.

Figure 24 Levee – Structural measures for flood management (Source: https://www.anacostiaws.org)

This concept has further evolved during last few decades in the agriculture sector with the introduction of new approaches in line with the CSA approaches which can be implemented hand-in-hand with conventional and novel structural approaches in flood management to improve the effectiveness of the interventions.

Figure 25 Pumpkin farming in Bangladesh helps some of the most vulnerable people to cope with floods & climate change and so escape poverty (Source: https://practicalaction.org)

The following section discusses such potential interventions that can be implemented in Thailand, Nepal and Sri Lanka depending on physical settings and river basins of respective countries.

6.2. Flood Plain Management Plans

1. This is a good starting point to reduce the risk from floods on agriculture in the river basins.

2. Preparing a floodplain management plan enables strategic decisions about where, what and how to develop the floodplain for agricultural activities while reducing the flood risk (for example, land at high elevations within the

floodplain landscape to be exclusively reserved for agricultural use in the master plan).

3. Local authorities can play a vital role by referring only to the overarching floodplain management plan without letting local communities or government and private sector agencies violate the conditions laid out in the master plan (lands reserved for agriculture will not be allowed for settlements or industries by any means). This kind of zoning will not only protect the agricultural land from flood risks, but other development initiatives in the plain as well, including community dwellings and properties. Leaving lands which will not be subject to inundation for agriculture also facilitates the building of critical facilities such as emergency hospitals and flood-free evacuation areas when there are no other practical alternatives during a flood.

Figure 26 Floodplain management plan to reduce risk for new development areas (Source: https://www.chiefscientist.qld.gov.au)

6.3. Flood Modification Measures

Flood modification measures aim to change the behaviour of floods by reducing flood levels, velocities or flows, or by excluding floodwaters from areas under threat up to their designed capacity. They are a common and proven structural means of reducing damage to existing agricultural areas and other properties downstream under threat from flooding. They tend to be more expensive than NSMs, but will often essentially protect vast areas of agricultural lands and their associated properties, sometimes including entire value chains of agricultural produce downstream.	
1	**One such measure is flood mitigation dams** that can reduce downstream flow velocity and flood levels by temporarily storing and later, releasing, floodwaters. Most of these dams can be used for supplying water to the community or irrigation for agricultural lands during dry spells and hydropower generation. However, they are successful only up to their design capacity, beyond which, occasionally, it might be more hazardous due to structural failures, especially under conditions where a proper reservoir operation plan is not in place. Under these circumstances, it is more advisable to construct several detention basins of small size which can collectively arrest a large volume of runoff water in the catchment at a given time. This minimizes the downstream flood risk while water collected in the basin will act as a recharge structure for ground water, maintaining a good base flow of streams in the catchment during dry seasons
2	**Levees** are generally raised embankments built to eliminate inundation on either side of river banks. During larger floods, levees can be overtopped with water flooding into lowlands, basically meant for rice-based cropping systems, inundating areas protected in smaller events. Levees trap local storm-water without entering the waterway. Thus, unless flood gates and pumps are provided, they may cause additional risks of inundation of lowland agricultural lands. On the other hand, levees, whether temporary or permanent, can increase flood levels in the upstream, causing inundation in unprotected lowlands, even with a minor flood.

3	**Waterway modifications** such as widening, deepening, re-aligning or desilting rivers and flow paths can enhance the velocity of floodwaters downstream and reduce the likelihood of blockage resulting in inundation of lowland or adjacent agricultural land uses. However, increased velocities can lead to river bank erosion and other adverse environmental impacts. It should also be noted that the benefits of desilting and clearing are only a temporary measure unless there is regular maintenance which can be easily entrusted to Farmers' Self Help Groups or other civil society organizations in these areas.
4	**Other structures** such as roads, railways and embankments, also have a positive impact on flood risk management in flood plain agricultural lands because they can alter flood flows and behaviour, if properly designed for the purpose. Floodgates can also be used to prevent backflow from river systems into primary and secondary drainage systems, subsequently, inundating lowlands in the back swamp where usually, agriculturally-related land uses exists.
5	Sometimes **emergency dikes or levees** are built following a flood forecast. Although they may be effective for the emergency situation, they should not be considered as permanent flood protection measures. Dykes, levees and walls that possess enough protection against all floods cannot feasibly be built in an emergency situation and the consequences of their overtopping and failure during a future major flood may be catastrophic. However, the removal of emergency measures often does not occur because of cost and lack of interest by the community after the hazard is over. Hence, priority should be given to dismantle such temporary structures on the floodplain immediately after the danger period is over, based on available weather forecast information
6	It should also be borne in mind that unless accompanied by appropriate non-structural measures, the structural measures could lead to a false sense of security and encourage floodplain agricultural land owners to use their lands inappropriately which will aggravate their flood risk. For this reason, some form of agricultural land use regulation should be imposed in the floodplain lands to reduce the flood damage to agriculture. For the completeness and comprehensiveness of the above discussion, it should be noted that structural works require a periodic and systematic inspection, rehabilitation and maintenance programme to ensure that design capabilities are maintained. For example, levees may be subject to weakening due to erosion during a past flood event, by the actions of burrowing animals or the construction of utility lines through the levee. Of

particular importance is an inspection programme and responsibilities assigned for rehabilitation and maintenance. Structures, such as dams, should be subject to a dam safety programme, usually at the national level, to ensure that the specialized expertise required is available for the inspection of all structures. Dam safety programmes are carried out in many countries and standards or guidelines are readily available (UN, 2002).

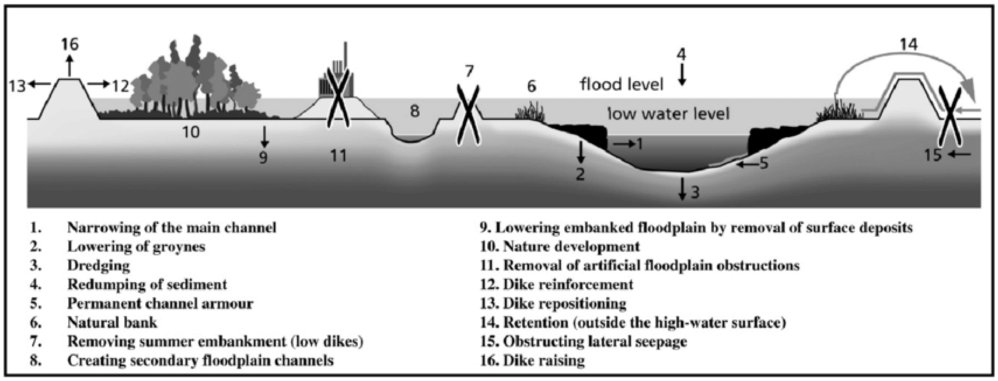


Figure 27 Floodplain Modification Plan (Source: Hudson et al., 2008)

Figure 28 Flood Mitigation Dam to reduce downstream water velocity (Source: https://www.bestnetfax.com/wp-content/uploads/2018/10/flood-control-wikipedia-how-do-floods-form.jpg)

6.4. Land Treatment Measure

Sl. No.	Measures
1	Modify floods by increasing infiltration and decreasing the amount and rate of runoff.
2	Well drained soil can absorb huge quantities of rainwater, preventing it from running into rivers.
3	These measures may also be viewed as modifying susceptibility to flood damage. They include vegetative cover, runoff interceptors and diversions, small detention and erosion control structures, terraces and crop management practices (which also serve to modify susceptibility to flood damage). Wetland drainage in upper river basins is also such a measure. Wetland pockets in upper river basins are already saturated and thus, they do not possess any great potential for the storage of water in flood risk events. Drainage networks act to lower the water table, hence, increasing soil moisture deficit and increasing the water storage in heavy rainfall events, lowering the downstream flood risk. In order to avoid any environmental degradation by lowering the water table, this kind of intervention should be carried out with the utmost care along with a continuous, monitoring programme.
4	These land treatment measures are generally effective in small headwater areas and function in combination with other measures to ameliorate flood conditions in larger watersheds. In most respects, land treatment measures produce changes in the broad range of flooding effects, although they become less effective as flood size increases. They can be especially important in reducing erosion and the resulting amount of sediment and pollutants carried downstream (Grant 2015, UN, 2002).

6.5. Integrated Water Resources Management Plan

This is an alternative to the dominant sector-by-sector, top-down management style of the old, conventional flood management approach. The IWRM concept aims at: a) integrating management of water resources at the basin or watershed scale, integrating both supply-side and demand-side approaches; b) taking an inter-sectoral approach to decision-making; c) improving and integrating policy, regulatory and institutional frameworks; d) promoting equitable access to water resources through participatory and transparent governance. While ensuring water security for multiple users, including agricultural users, of a river basin, this approach also leads to the mitigation of reducing flood risk downstream in the long run (UN, 2002).

6.6. Agronomic Measures

Seed Sowing and Seedling Transplanting
In lowland monsoon belts, establish rice seedlings as early as possible or if broadcasting is practiced sow seeds as early as possible. If the location is highly prone for flood –follow seedling transplantation. These seedling nurseries should be established in a location that do not vulnerable for flooding.
Select varieties with high seedling vigour to avoid damage during floods. If floods are most recurrent threat in lowland rice cultivations during monsoon periods it is always advisable to look for recommended long-age varieties and plant relative older seedlings with a good root system as cluster so that reduced tillering can be offset while withstanding the threat of flood with the required plant density for a good yield.
Application of additional fertilizer dose to the seedling nursery is recommended to improve the seedling vigour.
Flood-prone lowlands of the floodplains are generally rich in N, P, K, S, Ca, Mg, Fe, Mn, Zn and B to some extent through regular deposition silts. The only potentially deficient plant nutrient could be Nitrogen but adopting the usual recommendation for the region might lead to over fertilization with a chain of associated impacts and a waste of costly resources. Thus, soil test base or Leaf Colour Chart based (LCC) N fertilizer application for rice cultivation should be practised.
Lowlands in flood plains are always subject to invasion by floating weeds, resulting in heavy yield losses in rice cultivation
In order to arrest the floating weeds in floods, a protective fence (trash collector) can be erected around the rice fields which are subject to frequent flooding

Figure 29 Invasive floating weeds in paddy fields after floods (Source: http://hp.brs.nihon-u.ac.jp)

Drainage Management
In most cases during the monsoon in Asia, the threat of flood to agriculture is aggravated due to mismanagement and negligence of natural drainage ways, leading to flash floods and prolonged inundation in riverine floods.
Priority should be given to desilting both irrigation and drainage ways before the start of the season with collective voluntary participation through Farmers' Self Help Groups (SHOs) / Farmers' Organizations (FOs).
These institutional arrangements should introduce a penalty system for those who do not undertake the voluntary work to maintain the irrigation and drainage network of the floodplain

6.7. Water Management Measures

Adoption of Sorjan System
One of the other alternatives available for lowlands which are subject to frequent minor floods or prolonged inundation, is the 'raising land' concept, widely known as the Sorjan system. (developed by Indonesian farmers) which constructs an alternate of deep sinks and raised beds. Its features can adapt to both dry and wet seasons in most of the Asian countries where flood or inundation is a recurrent threat in floodplains.
In the flood-prone or swampy areas, the sink impounds more water and can tame the flow. Meanwhile, the raised beds and bunds constructed in making the sink, allow farmers to plant highland crops such as vegetables and cash crops.
The sink with the impounded water can be used for rice and fish production. The water stored in the sink can later be used for irrigation in the dry season. With Sorjan, the production can support the family's daily food requirements and expenses thus, saving the income from later rice production as capital for other, income generating endeavours (Pasiona, 2016).

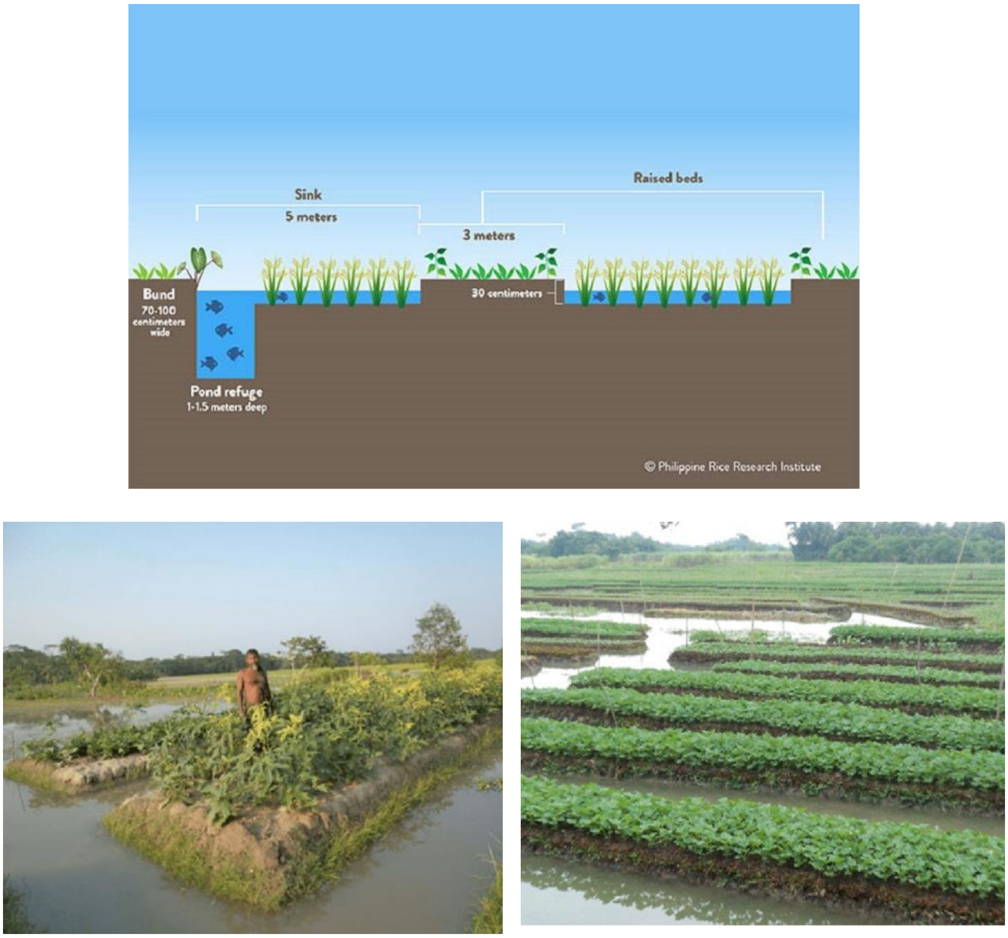


Figure 30 a) Schematic diagram of Sorjan system in flood prone areas (Source: Philippines Rice Research Institute); b) & c) Food Security and Risk Reduction in Bangladesh (Source: Climate Change and Food Security in Vulnerable Coastal Zones of Bangladesh,2015)

Use of flood tolerant rice varieties
During flooding, the rice plant elongates its leaves and stems to escape submergence. Deepwater rice varieties are able to do this rapidly enough to survive. High-yielding, modern varieties cannot elongate enough. If floods last for a couple of days, the rice varieties are unable to recover.
Plant breeders at the International Rice Research Institute, Philippines, have discovered that a single gene, the SUB1 gene, confers resistance to submergence of up to 14 days (IRRI, 2018). Improved varieties incorporated with the SUB1 gene have shown a yield advantage of 1–3 tons following flooding for 10–15 days.
Flood-tolerant varieties which have been released and are now being planted include Swarna Sub1 in India, Samba Mahsuri in Bangladesh and IR64-Sub1 in the Philippines. These three varieties can be introduced to flood-prone, rice-based cropping systems in Thailand, Nepal and Sri Lanka to improve their productivity under a changing and variable climate.

Figure 31 Flood tolerant rice varieties which can withstand submergence for 14 days (Source: https://www.ncbi.nlm.nih.gov)

Use of deep-water Rice Varieties
Rice production in Asia is being carried out in different rice eco-systems, namely: irrigated lowland, irrigated upland, rainfed lowland, rainfed upland and deep water or floating ecosystems.
Rice is the only cereal which can withstand water submergence and has the ability to survive in water depths of more than 50 cm for at least one month (Catling, 1992). 'Deepwater' areas are those with a depth of flooding of more than 1 m during the peak of the monsoon season and 'intermediate deep water' areas are lands with a flooding depth from 30 to 100 cm (Yamuna and Ashwini, 2016).
Rice is the only cereal crop plant adapted to aquatic environments because of its well-developed *aerenchyma* tissues which facilitate oxygen diffusion through continuous air spaces from shoot to root. It avoids anoxia development in the roots and has the capacity for rapid elongation when the plants become partially covered by floodwaters.
Almost all the deep water cultivars are strongly photoperiod sensitive. Photosensitivity fixes flowering time at a favourable point in the flooding period, enabling the plant to escape the adverse effects of low temperature in the reproductive phase which usually ensures crop maturity as soon as floods have receded. However, yields of deep water rice are comparatively low whereas yields of modern rice cultivars average about 6 t/ha; the average yield of deep water rice is only 2 t/ha (Catling, 1992). Nevertheless, it still plays a vital role in stabilizing household food security in heavily and frequently flood-prone floodplains where other forms of livelihoods are beyond possibility in Thailand, Nepal and Sri Lanka.

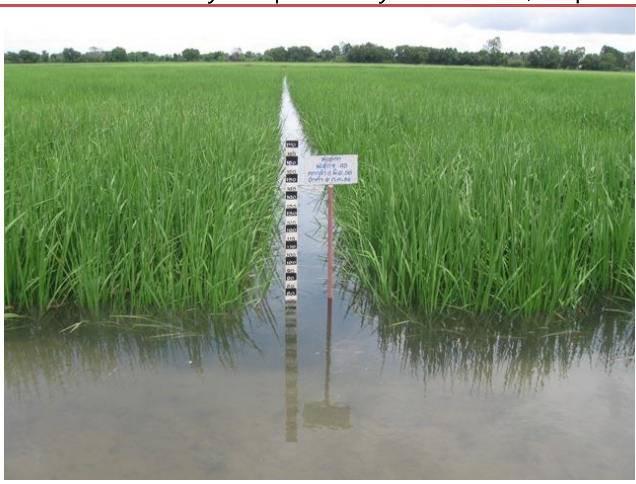


Figure 32 Deep water rice variety, RD45, stays alive in deep water for 2 to 3 months and comes out with its aroma still intact.

6.8. Landuse Planning and Watershed Management

Changes in the land use type, from natural forest to an urban landscape in a river basin, leads to increase in surface runoff.

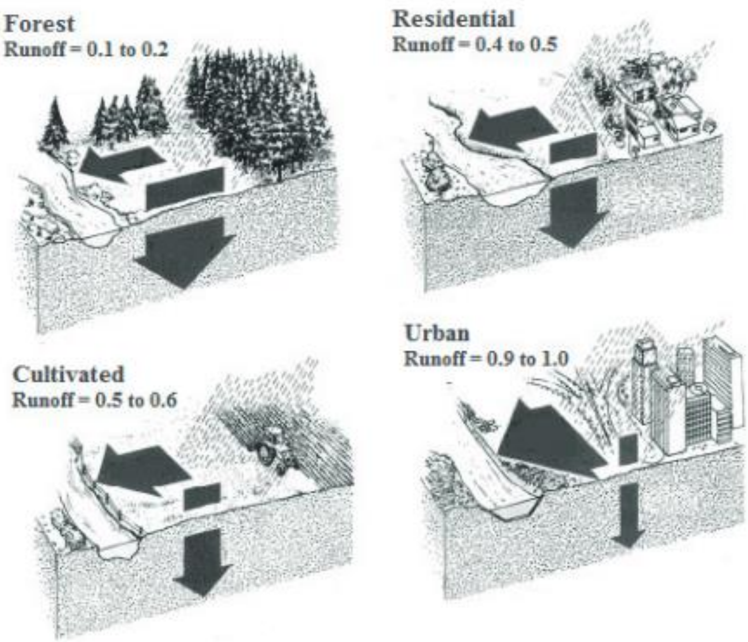


Figure 33 Modification of runoff depending on landuse pattern (FAO, 2016)

Hydrological responses to rainfall depend strongly on local characteristics of the soil, such as water storage capacity and infiltration rates. The type and density of vegetation cover and land use characteristics have an impact on the responsiveness of an area to a given rainfall event.

Figure 34 Soil and Water management as part of Watershed Management (Source: https://www.crs.org)

The water storage effect on vegetation, soil, shallow groundwater, wetlands and drainage has a direct impact on the flood level in downstream areas. Each of these storage media retain certain quantities of water for various periods of time and can influence the timing of tributary flows and hence, their contribution to a flood event. Saturated conditions, or conditions leading to quick saturation during a rainfall event, inhibit the infiltration of rainwater. The consequences are more abrupt and dangerous for high intensity rainfall over small, steep basins.

Upstream of such flood-prone river basins should be afforested, or have a similar land use, by means of scientific land use planning and watershed management approaches. These include reforestation, agro-forestry, adoption of soil and water conservation measures of relevance, lock and spill drains, stone bunds, Sloping Agriculture Land Technology – SALT, minimizing soil compaction through minimum tillage concepts and reducing the use of heavy machines. Other measures include contour planting, the structure stability of soil through organic manuring, cover cropping, mulching and switching from annual crop farming to perennial crops such as horticulture crops, filling gaps between tree plantations and plantation crops as quickly as possible, uprooting and timber felling of commercial plantations only during long, dry periods and conversion of abandoned croplands to grasslands for intensive livestock management. It should be borne in mind that of all the aforesaid interventions, afforestation and reforestation deserve special consideration in any given watershed as more moisture transpires to the atmosphere at a greater rate than replacement crops or grasses. This reduces the antecedent moisture of soil, enabling the absorption of more infiltrated rain water with consequently less runoff.

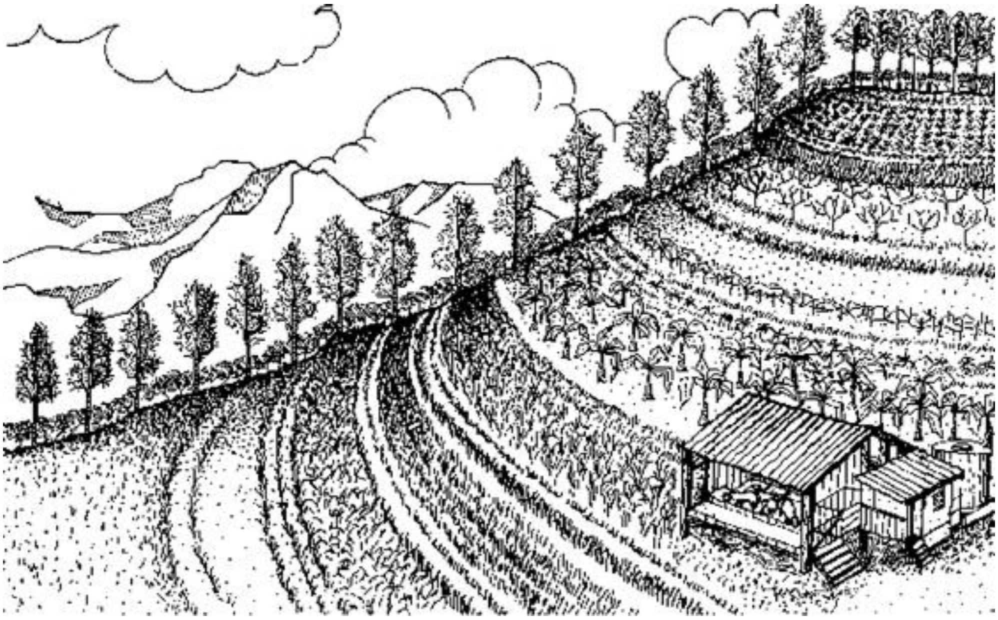


Figure 35 Sloping Agriculture Land Technology (Source: Osman, 2012)

The suitable practices for a particular watershed depend on its terrain, climate, vegetation and social environment. Hence, a methodical and holistic approach should be chosen through a participatory approach of all relevant stakeholders. In addition, legal enforcement of acts and ordnances of relevance to environmental conservation should be in place uniformly across the entire basin. Legal provisions on land, forest, river and streams, coastal eco-systems, waste disposal and wetland conservation, or their overarching policies, should be given high priority.

6.9. Planning for Potential Sea Level Rise and Storm Surge

Sea level rise due to climate change will result in decreased river slopes in reaches above the point where the river enters the ocean, thereby reducing the capacity of the waterways to pass flood flows. This increases the elevation of floods in coastal cities and villages..

While the rate of sea level rise is slow, most protective works, or floodplain delineation exercises, are sufficiently long-term in scope to warrant consideration of the predicted rise, giving ample time for mitigation measures.

Meanwhile, coastal farming communities must also be ready to deal with the implications of potential sea level rise on their present, coastal, arable lands for increased flood incidences and salinity intrusions.

Worldwide, river deltas are exposed to a rise in sea level and subsidence as a result of reduced sediment supply, ground water pumping and the extraction of minerals. This tends to be immediately linked to an increased risk of flooding. However, the influence of water levels in deltas as a result of river discharge, tidal movement and the average sea level is not a straightforward equation but the result of a complex interaction of mutually influencing physical processes.

Figure 36 Resilience by means of removing sea water defense in Bangladesh to counter sea level rise (Source: Cornwall, 2018)

Kuttanad below Sea-level Farming System (KBSFS) is practiced in a complex mosaic of fragmented agricultural landscape in the delta region of Kerala comprising of wetlands, waterways and elevated areas. These three landscape elements have been used and managed judiciously supported by ingenious practices of local communities to cultivate rice below sea level and enhance the complex ecosystem services for rice, fish-shell-clam production. FAO has recognized the Kuttanad Heritage Agriculture (KHA) as a Globally Important Agricultural Heritage System and such systems can be customised to ensure livelihood security of farmers in the coastal areas likely to be affected by sea level rise.

Figure 37 Kuttanad Paddy Framing below sea – level in Kerala, India (Source: https://i.pinimg.com)

6.10. Use of Climate Information System and Strengthening Flood Early Warning

Climatological forecasting, or seasonal forecasting, has now advanced to the point of being a useful tool in reducing the risk of flooding. Climatological forecasting, or weather forecasting, can be integrated into hydrological models to enhance the existing Flood Early Warning/ Monitoring System for better preparedness of the emergency response by relevant agencies. The existing flood early warning system can be strengthened to provide early warnings in the short-term/medium-term/ extended medium-term. This will enable the following:

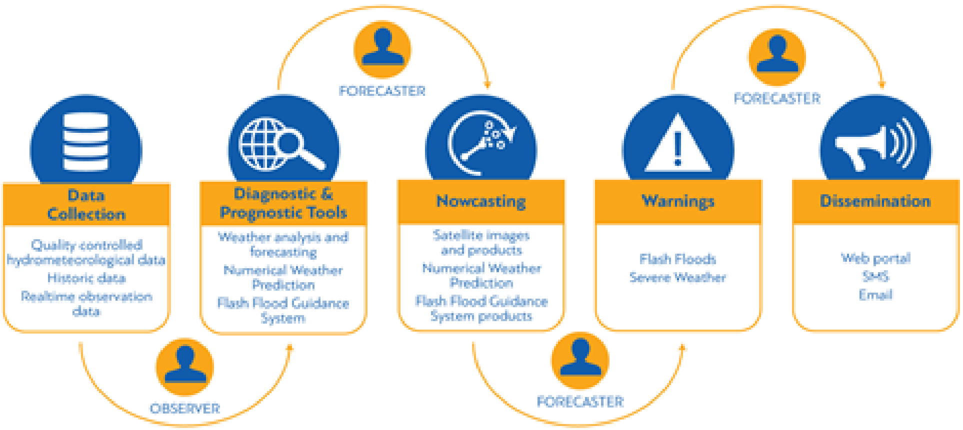


Figure 38 Schematic of an end to end early warning system including dissemination mechanism for flood hazard (Source: https://public.wmo.int/en/projects/Afghanistan-EWS)

Dissemination of weather forecast information to farmers by setting up of a dense network of telemetric enabled hydro meteorological instruments.

Figure 39 Automatic Weather Station and Automatic Rain Gauge network are one of the primary requirement for a robust Early Warning System for the agriculture sector (Source: Department of agriculture, Government of Bihar, India and ADPC)

Access to forecast generated by Numerical Weather Prediction to increase the degree of readiness of emergency response of relevant agencies

Regulate reservoir operation leading to minimize degree of flood damage in downstream agricultural lands and also aware downstream farmers of potential floods with sufficient lead time

Understanding which agricultural practices work best and making sure those practices are adopted by communities – farmers, decision and policy makers.

Support in critical farm decision making such as changing the entire cropping plan, changing planting dates, transplanting instead of direct sowing, on-farm water management, nutrient or other agro-chemical application, evacuation of stored materials to safer locations, move livestock and stored fodder and foods to safer places. All of these measures can reduce the impact of flooding, if it occurs.

Stockpiling of sandbags, emergency food and water supplies can be undertaken when the probability of the extreme flooding event is greater than normal. In some cases emergency measures such as temporary raising of flood protection works may also be carried out.

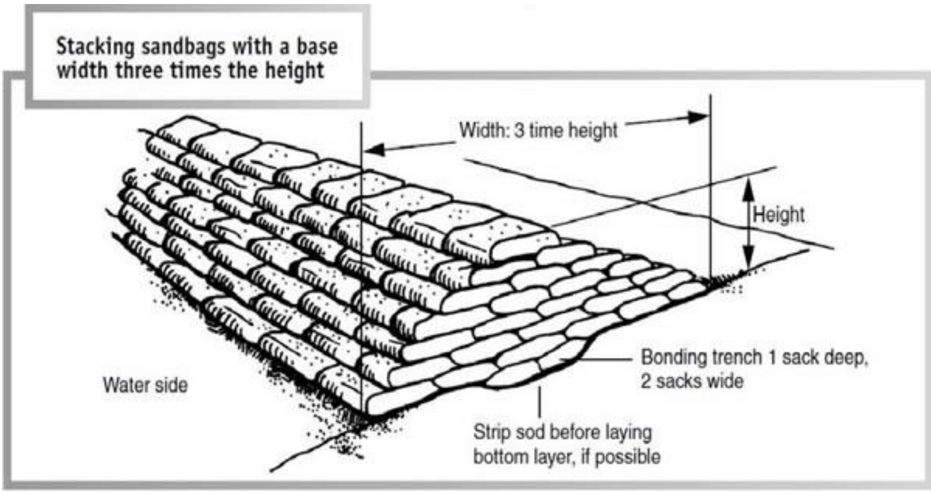


Figure 40 Sandbagging as emergency flood protection measure based on information from flood early warning (Source: https://articles.extension.org/pages/26483/sandbagging-for-flood-protection)

CHAPTER 7 AGRICULTURE INSURANCE AS A RISK TRANSFER MECHANISM FOR FLOOD HAZARD IN AGRICULTURE AND INSTITUTIONAL AND GOVERNANCE FOR DISASTER MANAGEMENT

7.1. Agriculture Insurance as a Risk Transfer mechanism for Flood Hazard in Agriculture

Problem	Agriculture sector is greatly exposed to natural hazards, especially floods, leading to significant crop damage and even, the complete loss of crops
Traditional solutions	'Informal' modalities such as sale of assets, borrowing from relatives and food crop sharing and so forth (FAO, 2011c) where the risk is not fully absorbed or transferred in a comprehensive manner.
Sustainable solution	Insurance can provide beneficial protection to vulnerable farming communities in these three countries suffering from floods and other natural hazards. Agricultural insurance schemes are currently available, either in a pilot form or a fully mature, national level programme, in only 20 out of the 44 countries in the Asian region, except China.
Issues in Insurance	No countries have fully comprehensive coverage for loss and damage to agriculture due to flood hazards owing to the non-availability of accurate estimations covering the extent of the damaged land caused by each flood event.
Limitations	Thailand and Nepal cover only the food crop sector through their agricultural insurance programme while Sri Lanka covers crops, livestock and plantation sectors. Corporate insurance sector is not willing to extend their product to the agriculture sector owing to inherently high risks associated with agricultural endeavours. State programmes in crop insurance in developing countries cannot survive without government subsidies (Skees et al., 1999).

Figure 41 Paying compensation to situations like this is challenging (Source: Centre for Strategic and International Studies)

In light of the increased occurrence of intense flood events under changing and variable climate regimes, research and the use of remote sensing technology are urgently needed to assess the losses and damage in the agriculture sector more accurately. This would provide guidelines and recommendations to policy-makers to promote sound and effective insurance programmes, with the emphasis on hydro-meteorological hazards, such as floods.

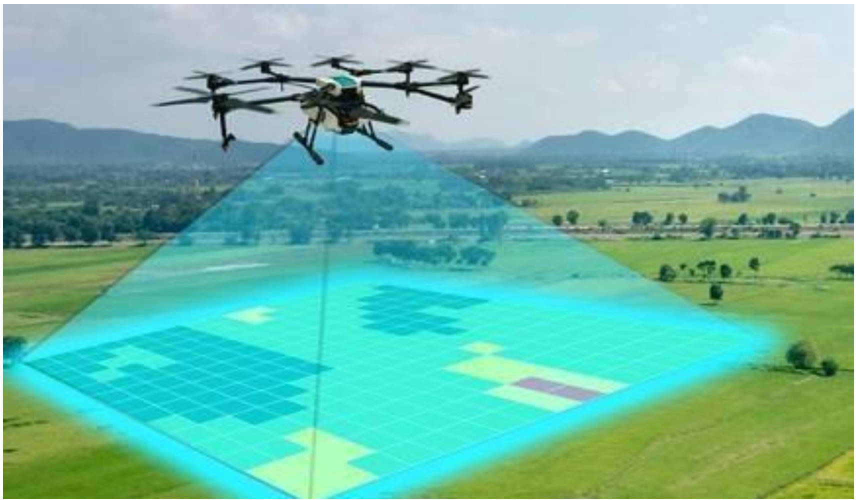


Figure 42 Drone base rapid PDNA as a reliable solution for compensation payment (Source: https://www.usna.edu)

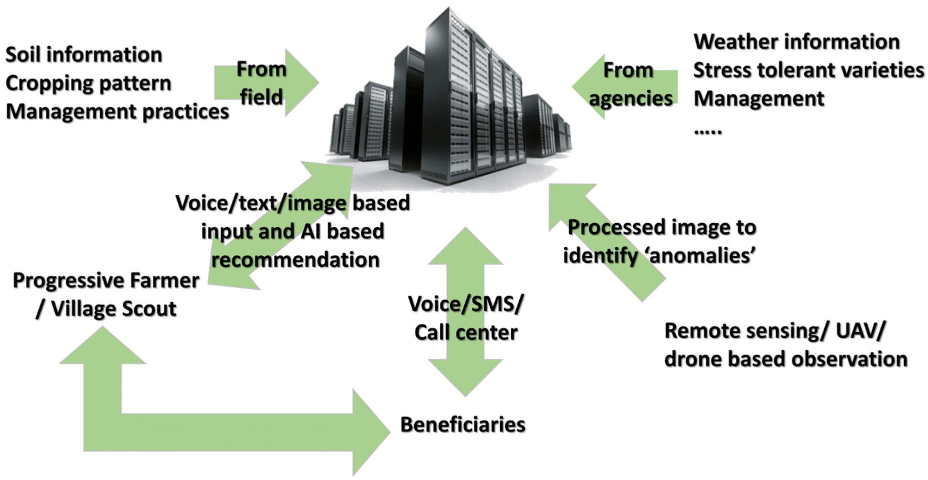


Figure 43 A Web-based Decision Support System with SMS-based Technology for Agricultural Information and Weather Forecasting (Source: Gangopadhyay et al., 2019)

In this aspect, climate information systems can play a vital role by computing weather-based indices to determine the premiums and compensations. It will create a conducive environment for the corporate sector to enter the market through agricultural insurance products, especially for hydro-meteorological hazards.

7.2. Institutional and Governance for Disaster Management

Role of the Government

Design road maps for implementation of disaster prevention and mitigation in agriculture sector collaboration with government and non-governmental organizations in line with other countries of the region.

Major phases of disaster management

Country, Region and Global level actions need to be taken to facilitate activities on disaster prevention, mitigation, preparedness measures especially in agriculture based economies and early response for populations vulnerable to disasters followed by facilitation of overall coordination of post-disaster activities such as relief, rehabilitation and reconstruction.

There is a greater need to establish a cohesive approach within each country and networking within the region and at global level to streamline decision on disaster management decisions as described below

Planning

- Planning and Implementation of disaster preparedness activities and creation of a culture of safety among communities

Early Warning

- Issuing and dissemination of Early Warning messages and developing linkages through regional cooperation schemes

Capacity Development

- Capacity development of key stakeholders involved in disaster early response teams and early relief activities at national and sub national levels.

Awareness

- Conduct disaster management awareness and training programs for pre determined target groups to facilitate coordination among key partners involved in disaster management.

Independent Agency

- Establish an independent agency or build on the strengths of existing agencies as supportive resources for quick delivery in case of extreme events.
- Within this diverse model, it is imperative that one agency be given the overall lead, and that agency be held accountable for the overall process.

Summary	
Objectives	• Reduce losses due to disaster • Sustainable agriculture • Food security • Environment protection
Challenge	• Non-availability of ideal model/ structure, as circumstances are quite different amongst countries, regions and situation for adoption • Develop country / event specific agenda and common agreements • Develop clear role for each player • Establish Inter institutional agencies for coordination • Assign leadership roles to responsible agencies • Training of local government leaders for disaster risk reduction actions
Parties	• Government agencies • Policy makers at local and central level • Land use planners • disaster management agencies • health authorities • Power and water • Meteorological office • Essential utility suppliers • Input suppliers

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