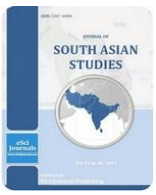

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OCCURRENCES OF FLOOD HAZARDS IN THE NORTHERN REGION OF SRI LANKA

[a]Piratheeparajah Nagamuthu*, [b]Kandiah Rajendram
[a] *Department of Geography, University of Jaffna, Jaffna, Sri Lanka.*
[b]*Department of Geography, Eastern University, Vantharumoolai, Chenkalady, Sri Lanka.*

A B S T R A C T

According to the report of the disaster management center, during the last forty years from 1974 to 2014, country faced flood impact several times (48.5%). Every year at least one of the areas of Sri Lanka faces flood impact due to heavy rainfall. Northern Province of Sri Lanka faces many challenges caused by flood frequently. The main objective of this study is to analyze the spatial and seasonal pattern of the flood occurrences in the Northern Province of Sri Lanka. Primary and secondary data were helped to conduct this study. Climatic data for thirteen stations of the Northern Province of Sri Lanka were obtained from the Department of Meteorology for the forty years period. To study the flood occurrences, rainfall data were analyzed using the Standardized Precipitation Index (SPI) and the SPI results mapped using the ArcGIS 9.2 version. According to the SPI analysis, flood years identified are 1979, 1984, 1993, 2004, 2006, 2008, 2011 and 2012. During the first inter monsoon season flood was identified in 1988, 2001, 2002 and 2006. During the second inter monsoon season flood was identified in 1977, 1979, 1981, 1993, 2004, 2005 and 2011. Compared to other seasons North East Monsoon Season has the highest number of flood occurrences. During this season, flood was identified in 1983, 1984, 1993, 1998, 2000, 2001, 2011 and 2012. During the North East Monsoon Season of 1984, extreme flood identified, in all stations of the Northern province of Sri Lanka, and the SPI index of all stations indicated it by scale above 2.00. South West Monsoon Season has the lowest number of flood occurrences and its severity is also low. Spatially, maximum number of flood was identified in kanukerny, Iranaimadu and Pavatkulam.

Keywords: Flood, Northern Province, Rainfall, Seasons, Spatial, Sri Lanka, Standardized Precipitation Index.

INTRODUCTION

Climatic hazards are the major problems in the world. All parts of the world face many threats due to the climatic hazards. But it must be admitted that no climatic hazard affects a country in a national scale. Certain types of climatic hazards do have their impacts spatially. But in the tropical areas, the impact of drought, flood and cyclones have been felt rather heavily. Sri Lanka is one of such tropical countries to have had widespread experiences on account of the above types of climatic hazards. The Northern Region of Sri Lanka has suffered a lot due to droughts and floods. According to the disaster history of the Northern Region of Sri Lanka, except for the tsunami of 2004, all other disasters are related to climate. Due to this, identifications and studies about the drought and flood hazards are vital to the future development and the planning activities of the Northern Region of Sri Lanka.

Following introduction of the recent climatic change phenomena, the people from all sectors in the world have become vigilant to these climatic hazards. Climatic factors of the Northern Region of Sri Lanka influence every aspect of the livelihoods of the people living in this region. There are some records of climatic hazards having their impacts on all parts of the Northern Region for quite a long period. The Northern region of Sri Lanka faces many challenges from Climatic hazards such as flood and drought due to its geographical set up and climate.

This chapter elaborates the drought and flood hazard occurrences during the last forty-two years from 1972 to 2012, based on the Standardized Precipitation Index (SPI) values. It describes the flood and drought hazards,

* Corresponding Author:
Email: npiratheeparajah@gmail.com

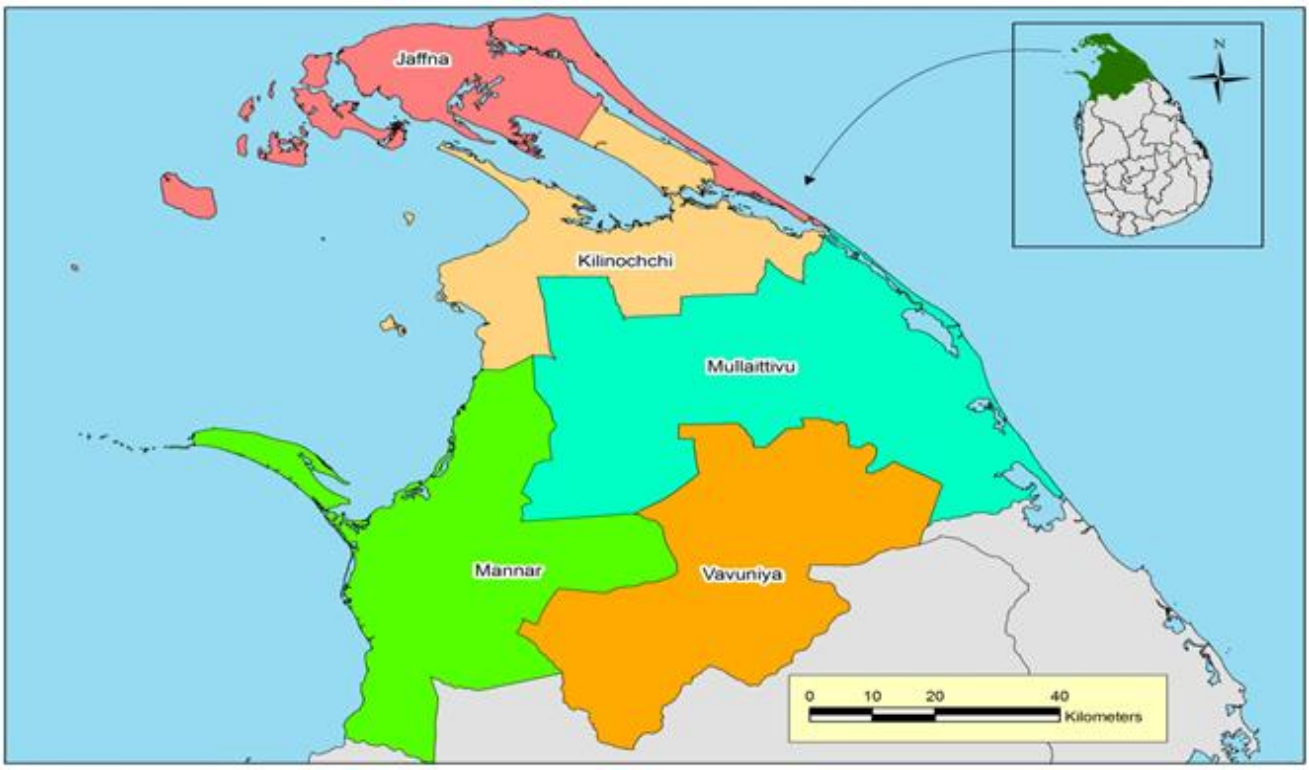
according to the scales of the SPI values. It also describes the spatial and temporal patterns of the flood and drought hazard occurrences in the study area. Thereby, terms like Flood years, Flood seasons and Flood months, Drought Years, Drought Seasons and Drought months have been identified. Based on the SPI Classifications, severity of floods and droughts such as extreme flood, severe flood, normal flood, extreme drought, severe drought and normal drought have been identified. This chapter explains the spatial and temporal patterns of the flood and drought hazards in the Northern Region of Sri Lanka during the forty years from 1972 to 2012.

Study Area: The study area for this research is the Northern Province of Sri Lanka. It is located in the northern most part of Sri Lanka. The northern boundary of the Northern Region is the Palk Strait, while in the east it is bounded by the Bay of Bengal. The Southern and Western boundaries are the North Central province and the Arabic sea respectively.

Administratively the Northern region has been divided into 5 Administrative Districts, 34 DS Divisions, 921 GN Divisions. For the purpose of Local Governance the region has been divided into one Municipal Council, 5 Urban Councils and 29 Pradeshiya Sabhas. The Northern Province has a total area of 8,848.58 sq kms (see table 1).

Table 1. Area of the Northern Region.

District	Total Area		Land Area		Inland Water	
	Sq.Km	Percent	Sq.Km	Percent	Sq.Km	Percent
Northern	8847.98	*100.00*	8596.61	*100.00*	*251.30*	*100.00*
Mullaitivu	2616.90	29.58	2516.90	29.28	100.00	39.79
Vavuniya	1966.90	22.23	1966.90	22.88	0.00	0.00
Mannar	2002.07	22.63	1991.00	23.16	11.00	4.38
Kilinochchi	1237.11	13.98	1192.81	13.88	44.30	17.63
Jaffna	1025.00	11.58	929.00	10.81	96.00	38.20



Source: Planning Branch, NPC, 2013.

Figure1.Map of the Northern Region.

OBJECTIVES

Objectives are as follows;

The first objective of this study is to identify the flood hazards during last four decades in the study area Second objective of this study is to analyze the severity of the flood hazards in the study area.

METHODOLOGY

Data: Various types of data ranging from primary to secondary have been used immensely in this research.

Primary data were collected using two methods such as interviews and discussions and direct observations. According to the objectives, the primary data were to help identify the economic impacts of the climatic hazards in the Northern Region of Sri Lanka.

Primary Data: Primary data to a great extent helped this study particularly to identify the trends and patterns of floods.

a) Interviews and Discussions: Interviews and discussions regarding such matters as the identification of flood level, flood impacts, flood patterns, flood prone areas, were held with the people who are living and working in the Northern Region. 100 samples from each district (totally 500 in the Northern Region) were collected during the interviews and discussions were held on the basis of stratified sampling method. In the 100 samples 50 from agricultural sector, 20 from fisheries sector, 10 from small-scale industries, 10 from commercial activities, and another 10 from other sectors in each district in the Northern Region (Table 2). During the selection of samples for the interviews, much priority was given to the most vulnerable areas of every district based on the data regarding the flood hazard impacts during the year 2012. Ten (10) samples collected from following each location for the interviews and discussions for this study. Unstructured questions were asked from that interviewee, based on the objectives of this study. In addition, to the identification of the economic impacts due to climatic hazards, some interviews were also held with the Government and Non-Government officers who are responsible for the economic activities of each district. A maximum of ten officers were selected for such interviews from each district. Altogether 50 samples were selected from these categories. All these interviews helped to elicit the qualitative information regarding the climatic hazards and their impacts on the economy of the Northern Province of Sri Lanka.

Table 2. Samples collected locations.

No.	Sample Location	No.	Sample Location
1	Thirunelvely	26	Muththaiyankaddu (Right)
2	Kopay	27	Kanukkerny
3	Karaveddy	28	Mullaitivu
4	Chunnakam	29	Mankulam
5	Kodikamam	30	Puthukkudiyiruppu
6	Punkuduthivu	31	Nedunkerny
7	Velanai	32	Kanakarayankulam
8	Uduppiddi	33	Omanthai
9	Sandilippai	34	Thandikkulam
10	Alaveddi	35	Pavtkulam
11	Akkarayankulam	36	Puliyankulam
12	Uruththirapuram	37	Thavasikulam
13	Murasumoddai	38	Vavuniya Town
14	Kandavalai	39	Cheddikulam
15	Tharmapuram	40	Nelukkulam
16	Vaddakachchi	41	Iluppaikkadavai
17	Thiruvaiyaru	42	Murunkan
18	Paranthan	43	Andankulam
19	Poonarin	44	Madhu
20	Skanthapuram	45	Nanaddan
21	Thunukkai	46	Uyilankulam
22	Pandiyankulam	47	Mannar
23	Oddusuddan	48	Thevanpiddi
24	Udaiyarkaddu	49	Peaslai
25	Muththaiyankaddu (Left)	50	Musali

b) Direct Observations: Direct observation was also one of the methods used in collecting primary data. This method helped to observe the flood events and their impacts; direct observations were made during the North East monsoon period of the year 2013. Direct observations helped to take photos and collect information. During the direct observations, interviews and discussions were also held.

c) Secondary Data: Secondary data also helped to identify the climatic hazards and their impacts on the economy of the Northern Province. Sources from the Departments mentioned in the following paragraph were used to obtain the necessary secondary data. Such secondary data can be classified into two types, based on the objectives of this study, those related to the climatic hazards, and those related to the economic impacts of climatic hazards.

Secondary data related to climatic hazards in the Northern Province of Sri Lanka, were obtained from the meteorological data kept at the Meteorological Department. Basic secondary data required for the study were collected from the Meteorological Department of Sri Lanka in Colombo. Data was collected for thirteen stations including Akkarayankulam, Ambalapperumal Kulam, Iranaimadhu, Thirunelveli, Kanukkerni, Karukkaikkulam, Murunkan, MuththaiyanKaddu, Nainathivu, Pavatkulam, Kariyalai Nagapaduvan, Thandikkulam, Vavuniya, and Vavunikkulam from 1972 to 2012. Data related to Temperature (Monthly Average, Monthly Maximum, and Monthly minimum), Rainfall (Monthly Total, and Annual Total), Relative Humidity, Atmospheric Pressure, and Wind velocity, Wind Direction, and Evaporation were obtained from the Meteorological Department.

Statistical Abstracts of the National Statistical and Information Department: Statistical Abstracts of this department for the period from 1970 to 2010 also served as secondary data. Information and statistics from the statistical abstracts related to the weather and climate of the five districts, in addition to agriculture, Fisheries, Industries and service sectors within the study area for thirty years were collected as secondary data. *Reports, Press Statements, Annual Symposium Proceedings and other Publications of the Disaster Management Centre:* This is an important source of secondary data to identify the natural disaster profile of the country and the impacts of the natural hazards and the mitigation measures adopted by the Ministry of Disaster management

d) Methods of Data Analysis: The second objective is to study the drought and flood hazard occurrences in the study area. To achieve this second objective, thirteen stations were selected on the basis of the availability of complete data and spatial distributions of meteorological/rainfall stations in the Northern Province. Monthly rainfall data were collected for each station from 1972 to 2012 to study the climatic hazards in the study area.

Based on the second objective, to study the occurrence of the drought and flood hazards, rainfall data of selected thirteen stations were analyzed using the Standardized Precipitation Index (SPI)

Meteorologist and Climatologist have developed various drought indices to study the drought and flood in past. Types of indices vary from simple indices to complicate. American scientists have simplified the indices to be simple and easy to calculate, which are more appropriate and sensible. Based on these concepts, in 1993, American scientists McKee, Doesken and Kleist developed the Standardized Precipitation Index (SPI).

The SPI is a very effective index that is simple to calculate. In fact, precipitation is the only required input parameter. SPI can be used to study the drought and flood (Edward and McKee, 1997). Ideally, one need at least 20-30 years of monthly values, with 50-60 years (or more) being optimal and preferred (WMO, 2012). The strength of this method, precipitation, is the only input parameters. The SPI could be used for various time intervals, provide early forecasting of drought and flood and assisted to measure the drought and flood severity.

Edward and McKee (1997) stated "The SPI can be calculated for any location which is based on the long term precipitation record for a desired period such as 1 month, 3 month, 6 month, 9 month, 12 month, 24 month, 48 month and 72 month. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period remain zero" (Edward et.al, 1997).

According to Edwards and McKee, a gamma probability density function to a given frequency distribution of precipitation totals for the station of interest is fitted as

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{\frac{-x}{\beta}} \quad \text{For } x > 0$$

Where α is a shape parameter $(\alpha > 0), \beta$ is a scale value for calculation $(\beta > 0), x$ is the precipitation amount $(x > 0)$ (Edward and Mckee, 1997) and

$$\Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y} dy$$

Where gamma function is $\Gamma(\alpha)$ (LuxinZhai QiFeng, 2009).

Then the shape parameter α and the scale parameter β are estimated for each time scale of interest (either weeks or months) and for each week or month of the year, depending on whether the weekly or monthly SPI is calculated:

$$\hat{\alpha} = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$\hat{\beta} = \frac{\bar{x}}{\hat{\alpha}}$$

"Where $A = \ln(\bar{x}) - [\sum \ln(x)]/n, n$ is number of precipitation observations, and $\bar{x}$ is mean precipitation over the time scale of interest. The cumulative probability of each observed precipitation event for the given time scale for the station of interest is then computed using the estimated shape and scale parameters. An equiprobability transformation is made from the cumulative probability to the standard normal random variable Z with mean zero and variance of one, where the SPI takes on the value of Z" (Hong Wu et.al., 2005).

Lower than median precipitation denoted by values in negative SPI and higher than the median precipitation is denoted by positive values in SPI.

Table 3. Values of SIP.

Table SPI Values	Category
Over 2.0	Extreme Flood
1.5 to 1.99	Severe Flood
1.0 to 1.49	Flood
-0.99 to 0.99	Neutral
-1.0 to -1.49	Drought
-1.50 to -1.99	Severe Drought
Below -2	Extreme Drought

Source: WMO, 2012.

For SPI analysis in this study, monthly rainfall data of the selected thirteen stations such Akkarayankulam, Ambalappermalkulam, Iranaimadu, Muththiayankaddu, Murungan, Kanukkerny, Thirunelvely, Nainathivu, Pallavarayankaddu, Karukkaikulam, Vavunikulam, Pavatkulam and Vavuniya have been computed using the SPI method. To obtain the annual SPI 12 months rainfall data, the First Inter Monsoon Seasonal (FIMS) SPI, 02 months rainfall data (March and April), the Second Inter Monsoon Seasonal SPI, 02 months rainfall data (October and November the North East Monsoon Seasonal SPI and 03 months rainfall data (December, January and February) and to obtain the South West Monsoon Seasonal SPI, 05 months rainfall data (May, June, July, August and September) have been analyzed adopting the Standardized Precipitation Index (SPI). The data of the missing months of some stations have been added from very nearest stations of the study area. The SPI results have been mapped using the Kriging method of the ARC GIS, 9.2 versions.

Spatially there are variations in the occurrence of droughts and floods of the study area. Some areas have a greater amount of drought and flood while other areas have a lesser amount of drought and flood. Nevertheless they undergo variations annually and seasonally. There are some variations in the annual drought and flood situations in every station.

RESULTS

Results of the aforesaid calculations are as follows;

Flood Years in the Northern Region of Sri Lanka: Forty-two years' continuous rainfall data of the thirteen stations in the Northern Region of Sri Lanka have been analyzed using the SPI method to identify the flood and drought hazards. According to the results of the SPI, 12 months' SPI indicates the various magnitudes of floods during different years, in the Northern Region of Sri Lanka. According to the 12 months (annual) SPI, the following years have been identified as flood years in the Northern Region of Sri Lanka, during the years of 1979, 1984, 1993, 2004, 2006, 2008 and 2011 many stations of the Northern Region of Sri Lanka, have experienced flood.

In 1979 Extreme Floods have occurred in Karukkaikulam and Ampalapperumal Kulam of which the SPI scales are 4.33 and 2.35 respectively, severe flood has occurred in Vavuniya (SPI 1.66) and flood was identified in the Vavunikkulam Station of which the SPI scale is 1.36, In this year SPI indicates that the other stations are very normal (Table 4).

Table 4. SPI Variations of the Northern Region of Sri Lanka in 1979.

Stations	1979	Categories
Pavatkulam	0.95	Normal Year
Vavunikkulam	1.36	Flood
Thirunelvely	0.42	Normal Year
Pallavarayan	0.80	Normal Year
Nainathivu	0.76	Normal Year
Muththaiyan	0.52	Normal Year
Murungan	0.48	Normal Year
Karukkaikulam	4.33	Extreme flood
Kanukkerny	0.97	Normal Year
Iranaimadu	0.48	Normal Year
Ampalapperumalkulam	2.35	Extreme flood
Akkarayankulam	-0.05	Normal Year
Vavuniya	1.66	Severe flood

According to the flood history of the Northern Region of Sri Lanka, 1984 is an abnormal year. During this year, in all thirteen stations of the Northern Region of Sri Lanka, SPI index is shown above flood level (Figure 2). The table 5 indicates the stations and the SPI in the year of 1984.

Table 5. SPI Variations of the Northern Region of Sri Lanka in 1984.

Stations	SPI	Types of Flood
Pavatkulam	1.18	Flood
Vavunikkulam	2.83	Extreme Flood
Thirunelvely	1.56	Severe Flood
Pallavarayan	2.57	Extreme Flood
Nainathivu	3.45	Extreme Flood
Muththaiyan	1.93	Severe Flood
Murungan	1.73	Severe Flood
Karukkaikulam	1.86	Severe Flood
Kanukkerny	3.34	Extreme Flood
Iranaimadu	2.55	Extreme Flood
Ampalapperumal	2.13	Extreme Flood
Akkarayankulam	2.50	Extreme Flood
Vavuniya	1.83	Severe Flood

During this year all parts of the Northern Region had experience flood. When the rainfall records were checked for the Northern Region in 1984, they also revealed the heavy rainfall recorded during that particular year in the study area. The highest rainfall for one week in the Northern Region of Sri Lanka has been recorded in Mullaitivu during this year.

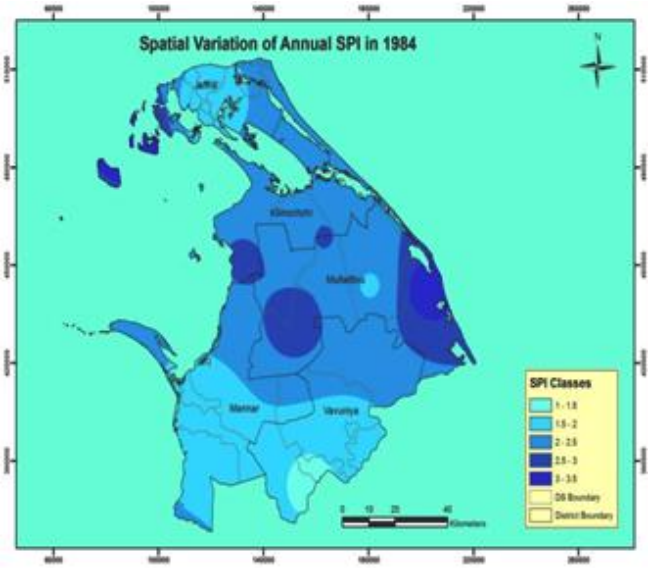


Figure 2. SPI index of 13 stations of the Northern Region of Sri Lanka.

The year 1993 is also identified as one of the Flood years in the Northern Region of Sri Lanka (Figure 3). During this year SPI of the some stations indicates well above from the normal. During this year, all stations of the Mullaitivu District show the various scales of flood while Akkarayankulam, Thirunelvely and Murungan stations also indicate the flood scale SPI. The SPI of the other stations of the Northern Region of Sri Lanka is near normal. The year 2004 is also identified as flood year in the Northern region of Sri Lanka. However, very few stations such as Nainathivu, Pallavarayankattu and Muththaiyankattu have records near normal SPI during this year.

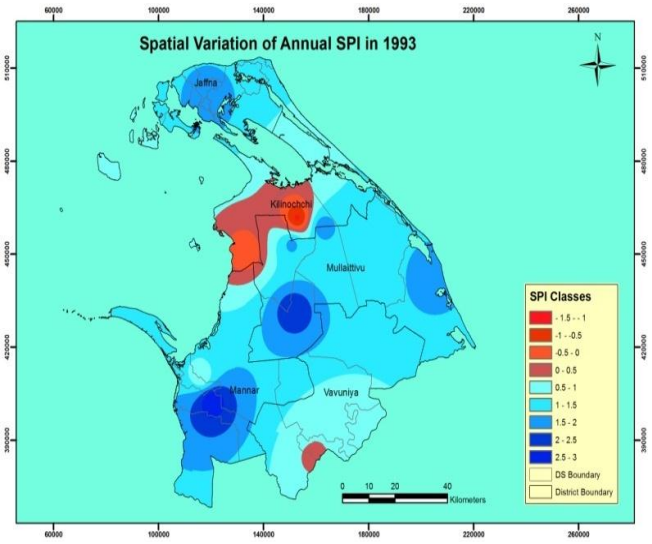


Figure 3. SPI index of one flood in Northern Region of Sri Lanka.

In the year of 2008, some stations have been identified as flood in the Northern Region of Sri Lanka and their SPI is over 1.00, while in the others the SPI is below -1.00. But 70% of the Stations have flood scale SPI. If we look into the spatial variations of the annual (12 month) SPI, the central part stations of the Northern Regions such as Pallavarayankaddu, Iranaimadu and Ampalapperumalkulam may seem to have drought SPI. But the SPI of the Southern, Northern, and Eastern stations of the Northern Region are over 1.00, whereby various scales of floods are shown. 2011 was an absolute flood year, because, SPI of many stations in the Northern Region was over 1.00. During this year all central stations of the study area had various magnitudes of flood impacts (Table 6).

Table 6. SPI Variations of the Northern Region of Sri Lanka in 2011.

	Stations	SPI	Scales of Flood
1	Pavatkulam	1.26	Flood
2	Vavunikkulam	1.32	Flood
3	Thirunelvely	0.49	Normal Year
4	Pallavarayankaddu	-0.08	Normal Year
5	Nainathivu	0.95	Normal Year
6	Muththaiyankaddu	2.52	Extreme Flood
7	Murungan	-0.08	Normal Year
8	Karukkaikulam	0.29	Normal Year
9	Kanukkerny	1.95	Very Flood
10	Iranaimadu	0.68	Normal Year
11	Ampalapperumal	0.97	Normal Year
12	Akkarayankulam	1.07	Flood
13	Vavuniya	1.64	Very Flood

Floods in the Seasons: details of floods during different seasons are as follows;

a) Floods during the First Inter Monsoon Seasons: There have been instances of floods occurring, during the first inter monsoon season. Extreme floods have been identified during the First Inter Monsoon Season (FIMS) in the years of 1984 and 2008 (Table 7) in all the stations of the Northern Region of Sri Lanka. In 1985, during the FIMS, flood occurred in all the areas of Northern Region of Sri Lanka, but not in the southern part of Northern region where drought was prevailing. Floods have also been identified during the FIMS in the years of 1988 (Figure 4), 2001, 2006 (Figure 5, 6) and 2008 (Figure 7).

Table 7 SPI Variations for Selected Stations during the FIMS in the Northern Region of Sri Lanka

Station	1984	1985	1988	2001	2002	2006	2008
Akkarayankulam	3.76	-0.72	0.44	2.46	0.61	-0.86	1.36
Ampalapperumal	2.85	1.54	0.22	1.72	0.02	0.08	1.44
Iranaimadu	2.00	0.49	1.00	0.36	-0.52	0.21	2.81
Kannukkeny	3.24	-0.7	1.96	-0.33	-0.80	1.83	1.44
Karukkaykulam	2.54	0.31	-0.02	0.61	1.29	1.30	3.05
Murunkan	1.85	-0.22	0.48	1.97	1.54	0.60	4.18
Muththaiyankulam	2.57	-0.47	1.40	1.06	-0.86	1.26	3.03
Nainathivu	4.05	-0.51	-0.51	-0.06	-0.51	0.98	2.97
Pallavarayankaddu	2.22	-0.35	1.36	2.68	2.45	0.17	-0.98
Pavatkulam	0.75	-1.05	0.77	-0.03	0.56	-0.02	3.49
Thirunelvely	-0.05	-0.46	0.79	0.35	0.31	-0.66	2.87
Vavunikkulam	3.70	-0.46	1.18	0.48	0.54	1.19	1.84
Vavuniya	3.43	-1.05	0.59	0.77	0.54	0.35	1.43

During the First Inter Monsoon Season (FIMS) there are some flood situations identified in the study area using the SPI analysis. During this season, study area is under the influence of the Inter Tropical Convergence Zone (ITCZ). Movement of the ITCZ and the cold air masses from the Bay of Bengal are the major reasons for the heavy rainfall and the flood vulnerability of the study area during the FIMS. This heavy rainfall is within a short period in the study area and creates flood vulnerability. Due to it, SPI of the FIMS is in flood level in some months and normal level in some months and drought is rare in the study area.

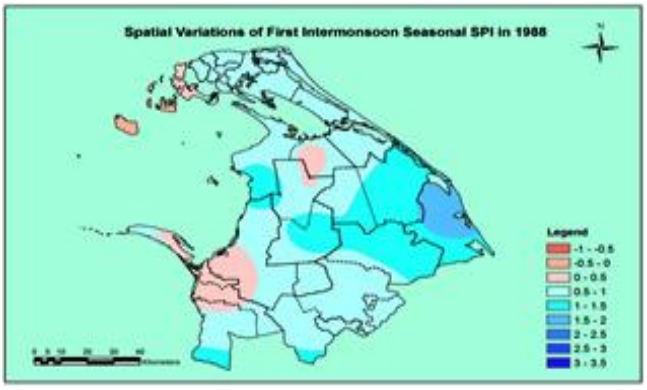
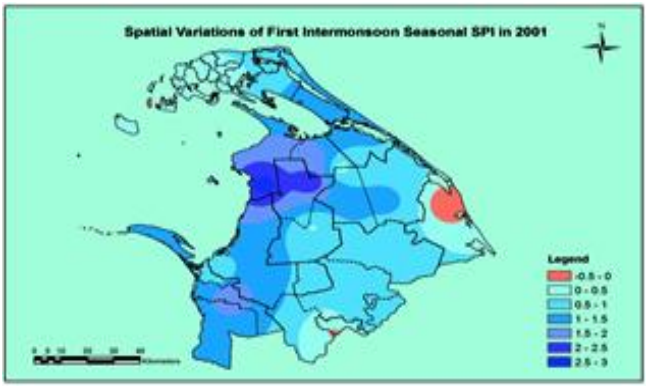


Figure 4.



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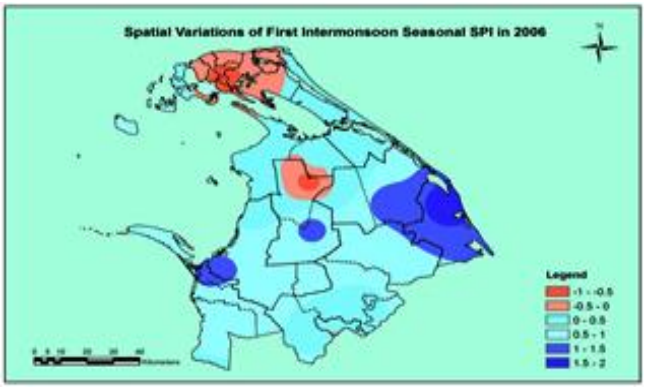

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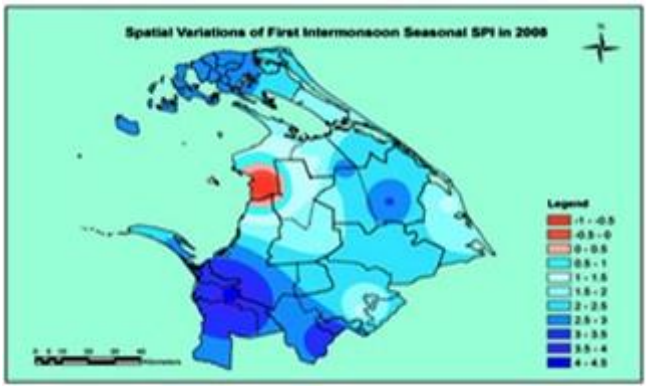

Figure 6.

Figure 4, 5, 6, & 7 show the First Inter Monsoon Season (FIMS).

Floods During the Second Inter Monsoon Season (SIMS): Floods occurred during the second Inter monsoon (SIMS) periods of the years 1977 (Figure 9), 1979 (10), 1981 (Figure 10), 1993 (Figure 8) 2004 (Figure 12) and 2005 (Figure 13). This is the season during which average rainfall is received in all stations in the study area. If the rainfall considerably exceeds the average, it has to be reckoned as flood. This is also the period identified as the Cyclonic Season in Sri Lanka. Much rainfall is received on account of the depressions formed in the Bay of Bengal (Thambyahpillai, 1960). This is also the season, which has the months of maximum rainfall in the Northern Region of Sri Lanka. During certain years SPI of the most of the stations in this season has been above 1.00.

Table 8. SIMS SPI for the Selected Stations in the Northern Region of Sri Lanka.

Station	1977	1979	1981	1993	2005	2011
Akkarayankulam	0.12	0.44	1.60	1.50	0.78	1.03
Ampalapperumal	0.72	3.14	1.42	1.38	1.22	1.16
Iranaimadu	1.28	0.85	2.91	1.39	1.17	0.74
Kannukkeny	0.89	1.81	1.37	2.35	1.69	1.43
Karukkaikulam	1.26	1.06	0.14	0.86	1.12	1.17
Murunkan	1.45	1.04	0.16	3.50	0.15	0.54
Muththaiyankaddu	0.93	1.07	0.63	0.81	1.50	1.54
Nainathivu	0.79	1.36	1.53	1.19	0.85	1.59
Pallavarayankaddu	1.60	1.61	0.40	0.14	1.05	0.65
Pavatkulam	1.55	1.97	0.56	0.73	0.34	1.57
Thirunelvely	1.65	0.82	1.01	1.71	0.05	0.82
Vavunikkulam	1.10	1.53	1.08	2.32	1.85	0.87
Vavuniya	1.34	2.41	0.24	0.56	0.08	0.89

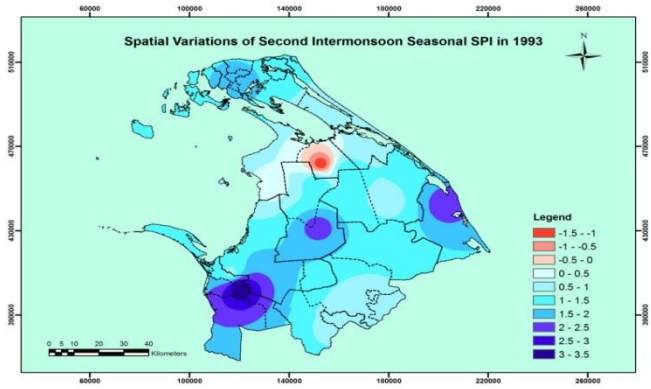

Figure. 8

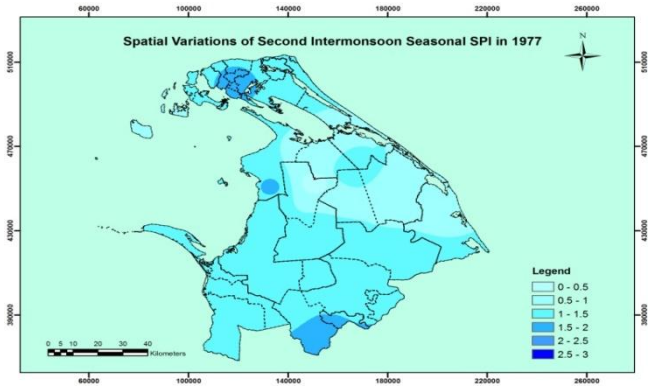

Figure. 9

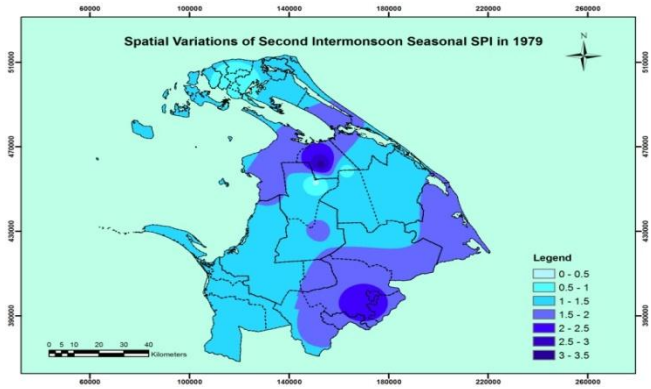

Figure. 10

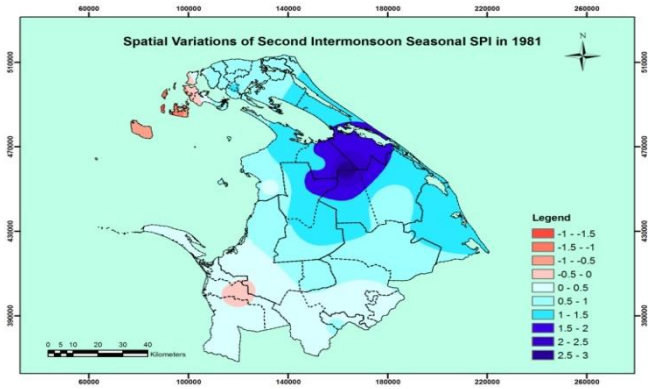

Figure. 11

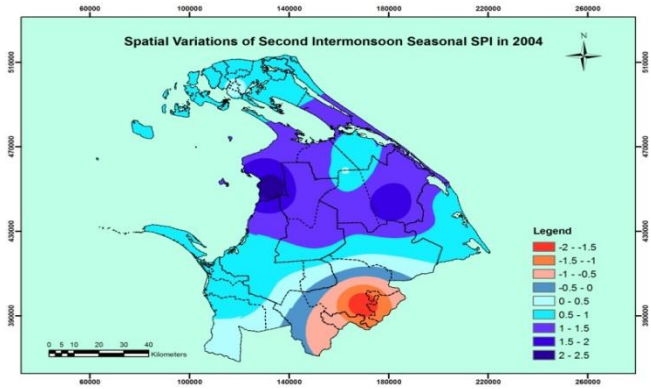

Figure. 12

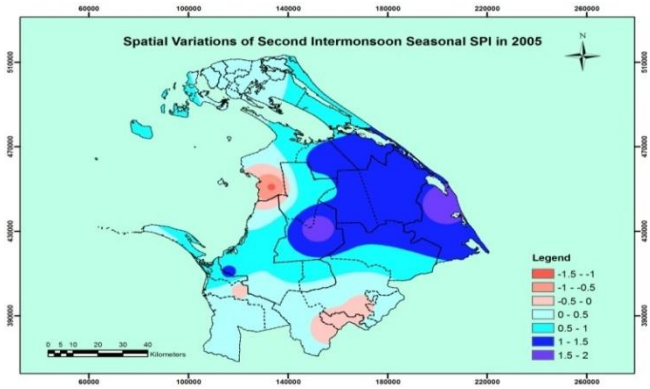

Figure. 13

Figures 8, 9, 10, 11, 12 & 13. show Second Inter Monsoon Season in different years.

Floods during the North East Monsoon Season (NEMS): North East Monsoon season is a very important season, because a number of severe floods and extreme floods in the study area occur during this season. Thus, floods during North East Monsoon season have been identified during the years of 1983 (Figure 16), 1984 (Figure 17), 1993 (Figure 15), 2001 (Figure 18) and 2011 (Figure 19) there is a chronological order in the occurrence of flood during the NEMS in the study area because these floods have occurred continuously for two years at particular intervals. For example 1983-1984, 2000-2001 and 2011-2012 (Table 9). In 1983 Normal and moderate floods occurred in many stations. Except Akkarayankulam, Nainathivu and Pallavarayankaddu, floods in the study area have affected all the other stations. During the year of 1984 extreme floods occurred in all areas of the Northern Region of Sri Lanka. According to the SPI values highest +SPI was recorded in these seasons in all the stations during 1984. All stations of the Northern Region were affected due to flood. Excess rainfall is the major cause for the floods in the study area. News items from the newspapers, pertaining

to this period also indicate the impacts of the floods on the North East Monsoon Season in 1984. Some stations such as Karukkaikulam, Murungan, Muththaiyankaddu, Pavatkulam, and Vavuniya have been affected due to floods that occurred during the NEMS in the study area in 2012. Interviews and Direct observations under this research also confirmed the flood impact in the year of 2012 in selected stations.

Table 9. SPI for the Selected Stations during the NEMS of the Northern Region

Station	1983	1984	Magnitude Of Flood	1993	1998	2000	2001	2011	2012
Akkarayankulam	0.82	2.62	Extreme	1.34	2.26	0.32	2.49	1.10	-0.25
Ampalapperumal	1.68	2.01	Extreme	-0.05	1.56	0.22	1.20	1.03	-0.46
Iranaimadu	1.05	3.48	Extreme	1.24	1.50	0.24	1.03	-0.06	-1.34
Kannukkeny	1.49	4.04	Extreme	0.79	-0.07	-0.51	0.37	1.84	0.85
Karukkaykulam	1.58	2.00	Extreme	1.25	1.21	1.41	1.45	-0.03	1.18
Murunkan	1.89	2.38	Extreme	2.30	1.85	1.42	0.99	-0.18	1.24
Muththaiyankaddu	1.28	2.67	Extreme	1.71	0.50	-0.34	1.64	2.42	1.50
Nainathivu	-0.90	4.42	Extreme	0.86	1.57	0.28	0.43	0.58	-0.90
Pallavarayankaddu	0.50	2.31	Extreme	-0.05	3.03	0.05	2.38	0.09	-0.29
Pavatkulam	1.97	2.64	Extreme	0.81	0.76	1.22	0.46	1.06	2.67
Thirunelvely	1.20	2.87	Extreme	1.90	2.30	0.23	1.01	0.13	-0.50
Vavunikkulam	1.55	2.77	Extreme	1.91	0.90	0.47	1.38	1.68	0.65
Vavuniya	1.18	1.80	Severe	0.72	1.65	1.64	0.55	2.38	1.53

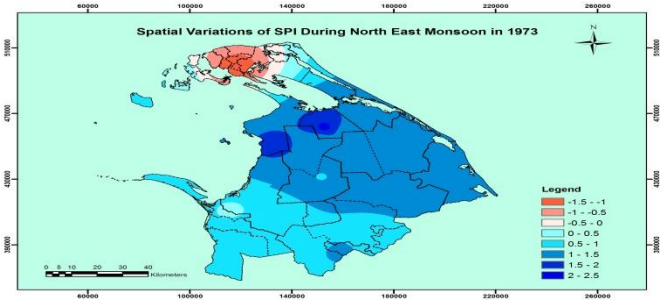

Figure. 14

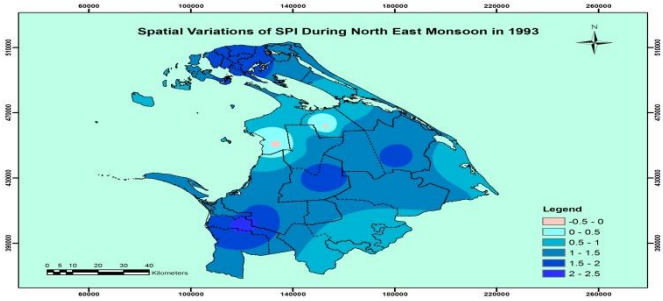

Figure. 15

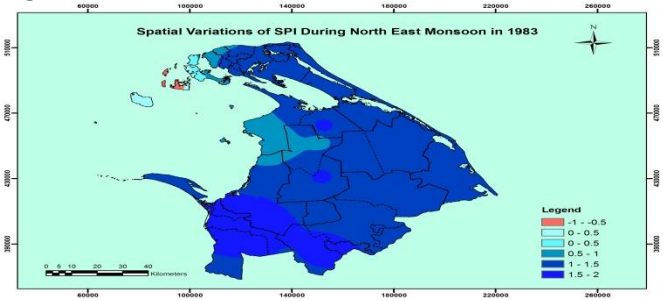

Figure. 16

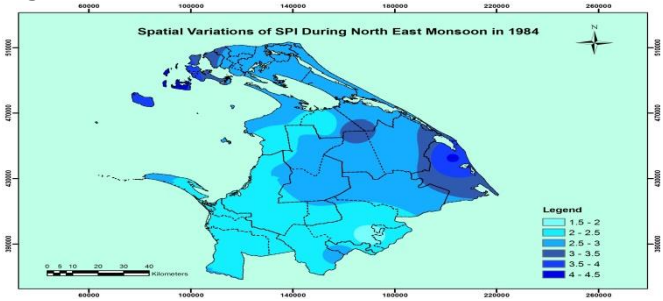

Figure. 17

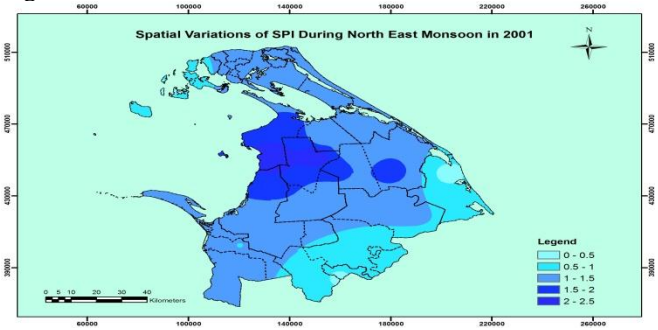

Figure. 18

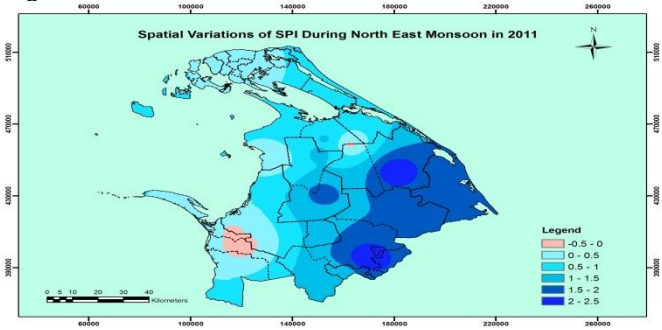

Figure. 19

Figure 14, 15, 15, 17, 18 & 19 show the North East Monsoon Season (NEMS) in different years.

During the North East Monsoon season, a number of floods at various scales had their impact on the Northern Region of Sri Lanka (Table 10). Throughout all seasons, the maximum number of flood, severe flood and extreme flood had been identified during the NEMS. The following table indicates the years of occurrence and the various scales of flood. Also it must be mentioned here, that there were no extreme droughts during the NEMS in the study area from 1972 to 2012.

Table 10. Details of Flood during NEMS.

Stations	Extreme flood	Severe flood	Flood
Akkarayankulam	1984,1998,2001	2002	1973,1993,2011
Ambalapperumalkulam	1973,1984	1983,2011,1998,2002	1979,2001
Iranaimadu	1984	1986,1998	1973,1983,1993,2001,2010
Kanukkerny	1984	1977, 1990, 2011,	1973,1983,1988,1991,1992, 1998,2001,2012
Karukkaikkulam	1984	1983	1993,1998,2000,2001,2012
Murungan	1984,1993	1983,1998	1985,2000,2012
Muththaiyankaddu	2011,2012	1993,2001	1985,2000,2012
Nainathivu	1984	1996,1998	2009
Pallavarayankaddu	1984,1998,2012	1973	
Pavatkulam	1984,2012	1983	1973,2000,2011
Thirunelveli	1984,1998,2001	1990,1993	1975,1983
Vavunikkulam	1984	1983,2011,1993	1990,2001
Vavuniya	2011	1984,1998,2012	1983,2000,2008

According to the SPI, higher number of flood was identified in the NEMS & SIMS and higher number of drought was identified in SWMS. According to the climatic pattern of the Northern Region of Sri Lanka, NEMS gets much amount of rainfall, because the North East monsoon wind burst starts in this season and high moisture wind blows from the Bay of Bengal and creates the intensity of the rainfall during the latter part of the month of November and the intensity of the rainfall increases in the middle or later part of December. Above high intensity of rainfall occurs within a short period, which does not exceed more than 10 days, creates the flood vulnerability during the NEMS and SIMS in the Northern Region of Sri Lanka.

In addition a number of cyclones have occurred during these seasons. According to Thambaiyapillai (1967) and Suppiah (1972), this is the cyclone season in Northern Region of Sri Lanka. During the cyclone periods, study area received much amount of rainfall, within a short period. For example, Nisha Cyclone in 2008, Neelam Cyclone in 2012. According to Thambaiyapillai (1967), in the 100 years history of Sri Lanka, more than 71% of the cyclones have occurred during the month of November and December. Due to this fact heavy rainfall creates flood vulnerability in the Northern Region of Sri Lanka. Therefore SPI is also over +1.00 and a large number of flood related SPIs were recorded during this seasons in the Northern Region of Sri Lanka.

Floods During the South West Monsoon Season: Sometimes unexpected extreme rainfall occurs within a short period and creates normal flood situation in the study area. There were some normal floods, which did not make any impacts on the study area during the season of the southwest monsoon. According to the climatic history of the Northern Region of Sri Lanka, this season normally has very low amount of rainfall. However, the SPI indicates normal flood levels. Reasons for such normal floods during the SWMS include unexpected atmospheric pressure variations and other extreme events. Normal floods during South West Monsoon seasons were identified in 1972, 1975 1979 1981 and 1998. Drought and flood years and seasons are identified on the basis of maximum drought or flood experienced in a particular area.

Some floods and droughts may have occurred during the other years or seasons, but all that would be taken for consideration within the floods and droughts of every station at annual and seasonal levels.

Spatial Pattern of Floods in the Northern Region of Sri Lanka: Spatially maximum numbers of floods (annual and all seasons) have occurred in Kanukkerny Thirunelveli, Pavtkulam, Vavuniya, and Iranamadu and maximum number of drought (annual and all seasons) occurred in Karukkiakulam, Nainathivu, Murungan and Vavunikkulam during the past 42 years in the study area from 1972 to 2012.

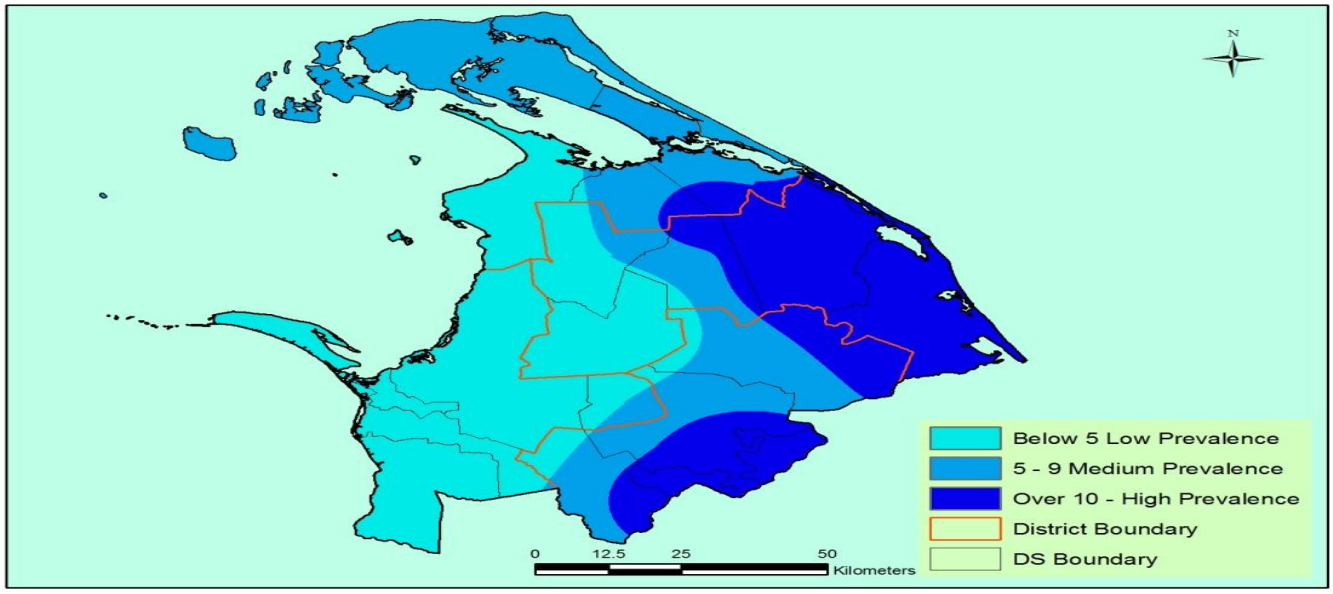

Figure 20. Spatial Pattern of Flood Occurrences in the Northern Region of Sri Lanka During the last 42 years (1972 to 2012.

CONCLUSION

In the conclusions of this study it has been established that, some floods have occurred during various years and seasons in various places. In all stations and all seasons, rainfall is the major cause to flood hazard. The study area has been affected due to flood once in every four years. There seems to be regularity in the occurrences of flood hazards after 2000. Flood occurred in the study area, in 2000, 2004, 2008 and 2012. It is predictable that, there will be flood in the study area in 2016.

In this way, using the Standardized Precipitation Index (SPI), some flood years and flood seasons have been identified large number of extreme and severe flood occurred in the NEMS and SIMS. Similarly flood years were identified in 1979, 1984, 1992, 1993, 2002, 2006, 2009, and 2012. Other than this, seasonal flood were also identified in the Northern Region of Sri Lanka. During the FIMS, flood was identified in 1984, 1985, 1988, 2001, 2002, 2006 and 2008. During the SIMS, flood occurred in 1977, 1979, 1981, 1993, 2005, 2008 and 2011. During the NEMS flood occurred in 1983, 1984, 1993, 1998, 2000, 2001, 2011 and 2012. During the SWMS flood occurred in 1972, 1979, 1998 and 2010. Extreme flood or severe flood made impact in the socio economic sectors of the study area; normal flood did not affect any sector in the study area. When compared to severe with extreme, extreme flood has made greater impact in the study area.

There are also some variations in the drought and flood spatially. During the FIMS, extreme flood were experienced in several areas. 03 in Iranaimadu, 03 in Thirunelveli, 03 in Pallavarayankaddu and 03 in Nainathivu station were identified in the Northern region using SPI method. During the SIMS, 02 extreme floods in Thirunelveli, 02 in Vavuniya, and 03 in Murungan, 02 in Akkarayankulam station, 07 severe droughts In Nainathivu and 05 in Vavuniya were also identified. During the NEMS, 03 extreme floods in Akkarayankulam, 03 in Ambalapperumalkulam and 03 severe floods, 03 extreme floods in Pallavaraykaddu, 03 severe floods in Muththaiyankaddu, 04 severe floods in Vavunikkulam station and 03 severe floods in Vavuniya were identified in the Northern region of Sri Lanka. Spatially some areas have affected many times to flood in the Northern Region of Sri Lanka. Comparatively, Eastern Part of the study area such Kanukkerny, Muththaiyankaddu and Iranaimadu stations have much potential to the flood hazards, because according to the SPI analysis of all seasons, much number of flood have been occurred in this stations. Also frequency of the flood occurrences gradually decreasing in the direction from the east to the west, following figure indicates above condition.

RECOMMENDATIONS

The flood or drought situation of the Northern Region of Sri Lanka depends on the rainfall (Piratheeparajah, 2014). People of the region should be aware of the effects of flood and the mitigation measures of flood. The following recommendations are given to mitigate the flood impacts, monitor the flood and to adopt the early warning system.

- Northern Region of Sri Lanka consists of oceans as their sides. In the developed countries a number of weather observation stations are located on the surface of the oceans. So at least 03 Ocean Weather Observation Center (OWOC) should be established in the Northern, Eastern and Western ocean surface of the Northern Region.
- A separate Regional Meteorological Department should be established in the central part of the Northern Region of Sri Lanka. According to Balasundarampillai (1980) Mankulam is the central part of the Northern Region. Hence Regional Meteorological Department (RMD) should be established in Mankulam. This department may coordinate with the other meteorological stations, rainfall stations and the Agro-meteorological stations and provide separate forecast to the Northern Region and it has to link with the other regions and national MET departments and stations.
- There are no early warning systems to predict the flood hazards in the study area. According to this research, there are some findings. As per these findings in flood seasons, the vulnerable areas have to be forecast to the people to reduce the impact on agriculture due to hazards. Analysis of the depression in the Bay of Bengal and help predict the flood in the Northern region of Sri Lanka.
- Government has to instruct to the people of the Northern Region of Sri Lanka, to be aware during the NEMS (December, January and February) and SIMS (October and November) to avoid the severe impacts due to flood occurrences. Because high number of flood have been occurred during above seasons in the study area.
- Building new tanks and ponds and renovating the existing tanks and ponds will reduce the flood damage and the drought impact in the study area. When compared to other areas.
- When compare with other areas, eastern part of the study area has high potential to the flood hazards (According to SPI analysis). So there should be an attention in the flood monitoring during the SIMS and NEMS, because during this season these areas are receiving much rainfall and caused to the flood impacts.
- There are some natural and artificial drainage systems in the Northern Region of Sri Lanka. Due to thirty years of internal war most of them are silted. The unplanned construction of Walls, Roads, Deforestation and Gardening are the major cause for the damage of the natural and artificial drainage pattern in the study area. Due to the disturbance of the drainage pattern, rainwater storage in the city areas, settlement areas and the farm field create flood valunarablity. New drainage and renovation of the old drainage systems should help to avoid the flood damages in the above places of the study area.
- Identification of flood prone areas should help to assist authorities during emergency. Geographical Information Systems and Remote Sensing (GIS & RS) techniques will help to adopt measures successfully in this regard.

Flood hazards occur in the Northern Region of Sri Lanka and cause many types of damages. Northern Region of Sri Lanka has suffered several times due to war and natural hazards it's high time the Northern Region got developed. In this context, this study would help to predict the drought and flood hazards and create awareness of the risk to be caused by flood and drought, to plan the future activities related to such hazards and mitigate them in the Northern Region of Sri Lanka.

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