Rapid Scan:
Colombo City Region Food Systems
and their vulnerability towards climate change related shocks

A report for the FAO-RUAF CRFS Programme

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Executive Summary

Climate change and related hazards have become central in the discussion on food systems and their vulnerability towards them. For the case of Colombo, there are reported impacts on food systems due to hazards, such as floods, droughts, extreme air temperatures, sea level rise, and extreme rainfall patterns. These superimpose themselves on existing trends of unsustainable practices and on soils that are already deficient of organic matter.

From a food system perspective, there are limited studies with an in-depth analysis of the effects of climate change related hazards.

Colombo, in this report described as the Colombo Municipal Council and its directly neighboring Divisional Secretariats, and its food system, which consists of large parts of the rural areas of the country, based the major commodities necessary for a balanced diet, has been assessed towards most likely scenarios of climate change related shocks and its vulnerability towards them.

While the food system was found to be consisted with earlier reports, this study concluded that a new evaluation of the Colombo Urban area will be necessary to reassess its boundaries. Taking the Western Megapolis development program steered by the Ministry of Megapolis and Western Region Development and the already merged urban areas of the overall Western Province, marks an essential development to for the food system as nearly half of the Sri Lankan Population (9 Mio) is projected to live in this area.

The vulnerability study revealed that among the stakeholder groups, food production, storage and processing, wholesale and distribution, and marketing and retail, each will need to adapt to various of the described hazards, as especially some areas of the food production are supposed to suffer from multiple threats.

It was further found that still there is no consistent data set on certain regions, the impact of im- and export, as well as food waste management on the vulnerability of the CRFS.

An in-depth study will need to investigate the findings of this reports, identify key stakeholders along the value chain and engage them in a policy dialogue to rationalize adaptation mechanisms and increase the resilience of the CRFS.

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Introduction

Today, 55 percent of the world population lives in urban areas (UNDESA, 2018). For Sri Lanka this percentage is much lower, estimated at around 18 percent according to the last census in 2012, ranking at the 11th lowest urban population density worldwide (UNDESA, 2018). However, the actual number of residents in urban areas in Sri Lanka is estimated to be much higher according to several reports, with estimates ranging from 35 up to 50 percent (UN-Habitat, 2018). This so called 'urban paradox' is most evident in Colombo itself. Colombo's official population according to the last census in 2012 was 561,314, however the conurbation that is happening around Colombo, creates a certain Megapolis (Western Region Megapolis, WRM) with almost six million residents, covering most of the Western Province (UN-Habitat, 2018). Thus, it is important to define what is seen as urban population to avoid an urban paradox.

Because more urban growth is expected, sustainable urban planning is needed, and therefore the 'data gap' on urban population (now between 18 - 50 percent) needs to be closed. Additionally, a clear definition of 'urban' is necessary to understand urban systems and work on a policy dialogue on sustainable urban food systems (UN-Habitat, 2018).

The role of city region food systems (CRFS) within the development of sustainable urban systems is essential. However, the complexity of food systems, being both linked to rural and urban systems, needs more attention. Rural-urban synergies are described in the FAO report on the Urban Food Agenda (2019), where the two key principles within the rural-urban synergy section are 1) recognizing the diversity of socio-geographical contexts and 2) understanding the role of food systems in breaking the rural-urban divide. The response to a change or shock can be very different for urban settings, therefore it is very crucial to acknowledge this diversity for policy-making. To ensure food security and nutrition, assessing the links between rural and urban systems is necessary for integrated and sustainable rural-urban development.

Food systems and food security within cities, experience pressure as a consequence of climate change (FAO, 2008). Especially large cities in development, cities near water bodies and cities with a complex food supply system. An UN ESCAP study, identified Sri Lanka to be one of the hotspots of food insecurity in the Asia-Pacific region (ESCAP, 2009). The relevant climate change related shocks for Sri Lanka are multiple and they all directly or indirectly affects Colombo's CRFS. The adverse effects these hazards can have may be felt within all phases of the food system, whether it be the production, food transport or processing, marketing or during the consumption of phase. The main climate related shocks identified for Sri Lanka are floods, droughts, extreme rainfall events, extreme temperatures and sea-level rise.

In this report the CRFS of Colombo will be described and the mentioned relevant climate shocks, will be elaborated on and explored, including future climate scenarios and the vulnerabilities to the CRFS caused by these shocks.

1 Colombo City and Megapolis

1.1 The City Region Food System (CRFS) Approach

In general, the City-Region is understood as a given geographical region that includes one or more urban centres and their surrounding peri-urban and rural hinterland across which flows of people, food, goods, resources and ecosystem services occur. A CRFS encompasses all food system actors and activities taking place in the city region and over which the local/regional government have planning and intervention powers. It is understood that any city region will always be fed by multiple food sources, be it local, regional, national or international, so that the city region food system does not exist in isolation from a global food system (FAO, 2018).

1.2 Colombo's evolution to become Western Region Megapolis

Sri Lanka's urban paradox is apparent in the capital Colombo. While its official population at the last census in 2012 was 561,314, conurbation was not taken into account (UN-Habitat, 2018).

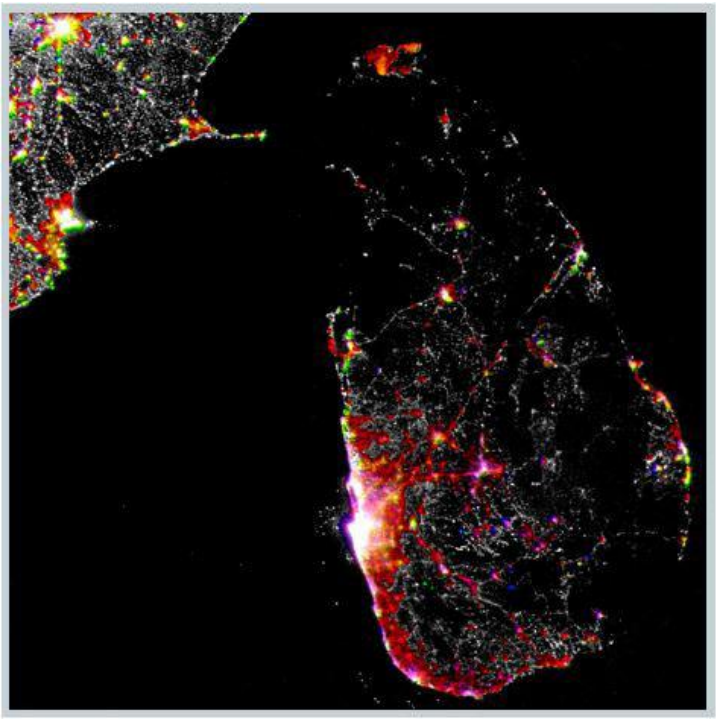


Figure 1: Sri Lanka Night-time light Image of Sri Lanka, Worldbank

The city and its neighbouring urban areas are growing fast as a result of significant infrastructure and construction investments and changes in macroeconomic policies, causing a merge of these areas. In 2012, the population of the Western Provincial Council area was around 5.8 million (approximately 30 percent of the population in Sri Lanka) living in six percent of the total land area. A trend that is expected to increase even further as a result of the Western Megapolis development program (UN-Habitat, 2018). Due to this rapid development, Colombo , earlier defined as the two Divisional Secretariats Colombo and Thimbirigasyaya, can no longer be described as independent from its direct urban surroundings. As an important part of the in-depth stakeholder assessment, it will be analysed, if the actual Urbanized area is already the so-called Western region of Megapolis (WRMP, 2016). However, in this report it is acknowledged that its direct neighbouring Divisional Secretariats Sri Jayewardenepura Kotte (Kotte) to the east and Dehiwala-Mount Lavinia to the south are part of the urban structure of the city and can be regarded as suburbs of Colombo City.

1.3 Colombo City

The Colombo City is the commercial, transport, industrial, and financial hub of the country and is the epicentre of the Sri Lankan economy. The area covered is 67 km^2. While its overall population density is only 11.200 P/km^2, it varies between highly populated areas of over approx. 17,000 P/km^2 in the city centre of Colombo and 6300 P/km^2 in Kotte. The trend of urbanisation is expected to increase the overall population of 758,200, however this will likely happen by means of merging with surrounding urban areas in the Western Province, which already inhabits 5,8 Mio. people and is expected to grow to approx. 9 Mio. citizens, representing nearly half of the country's population (UN-Habitat, 2018).

In comparison with other parts of Sri Lanka, Colombo contains nearly all important parts of the country's economic infrastructure. Colombo Harbour is the largest port in Sri Lanka and a significant feature of the city. Being among the top 30 container ports globally, it handles 31.4 million tonnes of cargo annually (Worldshippingcouncil.org). The city's manufacturing industries are based on the processing of raw materials exported through the port.

Furthermore, Colombo is the national public transport infrastructure (Trains and busses). Four rail corridors run from the main Railway station "Colombo Fort" to the other cities of the country passing through a number of urban, semi- urban and rural areas.

The Colombo city centre is the commercial hub of the island; the head offices of local and foreign banks, stock exchange market, government corporations, Ministries and the Supreme court are located here. The on-going Colombo Port City and Megapolis projects[10] will further enhance the position of Colombo as the commercial hub of Sri Lanka. The Sri Lankan government has taken the initiative to transform Colombo Port City into an international financial centre, aiming to create thousands of job opportunities for professionals and attract foreign capital. As Kotte is part of Colombo, it is also the political centre of the country with the parliament, and ministries being housed within its proximity. Recent construction activities will increase Kotte's importance in Colombo as several Ministries moved out of the City Centre.

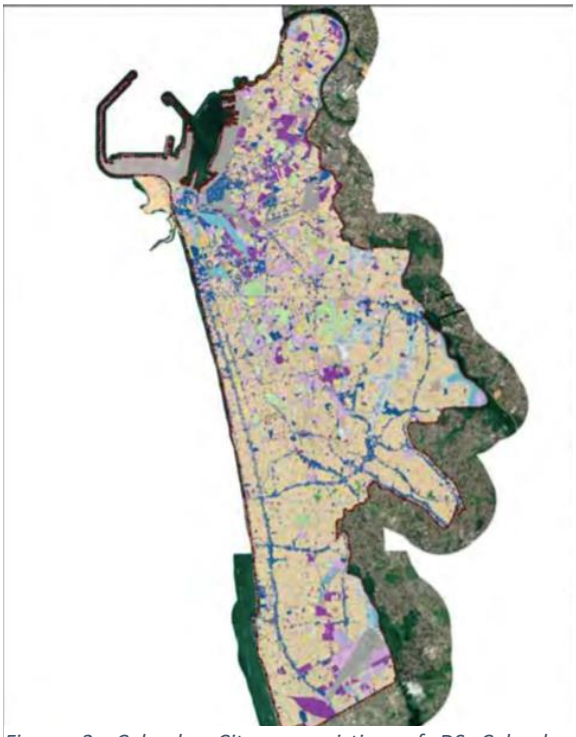


Figure 2: Colombo City, consisting of DS Colombo, Thimbirigasaya, Dehiwala-Mount Lavinia, and Sri Jyawarderapura-Kotte.

1.4 Demographic factors of the Colombo that impact in the City Region

Urban citizens can be a very diverse group, having a strong influence on the food-systems with regard to different consumption patterns, food security and nutrition.
Colombo as well as its Divisions while being differently populated show gender parity (table 1).

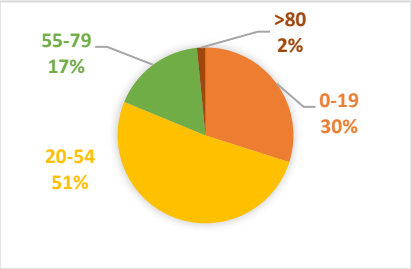
Table 1: Overall Population per Divisional Secretariat and percentages of female and male citizens, DCS, 2012

Divisions (DS)	***Population***	***male/female***
Colombo	323,257	50/50
Sri Jayawardanapura Kotte	107,925	58/52
Thimbirigasyaya	238,057	50/50
Dehiwala	88,962	49/51
Colombo City	**758,201**	**50/50**

Age is known to have larger influence on dietaries than gender, as toddlers and elderly have special requirements. Table 2 displays that 50% of the population living in the Colombo City are in the working age between 20-54. This will also be one of the main reasons why 18% of overall expenditures on food are on prepared meals (HIES 2016).

Table 2: Age groups in Colombo and its Divisions, DCS, 2012

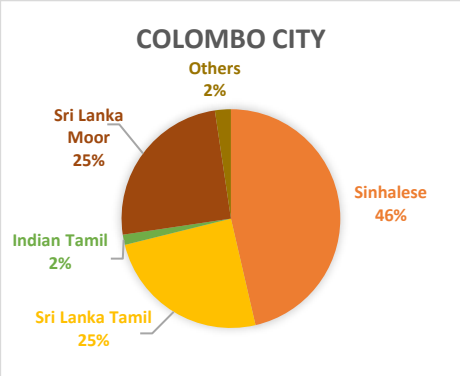
Division (DS)	***Age groups***			
	0-19	*20-54*	*55-79*	*>80*
Colombo	34%	50%	14%	1%
Sri Jayawardanapura Kotte	25%	52%	20%	2%
Thimbirigasyaya	27%	53%	18%	2%
Dehiwala	27%	50%	20%	2%
Colombo City	30%	51%	17%	2%



Apart from Age ethnic diversity has a great influence on food consumption patterns, because these are greatly influenced by traditions and practices. Those impact types of food consumed, preparations, quantities of different food types and seasonal consumption habits. Sri Lanka, the Western Province and therefore its foodsheds are very diverse.
However, this diversity cannot be observed in all Districts equally. While Sri Lanka's overall population consist of 75% Sinhalese, 115 Sri Lankan Tamils, 9% Sri Lankan Moors, and 4% Indian Tamils, distribution of these groups in Colombo City largely differ from these averages (table 3).

Table 3: Ethnic groups for each Divisional Secretariat and combined in the Colombo City, DCS, 2012

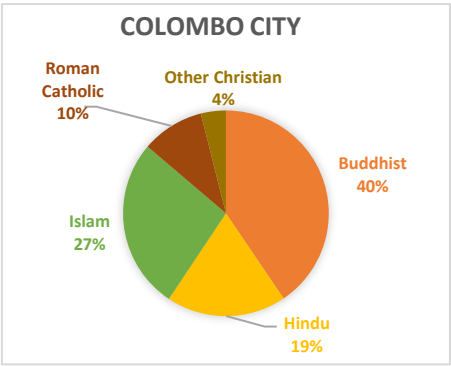
Divisions (DS)	*Ethnicity*				
	Sinhalese	Sri Lanka Tamil	Indian Tamil	Sri Lanka Moor	Others
Colombo	25%	31%	2%	40%	2%
Sri Jayawardanapura Kotte	85%	7%	1%	5%	2%
Thimbirigasyaya	53%	28%	1%	15%	3%
Dehiwala	60%	14%	1%	21%	3%
Colombo City	46%	25%	2%	25%	2%



Ethnic groups and religions are closely related. Most Sinhalese follow Buddhism, Tamils are Hindus, Moors are Muslims, while Christians consist of all ethnicities (table 4). Those especially influence the consumption and exclusion of certain meat and vegetarianism based on religious doctrines.

Table 4:Ethnic groups for each Divisional Secretariat and combined in the Colombo City, DCS, 2012

Divisions (DS)	*Religion*				
	Buddhist	Hindu	Islam	Roman Catholic	Other Christian
Colombo	19%	23%	42%	13%	3%
Sri Jayawardanapura Kotte	77%	5%	6%	7%	5%
Thimbirigasyaya	48%	23%	17%	8%	4%
Dehiwala	54%	12%	23%	7%	4%
Colombo City	40%	19%	27%	10%	4%



2 Climate Change and its impact on the Colombo CRFS

2.1 General climate description for Sri Lanka and Colombo City

Sri Lanka has four major different climate regions according to the Koppen–Geiger climate classification, showing tropical savannah (Aw) mainly in the north and south-east, tropical monsoon (Am) and tropical rainforest in the south-west and a temperate climate (Cfb) in the highlands (Kottek *et al.,* 2006), see figure 3. Sri Lanka experiences four rainfall periods during the year, the first inter-monsoon period in March and April, the south-west monsoon from May till September, the second inter-monsoon period in October and November and the north-east monsoon from December till February, this can be seen in figure 4 (Herath & Ratnayake, 2004; Jayatillake et al., 2005).

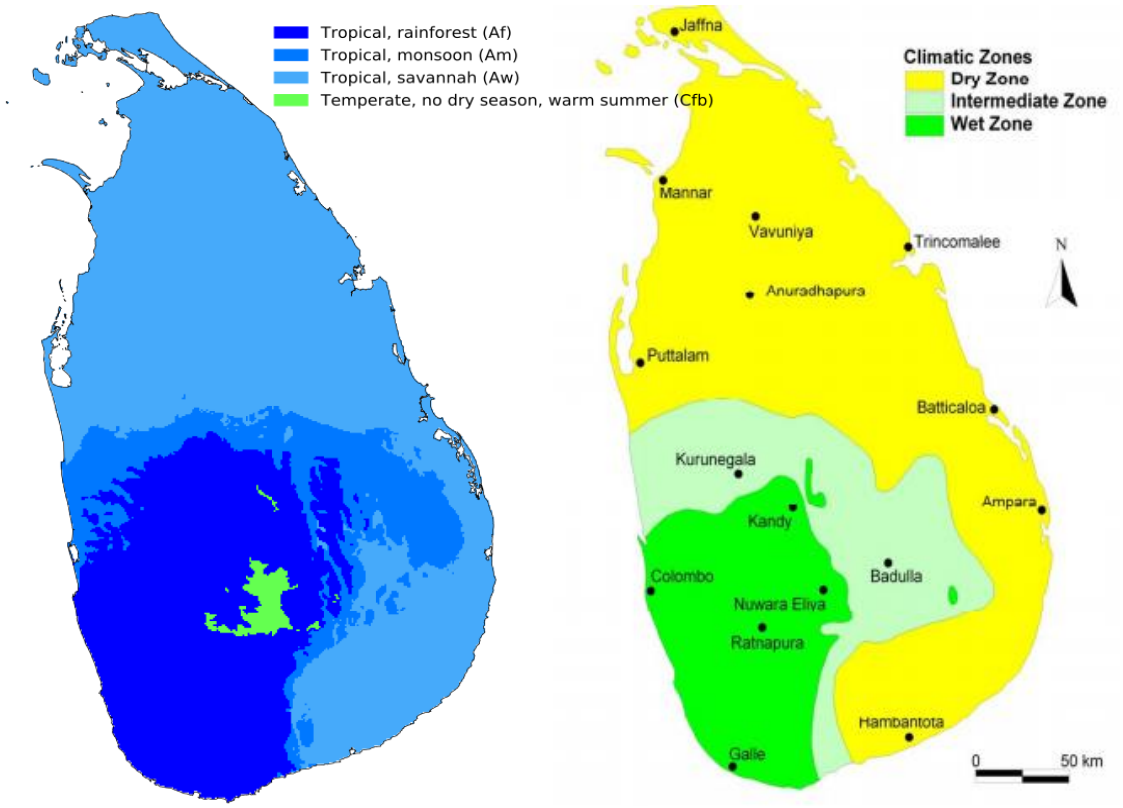


Figure 3: Four major climate regions of Sri Lanka according to the Koppen-Geiger climate classification (Kottek et al., 2006) and Sri Lanka divided in three different climatic zones; the dry zone, intermediate zone and wet zone (Esham & Garforth, 2013)

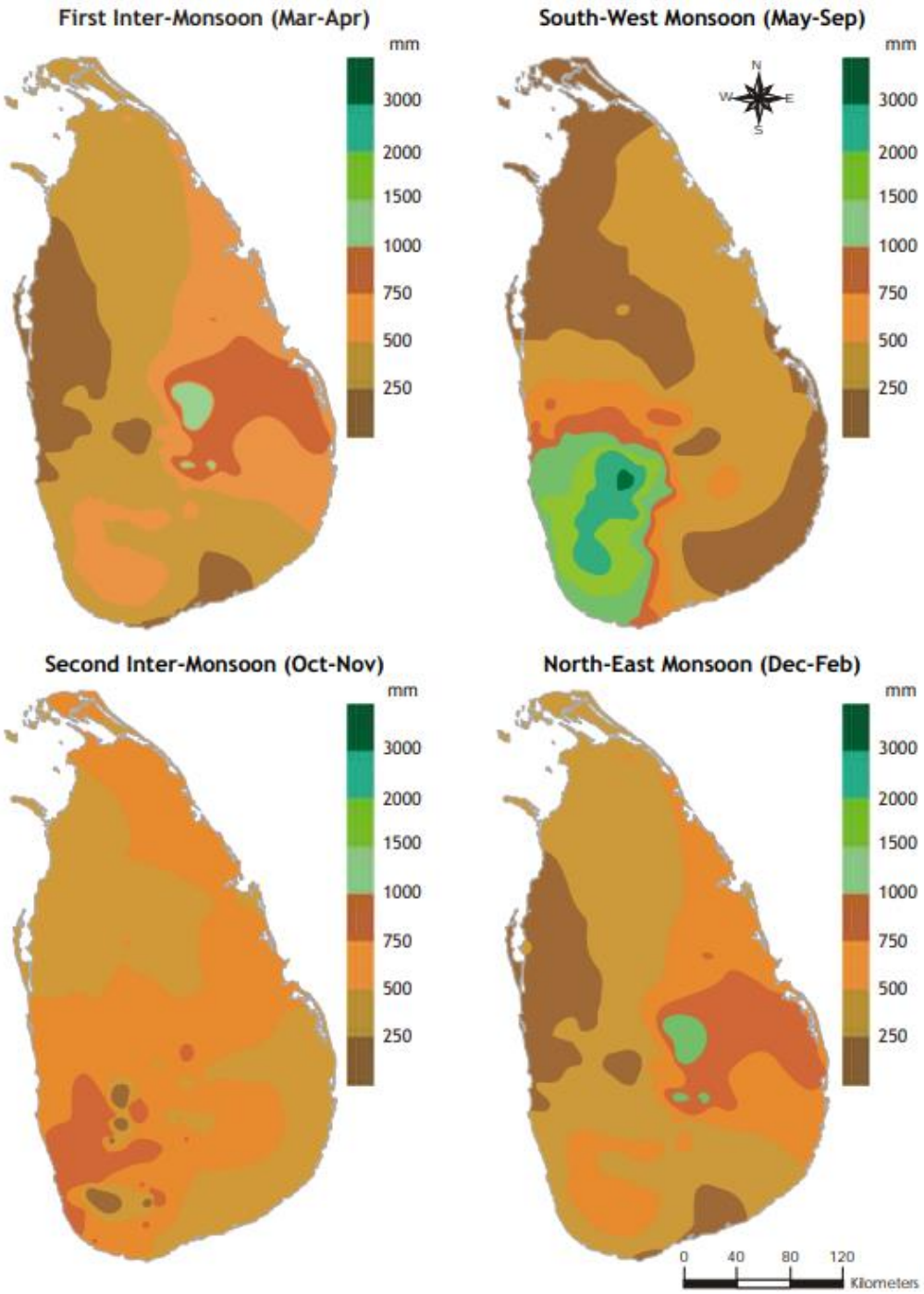


Figure 4: The different rainfall regimes for the four (inter)monsoon periods (Jayatillake et al., 2005).

More specifically, the Colombo Megapolis Region has a tropical rainforest climate (Af), with an average temperature of 27.0 °C and an annual average precipitation of 2348 mm. Precipitation and temperature regimes for Colombo are shown in figure 5. May and October are the wettest months of the year, while January and February show the lowest precipitation. The minimum temperature in the Colombo City is 24.1 °C and the maximum 30.7 °C.

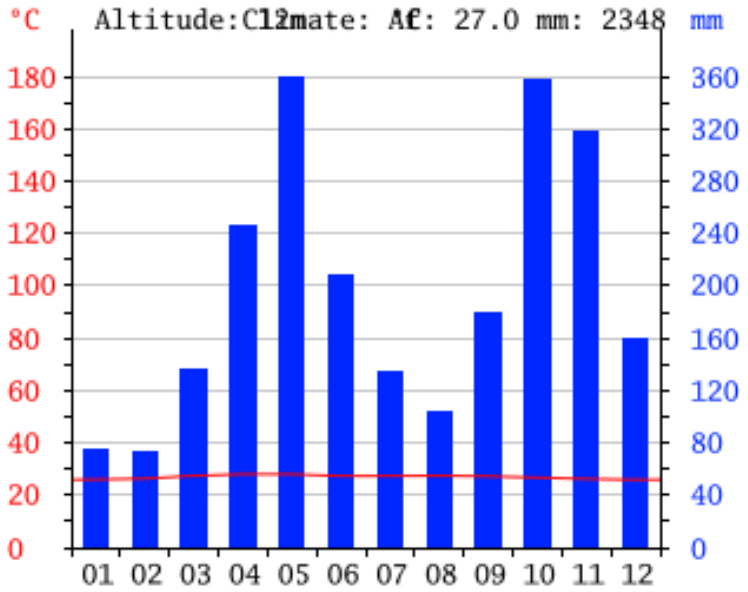


Figure 5: Monthly temperature (red) and precipitation (blue) for Colombo, using average data from 1982 – 2012 (climate-data.org).

Daily 24-hour weather data is observed by the Sri Lankan Department of Meteorology at 23 different climate stations throughout the country (Perera *et al.,* 2002). However, very few research is done with this data to predict changes in climate patterns. For example, temporal rainfall data can be a very good identifier to indicate changing tendencies in the climate. A recent trend in South Asia is a rise in rainfall intensity, but within less days, thus rainfall events will become more extreme (Senadeera et al., 2016).

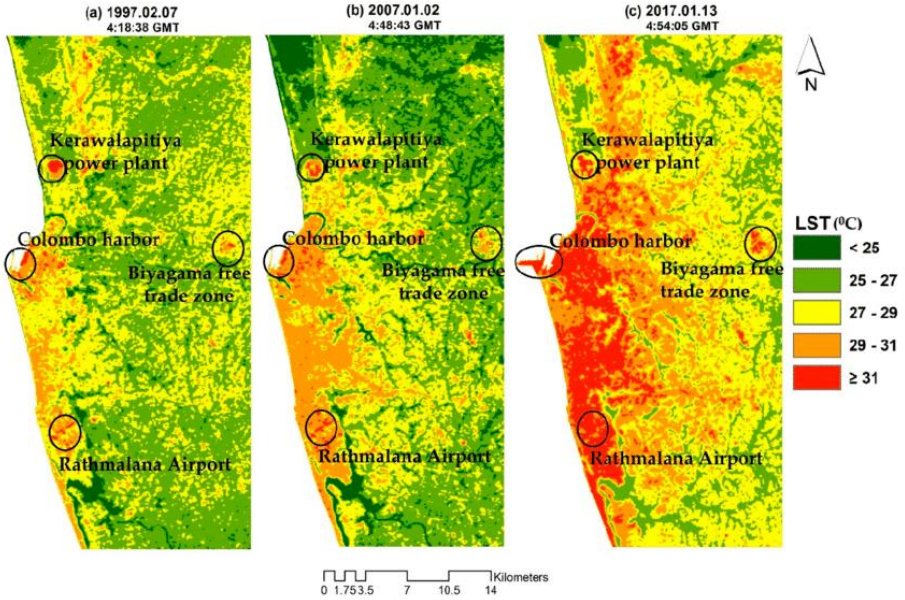


Figure 6: Land surface temperature (LST) maps of the Colombo Metropolis Region (Ranagalage et al., 2017).

Temperature in cities can be different from the area surrounding the city, as a result of higher emissions of industries and traffic, less vegetation and human and animal respiration. Most critical areas are at the harbor and around the main roads entering the city, creating so called 'urban heat islands'. It is recommended to keep those heat islands in mind for future urban spatial planning, because these areas can be a threat to the socioeconomic as well as the environmental systems in the area. More green spaces could recover the status of heat islands (Ranagalage *et al*., 2017).

2.2 Projected climate change scenarios for Sri Lanka

The increase of emission of greenhouses gasses has caused the warming of the atmosphere and the oceans. This has resulted in the melting of the ice caps, the rise of sea levels, the change in rainfall patterns, droughts and many more effects (IPCC, 2014). Global temperatures (land and ocean surface combined) have risen with 0.85 °C over a period from 1880 till 2012 and each decade has been successfully warmer than its previous decade (IPCC, 2014).

The effects of climate change are worldwide visible in both human and natural systems. Yet, natural systems seem to get the strongest negative impacts due to climate change, e.g. many terrestrial, freshwater and marine species had to change or shift their habitats, activities, migration patterns and interactions with other species (IPCC, 2014). Ecosystems are based on very complex interlinked relations; therefore, any change can disturb this equilibrium. However, impacts on human systems are also very evident, where for example crop yields are negatively affected by climate change (IPCC, 2014).

Future scenarios for climate change highly depend on climate policies and socio-economic development. Persistent increase of greenhouse gas (GHG) emissions will certainly intensify further global warming until a certain tipping point has reached and changing its effects becomes irreversible. Climate projections can go many directions, however IPCC's Representative Concentration Pathways (RCPs) are often used to identify different scenarios based on several driving indicators, like population increase, economic activity, energy use etc. The RCPs describe four major climate projection directions; with a rigid GHG mitigation plan RCP2.6 is calculated, where the aim is that global mean temperature increase is limited with 2 °C, RCP4.5 and RCP6.0 are two intermediate projections and RCP8.5 is the scenario with very high GHG emissions. So called 'baseline scenarios', meaning scenarios where no measures are taken to limit climate change, range between RCP6.0 and RCP8.5 (IPCC, 2014). The main outcomes of the RCPs are a change in average surface temperature and a change in average precipitation (see figure 8).

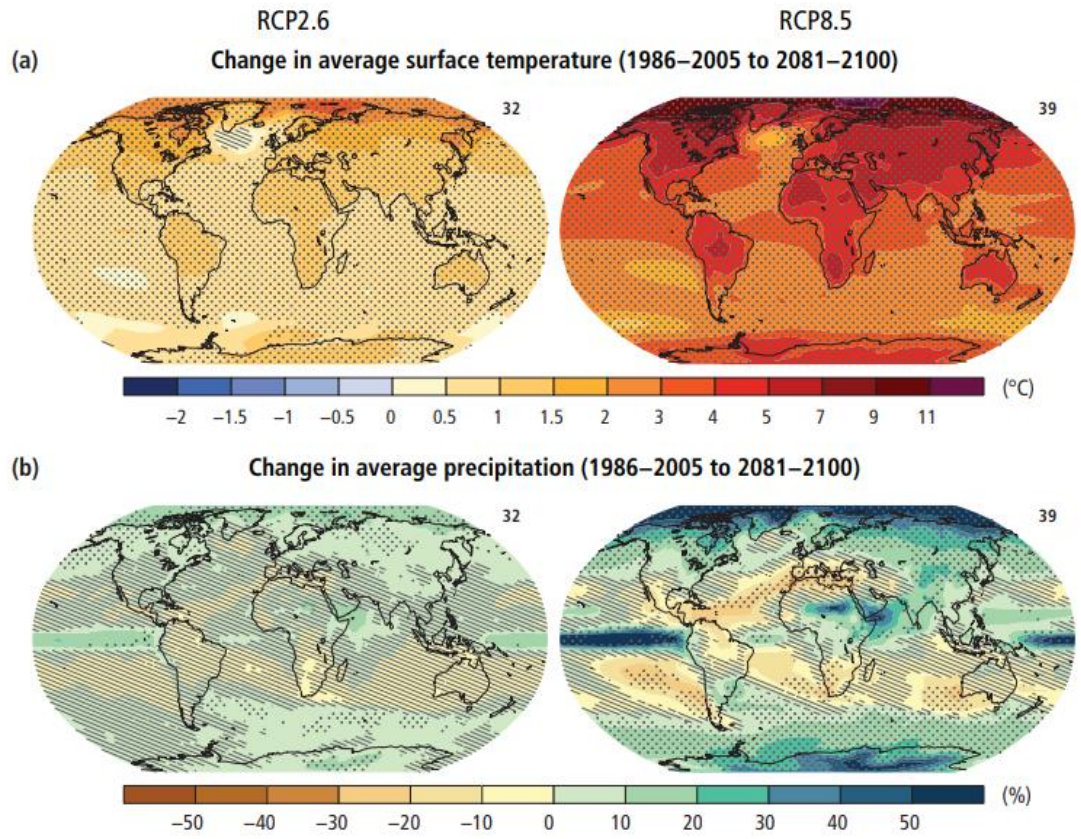


Figure 7: Change in average surface temperature (a) and change in average precipitation (b) for RCP2.6 representing the time period of 1986-2005 and RCP8.5 representing the time period of 2081-2100 (IPCC, 2014).

As can be seen for the RCP8.5 projections, Sri Lanka will have an average surface temperature increase of 2-4 °C and a precipitation change between 10-20 %, where more extreme precipitation events will likely become more intense and more frequent (IPCC, 2014).

More specific climate change projections for Sri Lanka are not profoundly provided by the IPCC, because their projections are given on a very coarse resolution that is not suitable for a small country like Sri Lanka, however the Ministry of Environment, which is the National Focal Point for the UNFCCC (United Nations Framework Convention on Climate Change), has taken the initiative to establish a Climate Change Secretariat that communicates more specific climate change projections and climate risks for Sri Lanka itself. Their Second National Communication on Climate Change was published in 2011 and the third Communication on Climate Change is in progress.

Even though a number of standard techniques are available to use the global IPCC models to make climate projections more specific and on a national level, Sri Lanka was not in the capacity to do so. Therefore, funds were obtained from the UNEP global project on Assessment of Impacts and Adaptation to Climate Change (AIACC) to undertake a detailed study to interpolate temperature and rainfall projections for Sri Lanka, using software developed by the International

Global Change Institute (IGCI) (Second National Communication on Climate Change, Sri Lankan Ministry of Environment (ME), 2011).

The outcomes regarding temperature increase are in line with the previous mentioned IPCC projections, however the outcomes for precipitation projections are more complex for the case of Sri Lanka, because it does not simply increase as is indicated by the IPCC projections. Precipitation is projected to increase in amount and intensity during the Southwest Monsoon (SWM) period (May-September), where in the present the average rainfall is up to 2500 mm within the SWM it could increase to 3500 mm by the year 2100 (see figure 9). During the Northwest Monsoon (NWM) the projection does not show a significant change in precipitation patterns according to this model.

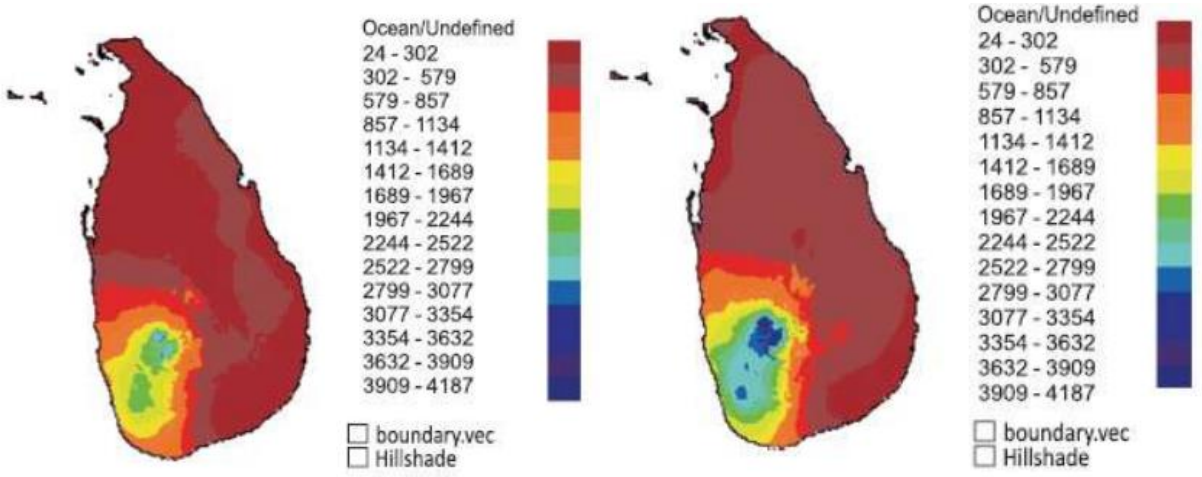


Figure 8: Baseline (1961-1990) average precipitation in the Southwest Monsoon months (left) and projected average precipitation for the year 2100 in the Southwest Monsoon months (ME, 2011).

However, several studies done by De Silva *et al.* (2009; 2013), were they made use of a regional model developed by the Hadley Center for Climate Prediction and Research, show slightly more extreme outcomes. The precipitation in the wet zone during the SWM had an outcome of an increase of 48% by 2050 compared to the rainfall received in the period 1961-1990. Additionally, during the NEM a decrease of rainfall is expected of 27-29%, this rainfall is mainly received in the drier northeast of Sri Lanka. So, this model outcome suggests that the wet zone will become wetter and the dry zone drier due to climate change (ME, 2011; De Silva *et al.,* 2009; 2013).

It should be noted that such scenario projections are highly complex and based on the use of a certain Global Circulation Model (CGM), most certainly using different parameters, and that the use of different models can have different outcomes.

The risks and impacts such shifts in temperature and precipitation entail, depend highly on adaptation and mitigation capacities of the specific natural or human system were these shifts take place. For natural systems, risks for animal and plant species are usually very high or even lead to extinction, since plant species especially cannot shift their habitat fast enough with the changing environment, as well many small mammals and freshwater organisms will not be able

to shift fast enough either (IPCC, 2014). In human systems, risks can be greater for vulnerable groups and communities in countries in development. The agricultural sector, amongst other sectors, is expected to be one of the highest affected by climate change. This was proved by a study carried out during the AIACC project, where the impact of climate change showed negative economic impact for several important crops (ME, 2011).

3.3 Climate hazards affecting Sri Lanka

Sri Lanka was ranked second on the Climate Risk Index fort the year 2017, after Puerto Rico and before Dominica (Eckstein, 2018). '*The Global Climate Risk Index analyses to what extent countries and regions have been affected by impacts of weather-related loss events*'. This index analyses the most reliable data sets on extreme weather events and related socio-economic data. In the next subchapter more climate hazards for Sri Lanka will be discussed.

Different climate change related shocks and stresses affect different regions of Sri Lanka, different commodities and in different stages of the commodity/food chain. This chapter will go deeper into the five main climate hazards described in IWMI's Climate Hazards Asia report (report nr. 170), that will affect Sri Lanka's food systems. Additionally, secondary data will be gathered about these shocks and stresses and risk scenarios for the most vulnerable areas will be highlighted.

Before describing the climate hazards affecting Sri Lanka, it is important to give definitions to terms used in the following paragraphs. A (climate-related) *hazard* is defined as a process or phenomenon that may cause loss of life, injury or health impacts, property damage, social and economic disruption or environmental degradation (UNISDR, 2017). The *vulnerability* to such a hazard can be described as the susceptibility of an individual, a community, asset or system towards a hazard (UNISDR, 2017). The *resilience* of a system, community or society is their ability to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard (UNISDR, 2017).

2.2.1 3.3.1 Floods

Floods have been a common occurrence in Sri Lanka, with predictions asserting that their frequency will only increase in the coming decades (USAID, 2018; Eriyagama et al., 2017). Alone over the last four years Sri Lanka was hit by two major floods, those of May 2016 and May 2017, wreaking havoc on the country and affecting a total of 493 000 and 880 000 people respectively (MDM, 2016 & 2017). The aftermath included the destruction of thousands of homes, the inundation of lowland cultivation land and landslides. The total estimated damage incurred by the 2017 flooding on the agriculture, livestock and fishery sector amounted to LKR 10,292.95 million, most of it affecting the tea plantations where a total of 3035 hectares were destroyed

(MDM, 2017). The most affected districts were Hambanthota, Galle, Kalutara, Matara and Rathnapura (MDM, 2017).

Figure 9: Floods in Colombo 2017 (CNN, 2017).

During 1974 – 2008, floods have taken place on 2300 occasions, in 13 districts, according to the second national communication on Climate Change (MDM 2016) An increase in vulnerability to the flooding hazard is tied to urban expansion, with peri-urban areas being the most vulnerable, due rapid sprawl development (Koresawa et al., 2018). Ratnapura and Nuwara Eliya are the two districts that are the most vulnerable to floods, based on the vulnerability index, put together in the 2010 IWMI report (Nr. 135) by Eriyagama et al.

Figure 10 display two maps depicting the districts of Sri Lanka colour-coded according to the Flood Exposure Index (left) and the Composite Vulnerability Index to floods (right). The flood exposure index is composed of a 0-100 scale and is a directly based on the frequency of past flood incidents from 1961-2004 color-coded according to its intensity. As can be seen, the majority of districts in Sri Lanka have an Exposure Index of over 80, indicating that a majority of the country is exposed to frequent flooding events.

The Composite Vulnerability Index to floods (right) is an index that consists of the flood exposure index, a sensitivity index and the adaptive capacity index. The sensitivity index is split into human sensitivity (rural population density) and livelihood sensitivity (composite index made up of the percentage of the population employed in agriculture, percentage of paddy area served by major irrigation schemes and agricultural diversity). The adaptive capacity index made up of socioeconomic asset ownership (percentage of the population passing the GCE Examination,

poverty headcount index, poverty gap ratio and share of agricultural GDP) and infrastructural asset ownership (road density, electricity coverage, number of landlines, number of cellular subscribers, and number of internet users, per 100 population).

No data was collected for the Northern region of the country due to it being a conflict zone at the time of the study (2010) and it being unavailable. In this map you can see that Ratnapura and Nuwara Eliya are the two most vulnerable districts (northern regions excluded), with 6 further districts being classed into the second highest vulnerability category.

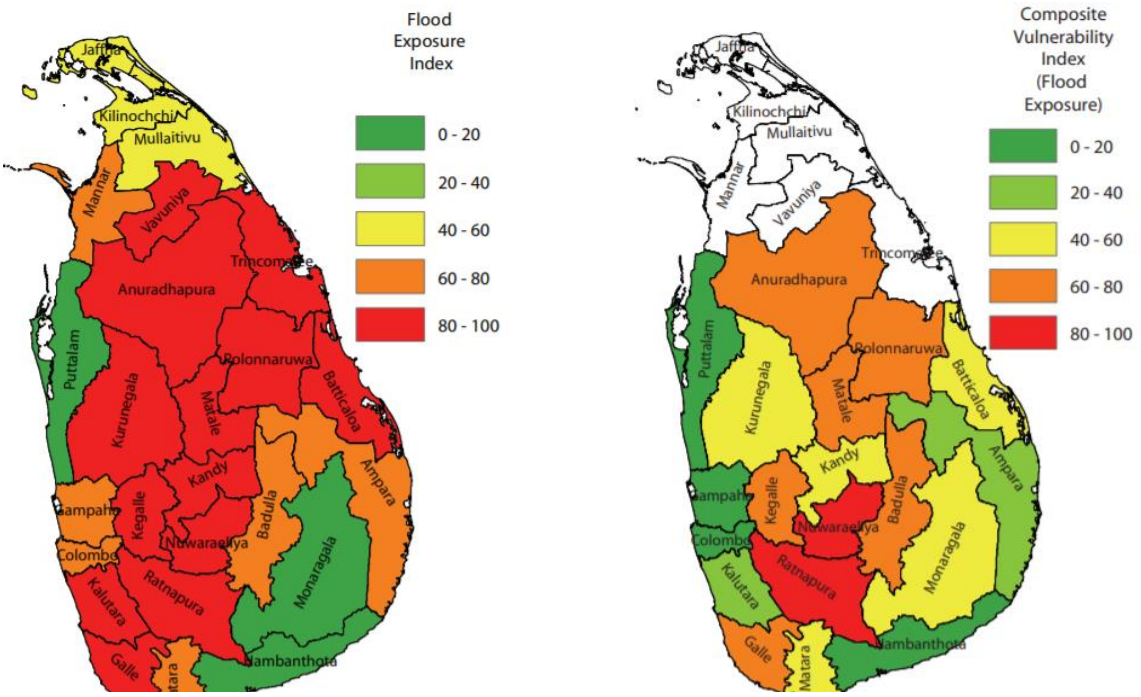


Figure 10: Flood exposure map, according to past frequency of flood occurrence (left) and a vulnerability map for flood exposure, compiled out of the exposure (frequency of climate extremes), sensitivity (rural population density, percentage of the population employed in agriculture, percentage of paddy area served by major irrigation schemes and agricultural diversity), and adaptive capacity (socioeconomic and infrastructural asset ownership) indices (right, no data in the north) (Eriyagama et al., 2010).

The outbreak of vector-borne diseases is a secondary effect tied to the occurrence of floods (Koresawa et al., 2018). With the occurrence of floods, infrastructures can be destructed and drainage systems might malfunction. Typically, ponds or other water residing areas are formed, which create the preferable conditions for the hosting parasites who lay their eggs in standing water. Although Sri Lanka has reached near elimination of one of the main global vector-borne diseases, malaria, dengue and leishmaniosis continues to be of presence (WHO, 2014).

2.2.2 3.3.2 Droughts

Droughts too, have an unfortunately high impact on the livelihoods of Sri Lankans, affecting the most people and incurring the highest economic damage, on average, out of any other natural disaster (Burchfield & Gilligan, 2016). The severe drought of 2014, affected the livelihoods of 1.5

million people (DMS, 2014). The impact of droughts on agricultural systems is particularly high with serious droughts occurring every three to four years and severe droughts every ten years in Sri Lanka and an increase in dry season droughts is expected (Burchfield & Gilligan, 2016; CCS, 2016). Over the 20-year time period between 1985 and 2004, 1400 droughts were recorded affecting over 8 million people and 280,000 ha of cropland, primarily in the dry zone of Sri Lanka (MOE, 2011).

Due to the prevalence of droughts and reduced water availability for rain-fed agriculture as a consequence of that, Nellemann et al. (2009; cited in De Zoysa & Inoue, 2014) predict agricultural productivity to decrease 0% - 15% by 2080. The dry zone is particularly vulnerable to droughts as the dependency on irrigation is much higher there. Unfortunately, the majority of the districts belonging to the dry zone are located in the northern conflict region and are not depicted in the Composite Vulnerability Index map in Figure 11 (right), but as

Of the remaining districts, Ratnapura, Pollanaruwa, Moneragala and Nuwara Eliya are the most vulnerable districts to droughts, based on the Composite Vulnerability index. However, judging by the Drought Exposure map (right), droughts will probably have a similar effect on the northern region as on the above mentioned districts, if not worse, as all northern districts are marked as being highly exposed.

Figure 11: Dry rice paddy fields in Jaffna in 2013 (Amantha Perera).

As the agricultural sector is one of Sri Lanka's main sector, the increased occurrence and severity of droughts will greatly compromise the domestic and export market as well as food security (USAID, 2018). Extended dry spells incur a large loss in productivity on the coconut industry in particular (Eriyagama et al. 2010).

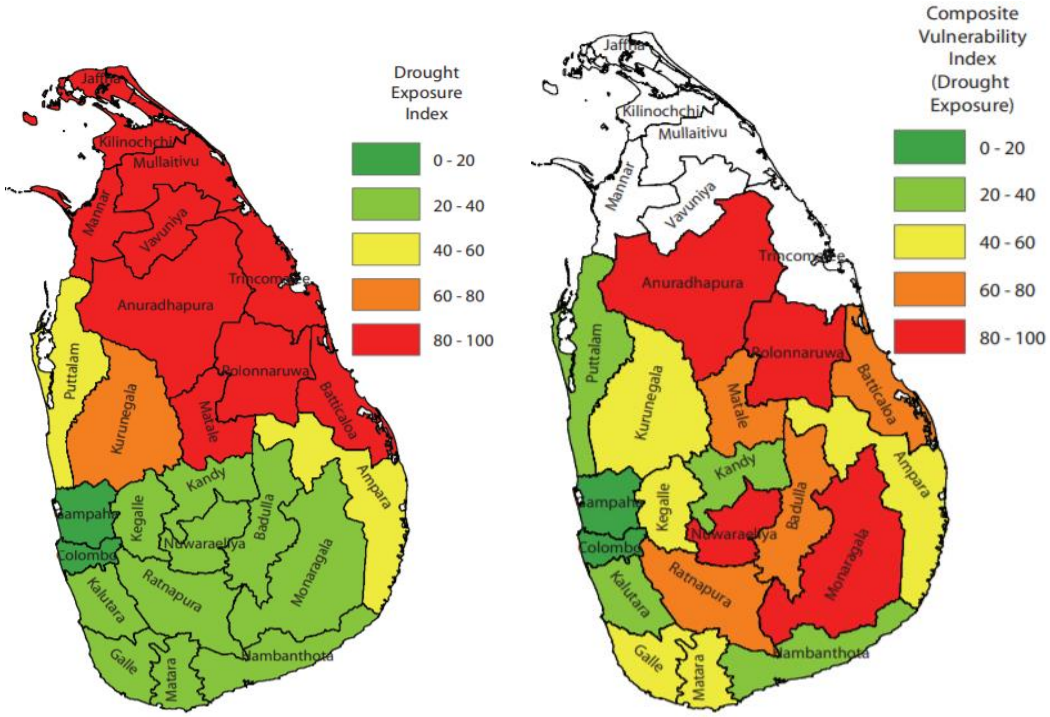


Figure 12: Drought exposure map, according to past frequency of drought occurrence (left) and a vulnerability map for drought exposure, compiled out of the exposure, sensitivity and adaptive capacity indices (right) (missing data in the northern districts) (Eriyagama et al., 2010).

2.2.3 3.3.3 Extreme air temperatures

Based on projections from the fourth and fifth assessment reports of the IPCC temperature levels are expected to continue to rise in South Asia, where they are already higher than the global mean (AR4, AR5). Estimates for South Asia reveal an increase of 1.3 – 1.8°C by 2050 based on different scenarios proposed by the IPCC (AR4; 2014). The strongest warming trend in South Asia was consistently observed in Sri Lanka over a 40 year period, from 1961 – 2001 across 7 different indices[1] and gathered from 11 temperature stations on the island (Sheikh et al. 2014). The evidence suggests that air temperature is gradually rising across nearly the whole island and the warming trend has become faster in recent years (CCS, 2016; Sheikh et al. 2014). Furthermore, an increase in the warmest day temperature has been observed (Sheikh et al. 2014). The regional average for summer days during which the maximum temperature exceeds 25 °C degrees has also seen a significant increase across Sri Lanka over the 30-year time period 1971 – 2000 (Sheikh

t al. 2014). The study suggests that a decrease in rainfall could account for the increase in extreme temperature. The staple foods coconut and rice are particularly sensitive to air temperature changes (USAID, 2018).

Coupled with air temperature rise, is the rise of coastal sea surface temperatures, bearing a number of harmful effects on the livelihoods of coastal inhabitants, who make up one quarter of the island's population (IPCC, 2014). Rise in sea surface temperature can also lead to coral bleaching and a loss of ocean and near island biodiversity (USAID, 2018).

2.2.4 3.3.4 Sea level rise

Sea level rise is another climate change induced environmental hazard that is of particular significance to Sri Lanka. While exact projections for the future vary, many researchers agree that the level of sea level rise in South Asia has seen an acceleration in recent years (CCS, 2016; Mani Murali et al., 2013; USAID 2018; IPCC, 2014). The rate of sea-level rise in South Asia is obtained from a total of 18 tidal gauge stations, only two of which are situated in Sri Lanka, one on either coast (Eriyagama et al., 2010). Projections for 2050 predict the sea level to rise by 0.2 – 0.6 m (USAID, 2018) and 0.28m - 0.98m by 2100 (IPCC, 2014).

Figure 13: Coastal damage due to sea level rise in coastal communities (Colombo Telegraph, 2015).

People living in the coastal regions of Sri Lanka are very vulnerable to sea level rise as this leads to coastal erosion, salinization of groundwater reserves and salt water intrusions on fertile strips of land situated near the coast (Werner et al., 2013). Of the nine provincial capitals, Colombo, Galle, Trincomalee and Jaffna are the most vulnerable to sea level rise according to the 2018 States of Sri Lankan Cities Report 2018. Figure 15 displays the vulnerability of the marine fishery sector to sea level rise, per Grama Niladhari (GN) division. The vulnerability index is used to assess the vulnerability of each GN, consisting of an exposure (Sea level rise in *m)*, a sensitivity (number of fisheries landing sites, % of livelihoods dependent on fisheries & average fishing yield) and an adaptive capacity index (% of the population above the poverty line, % of the population completing secondary education and % employed in sectors other than fisheries). The figure clearly illustrates that Puttalam as the most vulnerable district to sea level rise exposure, as well as Hambantota in the south. No data was available for the northern and eastern districts.

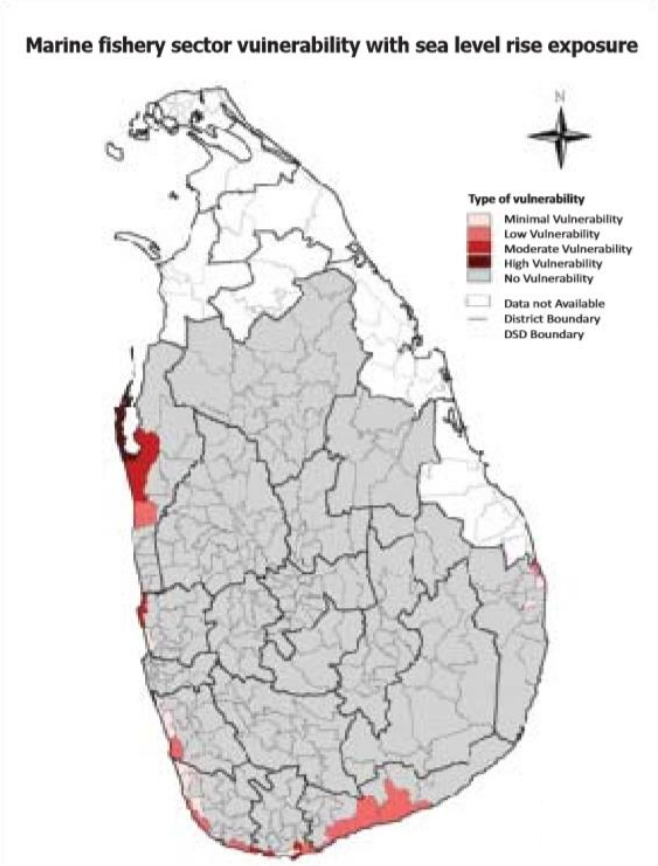


Figure 14: Vulnerability of the Marine Fishery Sector to Sea Level Rise (Athulathmudali et al., 2011).

Further studies reveal that 10% of both Galle and Jaffna's municipal built-up area is under risk of getting submerged by the turn of the century, based on the sea level rise projections of 0.50 m presented in the 4th IPCC assessment report, which have since been revised to 0.98 m, boding even greater risk (Koresawa et al. 2018; IPCC, 2014).

2.2.5 3.3.5 Extreme Rainfall

Despite negative trends being observed for various regions and rainfall seasons across Sri Lanka, the intensity and frequency of extreme climate events related to rainfall has increased and is predicted to increase further still (IWMI 135; IPCC AR4). The daily rainfall intensity and the average rainfall per spell have both increased in most parts of the country (Ratnayake and Herath, 2005). Interannual variability in precipitation for the Southwest monsoon is projected to increase as well (Cruz et al. 2007).

The occurrence of extreme wet events, defined as precipitation events exceeding the 95th percentile, is predicted to increase by as much as 400% in Sri Lanka during 2071-2100 compared to 1971-2000 (Ahmed et al. 2009).

Figure 15: Landslides affecting in Kalutara district in 2017, killing more than 90 people (CNN, 2017).

A further hazard presented by extreme rainfall is the occurrence of landslides. Not surprisingly a strong correlation between frequency of extreme precipitation events and landslides has been observed (Ratnayake and Herath, 2005). “Changing rainfall patterns and unexpected periods of high rainfall are expected to strain the capacity of irrigation systems and increase the risk of landslide in some areas.” (Koresawa et al. 2018). Furthermore, the provincial capitals Kandy, Ratnapura, Galle and Badulla are exposed to landslide risk (Koresawa et al. 2018). In Kandy 45% of residential land-use and 14% of total built-up area is located in zones of moderate landslide risk (Koresawa et al. 2018).

Figure 12, shows the distribution of landslides in Sri Lanka over the time period 1942-2002 (marked blue) and the distribution of landslides that occurred after the extreme rainfall event that took place in May of 2003 (marked red), reported to be the worst rainfall event in 56 years.

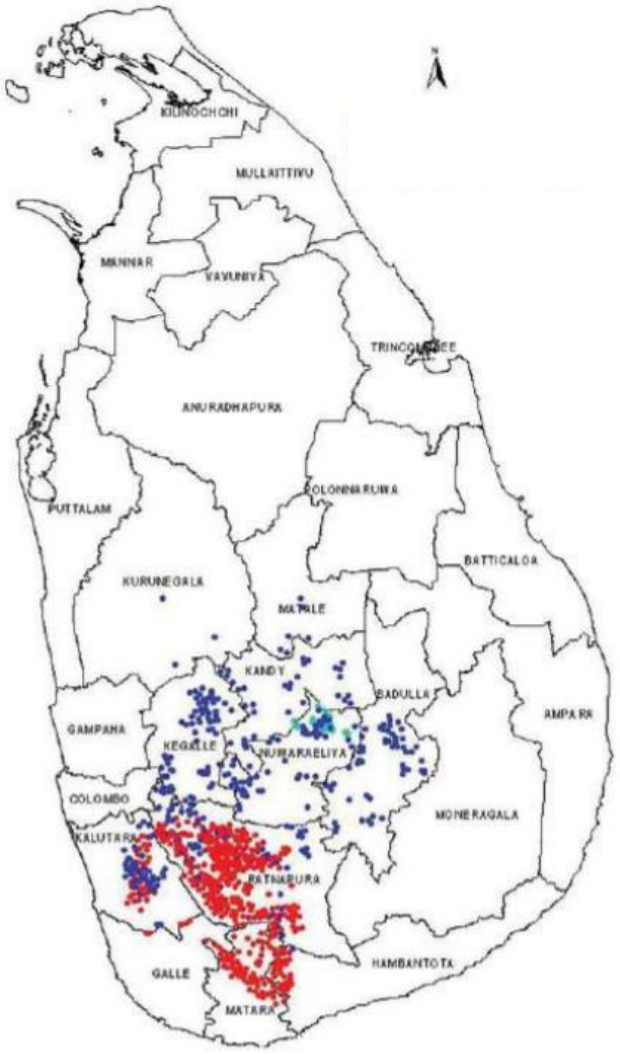


Figure 16: Distribution of landslides in Sri Lanka (NBRO, 2010).
Marked blue are all recorded landslides that occurred between 1942 and 2002.
Marked red are all landslides that occurred as a result of the 2003 extreme rainfall event.

3 Agricultural Outlook and Consumption Patterns

3.1 Agricultural land use and production systems

Agriculture is a major economic sector in Sri Lanka, contributing 10% to the nation's GDP and 28.5% of the national population is employed in the primary production of agricultural goods (FAO; Kumara, 2015). The total area under cultivation is 3,530,000 hectares and the average farm size is 0.5 hectare (FAO; Kumara, 2015). In general, farming systems are low in their level of mechanization and most systems are rain-fed instead of irrigated. Additionally, there is often a lack of market-oriented production and many farms fall under subsistence or only part-time farming (FAO; Kumara, 2015).

As can be seen in figure 18, large parts of the country are still covered under dense or open forests. Areas classified under 'garden' typically refer to smallholder farms with intercropped fields, producing a variety of crops. The classification 'others' may include a variety of farming systems, but mainly refers to mixed farming systems (fruit, vegetables & livestock) (Imbulana *et al.,* 2010).

Both plantation (estates) and smallholder farming systems are represented in the agricultural sector of Sri Lanka. Tea cultivation for example is still often produced within bigger tea plantations/estates, however 'only' 24% of the total 221,968 ha fall under plantations/estates, while 76% is produced by smallholder farmers, classified as being smaller than 4 ha (Wekumbura e*t al.,* 2017). Coconut cultivation is also mainly done by smallholder farmers, who make up 82% of the of the total 323,489 ha, under coconut cultivation (Coconut Research Institute).

Urban and peri-urban agriculture (UPA) in Sri Lanka and the Colombo CRFS more specifically can be considered as marginal (see figure 18), however the Ministry of Agriculture and the Ministry of the Western Province have been promoting urban agriculture between 2005 and

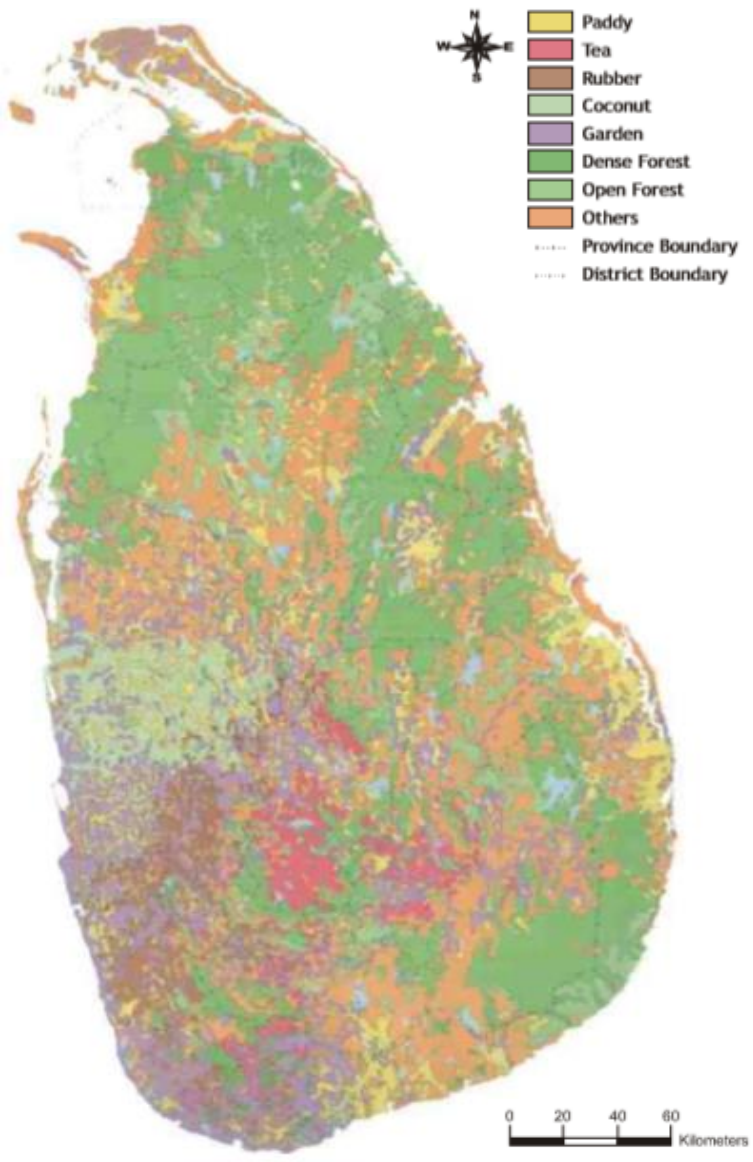


Figure 17: Land use map of Sri Lanka (Imbulana et al., 2010; National Atlas of Sri Lanka, Survey Department, 2006).

2010 with effective outcomes. The approach was to make the supply of seed, plants, fertilizers and equipment more accessible in urban areas. Additionally, the use of unutilized lands for crop cultivation is promoted by the Ministry of the Western Province, as it foresees the potential of these uncultivated lands. They could meet the high demand of fresh vegetables, demand of the urban areas, cut transportation costs and decrease post-harvest loss (Colombo CRFS Synthesis Report, 2018).

3.2 Main commodities per district

Through an expert and multi-stakeholder analysis, the main food commodities were defined for the Colombo CRFS (Colombo CRFS Synthesis Report, 2018). These commodities were selected to represent a varied diet of food items that embody all key macro- (carbohydrates, proteins, fats etc.) and micronutrients (vitamins and minerals). Rice is the main source of carbohydrates and it is eaten throughout all social classes and ethnic or religious groups. For proteins, most common sources are fish and beans (and other legumes), for fats coconut is mainly used and vitamins and minerals are sourced from fruits and vegetables. From the multi-stakeholder analysis, it became clear that the main vegetables consumed in the Colombo area are brinjals (eggplant) and beans, and the main fruits consumed are bananas and papayas. The number of different fruits and vegetables consumed in Sri Lanka is enormous, however the chosen items represent the ones that are the most consumed, and additionally they are often representative of the production areas of other fruits and vegetables. For example, brinjals are mainly produced in the districts Hambantota, Badulla and Monaragala, which are also the main producing districts for vegetables such as pumpkins and cucumbers. Also, for beans, Nuwara Eilya and Badulla are the main producing districts, but they also produce a variety of other vegetables such as carrots, beetroots, radish and cabbages. Monoragala is one of the main

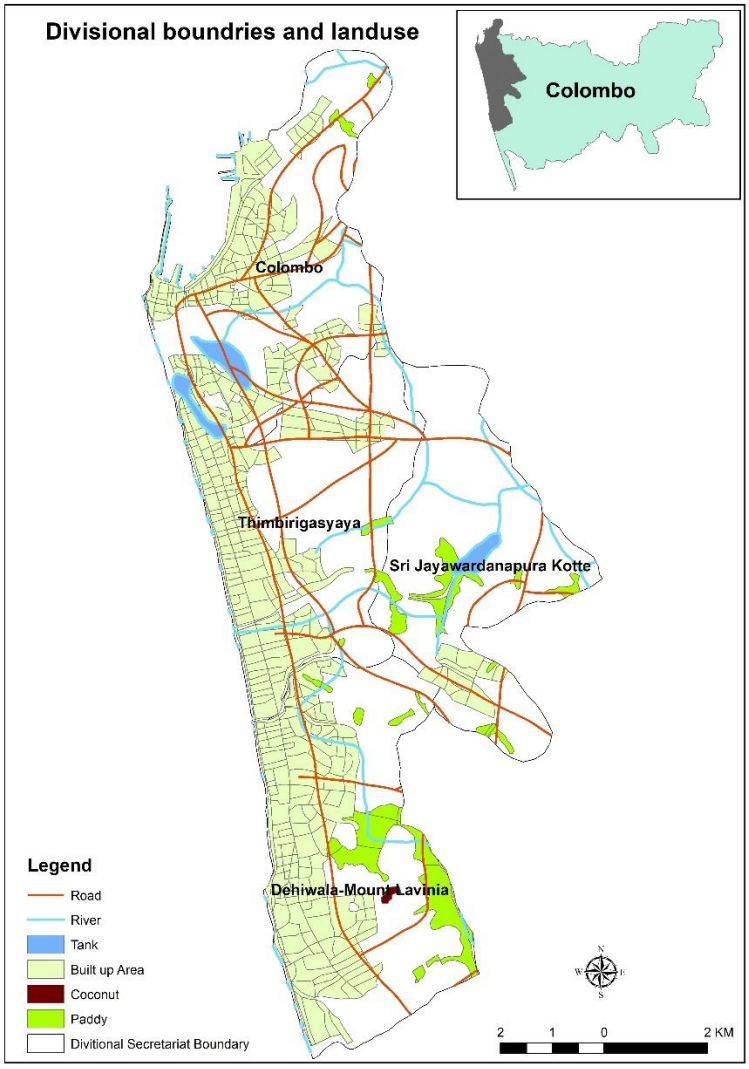


Figure 18: Divisional boundaries and land use map of Colombo city.

producers of bananas and it is also the highest producer of other fruits like watermelons and oranges (Ministry of Agriculture).

For clarification, the CRFS-approach is based on commodities that are consumed/marketed within this system, therefore (exported or industrial) commodities that are mainly produced for the export market like tea, rubber, palm oil, sugarcane, cinnamon, and other spices are not taken into account in the assessment of this report. However, it should be recognized that these crops form a major part of the national GDP of the country and occupy a vast area of arable land.

Additionally, for crops that are both being produced for the national market as well as for the export market (banana, mango etc.), the in-depth stakeholder analysis will evaluate which percentage is potentially marketed/consumed within the Colombo CR and which percentage is exported.

Table 5 shows the main commodities produced per district (25 districts in total) in metric tons per year. Seasonality of these commodities is not reflected upon in this data, however this should be of concern for further investigation, since seasonal yields might affect the Colombo CRFS throughout the year differently. These numbers are obtained from the Ministry of Agriculture, Department of Census and Statistics, the Coconut Research Institute and the Ministry of Fisheries and Aquatic Resources Development. As can be seen all districts produce rice to some extent, which makes it the main produced crop in Sri Lanka. However, fish for example is only produced in the coastal districts. The fish data is based only on the marine sector (both coastal and deep sea) and does not include the inland (freshwater) sector, however the marine sector is responsible for 86 % of the total fish production.

Table 5. Annual production of main commodities per district (Ministry of Agriculture, 2017).

District.	Rice (t)	Coconut (t)	Fish (t)	Brinjals (t)	Beans (t)	Banana (t)	Papaya (t)
Colombo	15,540	5,675	6,310	2,820	0	2,590	365
Gampaha	48,390	30,618	31,150	1,399	0	8,431	481
Kalutara	61,045	8,832	46,090	1,596	0	8,775	600
Galle	58,495	9,649	56,890	1,238	0	7,894	2,400
Matara	93,670	10,138	30,550	1,044	8	12,712	1,456
Hambantota	260,200	16,091	62,510	14,083	55	27,882	7,618
Badulla	111,320	2,217	0	10,367	43,076	3,323	755
Monaragala	213,440	8,699	0	11,825	573	82,085	7,913
Ratnapura	184025	12,620	0	9,404	9,213	117,035	5,915
Kegalle	55,145	12,027	0	1,530	600	16,800	0
Kurunegala	491,775	79,090	0	5,673	254	32,025	9,600
Puttalam	132,025	23,915	75,560	4,950	0	12,540	882
Kandy	77,245	5,972	0	4,119	8,763	16,035	2,065
Matale	120,315	6,877	0	2,907	5,560	1,005	570
Nuwara Eliya	22,665	855	0	6,830	22,375	7,852	176
Anuradhapura	537,567	11,453	0	10,190	913	3,600	800
Polonnaruwa	270,325	4,808	0	804	166	3,300	1,400
Jaffna	26,230	2,856	32,260	3,262	332	21,065	3,409
Killinochchi	89,665	2,036	14,560	5,555	44	6,982	1,164
Mannar	105,895	753	17,510	1,855	126	480	704
Vavuniya	102,490	643	0	6,016	282	8,064	2,413
Mullaitivu	70,585	2,196	11,140	7,680	168	5,043	1,730
Trincomalee	267,920	1,743	23,780	7,240	85	6,709	2,761
Batticaloa	288,705	2,728	28,500	2,743	132	2,484	168
Ampara	604,430	4,149	20,180	8,780	100	3,855	7,500
Total	**4,309,107**	**266,640**	**456,990**	**133,910**	**92,825**	**418,566**	**62,845**

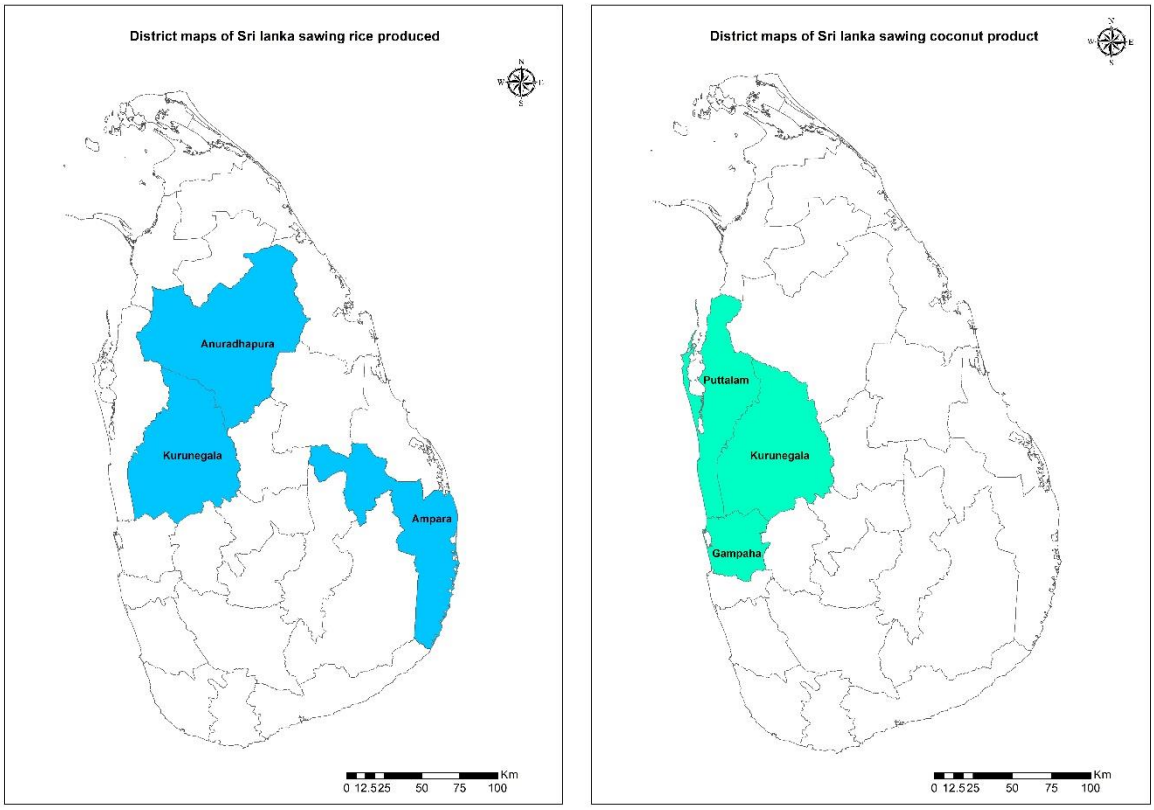


Figure 20: Main rice and coconut producing districts, responsible for 39% and 50% of total national production respectively (Ministry of Agriculture, 2017).

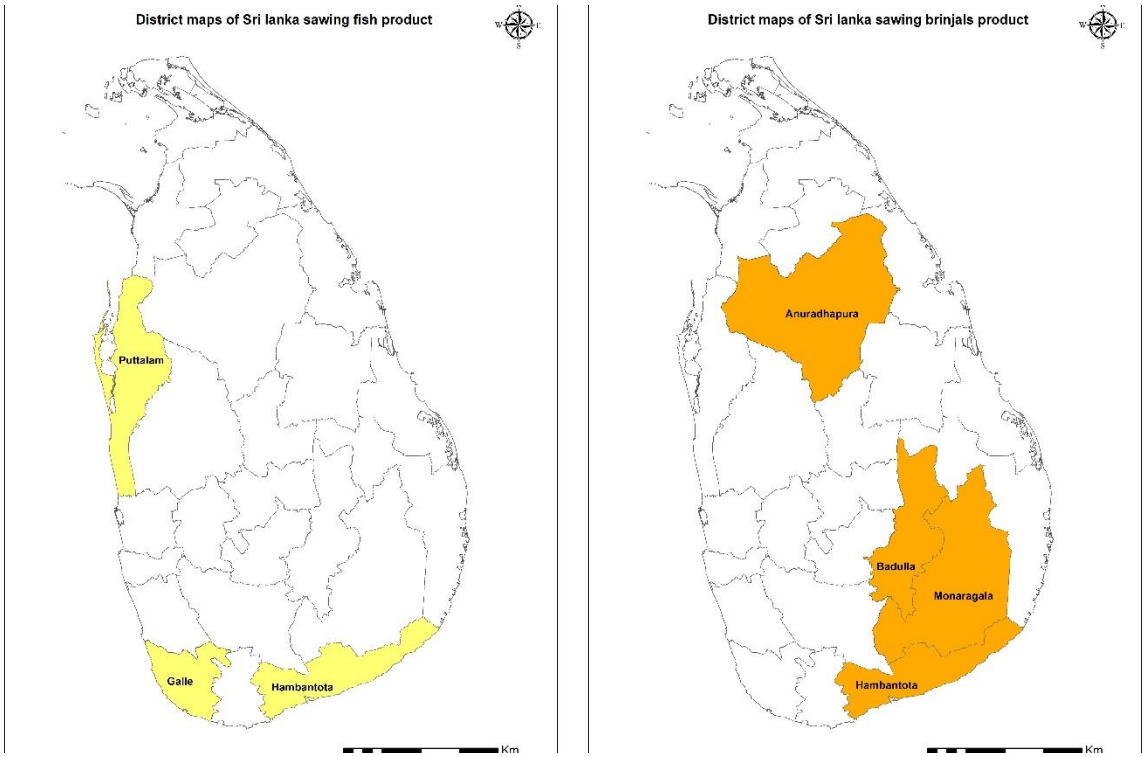


Figure 19: Main fish and brinjal producing districts, responsible for 43% and 35% of total national production respectively (Ministry of Agriculture, 2017).

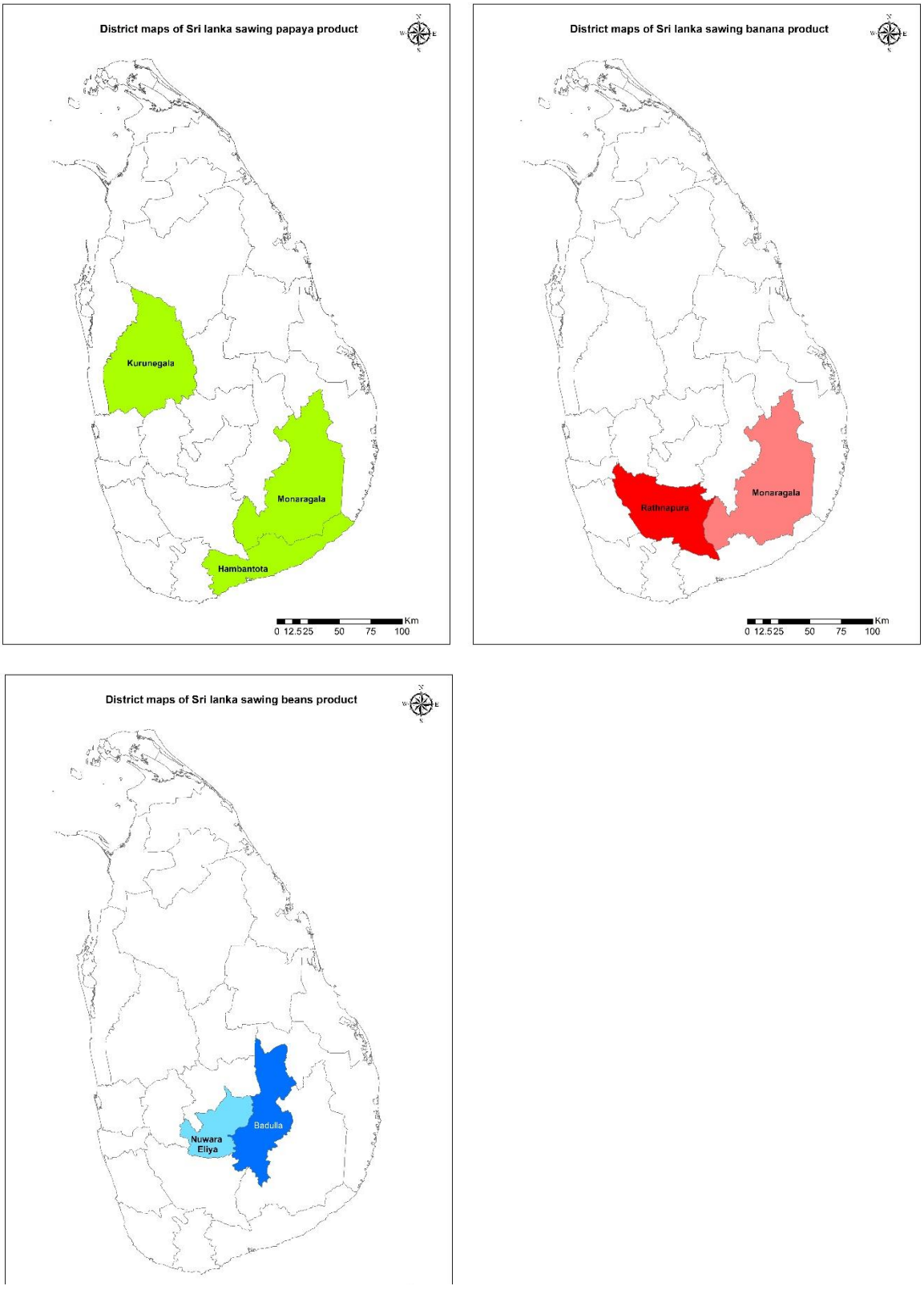


Figure 21: Main papaya, banana and bean producing districts, responsible for 40%, 28% and 71% of total national production respectively. Gradient in colours mean a significant difference in production between districts (Ministry of Agriculture, 2017).

3.3 Imported food items

Considering all imported and exported goods (including food items, petroleum, vehicles etc.) Sri Lanka has had a negative trade balance for at least twenty years. In 2017 for example, Sri Lanka exported $12B of goods and imported for $21B of goods. However, Sri Lanka produces about 85% of its food needs nationally, with a remaining 15% to be imported foods (Esham *et al.,* 2017). For food products the main imported goods are rice (1.5 % of total imported goods), concentrated milk (1.4% of total imported goods), wheat (1.2 % of total imported goods), raw sugar (1.0 % of total imported goods), dried legumes (0.9 % of total imported goods) and onions (0.6% of total imported goods) (OEC, 2017). The complete demand for wheat and red dhal lentils have to come from import, since they are not produced in Sri Lanka itself. The quantity of imported wheat in 2013 was 934,596 tonnes and for red dhal lentils this was 151,129 tonnes (Colombo CRFS Synthesis Report, 2018).

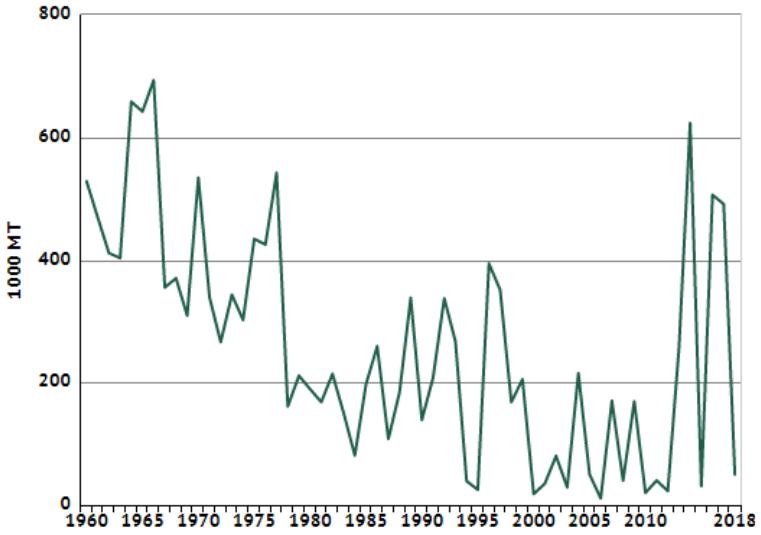


Figure 22: Imported rice by Sri Lanka per year (World Data Atlas, www.knoema.com)

Sri Lanka had approximately 380,000 hectares under rice cultivation in 2016, good for a production of more than 4,300,000 metric tons, however the demand of rice has been growing steadily higher that the national production can supply. Therefore, rice is imported from countries like India, Myanmar and Pakistan (Department of Census and Statistics; OEC). The fluctuation of rice import is very high over the years, changing from more than 600,000 tons per year (e.g. 2014, a year with severe droughts) to below 50,000 tons (e.g. 2015). This most likely lines up with national rice yield fluctuations. Wheat is barely produced in Sri Lanka, nevertheless the demand is rising annually. In 2018, 1,300,000 metric tons were imported, from mainly Canada and the U.S. (export.gov).

4 Vulnerability of the CRFS towards climate change related shocks

In this chapter the climate change vulnerability for all levels in the CRFS will be described. The CRFS is divided in six elements; 1) input supply and food production, 2) food storage, processing and manufacturing, 3) food wholesale and distribution, 4) food marketing, catering and retail, 5) food consumption and 6) food and organic waste management. In figure 22 the elements of the food system are shown. For all these elements the vulnerabilities will be described, including geographical locations of most vulnerable areas/actors. Additionally, a stakeholder analysis was made to assess the main actors within the specific CRFS element.

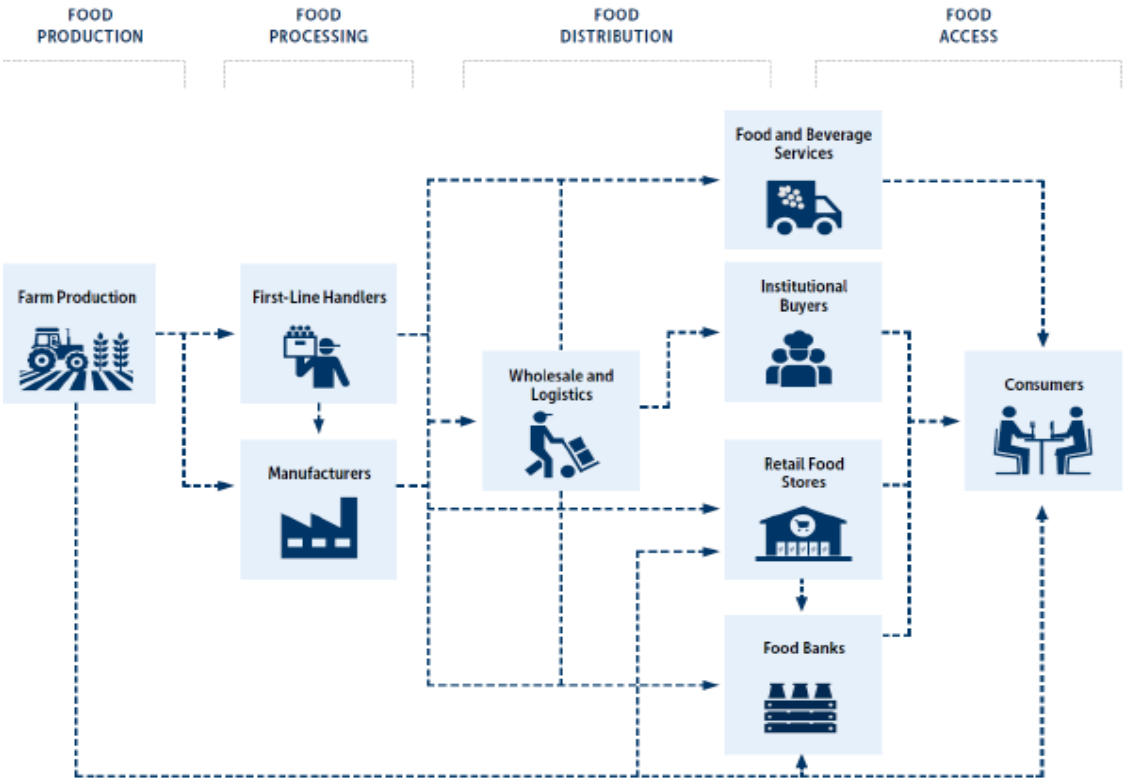


Figure 23: Main elements of the food system

4.1 Input supply and food production

The impacts of climate change on agricultural production systems will be described according to different climate change hazards. Within this level of the CRFS, vulnerability to climate change is very present. Basically, all production systems within the agricultural sector in Sri Lanka will experience complications due to climate change. However, for each production system there are different climate events that make the specific system vulnerable.

The production systems analyzed for their vulnerability are the production systems of the seven commodities mentioned in the previous chapter (rice, fish, coconut, beans, brinjals, papayas and bananas), that are the main commodities consumed in the Colombo CRFS. In figure 24 it can be seen which districts produce the highest amount (in tons) of the main commodities. The districts Kurunegala, Hambantota and Monaragala produce the most variety of the seven commodities in the highest quantities. However, Ampara for example produces the most in tons in terms of all districts, but this is only because it produces the highest quantity of rice (14% of total national rice production), for the rest Ampara in not an important district for the production of other commodities. Therefore, a climate hazard or stress affecting of the districts Kurunegala, Hambantota or Monaragala will likely have a higher impact on (the variety of) Colombo's food system than the district Ampara would have.

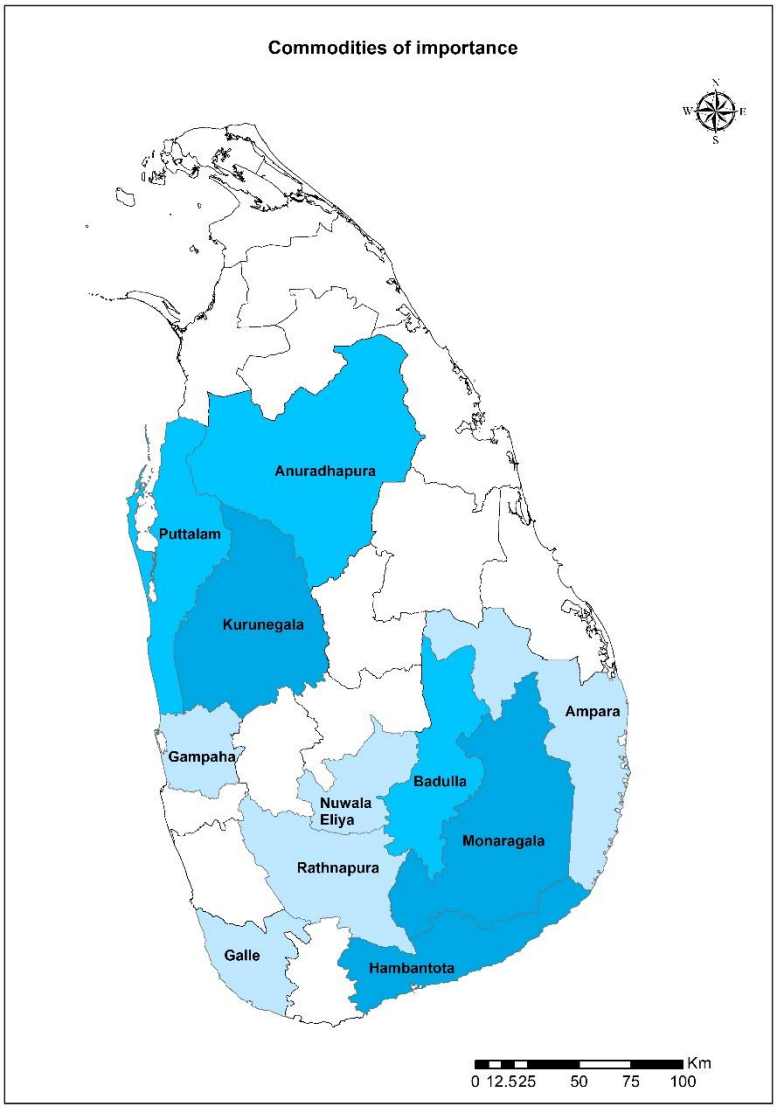


Figure 24: The Colombo city region food system, districts that produce highest amount and highest variety of main commodities. Gradient in colours signify difference of importance between districts.

4.1.1 Main stakeholders

The main stakeholders in this level of the food system are logically farmers and fishers, they are at the base of the food system and their livelihood will be impacted firsthand in case a climate hazard occurs. As mentioned before, more than 28% of Sri Lanka's population is employed in the agricultural sector (Kumara, 2015). To compare, in European countries this percentage is usually around 2-4%, consequently the population in Sri Lanka being vulnerable to climate hazards in this level of the food chain is very high. As most farmers in Sri Lanka are smallholder farmers, it is

likely that they might not have the capacity or financial means to deal with the effects of climate hazards. Hence, Sri Lanka has a big group that is vulnerable to the direct effects of climate change on their livelihoods.

4.1.2 Floods

As described in chapter 3.3.1, floods commonly occur in Sri Lanka, with in the past four years two major floods, affecting over 1,3 million people (MDM, 2016 & 2017). As can be seen in figure 11, many districts are colored red when it comes to flood exposure (frequency of historical exposure), however the districts most vulnerable to floods are Nuwara Eliya and Ratnapura (based on exposure, sensitivity and adaptive capacity). Nuwara Eilya's main produced commodity is tea, however in this analysis the focus lies on commodities important to the Colombo CRFS and not on exported products. Nonetheless, Nuwara Eilya and Ratnapura are after Badulla the main producers of beans in the country. If large parts of the bean production areas in these districts are affected by floods, Colombo's bean supply will be disrupted. Beans form the main protein intake of many Sri Lankans, thus if this source becomes less available or more expensive it will have a high negative impact on many households' diet. Additionally, the district of Ratnapura is the main producer for bananas (28% of total production), therefore the supply of bananas to Colombo might be affected strongly in case of floods happening in this area.
Due to floods, cultivated land might be directly affected (flooded), however indirectly production-related infrastructure might also be affected, such as irrigation structures, water basins or access to roads. Moreover, water resources might be contaminated or polluted due to floods.

4.1.3 Droughts

The districts that are affected by droughts and the districts that are projected to become vulnerable to droughts are mainly in the north, north-east and east of the country. In these districts the main commodities produced are rice, fish and a smaller amount of fruits and vegetables. For both irrigated and rain-fed production systems the impact of a drought can be severe. 75% of Sri Lanka's rice production happens in the dry zone, where major irrigation schemes and numerous tanks provide the necessary water. It is projected that the dry zone will receive less water in the future, putting these rice production systems at risk (Esham *et al.,* 2017). As these areas will be under water stress, the national rice supply will hamper and the Colombo CRFS will be affected as the main hub for rice distribution. Sri Lanka's rice demand is expected to increase, therefore rice production needs to be expanded or intensified, however with less water available, this will become a major challenge.

4.1.4 Extreme air temperatures

One of the main results of climate change is higher CO_2 levels in the atmosphere, which theoretically increase crop growth, according to the Center for the Study of Carbon Dioxide and Global Change in Temperature, Arizona (http://www.co2science.org/). This would mean an

increase in crop yield due to increased photosynthesis. This was observed for Sri Lanka's staple food, rice, as well as for other vegetables (Jayatillake and Droogers, 2004). Yet, atmospheric CO_2 increase also typically entails temperature rise, which does not necessary mean an increase in crop growth. By this time, rice is already being cultivated near its threshold of maximum temperature level. More increase or more extreme temperatures are likely to affect yields negatively. Rice is especially sensitive to high night time temperatures, with estimates that for each degree Celsius increase, yield decreases with 10% (Esham *et al.,* 2017). A temperature of more than 35 ^{o}C for at least an hour during flowering causes spikelet sterility, thus reducing rice yield (De Silva *et al.,* 2007). Extreme temperatures are predicted to become more severe in the whole country, however the districts that will be affected the most are the districts that produce crops that are particularly sensitive to temperature increase, like rice and coconut (USAID, 2018).

As mentioned in chapter 3.3.3, air temperature rise also affects coastal sea surface temperatures, which could lead to coral bleaching and loss of biodiversity in general. This might highly impact fisher communities that are dependent on fish species that have their habitat or breeding zone in these areas.

4.1.5 Sea level rise

Sri Lanka's population lives for 25% in coastal areas, 62% of industrial units are in those areas and more than 70% of the tourist sector is along the coast. The coastline is approximately 1,600 km long and embodies a range of different ecosystems, such as bays, beaches, dunes, estuaries, lagoons, mangroves and coral reefs. All of these ecosystems provide coastal communities in some way in their livelihoods. Direct effect of sea level rise on coastal communities is the loss of beach area, which could either functions as housing area or as beach access for fishermen. Indirectly, sea level rise or change in oceans flows may affect certain habitats of marine/freshwater species (Athulathmudali *et al.,* 2011). The main fish producing districts are Puttalam, Galle and Hambantota (figure 19), here sea level rise is a main threat. If the sea level rises with 1m, most of the coastal area will be inundated (Athulathmudali *et al.,* 2011).

4.1.6 Extreme rainfall

The direct effect of extreme rainfall is mainly felt in hilly/mountainous areas, whereas the indirect effect are floods downhill/down in the catchment. The effect of extreme rainfall on hilly areas are largely: severe erosion, gully formation and landslides. Eroded soils are still reversible, however formed gullies, or worse, landslides, are very hard to remediate. The districts most affected by landslides are Ratnapura, Kalutara, Kegalle, Nuwara Eliya and Badulla. The main crops in these areas are tea, palm oil and important for the Colombo CRFS: beans, brinjals and bananas. Most likely if these crops are cultivated in hilly areas, extreme rainfalls will severely impact the supply of these products within the Colombo CRFS. Intensive monoculture cropping systems are, in general, more likely to create bad circumstances for erosive rainfall events. Where natural vegetation or intercropped farming systems usually have more soil cover, monoculture cropping

systems usually have bare soil. Therefore, sustainable soil management is key to avoid further erosion that might lead to landslides.

4.2 Food storage, processing and manufacturing

Food processing makes up 29% of value addition and 19% of employment within the industrial sector, making it the largest manufacturing industry (DCS, 2013).

Of the 28.5% of the labour force engaged in the agricultural sector, about half are engaged in the cultivation, processing and manufacture of rice (Wijesooriya & Priyadarshana, 2013).

The rice milling industry is the largest agro based industry in Sri Lanka, having over 7000 mills and over 95% of the mills belong to the private sector (Wijesooriya & Priyadarshana, 2013). The remainder belong to cooperatives. The major milling districts in the country are Polonnaruwa, Anuradhapura, Kurunegala, Ampara, Hambentota and Gampaha (Wijesooriya & Priyadarshana, 2013). According to the 2013 study by Wijesooriya & Priyadarshana, a few millers control the entire market, both during season and off-season and this has become an issue regularly discussed by the media and the general public.

According to Esham et al. 2017 significant post-harvest losses in paddy production occur as a result of poor post-harvest handling, storage and poorly organised rice marketing channels.

A secondary cause for post-harvest losses bearing significant weight is the unpredictability of rainfall patterns as this affects grain threshing and drying, both processes requiring dry conditions (Esham et al. 2017). Poor storage management and lack of storage technologies incur losses on paddy as well, although it is favourable for many farmers as they prefer to take advantage of higher prices (Esham et al. 2017). A general lack of storage facilities also contributes to post-harvest losses along the rice marketing channels. The Paddy Marketing Board, the government's paddy purchasing body, only has 180 storage facilities, many of which are in poor condition (Senanayake and Premaratne 2016).

Another climate-related hazard that will incur further losses upon storage facilities is the rise of temperatures and the increasing occurrence of extreme weather events. Increased temperatures will decrease the shelf life of fruits and vegetables and exacerbate the losses of perishables.

The fishing industry is affected by a lack of refrigeration and other conservation techniques as well as processing technology (WFP 2012).

4.3 Food wholesale and distribution

There are 12 dedicated economic centres (DECs) in Sri Lanka, that accommodate a range of specialised crops. These serve as the central distribution centres that attract farmers, retailers and collectors from across the whole island (FAO 2018).

A 2015 FAO study estimated that nearly one third of all food gets lost before it reaches the consumer. These large losses can be attributed to poor post-harvest infrastructure, deficient marketing and climate related stress.
Along the supply chain the following commodities experience the following losses, as a percentage of the total goods produced: the paddy industry - 15% (Palipana, 2000), fruits & vegetables - 16-40% (Winkworth-Smith et al. 2014) and the fishery industry - 30-40% (Arunatilake et al. 2008) (cited in Esham et al. 2017).

As mentioned in Chapter 2, within the Colombo City, the socio-demographic profile is quite complex and its citizens access food items through a variety of channels.
For rice production, mill owners buy paddy from farmers, collectors as well as the Sri Lanka Paddy Marketing Board, which they will then sell to wholesalers, retailers and supermarkets. Over a quarter of the country's total rice production reaches the market this way, an about 12% of farmers sell their harvests to retailers directly (FAO 2018). Due to the large number of middlemen between the paddy farmer and the consumer, the supply chain grows in length and the share the farmer receives decreases (Dissanayake et al., 2012).
For coconuts, around 57% of farmers sell their harvest to large-scale collectors who then send them to auctions, primarily in Kuliyapitiya and Colombo, a minority (12%) use agents and around one quarter sell their coconuts directly from their farm (FAO 2018).
Fish reaches Colombo from Negombo and the southern region of which around 41% is sold at the harbour to agents and 31% to local retailers and collectors, who in turn sell it at Peliyagoda Central Fish Market, the primary fish distribution centre in the Colombo City.
Most fruits and vegetables make it processors and exporters from smallholder farmers, through contract suppliers or the spot markets. These traditional channels are vulnerable to oscillating climate conditions and extreme weather events (Esham *et al.,* 2017).
Due to the limited number of dedicated economic centres in the Colombo City, the CRFS is quite vulnerable to climate-related shocks, as one extreme event (such a rainfall or flood) can disrupt the entire supply chain.

4.4 Food marketing, catering and retail

Within and beyond urban Sri Lanka, there are two well-established branded supermarket chains, Cargills Food City and Keells, and in the Colombo area 18 large scale markets in addition to the Manning Market, mentioned in Ch. 2 (FAO 2018). Both Cargills Food City and Keells have their own purchasing and distribution centres. The farmers registered under these chains receive relatively high prices for their commodities and no inflation occurs due to the fact that no intermediaries operate these supply chains (FAO 2018).
The 18 large scale markets purchase their fruits and vegetables from Manning Market.
There are four dedicated economic centres with the Colombo City.

4.4.1 Food Access

A key component underscoring food security in Sri Lanka is the lack of physical and economic access to food. An estimated 60% of food produced in the country is considered to be marketable surplus (WFP, 2015).

With regard to physical access, while road density may not appear to be a problem in most parts of the country, road quality certainly is. Only 40% of all total roads are estimated to be in good condition, while a large proportion of the road network consists of small tertiary roads with a low chance of getting paved (WFP, 2015). Naturally, this impedes efficiency of transportation across all phases of the supply chain. Furthermore, due to the conflict in the northern and eastern regions of the country, a largescale destruction of infrastructure occurred in those regions impacting the access to roads.

Economic access to food remains a driving factor for food insecurity in Sri Lanka.

Economic access to food is defined by the financial capacity to purchase adequate and nutritious food (WFP 2015) and poverty rates serve as a proxy indicator of economic access to food across the country. The proportion of the population living below the poverty line has been declining rapidly across the last decades, falling from 15.2% in 2006/7 to 6.5% in 2012/13, however a large proportion of the population, especially amongst those who moved out of the poverty line, live precariously close to it. The Institute of Policy Studies estimated that a small adjustment of 10% to the poverty line would move 800 000 people into poverty (Nanayakkara 2013). In the eastern province more than half of all households could not afford an adequately nutritious diet due to a lack of financial means in 2014 (WFP 2015).

A study conducted by the Japan International Cooperation Agency (JICA) found that huge gaps in price across time and space exist along the supply chains for each agricultural product (2013).

For a majority of crops an overall lack of quality in the seeds makes it challenging for firmest to compete with imported products (WFP 2015).

A lack of fully functioning economic centres in the north of the country make it difficult for most producers to access the market.

Along the northern and the eastern coasts of the country many fishing households have difficulty accessing the market due to lack of marketing centres that focussed on fish and due to the high prevalence of middle-men resulting in a steep gap for the fishermen to overcome to access the market.

The vegetable supply chain is particularly prone to experience losses as much a majority of the vegetables are channelled through traditional markets, as oppose to supermarket chains, which have been found to more efficient and effective. (Esham et al. 2017)

They are most commonly transported in open trucks tightly stacked in woven polypropylene bags or poor-quality boxes (Esham et al. 2017).

Projected rises in temperatures will incur further post-harvest losses on retail stalls and open-air markets with no refrigeration (Esham et al. 2017).

Table 6, depicts how vegetable retail price in Nuwara Eliya were affected by rainfall variability.

Table 6: The impact of rainfall variation (%) on the vegetable retail price in Nuwara Eliya. (Central Bank Bulletin; DCC; cited in Escham et al., 2017)

Climate variability		Price change	
Period	Rainfall variation (%)	Period	Retail price increase (%)
2011/January	224.1	2011/January	28.1
2011/February	203.1	2011/February	21.8
2012/May	−1000	2012/June	32.0
2012/October	125.9	2012/November	43.6
2013/June	163.0	2013/June	16.7
2014/December	123.7	2015/January	25.3

Rainfall variation refers to a monthly change from 30 years (1961–1990) average; price increase refers to the average retail price change from the previous month

[a] Land at an altitude of 900 m above sea level

4.5 Food consumption

The impact of climate change on food prices in South Asia is described and identified by Bandara & Cai (2014), their results suggest that climate change have a negative impact on both food production and food prices. For a country like Sri Lanka, being very dependent on the agricultural sector, food price instability and food shortages can seriously affect its population (Bandara & Cai, 2014).

Within this level of the food system, the main stakeholders are the food consumers. The World Bank (2010) noted that domestic food prices are increased by droughts and erratic monsoon weather conditions. Climate change related hazards that increase food prices will mainly affect those that have a marginal budget to spend on food items. The proportion of household expenditure on food ranges from 38 – 50% in Sri Lanka (average of 12% in European Union), which is considerably high. According to the lasts census, the national average income per household is 62,237 Rs., approximately equal to 344 USD (DCS, 2016). The dietary energy consumption per capita of the urban poor in the western province was found to show the largest food insecurity of the country (Esham *et al.,* 2017).

As described by Esham *et al.,* (2017), low income households will, after food price escalations, due to climate change related shocks, have a common strategy of skipping a meal or reducing the quantities of their meals. These groups can be clearly identified as food insecure. The population that is food insecure and below the poverty line is also shown in figure 26 per district. It has been confirmed that during the global food crisis in 2008, the urban poor reduced their food intake, which mainly had an effect on macro- and micronutrients, which has serious nutritional consequences. This event also shows that the food prices of Sri Lanka are linked to global food prices. In that year the price of rice doubled, despite the fact that rice is produced locally in Sri Lanka. These kind of price escalations could lead to a decline of calorie intake, since Sri Lankans would substitute other food sources for rice, even if rice has an increased price.

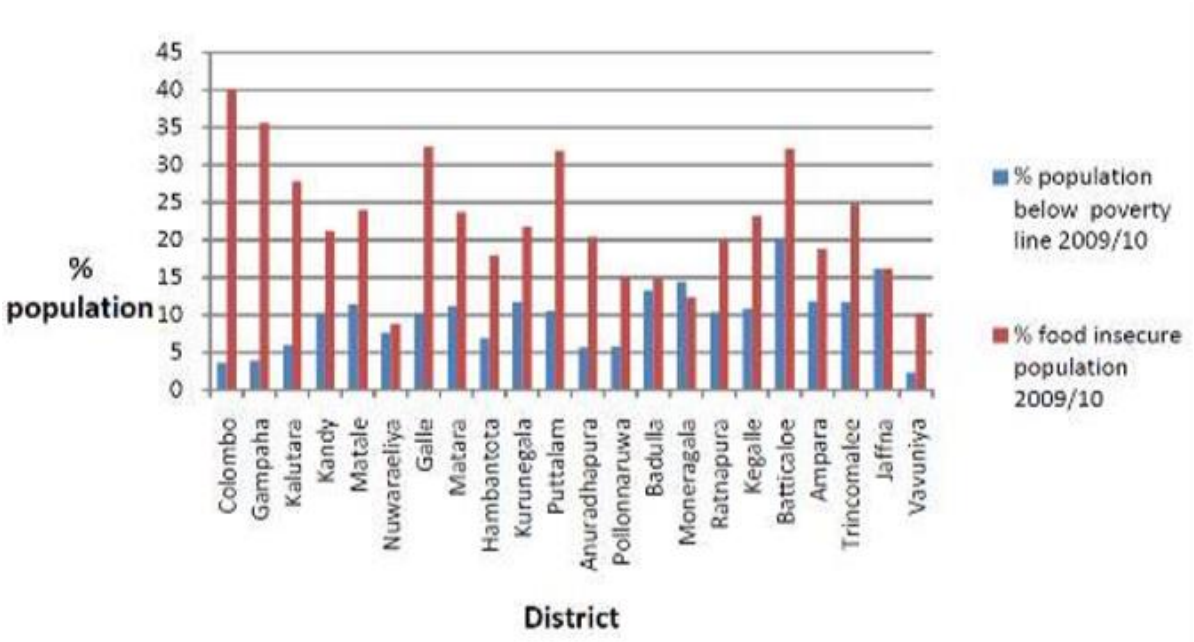


Figure 25: Poor and food insecure population per district (CRFS Situational Analysis Report, 2016).

Sri Lanka belongs to the bottom 5 of 22 Asian and Pacific countries when it comes to consumption of quality protein. Dietary wise, calories are mainly taken up from starchy food (70% above upper limit), not from quality protein, indicating poor dietary diversification (Esham *et al.,* 2017). In developing countries, dietary diversification is negatively correlated with food prices. In Sri Lanka this mainly holds for fruits and vegetables, which are the main source for macro- and micronutrients. It is a common phenomenon that prices of fruits and vegetables escalate during periods of (climate) stresses, which causes that these products are unaffordable for the low-income groups and then specifically the urban poor (Esham *et al.,* 2017).

4.6 Food and organic waste management

In a certain way, food waste puts pressure on a city region food system. A city with low food efficiency, meaning that it demands more food than it consumes, and therefore is wasting a big part of its food supply, is not sustainable. The exact (resource) efficiency for the Colombo City is hard to calculate, however it could be an output of further investigation.

Food or organic waste, also referred to as municipal solid waste (MSW), has the highest generation in the Western Province (60% of national total, 4200 t/day) and the Colombo District contributes half to this total. Between all Sri Lankan district, the Colombo District has the highest reliance on waste collection from local authorities, where in other districts people burn their waste, dispose it or compost it.

During climate change related hazards, such as floods or collapsed landfills, waste collection can be seriously hampered and cause public health issues. A different sort of waste, but also likely to threaten public health as a consequence of climate change related hazards, is wastewater (black water). The structures in place for the collection, treatment and disposal should be flood-proof in order to avoid public health risks.

5 Way forward

This report revealed major gaps which need to part of the next phase in depth analysis.

Climate change and its related shocks will need to be further investigated as projected risks instead of only data on historical exposure will need to be considered to generate knowledge and establish strategies to adapt and strengthen resilience.

Defining the CRFS needs more intense verification of seasonality of main commodities and their main production areas to assess the impact on the food system throughout the year.

While doing this it needs a more thorough analysis on the export market of those commodities to reassess, if the identified districts need to be changed in regard to their importance to the CRFS. This especially true for the northern region of the country, where data is generally still lacking.

As a yet not fully assessed factor, generation of food waste but even more important its mitigation could play an essential role in in reducing the pressure on the CRFS as an increase in its overall efficiency would release the pressure of high annual production rate of valuable commodities.

The City or urban area of Colombo will need to be evaluated on the recent findings, taking into account the especially urban areas are under constant changes and need to be projected towards their future development to enable policy makers to address topics like climate shock resilience in a nexus approach. The next phase will characterise the Megapolis area as the new urban area, where the Colombo city is only a part of, to give credit to these findings.

By doing this the stakeholders, their importance to the food system, their vulnerability and their capacities to increase their resilience will need to be reassessed accordingly.

This in-depth investigation and the to be identified gaps, will feed into the initiations of stakeholder policy dialogues, to strengthen the CRFS towards climate related shocks.

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