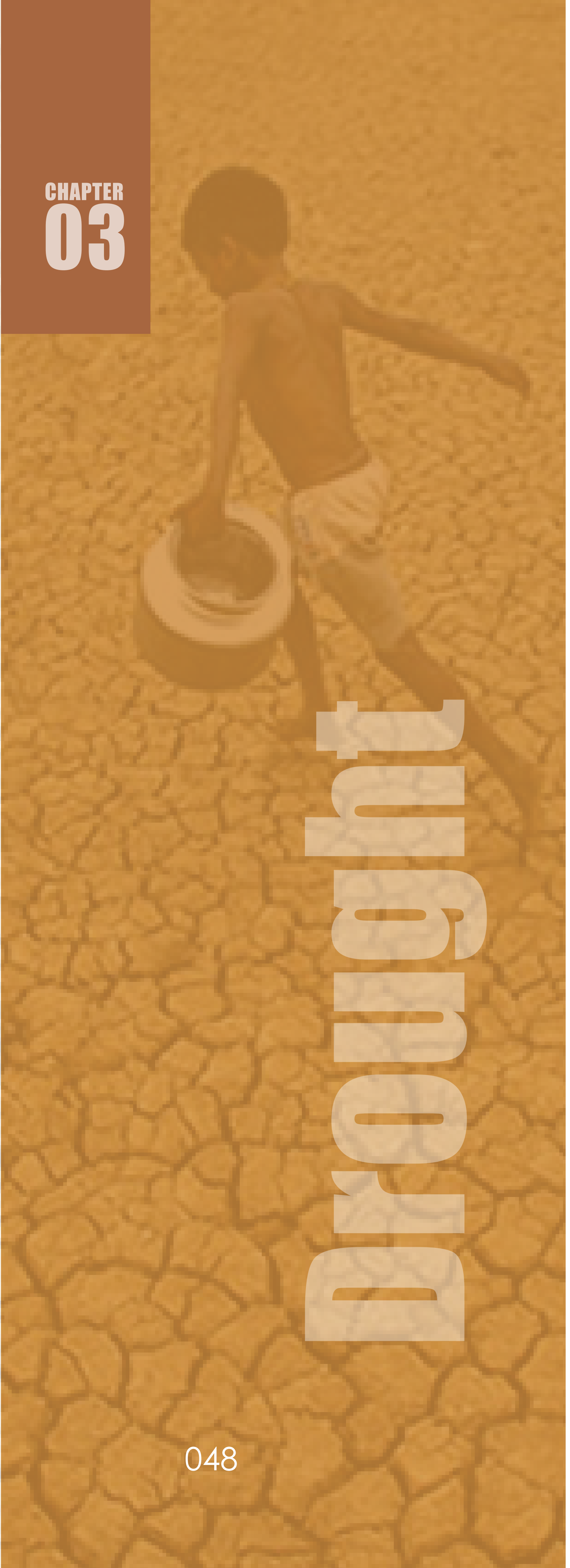
03
Drought



3.1 Background

There are four important geographical and topographical features in Sri Lanka which considerably influence the rainfall over the island (Jayamaha, 1975) namely; (1) Sri Lanka is a small island situated in the warm tropical Indian Ocean, (2) its proximity to the equator, (3) the existence of large mass of hills at the center of the island which is perpendicular to two approaching moisture laden monsoon wind streams and (4) the presence of vast land mass of the Indian sub-continent to the immediate north and northwest of Sri Lanka. These four factors, except the third directly enhances the rainfall regime of the island.

Despite their predominance in governing the rainfall regime of the country, drought has been a common feature of the Sri Lankan landscape since ancient times. These droughts have resulted in significant economic, environmental, and social impacts (Fig 3.1) from time to time underscoring our continuing and possibly increasing vulnerability to this natural hazard.

Drought is a slow-onset, normal, recurring feature of any climate in the world. In contrast to aridity, which is a permanent feature of climate, drought is a temporary aberration of weather: the consequence of a reduction in the amount of precipitation received over an extended period of time, usually a season or more, which results in a water shortage for some

Fig 3.1 Dried out Kala Wewa during 2012 drought (September 26, 2012)

activity, group or environmental sectors (Wilhite and Svoboda, 2000). Beyond this simple definition, there are other ways of understanding drought from a disciplinary perspective. These definitions and types are often grouped into four types: meteorological, agricultural, hydrological, and socio-economic.

3.1.1 Definitions to Drought

Meteorological drought is defined by a precipitation deficiency over a pre-determined period of time, while **agricultural drought** is defined more commonly by the lack of availability of soil water to support crop and forage growth. **Hydrological drought** is defined by deficiencies in surface and subsurface water supplies relative to average conditions and **socio-economic drought** reflects the relationship between the supply and demand for some commodity or economic good that is dependent on precipitation (UNISDR, 2009). However, it should be borne in mind that drought is among the most complex and least understood of all natural hazards, affecting more people than any other hazard. Despite its recurring and inevitable feature of climate, most of the countries including Sri Lanka have rarely planned for its repeated occurrence.

3.1.2 Causative Factors and other Characteristics

Under a changing and variable climate, the risk of drought is increasing worldwide. Sri Lanka has no exception to it and therefore, the Disaster Management Act No.13, 2005 of Government of Sri Lanka has identified drought as the most frequent natural disaster out of its 21 natural or man-made disasters. This section briefs the causative factors of drought and other characteristics of drought.

3.1.2.1 Causative Factors

The causative factors of meteorological drought or extreme rainfall anomalies experienced in Sri Lanka which occur under three major meteorological situations are given below:

i. 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 in Northeast monsoon season during December to February.

ii. Marked decrease in formation of "weather systems" (low-level atmospheric 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, the First inter-monsoon season, generally, occur due to convection under local thermal conditions and influence of the Inter-Tropical Convergence zone (ITCZ). 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.

iii. 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 of flow direction from its usual path. Under such situations, dry conditions are likely to occur in districts that lie across the Wet and Intermediate Zones.

Historical and legendary accounts show that even country's wettest region, Southwestern part of the central hills have had severe droughts in the past. Thus, it is apparent that almost all locations of the island have a potential vulnerability to drought occurrences.

3.1.2.2 Other Characteristics

Drought differs from other natural hazards of Sri Lanka in several ways. First, it is a "creeping phenomenon", making its onset and end difficult to determine. The effects of drought accumulate slowly over a considerable period of time and may linger for years after the termination of the event. Second, the societal impacts of drought are less obvious and extend over a larger geographical area than damages that result from other natural hazards such as flood, landslides and cyclones etc.

Third, drought seldom results in structural damage.

For these reasons, the quantification of impacts and its spatial variability is a far more arduous task than it is for other natural hazards.

Drought mitigation efforts during last few decades in Sri Lanka have always been non-systematic,without having committed drough-planning programms, where the main emphasis has been placed on short term solutions (i.e. emergency relief) without focusing on long term strategies for appropriate land and crop management practices as well as socio-economic issues. This is mainly attributed to the lack of clear understanding on spatial variability of droughts in Sri Lanka. Had such studies been undertaken, effects of major rainfall deficits would have been minimized while avoiding the impacts of less extreme rainfall deficits.

Hazard is generally defined as a potentially damaging phenomenon, substance, human activity or condition that may cause the loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental degradation (UNISDR, 2009).

Being an atmospheric and hydrological phenomenon, drought is categorized as a natural, and more specifically hydro-meteorological, hazard. Nevertheless, there is no internationally agreed general consensus on proper definition for drought. Thus, in the absence of a precise and universally accepted definition of drought makes it more difficult to identify and delineate the spatial variation of drought in a country.

3.2 Scope of the Study

The negative anomaly of rainfall has been widely used in identification of drought conditions of an area in most of the drought striking countries. Nevertheless, vulnerability of an area to drought conditions also depends on the atmospheric demand for water or more specifically, the evapotranspiration.

Hence, in the present study, spatial variation of drought proneness of Sri Lanka was assessed by considering it broadly as a hydro-meteorological hazard using time series of rainfall and evapotranspiration data. However a detailed study considering other factors contributing to drought is needed in order to produce a series of large scale maps to predict such events & systematic planning. Present chapter is a baseline study to initiate such detailed studies.

The output hazard map which indicates the potential drought regions of Sri Lanka could be used as a baseline map in short term & long term planning to mitigate the impacts of droughts experienced by the people living in such areas.

3.3 Methodology

For the assessment of drought hazard 14 indices were developed considering Agro Ecological Zones (AER) as the spatial units. Fig 3.2 illustrates the AER of Sri Lanka.

3.3.1 Development of Indices

As Sri Lanka has been delineated in to 46 AER based on rainfall, soil type, land use and terrain (Punyawardena, 2007), it is logical to select those regions as the spatial unit of the drought hazard assessment.

Meanwhile, it is understood that most of the available climatic data of the country have also been based on the same spatial unit. Thus, in this exercise, 14 indices were developed using daily and monthly rainfall and potential evapotranspiration data of respective AERs. These are:

1. **Total rainfall deficit per year**
   Deficit (or Excess) = Σ Rainfall – ET
   Thus, total rainfall deficit per year is the total of mean monthly deficits recorded throughout the year in a given agro-ecological region. It shows the shortage of rainfall during the year which may or may not be compensated by the rainfall received during the year.

2. **Highest total consecutive deficit**
   In computation of this index, it looks for all the months with a deficit and makes clusters of consecutive dry month. Then, only the highest total consecutive deficit period is taken. This index gives an idea about the longest water shortage period, the area will experience during the year due to lack of rainfall.

3. **Total number of months with deficit**
   This index counts how many months in a year show a water deficit.

4. **Highest consecutive number of months with deficit**
   As in index 2, this index looks for all the continuous dry periods recorded during the year and take the highest number of months with the deficit. It does not take the real value of deficit into account, instead only the number of months is taken in to consideration.

5. **Deficit over excess**
   This index can be easily explained using following equation.
   Deficit over excess = **Σ** Deficit of rainfall per year - **Σ** Excess of rainfall per year

6. **Highest deficit within a month**
   This is the highest single rainfall deficit recorded within one month period. It gives an idea about the shortage of water during the driest month of the year.
   Indices 7, 8, 9 and 10 are computed using only the mean monthly rainfall value.

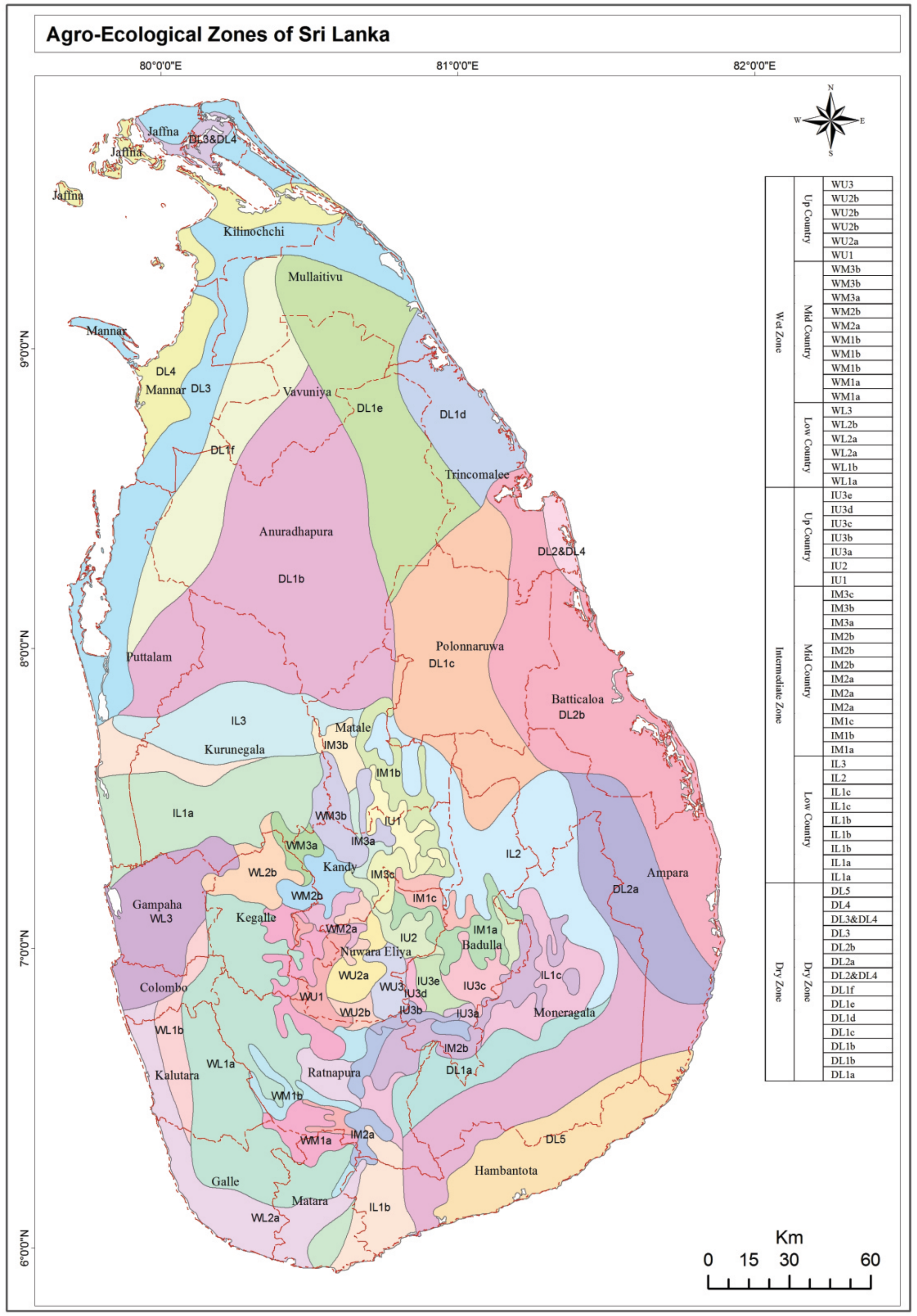


FIG 3.2. AGRO-ECOLOGICAL REGIONS OF SRI LANKA

7. **Number of months per year with rainfall less than 30 mm**

   Within a month, a rainfall of 30 mm is the minimum monthly rainfall requirement to compensate for 1 mm daily evapotranspiration water loss without allowing undergoing any water shortages. In this index, it gives an idea how many months per year are not receiving at least this 30 mm rainfall threshold.

8. **Highest number of consecutive months where rainfall is less than 30 mm**

   From the months with less than 30 mm rainfall, the highest number consecutive months with less rainfall less than 30 mm is taken in to account.

9. **Average rainfall of months where rainfall is less than 30 mm**

   This index is computed as follows: Average rainfall of months where rainfall is less than 30 mm = Sum of all less than 30 mm rainfalls/ number of months with less than 30 mm rainfall

10. **Lowest average rainfall where rainfall is less than 30 mm in consecutive months**

    Out of the months with consecutively less than 30 mm rainfall is recorded, the lowest consecutive average is taken to compute this index

11. **Total deficit rainfall less than 30 mm**

    Deficit is determined for each month with less than 30 mm rainfall and their summation is taken to compute this index.

    Indices 12, 13 and 14 have been computed using mean daily rainfall, mean daily ET and mean daily rainfall deficit

12. **Mean annual daily deficit**

    This index is computed using following equation Mean annual daily deficit = (Sum of all the daily deficits for 10 years/10)

13. **Mean annual non rainy days**

    When the total rainfall received during a 24 hour period is less than 0.3 mm, in meteorological terms it is considered as a non rainy day Mean annual non rainy days = Total number of non rainy days for 10 years/10

14. **Mean number of days per year where rainfall is less than or equal 1mm**

    Mean number of days per year where rainfall is less than or equal 1mm = Total number of days in 10 years where rainfall is less than or equal 1mm/ 10.

3.3.2 Drought Hazard Assessment and Mapping

Table 3.1 illustrates the results obtained for each of 14 derived indices used in the hazard assessment. Results have shown on the basis of agro-ecological region spatial unit. The Figures from 3.3 to 3.16 illustrate the spatial variation of all 14 indices used in the study.

Table 3.1 Values indices used in the hazard assessment

AEZ	1	2	3	4	5	6	7	8	9	10	11	12	13	14
WU1	-75.18	-75.18	3	3	1550.96	-34.02	0	0	Null	Null	Null	-425.78	194.30	
WU2a	-101.3	-101.30	3	3	1202.85	-49.71	1	1	25.89	25.89	-49.71	-431.68	254.90	205.40
WU2b	-69.05	-69.05	3	3	1020.27	-40.65	0	0	Null	Null	Null	-419.24	168.00	183.20
WU3	-84.68	-84.68	2	2	668.66	-42.52	1	1	29.25	29.25	-42.15	-404.79	240.00	197.30
WM1a	-36.25	-36.25	2	2	1641.36	-19.19	0	0	Null	Null	Null	-431.61	216.00	158.10
WM1b	-11.12	-11.12	1	1	1276.78	-11.12	0	0	Null	Null	Null	-516.37	240.00	195.70
WM2a	-160.84	-160.84	3	3	958.09	-60.54	1	1	23.46	23.46	-60.54	-490.14	228.00	199.10
WM2b	-219.03	-209.51	4	4	576.44	-83.44	2	2	14.34	14.34	-156.93	-663.13	228.00	243.33
WM3a	-218.6	-207.93	5	4	335.64	-83.23	2	2	17.44	17.44	-150.66	-701.31	264.00	257.75
WM3b	-169.54	-127.80	6	3	277.58	-70.52	0	0	Null	Null	Null	-655.67	242.20	242.50
WL1a	-35.98	-35.98	2	2	1608.46	-25.13	0	0	Null	Null	Null	-513.30	156.00	193.60
WL1b	-116.95	-116.95	3	3	1142.4	-48.90	0	0	Null	Null	Null	-558.57	264.00	206.70
WL2a	-63.99	-63.99	3	3	761.48	-23.50	0	0	Null	Null	Null	-581.34	259.10	201.10
WL2b	-217.09	-209.32	4	4	568.52	-83.15	2	2	11.2	11.2	-158.23	-690.13	240.00	254.90
WL3	-299.38	-226.01	6	4	264.41	-83.87	2	2	10.86	10.86	-162.35	-597.69	232.50	198.70
IU1	-77.76	-42.11	5	2	696.12	-36.49	0	0	Null	Null	Null	-658.29	216.00	240.00
IU2	-109.83	-61.25	5	3	612.56	-37.29	0	0	Null	Null	Null	-546.85	276.00	228.00
IU3a	-196.35	-176.35	5	3	537.5	-65.70	2	2	21.25	21.25	-123.71	-582.85	228.00	252.00
IU3b	-168.6	-147.82	5	4	464.31	-53.47	3	3	24.13	24.13	-147.14	-532.72	273.40	240.00
IU3c	-190.83	-153.92	5	3	341.43	-66.04	1	1	11.66	11.66	-66.04	-563.39	264.00	240.00
IU3d	-198.67	-110.59	6	3	73.93	-51.19	1	1	12.56	12.56	-49.84	-573.36	247.90	276.00
IU3e	-225.28	-152.85	6	4	103.46	-56.25	3	2	21.7	19.63	-148.04	-563.56	255.80	252.50
IM1a	-223	-186.66	7	5	463.81	-61.60	2	2	23.33	23.33	-117.74	-415.18	292.40	168.00
IM1b	-401.69	-348.42	7	5	208.49	-82.55	3	3	22.89	22.89	-230.46	-806.70	273.40	264.00
IM1c	-414.97	-353.30	7	5	0.7	-81.58	4	4	8.93	8.93	-304.41	-704.18	267.60	270.20
IM2a	-109.37	-69.38	6	3	365.53	-28.94	0	0	Null	Null	Null	-657.58	276.00	240.00
IM2b	-268.48	-223.74	7	5	204.91	-74.39	2	2	19.62	19.62	-142.5	-670.82	289.40	238.80
IM3a	-149.99	-139.61	5	3	272.3	-63.54	1	1	24.39	24.39	-57.93	-624.13	289.40	240.00
IM3b	-470.04	-335.63	7	5	-103.53	-88.35	3	2	23.15	23.15	-243.03	-864.51	289.90	276.00
IM3c	-213.54	-130.09	7	5	191.81	-49.17	0	0	Null	Null	Null	-584.44	282.11	240.00
IL1a	-433.29	-250.34	8	4	-148.66	-87.15	4	3	19	15.42	-315.15	-841.02	312.50	280.50
IL1b	-488.41	-478.55	10	10	-333.38	-83.87	2	2	21.15	21.15	-134.32	-913.20	252.00	276.00
IL1c	-425.32	-354.72	7	5	-119.86	-94.17	3	3	20.2	20.2	-267.22	-838.92	308.80	252.40
IL2	-532.72	-532.72	8	8	-59.65	-108.27	3	3	17.3	17.3	-302.97	-907.61	302.30	264.50
IL3	-656	-403.46	8	5	-449.15	-100.66	6	3	12.42	12.35	-542.3	-934.13	194.30	294.20
DL1a	-533.38	-409.62	8	5	-258.91	-99.14	5	4	14.61	11.53	-414.4	-847.29	254.90	278.58
DL1b	-765.25	-765.25	9	9	-593.28	-119.34	6	4	12.58	9.22	-618.13	-962.70	168.00	271.90
DL1c	-808.45	-808.45	9	9	-531.55	-138.36	5	4	14.47	12.76	-606.06	-1100.25	240.00	276.00
DL1d	-914.66	-914.66	9	9	-706.18	-134.24	7	7	10.88	10.88	-785.02	-973.80	216.00	293.20
DL1e	-855.73	-855.73	9	9	-603.62	-126.88	6	4	10.46	11.82	-659.12	-973.80	240.00	293.20
DL1f	-850.36	-850.36	9	9	-685.2	-124.66	8	5	9.06	9.76	-816.72	-1008.72	228.00	293.90
DL2a	-734.15	-734.15	8	8	-419.87	-127.34	5	4	20.13	18.51	-535.15	-1118.91	228.00	289.67
DL2b	-847.46	-847.46	9	9	-526.81	-135.93	5	3	17.16	15.07	-580.62	-1202.11	264.00	312.60
DL3	-943.37	-943.37	9	9	-775.25	-128.28	8	5	7.76	7.77	-873.26	-1001.88	242.20	273.30
DL4	-973.92	-973.92	9	9	-813.4	-133.48	8	5	5.09	4.38	-900.77	-1121.28	156.00	311.40
DL5	-910.28	-910.28	10	10	-856.69	-142.32	7	5	16	14.4	-773.59	-1179.39	264.00	323.20

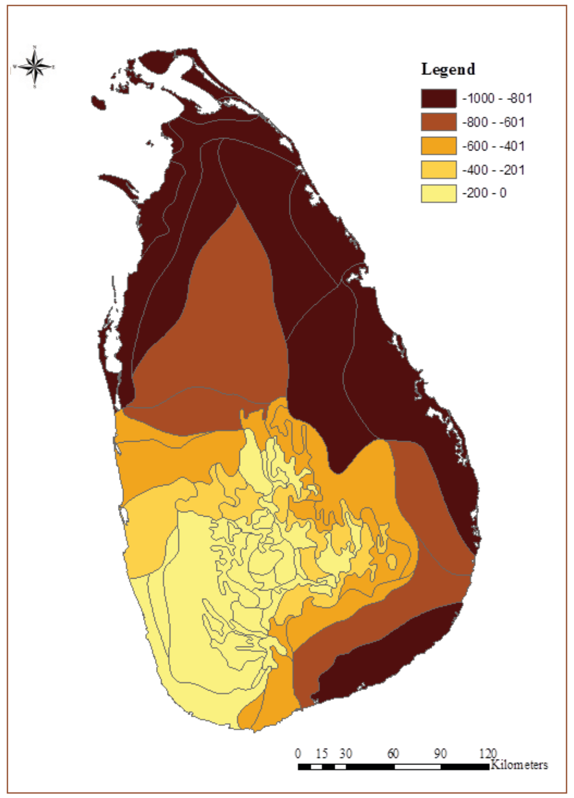


Fig 3.3: Total annual rainfall deficit - mm

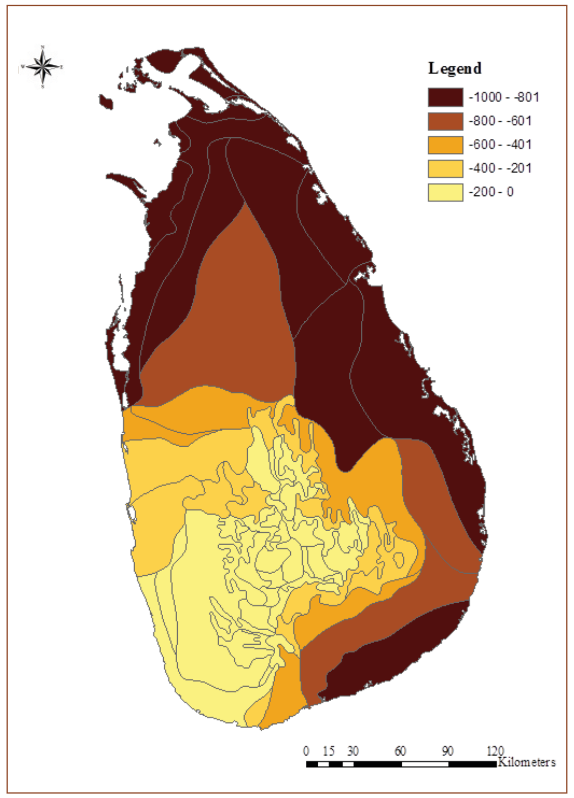


Fig 3.4: Highest total consecutive deficit - mm

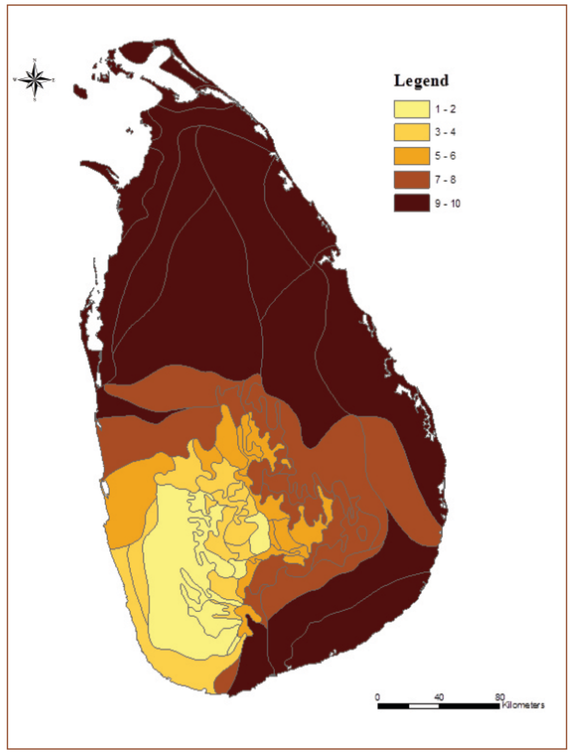


Fig 3.5: Total number of months with deficit

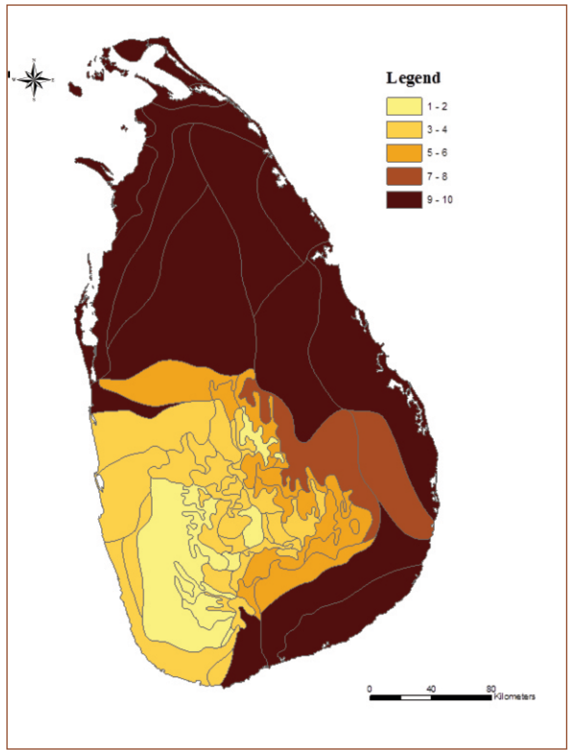


Fig 3.6: Highest consecutive number of months with deficit

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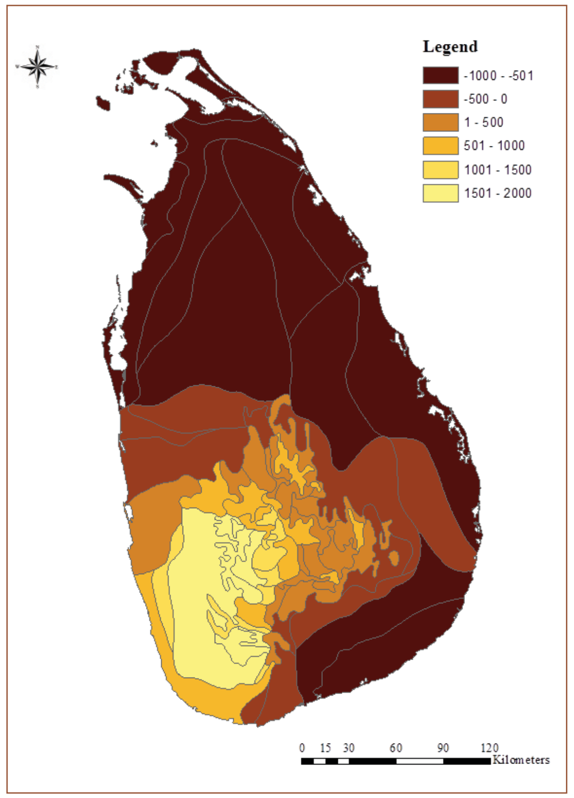

Fig 3.7: Total annual deficit over excess - mm

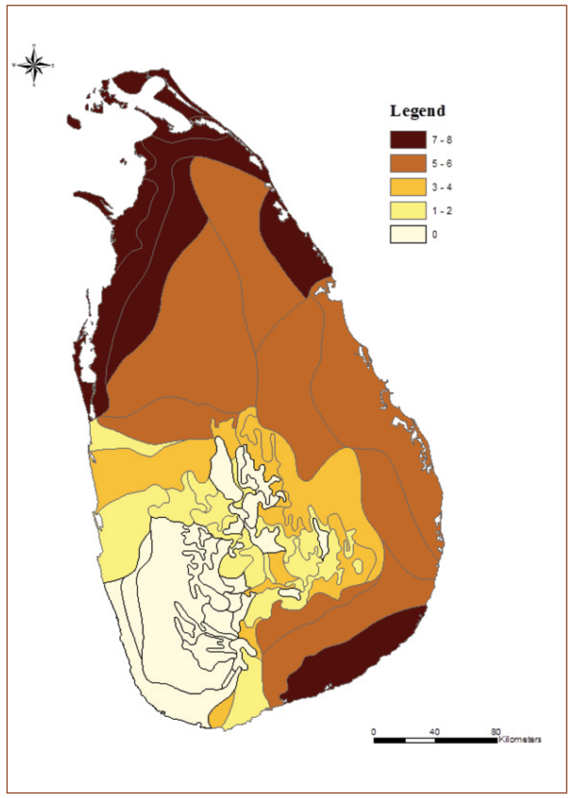

Fig 3.8: Highest deficit within a month - mm

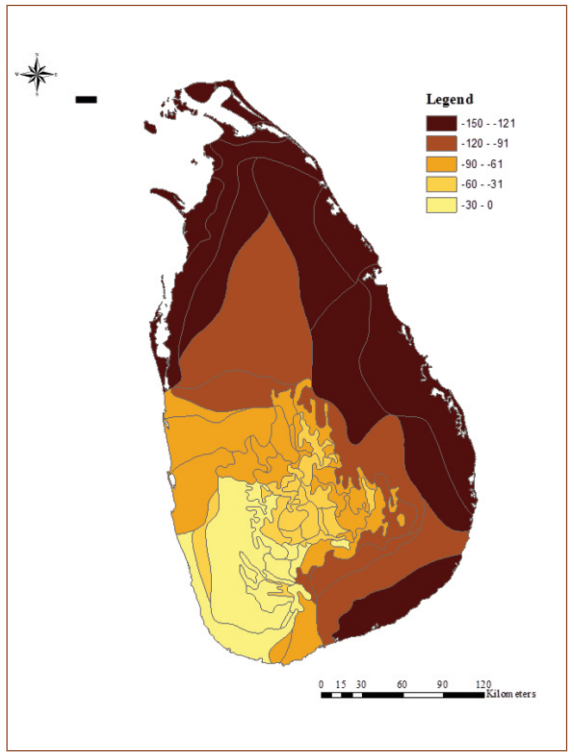

Fig 3.9: Number of months per year with rainfall less than 30 mm

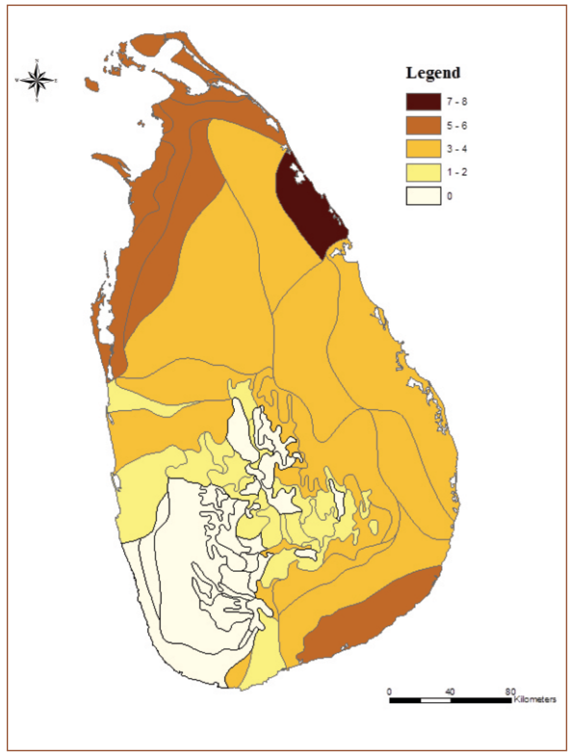

Fig 3.10: Highest number of consecutive months where rainfall is less than 30 mm

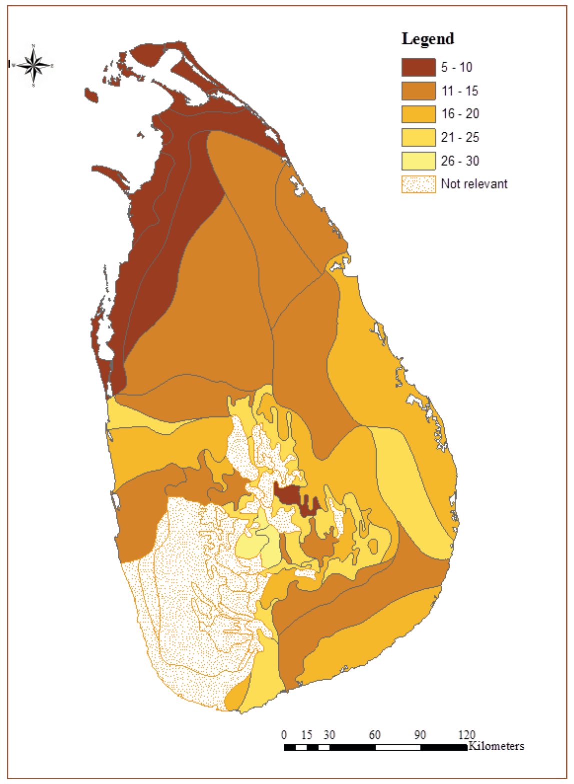

Fig 3.11: Average rainfall of months where rainfall is less than 30 mm

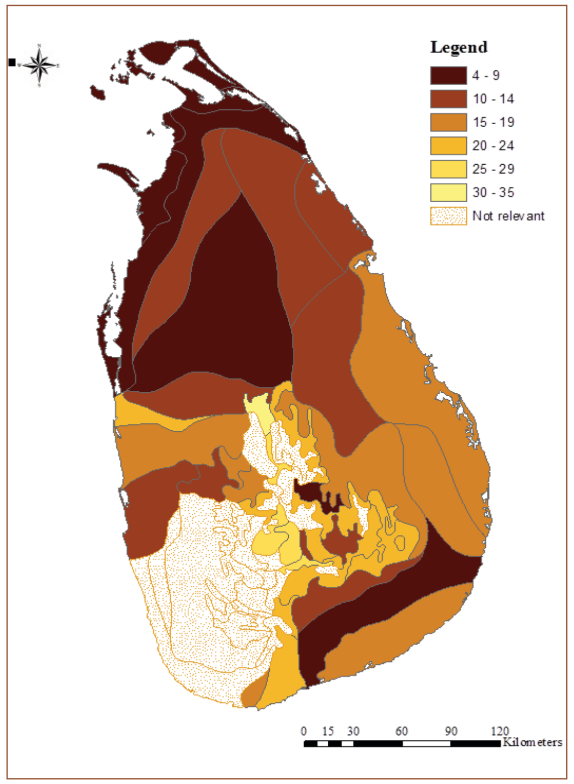

Fig 3.12: Lowest average rainfall where rainfall is less than 30 mm in consecutive months

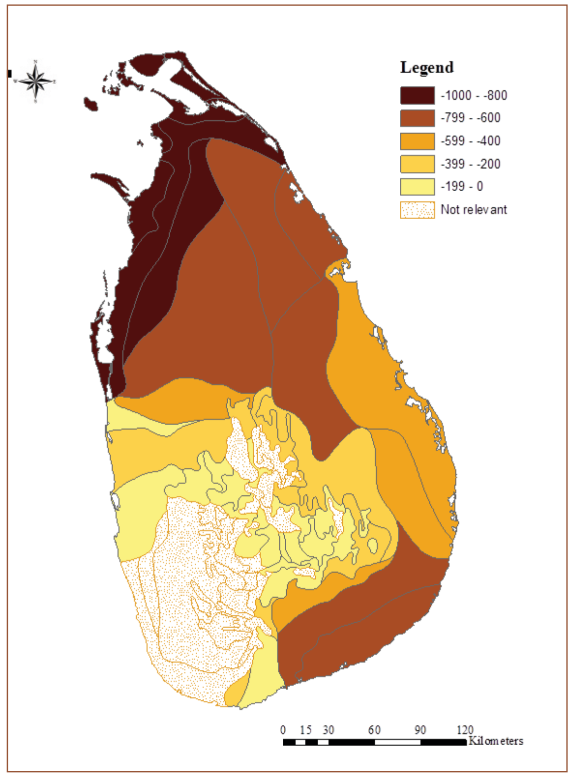

Fig 3.13: Total deficit rainfall less than 30 mm

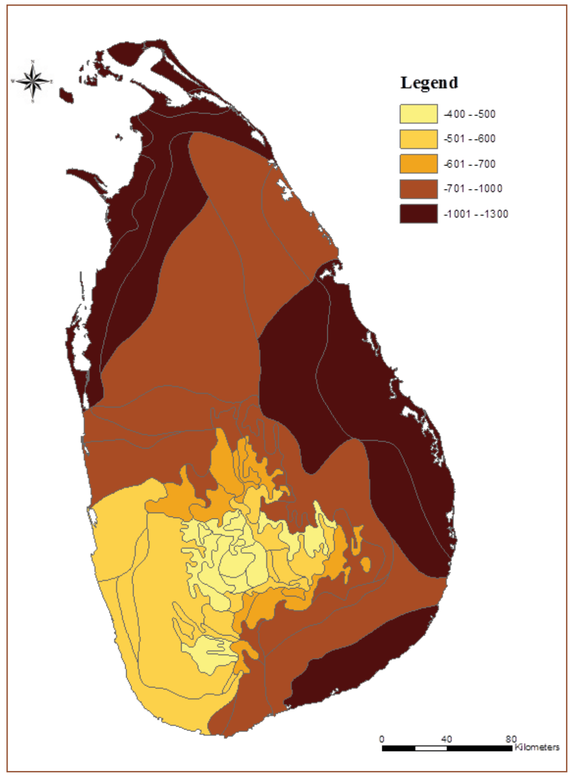

Fig 3.14: Mean annual daily deficit in mm

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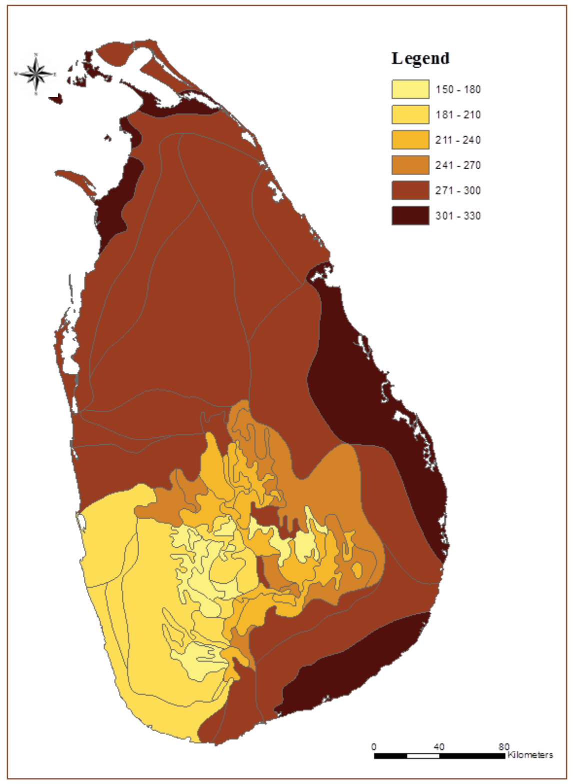

Fig 3.15: Mean annual non rainy days

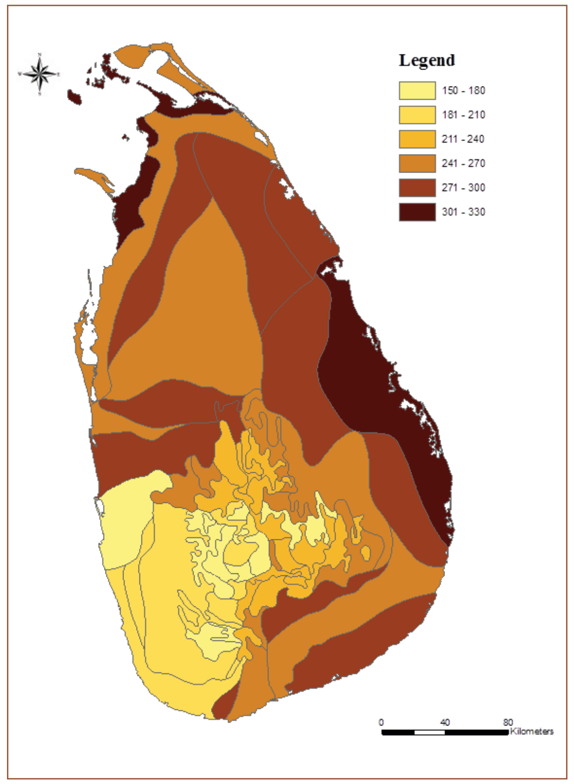

Fig 3.16: Mean number of days per year where rainfall is less than or equal 1mm

3.3.3 Factor Analysis for Hazard Assessment

As per the factor analysis carried out for Z values of all 14 variables using SPSS software, it was found that 76% of total variance could be explained by only using index 1, the Total rainfall deficit per year. Another 14% of the total variance was explained by the index 2, the highest total consecutive deficit. As 90% of the total variance is explained by these two indices, all 14 indices were categorized in to two factors as factor 1 and factor 2 using Principal Component Analysis. Accordingly, it was observed that index 9 and 10 come under factor 2 while the rest of indices remain with factor 1. Table 3.2 summarizes the results of principal component analysis. Using the loading for each factor, the final hazard index with five categories was derived for all AE zones (Fig 3.17).

3.4 Hazard Profile

The output drought hazard map is illustrated in Fig 3.17. This map was produced by considering the drought broadly as a hydro-meteorological hazard using time series of rainfall and evapotranspiration data. Therefore this map could be used as a baseline guide for identifying drought areas for planning mitigatory activities for drought prone areas.

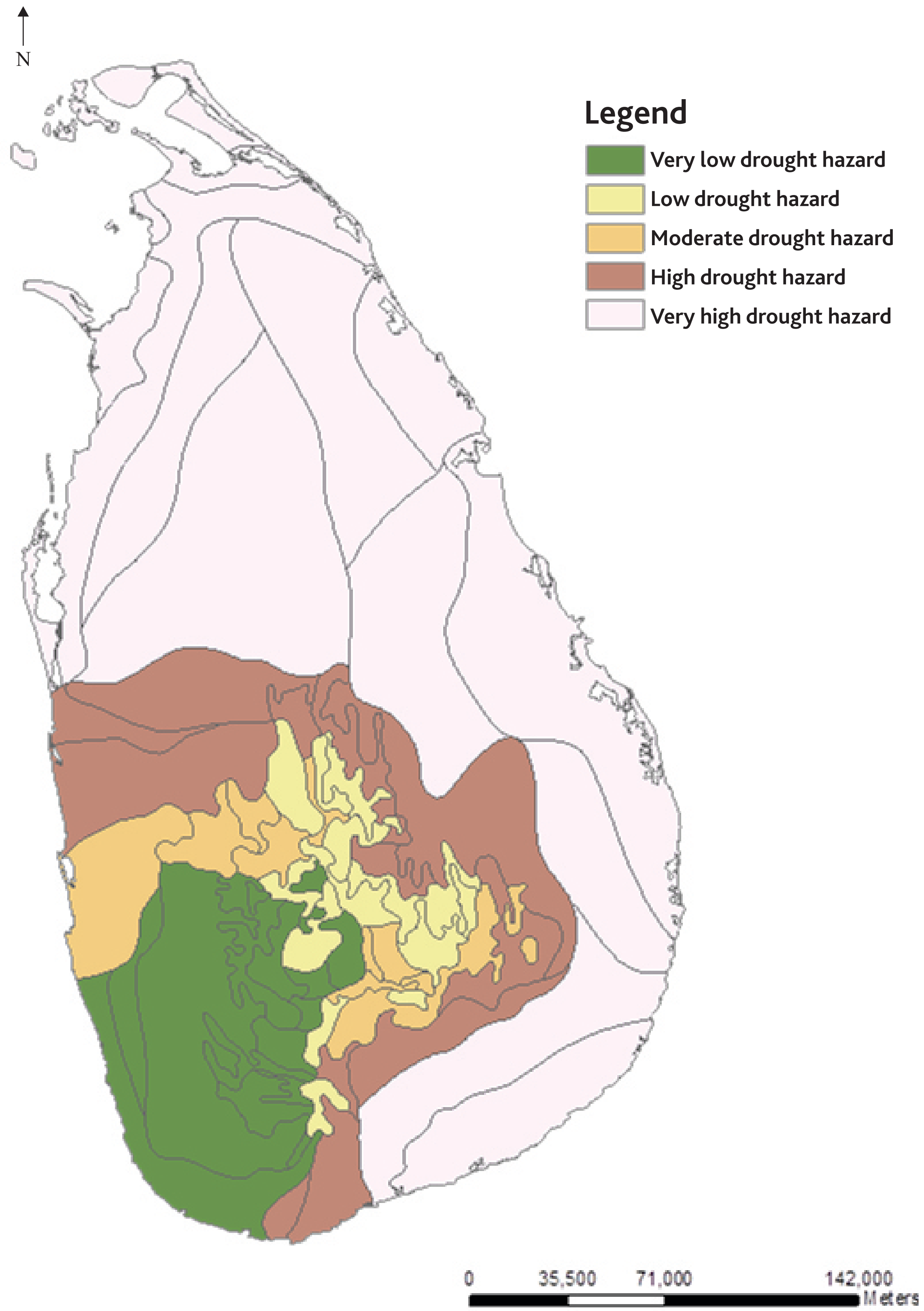

Fig 3.17: Drought hazard map of Sri Lanka

It is observed that all 11 AERs in the Dry zone of Sri Lanka posses 'Very High' degree of drought hazard while all 20 AERs in the Intermediate zone of Sri Lanka posses either 'Moderate' or 'High' degree of drought hazard. The 15 AERs found in the Wet zone of Sri Lanka posses either Very low or Low degree of drought hazard. The results are in agreement with a previous attempt of identifying agricultural drought in Sri Lanka (Chitranayana and Punyawardena, 2008).

Table 3.2 : Results of principal component analysis

Index	Component	
	1	2
Index 1	.979	-.116
Index 2	.954	-.134
Index 3	.911	-.020
Index 4	.922	-.073
Index 5	.947	.018
Index 6	.963	.045
Index 7	.945	-.017
Index 8	.922	.102
Index 9	.290	.954
Index 10	.255	.964
Index 11	.943	-.144
Index 12	.944	-.148
Index 13	.868	-.055
Index 14	.894	-.013

3.5 Conclusion

This study has attempted to construct and present an index of drought hazard in Sri Lanka using 14 indices derived from daily and monthly time series of rainfall and potential evaporation data. The results indicate that all 11 AERs in the Dry zone of Sri Lanka posses Very high degree of drought hazard while all 20 AERs in the Intermediate zone of Sri Lanka posses either Moderate or High degree of drought hazard. The 15 AERs found in the Wet zone of Sri Lanka posses either Very low or Low degree of drought hazard. As demand for water resources increases as a result of population growth and economic development, future droughts can be expected to produce greater impacts, with or without any increase in the frequency and intensity of meteorological drought.

3.6 Recommendations

General policy recommendations can be drawn from this study are as follows: Existing systematic spatial differences of drought hazard across three major climatic zones of Sri Lanka enables policy makers to formulate their broader drought management strategies on climatic zone wise while sub-activities at village level to be tailored assuring sustainable use of land and water resources of respective villages.

Secondly, due to the fact of the entire Dry zone of Sri Lanka is prone to Very high to High degree of drought hazard, it should be placed as a high priority area with drought mitigation plans within the broader developmental context or in other word it should be mainstreamed in to the national development agenda. An effective way to do this would be to integrate adaptation measures into

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sustainable development strategies, thereby reducing the pressure on natural resources, improving environmental risk management, and increasing the social well being of the poor.

Finally, policy makers and scientists should join hand together to develop more accurate drought early warning system as well as appropriate relief programms and agricultural insurance scheme.

3.7 Limitations

Present study was conducted to prepare the drought hazard map considering it broadly as a hydro-meteorological hazard using time series of rainfall and evapotranspiration data only. Therefore a detailed study considering other factors contributing to drought is needed in order to produce a series of maps with finer resolution to identify the drought hazard to use in future systematic planning. Present chapter is a baseline study to initiate such an analysis.

3.8 References

Chitranayana, R.D. and B.V.R. Punyawardena, (2008): Identification of drought prone agro-ecological regions in Sri Lanka. Journal of National Science Foundation of Sri Lanka. 36(2): 117-23.

Jayamaha, G.S.(1975): An analysis of droughts in Sri Lanka. Department of Meteorology. Sri Lanka

Punyawardena, B.V.R.(2007): Agro-ecology, (Map & accompanying text), National Atlas of Sri Lanka. Second edition. Department of Survey, Colombo, Sri Lanka.

Wilhite, D.A. and Svoboda, M.D. (200): Drought Early Warning Systems in the Context of Drought Preparedness and Mitigation. In: Early Warning Systems for Drought Preparedness and Management. Proceedings of an Expert Group Meeting, 5-7 September 2000, Lisbon, Portugal.

UNISDR (2009):. Drought Risk Reduction, Framework and Practices: Contributing to the Implementation of the Hyogo Framework of Action. Geneva: UNISDR.