AGROCLIMATIC ATLAS OF KERALA

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Preface

Unlike traditional agriculture, farmers today face enormous challenges and risks associated with farming. Advancement on farm technology beginning from improved seeds to harvest and beyond (post harvest technology), climate change and consequent mitigation strategies require more detailed information on weather, soil and moisture availability. Global warming a reality due to manifold reasons but the major reason is due to emission of green house gases.

Food production is highly vulnerable to vagaries in climate change as it is monsoon dependent. Growing concern for food security and dearth of proper understanding of the effects of impending global warming on cropping patterns and agricultural output are posing great challenges both to agricultural scientists and policy planners. Climate resilient agriculture is the need of the hour with focus on photo and thermo sensitive studies of varieties. The climate concerns can span a variety of time scales, ranging from seasonal to inter-annual to inter decadal variability.

Agricultural production in India is dependent not only on the onset of monsoon but to future progress throughout the subcontinent. Heavy rainfall events are increasing indicating increasing trends of floods and landslides. Similarly, increasing trend of temperature in higher region is more pronounced than midland or low land region. Drought is one of the most damaging of all the natural hazards. Most parts of the country are characterized by poor infrastructure and low resilience.

A proper understanding on the climate prevailing over a water shed or micro water shed is essential to improve or make recommendation in improving the productivity of agricultural systems. The benefits of understanding the weather aberrations help in the establishment of technique and controls that promote improved agricultural planning. The purpose of this atlas is to present climatic information, its importance to agriculture in the state and to make this information easily available to all stakeholders including agricultural producers, entrepreneurs and researchers.

Authors of this atlas have made a painstaking analytic work at the micro-level and I believe that besides catering to the needs of the farmers and agricultural scientists of Kerala, this atlas will serve as a reference material to all stakeholders both at the state and national level. Another plus point is that the authors welcome any constructive improvement of this Atlas.

12th November, 2015 **(Sajan Kurien)**

Acknowledgements

Agricultural production in the state of Kerala is at the mercy of onset of monsoon and its future behaviour. Climatic information at the micro-level is very much needed in crop planning as well as for day to day field operations. Compilation of weather data, crop data from various organization institution/Research stations of Kerala Agricultural University at one place and tried to extract the information from the above data and presented in a simple and usable form.

This atlas was prepared with financial assistance from the AICRP of Agricultral meteorology, ICAR, CDRIDA. The excellent support and cooperation from Dr. V.U.M. Rao, Project Coordinator, AICRPAM, CRIDA, throughout the preparation of Atlas.

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Executive summary

The agricultural development in Kerala is somewhat exceptional and distinct from many other States in India in terms of land utilization pattern and the cropping pattern. Kerala's agriculture as a whole is growing in terms of income generation from the mid eighties. This is mainly due to improvement in yield rates and to a smaller extent, due to change in cropping pattern to high valued crops. In spite of significant advances in industrial and service sectors, agriculture continues to be the largest provider of employment and source of revenue both at the national and state levels.

Weather and climate has a significant role in crop production, the major challenges for current crop production are climatic variation and occurrence of extreme weather events. This study aims to present an Agro climatic atlas of Kerala which includes all aspects of agrometereology

Agricultural scenario of Kerala

Agricultural crops in the state are broadly classified as food crops and non-food crops. Food crops are cereals & millets, sugar crops, spices & condiments, fresh fruits, vegetables, etc. The major non-food crops are rubber, betel leaves, lemon grass, etc. Another classification of crops is seasonal crops, annual crops and perennial crops which are based on their life time. Paddy, Pulses and grains include the category of food grains. The total area under cultivation of food grains during 2013-14 is 2,02,926 ha. The area under paddy cultivation in Kerala during the agricultural year 2013-14 is 1,99,611 ha with 564325 tonnes and a productivity of 2538 kg/ha. The total area of pulses during 2013-14 is 2,989 ha and with a production 3019 tonnes. Major cultivation of pulses in the state is in Palakkad district and the contribution to state total is 40%. The important spices and condiments crops being cultivated in our state are pepper, ginger, turmeric, cardamom, arecanut, tamarind, cloves, nutmeg *etc*. Major contribution of spices & condiments is from Idukki district in is 31% during 2013-14. The total area under the cultivation of spices & condiments during the year 2013-14 is 2,66,026 ha. Drumstick, amaranthus, bitter gourd, snake gourd, ladies finger, brinjal, green chillies, bottle gourd, little gourd (koval), ashgourd, pumpkin, cucumber, cowpea are the important vegetables cultivated in our state. The total area under the cultivation of vegetables during 2013-14 is 41,262 ha. It represents 4% area of total food crops. The important oil seeds being cultivated in our state are coconut, groundnut, sesamum, etc. Coconut represents 99.8% of the category of oilseeds. The total area under the cultivation of oil seeds during the agricultural year 2013-14 is 8,10,497 ha. The important plantation crops cultivated in the state are tea, coffee, rubber and cocoa. The total area of plantation crops during 2013-14 is 6,77,046 ha. Major cultivation of plantation crops is in Kottayam district and the representation to total area of plantation crops is 17%. Rubber has 1st position in area under the cultivation of plantation crops and the representation is 81%.

Climate in general

About 63% of the geographical area of Kerala is perhumid. Chittur station and Kollangode station (both stations are in Palakkad district) are only belongs to the category Humid (B1) (Moisture index 20-40) which is the lowest moisture index recorded in the Kerala state. In Kerala state moist sub-humid, dry sub-humid, semi arid and arid regions are not present

Rainfall

The mean annual rainfall of Kerala is 2909 mm with a coefficient of variation of 19%. Kerala is divided into 5 Agro-Climatological zones which are South zone, North zone, Central zone, High range zone, Problem area zones. Annual rainfall is highest over High range zone which includes Wayanad as well as Idukki districts having rainfall 3366 mm, lowest over South zone (Thiruvananthapuram, Kollam, Pathanamthitta) having 2107 mm. SWM rainfall accounts 64% of the annual rainfall on a state wise calculation but in Northern zone SWM contributes to 77% of the annual precipitation. NEM rainfall contributing 18% of the annual on a state basis and in Southern zone it is higher than from the state average (30%). Kerala receives 1986 mm rainfall during SWM season. When comparing the district level SWM, Kasaragode district received highest amount of rainfall (3076 mm) followed by Kannur district (2596 mm) and Idukki (2445 mm). Lowest rainfall was noticed in Thiruvananthapuram district (807 mm) followed by Kollam (1270 mm). When comparing rainfall pattern by zones North zone receives highest amount of rainfall (2428 mm) and least in South zone (1039 mm). Rainfall during NEM for the entire state is 526 mm with variability 39%. South zone receives highest amount of rainfall (632 mm) and lowest amount of rainfall received by North zone (429 mm). In district wise comparison Pathanamthitta shows highest amount of rainfall (689 mm) followed by Kollam (684 mm) and lowest in Kasaragode district(377 mm) followed by Wayanad district(381 mm). The mean summer rainfall obtained in Kerala state 370 mm. Summer rainfall contributes only 13% out of annual rainfall. Problem area zone receives highest amount of rainfall (476 mm) followed by South zone (390 mm). The mean winter rainfall is a negligible amount compared to all other seasons (27 mm). Among the zones Southern receive high amount of winter rainfall 50 mm.

Most of the rain events in Northern Zone occur during SWM season (83%) and lowest at South Zone (56%). On an annual basis rain occurs more frequently over Problem area having 126 rainy days (Table.10). Rainy days higher at Kottayam district (129 rainy day) and low at Thiruvananthapuram district has 96 rainy days. In SWM CV% is high at Thiruvananthapuram district (21%) and low at Malappuram (18%).

Trends in time series

Annual rainfall shows a decreasing trend in 56% of the available stations (31 out of 55 stations) in which 18% of the stations show a significant decreasing trend. Remaining twenty three stations shows increasing trend in which only four station's annual rainfall is increasing significantly.

Southwest monsoon rainfall is mostly declining in majority of the places of Kerala. The analysis reveals that 74% of available stations (41 out of 55 stations) show a decreasing trend. Significant decrease in SWM rainfall is found in fourteen stations, which is an alarming situation since 77% of annual rainfall is contributed by SWM rainfall. Only three station's rainfall shows a significant increasing trend in SWM rainfall.

As far as NEM rainfall is concerned, significant decreasing trend in NEM rainfall is found only for two stations and significant increasing trend in NEM rainfall is observed in three stations. Summer rainfall during March, April, May is found to be increasing in many places of Kerala. Around 78% of the stations (43 out of 55) show an increasing trend in summer rainfall in which ten station's summer rain is increasing significantly.

Contradictory to the annual rainfall trend, annual rainy days shows an increasing trend in 23 stations out of 35 stations in the State. Increasing trend is significant for Pattambi and Thrithala of Palakkad district and Punalur of Kollam district and Vellayini of Thiruvanathapuram and Pilicod of Kasargod district. Rainy days during SWM season also showed an increasing trend in many places of Kerala (24 stations out of 35). Significant increase is observed in northern zone stations, Malappuram and Panniyur of Kannur district. Significant decrease in rainy days is found at Varkala station of southern zone district Thiruvanathapuram.

In general, no significant trend has been observed in major parts of the state under both categories (75-100 mm and more than 100 mm). Decreasing trend in 75-100 mm rainfall events found in some parts of southern zone districts. In SWM season also, notable trend in heavy rainfall events (75-100mm, more than 100mm) could not be observed. However a significant decreasing trend in 75-100 mm rainfall events has found over southern zone stations viz., Kollam, Nedumangad and Varkala.

Maximum one day rainfall episodes showed an increasing trend in 17 stations out of 35 stations analysed and decreasing trend in 18 stations. Significant increase is found to be for three stations and significant decrease is found in two stations.

A significant decreasing trend in maximum cumulative five day rainfall events is found in the southern zone of Kerala and a non significant decreasing trend is observed in the northern zone of Kerala. Significant decreasing trend is found in 8 stations. A non significant increasing trend in maximum five day rainfall episodes is observed in most of the taluks in the central zone of Kerala.

The trend in mean one day rainfall intensity showed significant increasing trend in two stations (Kumarakam and Aryankavu) and significant decreasing trend in 4 stations (Kunnamangalam, Perumbavoor, Nedumangad and Neyyattinkara).

Decreasing trend in dry spell persists in 88% of the stations in which 3 stations showing a significant decreasing trend (Alathur, Kottayam and Pilicode). Decreasing trend is more prominent in central zone. Significant Increasing trend in dry spell is observed only in one station of Kozhikkode district.

Significant increasing trend in wet spells is observed over two stations (Panniyur and Perumbavoor). Significant decreasing trend in wet spells observed over two stations in Problem area zone (Mankombu and Kumarakam) and Vellanikkara station in central zone district Thrissur.

In majority of the districts, except Kasargod, Kozhikkod and Pathanamthitta, the rainy season commences in the $14^{th}/15^{th}$week and ends by 47^{th} week except Thiruvanthapuram district, where northeast monsoon is prominent.

In majority of districts of Kerala, dependable annual rainfall (at 75% probability) is more than 2000mm. Dependable annual rainfall less than 2000 in places comes under rain shadow region during SWM season viz., Thiruvananthapuram, some parts of Idukki and Palakkad.

Probability for moderate drought is 5-10% in majority of the districts of Kerala. The probability is high (more than 10%) in the southern zone district Thiruvanathapuram and some parts of Palakkad and Wavanad.

Probability for near normal condition during Southwest monsoon is above 50% for all the stations (59) considered for the study. In the case of moderately dry category, probability more than 15% is found in Pathanamthitta district and some parts of Idukki, Thrissur, Ernakulam, Palakkad and Wayanad. In the case of severe dry condition, 30% of the stations don't show any probability for severe dry conditions during SWM season in Kerala state. In the case of Extreme dry condition 63% of the stations do not show any probability values. However, highest probability is found in Neyatinkara station (11%) followed by Nedumangad (9%), both are in Thiruvananthapuram district.

Probability for near normal conditions is above 60% during the NEM season for all the stations. In the case of severe drought conditions, 27% of stations don't show any probability for severe dry condition during NEM season. In the case of extreme drought condition, 48% of available stations do not show any probability and Chittur station in Palakkad district shows 9% probability which is highest probability observed as compared all other stations.

Length of Growing Period (LGP)

Length of growing period is more than 250 days in most of the parts of Kerala. Northern and Central zone of Kerala has LGP between 250-300 days. Southern part of Ernakulam district, Idukki, Kottayam, Pathanamthitta and Kollam shows LGP more than 350 days. Southern zone district Thiruvanathapuram has LGP in between 300-350 days. Over 11 among 14 districts the growing season commences on an average during 21st Standard Meteorological Week (SMW) and in remaining districts the season commences during 22nd SMW.

Length of growing period is more than 30 weeks in 50% of the districts of Kerala for soils having low water holding capacity (50mm). For a 100 mm water holding capacity, LGP is between 30 to 40 weeks in almost all the places. Few places of Kerala except Pathanamthitta, Kottayam and some parts of Kollam, Alappuzha, Idukki , and some parts of Thiruvanathapuram, where LGP is in between 40-50 weeks. In soils with water holding capacity 150 mm, the LGP, more than 70 weeks is observed at northern zone district Kasargod and western coast of Thiruvanthapuram district. LGP is in between 40-60 weeks for 150mm water holding capacity is found in the districts of southern zone and problem area zone. In soils with water holding capacity 200 mm, the LGP more than 50 weeks is observed in southern zone districts and districts of problem area zone and some parts of Ernakulam, Idukki. LGP is in between 40-50 over the northern zone districts Kannur. Kasargod and some parts of Wayanad and Kozhikkod.

Other climatic elements

The mean annual maximum temperature over Kerala is 31^{0}C. The highest mean maximum temperature is observed during summer season 33^{0}C and lowest is SWM season (29^{0}C). Average maximum temperature over the state in NEM season is 31^{0}C and in winter season is 32^{0}C. The central zone has recorded highest seasonal mean maximum temperature (34^{0}C) at both winter and summer season. High range zone experiences lowest maximum temperatures among the zones during all the season.

The Kerala state as a whole experiences a mean minimum temperature 23^{0}C on an annual basis. The highest mean minimum temperature is observed during summer season 24^{0}C and lowest is 21^{0}C during winter season. In zone wise highest minimum temperature observed in northern zone (24^{0}C) and lowest

ninimum temperature observed in high range zone (18°C). In the case of mean annual minimum temperature lata Malappuram, Kannur, Kozhikode, Eranakulam, Thiruvananthapuram, Pathanamthitta and Alappuzha ecorded high temperature (24°C). On annual basis the Kerala state experiences 87% morning relative umidity. However zone to zone, relative humidity is varying. Relative humidity is found to be highest in High range zone (93%) and lowest in Northern zone (85%). On annual basis the Kerala state experiences 70% afternoon relative humidity, zone wise relative humidity almost similar except central zone it has ercentage of relative humidity 66% which is lowest relative humidity. The mean annual wind speed for he entire state is 2.8 m/s. Southern zone shows highest wind speed (3.4 m/s) on an annual basis. Lowest wind speed experiences in high range zone (2.1 m/s). Mean annual number of hours of bright sunshine for he state are 6.5 hr/ day with Southern zone receiving sunlight for a longer period (7.9 hr/day). Thiruvanathapuram district (7.9 hr/day) is the brightest district and Idukki is the dimmest (5.7 hr/day). The analysis showed that the mean annual evaporation of the state is 4.0 mm. Among the districts Kozhikode as maximum evaporation of mean value 5.1 mm followed by Thrissur district (4.5 mm) and lowest mean value recorded at Thiruvananthapuram (3.5 mm)

Agrometeorological production constraints and opportunities

The high humidity and temperature of the rice growing environments during the cropping periods ncreases the incidence of pests and diseases. Major insect pests include BPH, stem borer, gall midge, leaf oller and rice bug and minor pests include thrips, case worm, blue beetle, whorl maggot etc. The minor ests are slowly emerging as major pests threatening rice cultivation in the State. Fungal diseases like last, sheath blight, sheath rot, brown spot, false smut, leaf scald and grain discoloration, bacterial diseases ike bacterial leaf blight, and viral diseases like rice tungro virus, grassy stunt virus etc. cause severe lamage to rice crop in Kerala.

Cashew experiences severe moisture stress during reproductive phase from December to May, which dversely affects its flowering and fruit set causing flower drying and immature nut drop. Issue of agromet dvisories well in advance, would facilitate framers to resort to intercultural operations to conserve soil noisture.

Continuous rainfall favours the buildup of constant high relative humidity which aggravates *Phytophthora* infestation in coconut palms particularly in low lying areas causing bud rot and noticed especially during SW&NE monsoon periods. Irrigation is necessary to avoid nut dropping leading to eduction in yield if the delay of monsoon is up to 30days. Gradient outbreaks of scale insects and slug aterpillar and sporadic outbreaks of inflorescence caterpillar may occur in endemic spots during delayed nonsoon periods and this will affect yield. Black pepper does not tolerate excessive heat and dryness. Studies revealed that rainfall received after a period of stress induces profuse flowering in pepper. Growth of fruit bearing lateral shoots and photosynthetic rate are high during peak monsoon (June-July).

Adequate shade provision is needed for young plants if monsoon is delayed by 15 days/30 days/ lrought conditions and in the case of banana If monsoon is delayed by 15days/30days, most of the banana growing areas, usually planting of suckers/tissue culture plants should be taken up after the on-set of nonsoon. Foliar application of kaolinite (5%) during vegetative stage reduces the transpiration losses if ain deficit is at vegetative and reproductive stage.

1. General information

Kerala is located between 8°18' and 12°48' N latitude and 74°52' and 77°22' E longitude, covering an area 38863 sq km (3886287 ha) in the south western part of India. It is bounded by the Lakshadweep sea on the west, Karnataka on the north and east and Tamil Nadu on the south and east. Its coastal length is 580 km and the width ranges from 15 to 120 km. It has 14 administrative districts (Fig 1).

1.1 Land use pattern

The total geographical area of the State is 3886287 ha. Geographical area in Kerala has been classified according to twelve different uses of land during 2013-14 which is presented in Table 1. The net sown area under cultivation during the year 2013-14 was 20,50,994 ha, which occupies 52.78% of the total area in the State. The total cropped area is 26,16,670 ha during the year 2013-14.

1.2 Soil

In general, the soils of Kerala are acidic, kaolintic and gravelly with low CEC (Cation Exchange Capacity), low water holding capacity and high phosphate fixing capacity. Climate, topography, vegetation and hydrological conditions are the dominant factors of soil formation. On the basis of the morphological features and physico-chemical properties, the soils of the State have been classified into coastal alluvium, Alluvium, Acid saline, Karl saline, Laterite soil, Red soil, Hill soil, Black soil and Forest soil (Fig 2.)

1.2.1 Soil texture

Soil texture is an important soil characteristic that drives crop production and field management. The textural class of a soil is determined by the percentage of sand, silt, and clay. Soils can be classified as one of four major textural classes: sands, silts, loams and clays.

Based on landform types there are 4 landforms which are Khandalite, Charanockite, Granite-gnesis and Laterite land forms. These landforms are again classified into 54 soil series. Which are given in the Table.2. In Khondalite landform surface soil are gravelly sandy clay loam with 50-60% gravel, Charnockite landform has type of gravelly clay with 15-55% gravel, Granite-gneiss landform has sandy clay, gravelly sandy clay with 10-25% gravel and in the case of laterite landform the surface soil are sandy loam or sandy clay having gravel 25-60%.

1.2.2 Soil slope

Slope gradient is the angle of inclination of the soil surface from the horizontal. It is expressed in percentage which is the number of feet rise or fall in 100ft horizontal distance. In 54 soil series in Kerala, 72% of the soil series having soil slope up to 33%. There are 8 series out of 54 series having soil slope up to 25% and 7 series belong to soil slope up to 15% (Table.2).

1.2.3 Soil drainage

Soil drainage refers to the soil's natural ability to allow water to pass through it. Dense soil will hold water, while loose soil will allow water to pass through quickly. Soil drainage may determine which types of plants grow well in it. Kerala soils are well drained and slow to rapid runoff. 52 series out of 54 are belonging to this category and erosions are in moderate mode. Soil permeability also moderate in Kerala state (Table .2).

1.3 Climate

The climate is humid tropical in Kerala. Station wise rainfall, temperature data were taken from India Meteorological Department and Agricultural research stations. The average rainfall ranges from 1500-4000 mm. It is received from southwest monsoon (68%) (June to September) and northeast monsoon (18%) (October to

Table 1: Land use pattern of Kerala (km^2)

Sl. No.	Classification	1970-71	1980-81	1990-91	2000-01	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
1	Total Geographical Area	38850	38850	38850	38850	38863	38863	38863	38863	38863	38863
2	Forest	10550	10820	10820	10820	10820	10820	10820	10820	10820	10820
3	Land put to non agricultural use	2750	2700	2970	3540	4489	4627	4748	4790	4907	5135
4	Barren and uncultivable land	720	860	580	290	265	255	249	220	196	176
5	Permanent pastures and other grazing land	280	54	20	16	3	2.2	2.3	2.3	1.5	0.85
6	Land under miscellaneous tree crops not included in net area sown	1320	640	340	150	86	64	60	44	37	34
7	Cultivable waste	800	1290	950	600	903	928	962	980	917	954
8	Fallow other than current fallow	230	270	260	340	471	452	460	454	515	577
9	Current fallow	240	440	440	780	817	829	678	769	760	771
10	Net area sown	2172	2180	2247	2206	2101	2089	2089	2078	2072	2040
11	Area sown more than once	7610	7050	7730	8160	8161	6721	6059	5899	5759	6216
12	Total cropped area	29330	29810	30200	30220	29175	27610	26949	26687	26474	26618

Source: Agricultural statistics Kerala 2013-2014

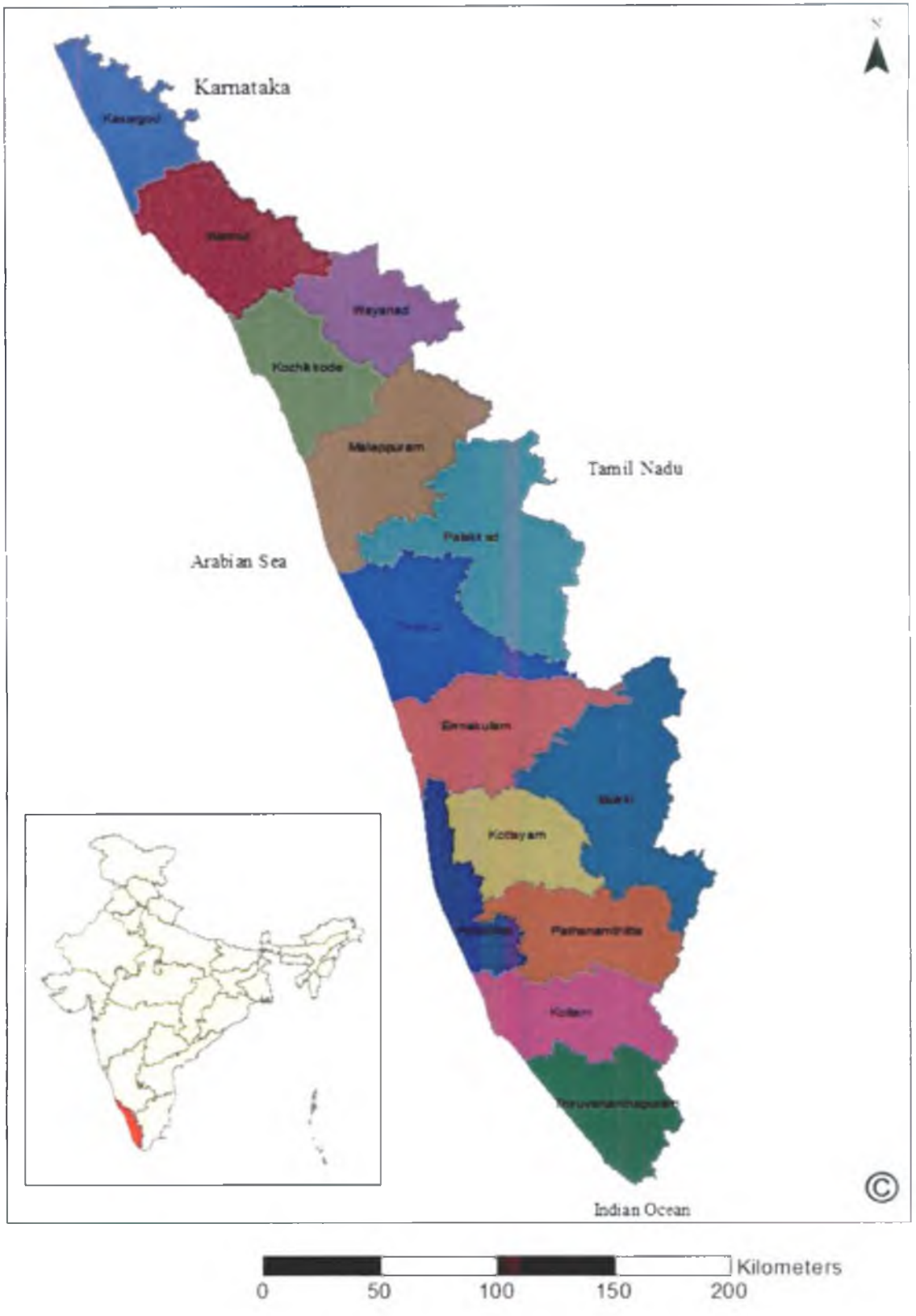


Fig. 1: Map showing district boundaries in Kerala

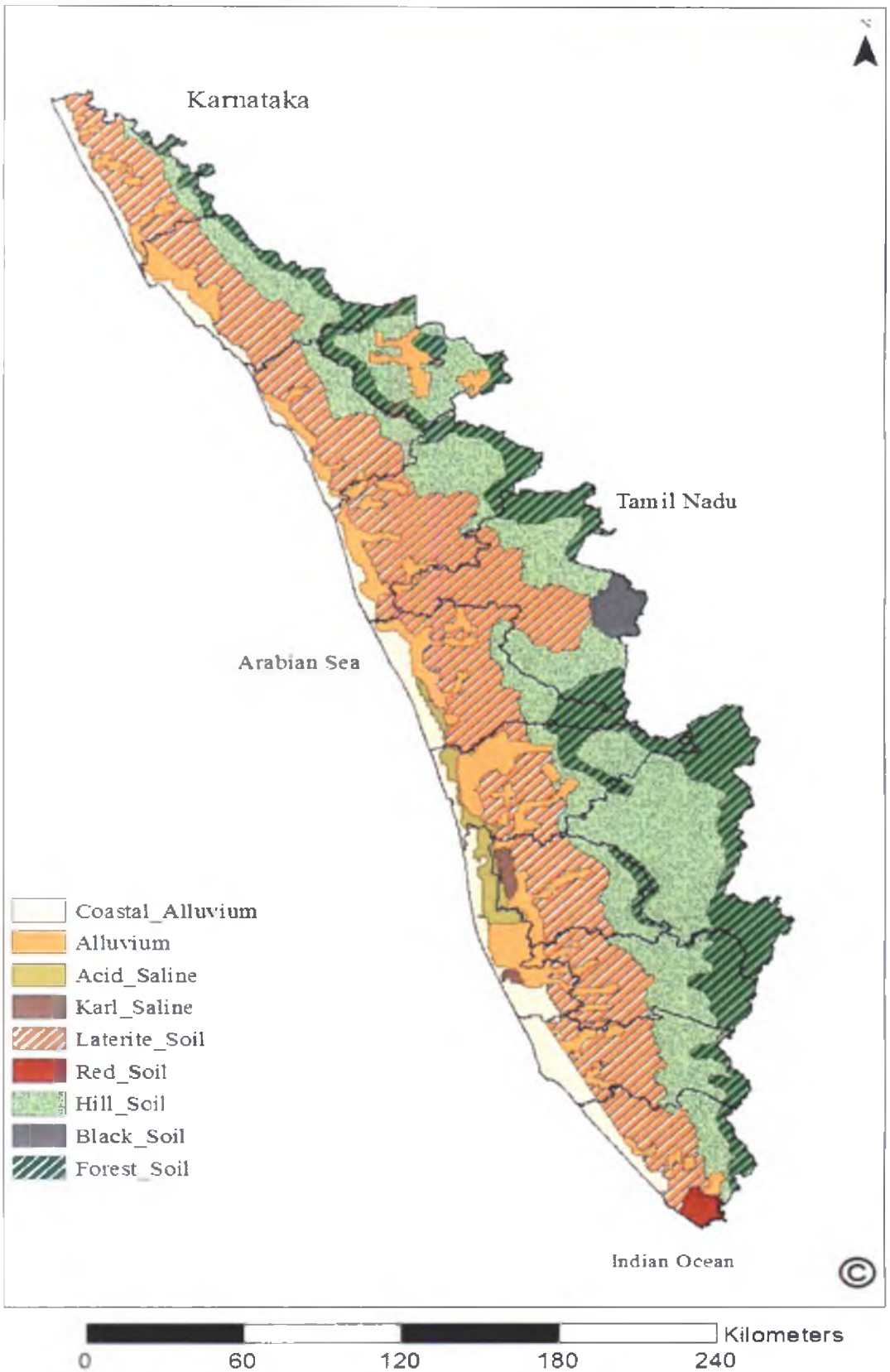


Fig. 2: Soil types of Kerala

Table 2: Soil series of Kerala

Sl.No.	District	Place	Slope (%)	Relief	Erosion	Drainage	Permeability
1	Pathanamthitta	Kirukuzhi,Adoor	5 to 15	normal	moderate	welldrained,slow to rapid runoff	moderate
2	Thiruvananthapuram	Annappara,Nedumangad	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
3	Kollam	Madhuri Mala,Kottarakkara	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
4	Kollam	Anakkattur,Kottarakkara	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
5	Kollam	Koluthuruthi,Pathanapuram	15 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
6	Kollam	Thevalapuram,Kottarakkara	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
7	Kollam	Mailam,Kottarakkara,Kollam	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
8	Kollam	Thrikkannamangal,Kottarakkara	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
9	Pathanamthitta	Vallikkod,Kozhencherry	3 to 25	normal	moderate	welldrained,slow to rapid runoff	moderate
10	Kottayam	Angel Valley,Kanjirapally	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
11	Ernakulam	Tekkumaradi,Muvattupuzha	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
12	Kottayam	Chelikkuzhi,Mundakkayam,Kanjirapally	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
13	Kottayam	Kappad,Kanjirapally	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
14	Pathanamthitta	Chungappara,Mallappalll	10 to 33	excessive	moderate	welldrained,slow to rapid runoff	moderate
15	Pathanamthitta	Ittiyappara,Ranni	5 to 25	normal	moderate	welldrained,slow to rapid runoff	moderate
16	Palakkad	Kalradi,Alathur	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
17	Kottayam	Kanjirapally,Kanjirapally	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
18	Ernakulam	Kadati,Muvattupuzha	3 to 25	normal	moderate	welldrained,slow to rapid runoff	moderate
19	Kottayam	Koruthode,Kanjirapally	3 to 33	normal	moderate	welldrained,slow to	moderate

						rapid runoff	
20	Alaprakadu	Alaprakadu	25 to 33	excessive	moderate	welldrained,slow to rapid runoff	moderate
21	Pathanamthitta	Chethackal,Ranni	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
22	Kottayam	Thambalakkad,Kanjirapally	5 to 33	excessive	moderate	welldrained,slow to rapid runoff	moderate
23	Pathanamthitta	Lahai,Ranni	1 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
24	Kottayam	Manimala,Kanjirapally	3 to 33	excessive	moderate	welldrained,slow to rapid runoff	moderate
25	Kottayam	Mekkadembu,Muvattupuzha	1 to 15	normal	slight	welldrained,slow to rapid runoff	moderate
26	Kottayam	Minkunnam,Muvattupuzha	10 to 15	normal	moderate	welldrained,slow to rapid runoff	moderate
27	Pathanamthitta	V.Kottayam,Adoor	5 to 15	normal	moderate	welldrained,slow to rapid runoff	moderate
28	Kottayam	Ananakara,Meenachil	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
29	Malappuram	Pullangod,Kallkkavu,Ernad	10 to 33	excessive	moderate	welldrained,slow to rapid runoff	moderate
30	Kottayam	Kappadu,Kanjirapally	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
31	Kottayam	Thrikkothamangalam,Kottayam	1 to 33	normal	moderate	welldrained	
32	Pathanamthitta	Tulappallli,Ranni	3 to 33	excessive	moderate	welldrained,slow to rapid runoff	moderate
33	Kottayam	Pulimavu,Kanjlrapally	3 to 33			welldrained,slow to rapid runoff	moderate
34	Kottayam	Marangattupalli,Meenachil	1 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
35	Kottayam	Manarcad,Vijayapuram	1 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
36	Kozhikkode	Kinalur,Quiland	10 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
37	Ernakulam	Ayavana,Muvattupuzha	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
38	Palakkad	Kalladikkod,Mannarkkad	3 to 25	normal	moderate		
39	Ernakulam	kallurkkad,Muvattupuzha	3 to 25	normal	moderate	welldrained,slow to rapid runoff	moderate

40	Ernakulam	kaloor,Muvattupuzha	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
41	Kozhikkode	Kinalur,Quilandy	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
42	Palakkad	Kongad,Ottappalam	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
43	Kottayam	Manjalloor,Muvattupuzha,Kottayam	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
44	Ernakulam	Neriyamangalam,Kothamangalam	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
45	Palakkad	Pallippadi,Mannarkka	3 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
46	Kozhikkode	Perambra,Quilandy	5 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
47	Ernakulam	Valoor,Muvatupuzha	5 to 25	normal	moderate	welldrained,slow to rapid runoff	moderate
48	Kollam	Churanad north,Kunnathur	1 to 15	normal	moderate	welldrained,slow to rapid runoff	moderate
49	Kottayam	Amalagiri,Kottayam	1 to 15	normal	moderate	welldrained,slow to rapid runoff	moderate
50	Alappuzha	Chunakkara,Mavelikkara	5 to 25	normal	moderate	welldrained,slow to rapid runoff	moderate
51	Kottayam	Kaipuzha,Amalagiri,Kottayam	1 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
52	Kollam	Churanad,Kunnathur	3 to 15	normal	moderate	welldrained,slow to rapid runoff	moderate
53	Kottayam	Mannanam,Kottayam	1 to 33	normal	moderate	welldrained,slow to rapid runoff	moderate
54	Kottayam	Panachikkad,Kottayam	3 to 25	normal	moderate	welldrained,slow to rapid runoff	moderate

Source: Soil series of Kerala (National Bureau of Soil Survey and Land use Planning)

December). The southwest monsoon normally sets in between the last week of May and the first week of June and advances northward. The onset of northeast monsoon is in the middle of October. Pre-monsoon rain is received in March, April and May and winter rain in January to March. Pre-monsoon higher in the central and northern portions of the tract than in the southern portion. The highest rainfall (3743 mm) is at Kasargod district and the lowest (1760 mm) is at Thiruvananthapuram district (Table.8).

In the southern portion of the tract two peaks of rainfall occur, one during the southwest monsoon in June-July and the other during the northeast monsoon in October. In general, the northern portion receives the highest rainfall in July and the central and southern portions in June

Northeast monsoon rainfall is more in the southern zone than in the central and northern zones. Rainfall of this season gradually decreases northward from Thrissur, the lowest being recorded in Kannur and Kasaragod districts. This is reflected in the number of dry months (less than 50 mm rain), three and less dry months in southern zone and greater than three dry months in the northern zone.

The rainfall less than 100 mm is received in January, February and March in most of the area (Soil series of Kerala). The pre-monsoon showers bring a significant amount of rain over the area, which is generally higher in the midlands than in the highlands.

2. Agroclimatic zonation

According to the FAO (1983), an Agroclimatic zone is a land unit in terms of major climate and is climatically suitable for a certain range of crops and cultivations within such a zone. Local conditions may result in several subsystems each with its own climatic conditions. An agroclimatic zone, in fact, has a greater degree of commodity of the relevant basic features of soils, topography, climate and water resources (Fig.6). The five zones are

1. Northern zone
2. Central zone
3. Southern zone
4. High range zone
5. Problem area zone

The mean rainfall of respective districts in one zone is considered as zonal mean rainfall. Northern zone consists of four districts viz. Kannur, Kozhikode, Malappuram and Kasargode. The central zone consists of three districts in central region *viz* Ernakulam, Thrissur and Palakkad. The districts situated in the south most part of Kerala such as Thiruvanathapuram, Kollam and Pathanamthitta is included in the Southern zone. The districts, Idukki and Wayanad is in the high range zone of Kerala. Alappuzha, is the district lies below the mean sea level and Kottayam includes in the problem area zone. (Table.3 and Fig.3)

2.1 Agro ecological zone

The parameters that together evolve distinct agronomic environments where in a distinct cropping pattern flourishes are altitude, rainfall, temperature, wind, soil type and topography. The parameters and their levels used for delineating agro-climatic zones are summarised in Table 4. The levels of each parameter are broadly determined to avoid complexity in the process of land evaluation. In reality, there can be several more levels for each parameter.

Following the above approach and using a matrix built upon altitude, rainfall, soil and topography, the state has been delineated into thirteen agro-climatic zones (Table.4.1). Block panchayat has been taken as the unit for purposes of delineation. All the blocks, municipalities and corporations have been grouped into appropriate agro-ecological zones (Fig 4).

Table 3: Agro-climatic Zones of Kerala

Sl. No.	Zones	Geographical extent	Annual rainfall (mm)	Soil type	General soil fertility
1	Northern zone	Kannur, Kozhikode, Malppuram and Kasaragode	2883	Laterite soil	Available N greater than 560 kg/ha, available P greater than 24 kg/ha, available K greater than 275 kg/ha
2	Central zone	Eranakulam,Thrissur and Palakkad	2897	Saline hydromorphic, Black soil in Chittur taluk	Available N 280-560 kg/ha, available P greater than 24 kg/ha, available K greater than 275 kg/ha
3	Southern zone	Thiruvananthpuram, Kollam and Pathanamthitta	2370	Red loams(tvm), Riverine alluvium(klm), Onattukkara alluvium	Available N 280-560 kg/ha, available P 10-24 kg/ha, available K less than 115 kg/ha
4	High range zone	Idukki,Wayanad	3132	Forest loam	Available N 280-560 kg/ha, available P greater than 24 kg/ha, available K greater than 275 kg/ha
5	Problem area zone	Alappuzha, Kottayam	2888	Kuttanad Alluvium/Acid saline soil	Available N less than 280 kg/ha, available P greater than 24 kg/ha, available K 115-275 kg/ha

Source: http://www.iiss.nic.in/mapd_15.htm

Table 4: Parameters for identifying agro-ecological zones

Parameter	Level	Description		
I. Altitude	Type I	Altitude Up to 500 m above MSL (Low altitude zone- hot humid tropics, spread over the entire state)		
	Type II	More than 500 m above MSL		
II. Rainfall	Pattern I	Both the southwest and northeast monsoons are active and moderately distributed. Southwest monsoon with June maximum (South of 11ºN latitude)		
	Pattern II	Poorly distributed rainfall; southwest monsoon with July maximum and concentrated in 3-4 months. Northeast monsoon relatively weak (North of 110 N Latitude).		
III. Soil types	1	Alluvial soil (Spread over river banks)		
	2	Sandy soil (Coastal areas)		
	3	Sandy loam soil (Coastal areas)		
	4	Laterite soil with well defined B horizon (Natural midlands)		
	5	Laterite soil without B-horizon (Natural highlands).		
	6	Red soil (Southern-most Kerala)		
	7	Black soil (Chittur taluk of Palakkad district)		
	8	Peat (kari) soil (Kuttanad)		
	9	Acid-saline soil (Pokkali and Kaipad areas)		
IV. Topology		Vallyes	Hill Tops	Slopes
	Model I	Extensive valleys with level but raised garden lands		
	Model IIa	Valleys less extensive	Hills with moderate gradients	Slopes having mild gradients
	Model IIb	Valleys less extensive	Hills with moderate gradients and top with egg shaped hump	Steep slopes
	Model IIc	Valleys less extensive	Hills with table tops	Steep slopes
	Model III	Narrow valleys	Hills with steep gradients	Steep slopes

No.	Zones	Altitude type	Rainfall pattern	Topography model	Soil type
I	Onattukara	I	I	I	Sandy loam
II	Coastal Sandy	I	I	I	Sandy loam
III	Southern midlands	I	I	III	Laterite without B-horizon
IV	Central midlands	I	I & II	IIa	Laterite
V	Northern midlands	I	II	IIb	Laterite
VI	Malappuram type	I	II	IIc	Laterite
VI	Malayoram	I	I	IIII	Laterite without B
VIII	Palakkad plains	I	II	II	Red loam
IX	Red loam	I	I	III	Red loam
X	Chittoor black soil	I	II	IIa	Black soil
XI	Kuttanad	I	I	I	Peat (kari)
XII	Riverbank alluvium	I	I	I	Alluvium
XIIIII	High ranges	II	I& II	III	Red loam

Table 4.1 : Distribution of Agro-ecological zones of Kerala

Sl.No.	Zones	Distribution
I	Onattukara	Quilon (C), Chavara, Karunagappally, Ochira, Kayamkulam (M), Mavelikkara, Mavelikkara (M), Muthukulam1, Haripad2
II	Coastal Sandy	Ambalapuzha2, Alleppey (M)2, Aryad3, Kanjikuzhy3, Cherthalai(M), Pattanakad3, Thykkattussery3, Vaikom (M), Vaikom3, Vyttila4, Edappally4, Palluruthy4, Kochi(C) 4, Vypeen4, Parur4, Parur (M), Kodungallur, Thalikkulam, Mathilakom, Chavakkad, Andathode5, Ponnani5
III	Southern midlands	Trivandrum (C), Trivandrum Rural, Kazhakkuttam, Chirayinkeezh, Attingal (M), Varkala, Kilimannoor, Ethikkara, Mukhathala, Anchalummude, Chadayamangalam, Kottarakkara, Vettikkavala, Chittumala, Sasthamkotta, Elanthur, Pandalam, Kulanada, Bharanikkavu, Chengannur7, Koippuram7, Thiruvalla (M)7, Mallappilly7, Changanacherry (M), Madappally2, Pallom, Kottayam (M), Ettumannur2, Kaduthurithy
IV	Central midlands	Pampakuda, Vadavucode, Koovappady, Perumbavoor (M), Vazhakkulam, Aluva (M), Alangad7, Parakadavu7, Angamaly, Mulanthuruthy, Mala, Vellangallur5, Irinjalakkuda (M), Irinjalakkuda5, Cherpu5, Anthikkad5, Thrissur (C),, Puzhakkal5, Mullassery, Kunnamkulam (M), Chowannur, Trithala, Pattambi, Ottappalam.
V	Northern midlands	Pandalayani8, Balusseri, Perambra, Meladi, Vadakara (M), Thodannur, Kunnummel, Tuneri, Badagara, Thalassery6, Thalassery(M), Kuthuparamba, Edakkad, Cannanore (M), Irikkur, Cannanore6, Taliparamba, Payyannur
VI	Malappuram type	Tirur, Kuttipuram, Tanur, Tirurangadi, Vengara, Malappuram, Manjeri, Kondotty, Kozhikode8, Kozhikode (C), Chevayur, Kunnamangalam, Koduvally, Nileshwar8, Kanhangad9, Kasargod9, Manjeshwar9
VI	Malayoram	Perumkadavila, Vellanad, Nedumangad, Vamanapuram, Anchal, Pathanapuram, Parakode, Konni, Ranni, Vazhoor, Kanjirappally, Pampady, Erattupetta, Lalam, Pala (M), Uzhavoor, Thodupuzha, Elamdesam, Muvattupuzha, Muvattupuzha(M), Kothamangalam, Chalakudy7, Kodakara7, Ollukkara, Pazhayannur, Mannarkkad, Sreekrishnapuram, Perinthalmanna, Mankada, Vandur
VIII	Palakkad plains	Alathur, Palakkad, Palakkad (M), Kuzhalmannam, Nemmara10
IX	Red loam	Nemom, Neyyattinkara (M), Athiyannur, Parassala
X	Chittoor black soil	Chittur, Kollengode
XI	Kuttanad	Chambakulam, Veliyanad, Pulikeezhu7
XII	Riverbank alluvium	Distributed as narrow stretches in the river banks all over Kerala
XIIIII	High ranges	Arudai, Devikulam, Attapadi, Kalpetta, Sultan Battery, Mananthavady

M-Municipality; Corporation; 1-Kayal land; 2-Kuttanad; 3-Kariland; 4-Pokkali land; 5-Kole land; 6-Kaippad lands; 7-River bank alluvium; 8-Brown sands; 9-Sandy; 10-High ranges

(Source: Kissan kerala)

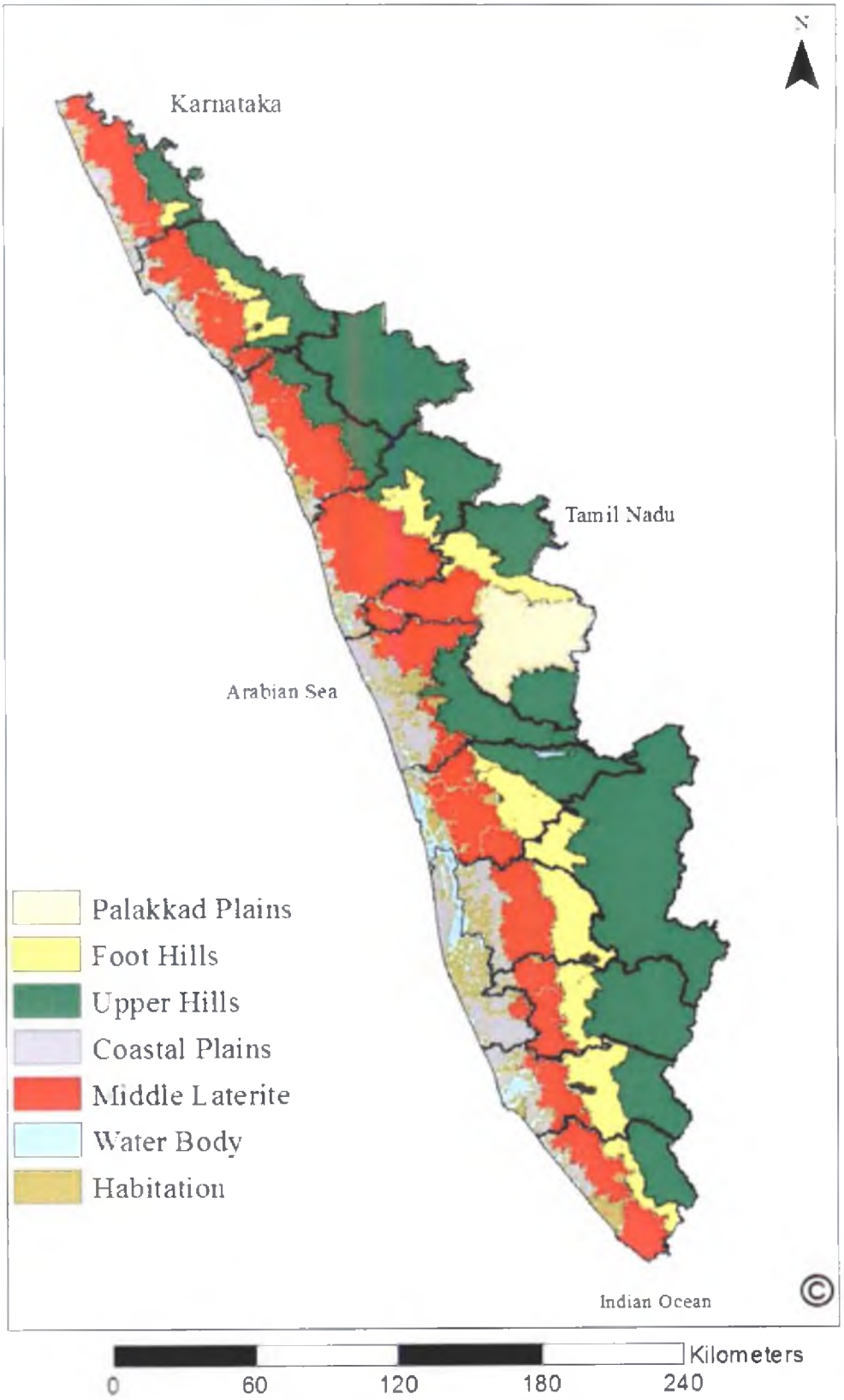


Fig. 3: Map showing Agricultural Zones of Kerala

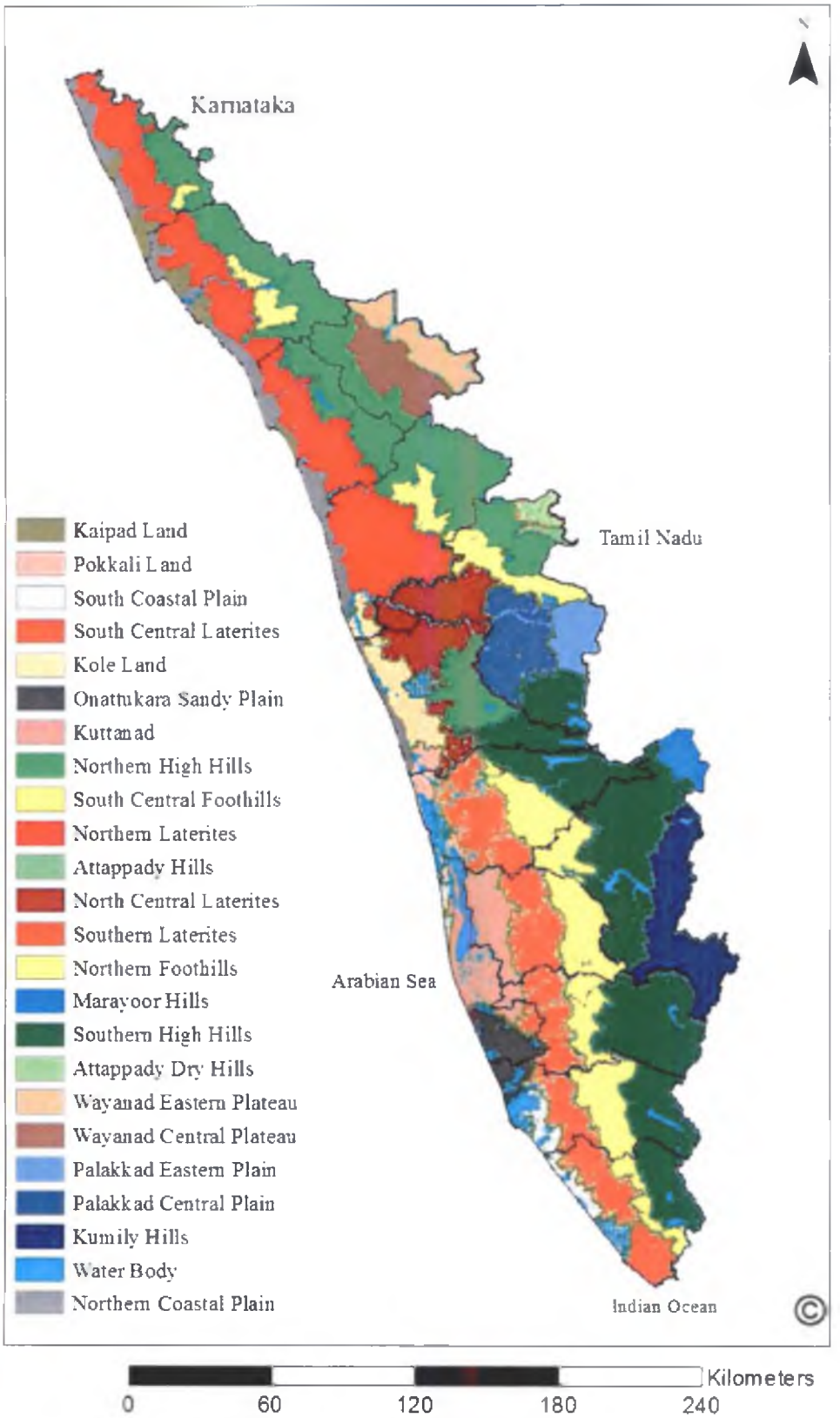


Fig. 4: Map showing Agricultural Units of Kerala

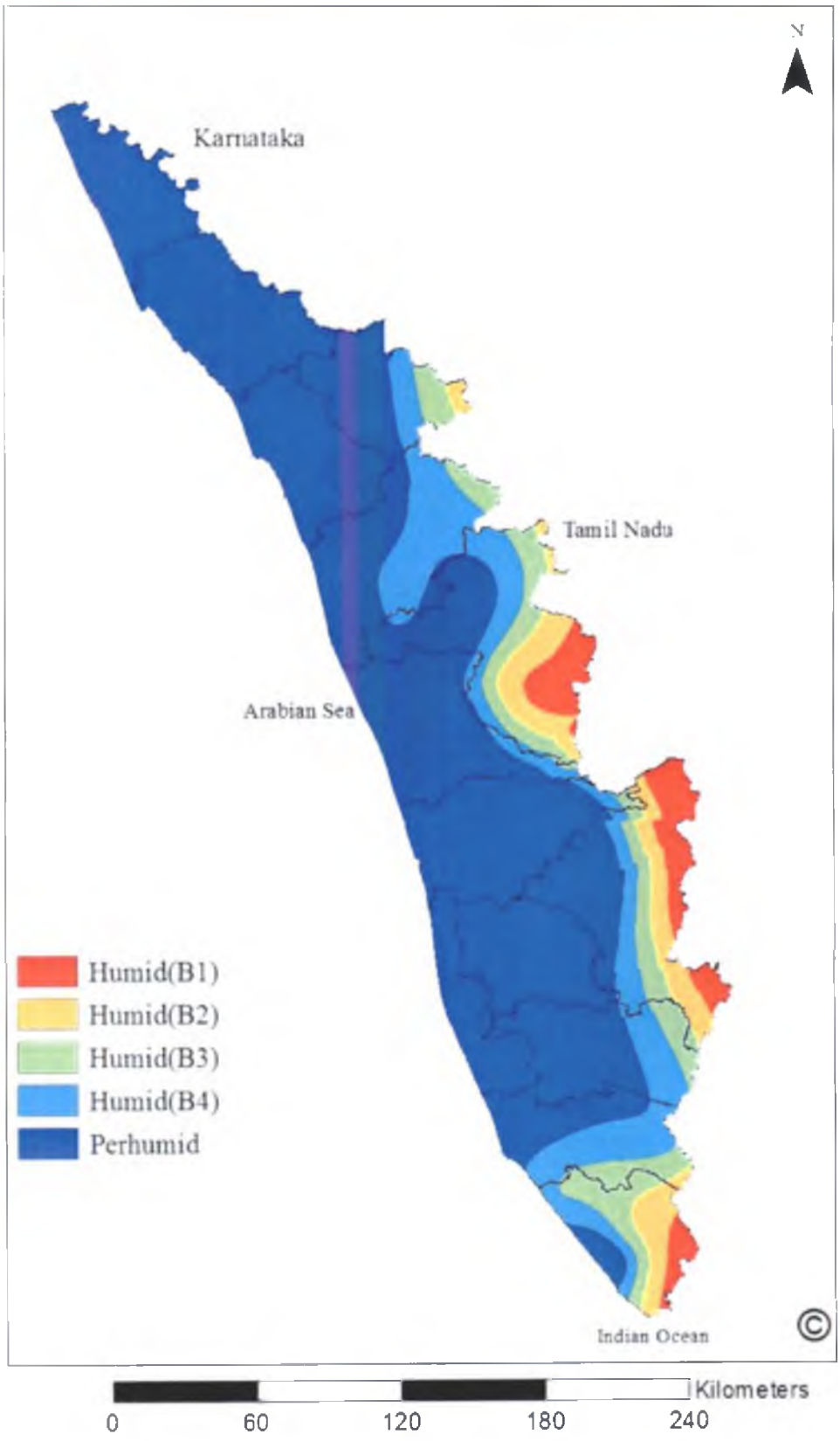


Fig. 5: Regions having different climatic types

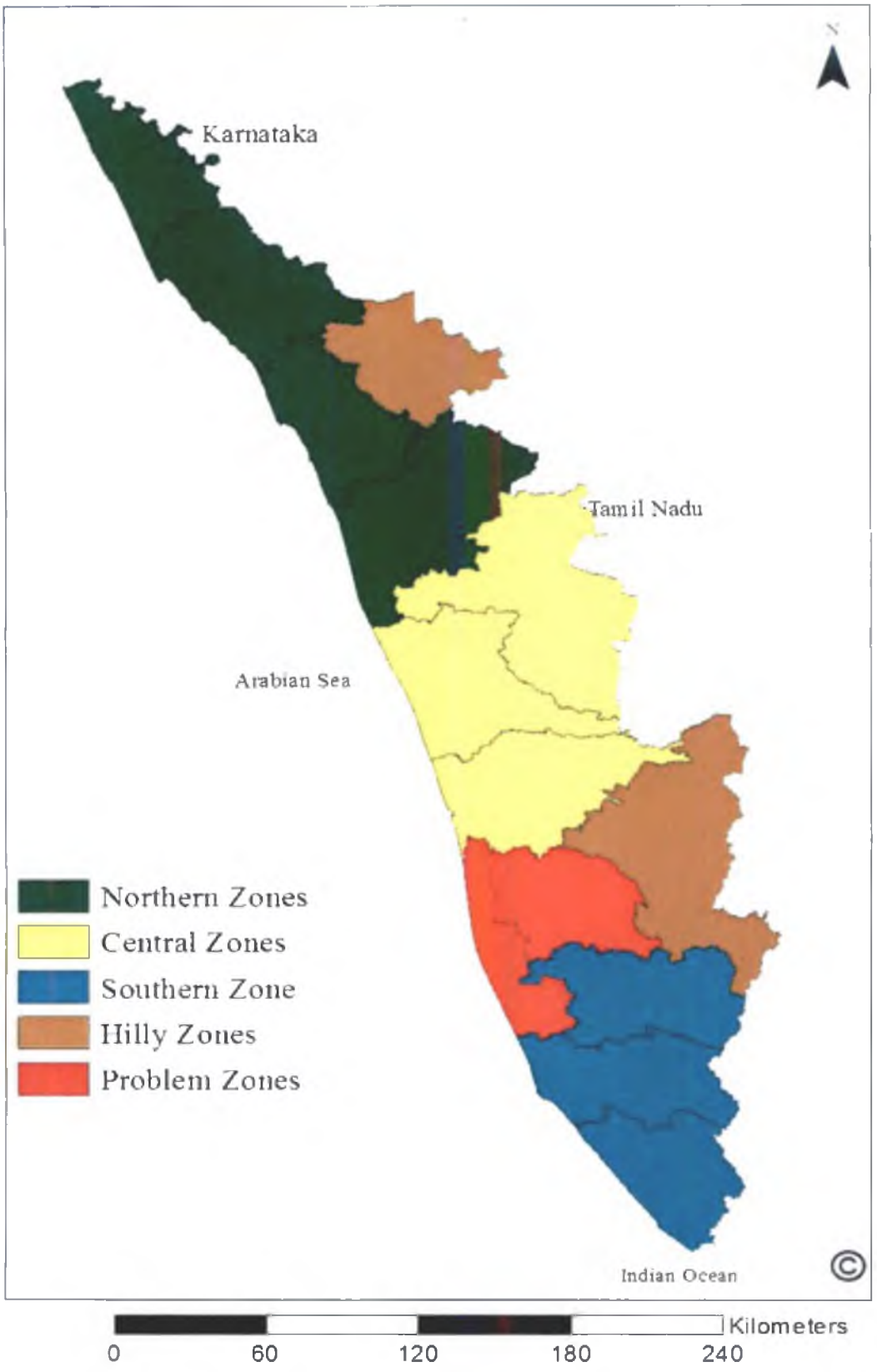


Fig. 6: Map showing Agro climatic Zones of Kerala

3. Agricultural scenario of Kerala

Agricultural crops in the state are broadly classified as food crops and non-food crops. Food crops are cereals & millets, sugar crops, spices & condiments, fresh fruits, vegetables, etc. The major non-food crops are rubber, betel leaves, lemon grass, etc. Another classification of crops is seasonal crops, annual crops and perennial crops which are based on their life time.

Seasonal crops: Paddy, pulses, tapioca, vegetables, sweet potato, tubers, groundnut, ginger, turmeric, cotton, tobacco, onion, etc.

Annual crops: Sugarcane, banana, plantain, pineapple etc.

Perennial crops: Coconut, arecanut, cashew, mango, jack, tamarind, pepper, rubber, tea, coffee, cardamom, cloves, nutmeg, cinnamon, cocoa, papaya, etc.

3.1 Food Grains

Paddy, Pulses and grains include the category of food grains. The total area under cultivation of food grains during 2013-14 is 2,02,926 ha. The area of food grains increased by 1% during 2013- 14 from the year 2012-13. When comparing with 2001-02 total area under food grains decreased by 40%

Paddy:

Paddy is cultivated in three seasons in all the districts of Kerala except Wayanad district. In Wayanad there is no autumn paddy cultivation. The area under paddy cultivation in the state is decreasing regularly (Fig.7). Area of paddy is collected in three seasons and its area is estimated even in panchayath level. Upland cultivation of paddy is the new change in Kerala (Fig 15-16).

The total paddy area during the year 1961-'62, was 7.53 lakh hectares and in 1975-'76 it was 8.76 lakh hectares. Thereafter a steady decrease in paddy cultivation and reached to 2.29 lakhs hectares during the agricultural year 2007-08. But in 2008-09, area of paddy cultivation was increased as 2.34 lakh hectares. On comparing with the year 1975-76, area of paddy cultivation is decreased 77% during the year 2013-14. The area under paddy cultivation in Kerala during the agricultural year 2013-14 is 1,99,611 ha. Paddy area is increased by 2334 ha (1.2%) than the previous year 2012-13. On comparing with 2001-02, 38% of paddy area decreased during 2013-14. On analyzing the area of last 10 years, paddy cultivation is high during the year 2004-05 and the area is 2,89,974 ha. Paddy accounted 7.6% of the total cropped area in the state during 2013-14 (Fig 17).

Pulses

Pulses cultivate in autumn, winter and summer seasons. The area under the cultivation of pulses shows a decreasing trend in the state. During 1975-76, the total area under pulses including tur was 37,485 ha. The total area of pulses including during 2013-14 is 2,989 ha whereas it was 2,948 ha during 2012-13. Major cultivation of pulses and in the state is in Palakkad district and the contribution to state total is 40%. On analyzing the area of last 10 years, pulses is maximum during the agricultural year 2005-06 and the area are 10,562 ha.

3.2 Spices and condiments

The important spices and condiments crops being cultivated in our state are pepper, ginger, turmeric, cardamom, arecanut, tamarind, cloves, nutmeg *etc*. Major contribution of spices & condiments is from Idukki district in all the years and is 31% during 2013-14. Pepper contributes 32% area to the total area of spices. The total area under the cultivation of spices & condiments during the year 2013-14 is 2,66,026 ha.

3.3 Vegetables

Drumstick, amaranthus, bitter gourd, snake gourd, ladies finger, brinjal, green chillies, bottle gourd, little gourd (koval), ash gourd, pumpkin, cucumber, cowpea are the important vegetables cultivated in our state. The total area under the cultivation of vegetables during 2013-14 is 41,262 ha. It represents 4% area of total food crops. Total area under vegetables has an increase of 1% in the year 2013-14 comparing to the previous year 2012-13. Palakkad (17%), Idukki (13%) and Malappuram (11%) districts have 1st, 2nd and 3rd positions in area under the cultivation of vegetables during 2013-14.

3.4 Oil seeds

The important oil seeds being cultivated in our state are coconut, groundnut, sesamum, etc. Coconut represents 99.8% of the category of oilseeds. The total area under the cultivation of oil seeds during the agricultural year 2013-14 is 8,10,497 ha. On comparing with 2012-13, an increase of 1.3% can be seen in this category during the year 2013-14.

3.5 Plantation Crops

The important plantation crops cultivated in the state are tea, coffee, rubber and cocoa. The total area of plantation crops during 2013-14 is 6,77,046 ha, whereas it was 6,68,142 ha during the last year 2012-13. There is an increase of 1.3% in the area of plantation crops in 2013-14 from 2012-13. Major cultivation of plantation crops is in Kottayam district and the representation to total area of plantation crops is 17%. Rubber has 1st position in area under the cultivation of plantation crops and the representation is 81%.

3.6 Fresh fruits

Fresh fruits representing 33% area of food crops during the agricultural year 2013-14. The important fresh fruits cultivated in our state are jack, mango, banana, plantain, pineapple, papaya, etc. The total area of fresh fruits during the year 2013-14 is 3,19,749 Ha. Palakkad is the district with fresh fruits largely cultivated in the state and the contribution is 15%. Malappuram (9.6%) and Idukki (9.4%) districts have 2nd and 3rd positions in the area under cultivation of fresh fruits during 2013-14. The area of jack cultivation during 2013-14 is 90,225 ha. It occupied 28% of the category of fresh fruits and it has top position in this category. Idukki, Kozhikode and Kannur districts stand 1st, 2nd and 3rd positions with 16%, 11% and 9% area respectively during 2013-14. The area under cultivation of mango during 2013-14 is 77,158 ha. It occupied 24% of the category of fresh fruits and it has 2nd top position in this category. Palakkad, Kozhikode and Malappuram districts stands 1st, 2nd and 3rd positions with 12%, 11% and 10% areas respectively. The area of banana cultivation during 2013-14 is 62,261ha. It occupied 19% of the category of fresh fruits and it has 3rd top position in this category 2% area is increased during 2013-14 in banana cultivation than 2012-13 and 22% increased from 2001-02. Palakkad, Wayand & Malappuram districts stands 1st three positions with areas 28%, 19% and 12% respectively during 2013-14. The area under cultivation of pineapple during 2013-14 is 8,002 ha. It occupied 2.5% of the category of fresh fruits and it has 7th top position in this category. A decrease of 6% in area observed in 2013-14 under pineapple cultivation from that in 2012- 13 and there is a decrease of 28% from the year 2001-02. The area under cultivation of papaya during 2013-14 is 16,640 ha. It occupied 5% of the category of fresh fruits and it has 5th top position in this category.

3.7 Tuber crops

Tubers represent 2% area of food crops during the year 2013-14. Elephant foot yam, colocasia, yam (kachil), sweet potato, etc include the category of tubers. The total area of tubers during 2013-14 is 18,602 ha, where as it was 19,789 ha during the last year 2012-13. Major cultivation of tubers is in Kollam district and the contribution to total area of tubers is 19% during 2013-14. Pathanamthitta (14%) and Palakkad (12%) districts are 2nd & 3rd positions under the cultivation of tubers in the state during 2013-14. Colocasia has 1st position in area under the cultivation of tubers and the percentage of colocasia to the total area of tubers is 41%.

Tapioca was one of main food crops in Kerala for the past years and so this crop was cultivated extensively in our state. But analyzing the cropping pattern of the last 15 years we can see that major portion of land under tapioca cultivation has been shifted to rubber cultivation. During 1975-76, the area under tapioca cultivation was 3.27 lakh hectares. Thereafter the area was decreased. The total area of tapioca cultivation during the year 2013-14 is 67,589 ha. Area of tapioca representing 7% area of food crops during 2013-14 and is cultivated i autumn, winter & summer seasons. The area under cultivation of tapioca in autumn, winter & summer seasons are 12,539 ha (19%), 21,699 ha (32%) & 33,351 ha (49%) respectively. Kollam, Thiruvananthapuram & Idukki districts stand 1st, 2nd & 3rd positions in tapioca cultivation with area of 24%, 21% and 9% respectively during the year 2013-14. (Agricultural statistics Kerala 2013-2014).)

Table.5: Delineation of net sown area into different production zones of principal crops of Kerala

Crops	Primary Zones		Secondary Zones		Tertiary Zones	
	Districts	Area(ha)	Districts	Area(ha)	Districts	Area(ha)
Paddy	*Palakkad*	*81048.5*	*Alapuzha* *Kottayam* *Thrissur* *Wayanad*	86999.0	Thiruvananthapuram Kollam Pathanamthitta Idukki Ernakulam Malappuram Kozhikkode Kannur Kasargod	30396.5
Coconut	*Kozhikkode*	*123967.0*	*Thirruvananthapuram* *Kollam* *Ernakulam* *Thrissur* *Palakkad* *Malappuram* *Kannur* *Kasargod*	571974.0	Alapuzha Kottayam Pathanamthitta Idukki Wayanad	110122.6
Areacanut	Kasargod Malappuram	38240.0	Thrissur Palakkad Wayanad Kozhikkode Kannur	48246.0	Thiruvananthapuram Kollam Pathanamthitta Alapuzha Kottayam Idukki Ernakulam	14780.7
Banana	Malappuram Wayanad	19467.0	Thirruvananthapuram Kollam Kottayam Idukki Ernakulam Palakkad	20687.75	Pathanamthitta Alapuzha Thrissur Kozhikkode Kannur Kasargod	9084.5
Nutmeg	Ernakulam Thrissur	12307.5	Kottayam Idukki	4428.0	Thiruvananthapuram Kollam Pathanamthitta Alapuzha Palakkad Malappuram Kozhikkode Wayanad Kannur Kasargod	2309.0
Black Pepper	Idukki	43339.5	Kannur Wayanad	14127.5	Thiruvananthapuram Kollam Pathanamthitta Alapuzha Kottayam Ernakulam	26894.0

					Thrissur Palakkad Malappuram Kozhikkode Kasargod	
Cardamom	Idukki	32443	Wayanad Palakkad	6877	Thiruvananthapuram Kollam Pathanamthitta Alapuzha, Kottayam Ernakulam Thrissur Malappuram Kozhikkode Kannur Kasargod	1593
Cashew	Kannur	22887.5	Kollam Palakkad Malappuram Kasargod	17928	Thiruvananthapuram Pathanamthitta Alapuzha Kottayam Idukki Ernakulam Thrissur Kozhikkode Wayanad	12253.5
Coffee	Wayanad	67364	Idukki Palakkad	17995	Thiruvananthapuram Kollam Pathanamthitta Alapuzha Kottayam Ernakulam Thrissur Malappuram Kozhikkode Kannur Kasargod	0
Tea	Idukki	21970	Kottayam Wayanad	7285	Thiruvananthapuram Kollam Pathanamthitta Alapuzha Ernakulam Thrissur Palakkad Malappuram Kozhikkode Kannur Kasargod	2929
Rubber	Kottayam	114045	Thiruvananthapuram Kollam Pathanamthitta Idukki, Ernakulam Palakkad,Malappuram Kannur,Kasargod	377687.5	Alapuzha Thrissur Kozhikkode Wayanad	52157.85

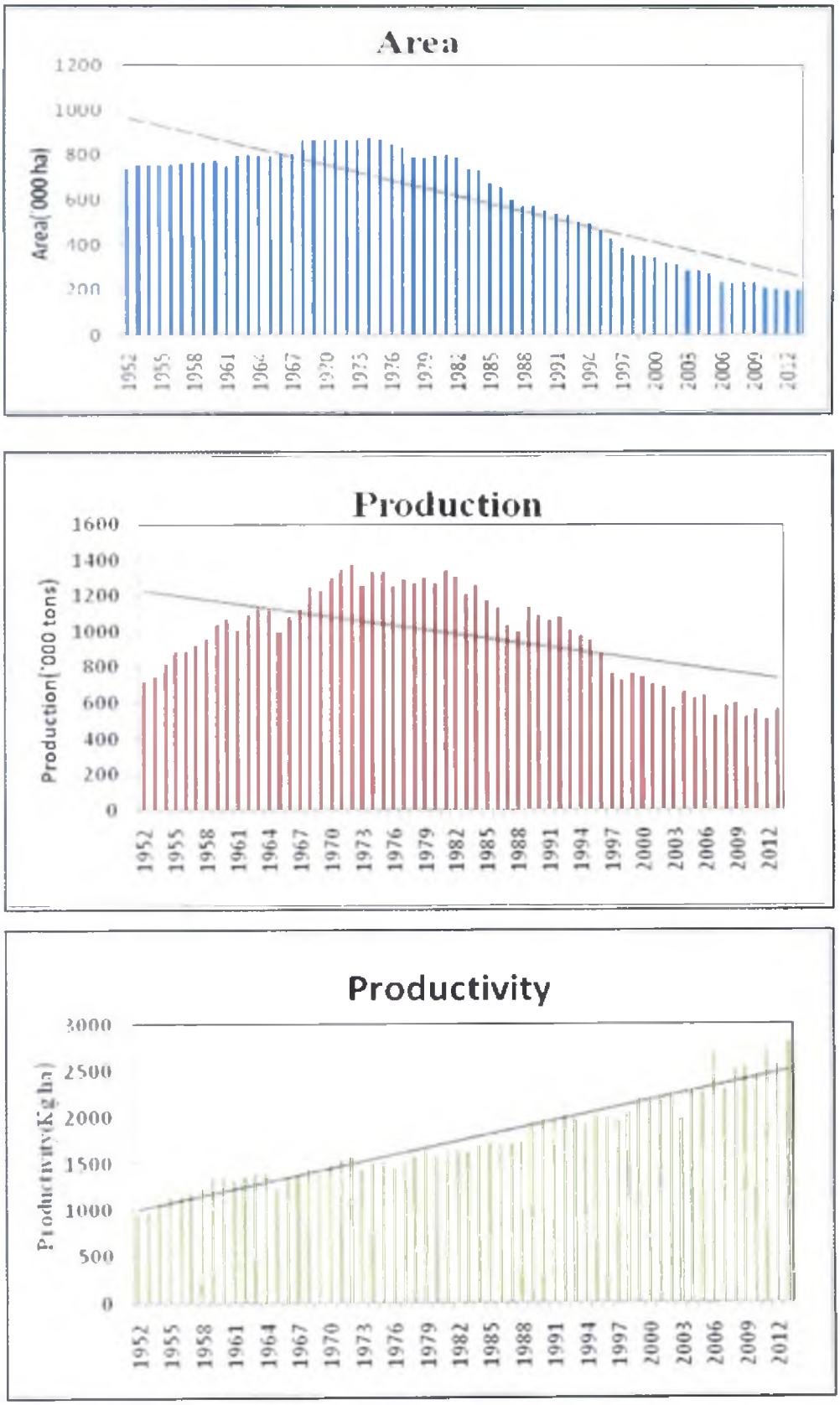


Fig.7 : Trends in area, production and productivity of paddy in Kerala(1952-2014)

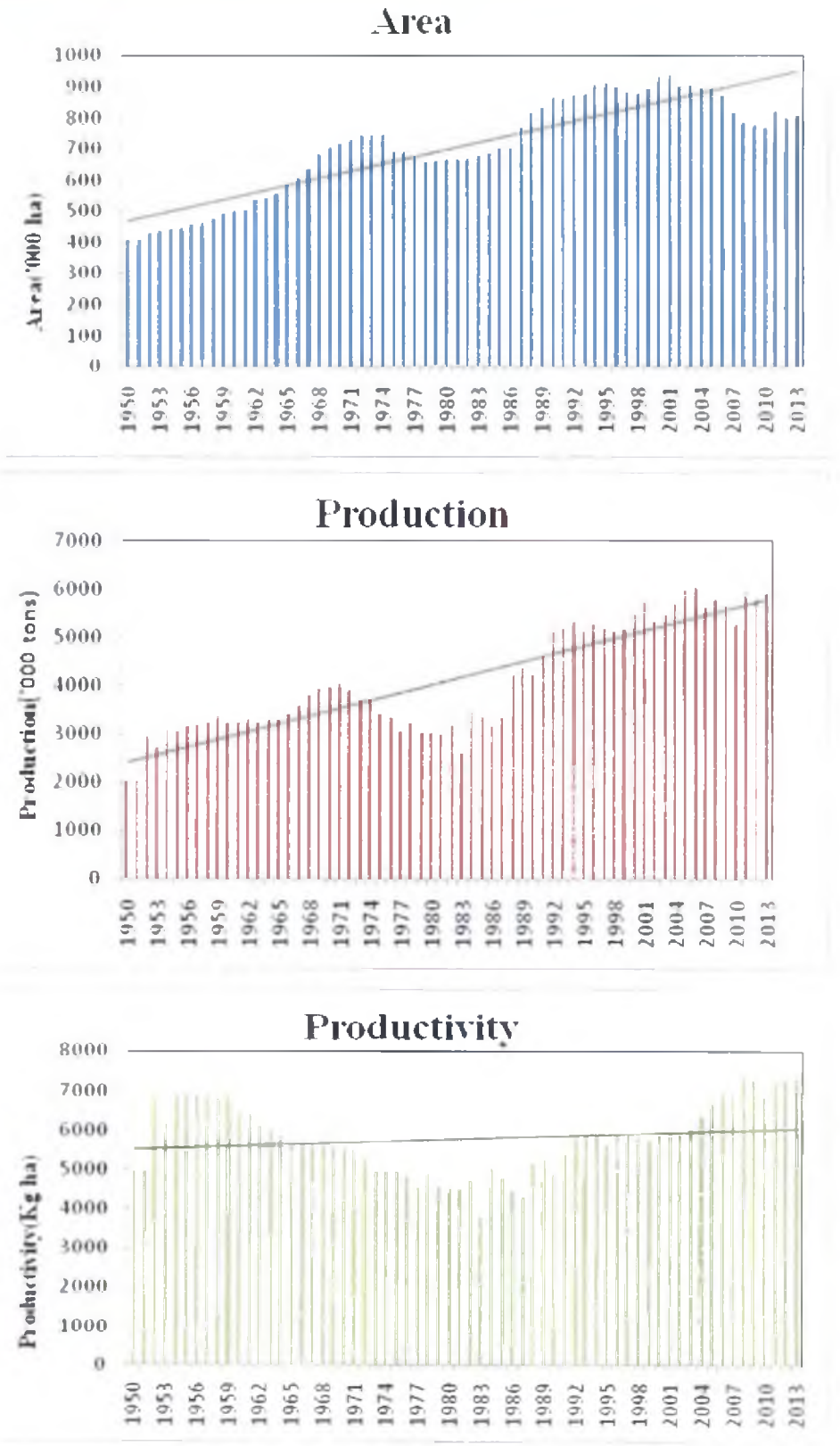


Fig.8: Trends in area, production and productivity of coconut in Kerala(1952-2014)

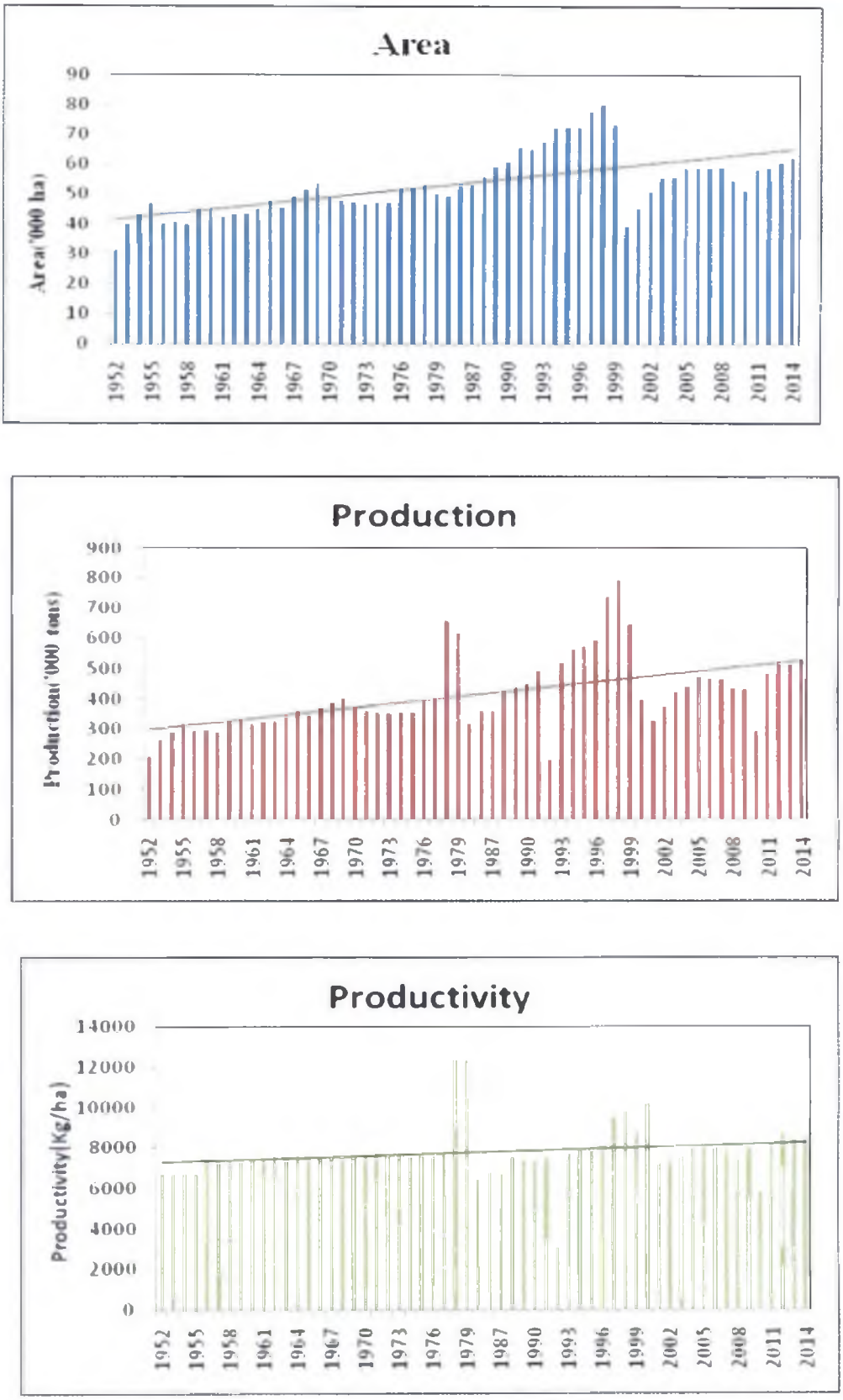


Fig.9: Trends in area, production and productivity of Banana in Kerala(1952-2014)

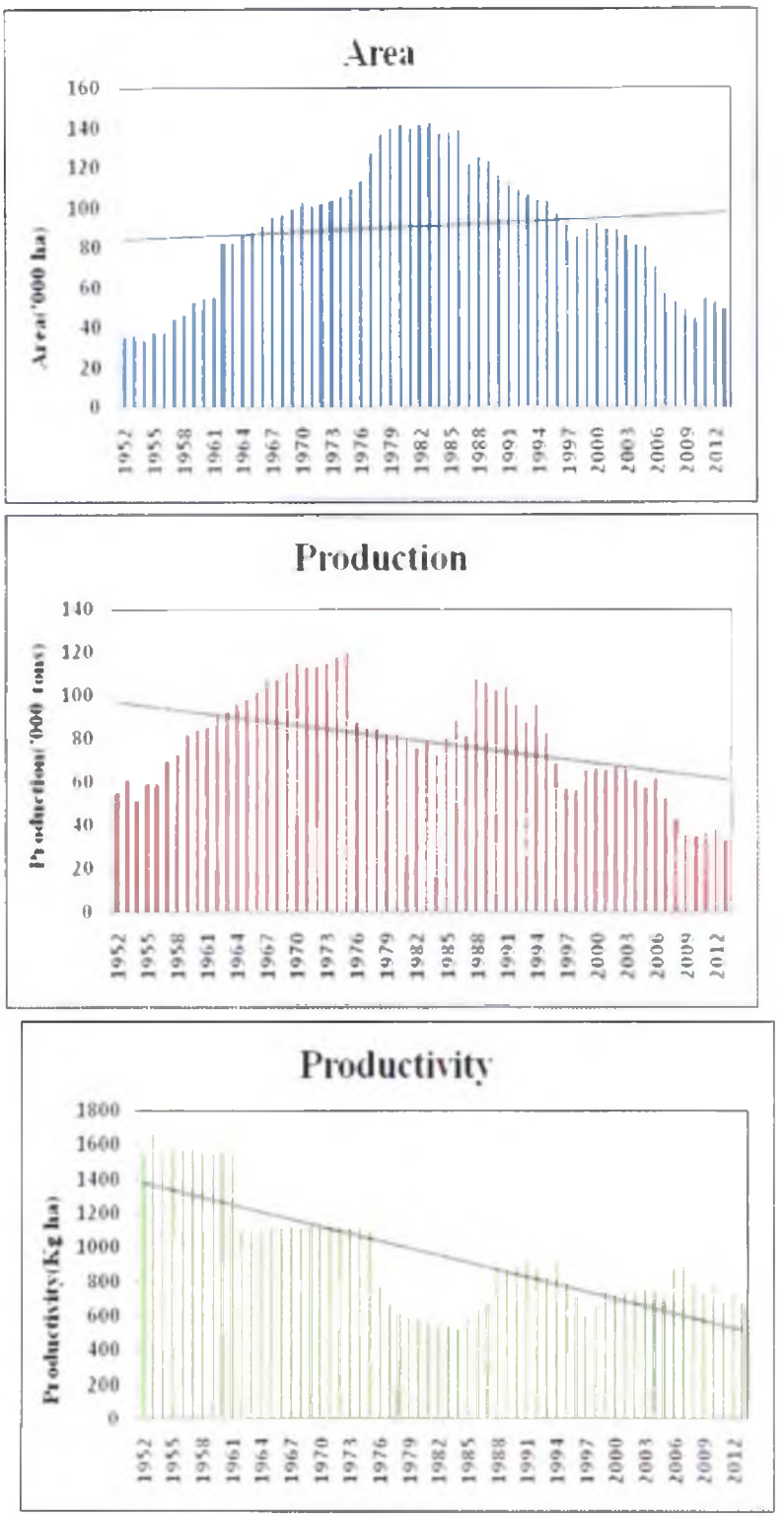
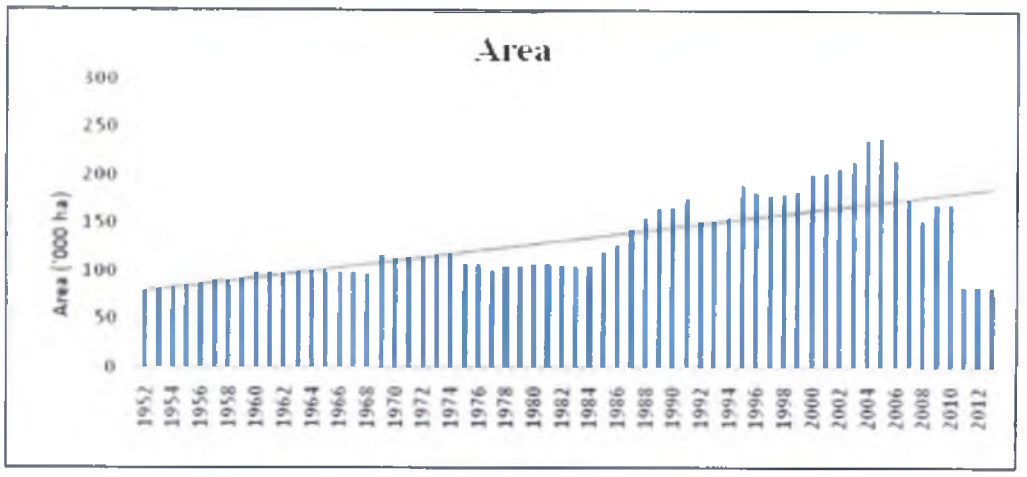
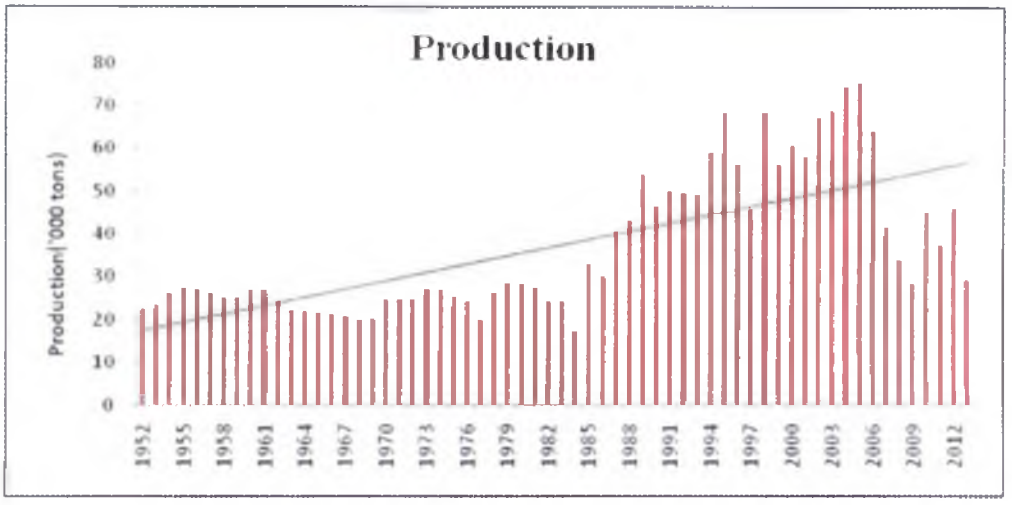


Fig.10: Trends in area, production and productivity of cashew in Kerala (1952-2014)





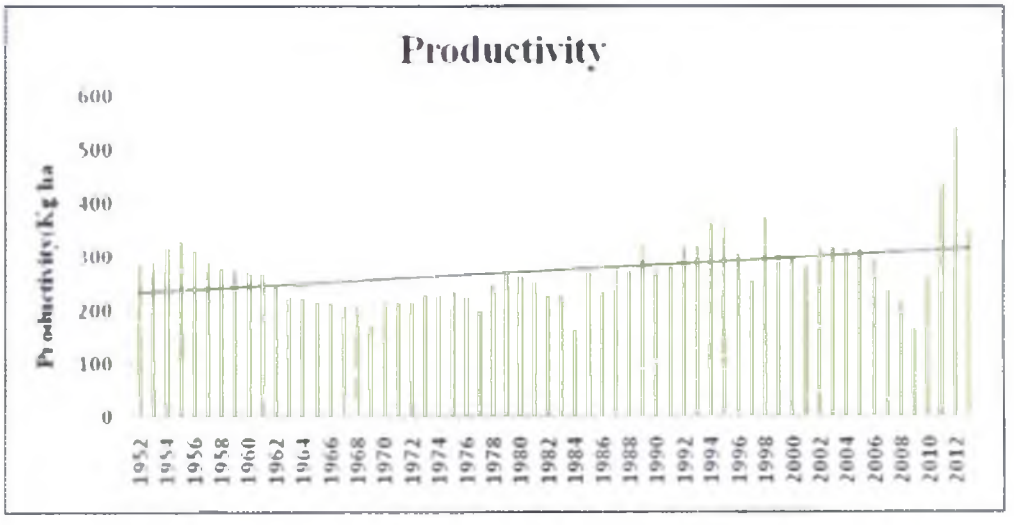


Fig.11 : Trends in area, production and productivity of pepper in Kerala(1952-2014)

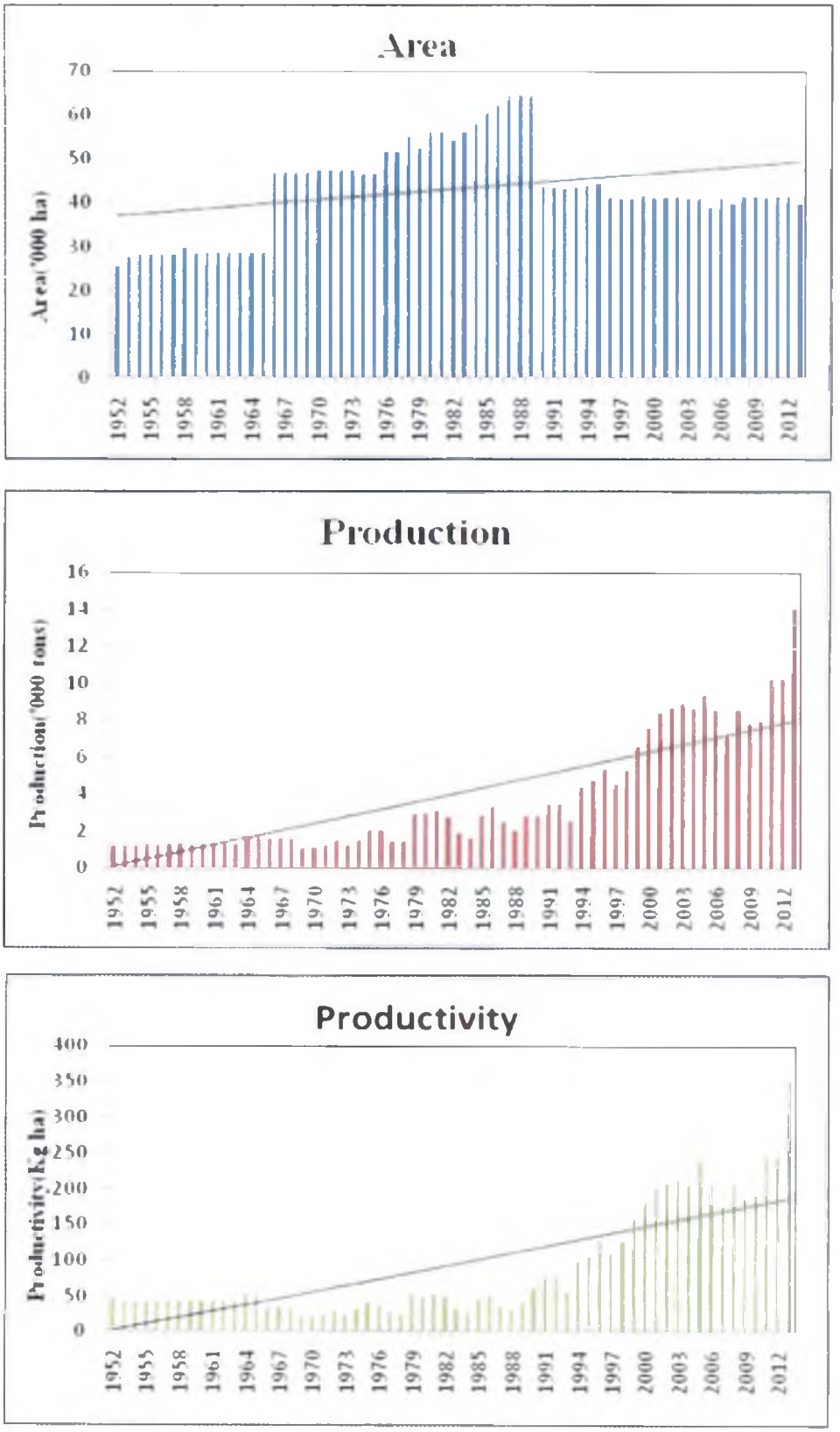


Fig.12: Trends in area, production and productivity of cardamom in Kerala (1952-2014)

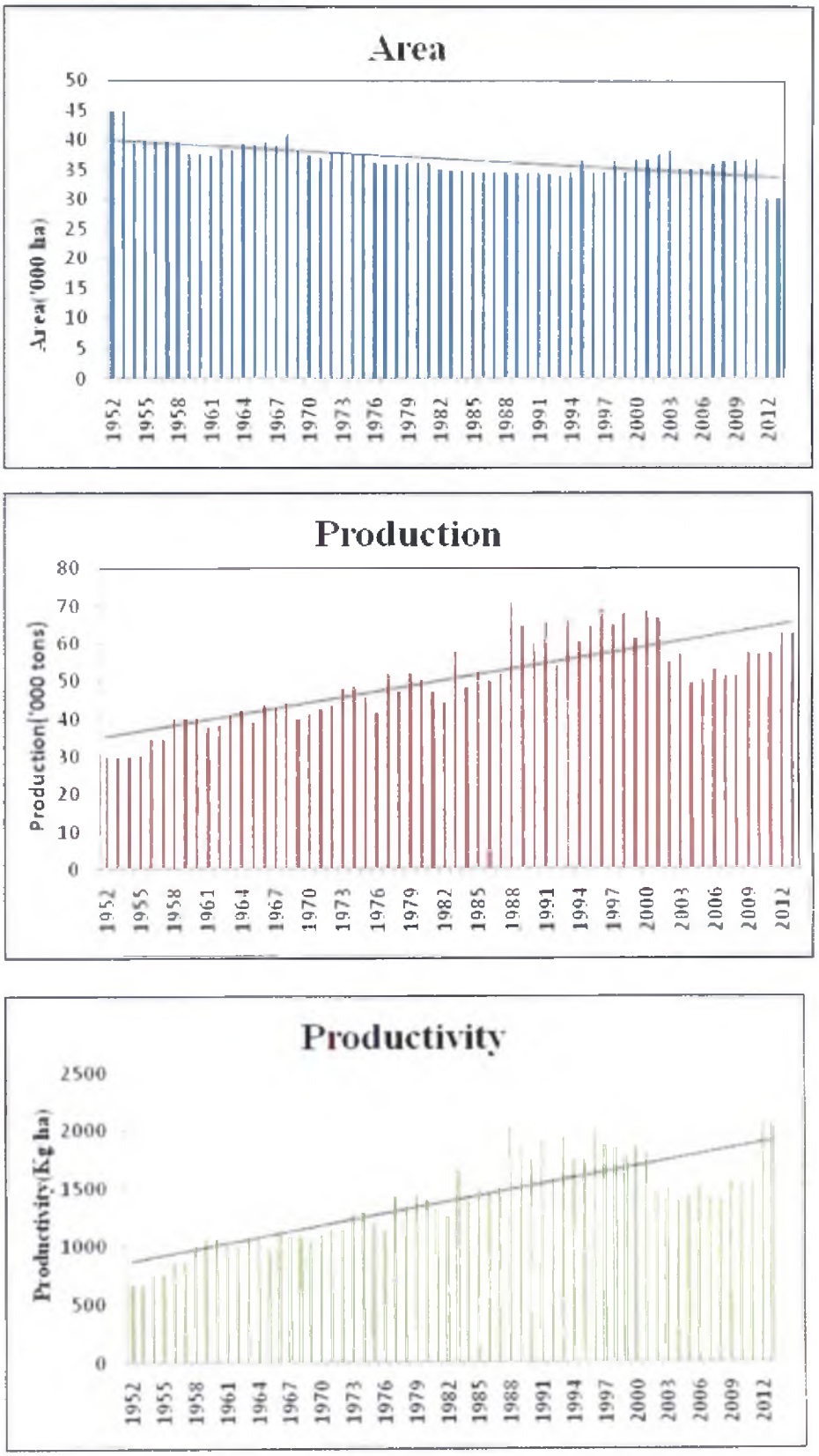


Fig.13 : Trends in area, production and productivity of tea in Kerala (1952-2014)

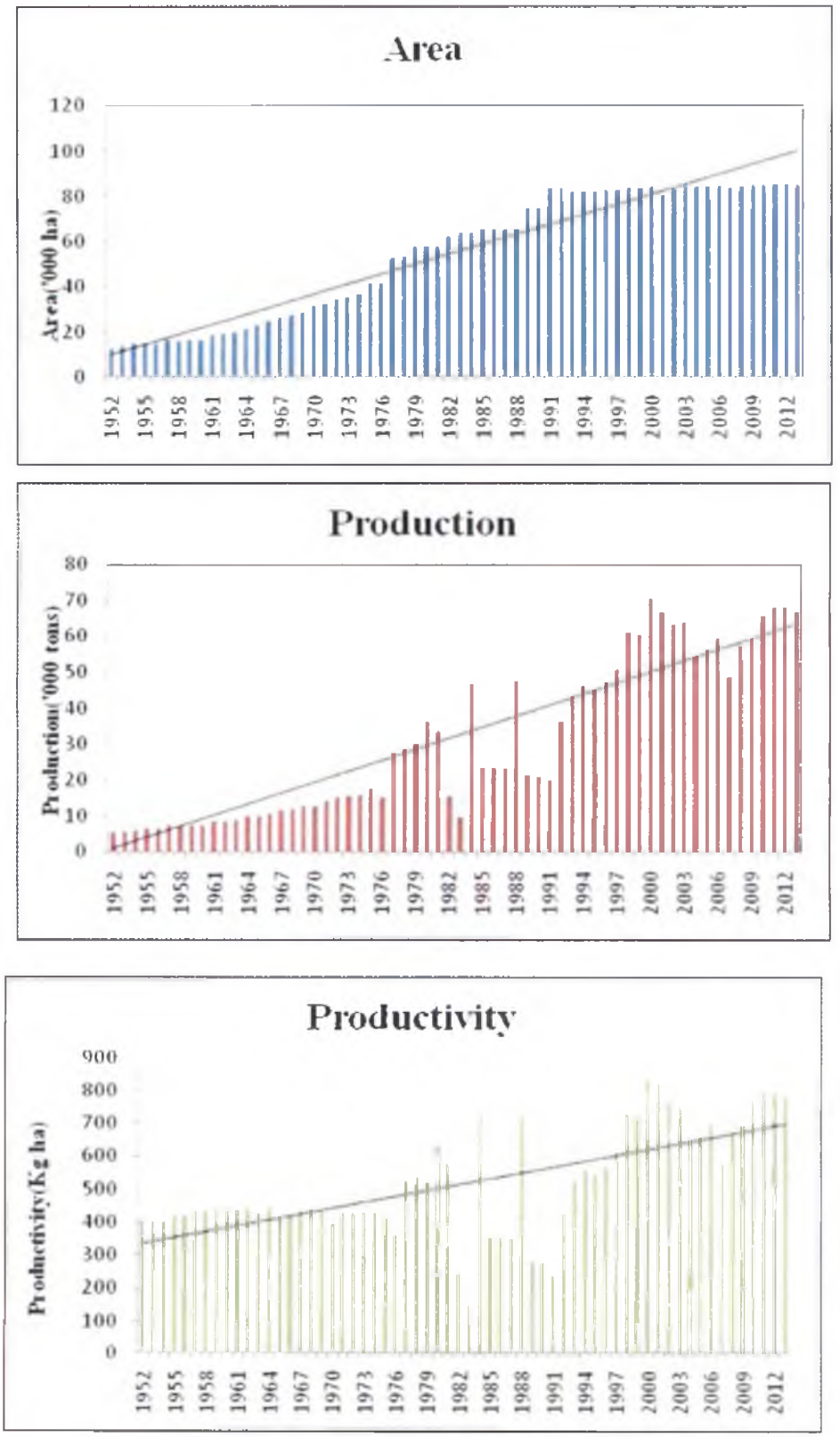


Fig.14 : Trends in area, production and productivity of coffee in Kerala(1952-2014)

3.8 Delineation of production zone

The net sown area in the state has been classified / demarcated into different categories of production zones of the widely grown crops 2012-2013. The criteria adapted for the categorization is the area under each crop and those districts contributing above 15% of the area in the state are termed as primary zone and districts contributing in between 5-15% of net area sown under the crop consideration are classified as secondary and the rest of the districts (below 5%) as tertiary zone. This type of categorization helps in planning and implementing projects to expand areas under the crops currently grown or to introduce new crops or their cultivars into the new area (Table.5)

Trends in area, production and productivity of different crops in Kerala from the year 1952 to 2014 are depicted in (Fig 7 to 14)

3.9 Demarcation of productivity (yield) zones

The difference between the potential productivity of a crop in a region and its yield at farm level can be quantified using yield gap analysis. The analysis helps in the 14 development of suitable strategies to improve the production at farm level. Usually the yield gap analysis is done using experimental data, here an attempt is made to identify the regions with high productivity and regions with low productivity retaining heterogeneity of practical farming at district level. This comparison may ultimately result in identifying production constraints so as to bring all the zones to higher productivity levels. The criteria adopted in the demarcation of the zones are based on area as well as yield of different crops. It is presented in Table 6.

Table 6: Criteria adopted for categorization of productivity zones of different crops

Crops	Area(ha)			Yield(kg/ha)		
	High	Medium	Low	High	Medium	Low
Paddy	>35000	10000-35000	<10000	>2500	2000-2500	<2000
Coconut	>75000	35000-75000	<35000	>8000	7000 8000	<7000
Arecanut	>10000	5000-10000	<5000	>1000	600-1000	<600
Nutmeg	>6000	500-6000	<500	>600	500-600	<500
Black pepper	>5000	2000 5000	<2000	>500	300-500	<300
Banana	>5000	2000-5000	<2000	>9000	8000-9000	<8000
Rubber	>50000	20000-50000	<20000	>1400	1200-1400	<1200
Cashew	>8000	1000-8000	<1000	>500	250-500	<250
Cardamom	>4000	100-4000	<100	>150	10-150	<10
Ginger	>1000	200-1000	<200	>4000	2500-4000	<2500

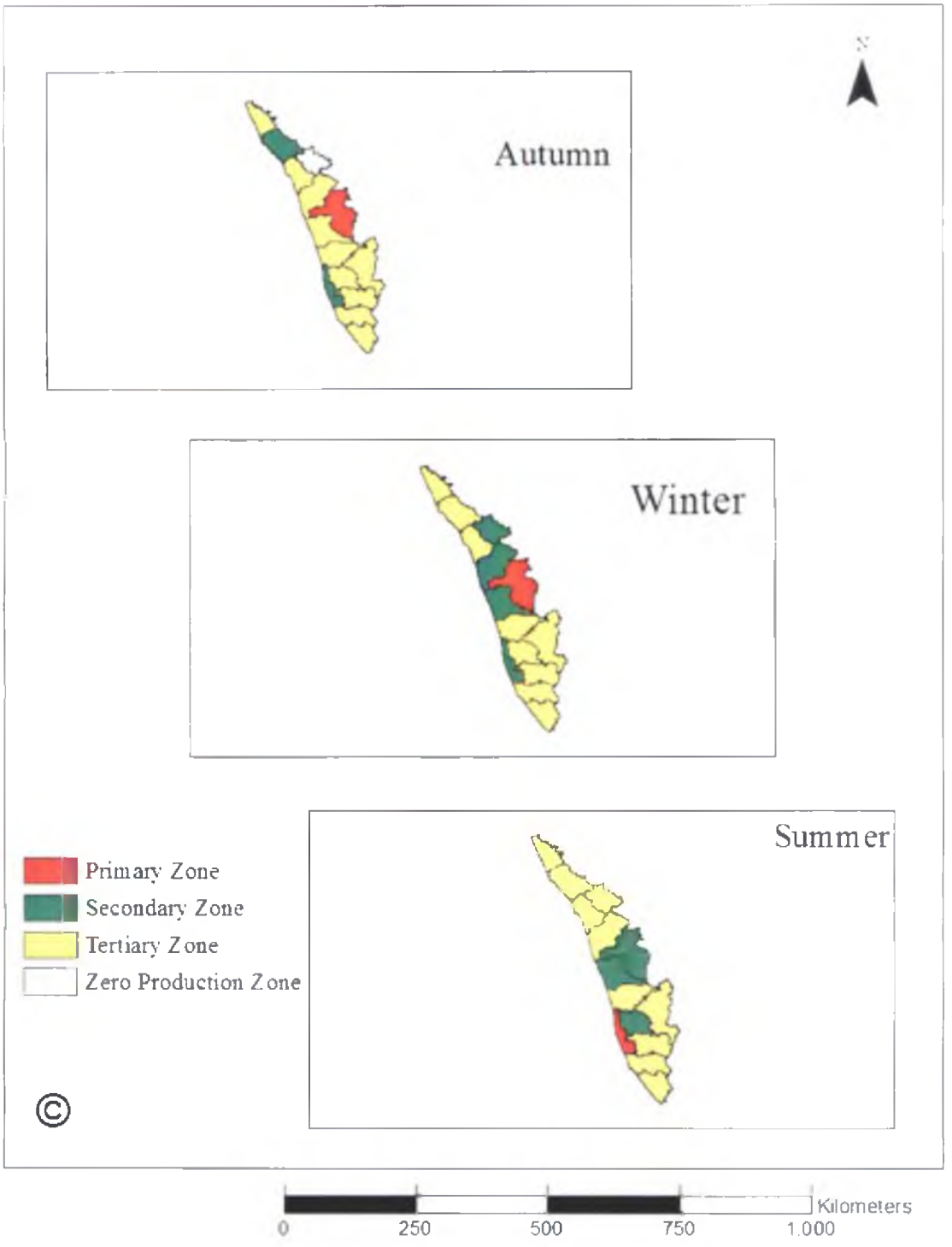


Fig. 15: Area of paddy in all season in Kerala

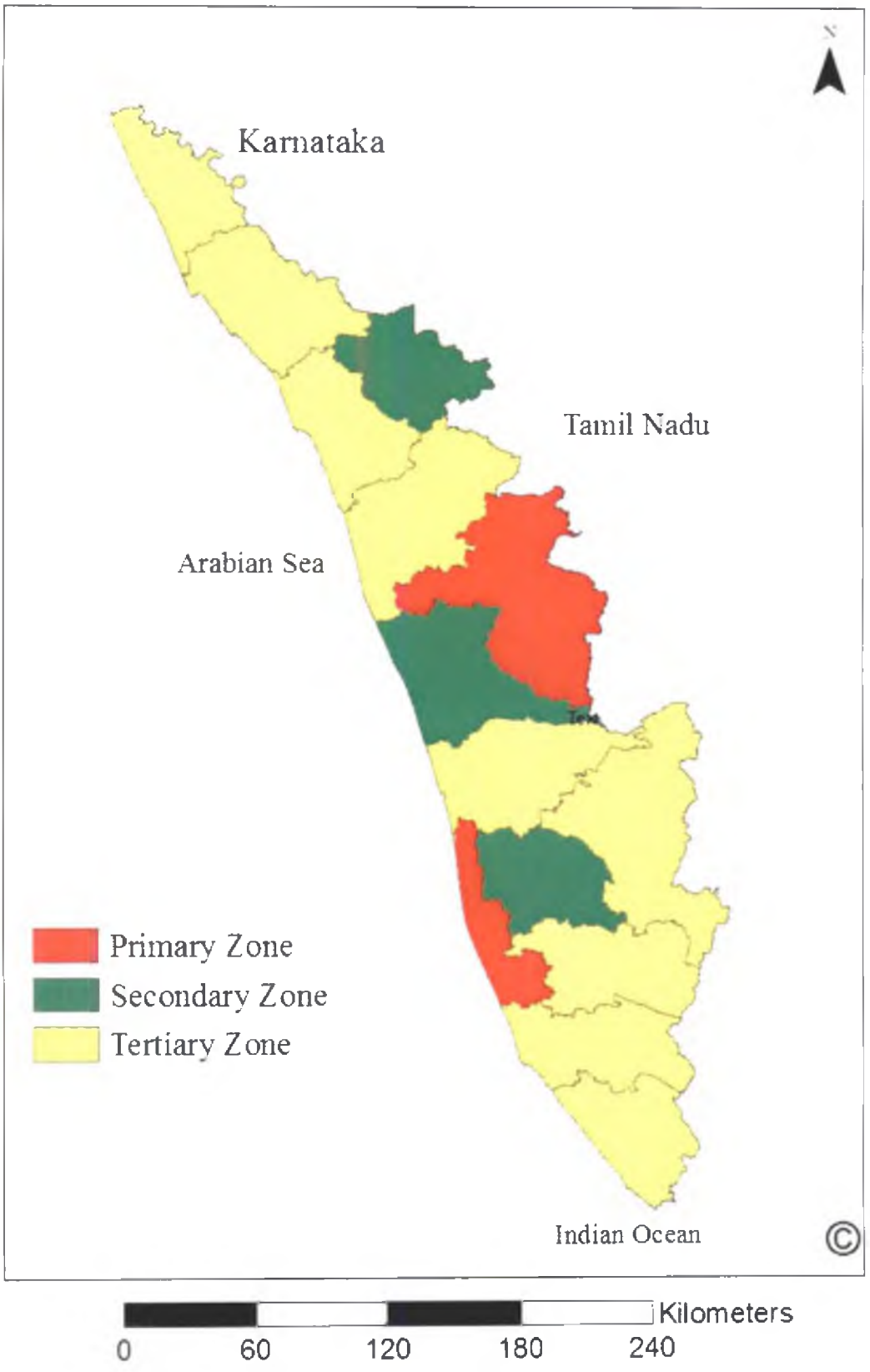


Fig. 16: Area of paddy in Kerala

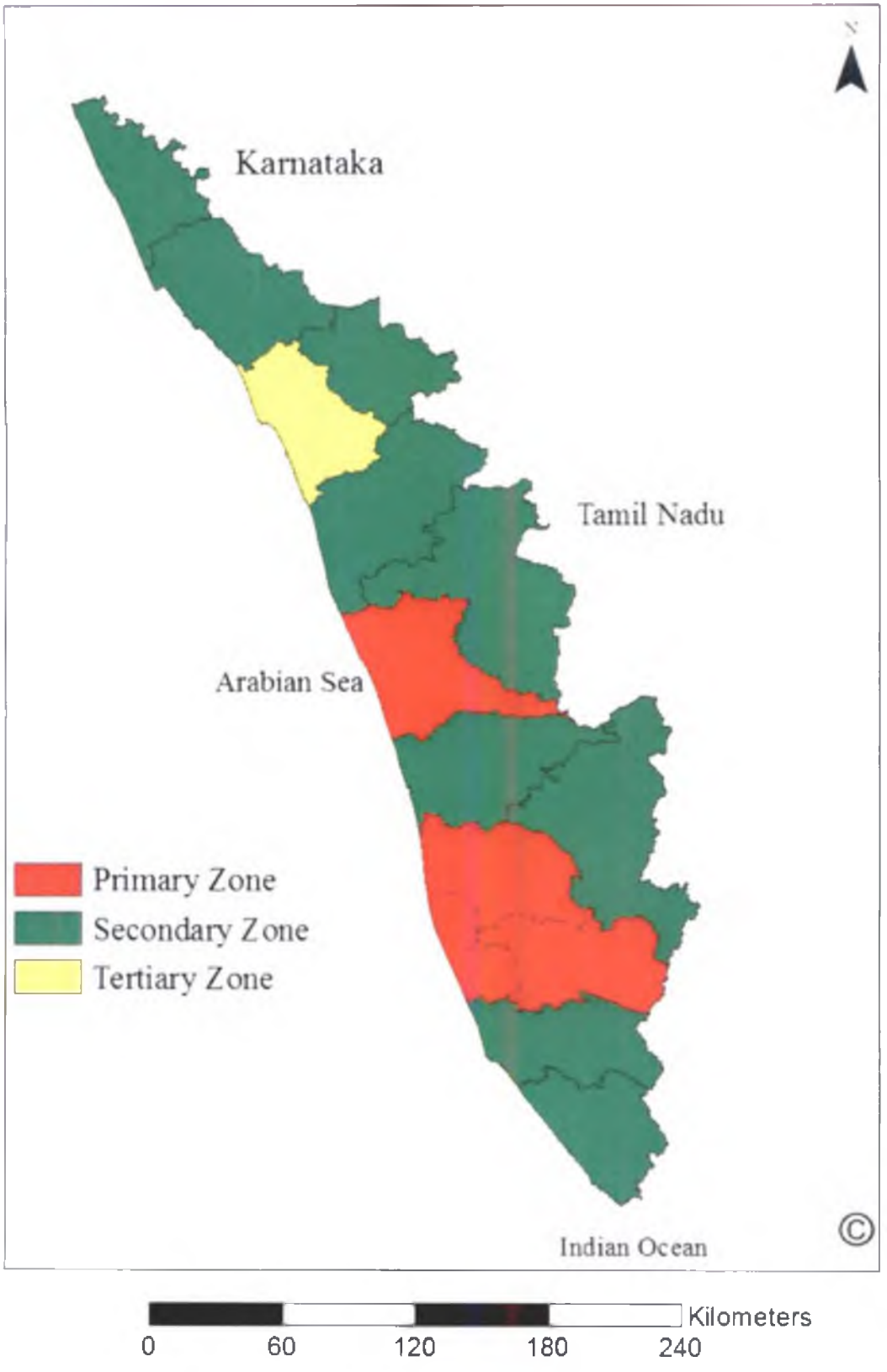


Fig. 17: Production zones of Paddy in Kerala

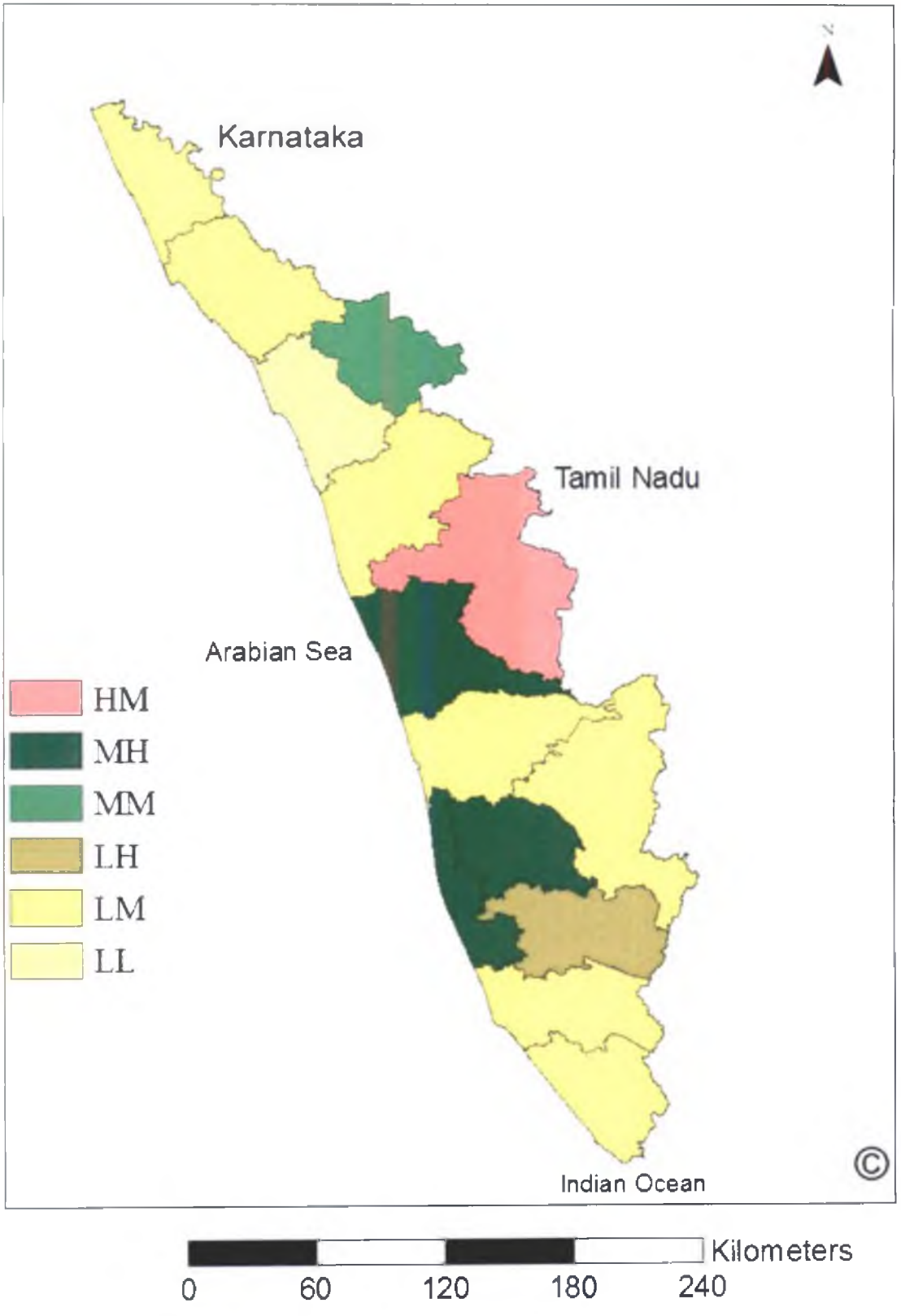


Fig. 18: Delineation of different productivity zones of Paddy in Kerala

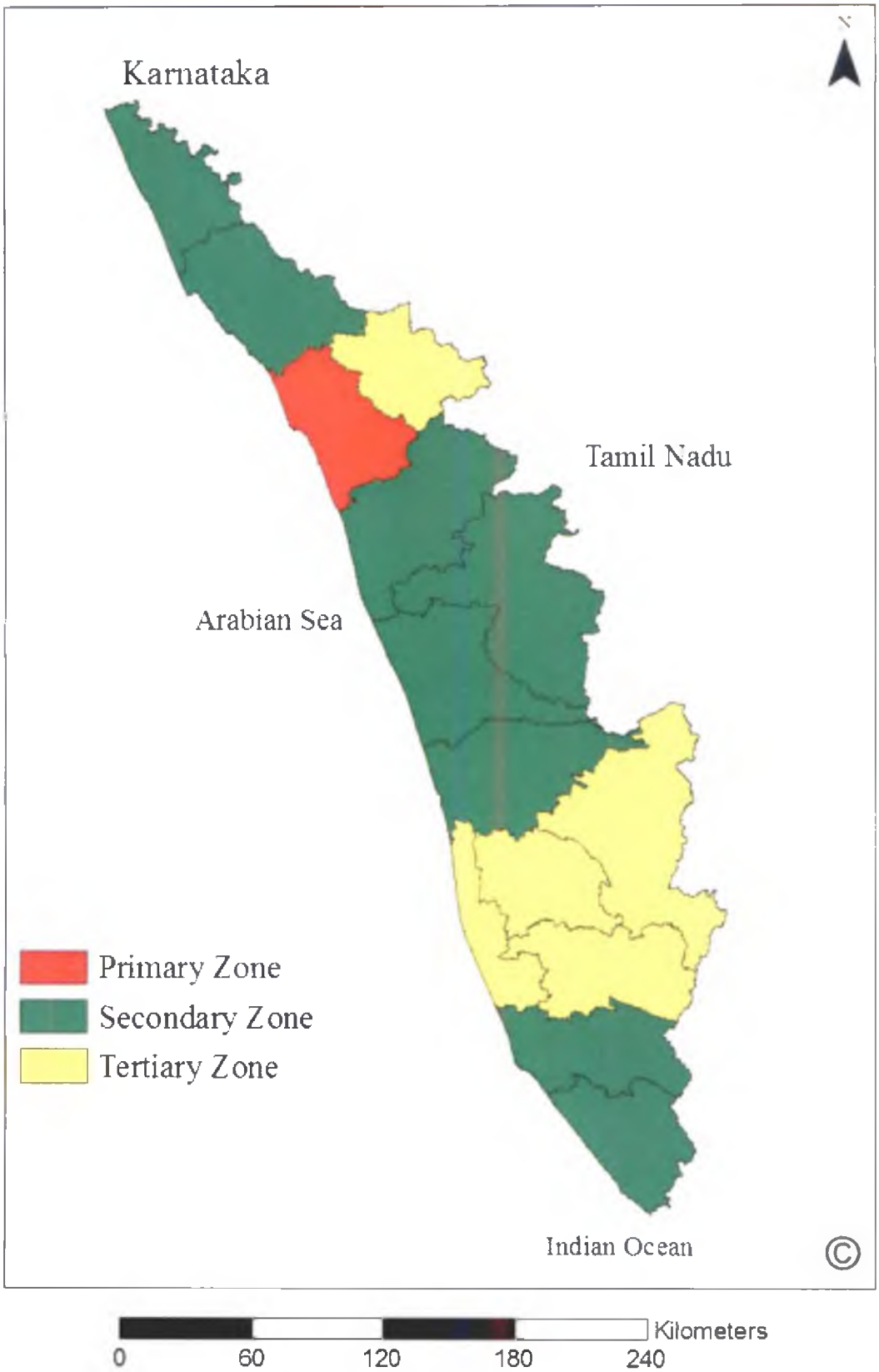


Fig. 19: Area of Coconut in Kerala

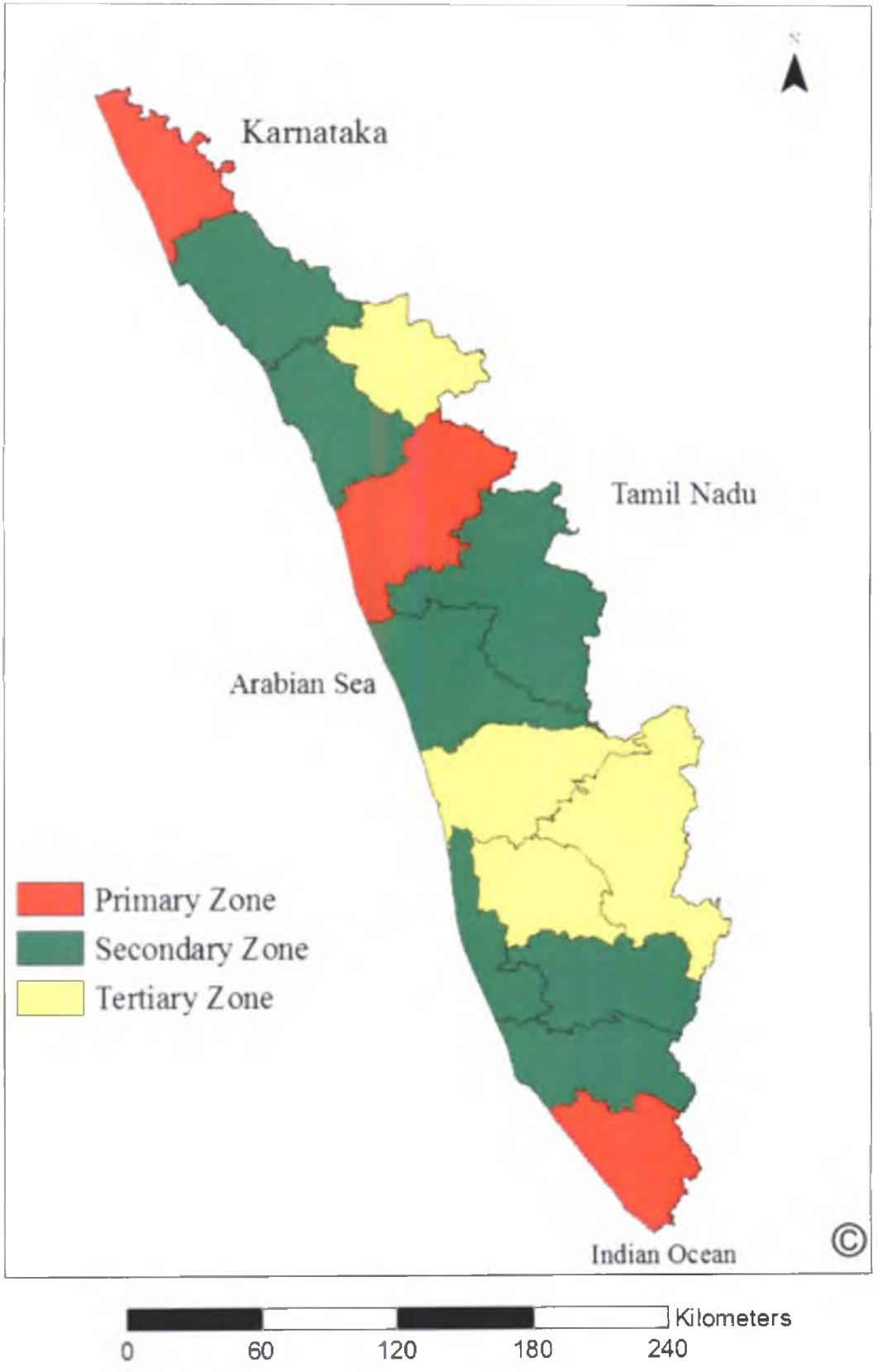


Fig. 20: Production zones of Coconut in Kerala

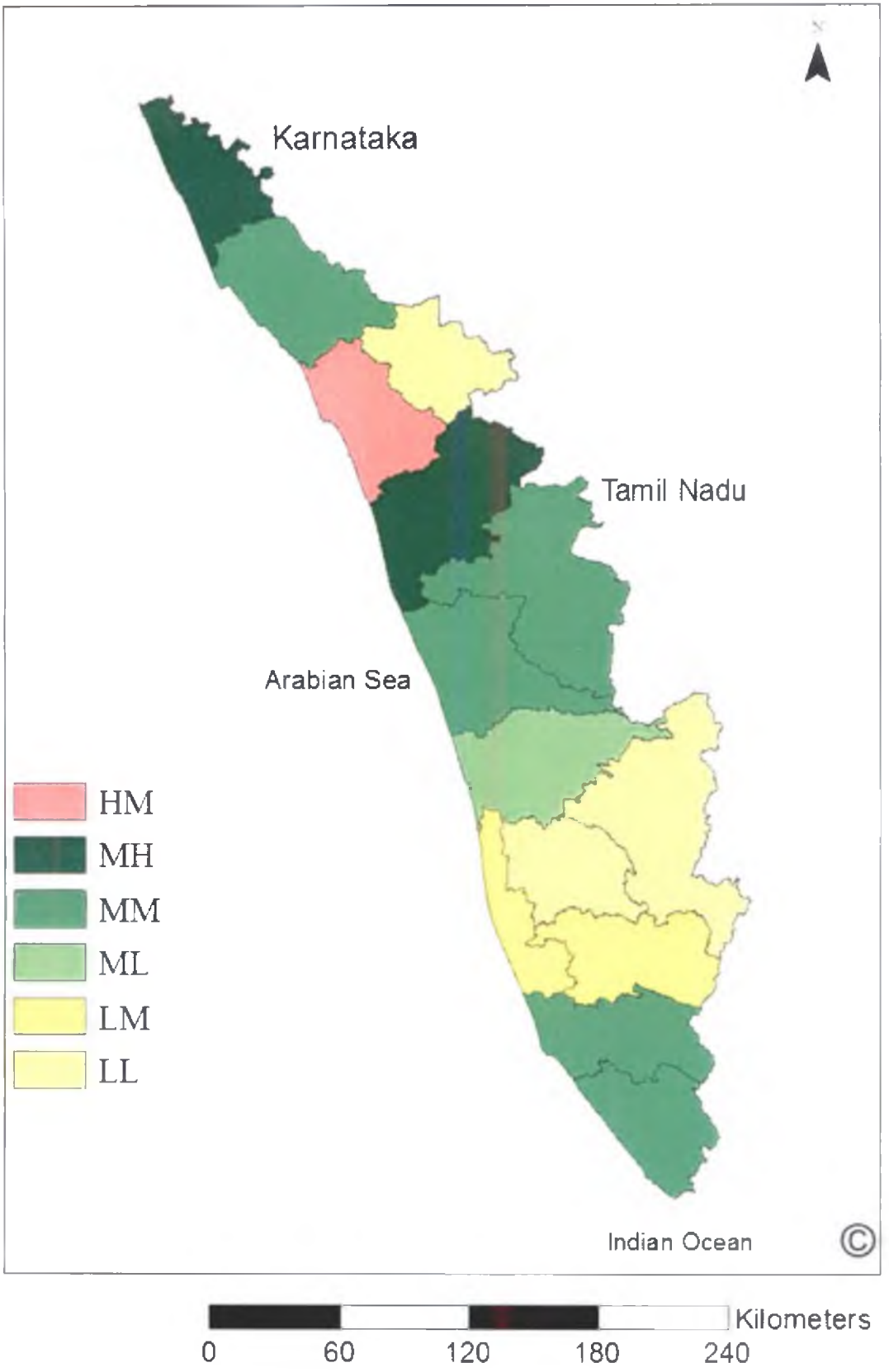


Fig. 21: Delineation of different productivity zones of Coconut in Kerala

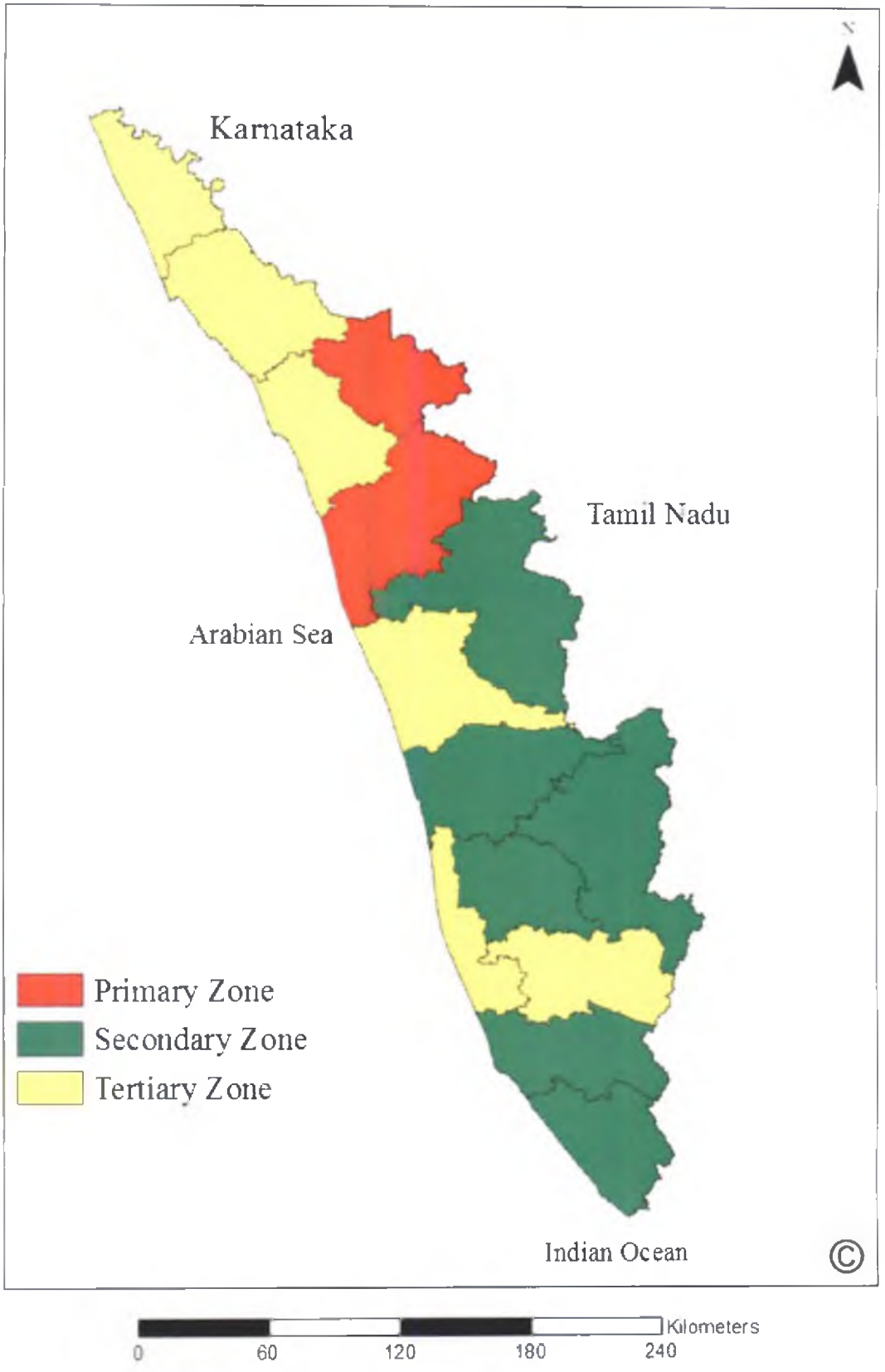


Fig. 22: Area of Banana in Kerala

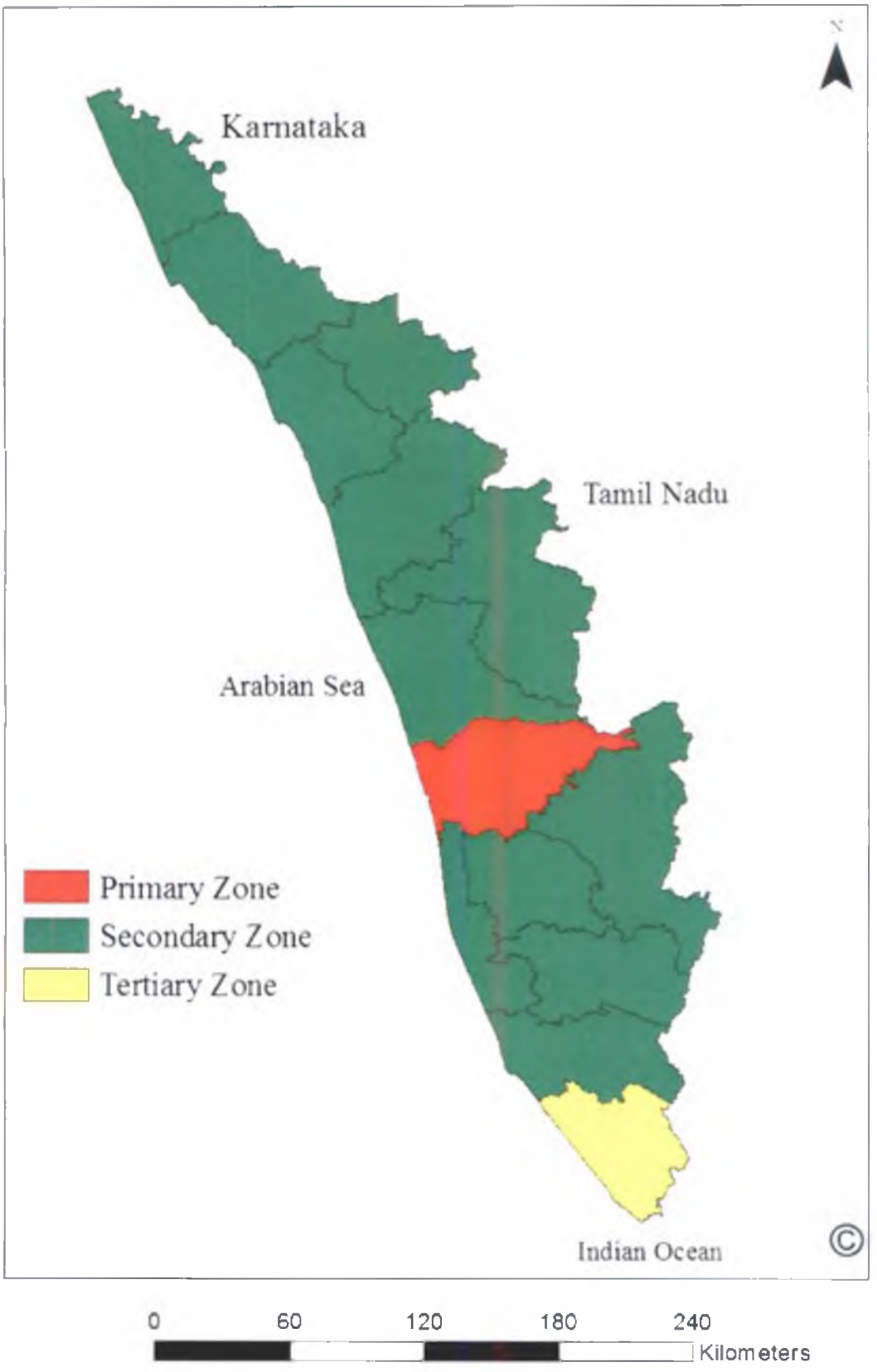


Fig. 23: Production zones of Banana in Kerala

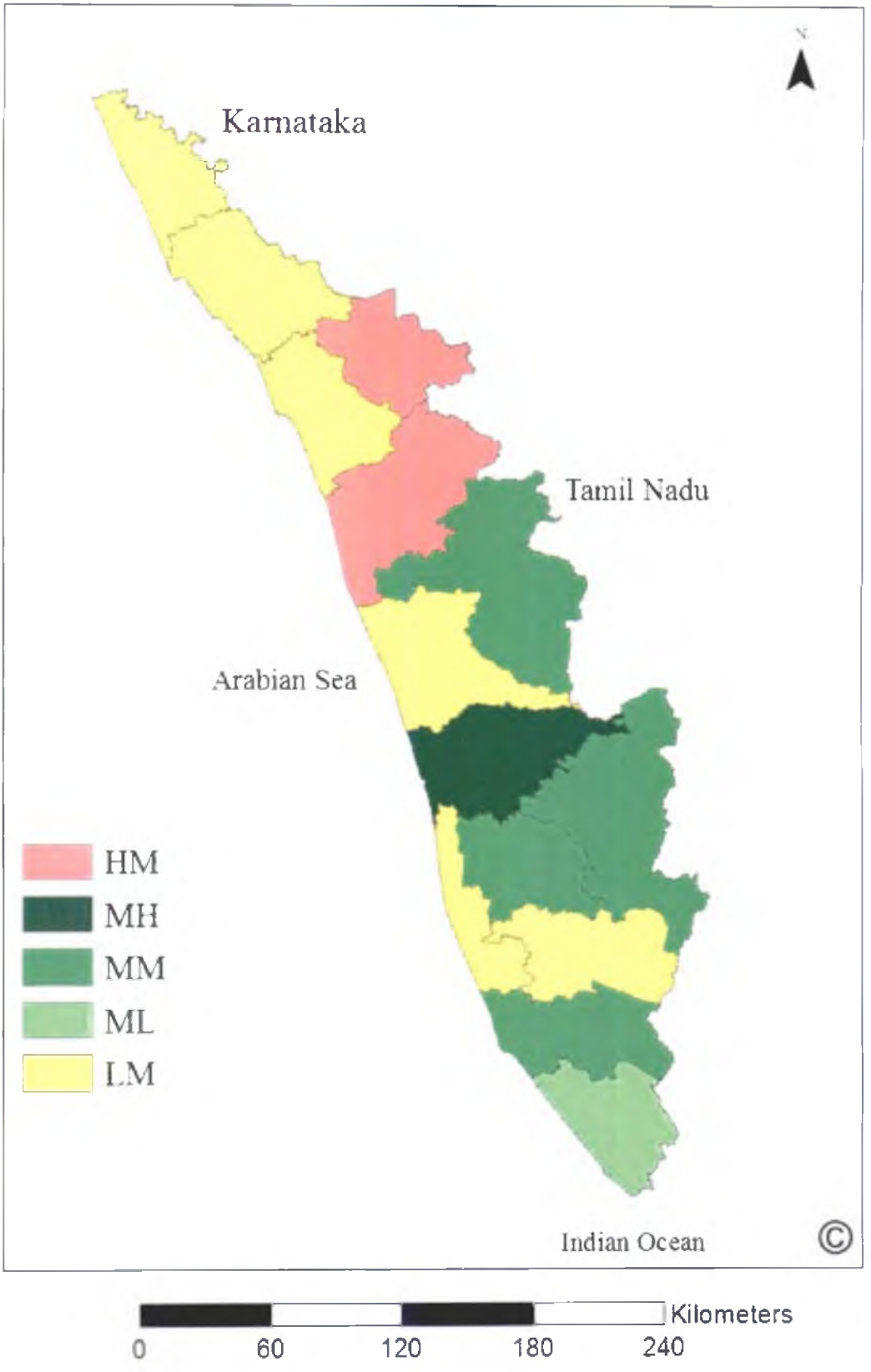


Fig. 24: Delineation of different productivity zones of Banana in Kerala

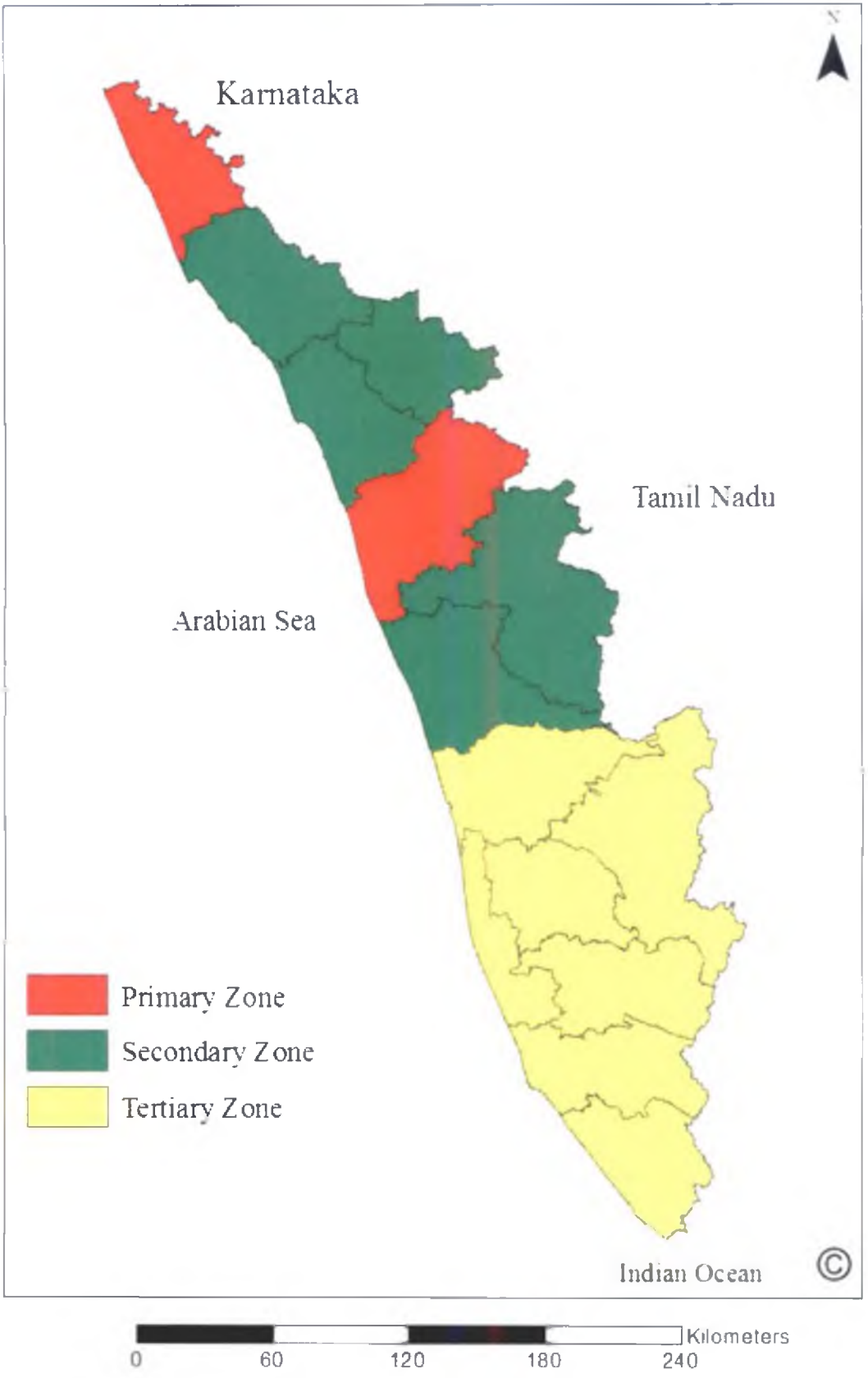


Fig. 25: Area of Arecanut in Kerala

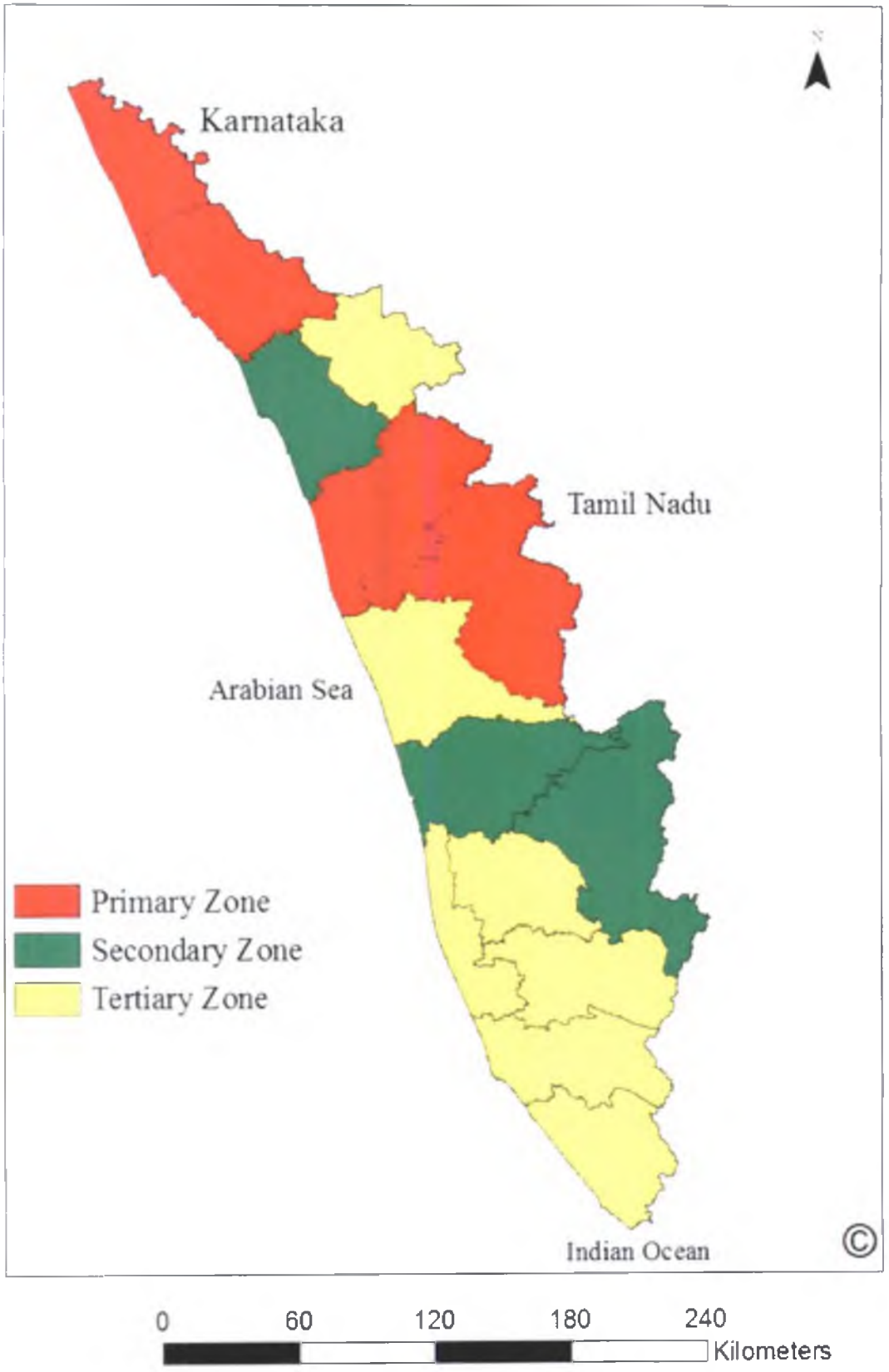


Fig. 26: Production zones of Arecanut in Kerala

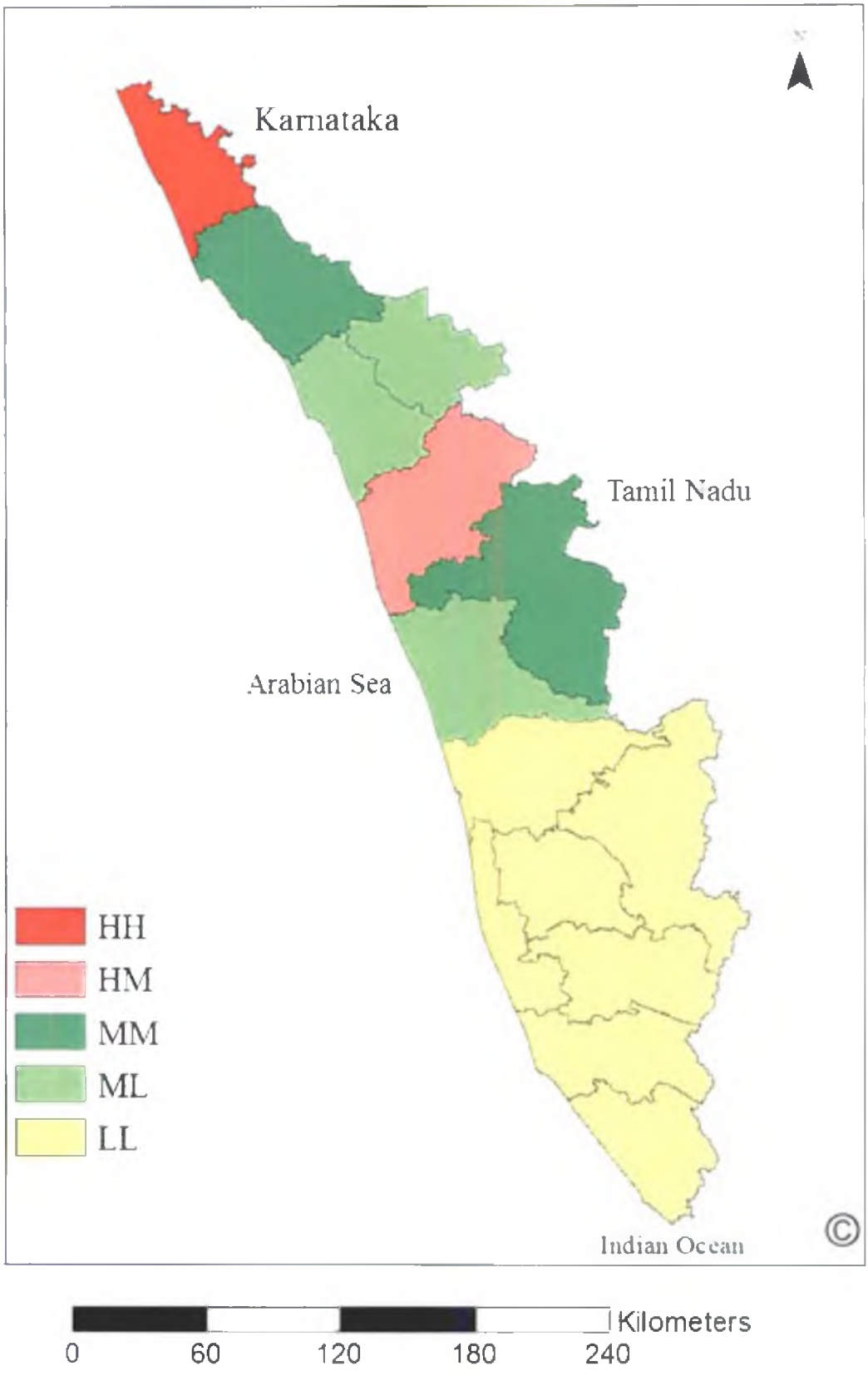


Fig. 27: Delineation of different productivity zones of Arecanut in Kerala

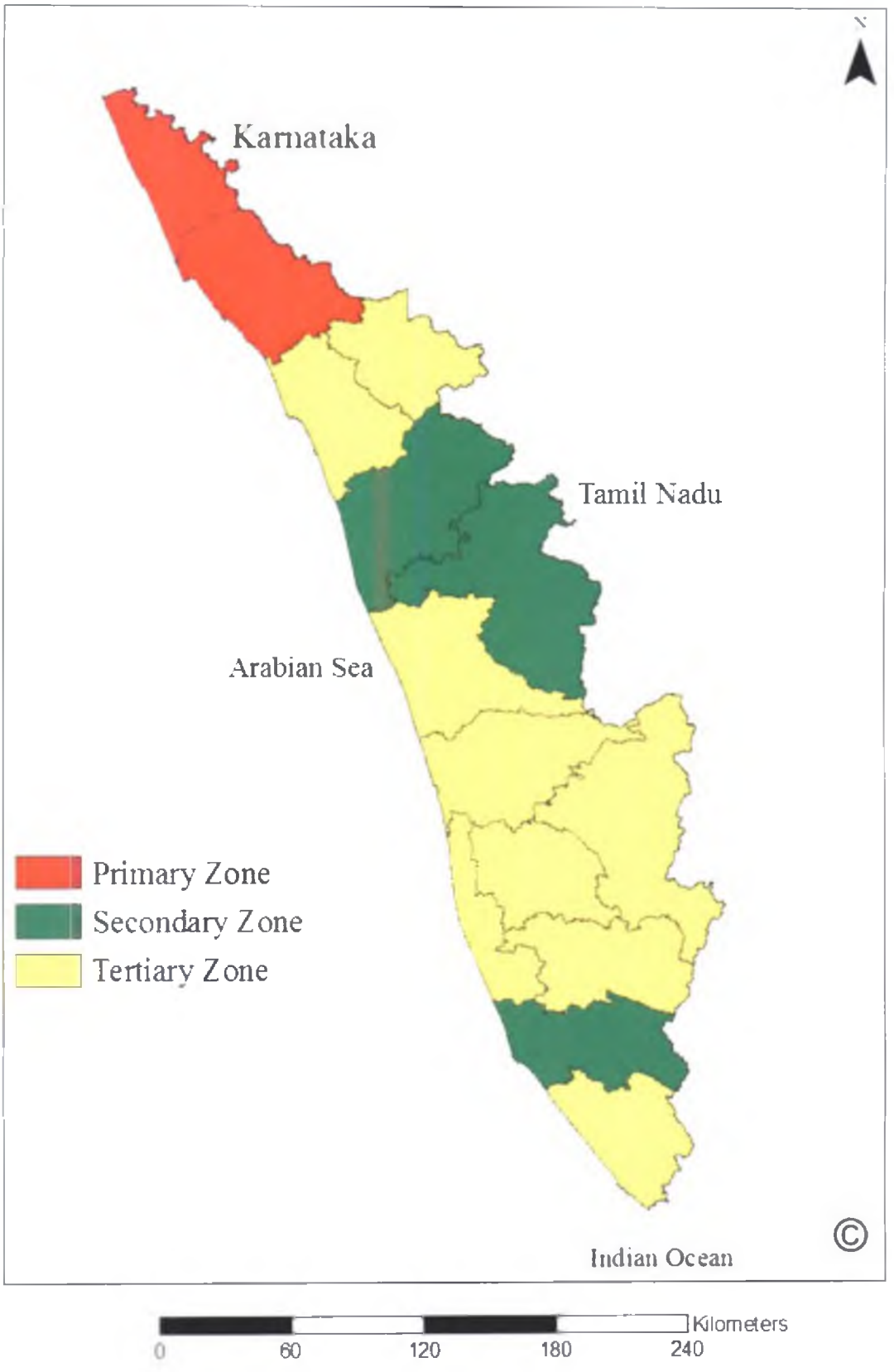


Fig. 28: Area of Cashew in Kerala

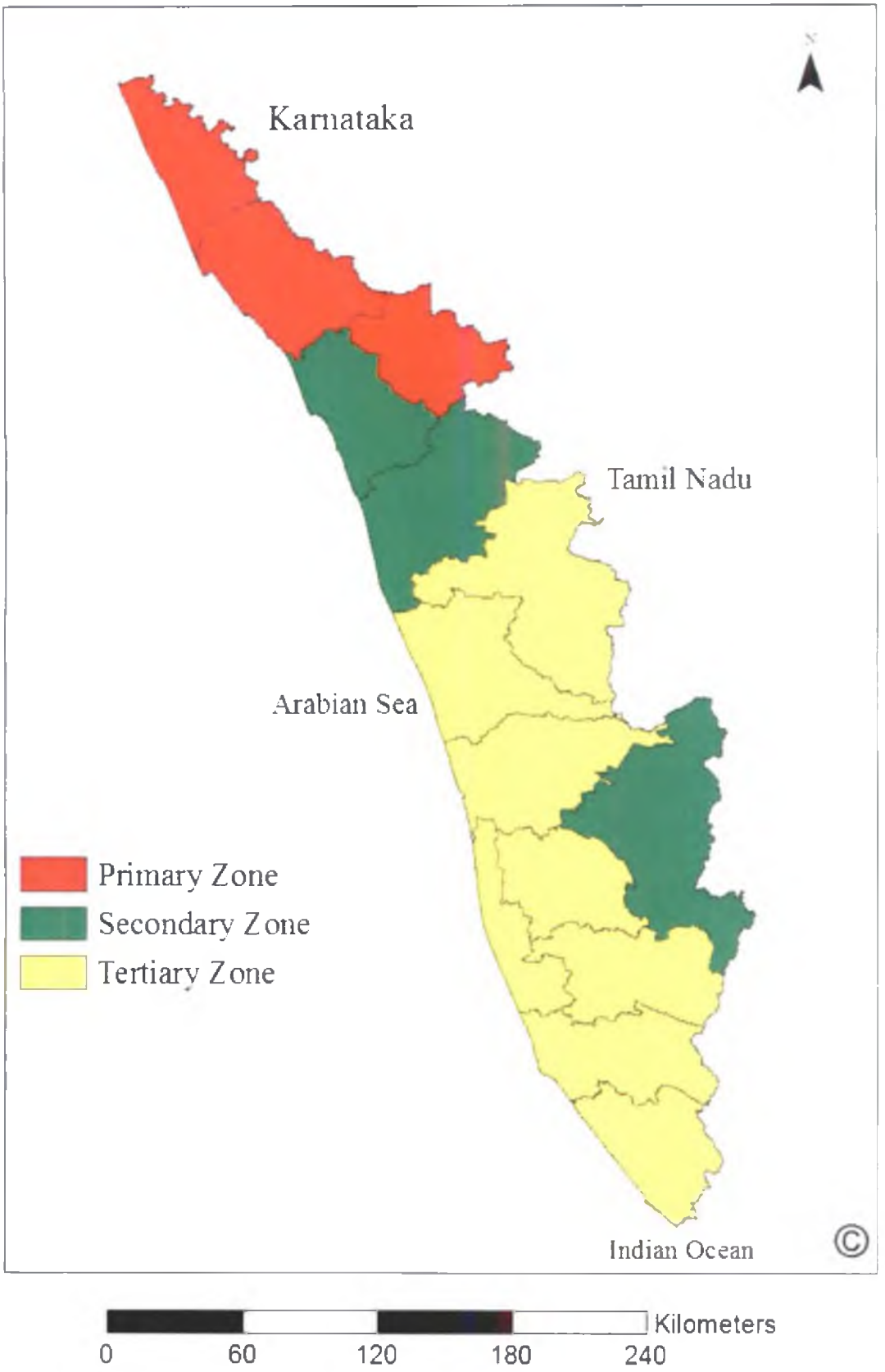


Fig. 29: Production zones of Cashew in Kerala

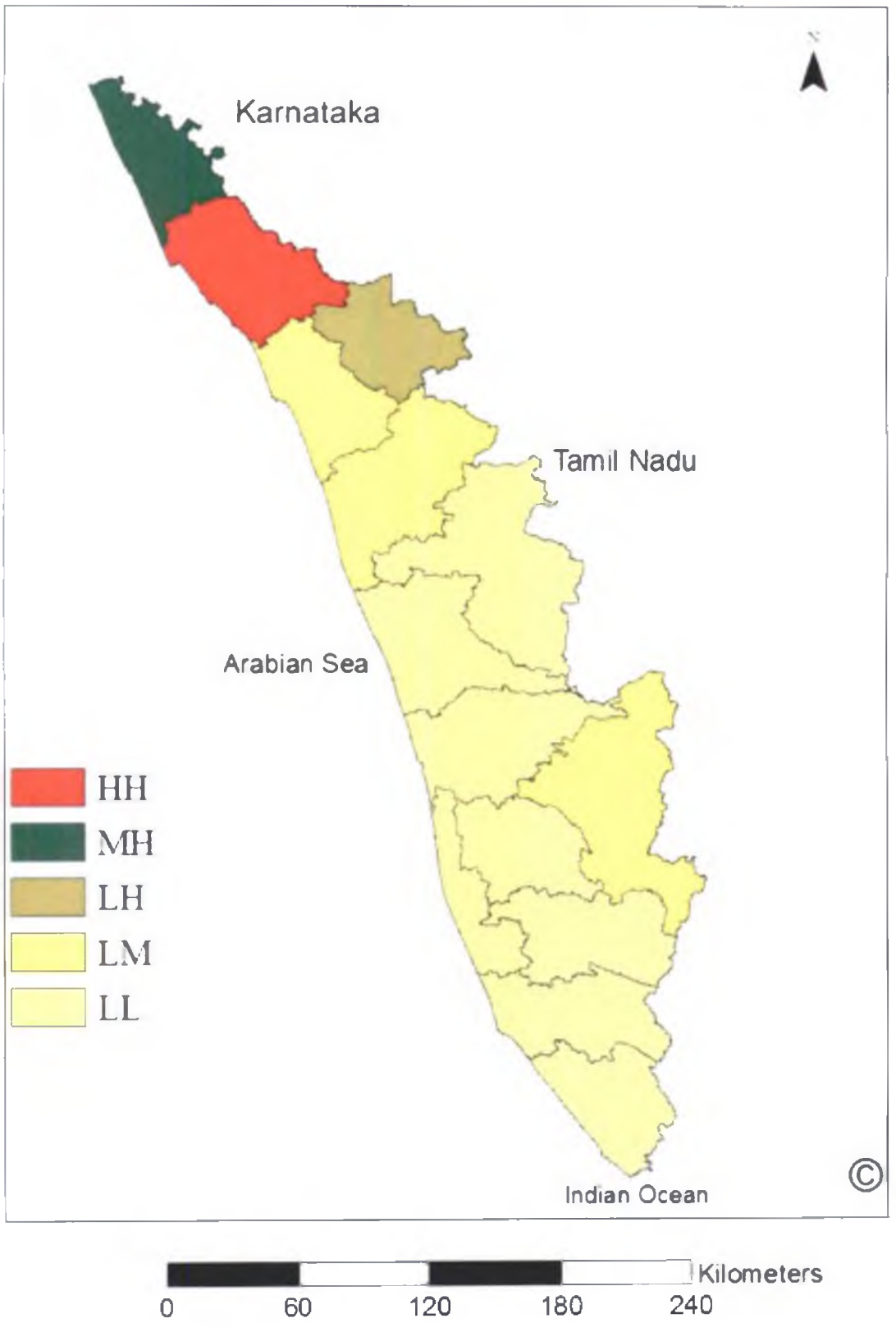


Fig. 30: Delineation of different productivity zones of Cashew in Kerala

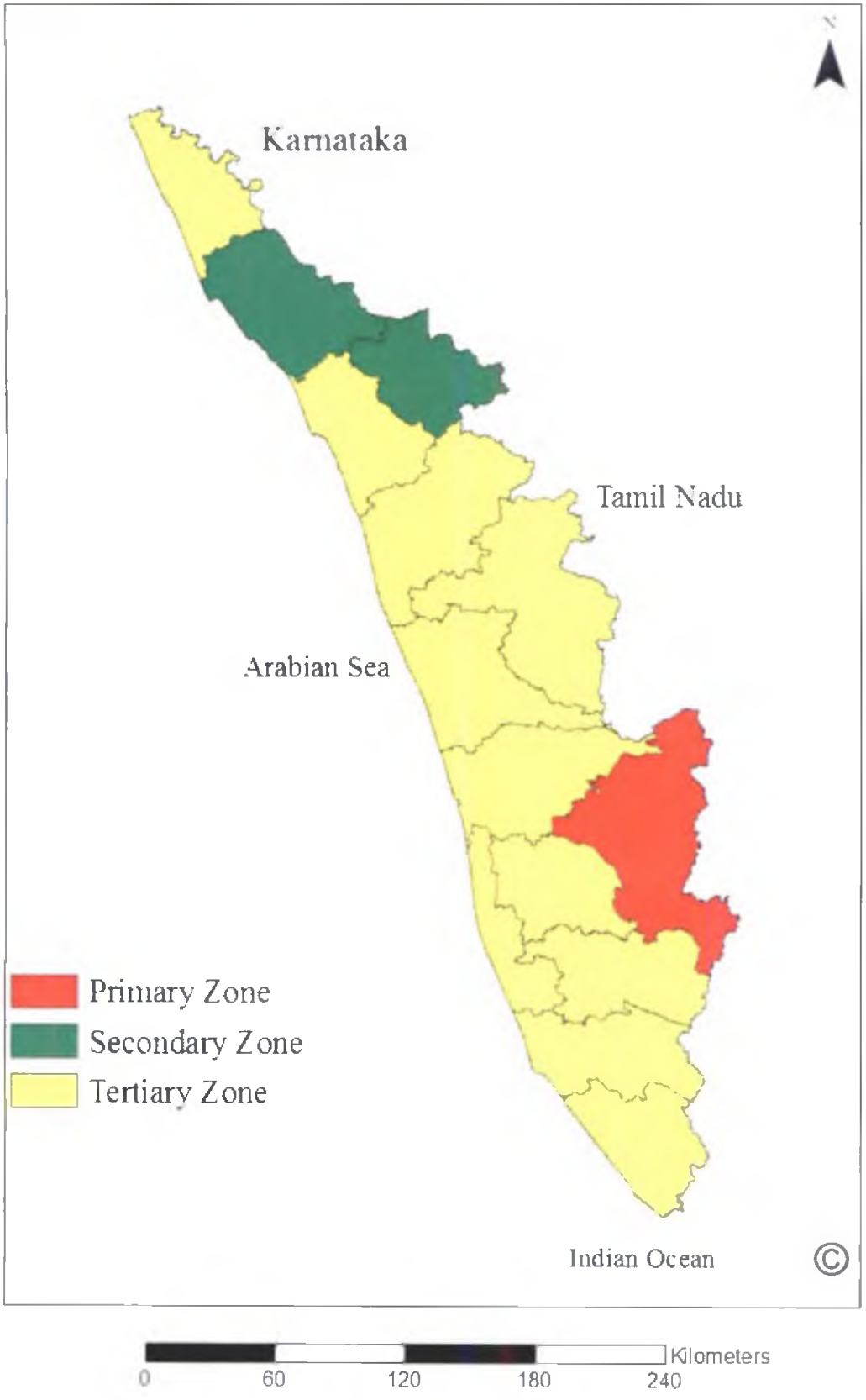


Fig. 31: Area of Black Pepper in Kerala

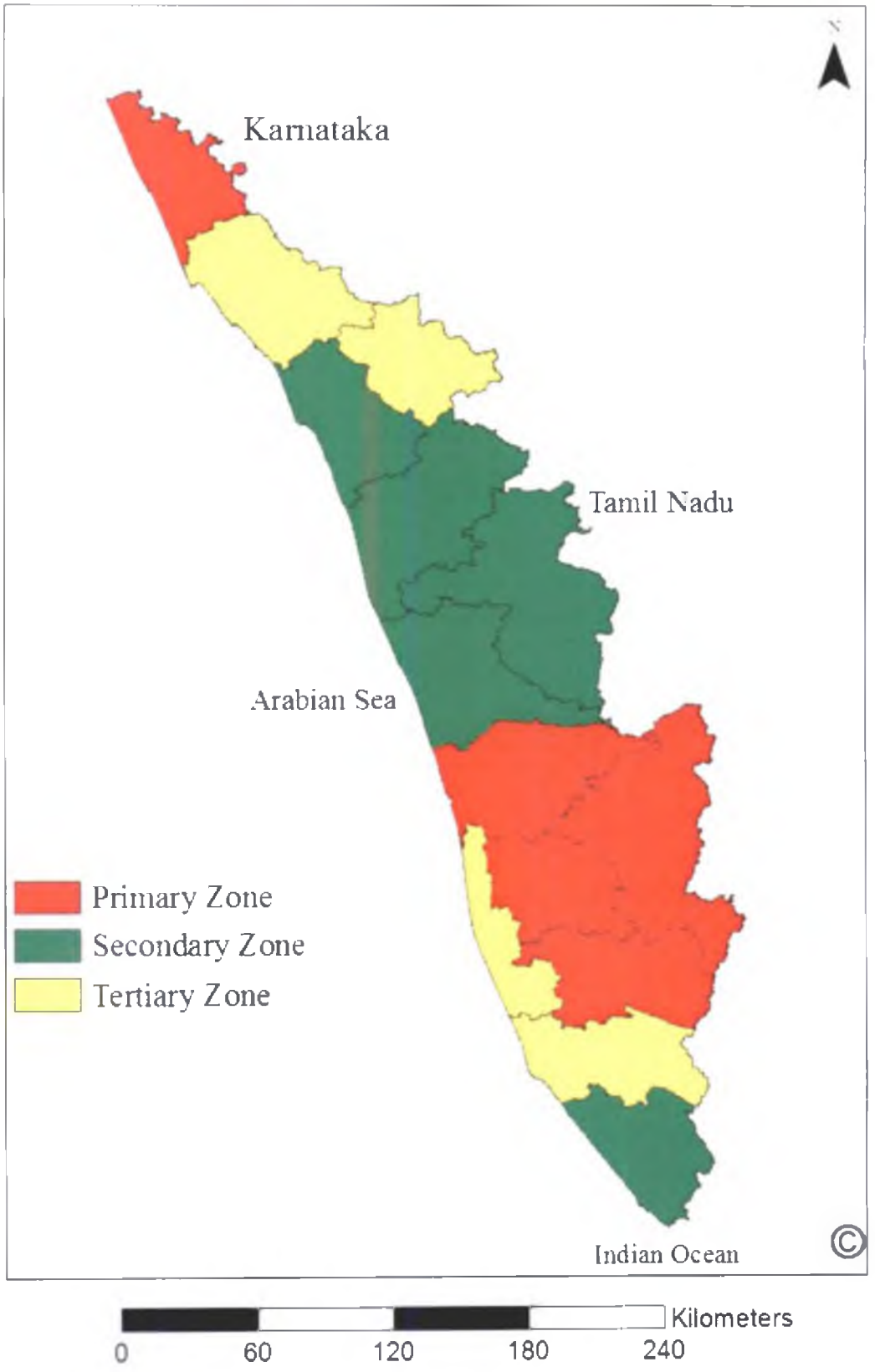


Fig. 32: Production zones of Black Pepper in Kerala

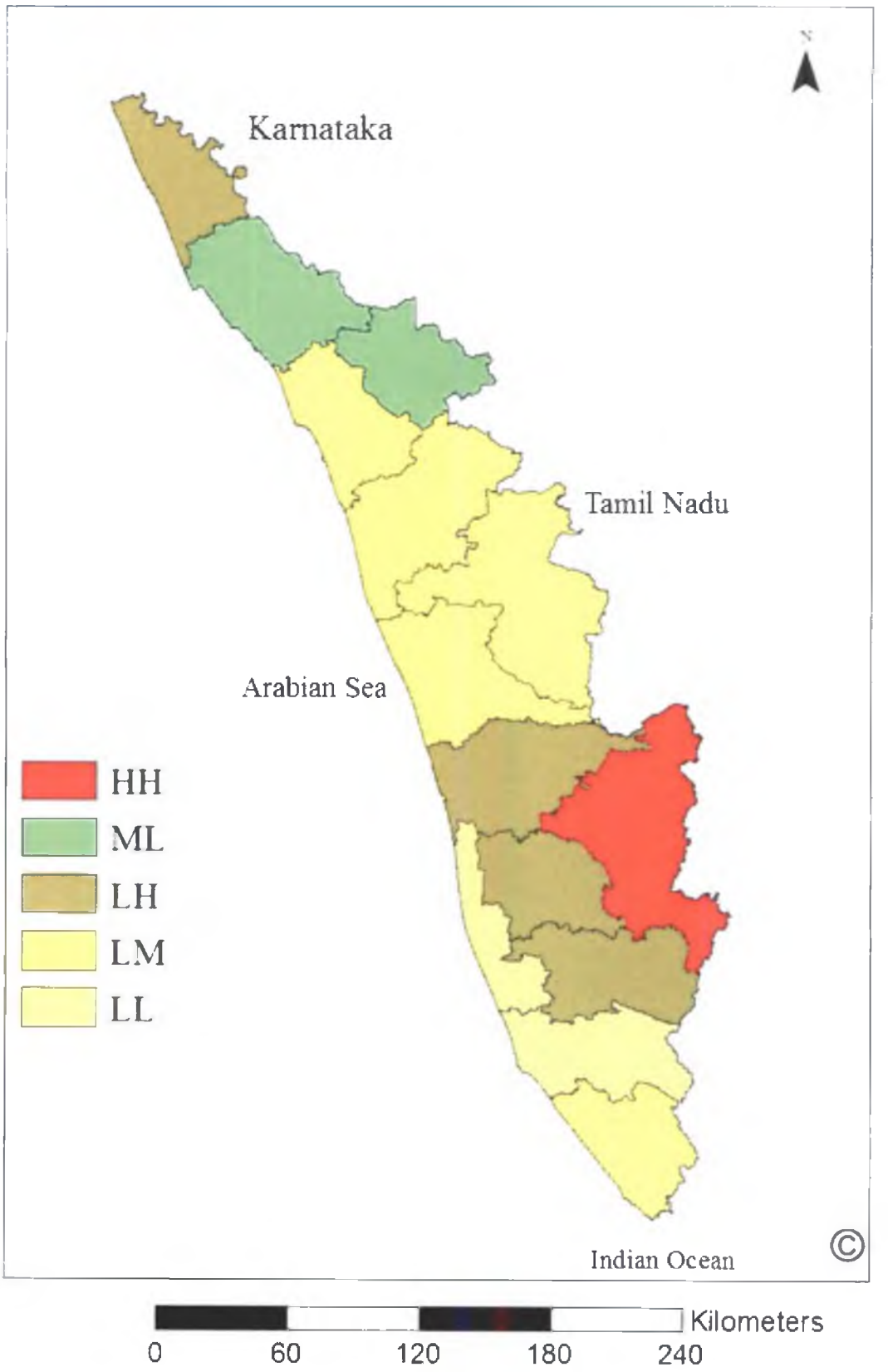


Fig. 33: Delineation of different productivity zones of Black Pepper in Kerala

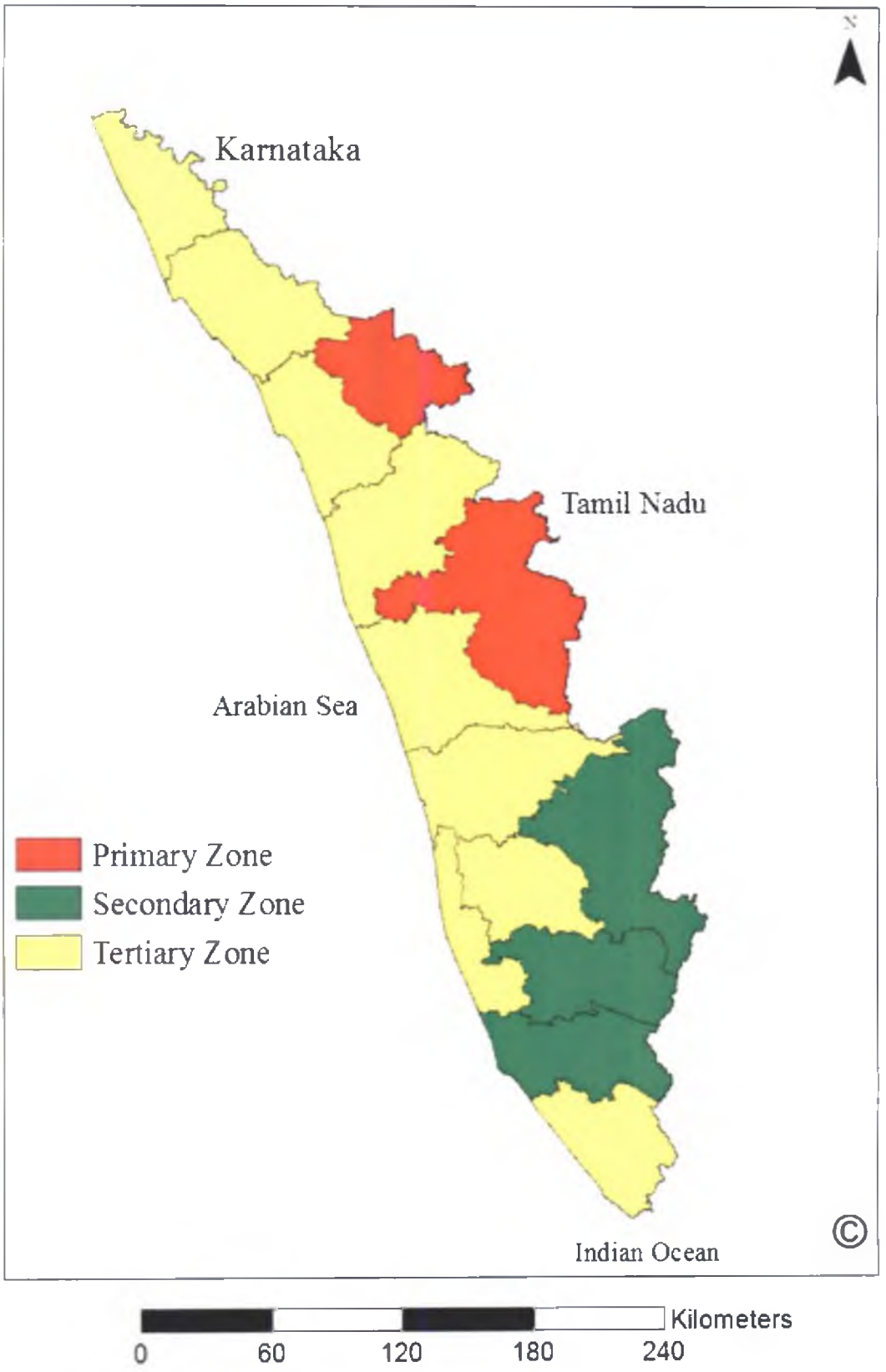


Fig. 34: Area of Ginger in Kerala

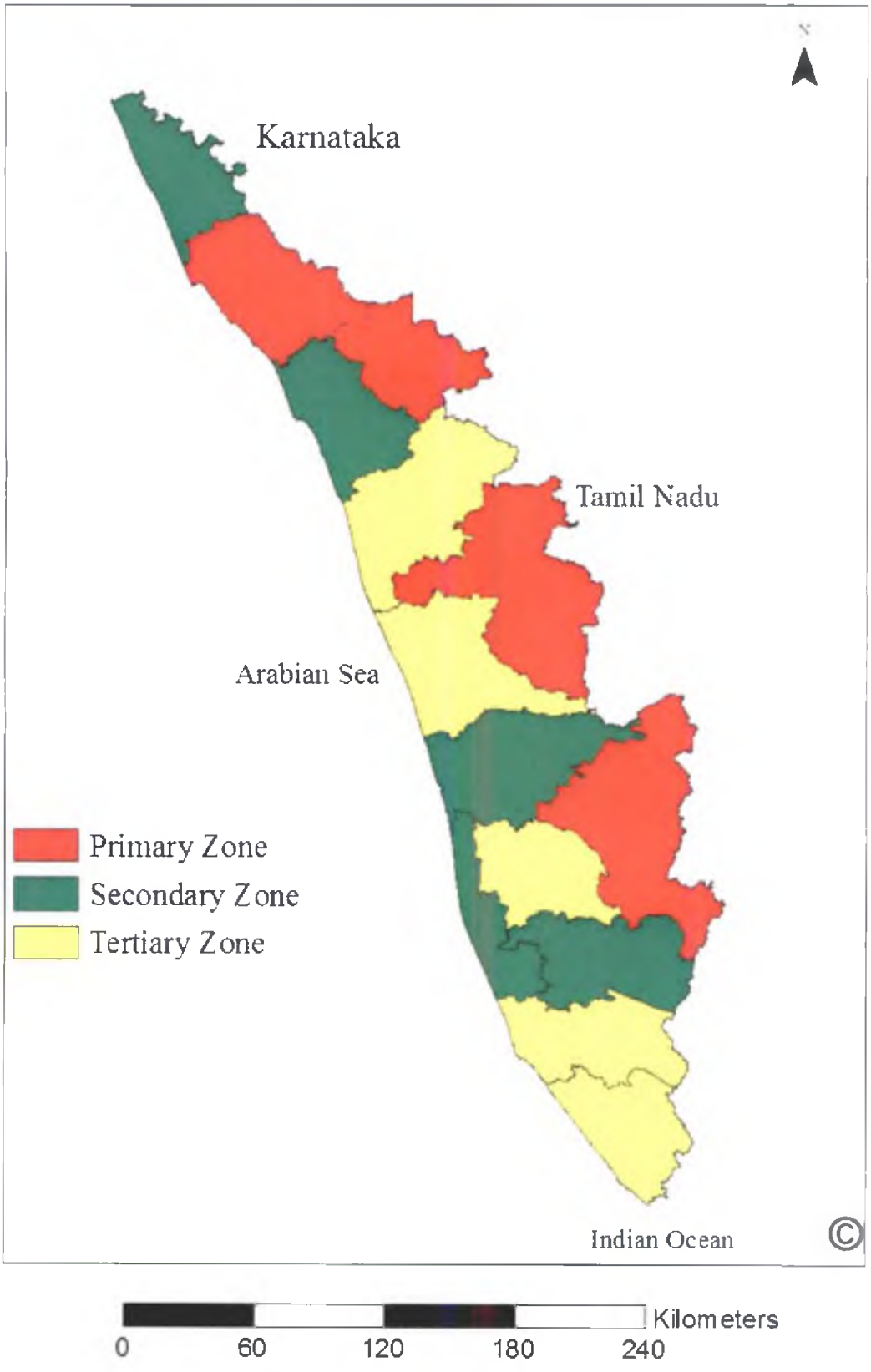


Fig. 35: Production zones of Ginger in Kerala

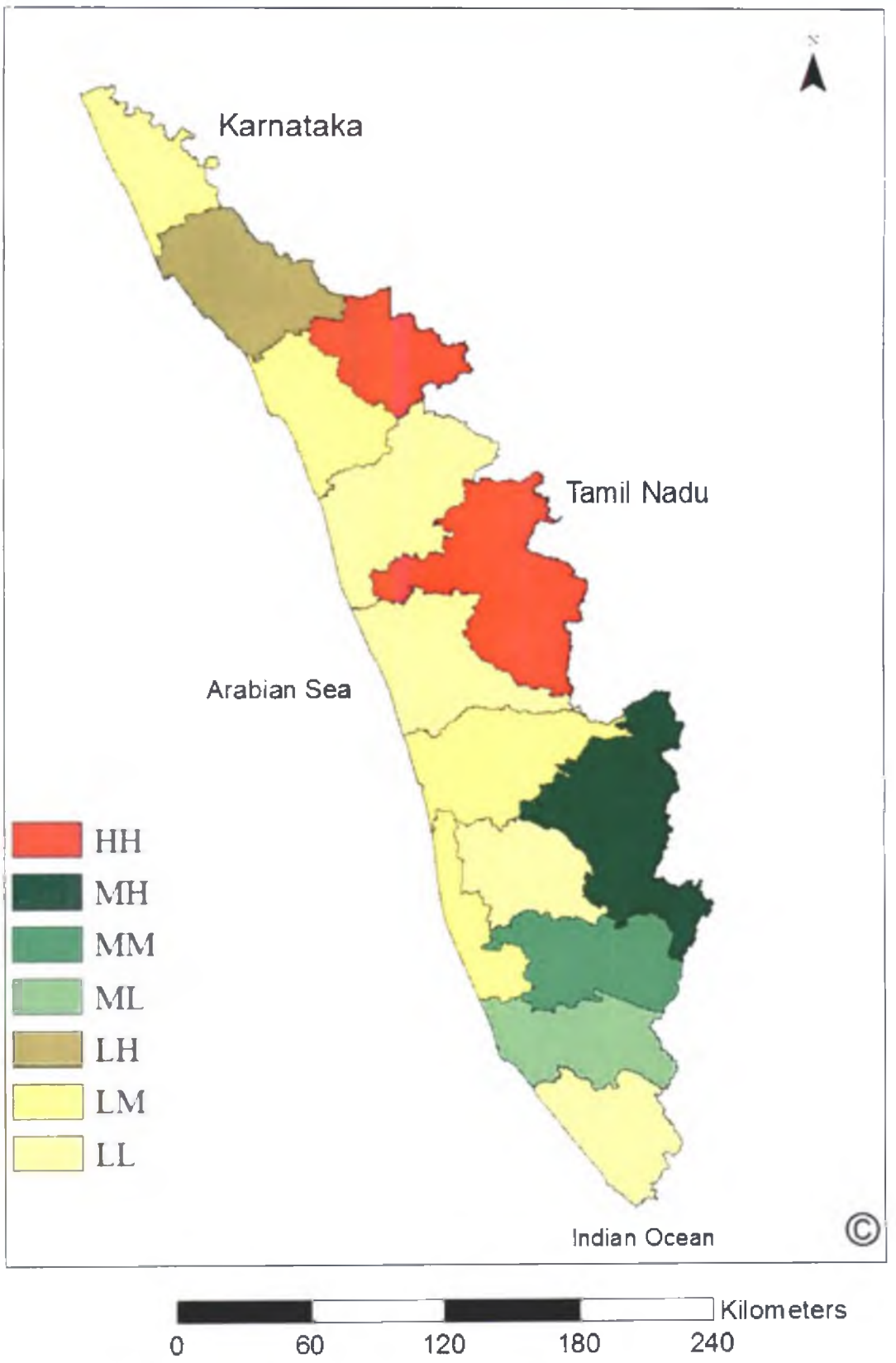


Fig. 36: Delineation of different productivity zones of Ginger in Kerala

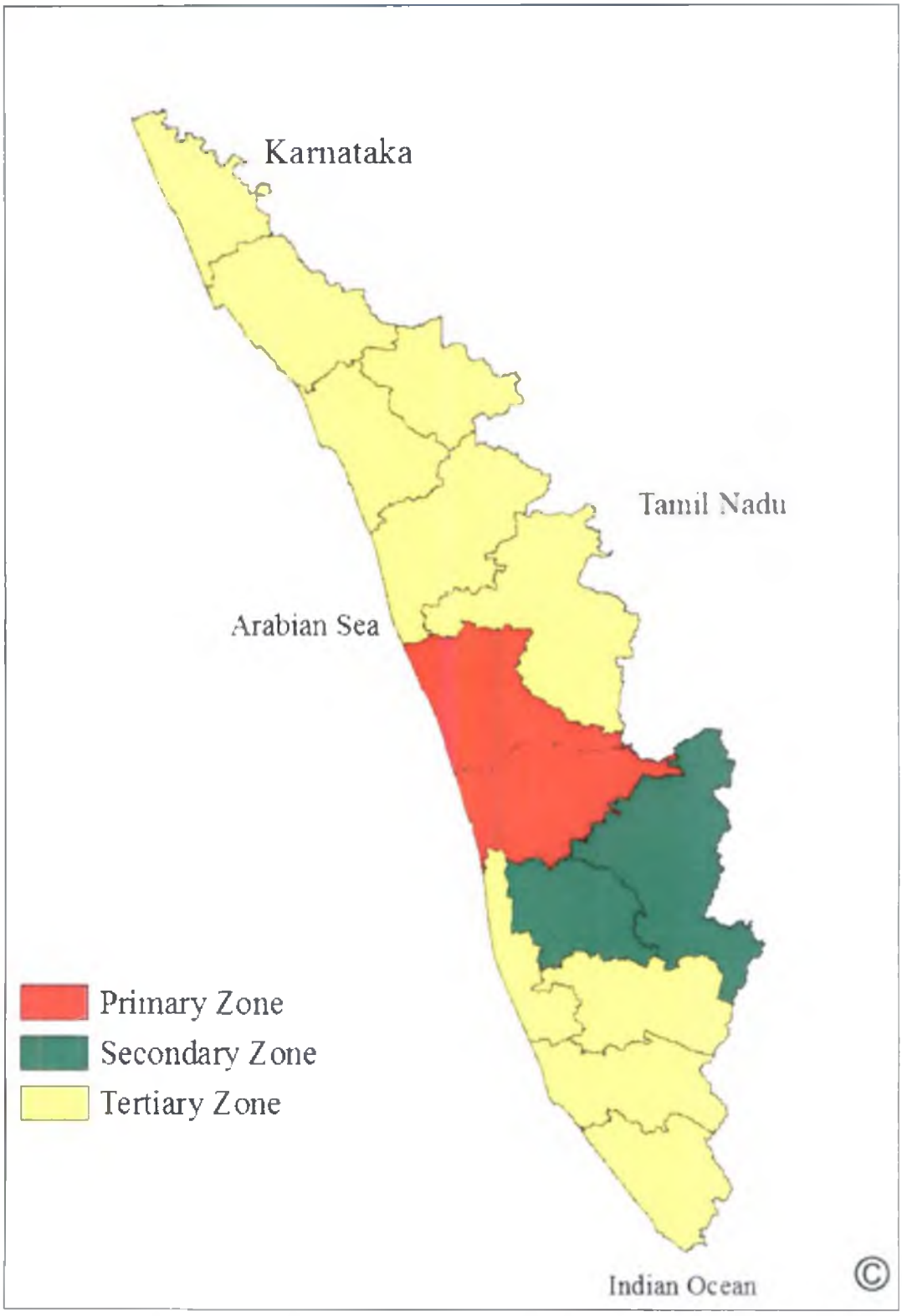


Fig. 37: Area of Nutmeg in Kerala

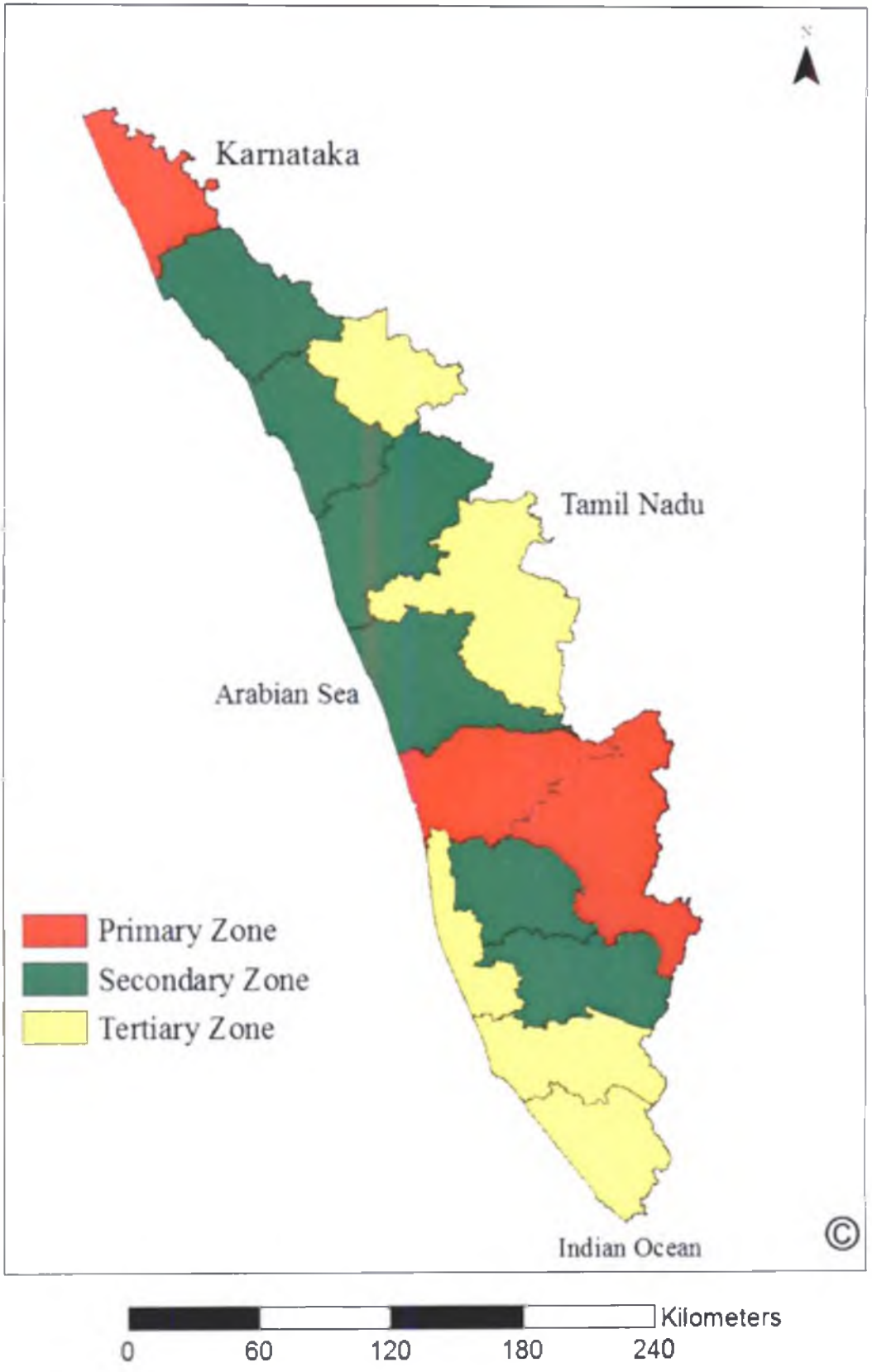


Fig. 38: Production zones of Nutmeg in Kerala

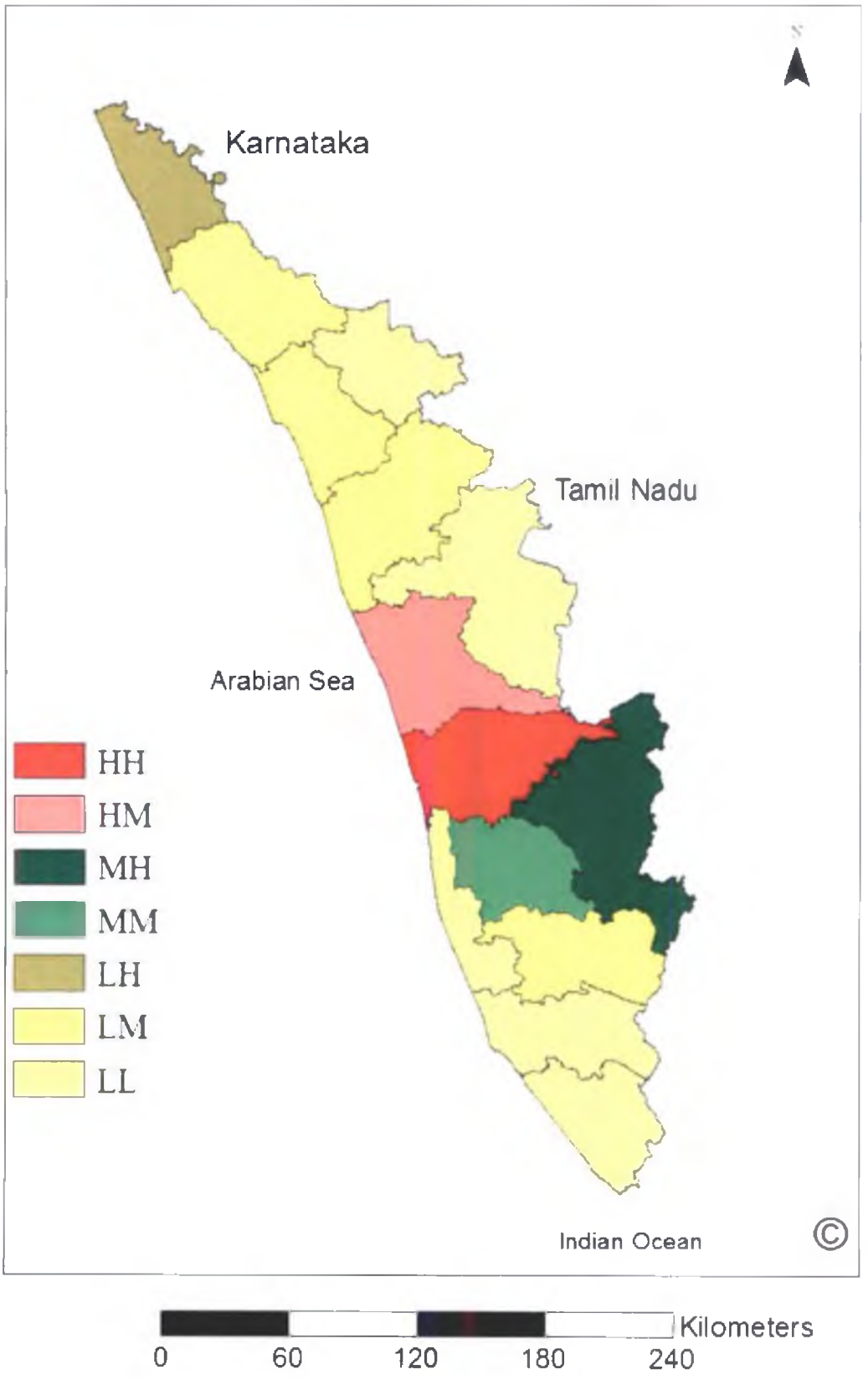


Fig. 39: Delineation of different productivity zones of Nutmeg in Kerala

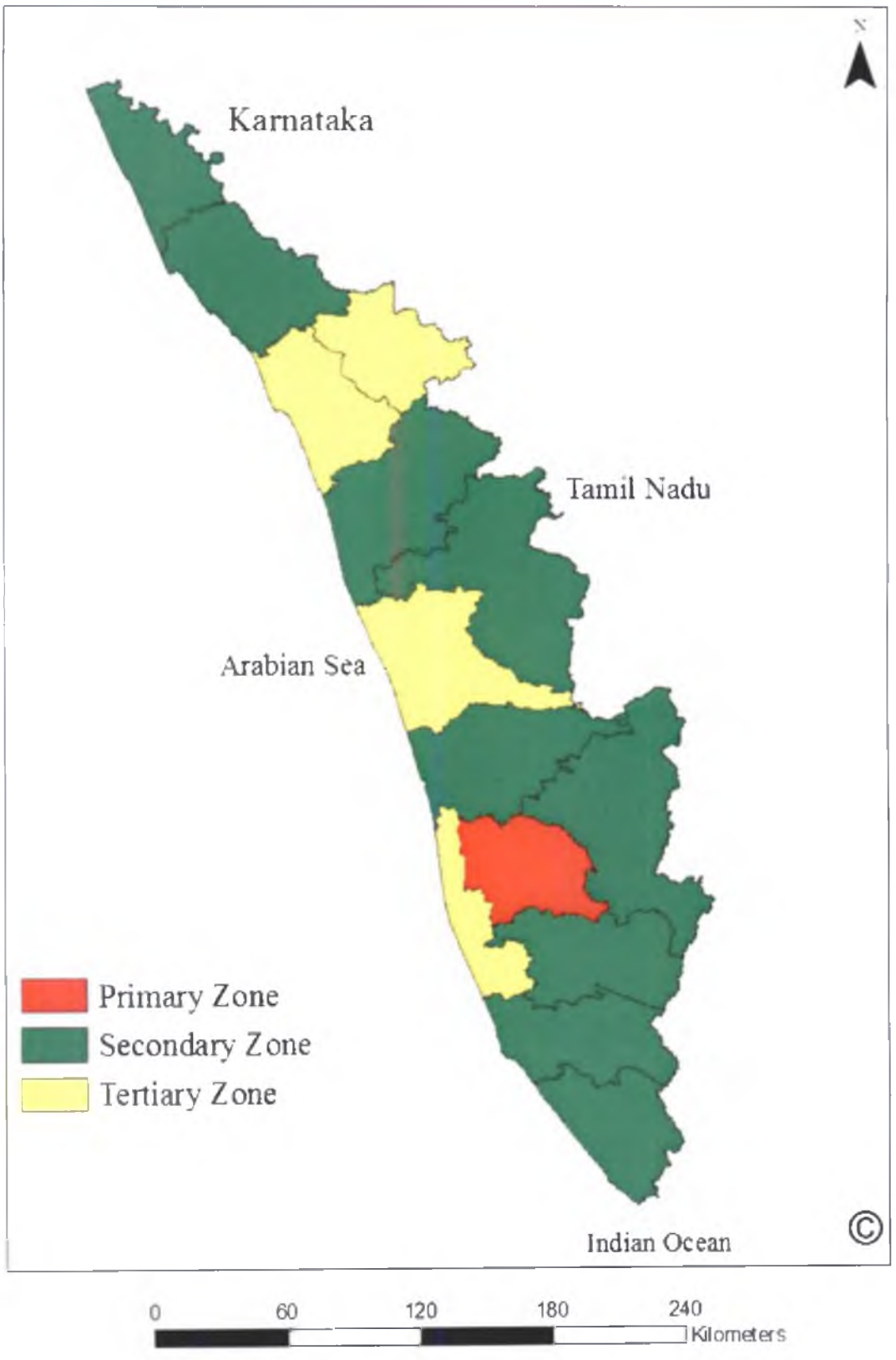


Fig. 40: Area of Rubber in Kerala

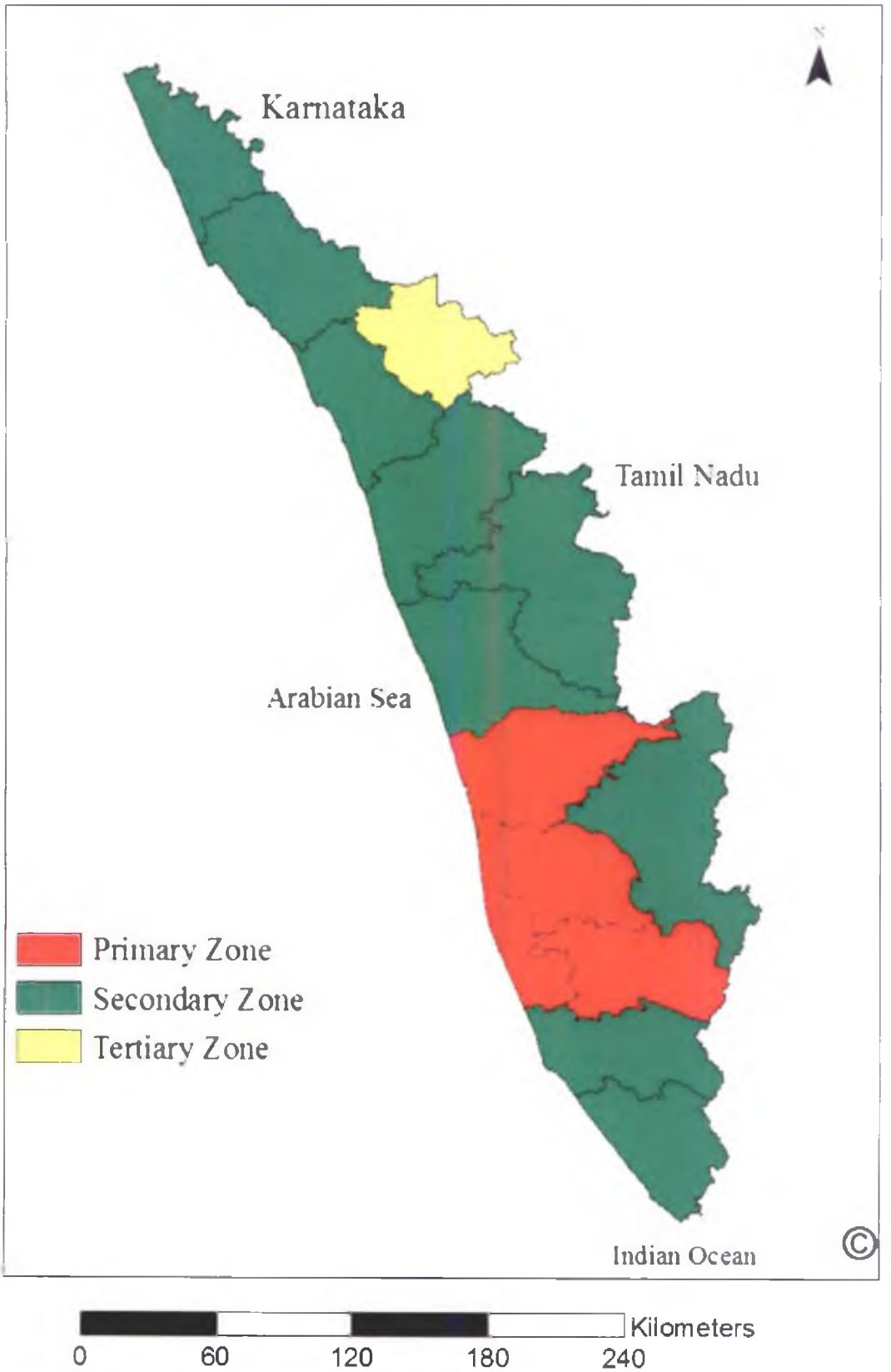


Fig. 41: Production zones of Rubber in Kerala

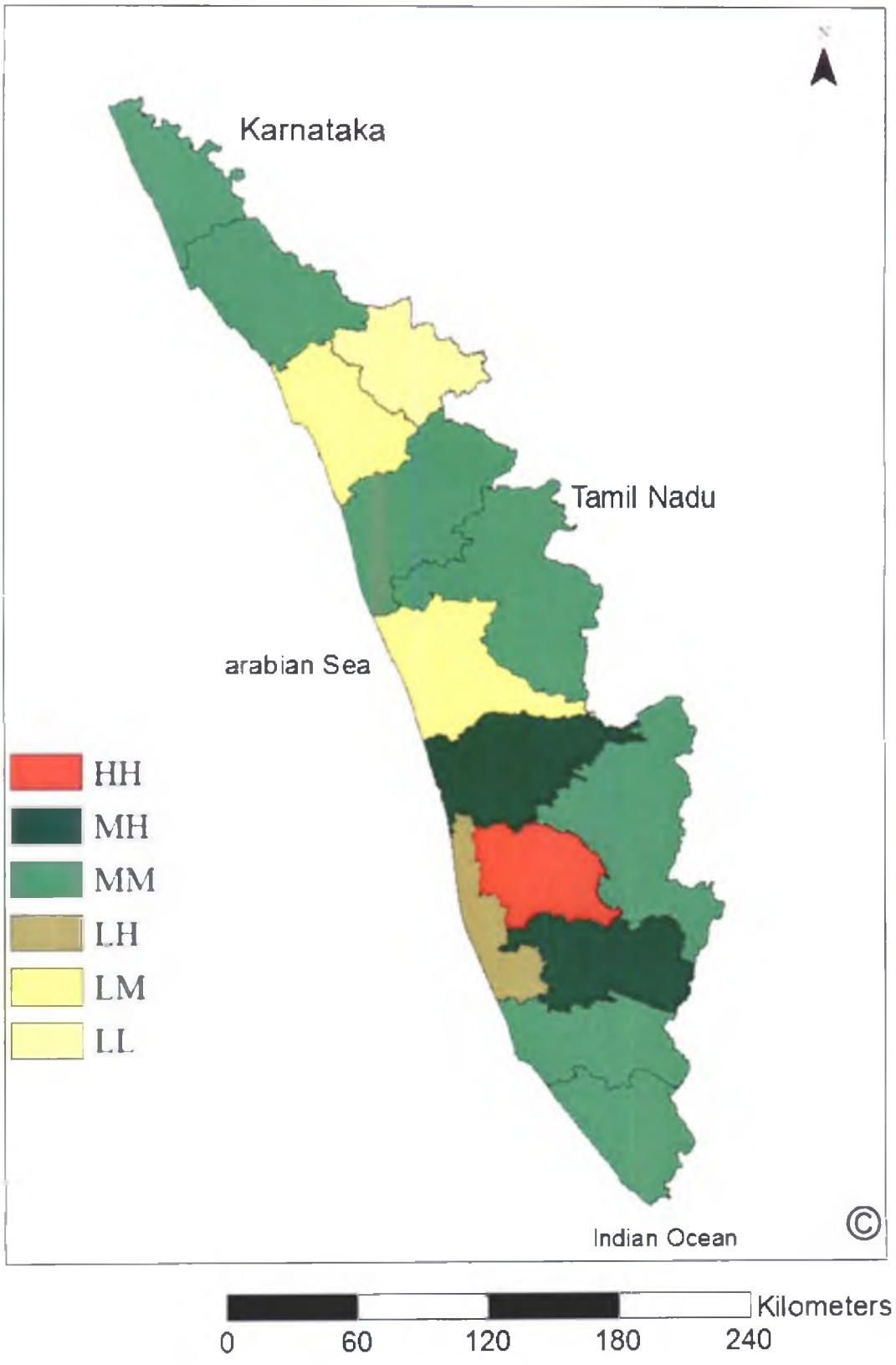


Fig. 42: Delineation of different productivity zones of Rubber in Kerala

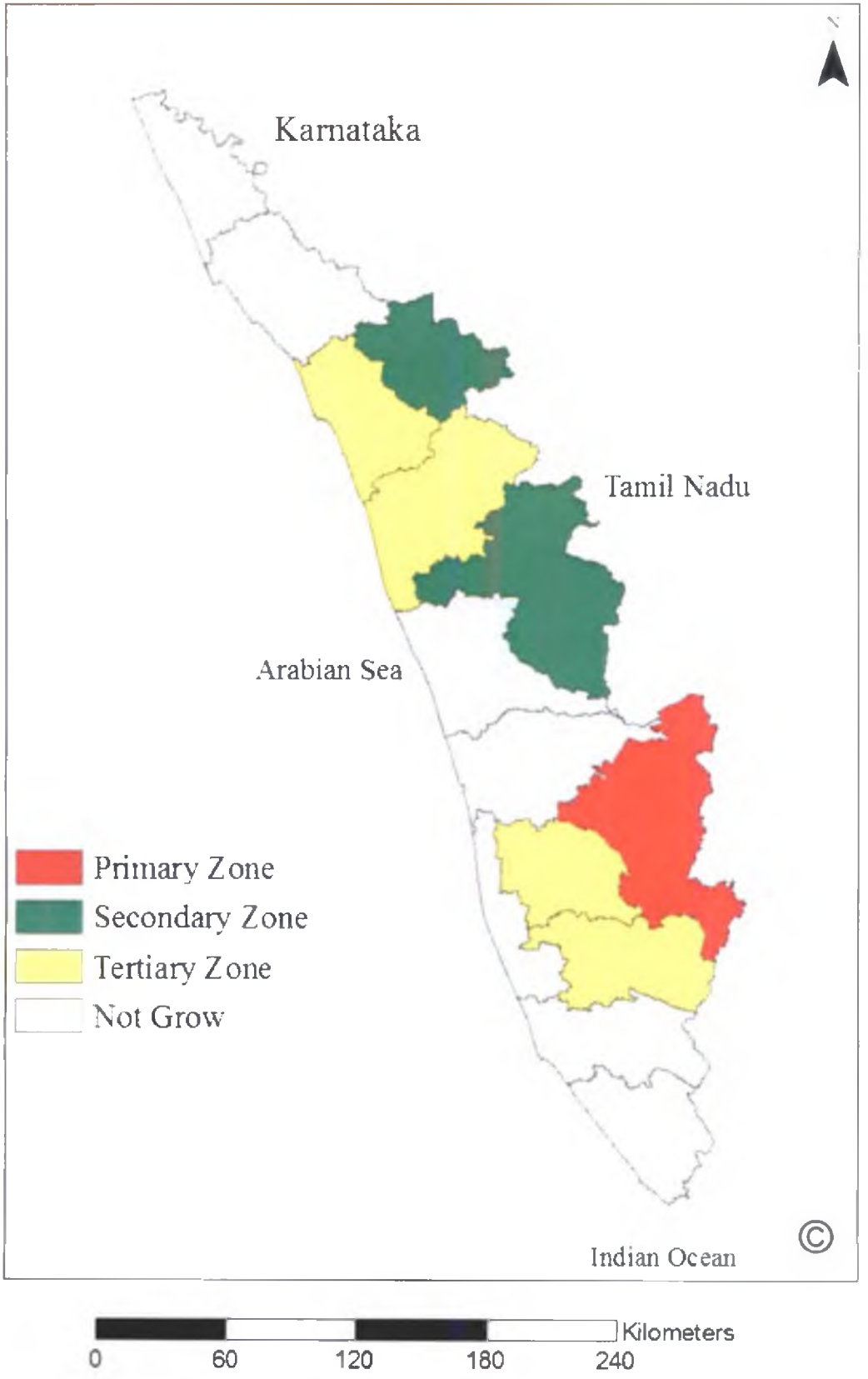


Fig. 43: Area of Cardamom in Kerala

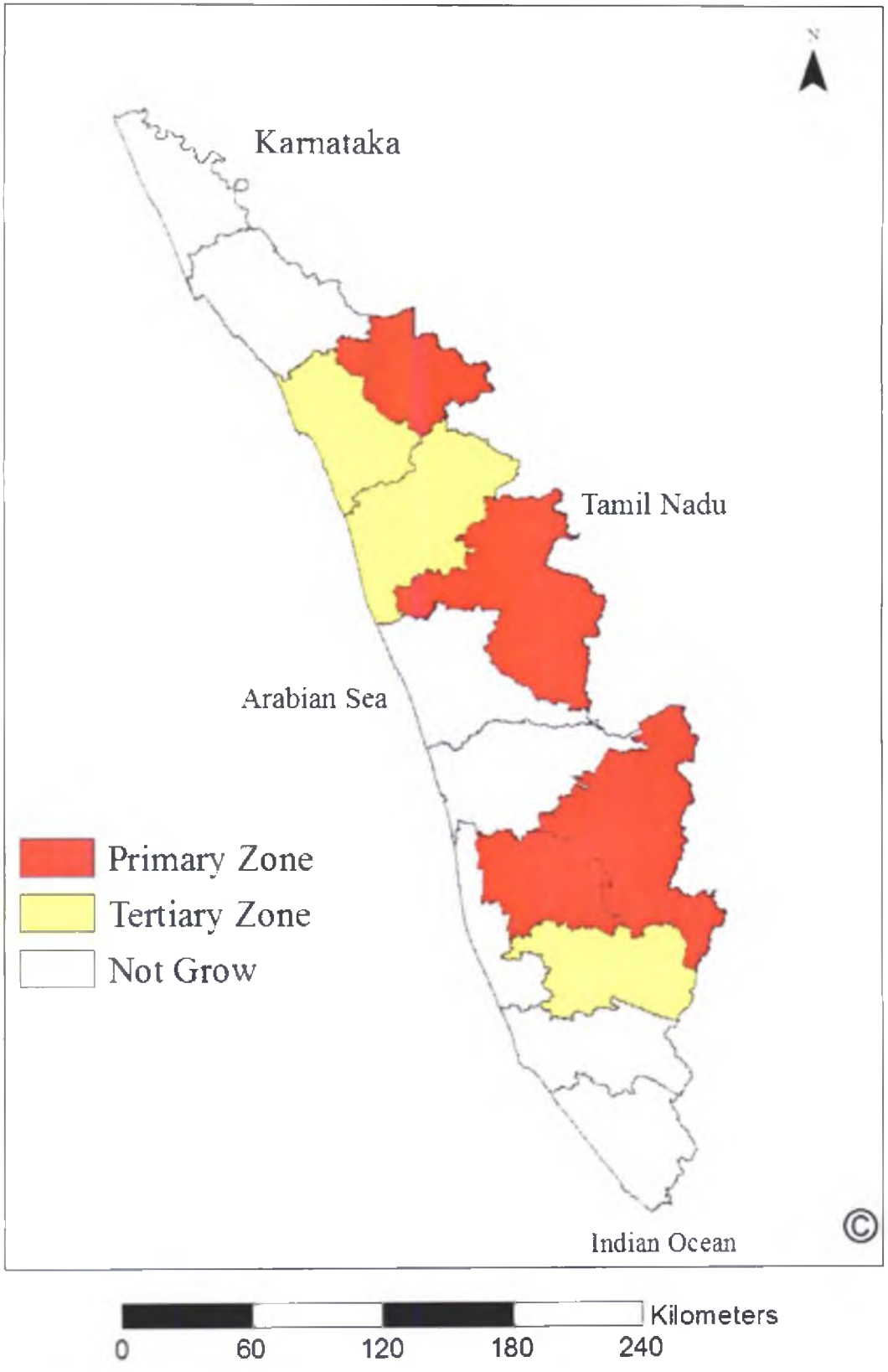


Fig. 44: Production zones of Cardamom in Kerala

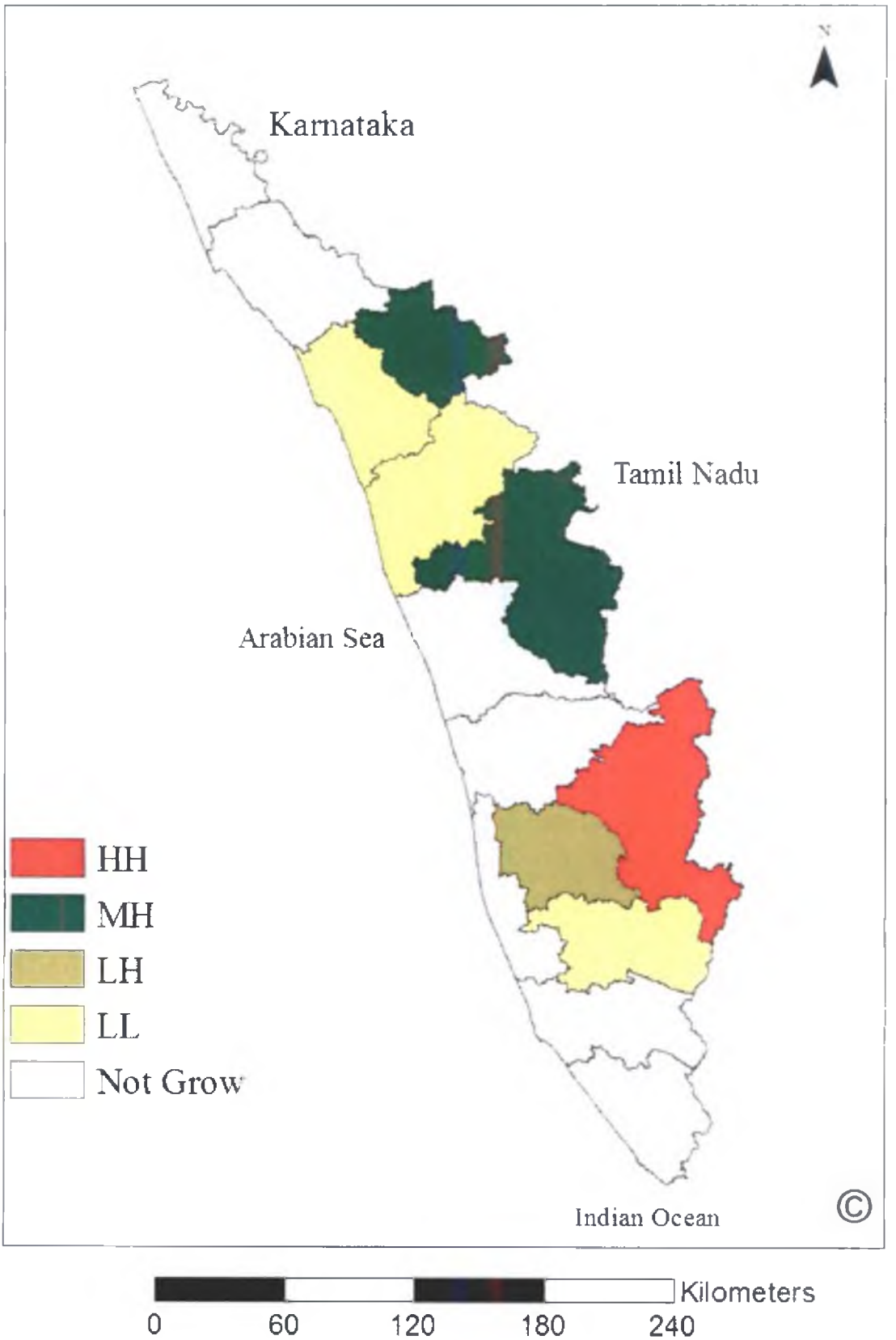


Fig. 45: Delineation of different productivity zones of Cardamom in Kerala

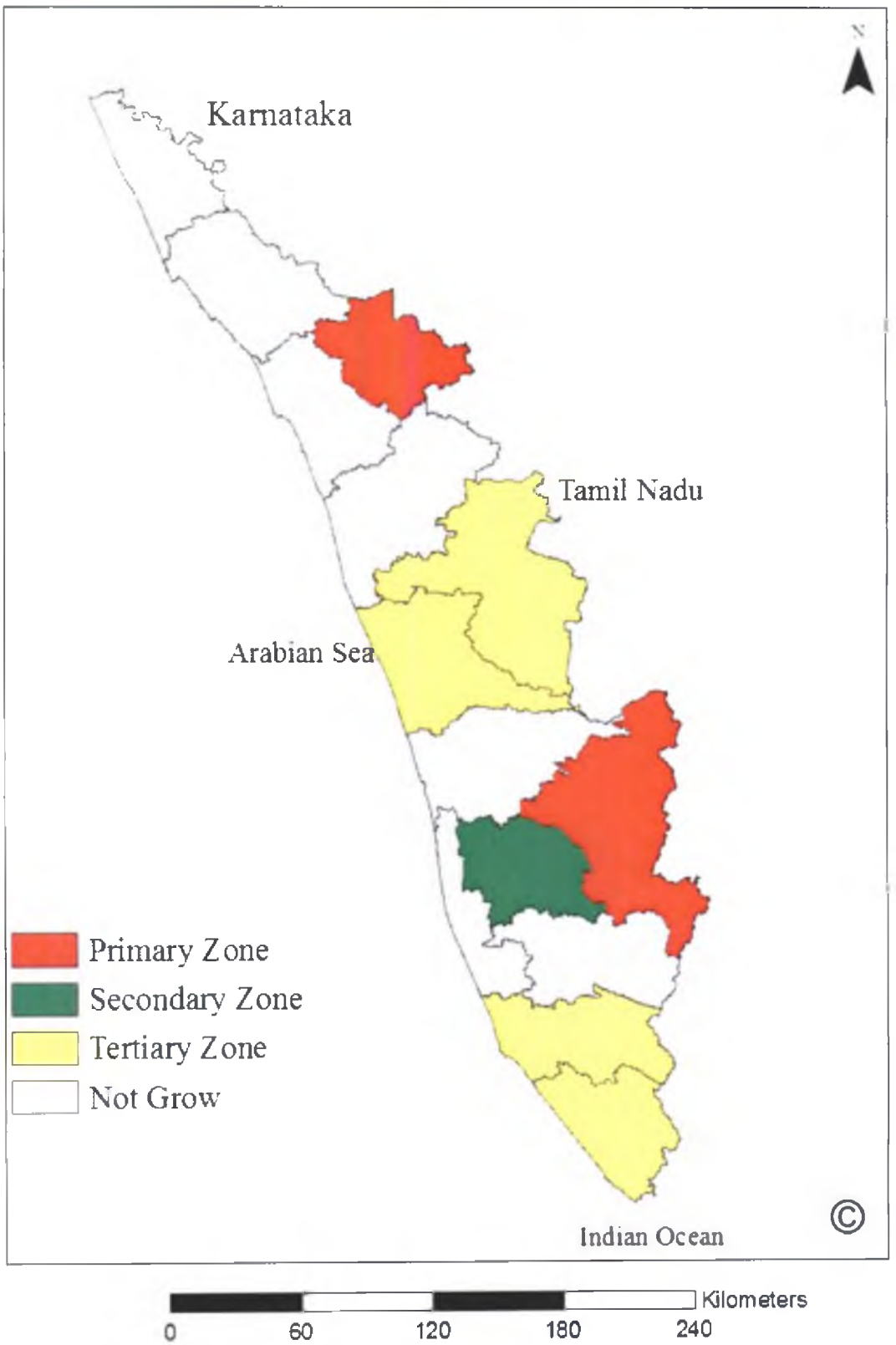


Fig. 46: Area of Tea in Kerala

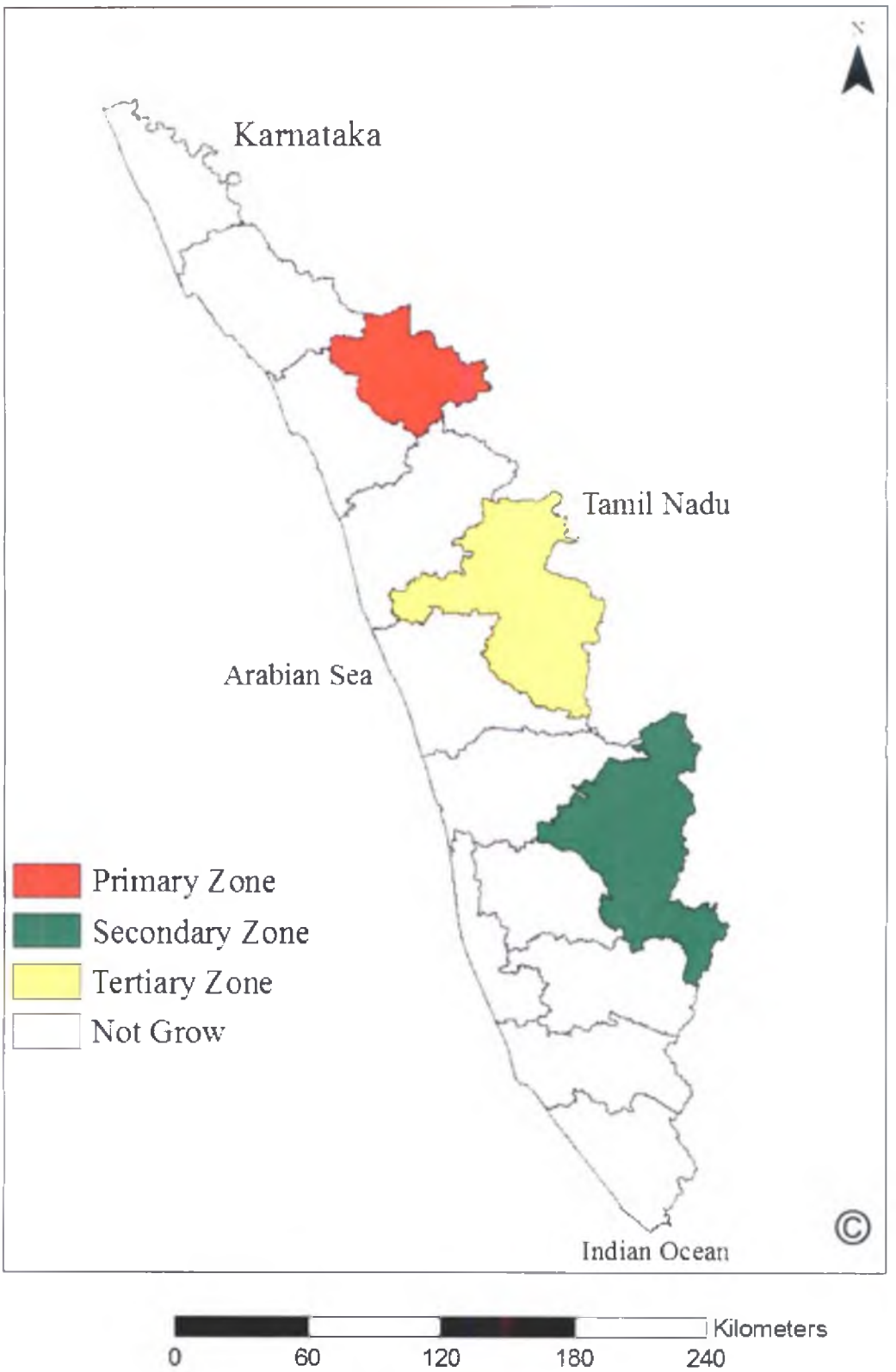


Fig. 47: Area of Coffee in Kerala

Districts are placed in different category depending upon the area and productivity levels and nine categories are considered viz., High area-High yield (HH), High area - Medium yield (HM), High area - Low yield (HL), Medium area - High yield (MH), Medium area - Medium yield (MM), Medium area - Low yield (ML), Low area - High yield (LH), Low area - Medium yield (LM) and Low area - Low yield (LL).

Paddy is the principal crop extensively cultivated in all the districts of the state having a unique three season pattern viz virippu (April- May to September –October) Mundakan (September – October to December – January) and Puncha (December – January to March- April). The production of rice increased from 5, 08,299 tonnes to 5,64,325 tonnes over the previous year which shows an increase of 11.02 %. The yield rate of rice is 2827 kg/ha against the previous years of 2577 kg/ha. The productivity of rice in Virippu, Mundakan and Puncha seasons were 2720, 2833, 2933 respectively. The productivity of rice in virippu season was highest in Alappuzha district and lowest in "15 Kozhikode district. In Mundakan the highest productivity in Kottayam district and lowest is in Kozhikode district. In Puncha season the productivity was highest in Malappuram district and the same was lowest in Kollam district. As usual, Palakkad district occupied the first position in the production of rice and lowest in Idukki district. The area of paddy cultivation is high in Palakkad and Alappuzha. The productivity of paddy is found to be high in Thrissur and Pathanamthitta district. But the area of paddy cultivation is low in the Pathanamthitta district and medium in the Thrissur district. So the extension of area for paddy cultivation is suggested for these districts, (Fig.15 & 16).

Coconut is generally grown all over the state. Production of coconut is concentrated specifically in Kozhikode district followed by Malappuram. The lowest production is in Wayanad district. High yield of coconut is at Malappuram, where the area is medium. Broadening of area of coconut cultivation in this district will be beneficial. Low yield is found in the Ernakulam district where area is medium. So the steps has to be taken to improve the yield of coconut in this district.

Area of banana cultivation is high in Malappuram and Wayanad district where the yield is medium. So scope exists for yield improvement in these districts. Banana cultivation is less over districts Kasargod, Kozhikode, Kannur, Thrissur and Pathanamthitta.

The production is highest in Idukki district (about 51%) and it is lowest in Alappuzha district. The productivity is highest in Kasargod district and it is lowest in "16 Malappuram district. (Fig.32). However, scope exists to improve the productivity of Black pepper in Kasaragod, Eranakulam, Kottayam and Pathanamthitta.

Ginger cultivation is high in the Thrissur and Wayanad district and yield is also in high in these districts. Nutmeg is seen in almost all districts in the state. Nutmeg cultivation is more in the central zone districts such as Eranakulam and Thrissur. Kasaragod district even though area of cultivation is less, the productivity is found to be high. When analyzing the case of Rubber, production is maximum at Kottayam district and minimum at Alappuzha district. (Fig 41). The area as well as the productivity of rubber is high in Kottayam district. Rubber cultivation is medium to high in all districts except Wayanad, Kozhikode, Thrissur and Alappuzha. Even though area of rubber cultivation less in Alappuzha the productivity is high. The area of cultivation of cardamom is high in idukki and medium in Wayanad and Palakkad

3.10. Agro meteorological production constraints and opportunities for sustaining production of crops grown in Kerala

RICE

Flash floods and saline water intrusion in the coastal areas and Kuttanad, drought in Palakkad and Onattukara, and soil problems including acidity, iron toxicity, sulphide injury etc. (S. Leena Kumari, Status Paper on Rice in Kerala) in the Kari soils are the major abiotic stresses limiting rice production in the state. In Palakkad and

Onattukara ecosystems, drought is a stress limiting rice production in *kharif* season. Drought is also experienced during the fag end of Rabi season in Eastern Palakkad, where maximum area is under irrigation and water shortage is experienced during summer. In High ranges, cold stress is experienced in Winter which coincides with the *punja* crop. The wet humid tropical climate of Kerala is conducive to the cultivation of rice. Kerala is a hot spot for pests and diseases. The high humidity and temperature of the rice growing environments during the cropping periods increases the incidence of pests and diseases. Major insect pests include BPH, Stem borer, Gall midge, leaf roller and rice bug and minor pests include thrips, case worm, blue beetle, whorl maggot etc. The minor pests are slowly emerging as major pests threatening rice cultivation in the State. Fungal diseases like Blast, Sheath blight, Sheath rot, Brown spot, False smut, Leaf scald and grain discoloration, Bacterial diseases like bacterial leaf blight, and viral diseases like Rice Tungro Virus, Grassy Stunt Virus etc. cause severe damage to rice crop in Kerala. The production constraints in different areas and regions may be identified and separate packages need be formulated for increasing productivity. Maximum productivity potentials can be achieved by developing appropriate irrigation facilities for double cropping in lowland areas. This is especially relevant is the Districts of Palakkad, Malappuram and Wayanad, where the higher productivity of Rabi/ Summer rice can be exploited by creating or improving the irrigation facilities. Adoption of run-off rain water management practices suited to the conditions of individual farm holding as well as watershed as a whole, motivating the farmers to provide life saving irrigation to the crop wherever possible during long dry spells.

COCONUT

Economic utilization of available irrigation water and adoption of the soil moisture conservation practices for containing drought. In order to conserve moisture and thereby avoid stresses to the palms during dry periods, coconut husk can be buried in the field itself. Irrigation is necessary to avoid nut dropping leading to reduction in yield if the delay of monsoon is up to 30days. Continuous rainfall favours the buildup of constant high relative humidity which aggravates *Phytophthora* infestation in coconut palms particularly in low lying areas causing bud rot and noticed especially during SW&NE monsoon periods. Gradient outbreaks of scale insects and slug caterpillar and sporadic outbreaks of inflorescence caterpillar may occur in endemic spots during delayed monsoon periods and this will affect yield. Fruit rot is common in high rainfall areas during monsoon season (http://www.kissankerala.net/kissan/kissancontents/coconut.htm). Irrigation during summer months helps to sustain the yield of root wilt affected palms. Incidence of *Colletotrichum gleosporioides* was higher in frequency and population during monsoon with a peak in June-July. Its incidence is positively correlated with maximum temperature and sunshine hours. Incidence of basal stem rot may be due to lack of soil moisture during summer months and water logging in rainy seasons. Advance information on heavy rains would allow time to the farmers to intensify measures to drain excess water. The incidence was more between March and August. It is positively correlated with the mean maximum temperature and not with the minimum temperature, rainfall and relative humidity. All these field problems can be addressed by proper and timely agromet advisories.

BANANA

If monsoon is delayed by 15days/30days, most of the banana growing areas, usually planting of suckers/ tissue culture plants should be taken up after the on-set of monsoon. (http://www.icar.org.in/files/Advisories_Horticultural). Foliar application of kaolinite (5%) during vegetative stage reduces the transpiration losses if rain deficit is at vegetative and reproductive stage. Banana crop cannot tolerate the wind speed of even 30 km/hr. Banana being a shallow rooted crop requires proper propping with bamboo or casurina poles to avoid lodging during windy seasons. The supporting poles should be tied against the peduncle of developing bunches, so

that it protects the plant from lodging during windy seasons and bears whole weight of developing bunch. In such situations, advisories on wind speed and direction are crucial. The water scarcity situation during summer months could be overcome by adopting drip irrigation. Use of plant waste mulches viz., Banana leaf mulches, sugarcane trashes, paddy straw mulches around the plants conserves soil moisture and also promotes production of more feeder roots

CASHEW

After the onset of monsoon from June to September, cashew is planted. If there is delay in onset of monsoon (15-30 days), planting should be delayed coinciding with monsoon. Cashew experiences severe moisture stress during reproductive phase from December to May, which adversely affects its flowering and fruit set causing flower drying and immature nut drop. Issue of agromet advisories well in advance, would facilitate framers to resort to intercultural operations to conserve soil moisture.

NUTMEG

Nutmeg being a shallow rooted crop is sensitive to water logging, moisture stress and drought. If the dry spell continues for a long period uopto the onset of monsoon in the first week of June, will affect badly the nutmeg crop (http://www.thehindubusinessline.com). Irrigation is necessary to avoid nut dropping leading to reduction in yield if the delay of monsoon is up to 30days. In order to conserve moisture and thereby avoid stresses to the palms during dry periods, mulching can be provided. Heavy rainfall, lack of drainage in fields and inadequate space between plants aggravate the increased spread of dieback disease in nutmeg trees in Thrissur and Ernakulam districts. Proper drainage during the heavy rainfall is recommended

PEPPER

It is a plant of humid tropics, requiring 2000-3000 mm of rainfall, tropical temperature and high relative humidity with little variation in day length throughout the year. Black pepper does not tolerate excessive heat and dryness. Studies revealed that rainfall received after a period of stress induces profuse flowering in pepper (http://www.indianspices.com). Growth of fruit bearing lateral shoots and photosynthetic rate are high during peak monsoon (June-July). Irrigating pepper plants from November-December till the end of March and withholding irrigation till monsoon break increases pepper yield by about 50 %.

4 Rainfall characteristics

Precipitation, chiefly rain, has a remarkable effect on agriculture. All plants need at least some water to continue to exist; therefore rain (being the most effective means of watering) is important to agriculture. While a regular rain pattern is usually vital to healthy plants, too much or too little rainfall can be harmful, even overwhelming to crops. Not only the total quantity of rain during a crop season is important but also its distribution is vital to realize maximum yields.

4.1 Annual and seasonal rainfall

The mean annual and seasonal rainfall for the state for 14 districts is furnished Table.8 and Fig.48. The mean annual rainfall of Kerala is 2909 mm with a coefficient of variation of 19% (Table.7). Kerala is divided into 5 Agro-climatological zones which are South zone, North zone, Central zone, High range zone, Problem area zones. Annual rainfall is highest over High range zone which includes Wayanad as well as Idukki districts having rainfall 3366 mm, lowest over South zone (Thiruvananthapuram, Kollam, Pathanamthitta) having 2107 mm (Table.8).

The variability in the rainfall during SWM, was found to be highest in Thiruvananthapuram (35%) followed by Wayandad district (28%) and the least in Kasaragod (19%) (Table.14 and Fig.52).The mean variability during the NEM period is high in comparison to SWM monsoon. The highest variability during the NEM rainfall is noticed in Pathanamthitta (48%) followed by Kottayam (46%) and least in Kozhikode (27%) (Table.8 and Fig.55).

SWM rainfall accounts 64% of the annual rainfall on a state wise calculation but in Northern zone SWM contributes to 77% of the annual precipitation. NEM rainfall contributing 18% of the annual on a state basis and in Southern zone it is higher than from the state average (30%) (Table.9)

4.2 Rainy days

Rainy day may be defined as rainfall amount realized in a day is 2.5 mm or more. The numbers of rainy days closely follow the total rain received. Most of the rain events in Northern Zone occur during SWM season (83%) and lowest at South Zone (56%) (Table.10 and Fig.53). On an annual basis rain occurs more frequently over Problem area having 126 rainy days (Table.10). Rainy days higher at Kottayam district (129) day and low at Thiruvananthapuram district has 96 rainy days. In SWM CV% is high at Thiruvananthapuram district (21%) and low at Malappuram (18%) (Table.10). Winter season rainy days are highly variable when compared to all other season.

4.3 Features of SWM rainfall

Kerala receives 1986 mm rain during SWM season, at the district level Kasaragode district received highest amount of rainfall (3076 mm) followed by Kannur district (2596 mm) and Idukki (2445 mm). Lowest rainfall is noticed in Thiruvananthapuram district (807 mm) followed by Kollam (1270 mm) (Table.8 and Fig.51). When rainfall pattern comparing by zones North zone receives highest amount of rainfall (2428 mm) and least in South zone (1039 mm).

Kerala state as a whole is subjected to 25% variability in southwest monsoon rainfall and 14% rainy days. Zone wise highest rainfall variability observed in Northern zone (68%) and lowest variability in South zone (39.7%). In district wise highest rainfall variability noticed in Thiruvananthapuram (35%) and lowest in Kasaragode (19%) (Fig.52).

On an average SWM rainfall in the state spread over 75 days (Table. 10). At the zone level highest numbers of rainy days are noticed Northern zone (83) and lowest over South zone (56). When comparing rainy days at district level Kannur district recorded maximum (91) and minimum at Thiruvananthapuram (49) (Table.10 and Fig.53).

4.4 Features of NEM rainfall

Rainfall during NEM for the entire state is 526 mm with a variability 39%. South zone receives highest amount of rainfall (632 mm) and lowest amount of rainfall received by North zone (429 mm). In district wise comparison Pathanamthitta shows highest amount of rainfall (689 mm) followed by Kollam (684 mm) and lowest in Kasaragode district(377 mm) followed by Wayanad district (381 mm) (Table.8 and Fig.54).

Variability in rainfall is observed high at Pathanamthitta (48%) and low at Kozhikode district (27%). High variability in rainfall noticed at southern zone (41%) and low at High range zone (Table.8 and Fig.55)

Average number of rainy days during NEM season is 24 days. Maximum number of rainy days obtained at Idukki, Kollam and Kottayam districts (28) and minimum number of rainy days at Kasaragod (15). When rainy days obtained in zone wise, South zone, Highrange zone and Problem zone are obtained maximum number of rainy days (27) and minimum on Northern zone (21) (Fig.56 and Table.10).

4.5 Features of summer and winter rainfall

The mean summer rainfall obtained in Kerala state 370 mm. Summer rainfall contributes only 13% out of annual rainfall. Problem area zone receives highest amount of rainfall (476 mm) followed by South zone (390 mm). In district wise summer rainfall pattern Pathanamthitta district receives highest amount of rainfall followed by Kottayam (486 mm) and low at Kasaragode (231 mm). Kerala has mean summer rainy days in a year is 16. Kollam and Alappuzha have higher number of rainy days (22). (Table.10 and Fig.59).

The mean winter rainfall is a negligible amount compared to all other seasons (27 mm). Among the zones Southern receive high amount of winter rainfall 50 mm (Table.8 and Fig.62).

4.6 Monthly rainfall and distribution of rainy days

Monthly rainfall is an important and essential parameter for agriculture planning. It also help for proper crop planning run off estimation, determining crop water needs, and for designing watersheds and ultimately for irrigation system. Analyzing monthly rainfall pattern of Kerala reveals that July is the Wettest month in the state (662 mm) followed by June (639 mm). In July month Kasaragode district receives highest amount of rainfall (1041 mm) followed by Wayanad district (982 mm) and lowest in Thiruvananthapuram (197 mm), However except 5 districts (Kannur, Malappuram, Wayanad, Palakkad, Idukki) June rainfall is dominant over July rainfall. January (10 mm) and February (17 mm) receives very less amount of rainfall during winter season. Which indicates that Kerala receives less amount of rainfall during winter season (Table.11 and Fig.64(a) to 64(l)).

4.7 Distribution of weekly rainfall

Commencement of growing season, length of growing season, choice of cropping systems, allocation of resources and inputs depend significantly on the weekly distribution of rain. Distributions of rain on a weekly basis for the state and for the individual districts along with their statistics are presented in (Table.13). Considerable rain (>20 mm/week) over the state occurs in the period from 14th Standard meteorological week (SMW) (April 2 to April 8) to 47th SMW (Nov19 - Nov 25). This indicates a total growing period of 34 weeks (around 238 days). The variability is less than 50% during this period (14th to 47th week) except for the 21st week. The variability is found to be high during winter weeks and reaches up to 192% in the 4th week.

The rainy season starts early at 14th week for the districts, Thrissur, Palakkad, Malappuram Alappuzha, Kottayam, Kollam, Thiruvananthapuram and Ernakulam and 15th week for Kannur, Idukki and Wayanad. For all the other districts, rainy season starts after 17th week.

The rainy season ends 47th week for all the districts except for Thiruvanathapuram and Wayanad. Kannur district has recorded the highest weakly rainfall of 286 mm in 25th SMW week.

4.8. Distribution of dependable annual rainfall (@ 75 per cent probability)

Average values of rain are simple indicators of rainfall over a period or a region. The associated risks with quantum information of rain are not considered. The amount of rain that can be depended upon enables development of several farm decisions / strategies. By analyzing probability analysis, of receiving a certain amount of rainfall, the variability in the rainfall can be accounted for and strategies can be evolved accordingly. Dependable rainfall for agricultural purposes is generally taken as the expected amount of rainfall with 75% probability. Hargreaves (1974) defined the dependable precipitation as the rainfall amount received at 70% probability. In rainfed agriculture, dependable / assured rainfall helps in proper crop planning. For moisture sensitive crops or high-value crops, a higher level of probability may be more appropriate (Sivakumar and Gnoumou, 1987). Keeping its importance in view, expected rainfall at 75 per cent probability were worked out using an incomplete gamma distribution method on annual and seasonal basis for all stations of Kerala.

4.9. Annual rainfall at 75 per cent probability

Highest annual rainfall to the tune of more than 2500 mm is noticed in the stations of central zone districts (one station of Thrissur, two station of Ernakulam) and northern zone district (one each station of Kannur and Kasargod district). Expected annual rainfall ranges between 2000 and 2500 is observed in Central zone districts (four stations of Thrissur, two stations of Palakkad, one station of Ernakulam) , Northern zone district Kozhikkod (one station) and problem area zone districts (one each in Alappuzha and Kottayam) and high range zone district Wayanad. Dependable rainfall in the range 1400-2000mm is found Kollam (three stations) , High range districts (one station in Idukki), Central zone district Palakkad (three stations) and northern zone districts Malappuram. Dependable rainfall is found to be less than 1400mm in all the stations (six stations) of Southern zone district Thiruvananthapuram and two stations of Central zone district Palakkad. (Table.14). Spatial Pattern of annual dependable rainfall at 75% probability is shown in the figure 66.

4.10.1 Trends in annual, seasonal rainfall and rainy days

Daily precipitation has been segregated into seasonal (Southwest monsoon) and annual rainfall. The significance of the trends was tested by Mann-Kendall test (Fig 67-72). Annual rainfall shows a decreasing trend in 56% of the available stations (31 out of 55 stations) in which 18% of the stations showed a significant decreasing trend (Signifcant at 0.01% level at Chengannur, Ponnani). Remaining 23 stations shows increasing trend in which only four stations (Cherthala and Kumarakam of Alappuzha district and Parambikulam of Palakkad district and Vellayini of Thiruvanathapuram district) annual rainfall is increasing significantly.

Southwest monsoon rainfall is mostly declining in majority of the places of Kerala. The analysis reveals that 74% of available stations (41 out of 55 stations) show a decreasing trend. Significant decrease in SWM rainfall is found in 14 stations, which is an alarming situation since 77% of annual rainfall is contributed by SWM rainfall. Only three station's rainfall shows a significant increasing trend in SWM rainfall.

As far as NEM rainfall is concerned, significant decreasing trend in NEM rainfall is found only for two stations and significant increasing trend in NEM rainfall is observed in three stations. Summer rainfall during March, April, May is found to be increasing in many places of Kerala. Around 78% of the stations (43 out of 55) show an increasing trend in summer rainfall in which ten station's summer rain is increasing significantly.

Contradictory to the annual rainfall trend, annual rainy days shows an increasing trend in 23 stations out of 35 stations in the State. Increasing trend is significant for Pattambi and Thrithala of Palakkad district and Punalur of Kollam district and Vellayini of Thiruvanathapuram and Pilicode of Kasargod district. Rainy days during SWM season also showed an increasing trend in many places of Kerala (24 stations out of 35). Significant increase is observed in northern zone stations, Malappuram and Panniyur of Kannur district. Significant decrease in rainy days is found at Varkala station of southern zone district Thiruvanathapuram.

Table.7: District wise mean annual rainfall and seasonal rainfall (mm) with its standard deviation (mm) and coefficient of variation (%).

District	Annual			Southwest monsoon			Northeast monsoon			Summer			Winter		
	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%
Alappuzha	2748	452	16	1652	342	21	588	204	35	465	197	42	43	42	98
Kannur	3325	537	16	2596	543	20	440	167	40	283	202	72	6	6	147
Kasargode	3743	397	15	3076	491	19	377	143	45	286	201	87	4	2	185
Kozhikkode	3135	605	19	2347	629	27	451	120	27	328	203	62	9	13	144
Kottayam	3029	675	22	1881	471	25	620	284	46	486	194	40	42	49	116
Malappuram	2459	455	19	1692	406	25	448	156	37	307	145	50	12	16	152
Pathanamthitta	2903	448	15	1611	331	21	689	331	48	546	204	37	57	45	80
Wayanad	3113	602	21	2445	637	28	381	137	40	274	166	56	13	24	133
Idukki	3366	766	23	2344	659	28	590	197	33	399	225	56	33	27	83
Ernakulam	3496	717	21	2373	588	25	637	263	41	455	233	51	31	46	147
Palakkad	2217	483	22	1560	426	27	395	144	37	247	127	52	15	27	169
Thrissur	2981	530	18	2153	525	24	480	209	44	331	183	55	17	32	188
Thiruvananthapuram	1760	439	25	807	281	35	580	241	42	333	147	44	40	43	109
Kollam	2454	424	17	1270	314	25	684	224	33	446	167	37	54	52	98
State	2909	541	19	1986	484	25	526	201	39	370	194	53	13	35	132

Table.8: Annual rainfall distribution in different regions and rainfall in different seasons as percent of annual

Zones	Rainfall (mm)					% of annual rainfall			
	Annual	SWM	NEM	Summer	Winter	SWM	NEM	Summer	Winter
Southern Zone	2107	1039	632	390	47	49	30	18	2
Northern Zone	3166	2428	429	301	7.75	77	14	10	0
Central Zone	2898	2029	504	344	21	70	17	12	1
High range Zone	3366	2395	486	337	23	71	14	10	1
Problem area Zone	2889	1767	604	476	43	61	21	16	1

Table 9: District wise mean annual seasonal rainy days with its standard deviation and coefficient of variation (%)

Districts	Annual			Southwest monsoon			Northeast monsoon			Summer			Winter		
	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV(%)	Mean	SD	CV(%)	Mean	SD	CV (%)
Alappuzha	123	11	9	73	9	13	26	6	22	22	6	27	2	2	104
Ernakulam	124	18	15	79	13	16	24	8	32	18	6	35	1	2	117
Idukki	117	10	9	72	12	16	28	6	20	14	5	36	2	2	116
Kannur	126	10	8	91	9	10	21	4	18	14	6	45	1	1	123
Kasargod	107	12	11	84	10	11	15	6	40	8	3	36	0	0	283
Kollam	118	12	10	64	8	13	28	6	23	22	6	27	3	2	75
kottayam	129	10	8	77	7	9	28	8	28	22	6	25	3	3	102
Kozhikkod	114	11	9	80	9	11	21	5	25	12	6	45	1	1	171
Malappuram	122	13	13	77	12	18	25	5	33	19	4	36	1	1	176
Palakkad	105	16	15	71	11	16	20	7	34	13	5	40	1	1	127
Thiruvananthapuram	96	17	17	49	10	21	26	7	27	19	7	37	3	2	92
Thrissur	117	12	10	80	9	11	21	6	30	15	6	41	1	1	148
Wayanad	119	12	11	76	9	13	26	4	21	16	5	23	1	1	92
State	117	13	11	75	10	14	24	6	27	16	5	35	2	1	133

Table 10: Zone-wise and season wise distribution of annual rainy days and as percent of annual

Zones	Rainy days					% of annual rainy days			
	Annual	Winter	Summer	SWM	NEM	Winter	Summer	SWM	NEM
Southern Zone	107	3	21	56	27	3	20	52	25
Northern Zone	117	1	15	83	21	1	13	71	17
Central Zone	115	1	15	77	22	1	13	67	19
High range Zone	118	2	15	74	27	1	13	63	23
Problem area Zone	126	2	22	75	27	2	17	60	21

Table 11: Average monthly rainfall in different districts of Kerala

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alappuzha	14	29	48	138	279	550	501	325	276	356	185	47
Kannur	4	2	20	64	199	869	907	535	285	297	124	19
Kasargode	2	2	35	50	201	982	1041	688	365	241	114	22
Kozhikkode	5	4	17	77	234	842	800	453	252	278	146	27
Kottayam	19	23	62	147	277	625	563	392	301	365	197	58
Malappuram	3	9	29	94	184	549	580	326	237	291	140	17
Pathanamthitta	18	39	75	197	274	518	508	329	256	419	231	39
Wayanad	6	7	20	89	165	680	982	538	245	238	120	23
Idukki	12	21	46	139	214	642	803	536	363	376	169	45
Ernakulam	13	18	46	145	264	765	764	461	383	392	204	41
Palakkad	3	12	27	89	131	486	554	315	205	259	120	16
Thrissur	4	13	20	89	222	730	692	434	297	346	117	17
Thiruvananthapuram	18	22	39	119	175	289	197	146	175	305	214	61
Kollam	20	34	63	162	221	420	370	253	227	415	222	47
Mean State	**10**	**17**	**39**	**114**	**217**	**639**	**662**	**409**	**276**	**327**	**165**	**34**
SD	**7**	**11**	**18**	**40**	**44**	**182**	**229**	**135**	**59**	**60**	**42**	**15**
CV%	**66**	**68**	**45**	**35**	**20**	**28**	**35**	**33**	**21**	**18**	**25**	**45**

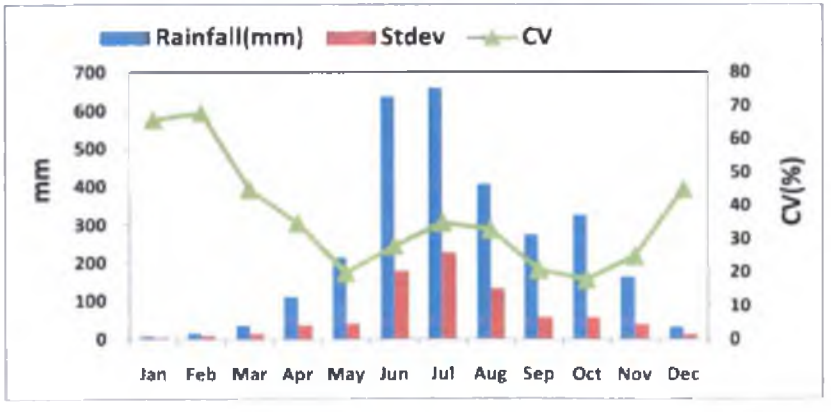


Fig.63. Average Monthly rain of Kerala

Table 12: Mean monthly distribution of rainy days in different districts of Kerala

Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alappuzha	1	1	3	8	12	22	22	17	13	15	9	2
Ernakulam	1	1	2	7	10	23	25	19	14	15	9	2
Idukki	1	1	2	6	7	19	22	18	13	14	10	4
Kannur	0	0	1	4	8	24	28	23	15	14	7	1
Kasargode	0	0	2	4	7	25	27	24	17	13	7	2
Kollam	1	2	4	8	10	19	19	14	12	16	10	2
Kottayam	1	2	3	8	11	22	23	18	14	15	10	3
Kozhikkode	0	0	1	4	8	23	25	20	13	12	8	1
Malappuram	0	0	1	4	6	19	21	16	11	10	6	0
Palakkad	0	1	1	5	7	20	23	17	11	13	6	1
Thiruvanathapuram	1	2	3	7	9	16	13	10	9	12	10	3
Thrissur	0	1	1	5	9	23	25	19	13	14	6	1
Wayanad	0	0	2	6	8	21	23	20	12	15	9	2
State mean	1	1	2	6	9	21	23	18	13	14	8	2
SD	0	1	1	2	2	3	4	4	2	2	2	1
CV%	93	81	51	27	21	12	17	20	15	12	20	59

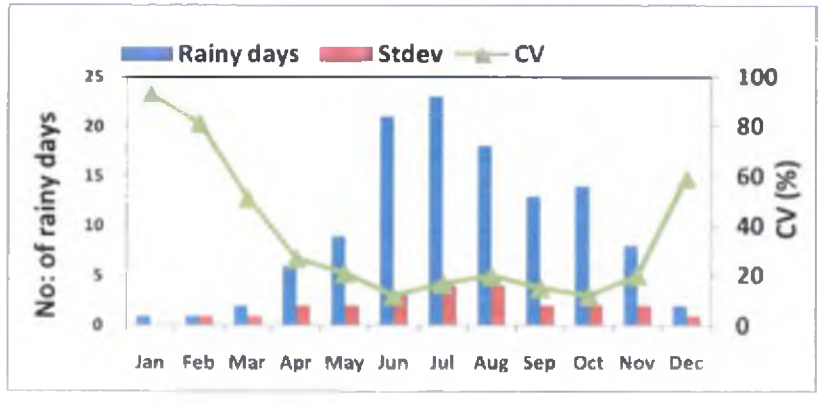


Fig.65. Average Monthly rainy days of Kerala

Table 13: Mean weakly rainfall of different district of Kerala

Week no	Kannur	Kasargode	Kozhikkode	Malappuram	Ernakulam	Palakkad	Thrissur	Thiruvanathapuram	Kollam	Idukki	Wayanad	Alappuzha	Kottayam	State	SD	CV(%)
1	1	2	2	1	3	1	0	7	9	6	1	6	9	4	**3**	**77**
2	2	1	0	1	1	0	1	7	4	4	2	4	5	2	**2**	**90**
3	0	0	0	0	5	1	2	3	4	5	1	1	7	**2**	**2**	**87**
4	0	0	0	0	1	1	0	1	1	1	0	3	4	**1**	**2**	**192**
5	0	1	1	4	5	2	4	4	4	4	3	7	2	3	**3**	**90**
6	1	1	1	1	4	2	2	9	12	4	0	3	3	3	3	**87**
7	2	3	1	3	3	1	2	6	6	1	1	5	7	3	4	**114**
8	0	1	0	2	**5**	5	2	5	10	8	1	14	10	**5**	**4**	**76**
9	1	2	0	5	5	6	5	5	9	6	1	2	4	4	**3**	**79**
10	2	4	2	4	4	2	2	7	12	11	2	3	8	**5**	**6**	**135**
11	6	**13**	3	21	16	**11**	7	13	21	8	5	19	20	13	7	**54**
12	23	28	6	12	10	5	5	13	13	5	7	16	14	**12**	**6**	**53**
13	1	5	4	3	10	9	5	13	14	6	6	9	18	**8**	**11**	**141**
14	10	12	11	21	37	20	22	31	37	15	15	31	38	**23**	**10**	**41**

15	23	10	18	28	33	21	21	34	38	25	22	31	42	27	8	29
16	20	19	14	22	32	22	20	29	35	26	15	28	26	24	8	35
17	21	17	21	28	37	25	24	37	45	24	24	43	36	29	10	35
18	24	20	15	31	32	24	32	42	45	27	19	46	51	31	10	32
19	41	26	42	32	50	23	42	31	38	26	33	44	41	36	9	26
20	34	22	34	37	49	28	46	35	42	19	27	46	54	36	15	41
21	59	46	46	47	67	33	52	53	55	19	28	74	67	50	36	73
22	137	162	108	86	132	57	99	70	74	32	68	121	105	96	44	46
23	177	166	180	114	188	90	173	101	131	61	118	174	158	141	49	34
24	249	215	203	170	221	137	196	73	101	79	152	146	147	161	60	38
25	286	264	234	172	189	132	170	69	95	84	161	113	149	163	66	40
26	218	297	186	103	186	131	173	52	83	84	127	128	151	148	62	42
27	227	272	194	139	174	131	158	56	82	76	147	111	130	146	54	37
28	186	238	164	109	170	124	149	50	92	79	156	118	129	136	56	41
29	218	290	194	146	182	123	168	61	86	78	149	119	131	150	56	38
30	216	204	154	108	165	125	147	44	73	92	122	91	107	127	48	38
31	205	221	156	119	141	113	131	44	77	79	131	120	108	126	56	44
32	196	267	116	110	107	78	109	30	49	64	103	61	108	107	49	46
33	128	136	111	71	105	73	102	30	53	73	73	79	92	87	27	31
34	75	98	91	41	93	56	83	31	53	50	73	85	81	70	22	31
35	77	128	82	75	93	58	76	42	60	40	71	70	70	72	27	37

36	119	143	64	70	106	57	80	44	54	30	55	81	79	**76**	**29**	**38**
37	112	119	67	78	91	52	73	40	42	33	63	58	70	**69**	**22**	**31**
38	47	79	61	49	69	39	50	47	50	49	40	81	71	**56**	**14**	**24**
39	61	78	59	46	80	42	69	46	63	57	51	49	78	**60**	**16**	**27**
40	48	76	71	78	92	60	88	78	100	48	62	81	84	**74**	**16**	**21**
41	91	51	73	63	98	59	84	76	95	56	64	77	89	**75**	**16**	**22**
42	77	45	57	78	109	69	87	77	98	66	59	88	86	**77**	**15**	**20**
43	81	66	57	73	71	51	56	63	75	66	56	60	83	**66**	**10**	**15**
44	50	54	77	63	77	55	58	62	81	61	59	79	72	**65**	**12**	**18**
45	57	57	50	53	63	48	39	79	80	59	50	50	77	**59**	**15**	**26**
46	36	49	35	50	43	22	27	53	52	43	37	27	39	**39**	**11**	**27**
47	17	44	25	43	37	17	19	43	44	34	26	40	39	**33**	**13**	**40**
48	11	6	14	9	11	7	5	29	15	14	22	17	18	**14**	**7**	**50**
49	7	10	6	4	7	3	4	23	15	17	6	19	19	**11**	**7**	**63**
50	0	6	7	4	8	7	5	15	13	18	9	6	25	**9**	**6**	**62**
51	0	3	5	2	12	2	4	10	7	13	3	4	10	**6**	**4**	**72**
52	7	10	2	2	5	2	2	12	10	8	2	8	13	**6**	**4**	**65**

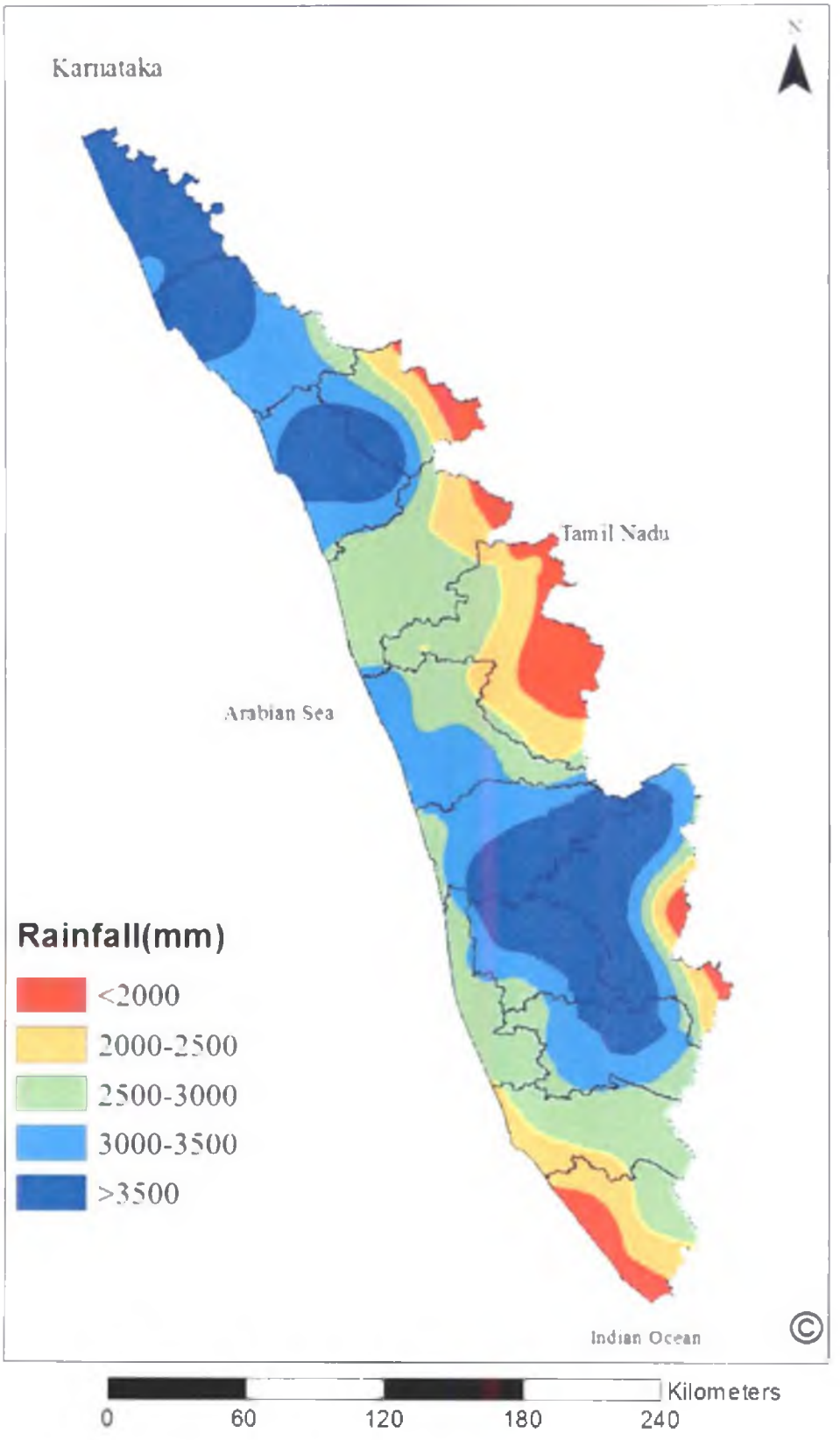


Fig. 48. Annual rainfall (mm) over Kerala

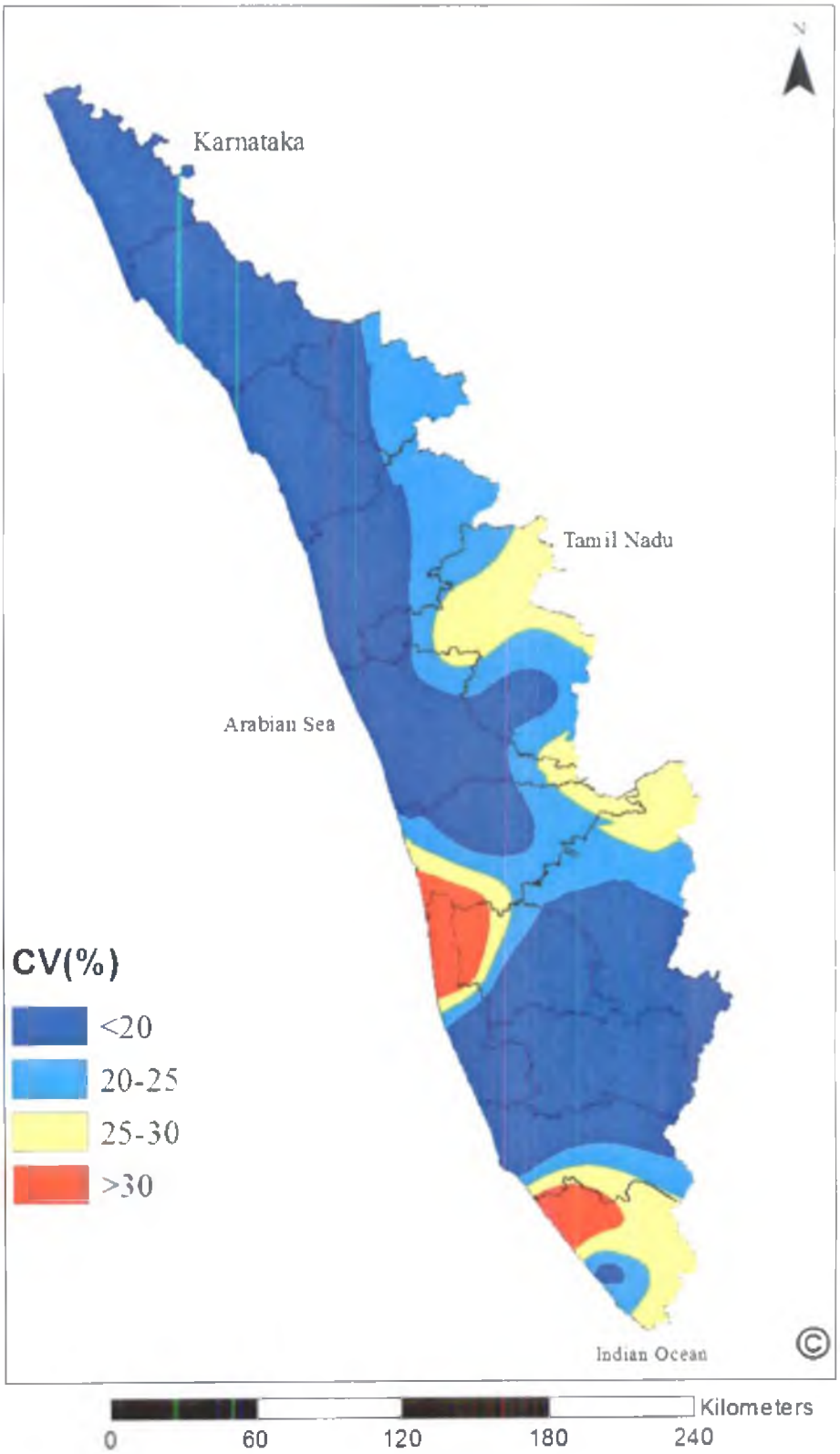


Fig. 49. Spatial variablity (CV%) of annual rainfall in Kerala

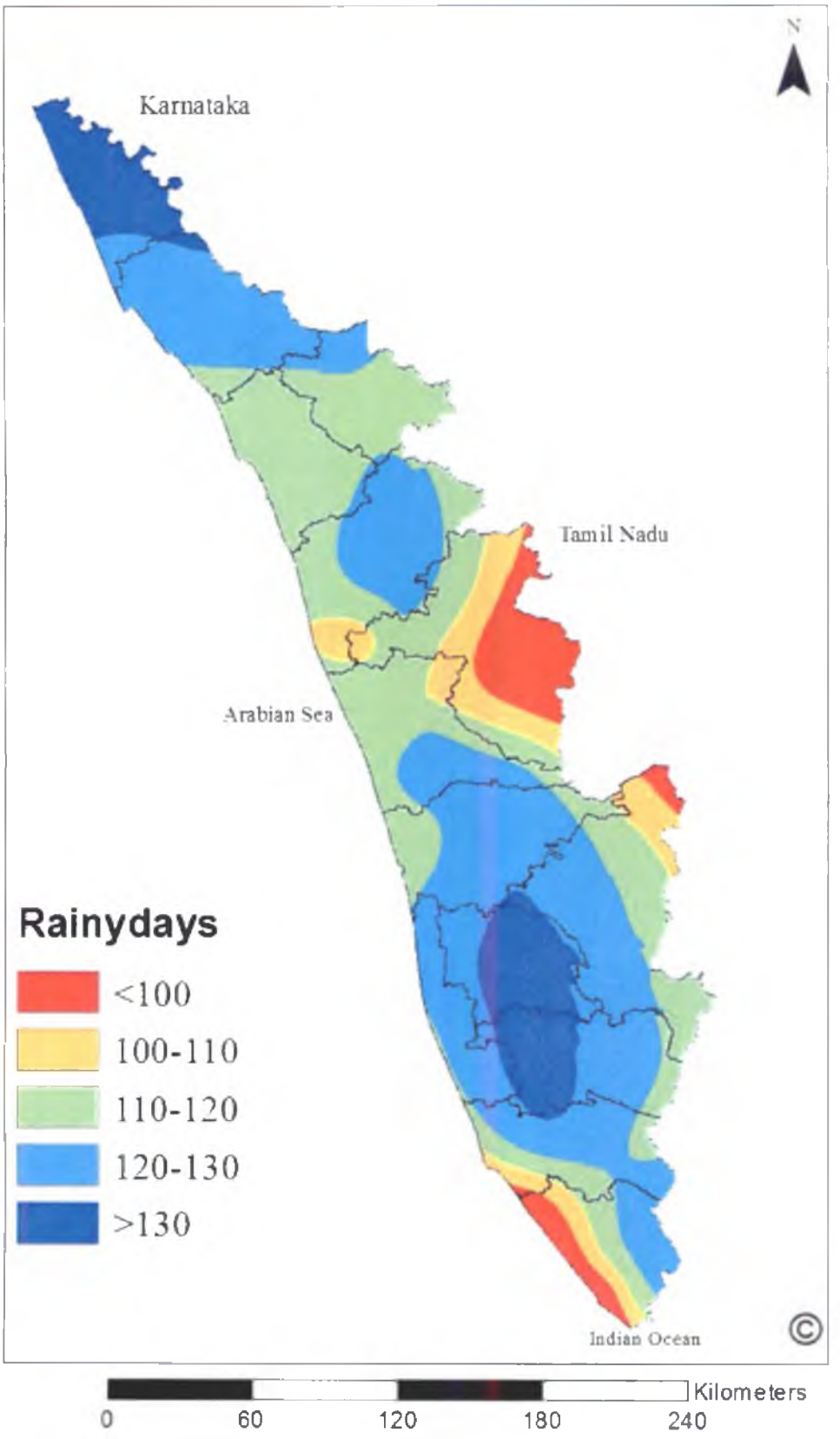


Fig. 50: Annual number of rainy days in Kerala

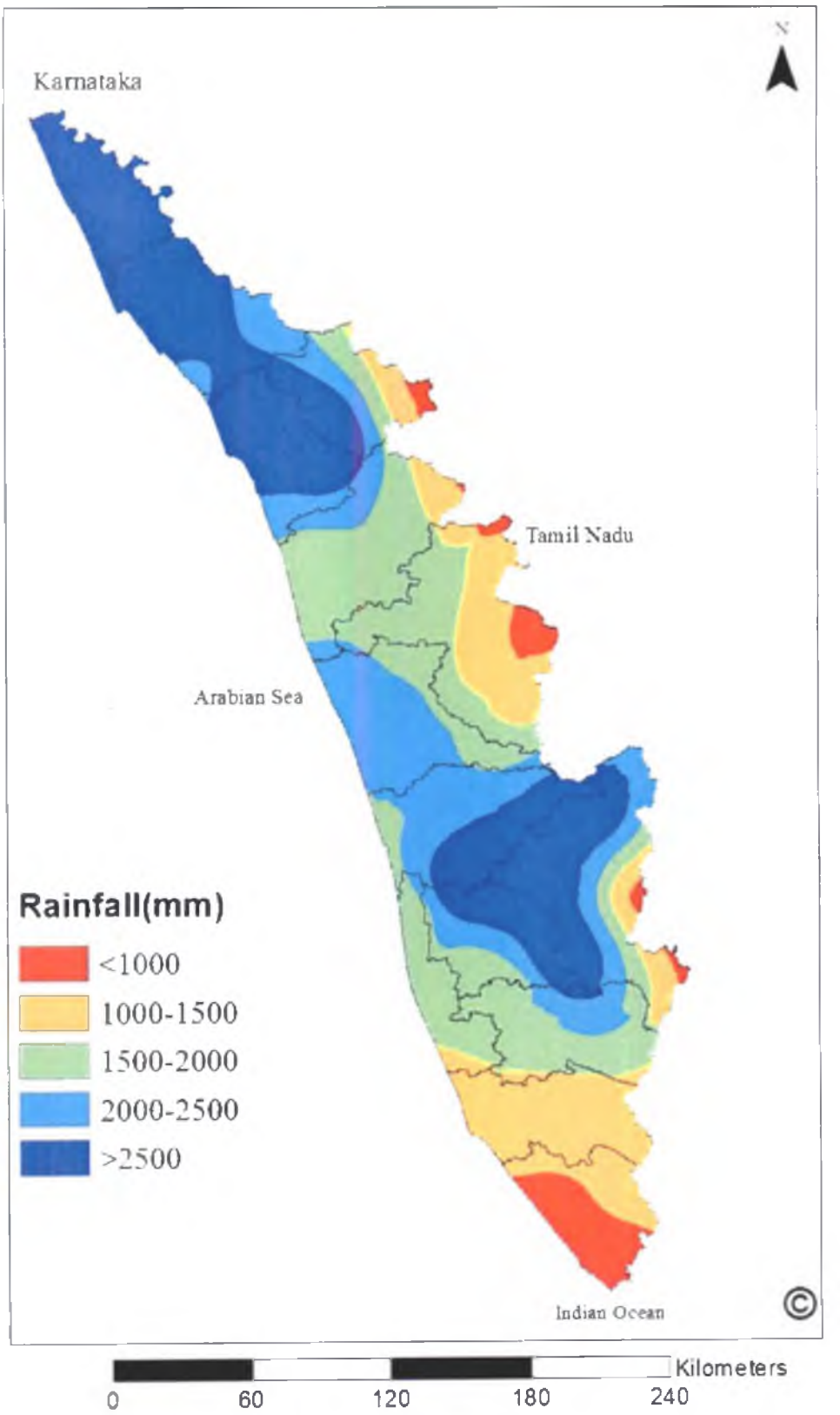


Fig. 51. Southwest monsoon rainfall (mm) over Kerala

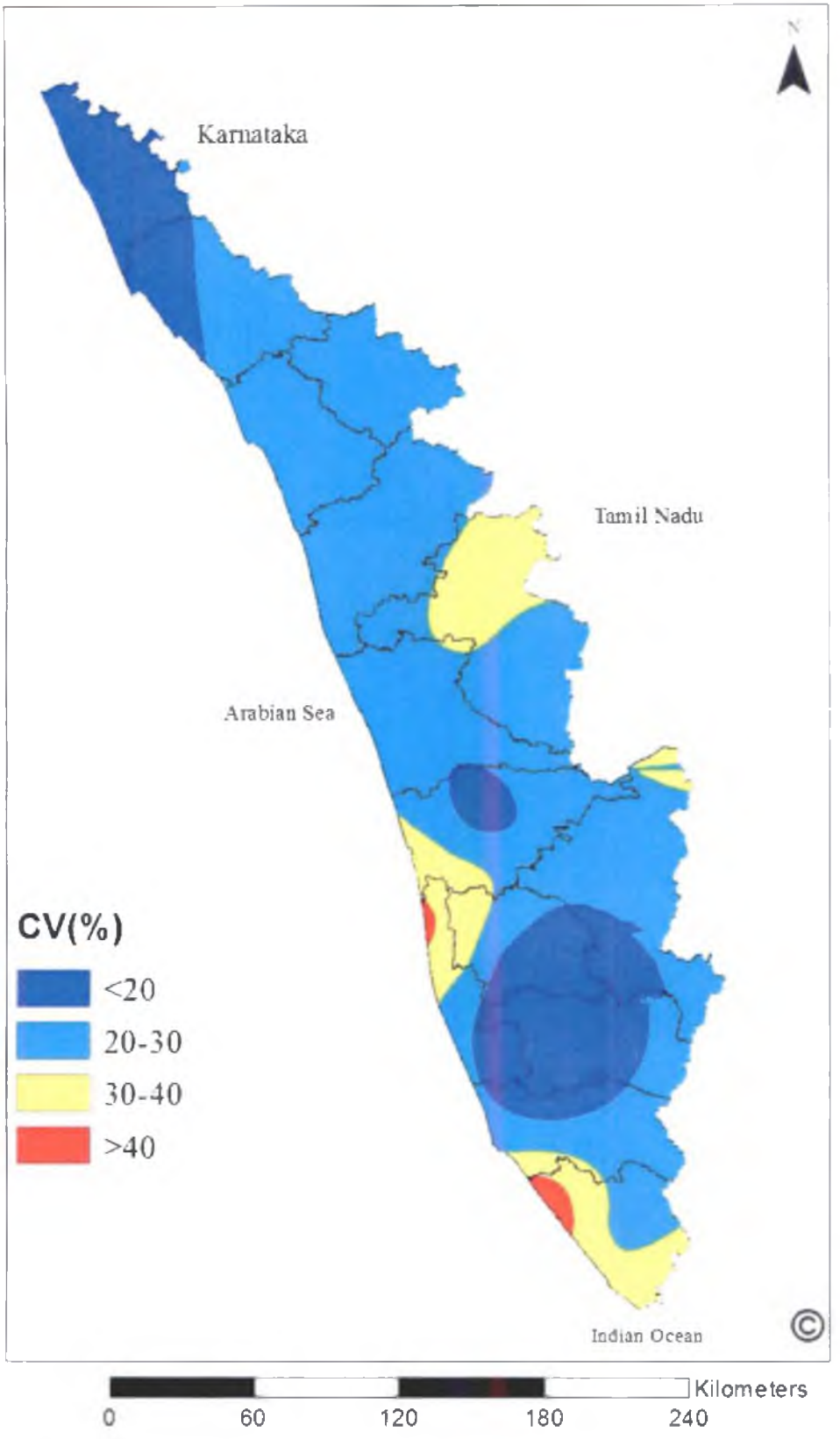


Fig. 52: Variability (CV %) in Southwest monsoon rainfall over Kerala

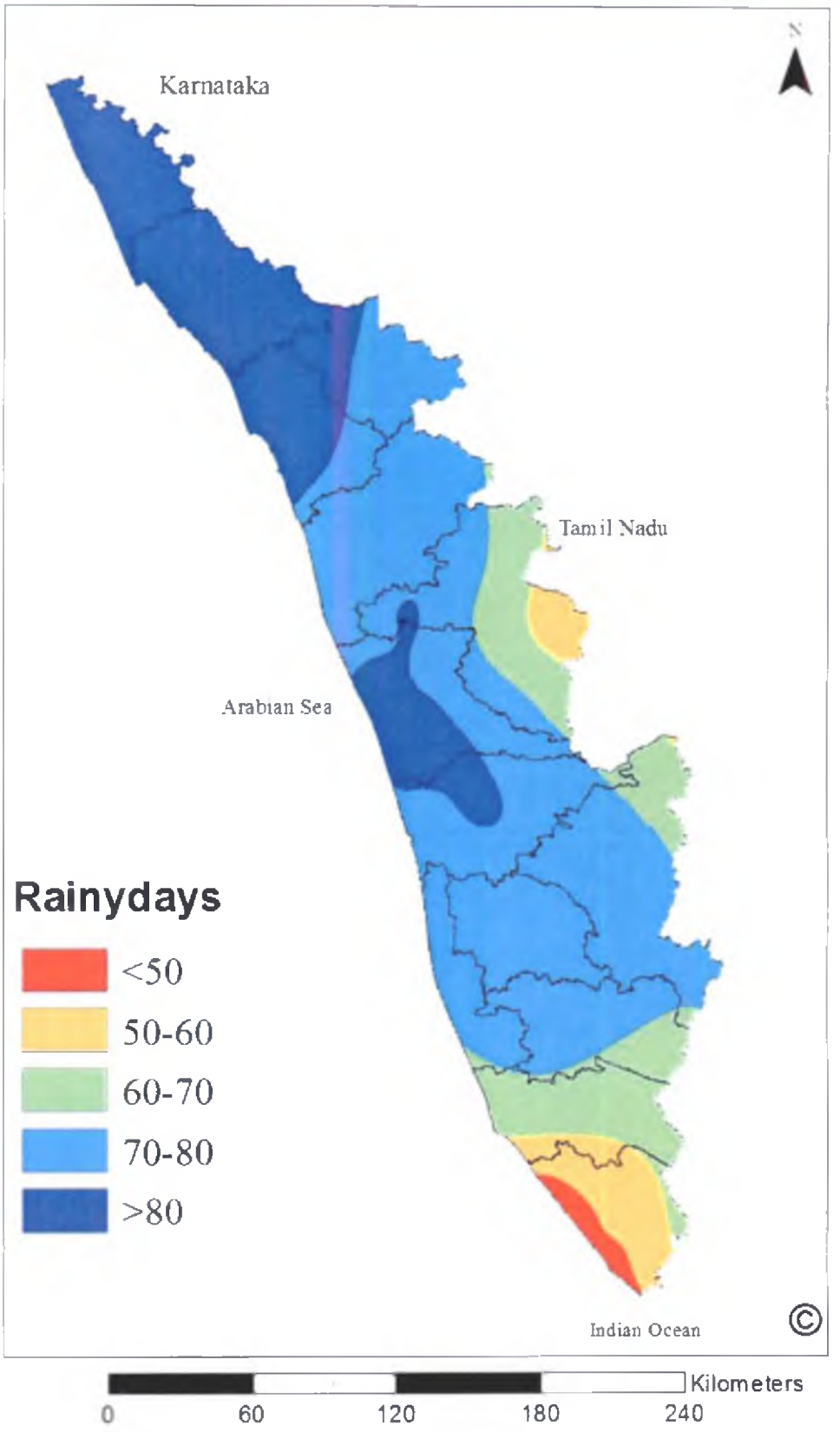


Fig. 53: Number of rainy days during Southwest monsoon season over Kerala

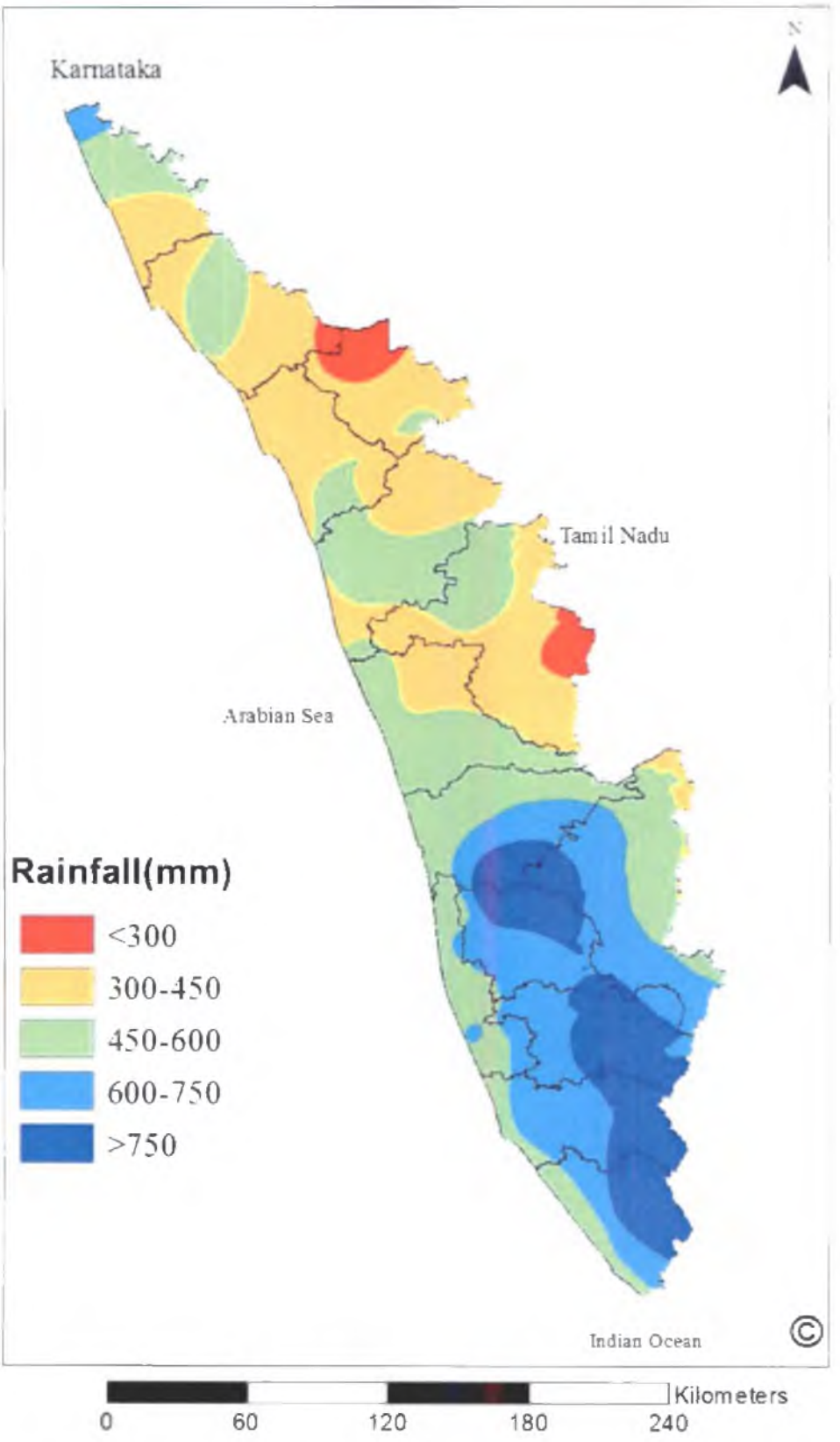


Fig. 54: Northeast monsoon rainfall (mm) over Kerala

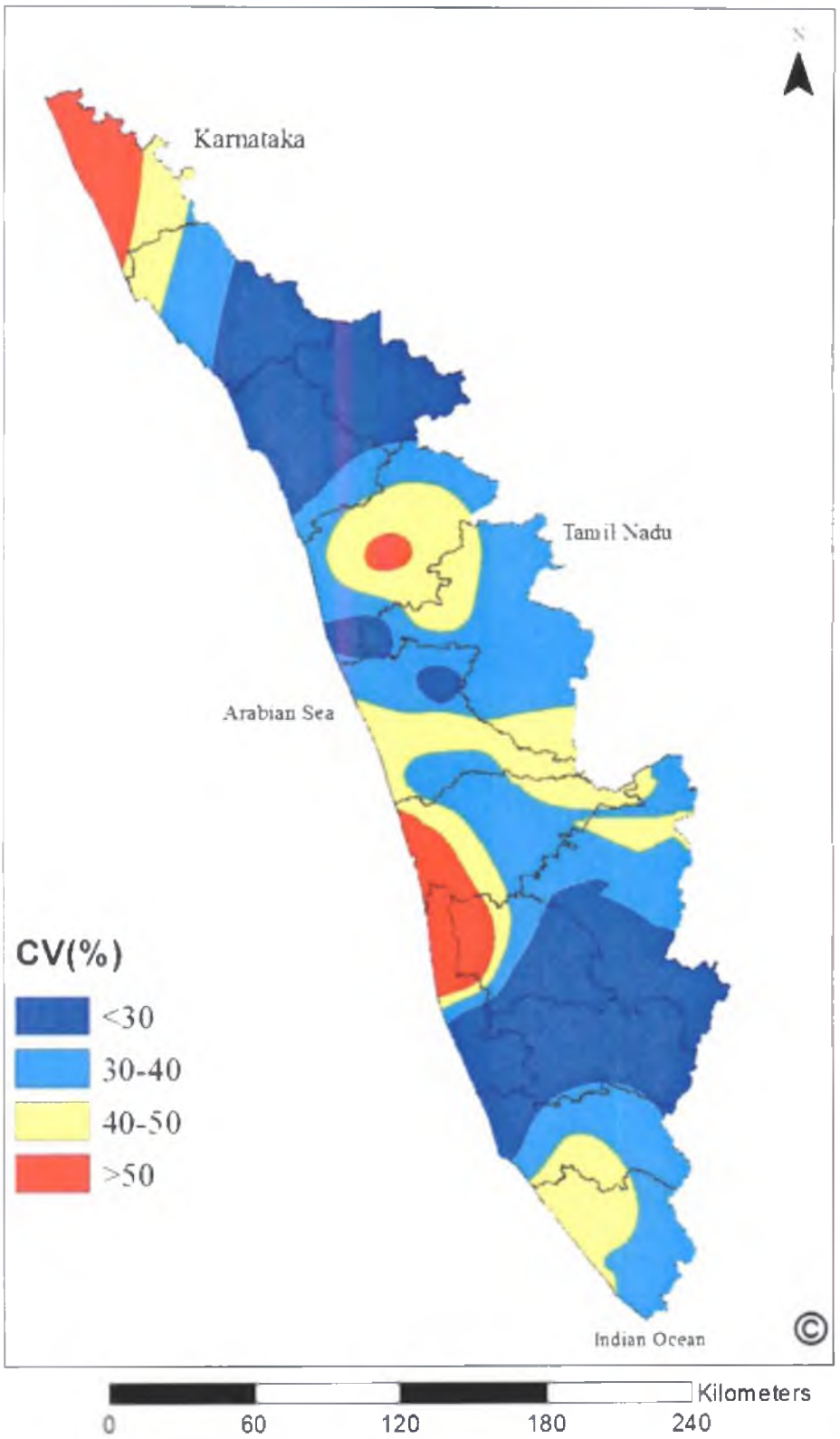


Fig. 55: Variability (CV %) in Northeast monsoon rainfall over Kerala

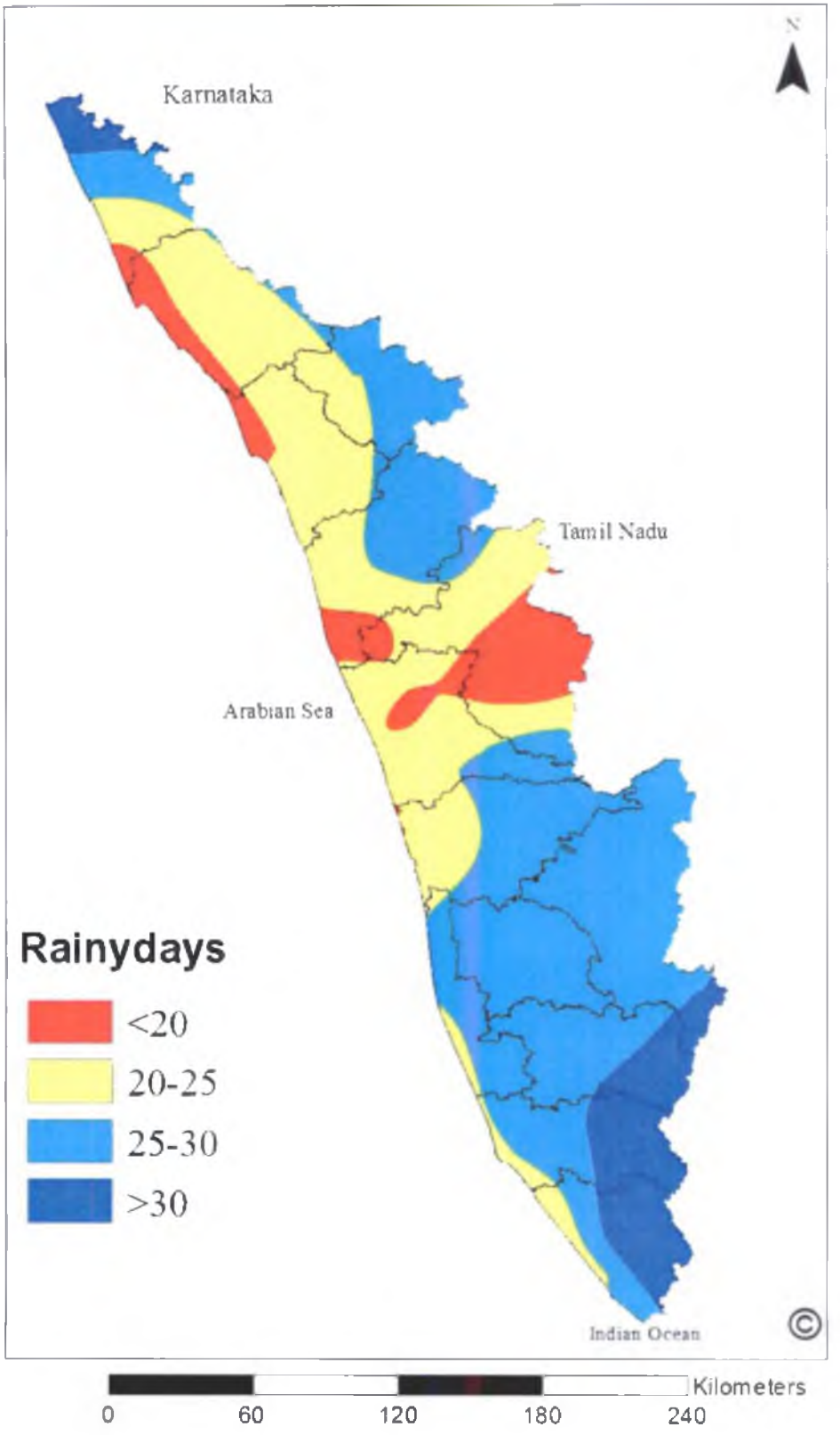


Fig. 56: Number of rainy days during Northeast monsoon season over Kerala

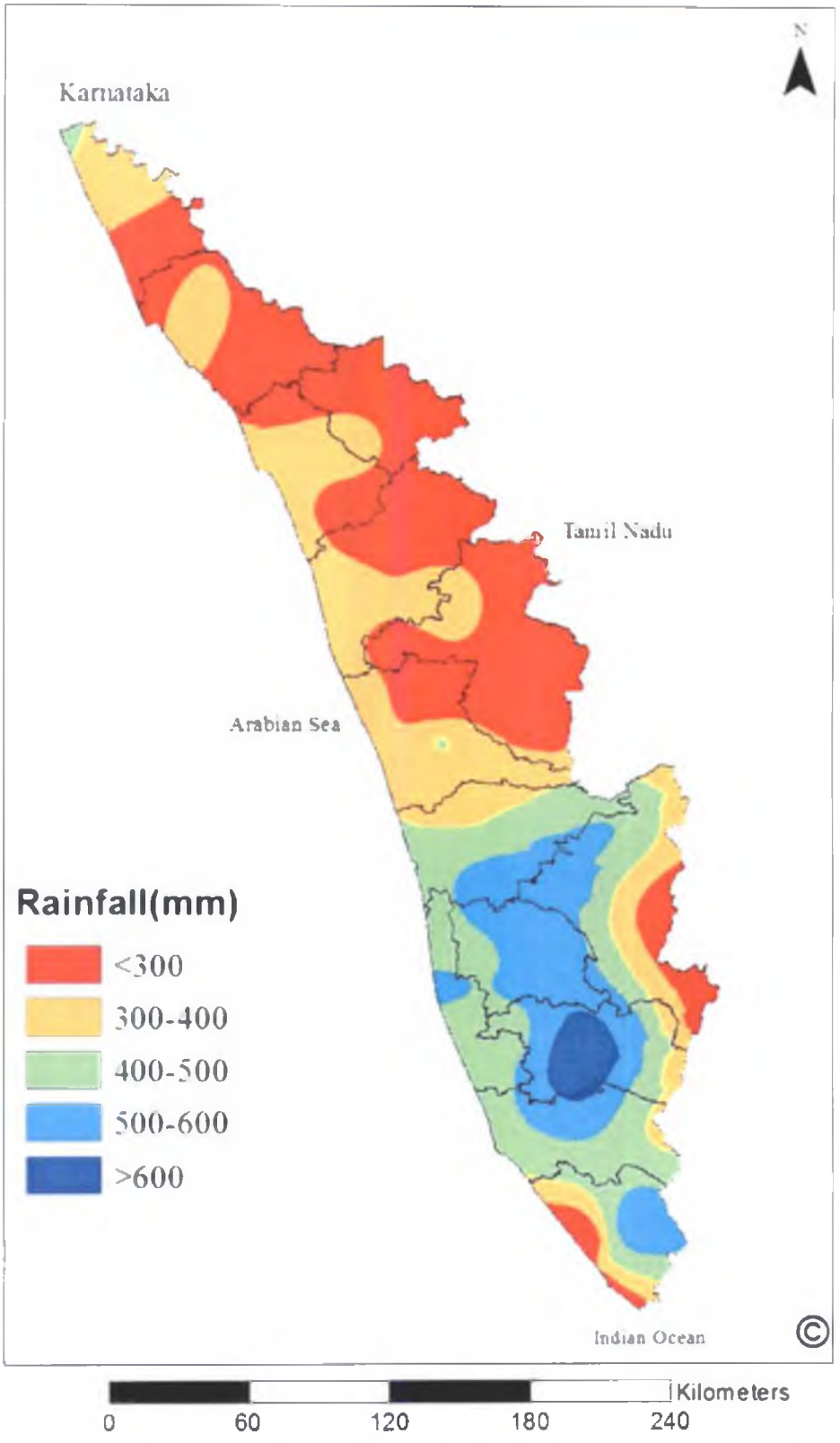


Fig. 57: Summer season rain (mm) over Kerala

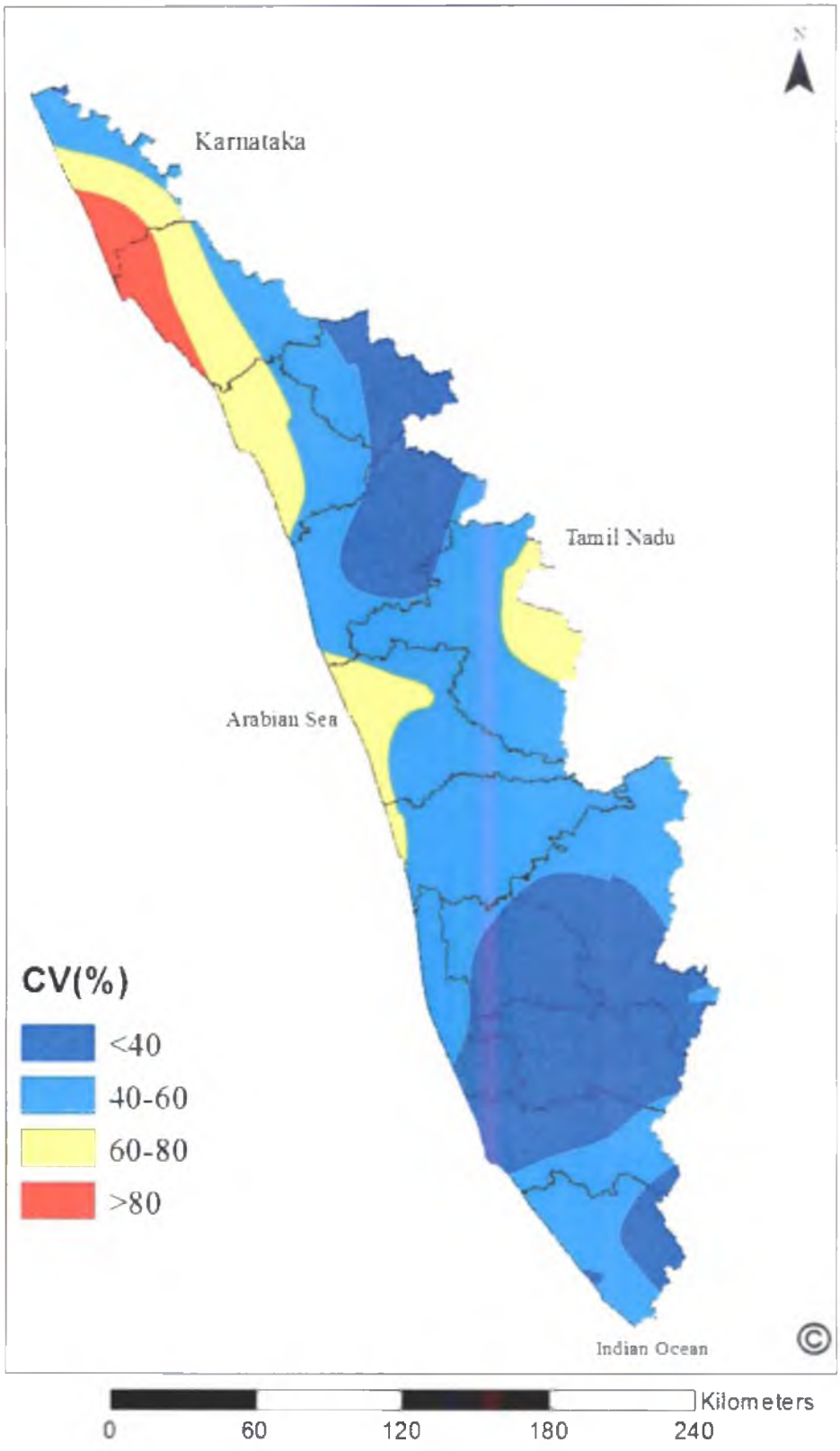


Fig. 58: Variability (CV %) in Summer season rainfall over Kerala

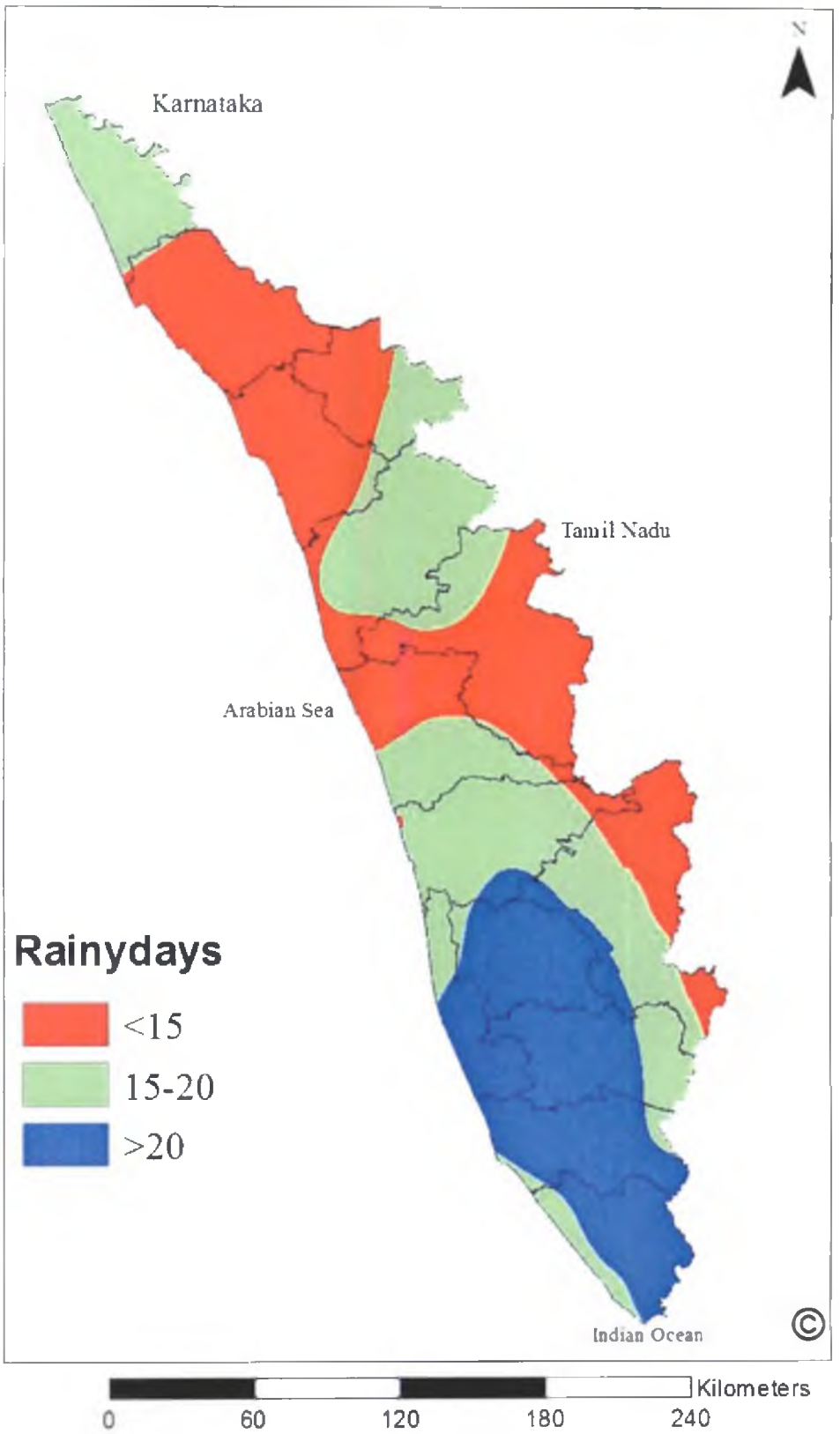


Fig. 59: Number of rainy days during Summer season over Kerala

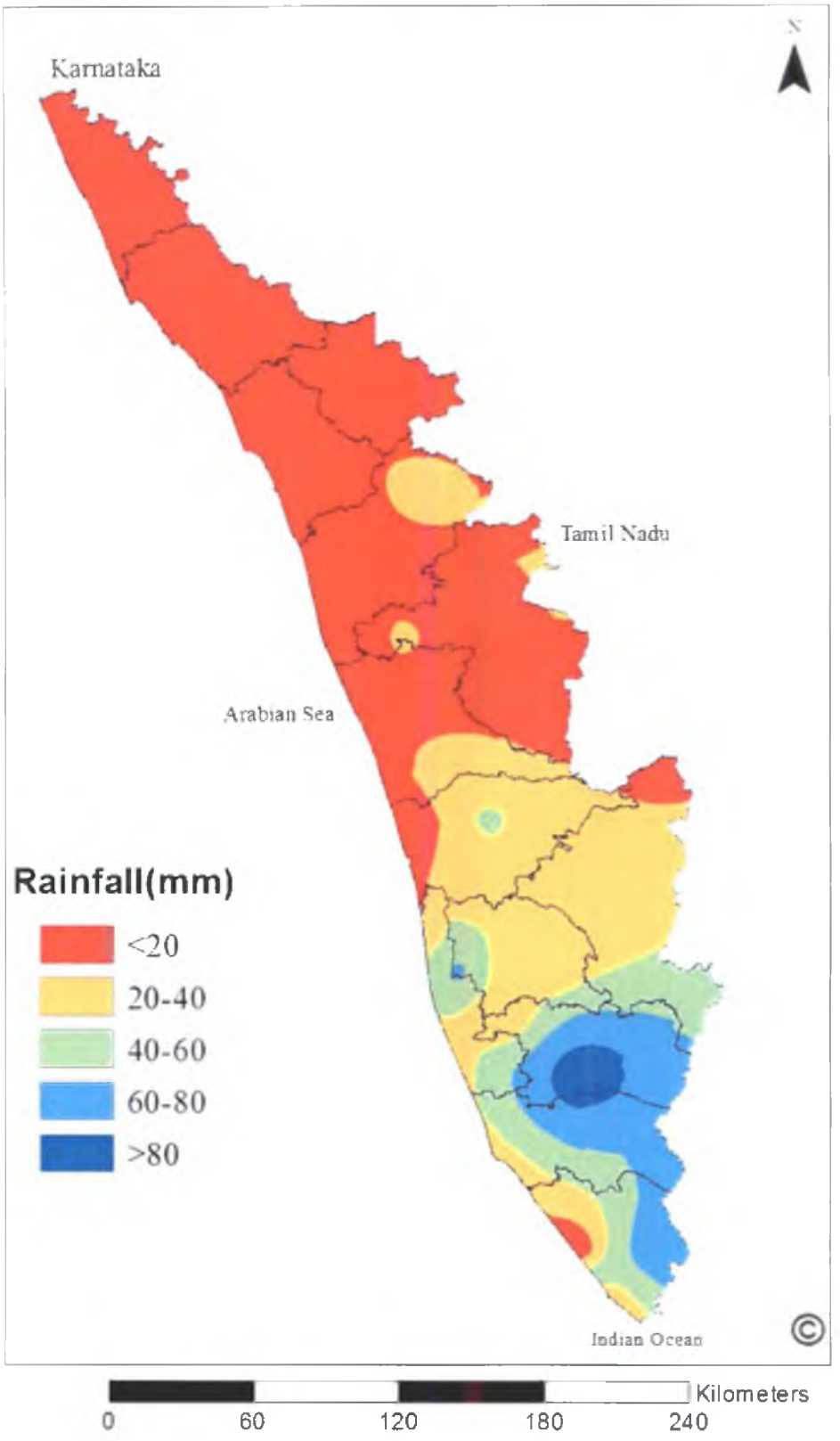


Fig. 60. Winter season rainfall (mm) over Kerala

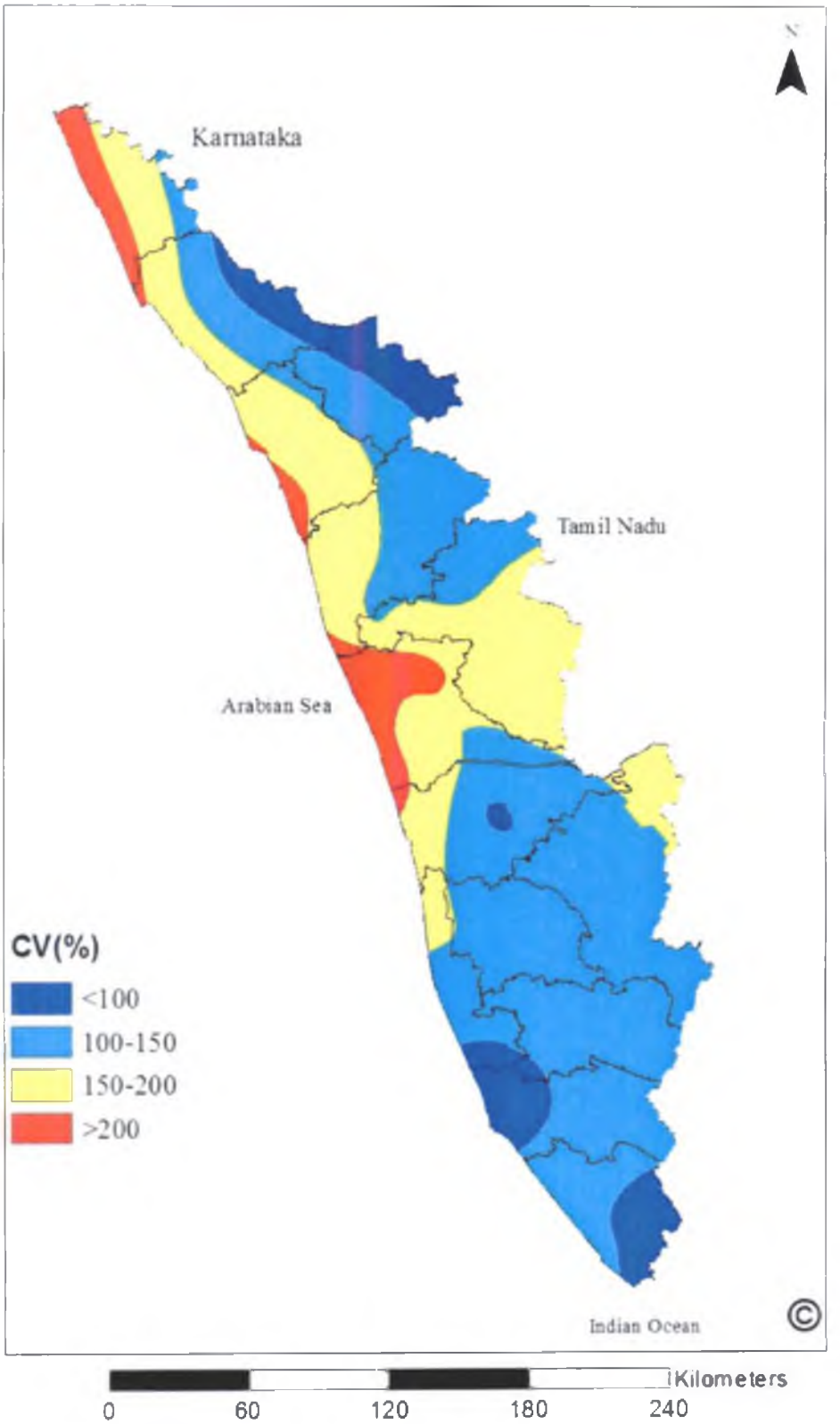


Fig. 61: Variability (CV %) in Winter season Rainfall over Kerala

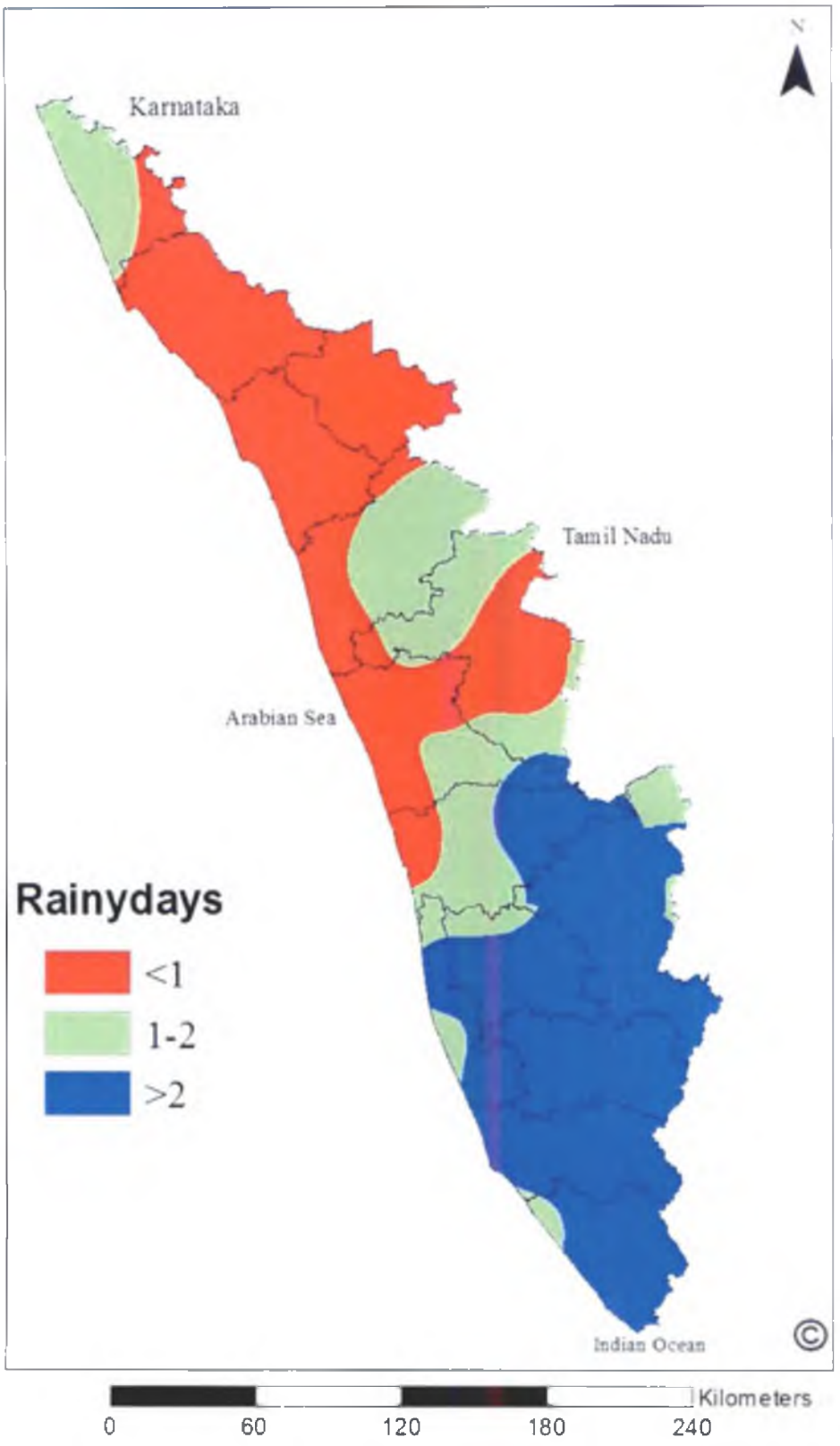


Fig. 62: Number of rainy days during Winter season over Kerala

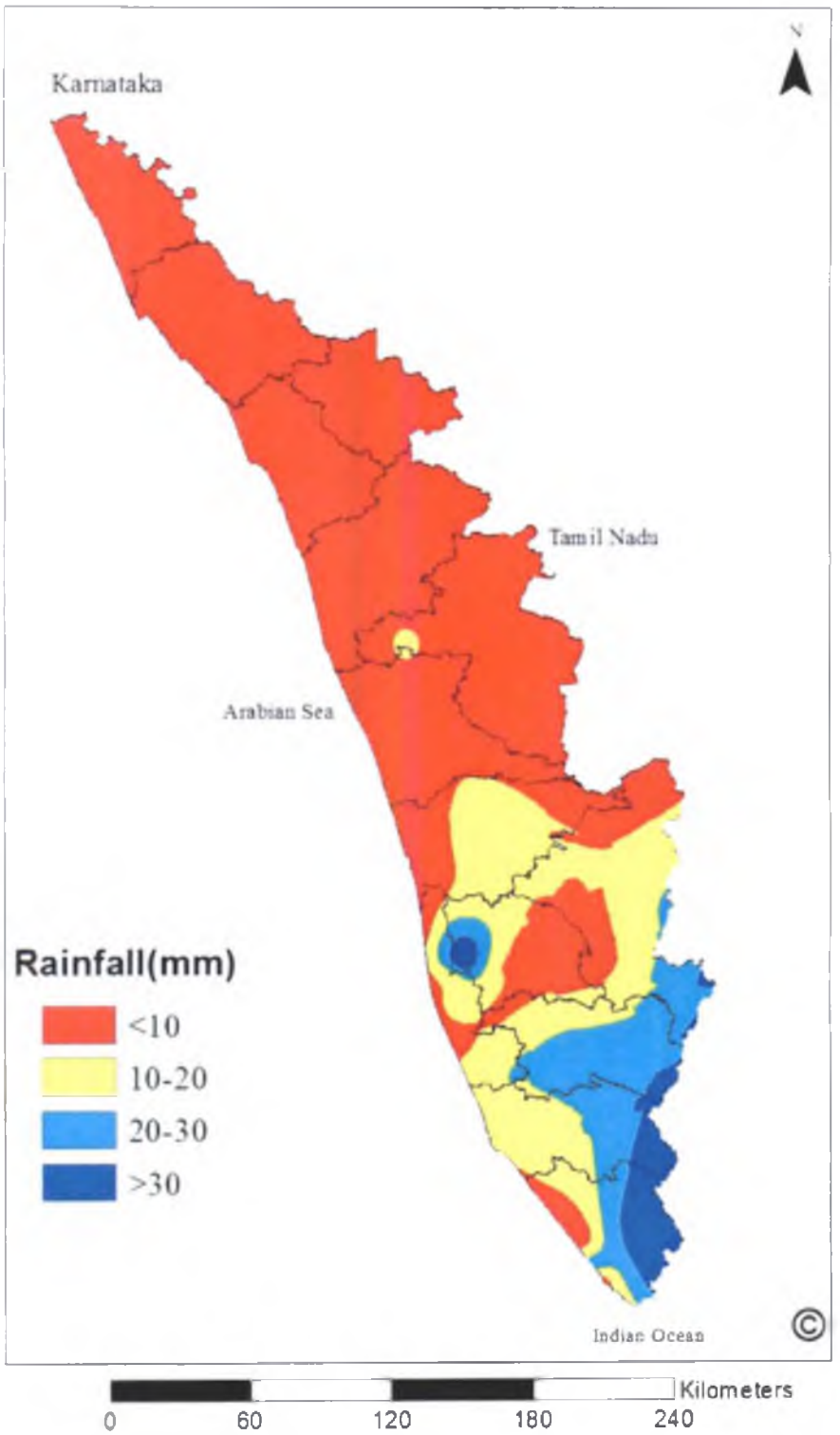


Fig. 64 (a). Rainfall in January in Kerala

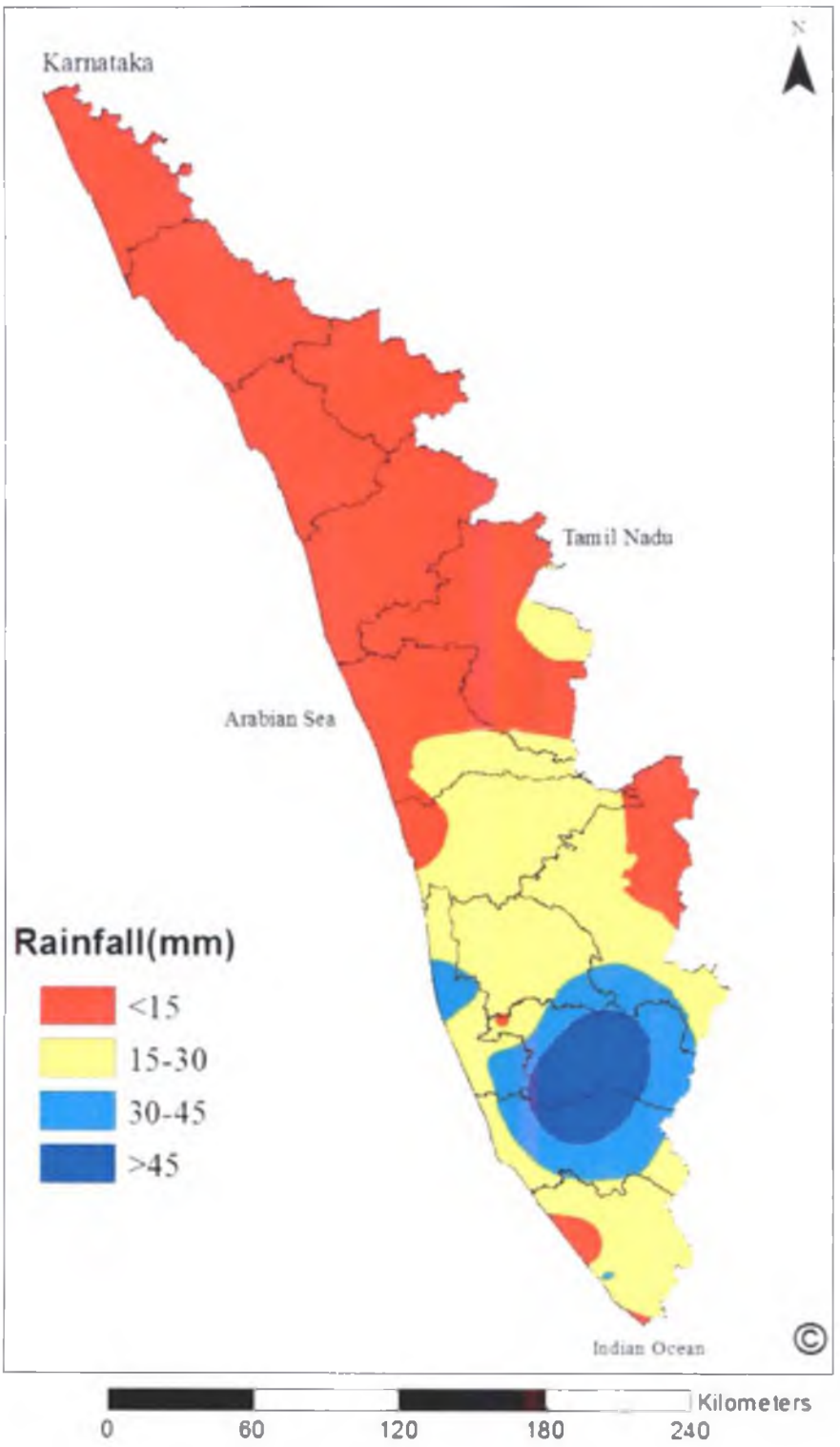


Fig. 64 (b). Rainfall in February in Kerala

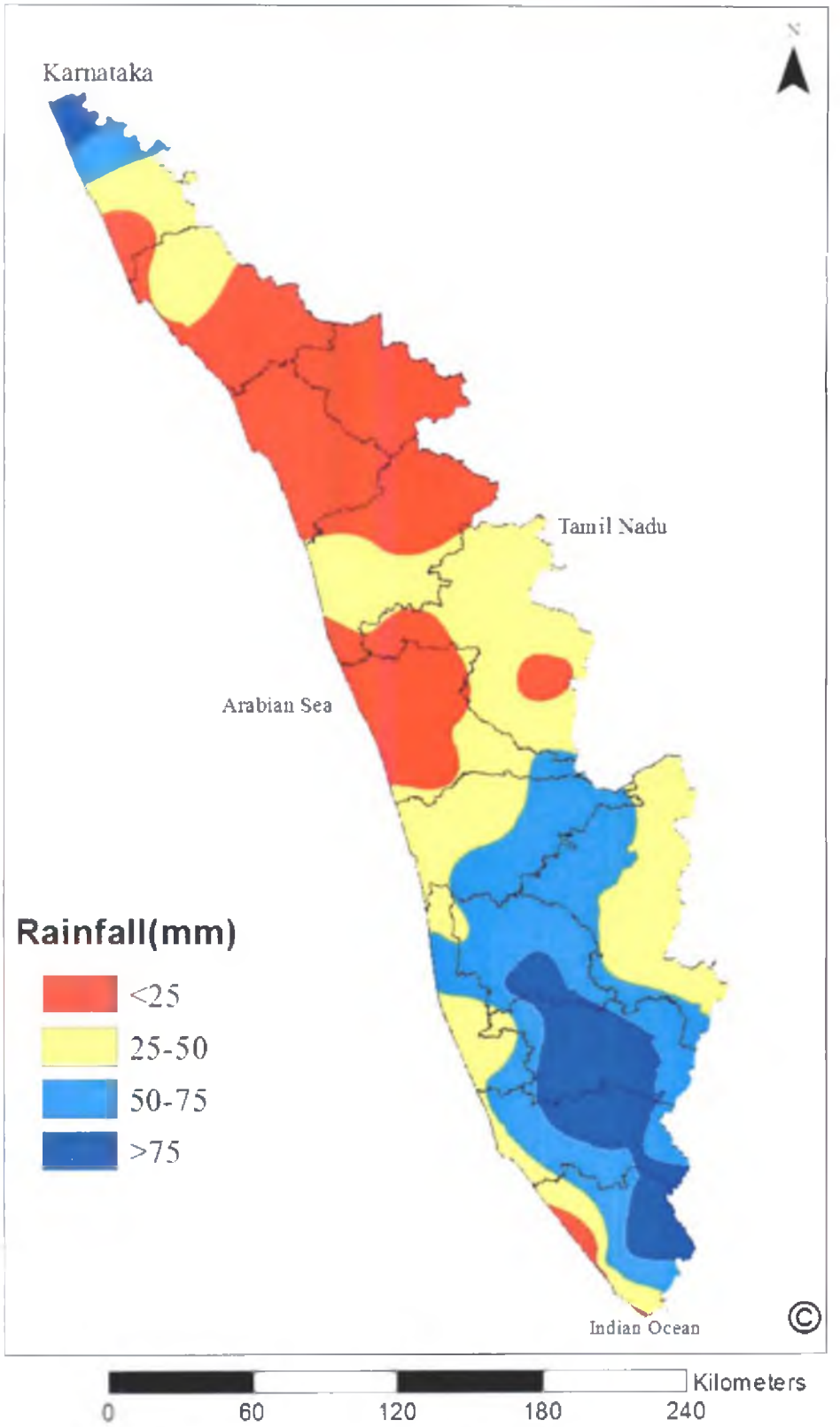


Fig. 64 (c). Rainfall in March in Kerala

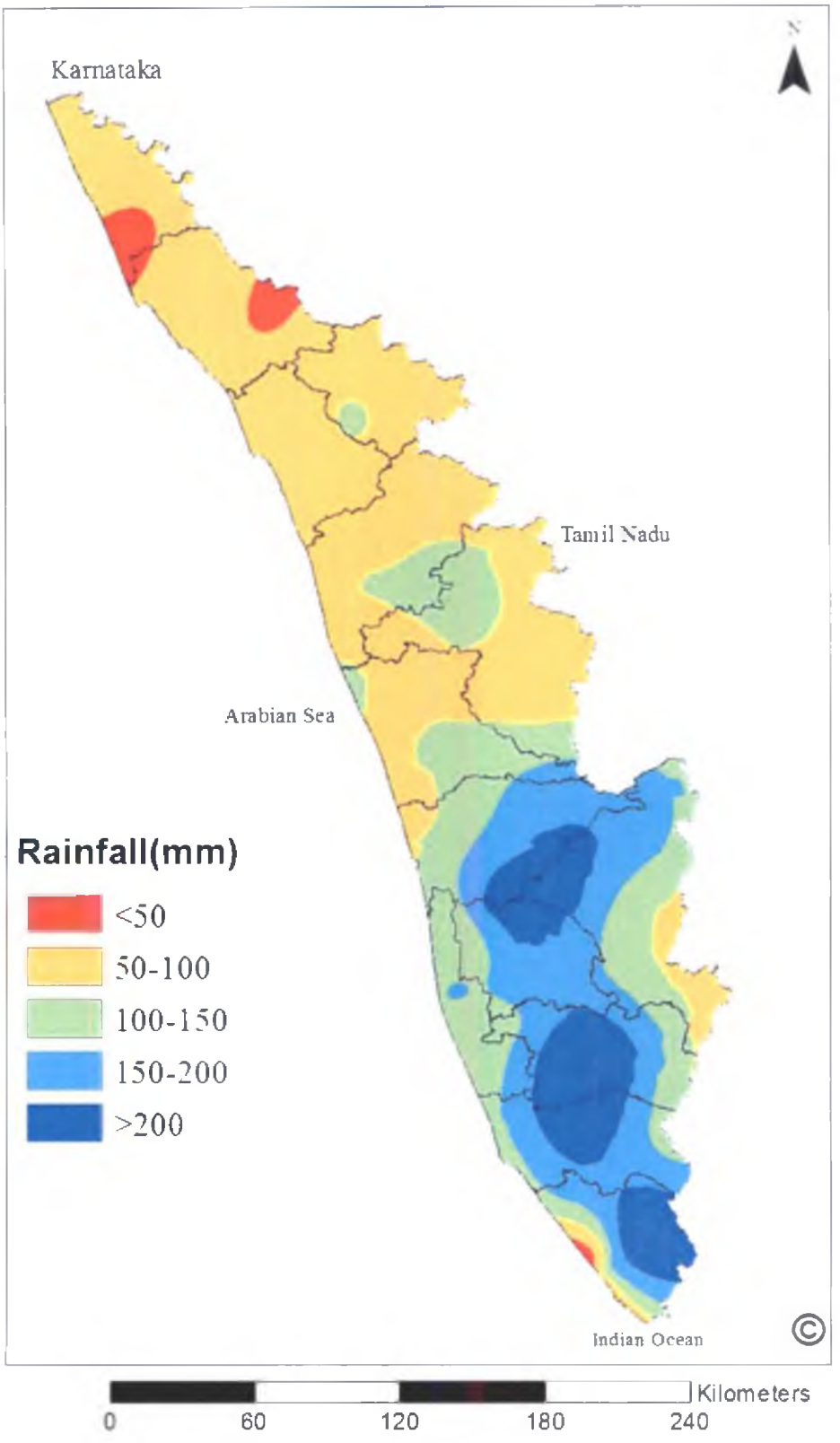


Fig. 64 (d). Rainfall in April in Kerala

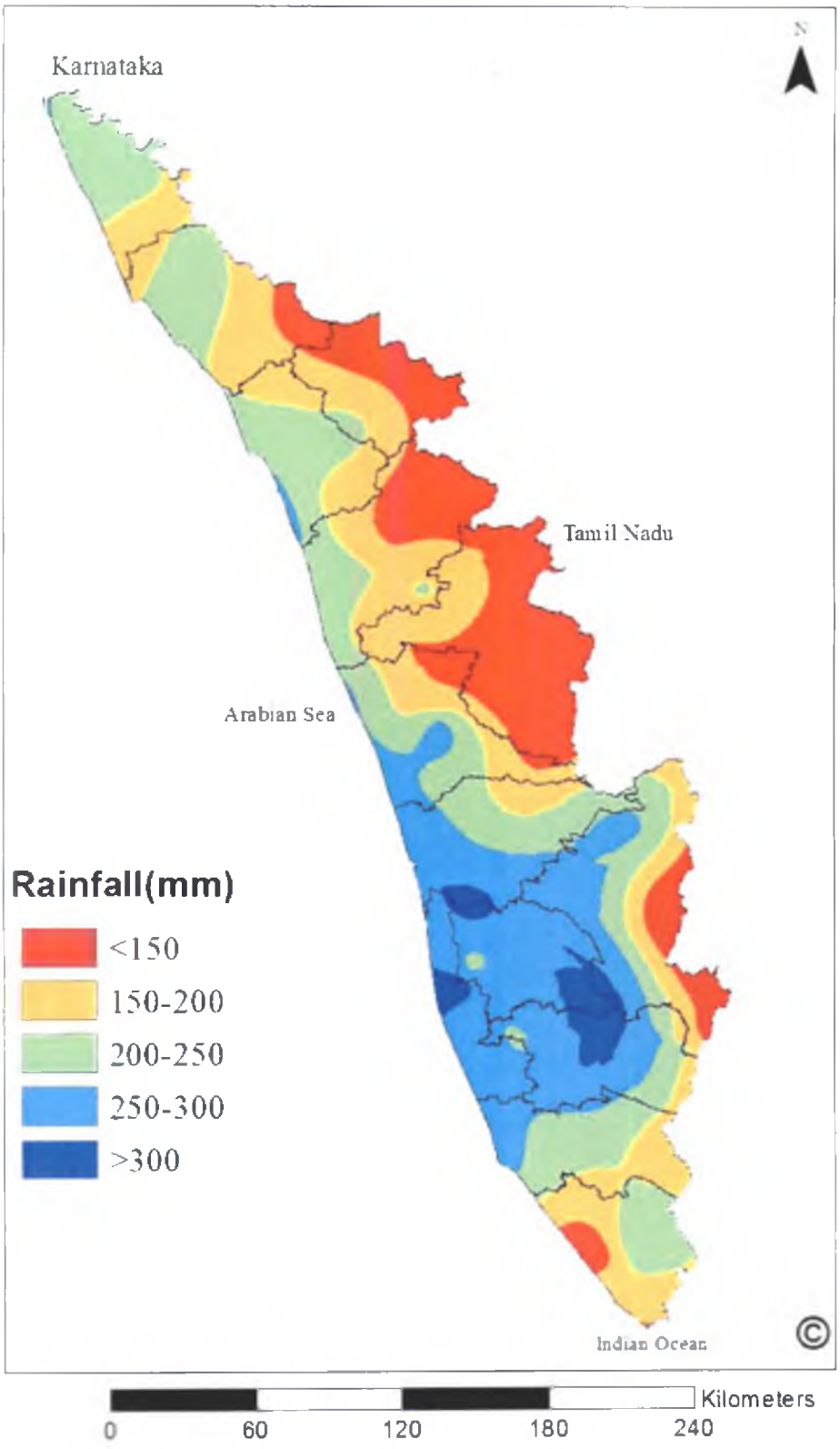


Fig. 64 (e). Rainfall in May in Kerala

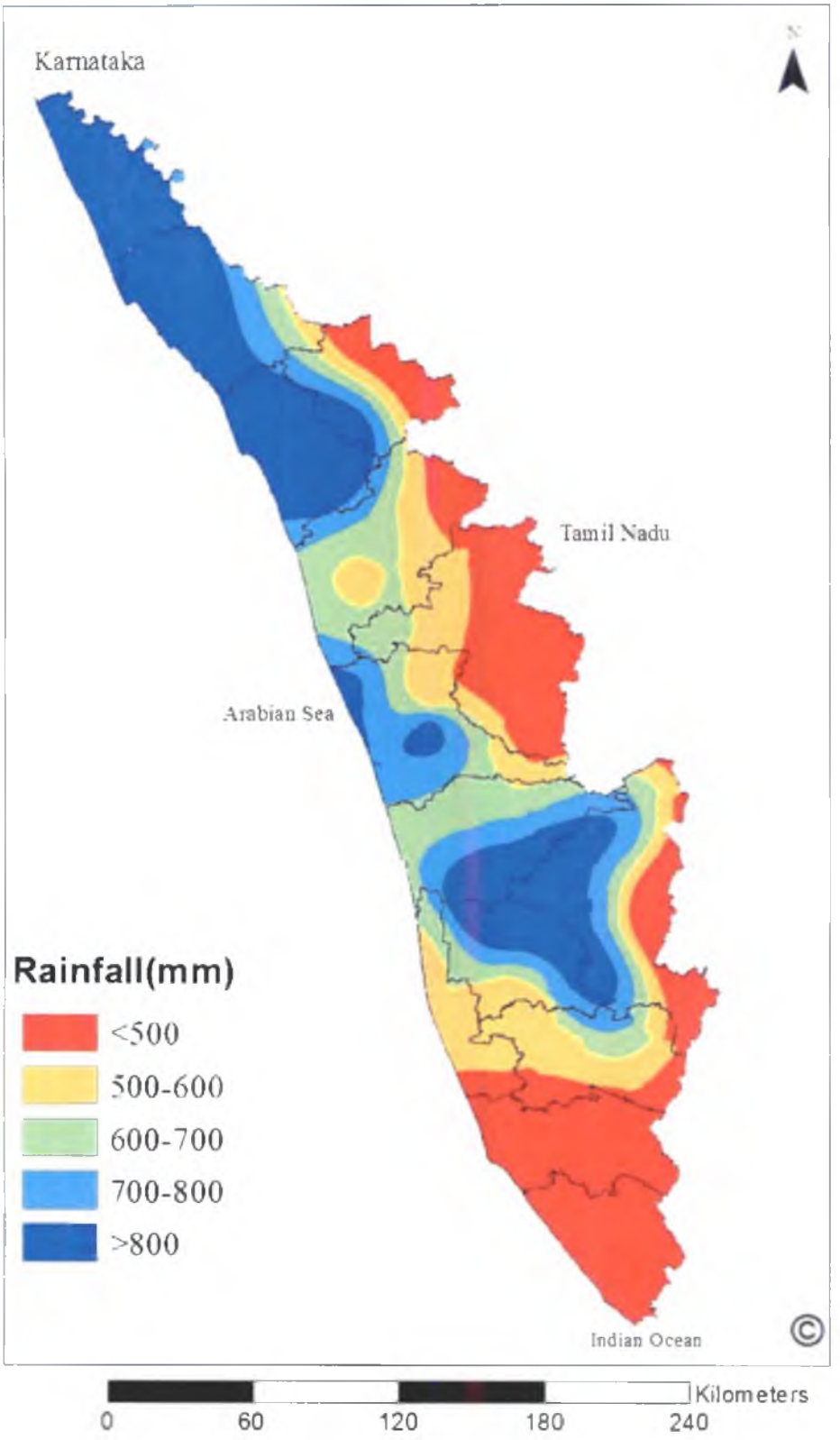


Fig. 64 (f). Rainfall in June in Kerala

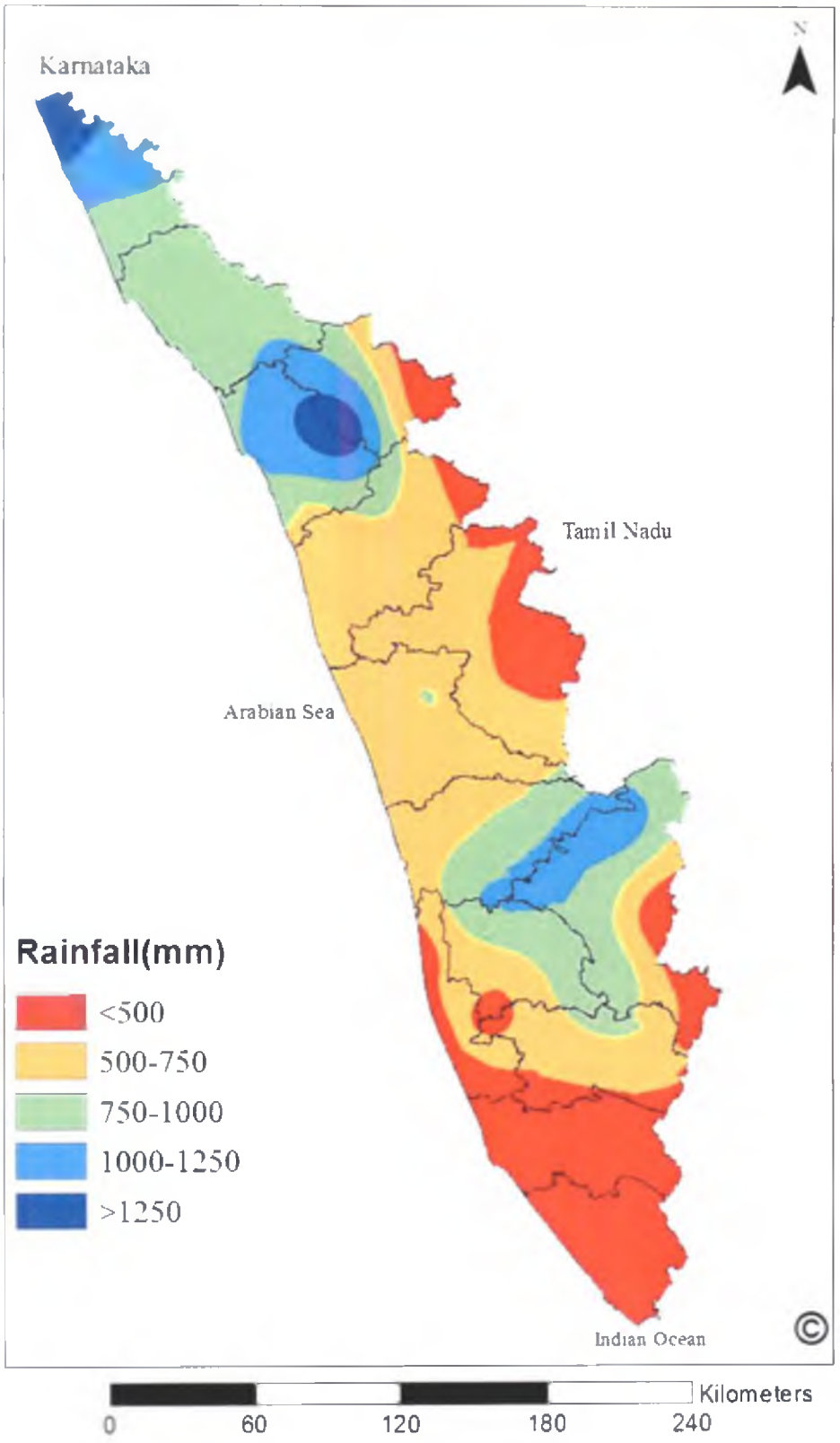


Fig. 64 (g). Rainfall in July in Kerala

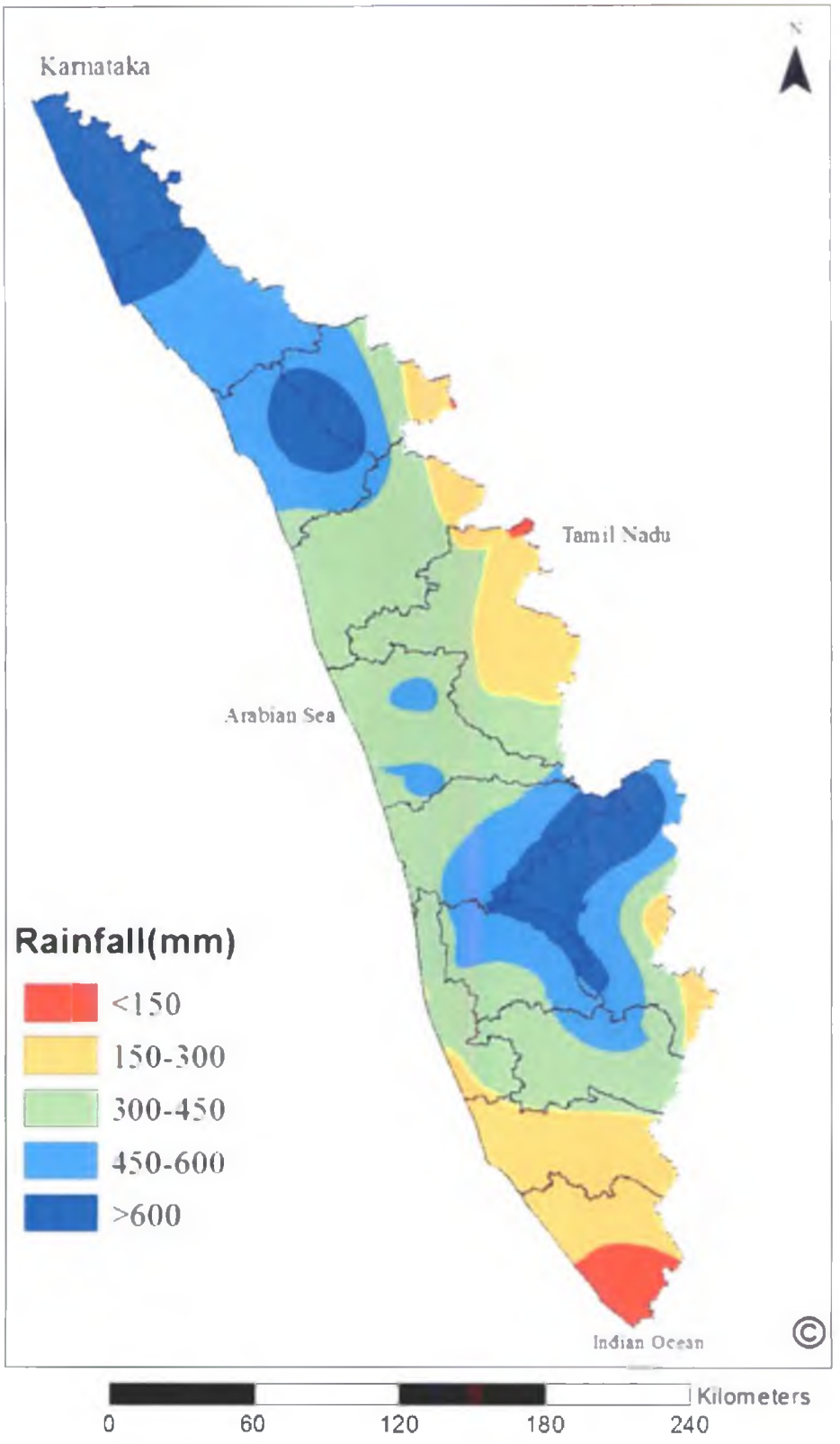


Fig. 64 (h). Rainfall in August in Kerala

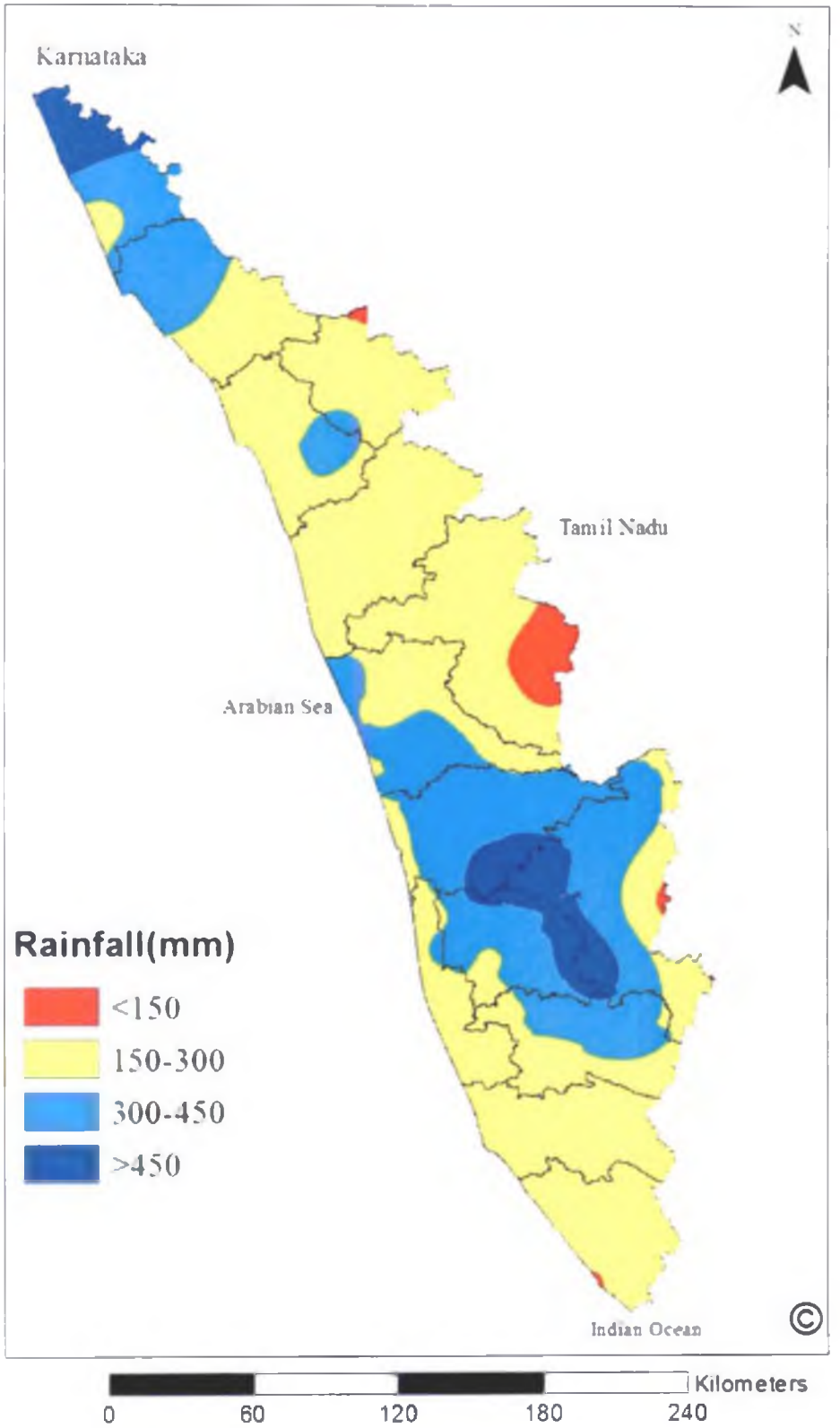


Fig. 64 (i). Rainfall in September in Kerala

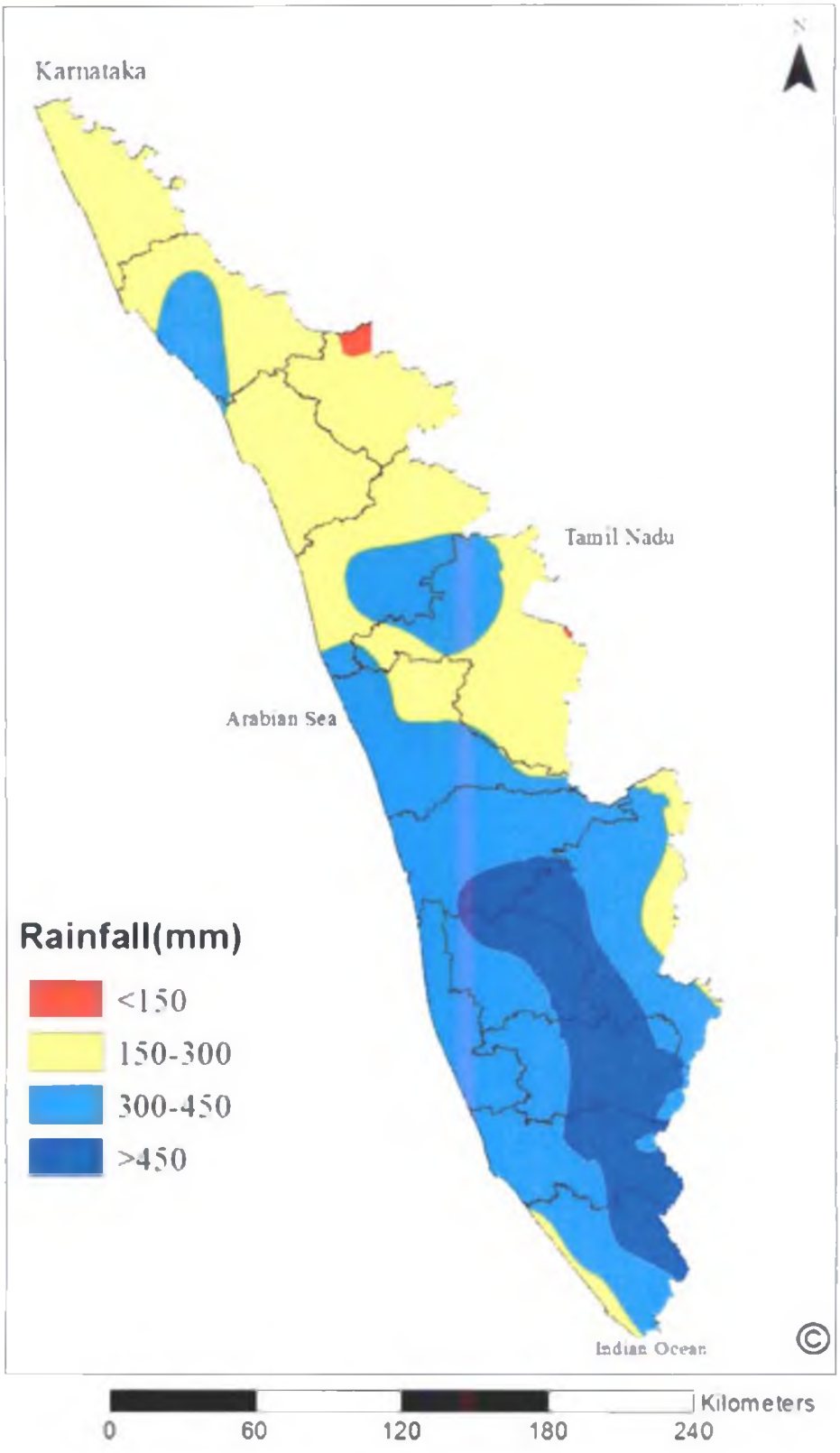


Fig. 64 (j). Rainfall in October in Kerala

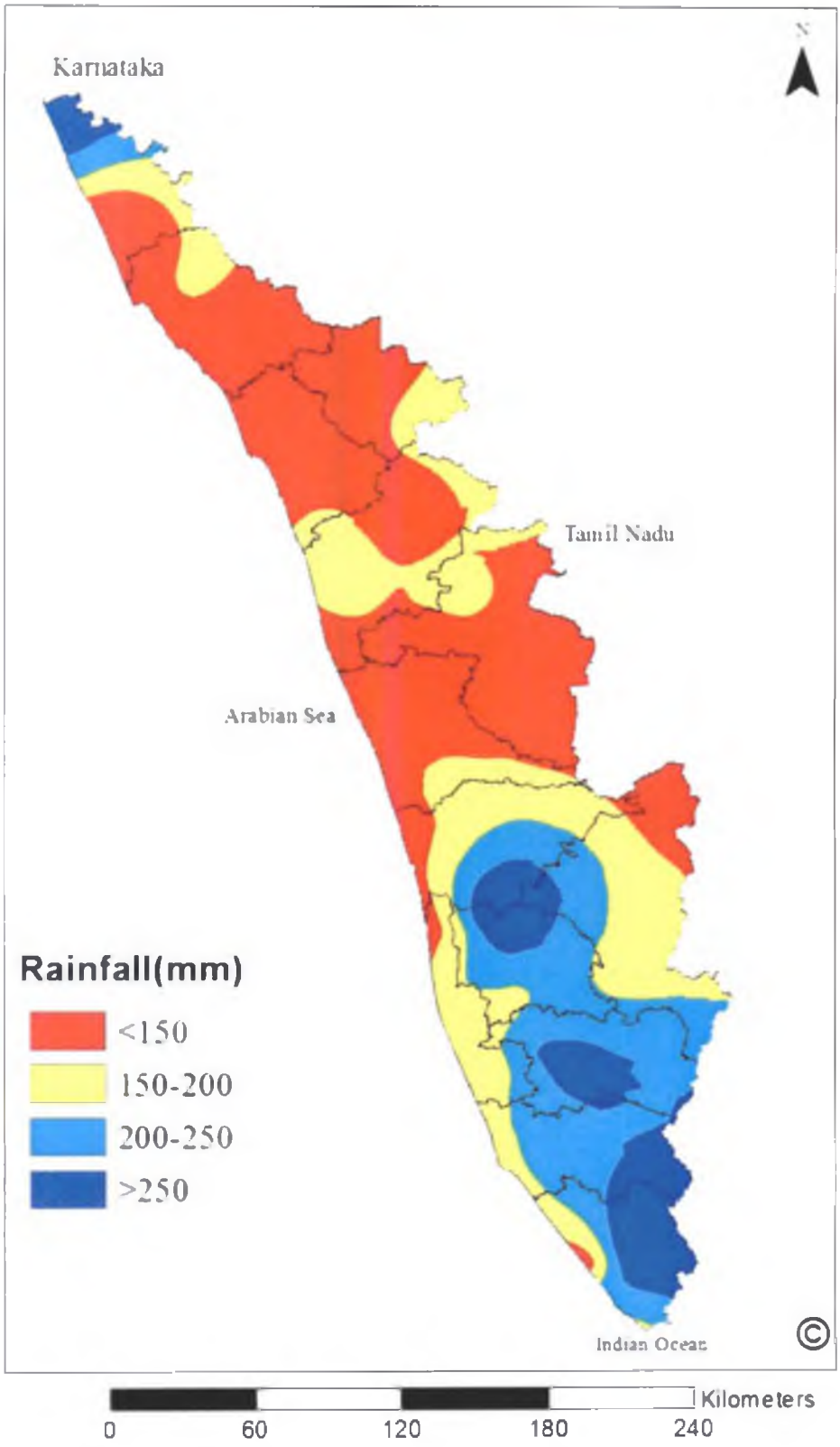


Fig. 64 (k). Rainfall in November in Kerala

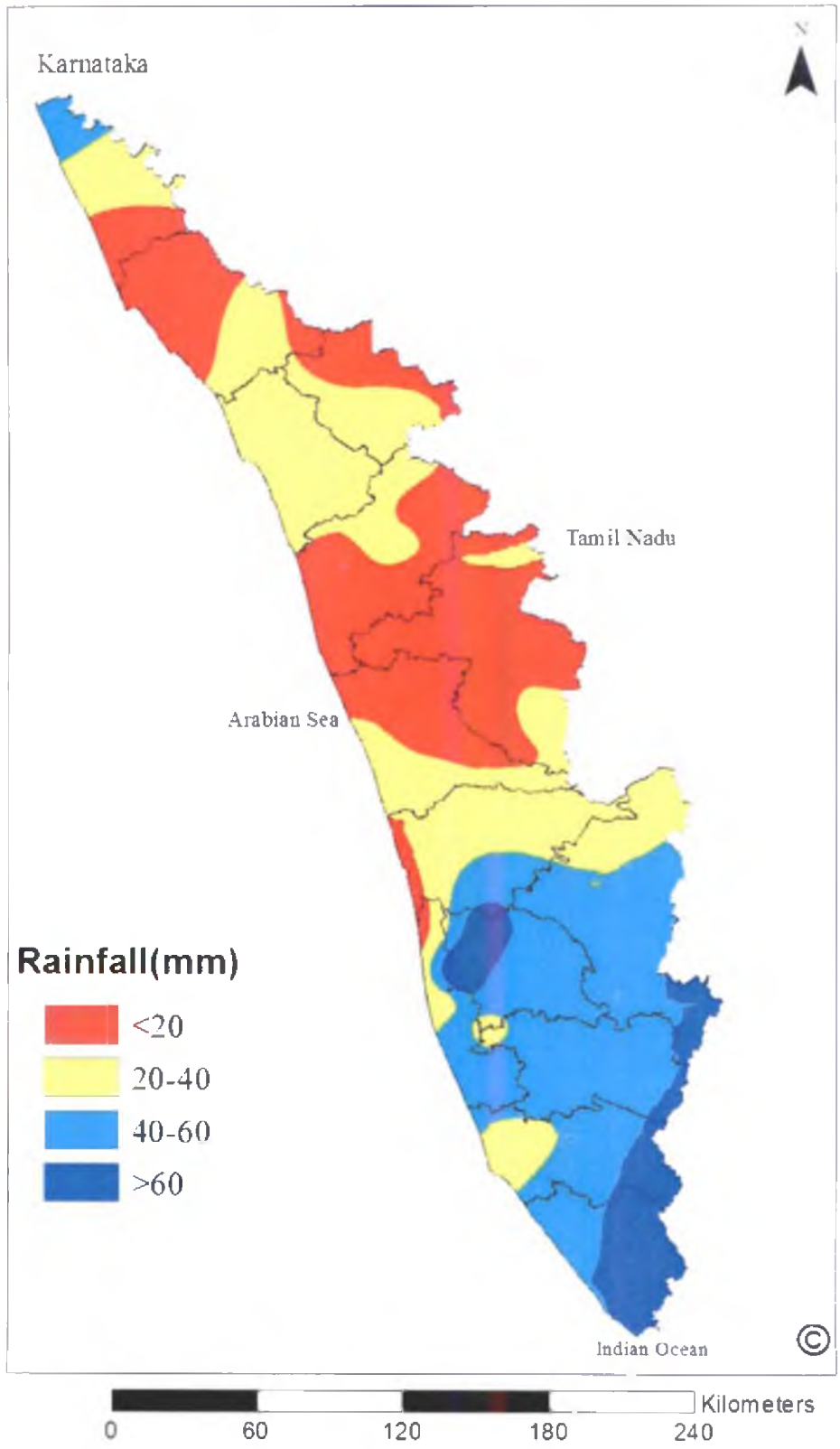


Fig. 64 (l). Rainfall in December in Kerala

4.10.2 Trends in receipt of heavy rainfall events in various districts in Kerala

The impact of climate change has been affected agriculture sector at a large extend either by low rainfall or excessive rainfall for any particular time within the crop cycle. According to Intergovernmental panel for climate change (IPCC), the climate variability is projected to increase, leading to uncertain onsets of monsoon and more frequent extremes of weather, such as more severe weather droughts and floods. As noted in the latest assessment of the Intergovernmental Panel on Climate Change (Houghton *et al.*, 2001), climate models generally predict an increase in extreme precipitation events given a build-up of greenhouse gases, and in many parts of the world an increase in these large precipitation events has been observed during the period of historical records. Extreme rainfall events have been studied by several authors in India. By using a daily rainfall data, B.N. Goswamy *et. al* (2006) showed a significant rising trends in frequency and the magnitude of extreme rain events and a significant decreasing trend in the frequency of moderate events over central India during the monsoon season from 1951-2000. Considering the extensive crop damage due to heavy rainfall events, policy makers are interested to identify areas vulnerable to heavy rainfall events. Hence, trends in heavy rainfall events on seasonal (Southwest monsoon) and annual rainfall basis under two categories *viz.,* 75-100 mm and more than 100 mm rain recorded in 24 hour period using station level daily rainfall data for the state of Kerala has been assembled. Mann-Kendall test has been applied to understand the significance of heavy rain events.

4.10.3 Annual trend in respect of heavy rainfall in Kerala

In general, no significant trend has been observed in major parts of the state under both categories (75-100 mm and more than 100 mm). Decreasing trend in 75-100 mm rainfall events found in some parts of southern zone districts. Kollam, Kollengod and Kunnamkulam show a significant decreasing trend and Parambikulam of Palakkad district shows a significant increasing trend in HRF of 75-100mm category. In the case of more than 100mm rainfall category, Kumarakam and Parambikulam shows significant increasing trend while significant decreasing trend is observed at Alathur, Aryankavu, Kasargod and Kunnamkulam. The spatial pattern of trend in heavy rainfall events in annual basis of different taluks of Kerala is shown in Fig.73 & 74.

4.10.4 Heavy rainfall events during Southwest monsoon season in Kerala

In SWM season also, notable trend in heavy rainfall events (75-100mm, more than 100mm) could not be observed. However a significant decreasing trend in 75-100 mm rainfall events has found over southern zone stations viz., Kollam, Nedumangad and Varkala. Non significant increasing trend in 75-100mm rainfall has observed in many places of Central zone district and non significant decreasing trend in 75-100 mm rainfall events has seen at Northern zone stations indicated by the Fig.75. A decreasing trend in heavy rainfall events in more than 100mm category is observed in majority of the taluks of Kerala. Significant decrease in HRF more than 100mm is found in Kunnamkulam of Thrissur district and significant increase is found in Kumarakam of Alappuzha district. The spatial pattern of trend in heavy rainfall events of different taluks of Kerala during southwest monsoon season is shown in Fig.75 & 76.

Table 14: Amount of dependable annual rain (90, 75 and 50% probability) occurred in different districts of Kerala

Districts	Rainfall (mm) at (90,75 and50% probability		
	90	75	50
Alappuzha	1797	2230	2790
Ernakulam	2275	2813	3506
Idukki	1226	1518	1895
kollam	1469	1902	2478
Kannur	2391	2968	3712
Kasargode	1780	2339	3108
Kottayam	2004	2454	3030
Kozhikkode	2131	2566	3117
Malappuram	991	1431	2061
Palakkad	1352	1725	2222
Thiruvananthapuram	924	1266	1762
Thrissur	1909	2379	2990
Wayanad	1021	1391	1901

4.11 Potential Evapotranspiration

Potential evapotranspiration is defined as the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass over of uniform height, actively growing, completely shading the ground and not short of water. Temporal variations of PET and quantification of its trend can serve as valuable reference data for the regional studies of hydrological modeling, agriculture water management and irrigation planning and water resource management.

The PET values in the present analysis are estimated using "PET Calculator v3.0" (Bapuji Rao, B. *et. al.*, 2012). The input data (mean temperature, relative humidity, sunshine and wind speed) on monthly basis are sourced from *http://www.cru.uea.ac.uk*. Spatial maps are prepared by estimating PET normal's for each grid. The PET thus estimated are averaged for different time periods *viz.*, monthly, seasonal and annual.

4.11.1 Annual

The mean daily PET on an annual basis ranged from 4.9 to 5.5 mm/day in the state. Spatial differences are noticed. Highest PET (5.5 to 5.6 mm/day) is observed in majority area of Palakkad district and western part of Malappuram district. Large geographical area of the state experience PET values in the range of 5.3 to 5.5 mm/ day. Lowest PET (4.9 to 5.1 mm/day) values are recorded in Wayanad district which is in high altitude. Fig.77.

4.11.2 Southwest monsoon season

This is the major rainy season of the state for all of the districts. PET rates of major geographical area of the state ranged from 4.6 to 5.2 mm/day during the season. Highest rates (5.2mm/day) are noted in parts of Palakkad district in the area of Patambi station. Lowest rates (4.6 to 4.9 mm/day) are noted in parts Wayandad district which is a hill area and situates in high altitude area. Fig.78.

4.11.3 Northeast monsoon season

During this season major area of state experiences PET rates in the range of 4.3 to 5.1 mm/day. Lowest rate is 4.38 to 5.01 mm/day in parts of Wayanad which is a high range zone (Fig.79).

4.11.4 Summer season

Summer is the hottest season of the year and PET values for major geographical area range between 5.72 to 6.61 mm/day. Parts of Kannur district showed highest PET values 6.3 to 6.6 mm/day (Fig.80).

4.11.5 Winter season

During winter season 5.60 to 5.76 mm/day are noted in parts of Calicut district and lowest values (5.16 to 5.3 mm/day) parts of Eranakulam district. (Fig.81).

4.12 Meteorological drought

The frequencies of moderate and severe meteorological droughts were computed based on departures from normal annual rain for all the station of Kerala (as per IMD criteria i.e., 26-50% deficiency is moderate drought, and >50% is termed as severe meteorological drought).

Drought with a probability 0-5% mainly showing coastal area of the districts of Thrissur, Malappuram, Kozhikode.5-10% drought probability occur in most of the districts of Kerala except Thiruvananthapuram. Some parts of Wayanad and Thiruvananthapuram district show 10-15% probability, primarily seen in Thiruvannathapuram district (Fig.82).

4.12.1 Drought frequency based on Standardised Precipitation Index

Probabilities of occurrence of drought over Kerala based on the IMD criteria (moderate and severe drought) have been discussed in the earlier section

However, number of drought indices (Deciles, Per cent Normal, Palmer Drought Severity Index have been used world-wide. Effective drought Index has been suggested by Bhalme and Mooley (1981) to classify the severity of droughts. Amongst different methods, Standardized precipitation index (SPI) is widely used. Main advantage of SPI is, that the rainfall is normalized using the probability distribution, so that values of SPI are actually related to standard deviation from the median. Drought probabilities for different stations of Kerala based on SPI methodology were computed for three time scales (Annual - 12 months scale, Southwest monsoon - 4 months scale and Northeast monsoon - 3 months scale) for which daily rainfall data for 20 years or more is available. The criteria used in classifying drought severity using SPI values are given in Table 15. Drought event begins any time when the SPI is continuously negative and ends when the SPI gains a positive value.

Table 15: Categorization of climatic based on SPI

SPI	Category
More than +2.0	Severely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
0.99 to +0.99	Near Normal
1.0 to -1.49	Moderately dry
1.5 to -1.99	Severely dry
Less than -2.0	Extremely dry

Thematic maps depicting probability levels for different drought severities for the selected three time scales are presented and discussed in the following sections

4.12.2. Drought probability on annual scale

Probability for near normal condition of rain is above 50% for all the stations considered for the analysis. Highest probability is observed in Nedumangad station (82%) in Thiruvananthpuram district followed by Kunnamkulam station (74%) in Thrissur district. Probability for near normal condition is more than 70% in Thiruvanathapuram, Kottayam, Ernakulam, Kannur and Kasargod. Probability of 70% and above has been considered generally as benchmark for making decisions on agricultural operations and this is observed 33% of the stations considered across the state for near normal condition. Lowest probability for normal condition is noted in Kollengode station (52%) in Palakkad district followed by Vellayini station (56%) in Thiruvananthapuram district.

Highest probability of occurrence for moderately dry condition is seen in Parambikulam station (19%) in Palakkad district followed by Thrithala station (17%) which is also in Palakkad district. Moderately dry condition does not occur in Pampadumpara station in Idukki district. Central zone shows 10% of moderately dry probability.

Probability of Severe drought condition in the highest form in Emackal station and Chengannur station (13%) followed by Kannara (12%). Emackal and Kannara stations are in Thrissur district. 27% of the stations don't show any probability for severe drought conditions as indicated figure. In the case of extreme drought, Neyattinkara shows highest probability (11%) of Thiruvananthapuram district followed by Aluva station (9%) in Eranakulam district. 47% of stations in Kerala do not showing any probability for extreme droughts. (Fig 83(a) to 83(d)).

4.12.3 Drought probability during SWM season

Probability for near normal condition during Southwest monsoon is above 50% for all the stations.The highest probability for near normal condition is observed in Nilambur (Malappuram) and Peerumed (Idukki) station (81%) followed by Irikkur of Wayanad (77%). In the case of moderately dry category, probability more than 15% is found in Pathanamthitta district and some parts of Idukki, Thrissur, Ernakulam, Palakkad and Wayanad. The highest probability is noted at Kannara station (24%) in Thrissur district followed by Aluva station (23%) in Eranakulam district. In the case of severe dry condition, 30% of the stations don't show any probability for severe dry conditions during SWM season in Kerala state. Vythiri station of Wayanad district shows highest probability for severe drought condition (18%). In the case of extreme dry condition 63% of the stations do not show any probability values. However, highest probability is found in Neyatinkara station (11%) followed by Nedumangad (9%), both are in Thiruvananthapuram district (Fig 84(a) to 84(d)).

4.12.4 Drought probability during NEM monsoon season

Probability for near normal conditions is above 60% during the NEM season for all the stations. Highest probability 93% for near normal condition has been noted in Pattambi station in Palakkad district followed by Manjeri station (81%) of Malappuram district and lowest probability for near normal condition shows Piravam station (59%) in Eranakulam district, Chengannur of Alappuzha district and Munnar of Idukki district. Highest probability for moderate dry condition is seen in Piravam and Munnar (23%). In the case of severe drought conditions, 27% of stations don't show any probability for severe dry condition during NEM season. Ottappalam and Thrithala show highest probability (13%) for severe drought condition in this season. In the case of extreme drought condition, 48% of available stations do not show any probability and Chittur station in Palakkad district shows 9% probability which is highest probability observed as compared all other stations (Fig 85(a) to 85(d)).

4.13.Climatic Water balance

The term climatic water balance refers to balance obtained by comparing the precipitation as input with evapotranspiration as output. Water balance has been used for classification of climates, estimation of seepage from reservoirs, irrigation scheduling, designing of irrigation projects, forecasting river flows, and for stream flows, etc. For evaluation of the complete water balance of a location, it is necessary to compare precipitation (water supply) with potential evapotranspiration (water need) after making an allowance for the storage of water in the soil and its subsequent utilization for crop evapotranspirational purposes. The availability of water in right quantity at the right time and its management with suitable agronomic practices is essential for better crop growth and its yield. The water balance elements *viz.,* Precipitation (P), Potential evapotranspiration (PE), Actual evapotranspiration (AE), Water surplus (WS), Water deficit (WD) and also the water balance indices such as humidity index (Ih), aridity index (Ia) and Moisture Index (Im) for all stations on an annual basis were estimated to calculate climatic water balance.

The water balance elements *viz.,* precipitation, potential evapotranspiration (PE), actual evapotranspiration (AE), water surplus (WS) and water deficit (WD) were computed by the revised book-keeping procedure of Thornthwaite and Mather (1955). The information on field capacity of the soil to hold the moisture for each station was extracted from Soils of India Series, published by NBSS & LUP, Nagpur.

Water balance indices such as humidity index (Ih) and aridity index (Ia) and moisture index (Im) were calculated using formulae:

1. Humidity index Ih = WS / PE X 100
2. Aridity index Ia = WD / PE X 100
3. Moisture Index Im = Ih - Ia

Based on Aridity index and Humidity index, the moisture index was calculated. Using moisture index (Table 16), stations have been classified into different climatic types and thematic map has been prepared. It is presented as Fig 5.

Table 16: Classification of climates according to the moisture index

Moisture Index Im (%)	Climate type (Symbol)
Above 100	Per-humid (A)
100 - 80	Humid (B4)
80 - 60	Humid (B3)
60 - 40	Humid (B2)
40 - 20	Humid (B1)
0 - 20	Moist Sub-humid (C2)
0 to – 33.3	Dry Sub-humid (C1)
-33.3 to - 66.7	Semi-arid (D)
Less than – 66.7	Arid (E)

According to the data from 35 stations, In Kerala state most of the area belongs to perhumid (A) type. 22 out 35 stations belong to perhumid area type (Moisture index greater than 100%). In Kerala state moist sub-humid, dry sub-humid, semi arid and arid regions are not present

Aryankavu, Thrissur and Varkala stations includes in the category of Humid (B4), after calculating average of stations in districtwise Alappuzha having highest moisture index (244%) and belong to perhumid area. Southern districts Thiruvananthapuram and Kollam belong to the category of humid (B4).In northern zone all the district are perhumid except malappuram which only belongs to humid (B3).The central zone also perhumid condition except Palakkad district (Humid B4). Hill range zones are humid B2.

From these data, it can be concluded that the 63% of Kerala state experiences perhumid condition. Only 0.06 % of the area of the state experiences humid (B2) condition.

4.14 Length of growing period (FAO method)

The Agro-ecological zones project of the Food and Agriculture Organization of the UN (FAO, 1978) suggested a method to calculate (LGP) as the period (in days) during a year when precipitation exceeds half the potential evapotranspiration. Information on LGP helps in the selection of suitable crops, cropping systems, and crop cultivars. The length of the growing season (LGP) in any given region represents the climatically determined number of days during which a crop receives enough moisture for its growth. Potential evapotranspiration (PET) in the present study has been computed using ET0 calculator (Hargreaves method). Monthly values for precipitation and PET were considered for computing LGP for all the stations. Thematic map was prepared depicting the spatial distribution of LGP

Length of growing period is more than 250 days in most of the parts of Kerala. Northern and Central zone of Kerala has LGP between 250-300 days. Southern part of Ernakulam district, Idukki, Kottayam, Pathanamthitta and Kollam shows LGP more than 350 days. Southern zone district Thiruvanathapuram has LGP in between 300-350 days (Fig. 86)

4.14.1 Start and end of growing season for different soil moisture holding capacities

Information on the start and end of rainy season aids in planning several field operations like land preparation and harvesting schedule. The difference between these two in days is the LGP. Apart from rainfall features like type of soil, soil depth, water holding capacity and moisture release characteristics of the soil as well as soil moisture storage at the end of the rainy season, the post-rainy season and winter rainfall, which can all meet the crop water needs determine the start and end of the growing season in each *station*. Weekly rainfall for all the *stations* and PET estimated by ET0 calculator for one representative station in each district was used to calculate Moisture Adequacy Index (MAI) through weekly water balance procedure for major soil groups having water holding capacities 50, 100, 150 and 200 mm in the root profile (Fig.87(a) to 87(d)). It is assumed that the season commences in a week after the 23rd SMW if the MAI value of two consecutive weeks is e" 0.5. Likewise, growing season is assumed to end if MAI is d"0.25 for three consecutive weeks after 36th SMW.

The onset of monsoon determines the start of growing season but the soil type as an important role to play on the feasibility of sowing of crops due to differences in depth of wetting by rainfall and workability of soil. Therefore, the start of growing season in each station is computed and presented in Table.17 for four soil water holding capacities (50, 100, 150 and 200) (Fig. 88(a) to 88(d)). Over 11 among 14 districts the season commences on an average during 21st Standard Meteorological Week (SMW) and in remaining districts the season commences during 22nd SMW.

Length of growing period is more than 30 weeks in 50% of the districts of Kerala for soils having low water holding capacity (50mm). Malappuram, Palakkad and some parts of Kottayam, Idukki and Pathanamthitta show LGP less than 30 weeks. For a 100 mm water holding capacity, LGP is between 30 to 40 weeks in almost all the places few places of Kerala except Pathanamthitta, Kottayam and some parts of Kollam, Alappuzha, Idukki , and some parts of Thiruvanathapuram, where LGP is in between 40-50 weeks. LGP more than 50 weeks for 100mm water holding capacity is observed in the western coast of Thirvanathapuram.

In soils with water holding capacity 150 mm, the LGP, more than 70 weeks is observed at northern zone district Kasargod and western coast of Thiruvanthapuram district. LGP is in between 40-60 weeks for 150mm water holding capacity is found in the districts of southern zone and problem area zone. LGP is less than 40 weeks in the central zone districts except Ernakulam and Northern zone district except Kasargod. In soils with water holding capacity 200 mm, the LGP more than 50 weeks is observed in southern zone districts and districts of problem area zone and some parts of Ernakulam, Idukki. LGP is in between 40-50 over the northern zone districts Kannur. Kasargod and some parts of Wayanad and Kozhikkod. LGP is found to be less than 40 weeks in Malappuram and central zone districts, Thrissur and Palakkad and some parts of Kozhikkod and Wayanad.

4.14.2 LGP-water balance

Water balance calculation has been carried out for 35 stations in Kerala. The results are presented in figure (97). Wet period is more than nine months (starting from March) is found in the stations of Sotuhern zone districts. Thus Length of growing period more than 70 weeks is observed at Southern zone district Thiruvanathapuram for a water holding capacity 200mm.

4.15 Analysis of extreme weather events

Using Rclimdex v 1.0 developed by WMO CLIVAR, the trend in occurrence of extreme rainfall, length of dry and wet spell has analyzed (Fig 91 to 95). A set of five indices were selected to analyze the rainfall behavior viz., the maximum one day rainfall, maximum five day rainfall, daily rainfall intensity, maximum length of dry spell and maximum length of wet spells.

4.15.1 Episodes of maximum one day rainfall

Maximum one day rainfall episodes showed an increasing trend in 17 stations out of 35 stations analysed. Among them three stations (Ottappalam, Kollam and Kumarakam) were showing a significant increase. 18 stations (out of 35 stations) show a decreasing trend for the same two stations among them showing a significant decreasing trend (Aryankavu and Mankombu) (Fig.91).

4.15.2 Trends in maximum cumulative amount of five day rainfall events in Kerala

A significant decreasing trend in maximum cumulative five day rainfall events is found in the southern zone of Kerala and a non significant decreasing trend is observed in the northern zone of Kerala. Significant decreasing trend is found in 8 stations (Aryankavu, Kollam, Kottayam, Kunnamkulam, Mankombu, Nedumangad, Neyyattinkara and Varkala) out of 35 stations. A non significant increasing trend in maximum five day rainfall episodes is observed in most of the taluks in the central zone of Kerala as indicated in the figure 92.

4.15.3 Trends in mean daily rainfall intensity

The trend in mean one day rainfall intensity is presented in the Fig.93. Mean one-day amount of rain is calculated by dividing the annual rainfall by the number of wet days (rainfall > 1 mm) in the year. From the figure it can be noted that 2 stations Kumarakam, Aryankavu) showed significant increasing trend among 35 stations and 4 stations showing significant decreasing trend (Kunnamangalam, Perumbavoor, Nedumangad and Neyyattinkara).

4.15.4 Trends in maximum length of dry spells

The length of dry spell during crop growing season determines quality as well as the productivity of crops. Decreasing trend in dry spell persists in 88% of the stations in which 3 stations showing a significant decreasing trend (Alathur, Kottayam and Pilicod). Decreasing trend is more prominent in central zone. Significant Increasing trend in dry spell is observed only in one station of Kozhikkod district. (Fig 94)

4.15.5 Trends in maximum length of wet spells

Significant increasing trend in wet spells is observed over two stations (Panniyur and Perumbavoor). Significant decreasing trend in wet spells observed over two stations in Problem area zone (Mankombu and Kumarakam) and Vellanikkara station in central zone district Thrissur. (Fig.95).

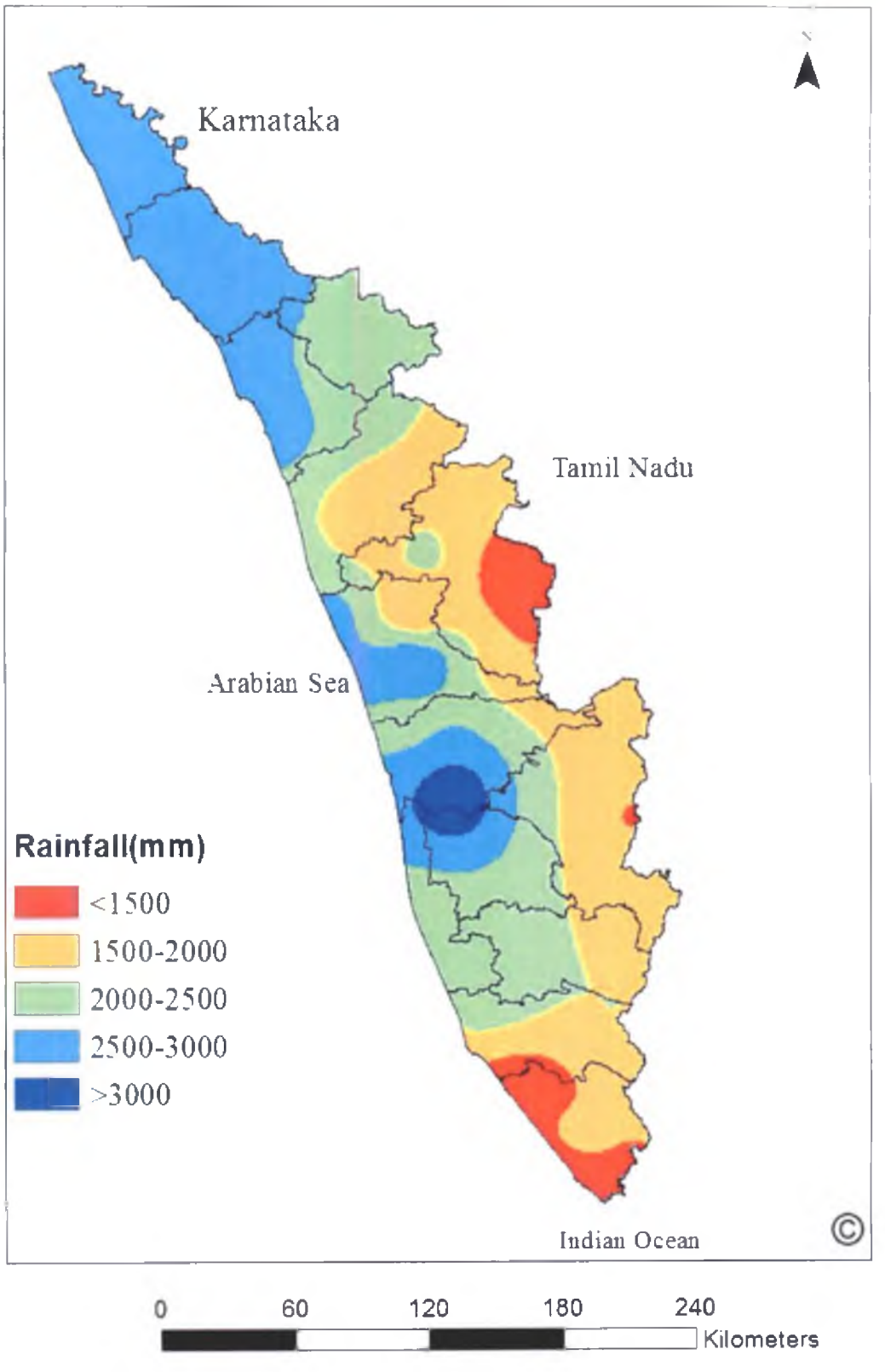


Fig. 66. Area with ≥75% probable annual rainfall in Kerala

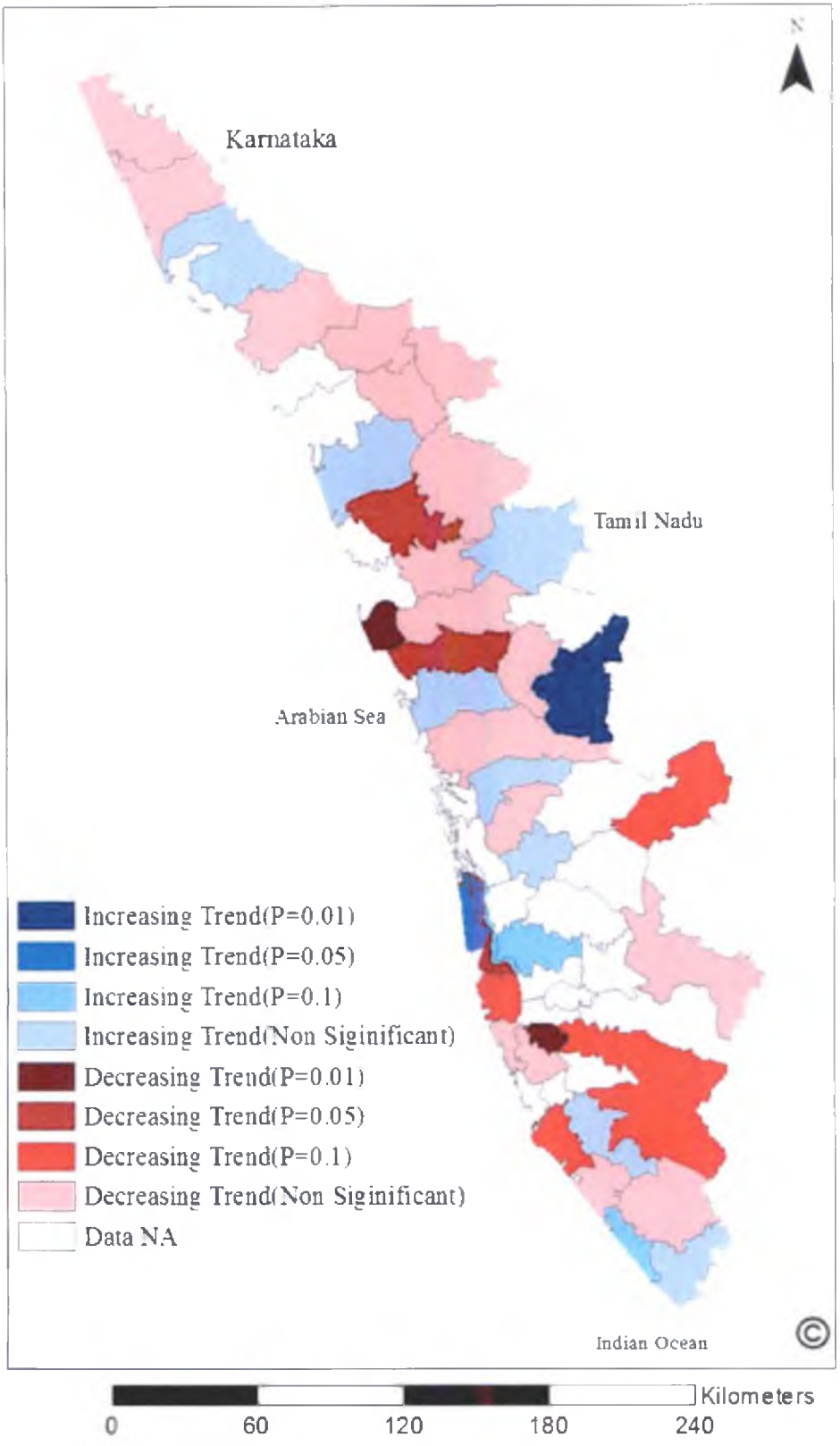


Fig. 67: Taluks in Kerala showing a change in Annual rainfall Pattern

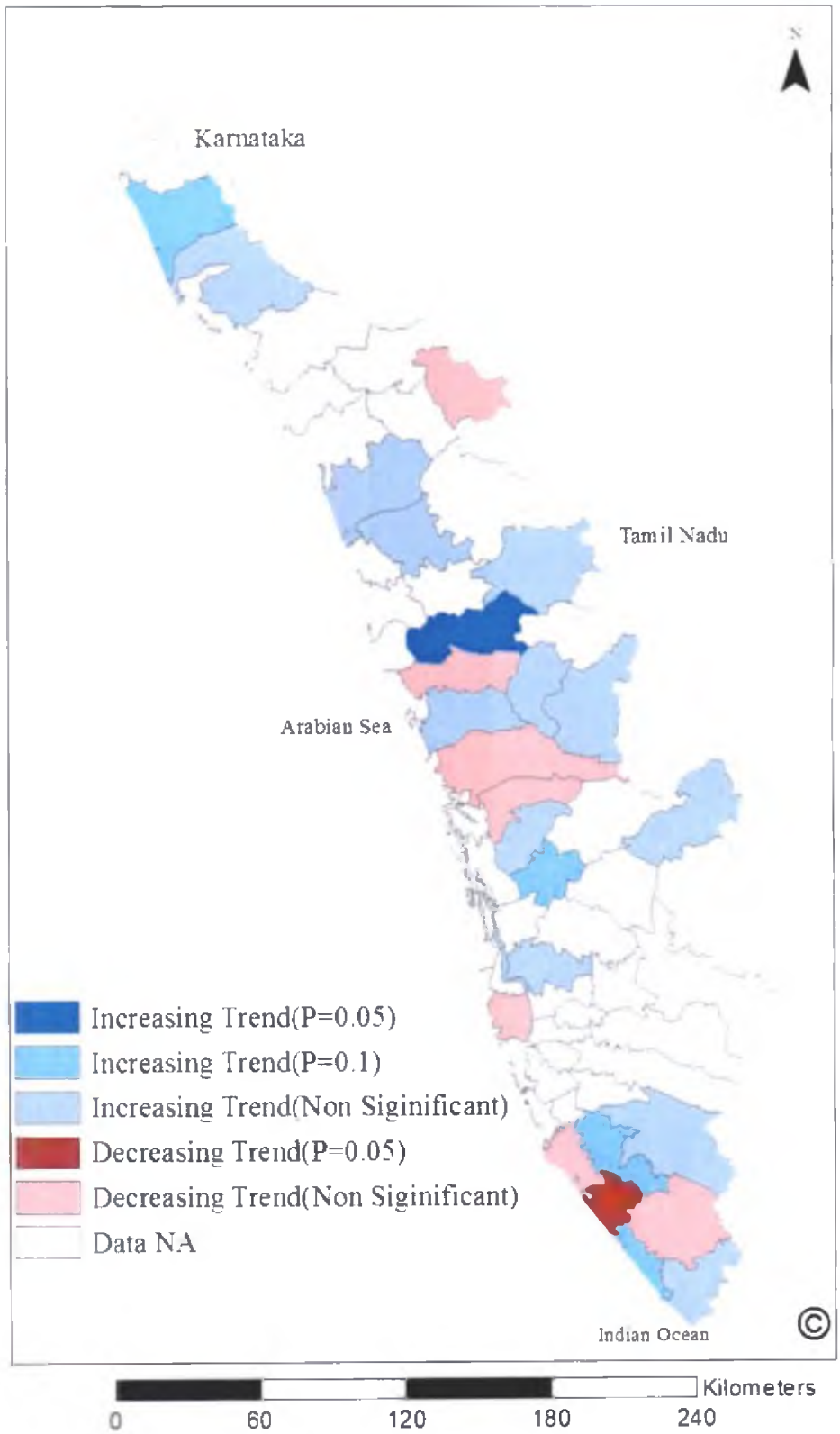


Fig. 68: Taluks in Kerala showing a change in Annual rainy days Pattern

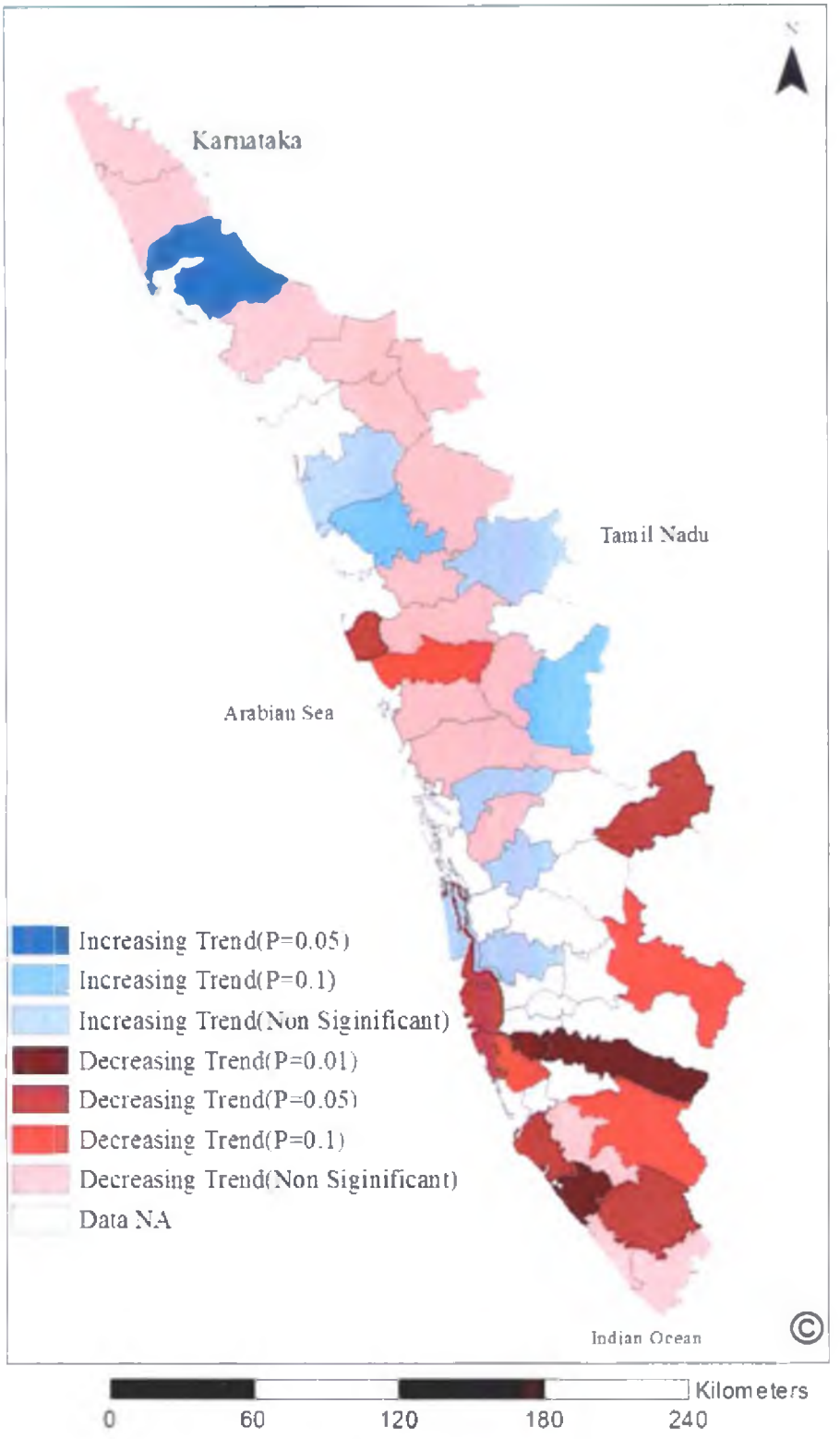


Fig. 69: Taluks in Kerala showing a change in southwest monsoon season rainfall Pattern

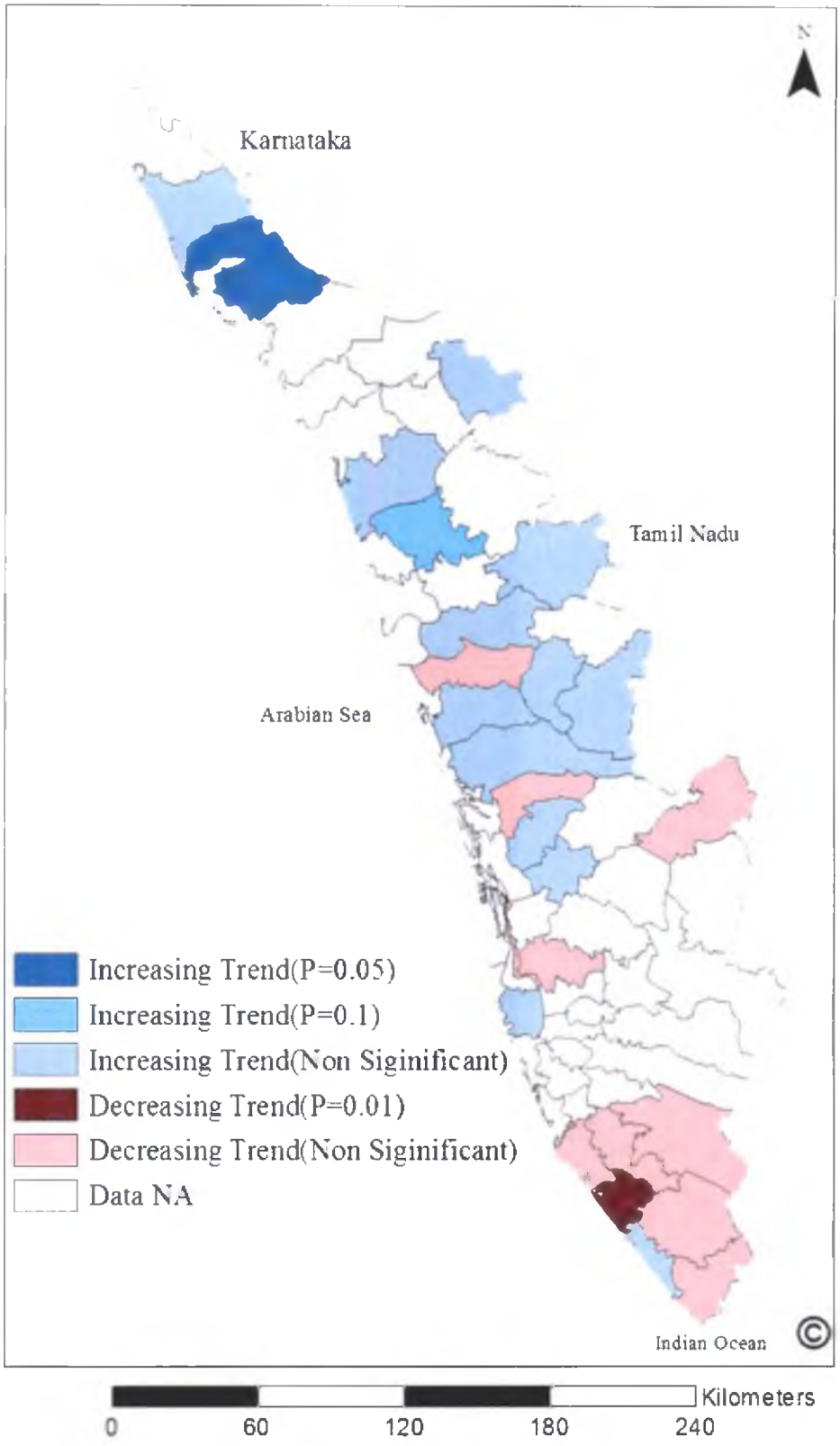


Fig. 70: Taluks in Kerala showing a change in Number of rainy days during Southwest Monsoon Season

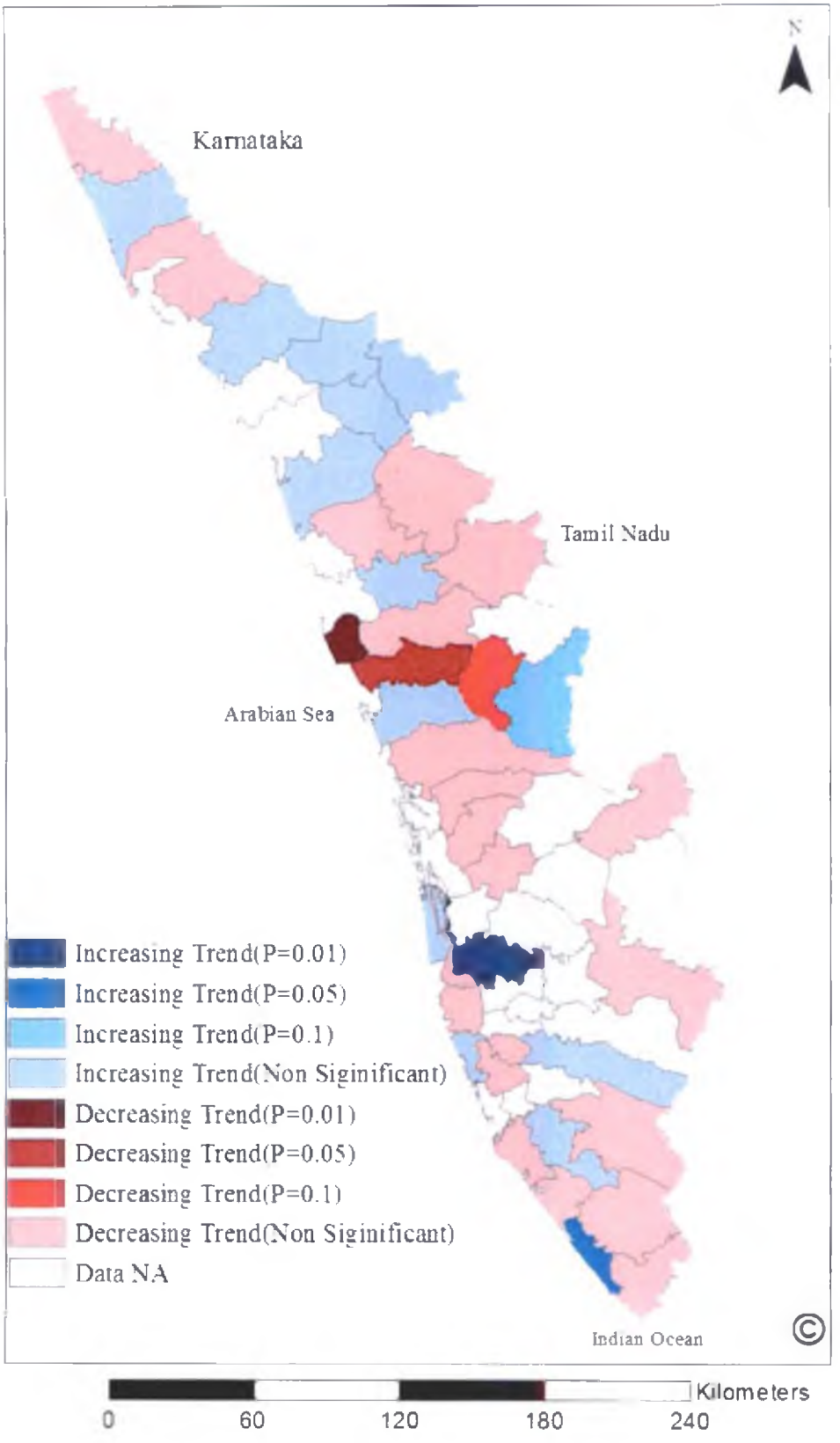


Fig. 71: Taluks in Kerala showing a change in Northeast Monsoon season rainfall pattern

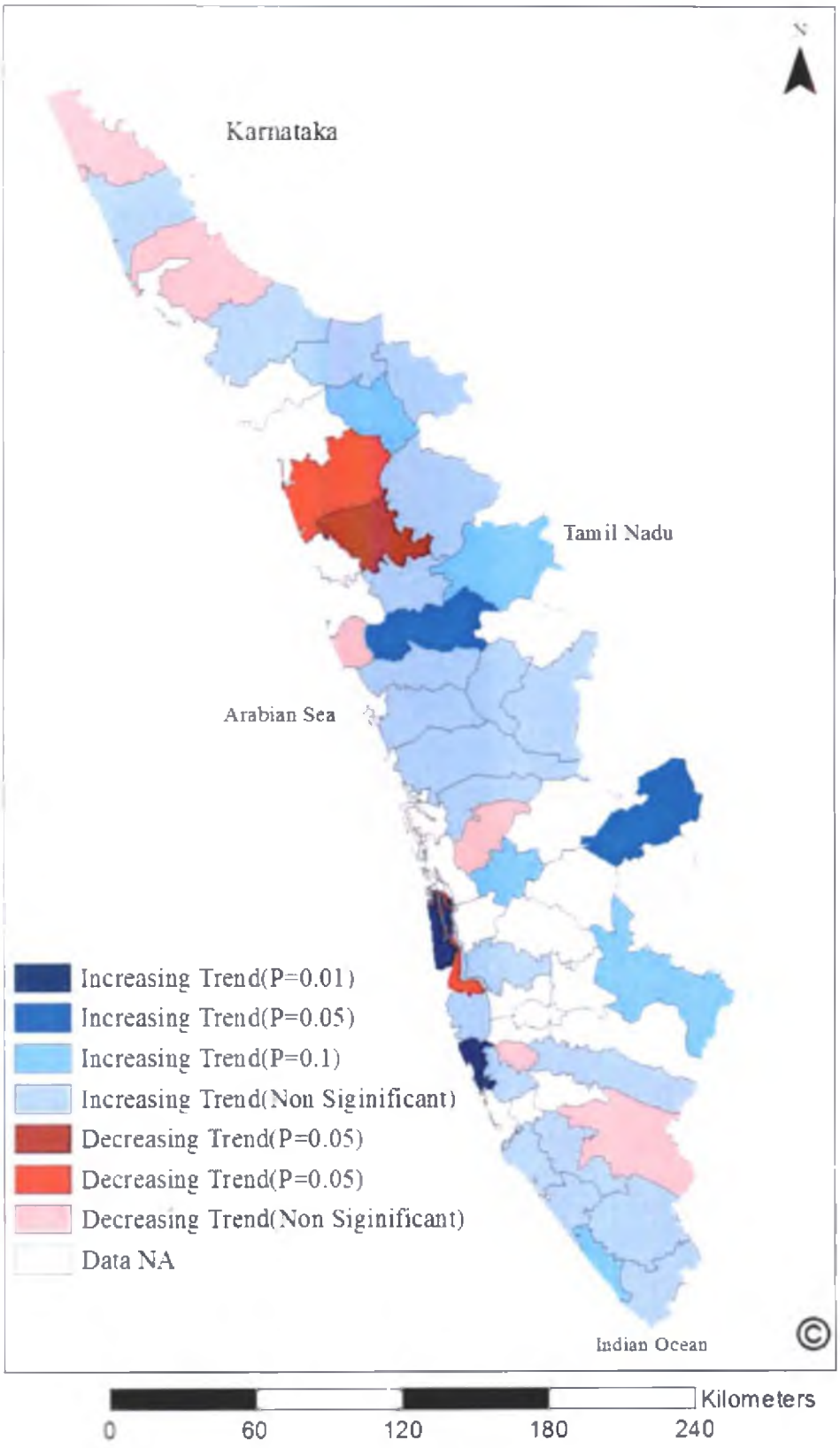


Fig. 72: Taluks in Kerala showing a change in Summer season rainfall pattern

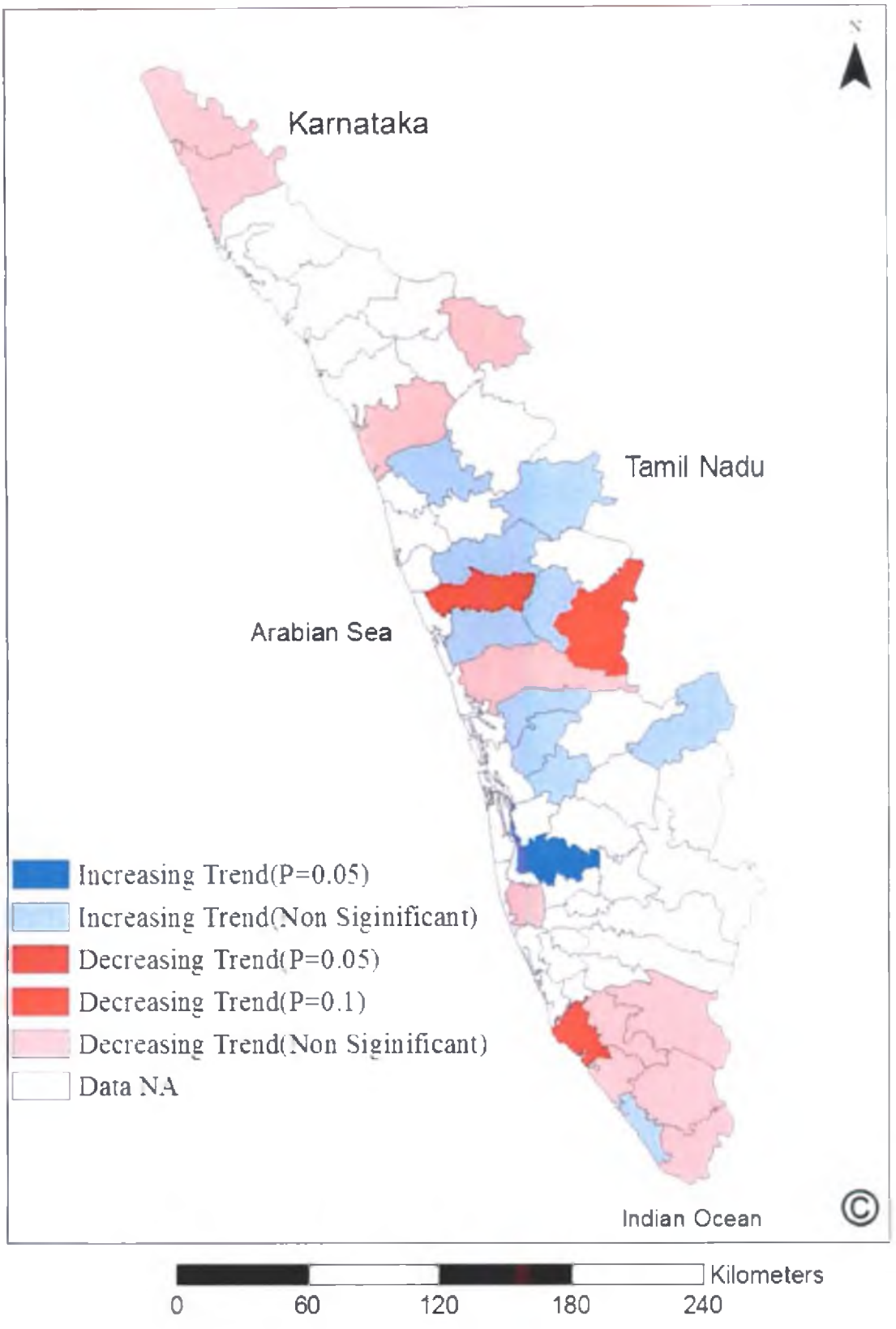


Fig. 73: Taluks In Kerala showing changes in annual rainfall **events in the 75- 100 mm category**

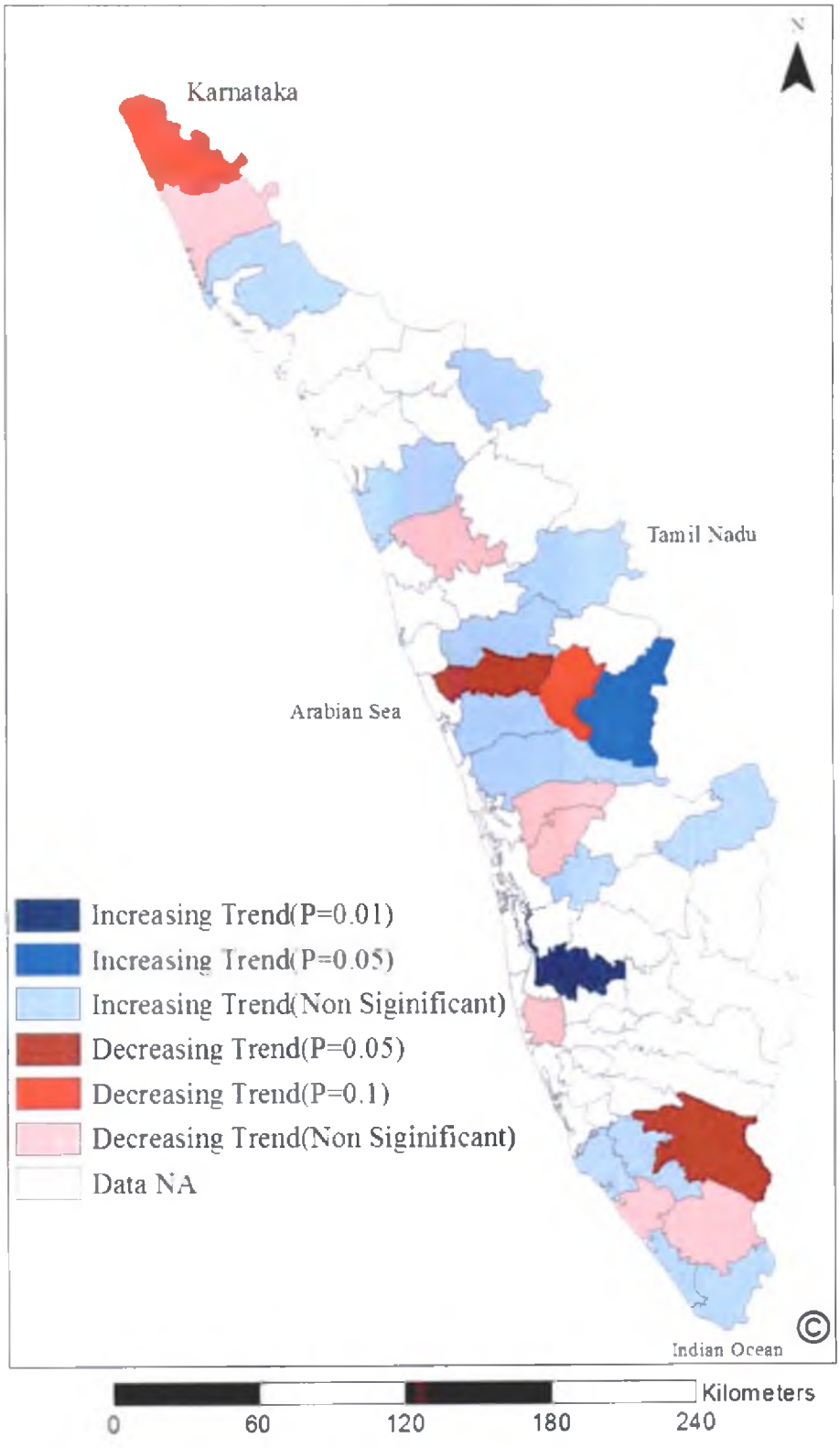


Fig. 74: Taluks In Kerala showing changes in annual rainfall events in the >100 mm category

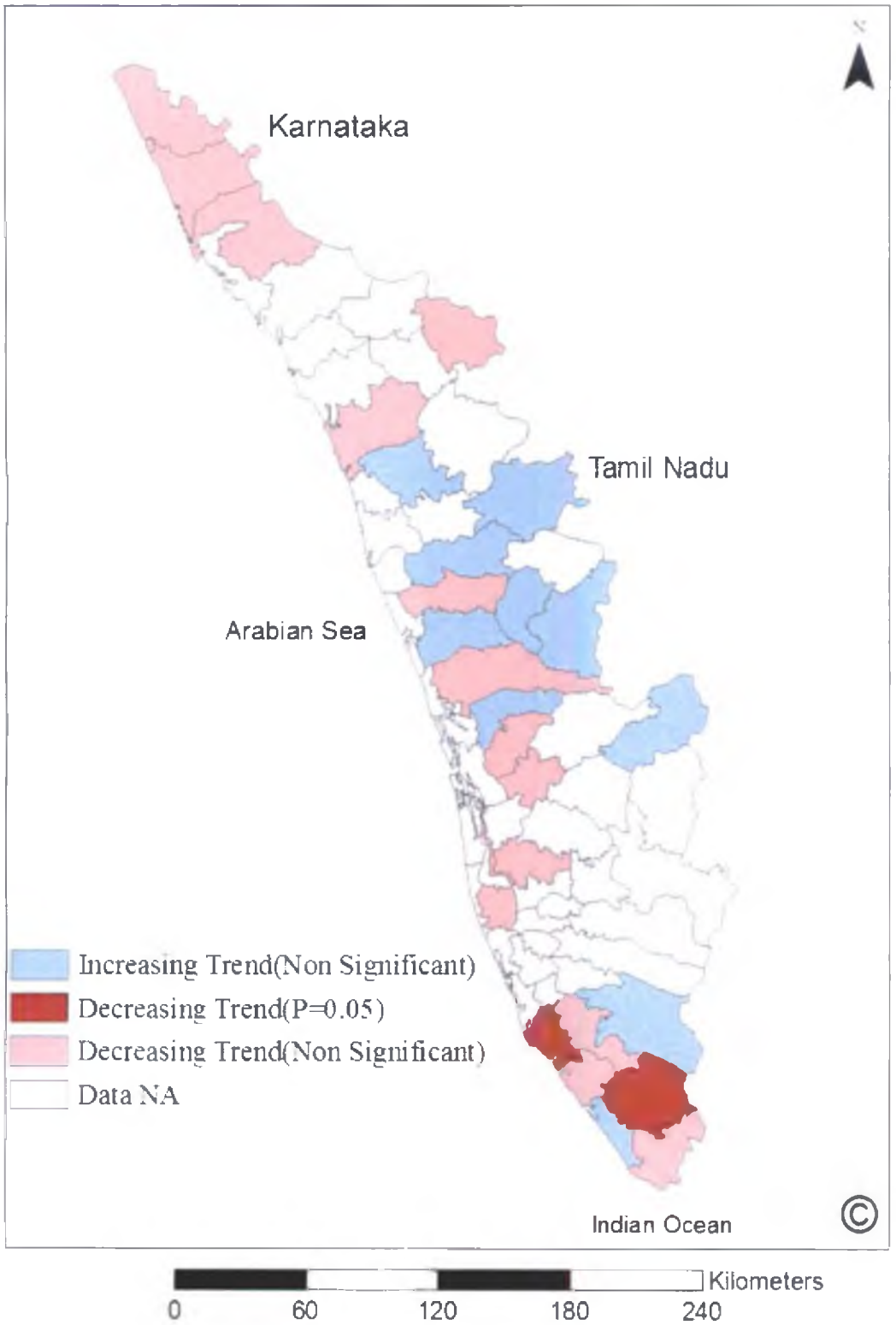


Fig. 75: Taluks In Kerala showing changes in Southwest monsoon rainfall events in the 75-100 mm category

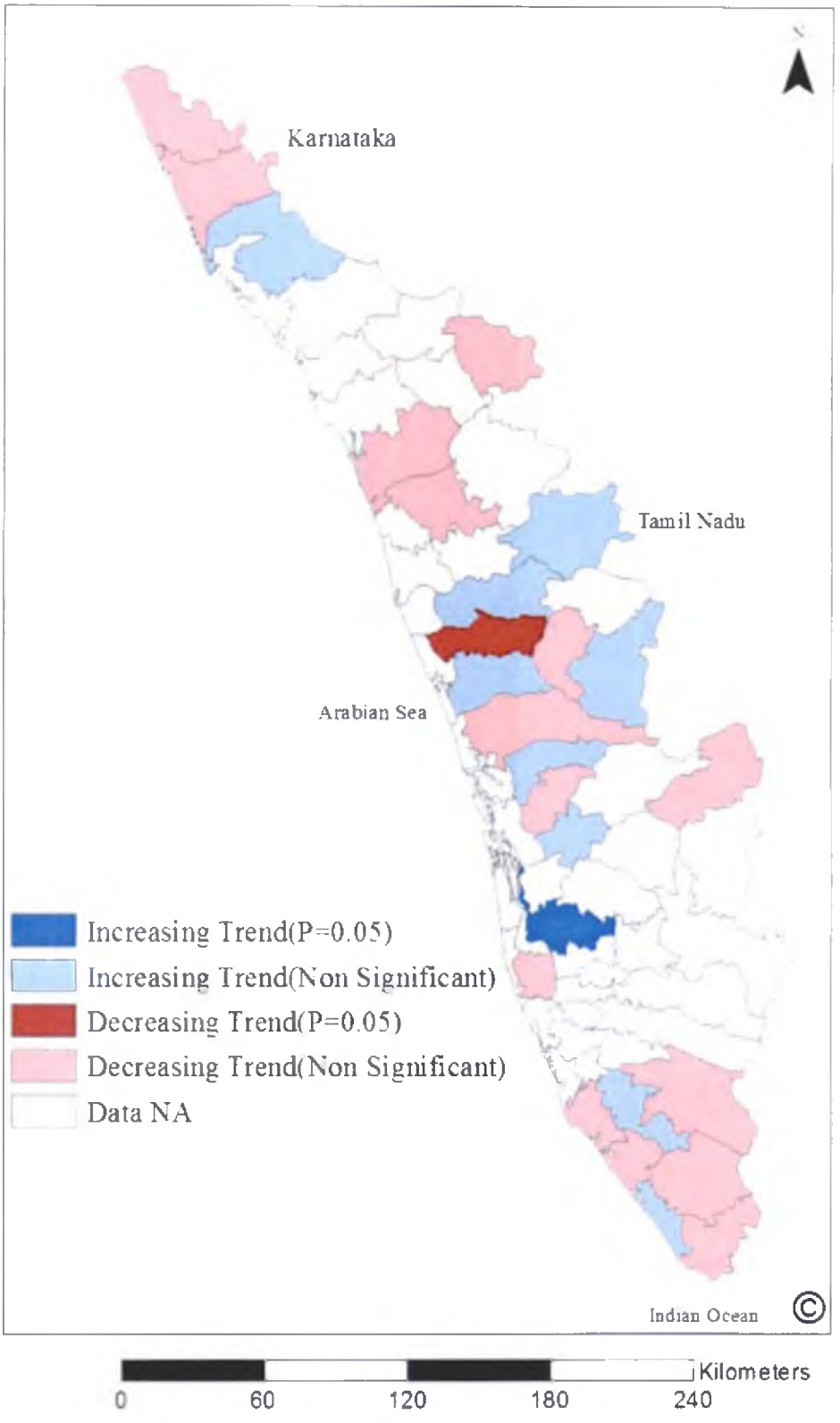


Fig. 76: Taluks In Kerala showing changes in Southwest monsoon rain events in the >100 mm category

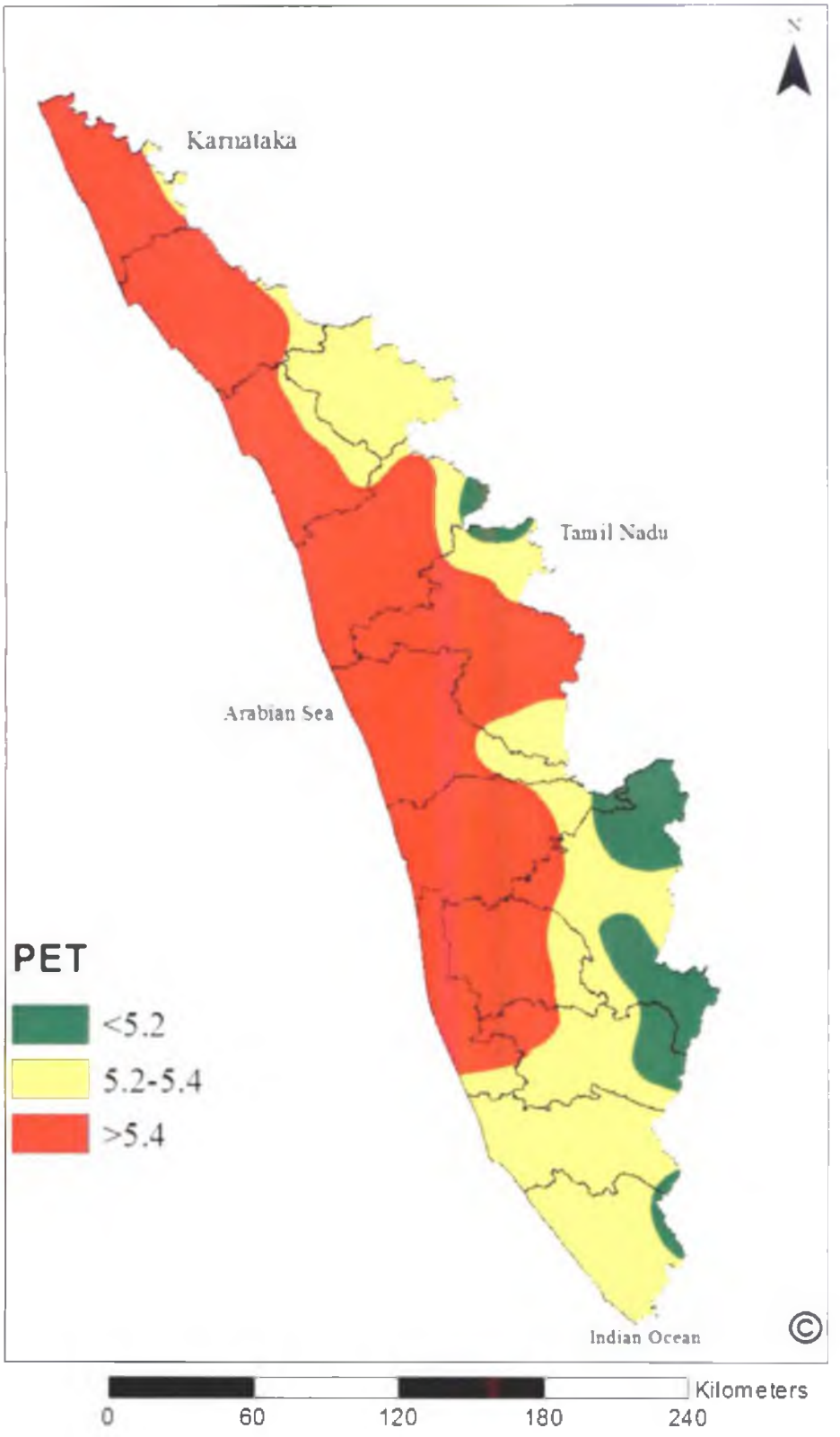


Fig. 77: Annual potential evapotranspiration (mm/day) over Kerala

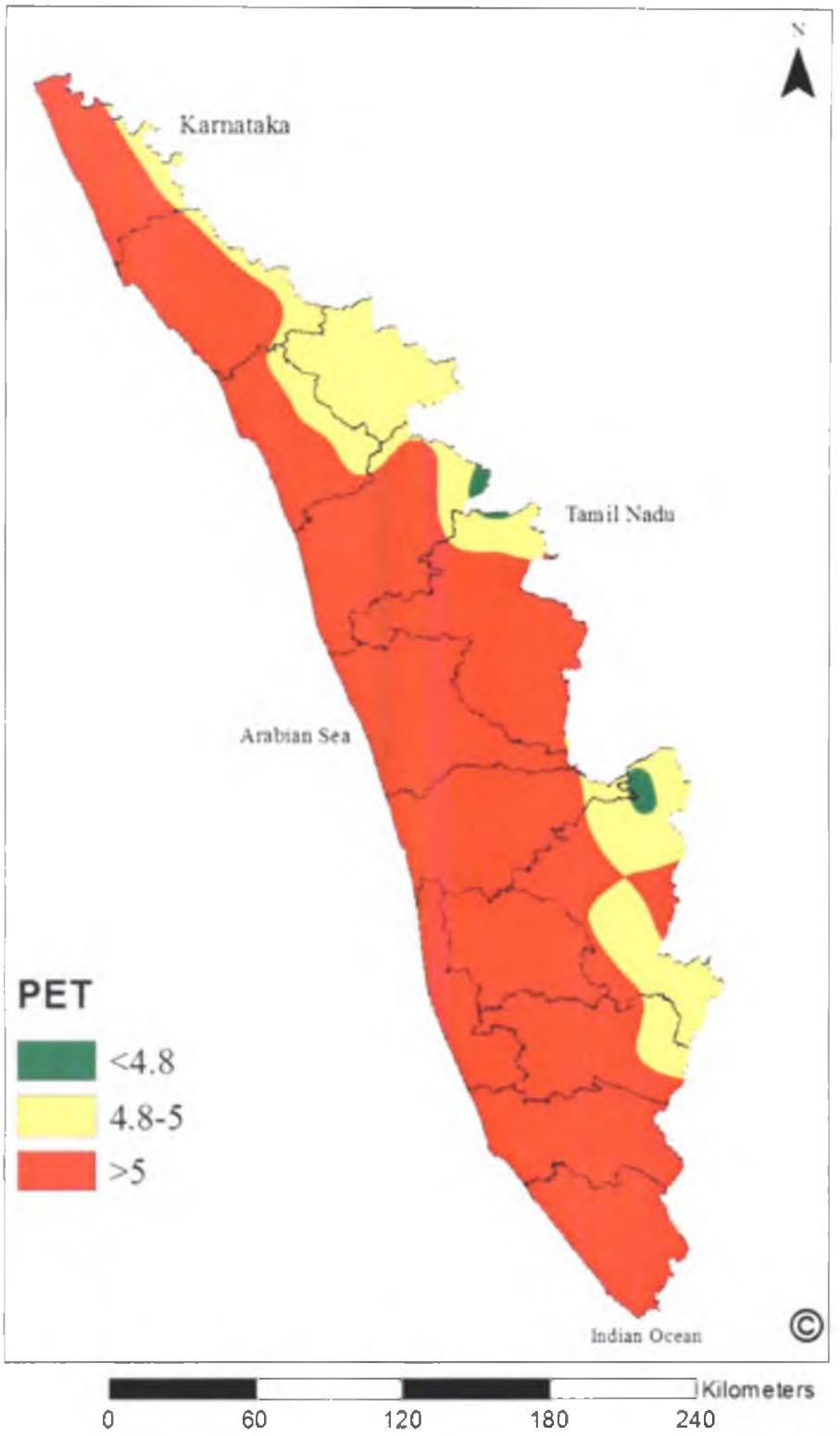


Fig. 78: Southwest monsoon season potential evapotranspiration (mm/day) over Kerala

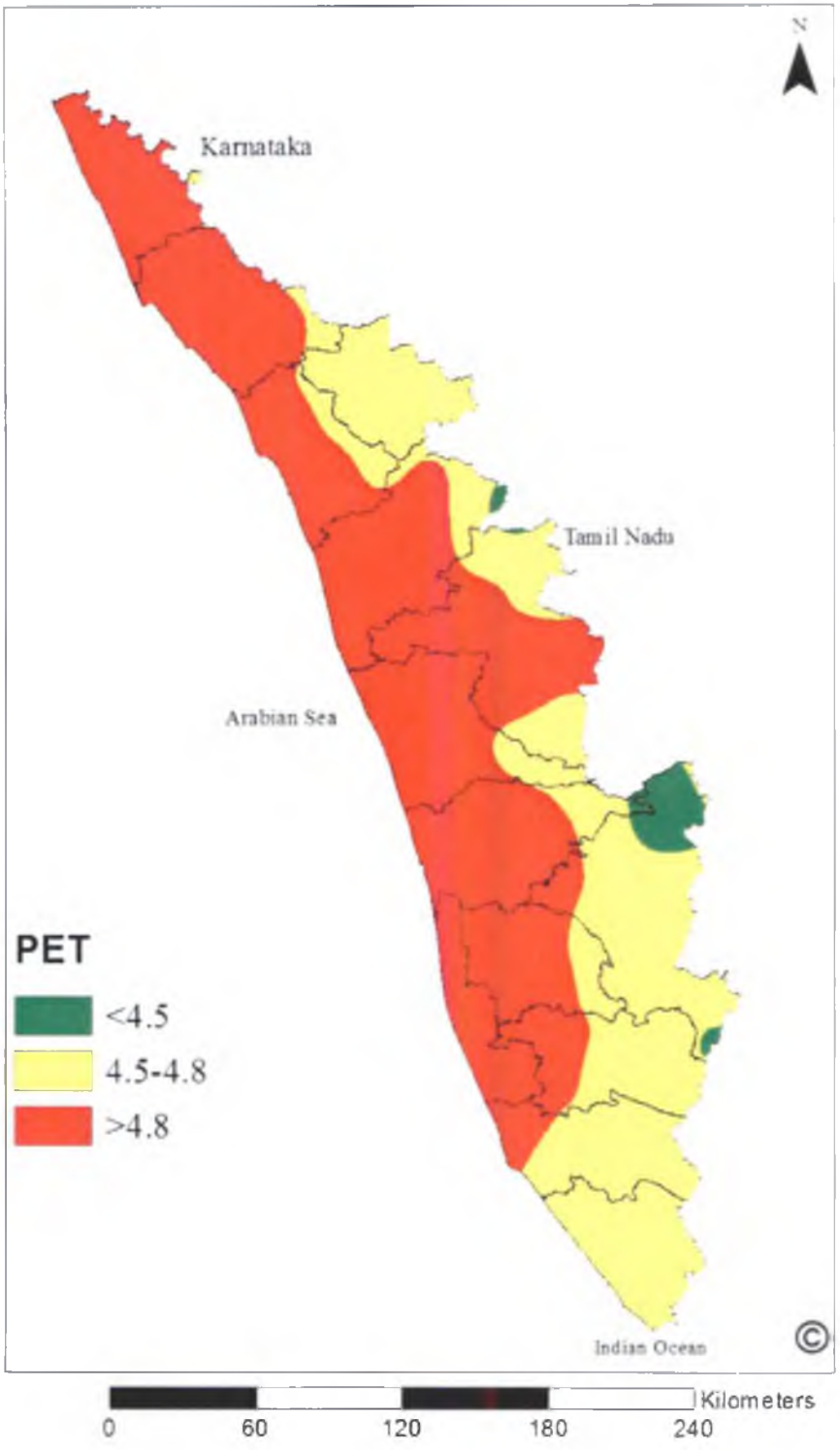


Fig. 79: Northeast monsoon season potential evapotranspiration (mm/day) over Kerala

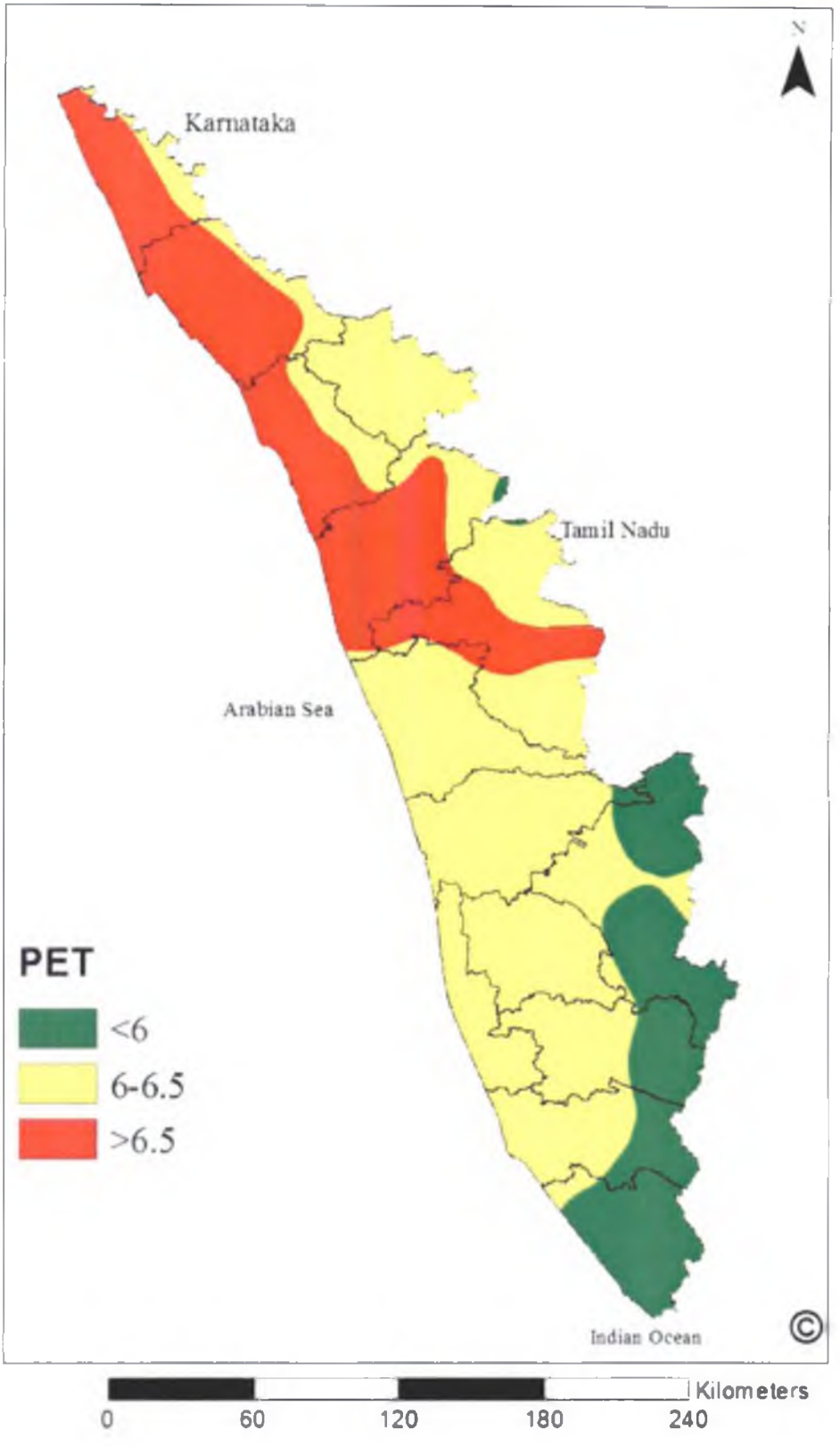


Fig. 80: Summer season potential evapotranspiration (mm/day) over Kerala

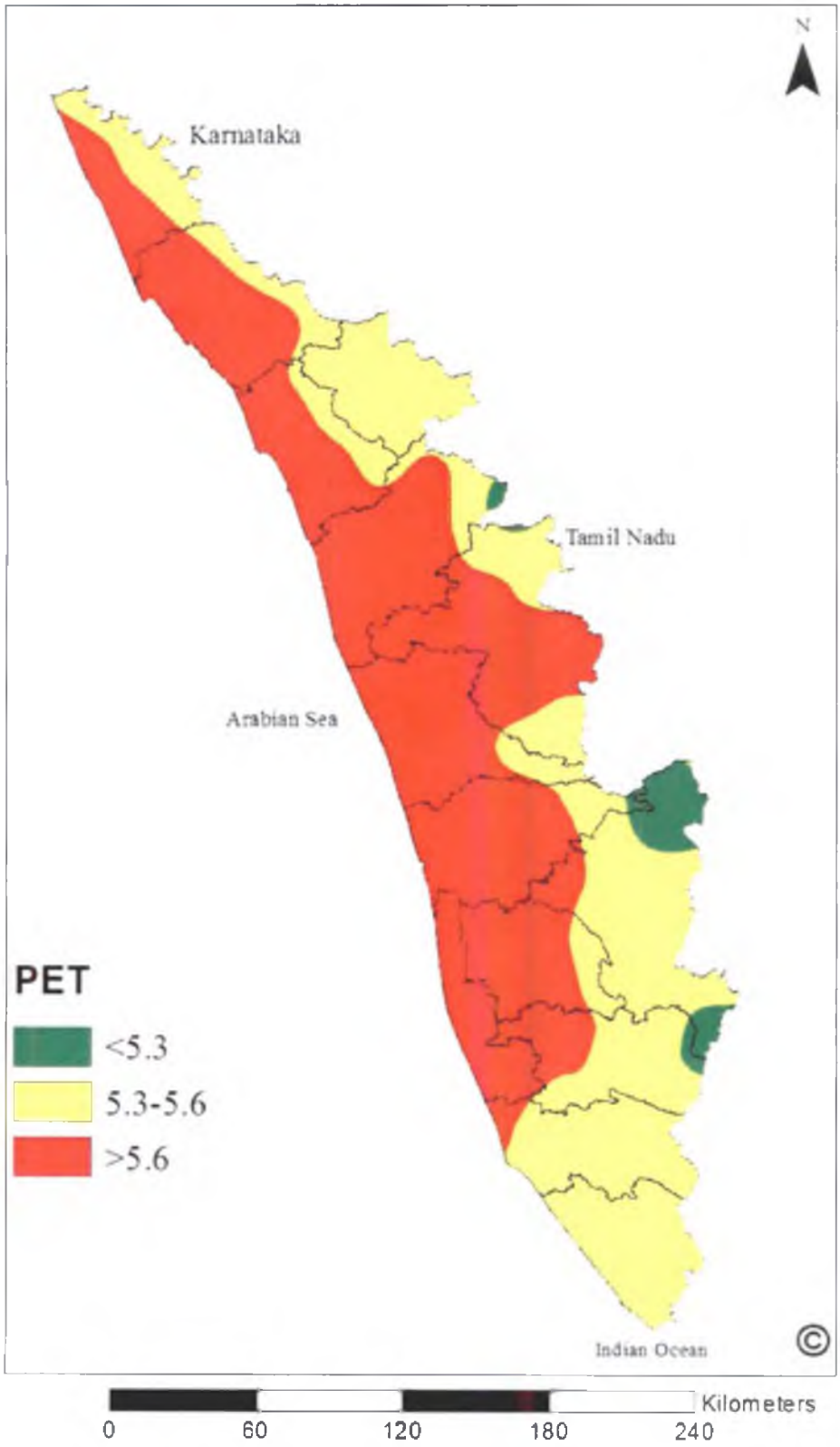


Fig. 81: Winter season potential evapotranspiration (mm/day) over Kerala

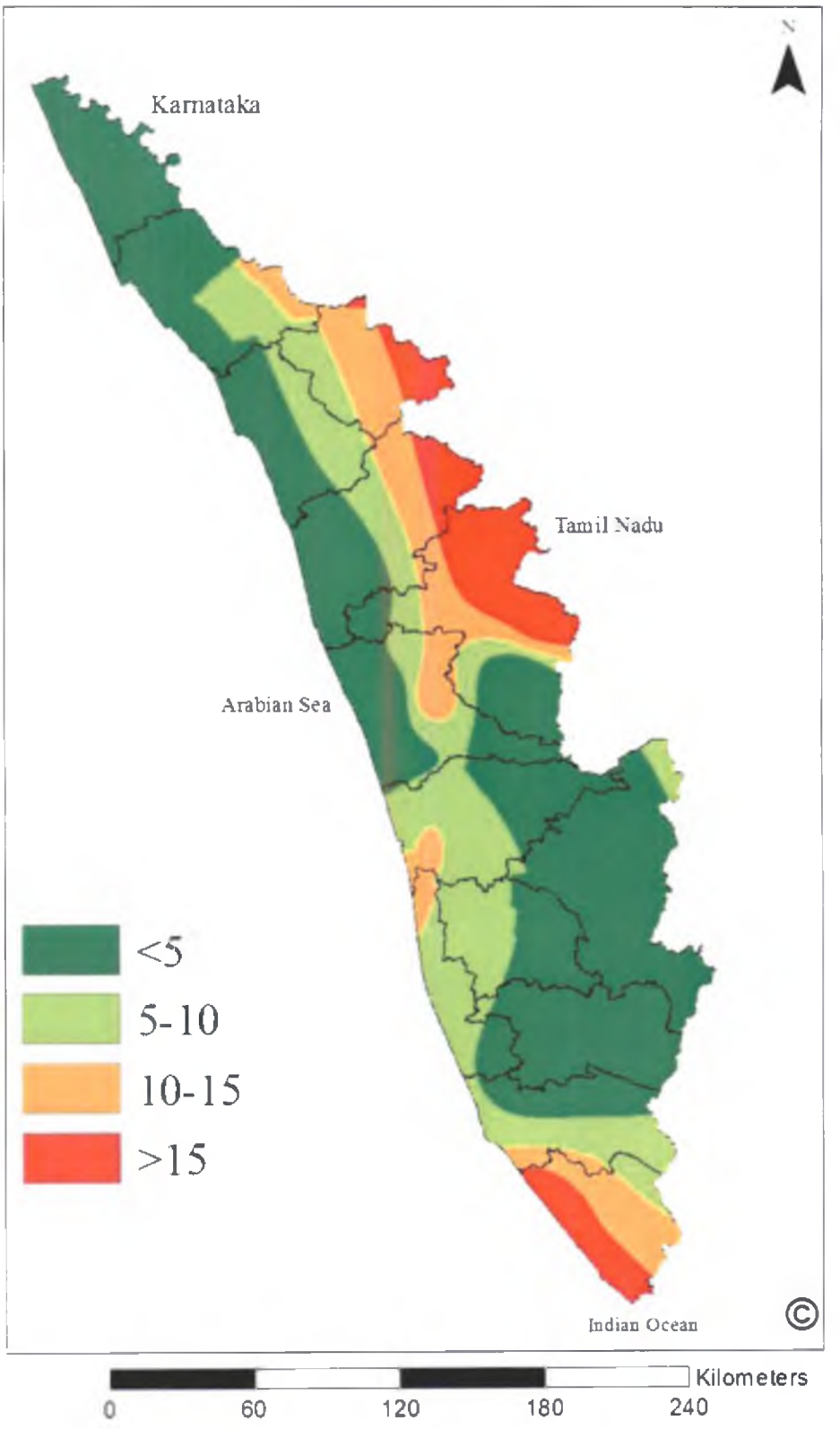


Fig. 82: Probability of occurrence of moderate drought in Kerala

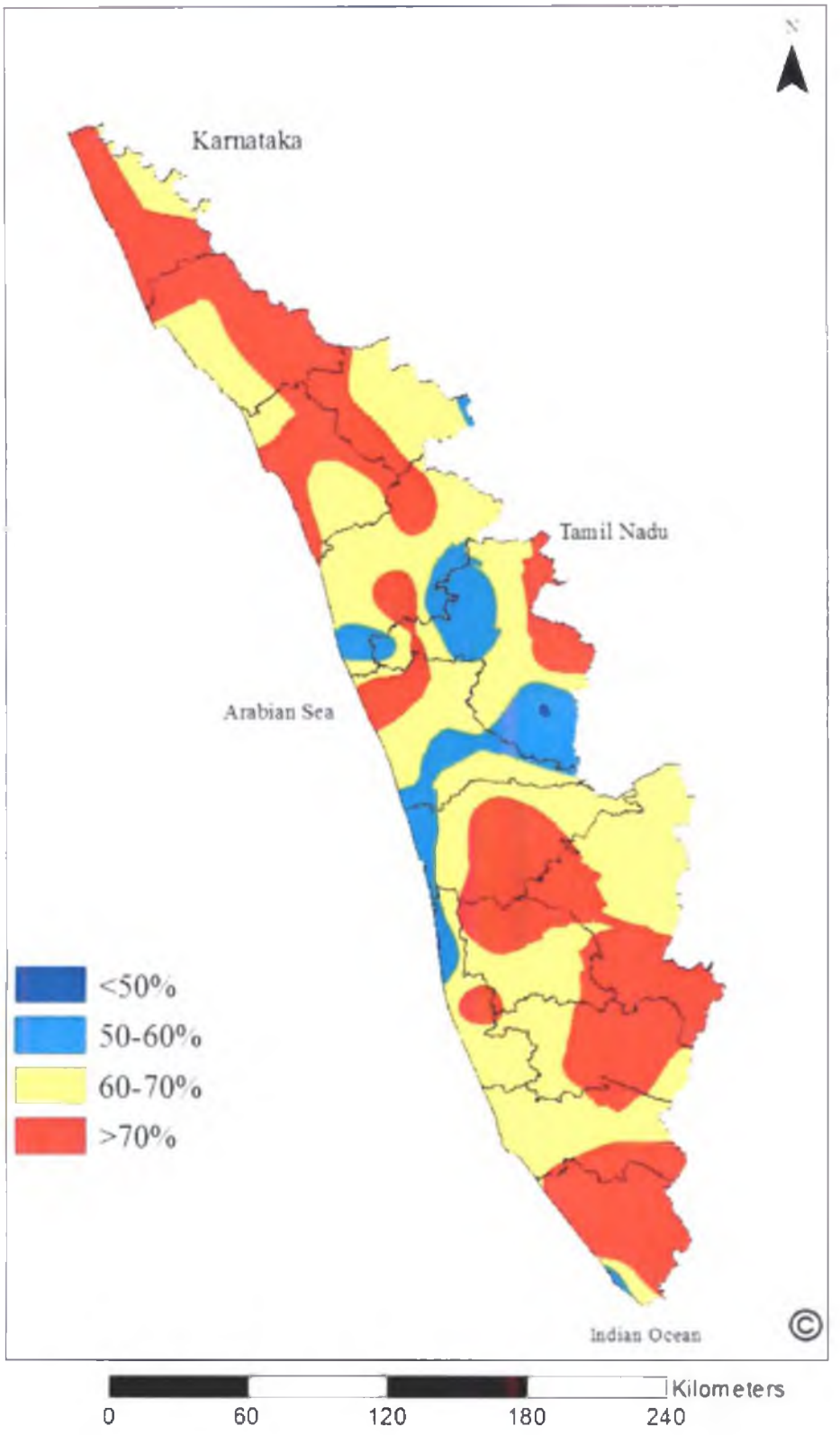


Fig. 83 (a): Probability of experiencing near normal conditions based on annual basis (SPI between -0.99 to +0.99)

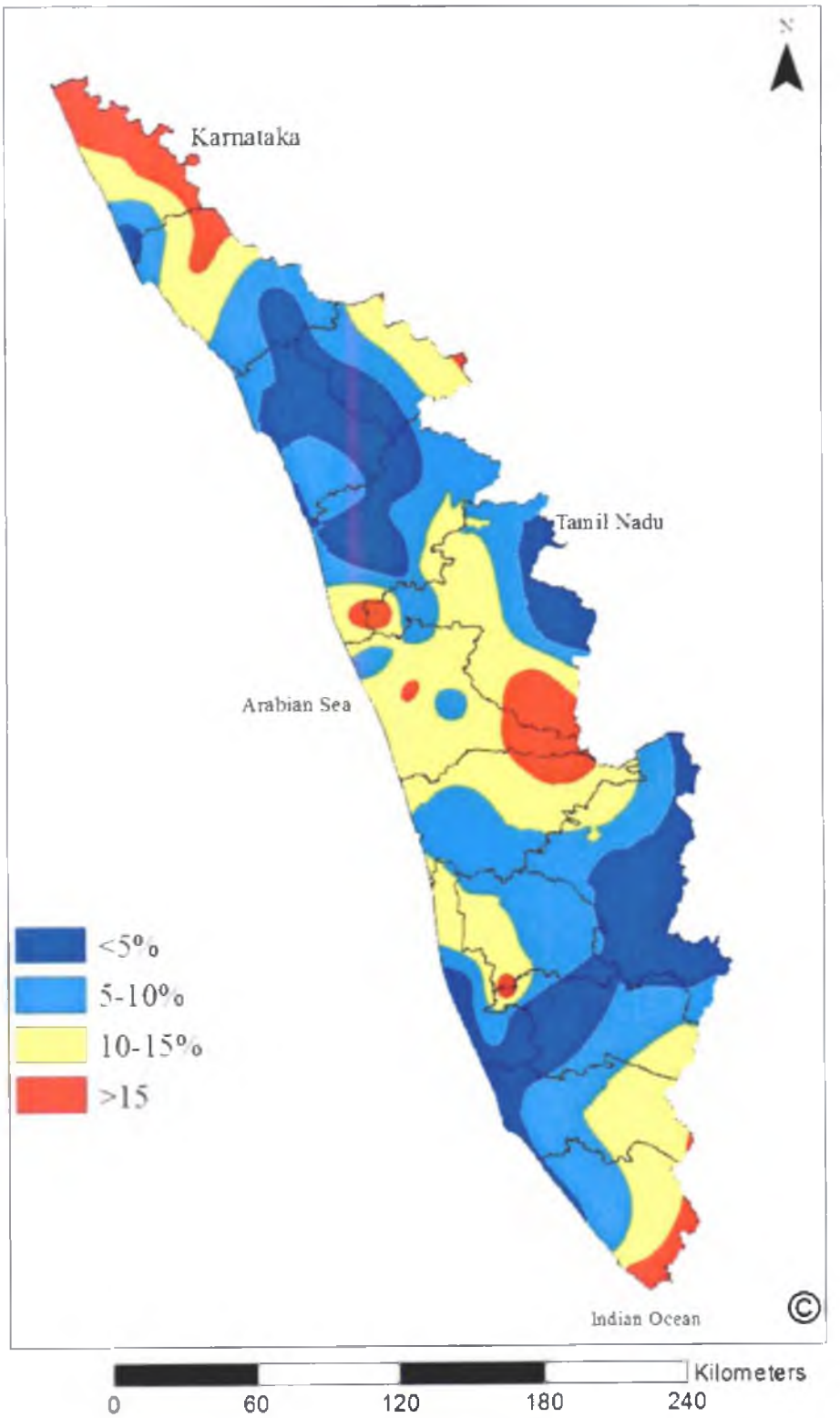


Fig. 83(b): Probability of experiencing moderately dry conditions based on annual basis (SPI between -1.00 to -1.49)

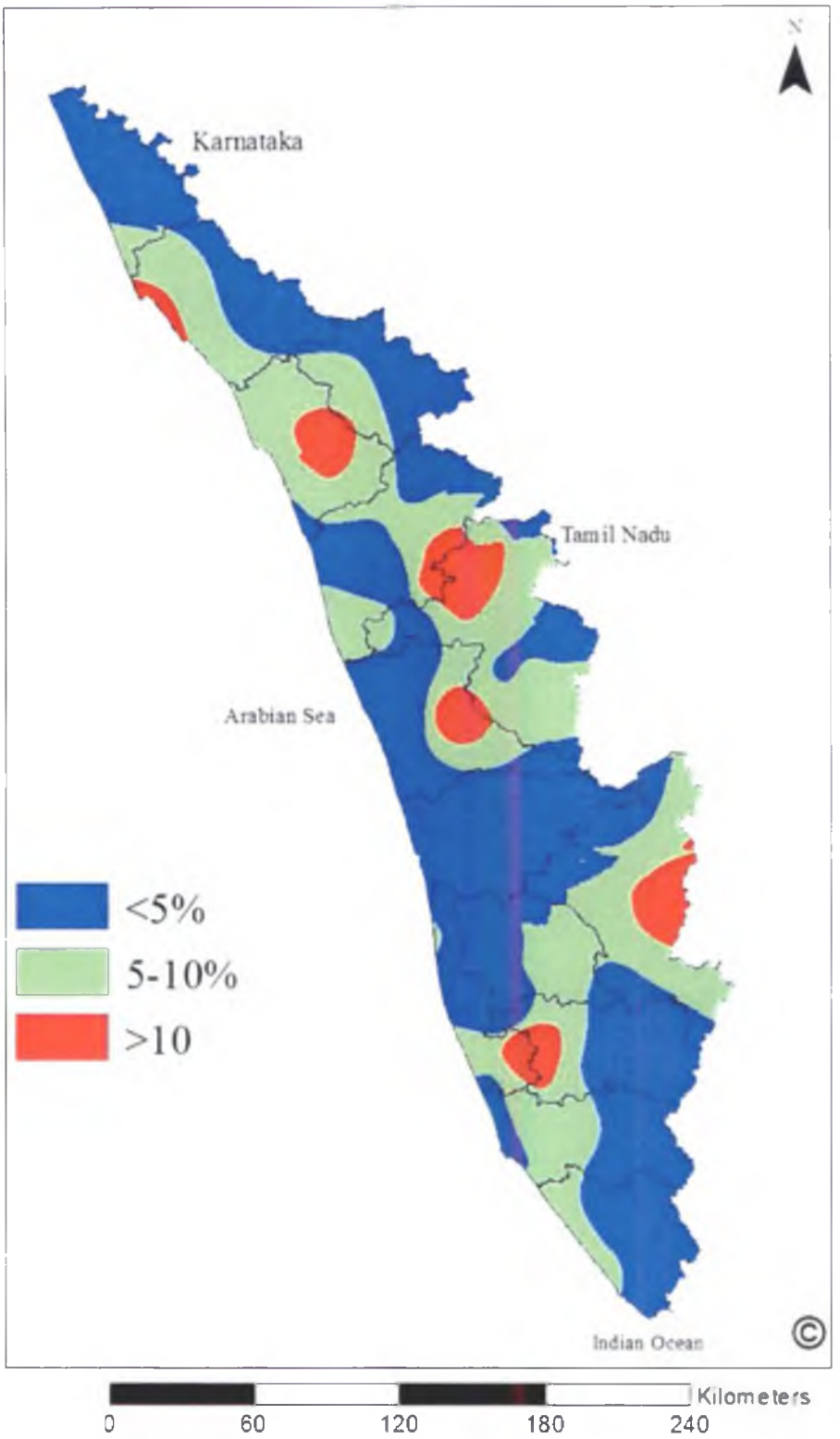


Fig. 83 (c): Probability of experiencing severely dry conditions based on annual basis (SPI between -1.5 to -1.99)

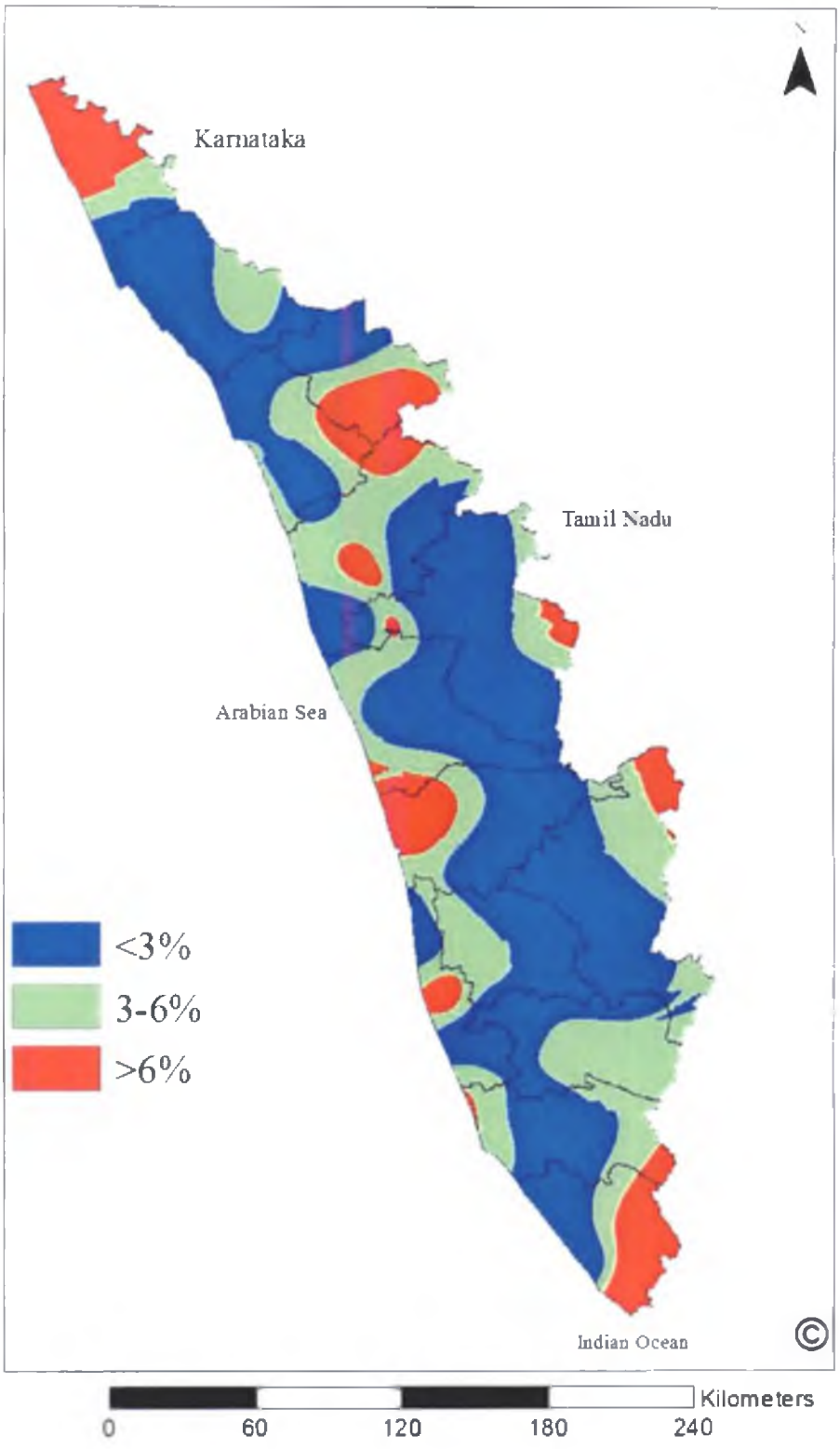


Fig. 83 (d): Probability of experiencing extremely dry conditions based on annual basis (SPI less than -2.0)

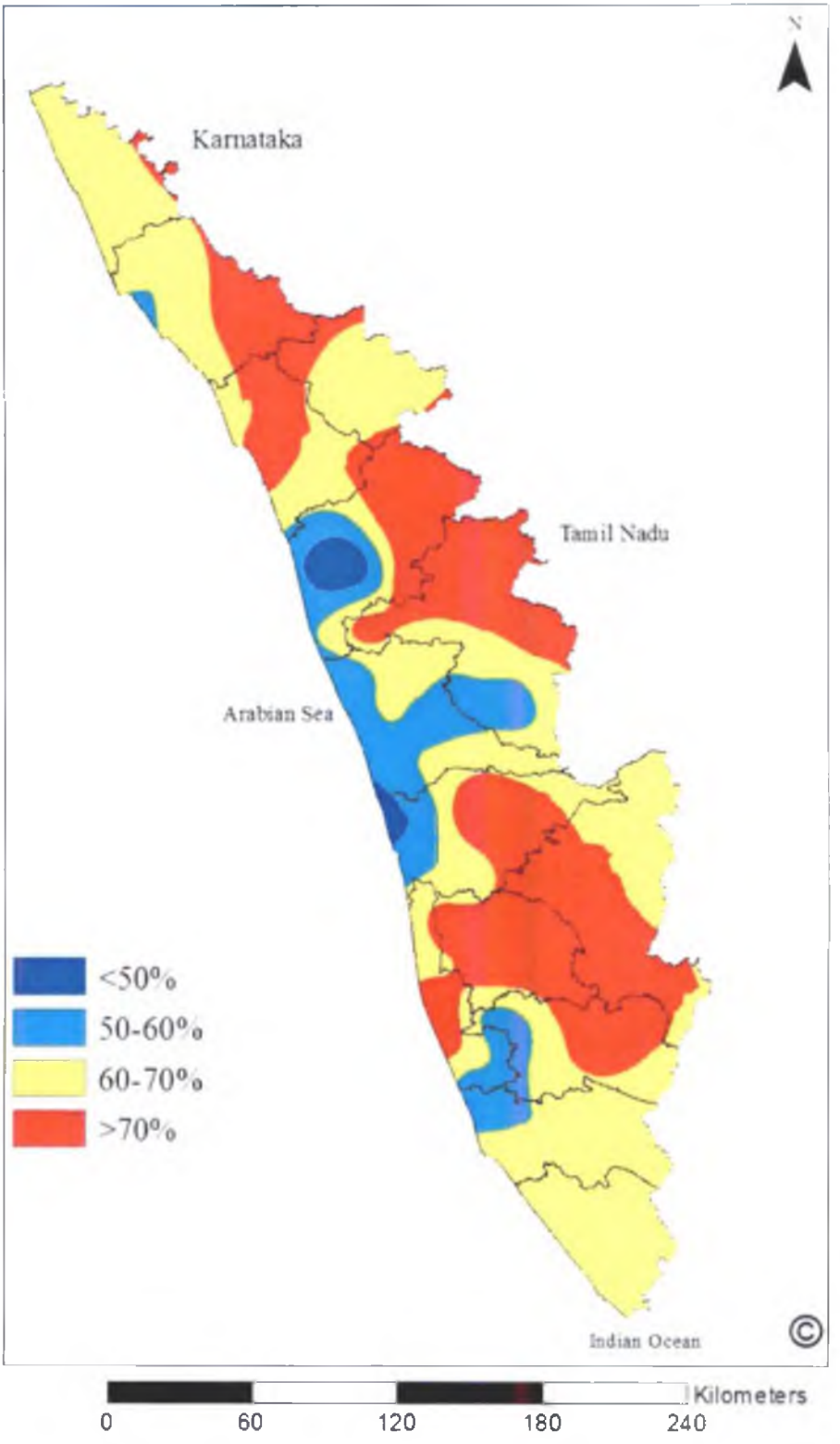


Fig. 84 (a): Probability of near normal rainfall during Southwest monsoon (SPI between -0.99 to +0.99) in Kerala

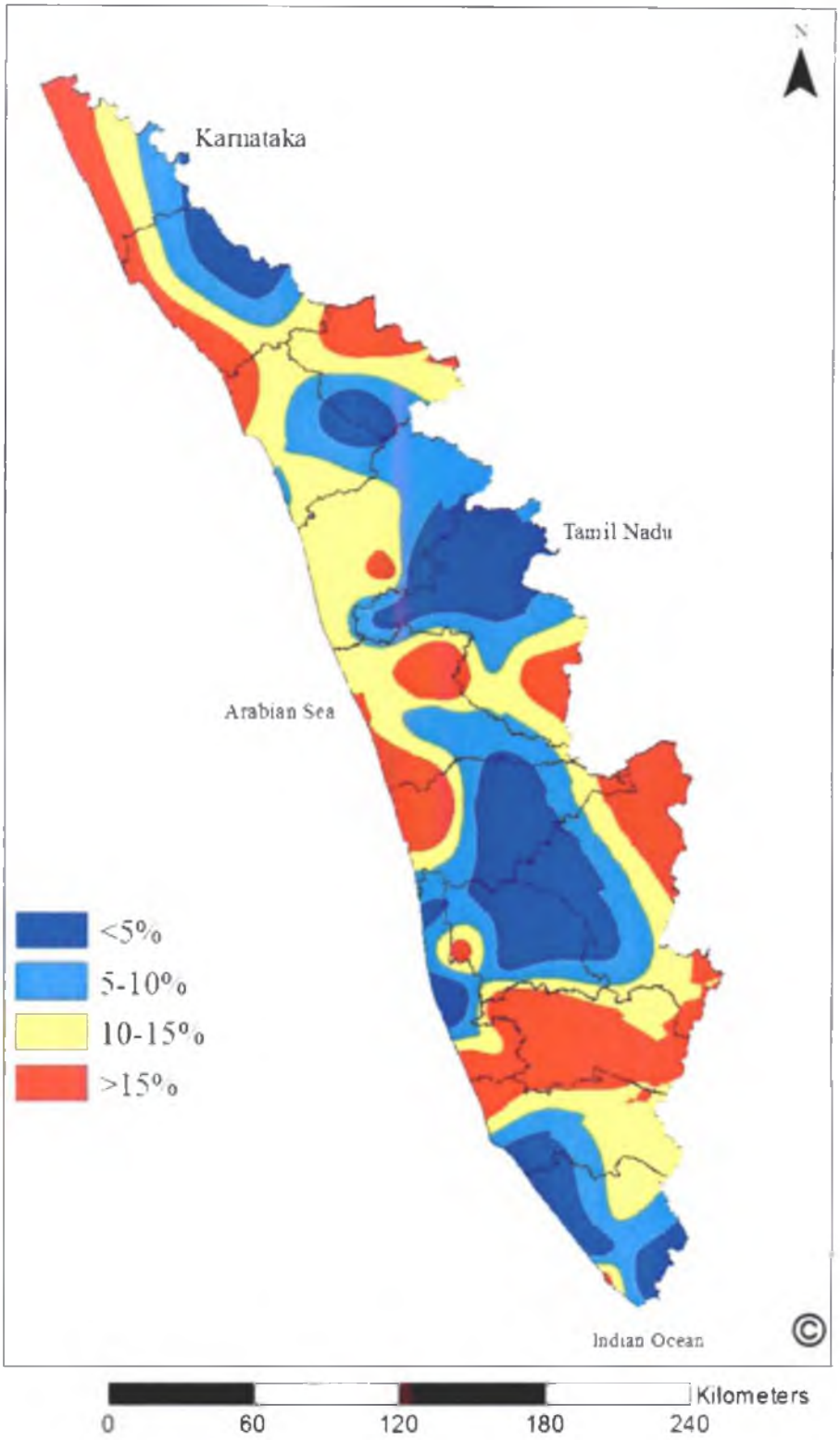


Fig. 84 (b): Probability of moderately dry rainfall during Southwest monsoon (SPI between -1.00 to -1.49) in Kerala

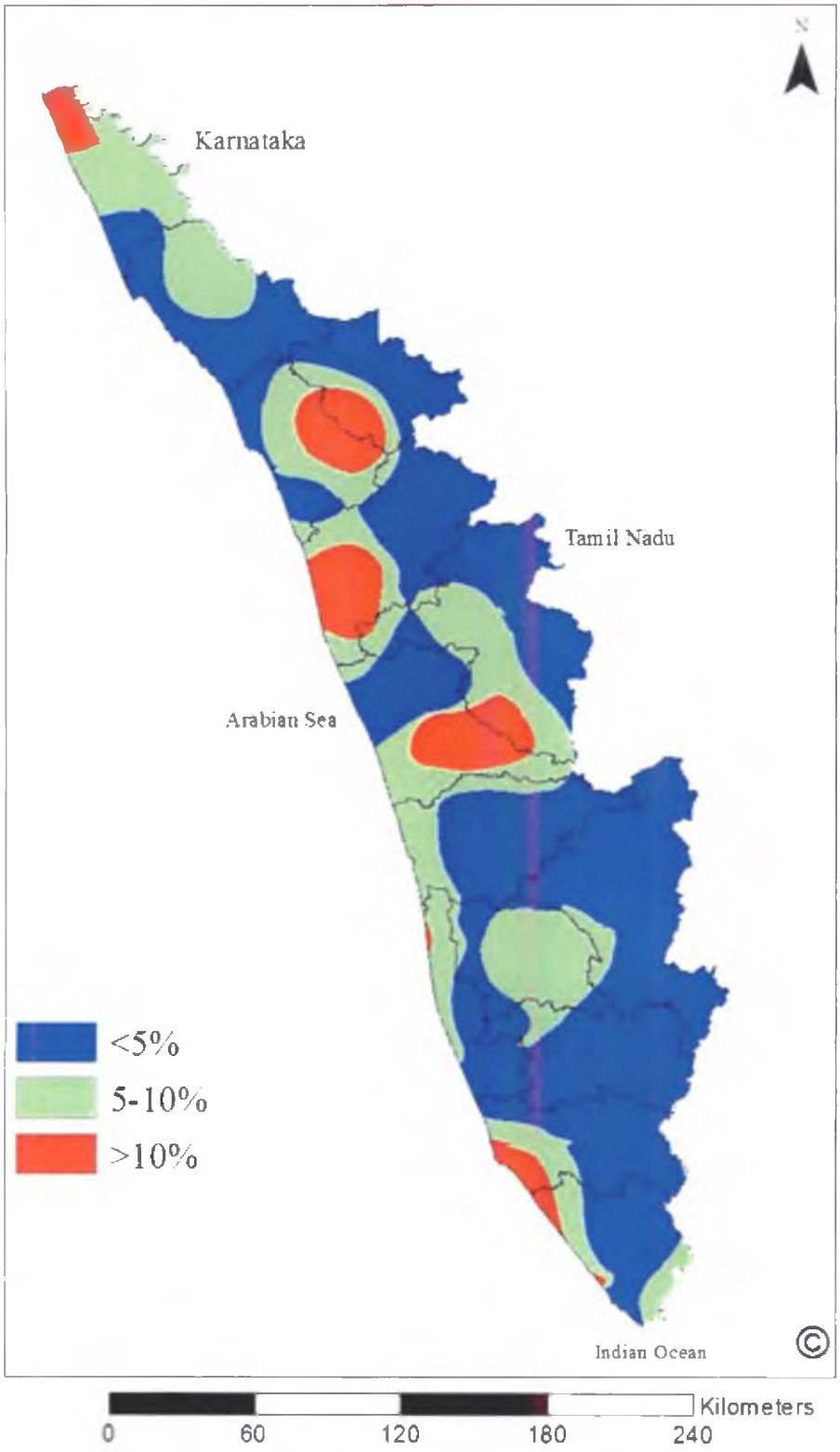


Fig. 84 (c): Probability of severely dry rainfall during Southwest monsoon (SPI between -1.5 to -1.99) in Kerala

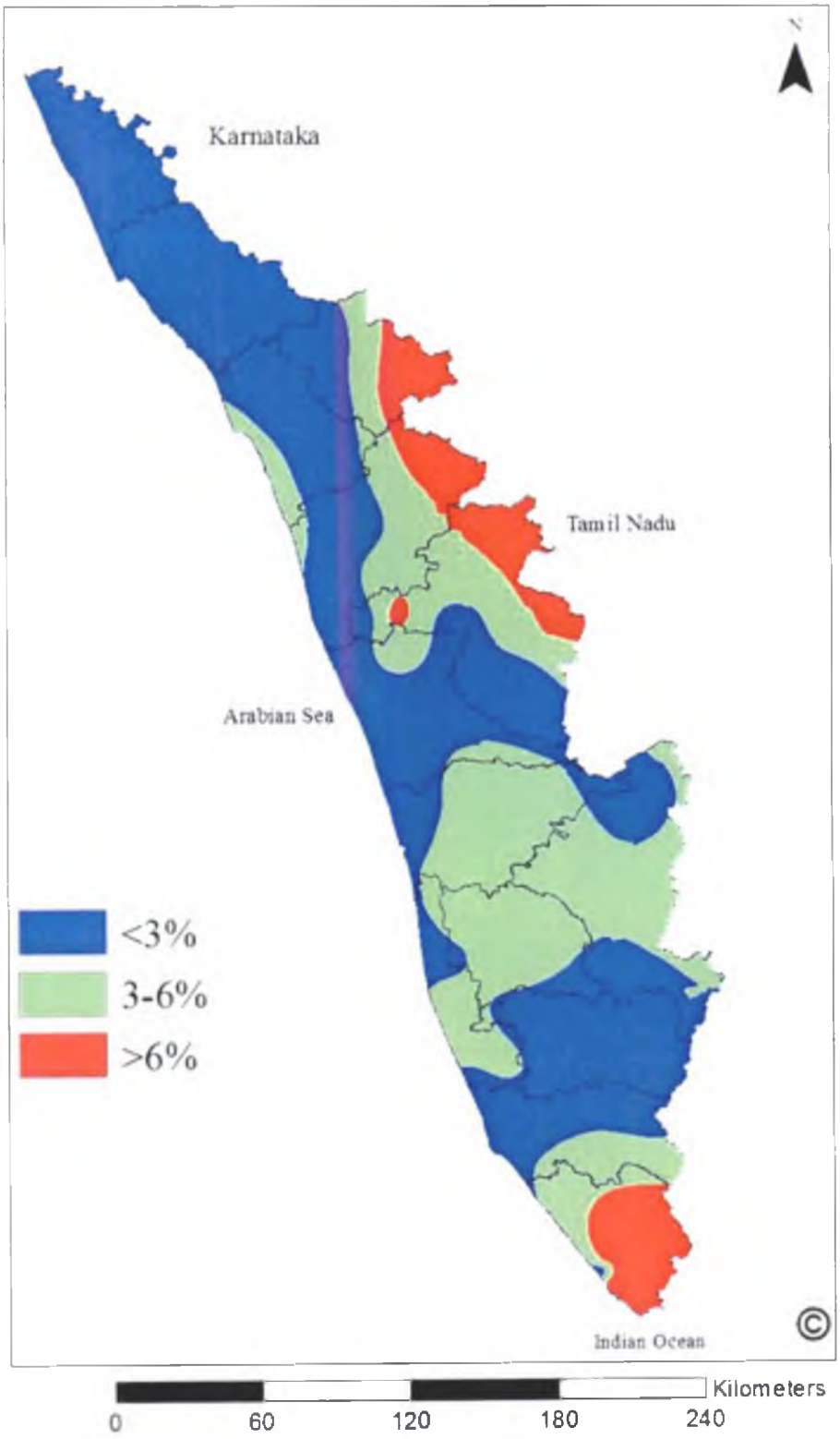


Fig. 84 (d): Probability of extremely dry rainfall during Southwest monsoon (SPI less than -2.0) in Kerala

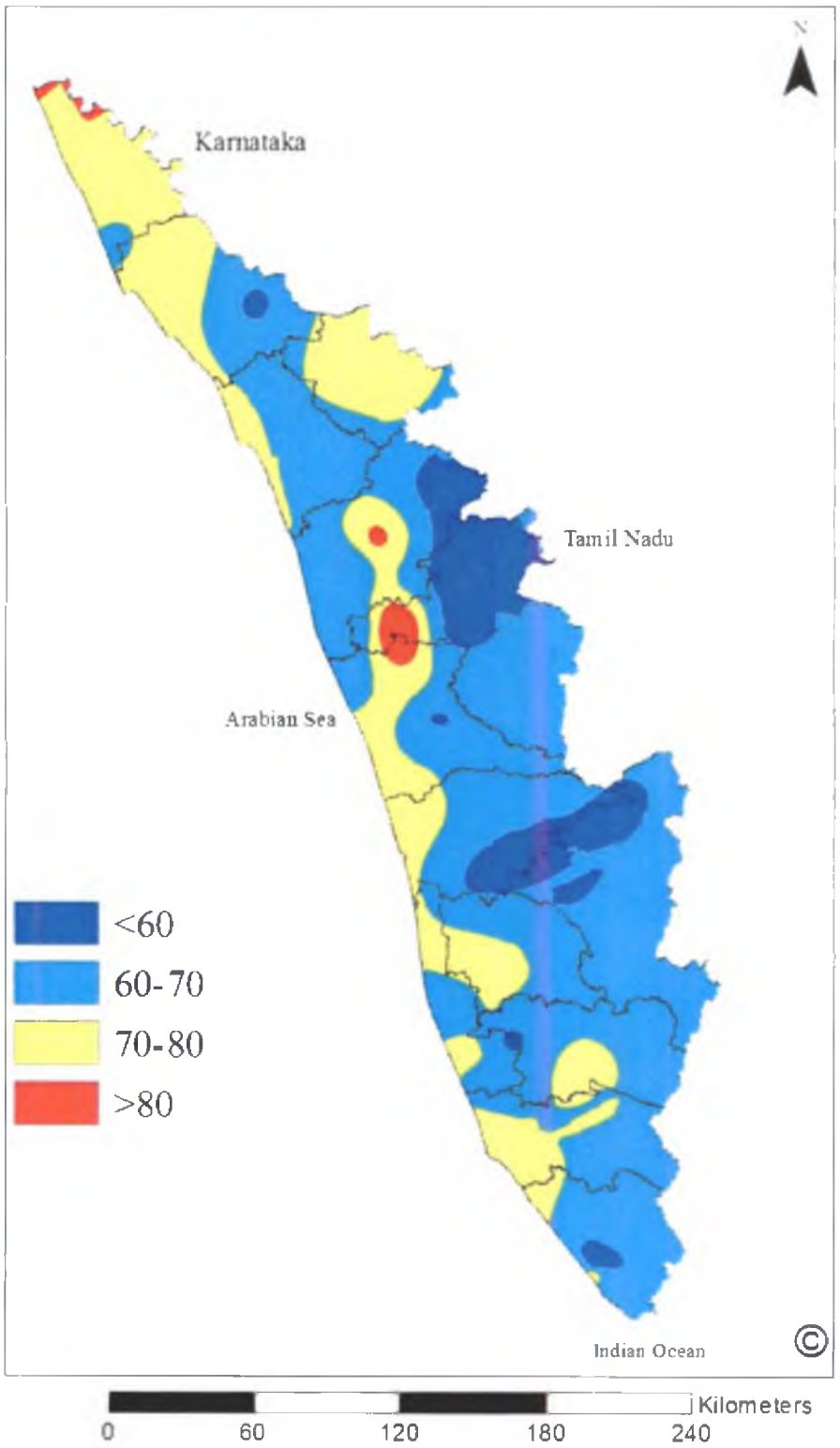


Fig. 85 (a): Probability of near normal rainfall during Northeast monsoon (SPI between -0.99 to +0.99) in Kerala

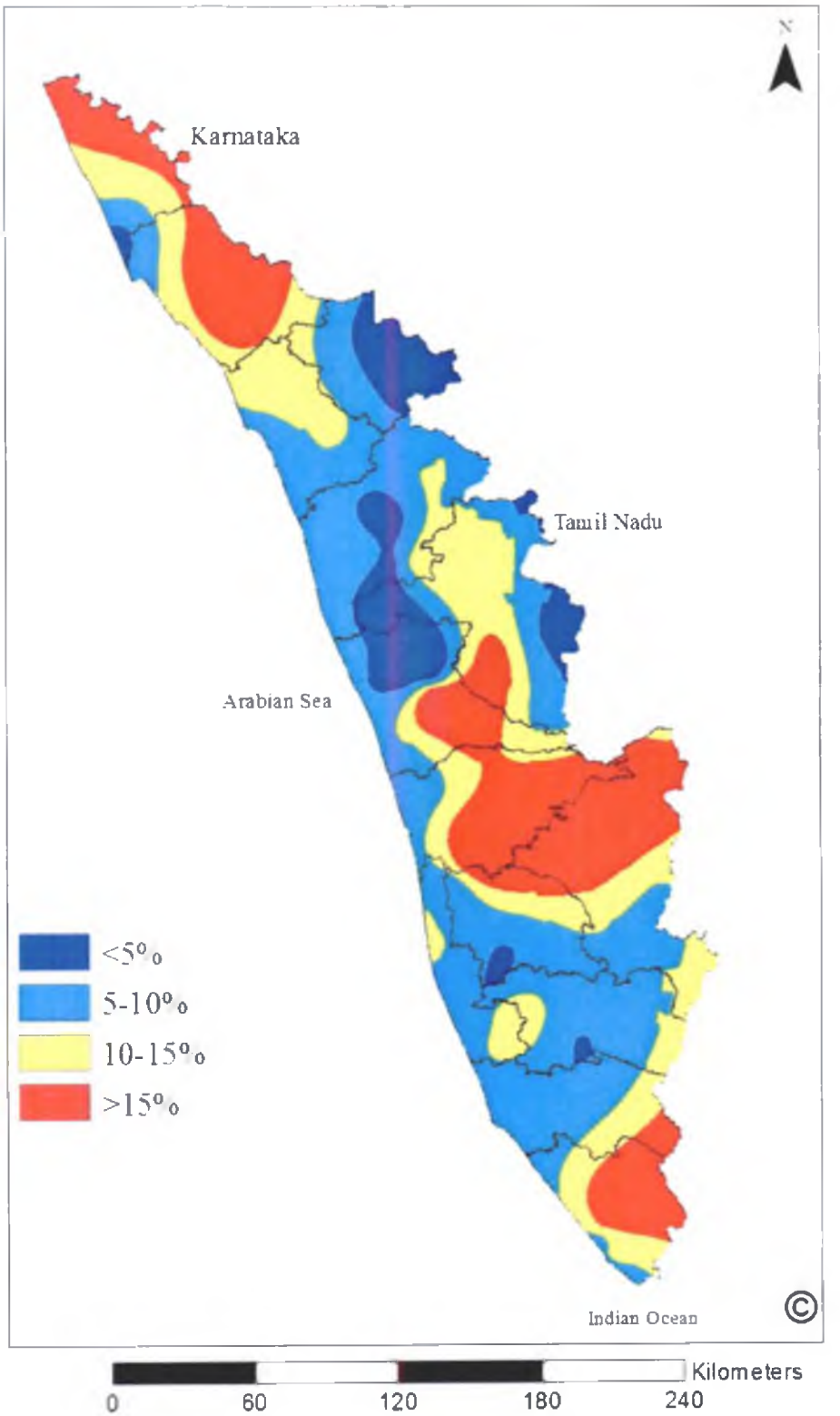


Fig. 85 (b): Probability of moderately dry rainfall during Northeast monsoon (SPI between -1.00 to -1.49) in Kerala

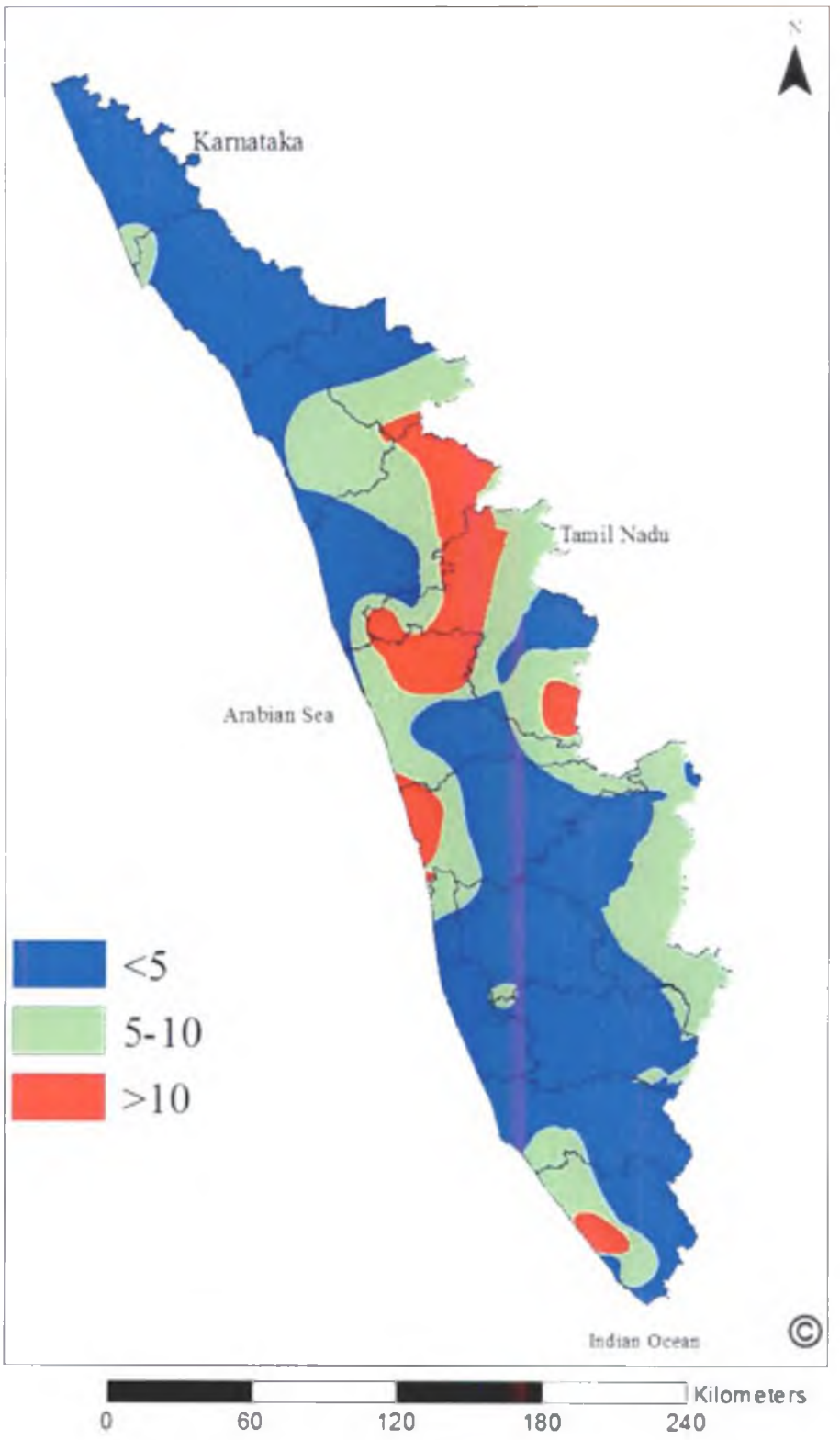


Fig. 85 (c): Probability of severely dry rainfall during Northeast monsoon (SPI between -1.5 to -1.99) in Kerala

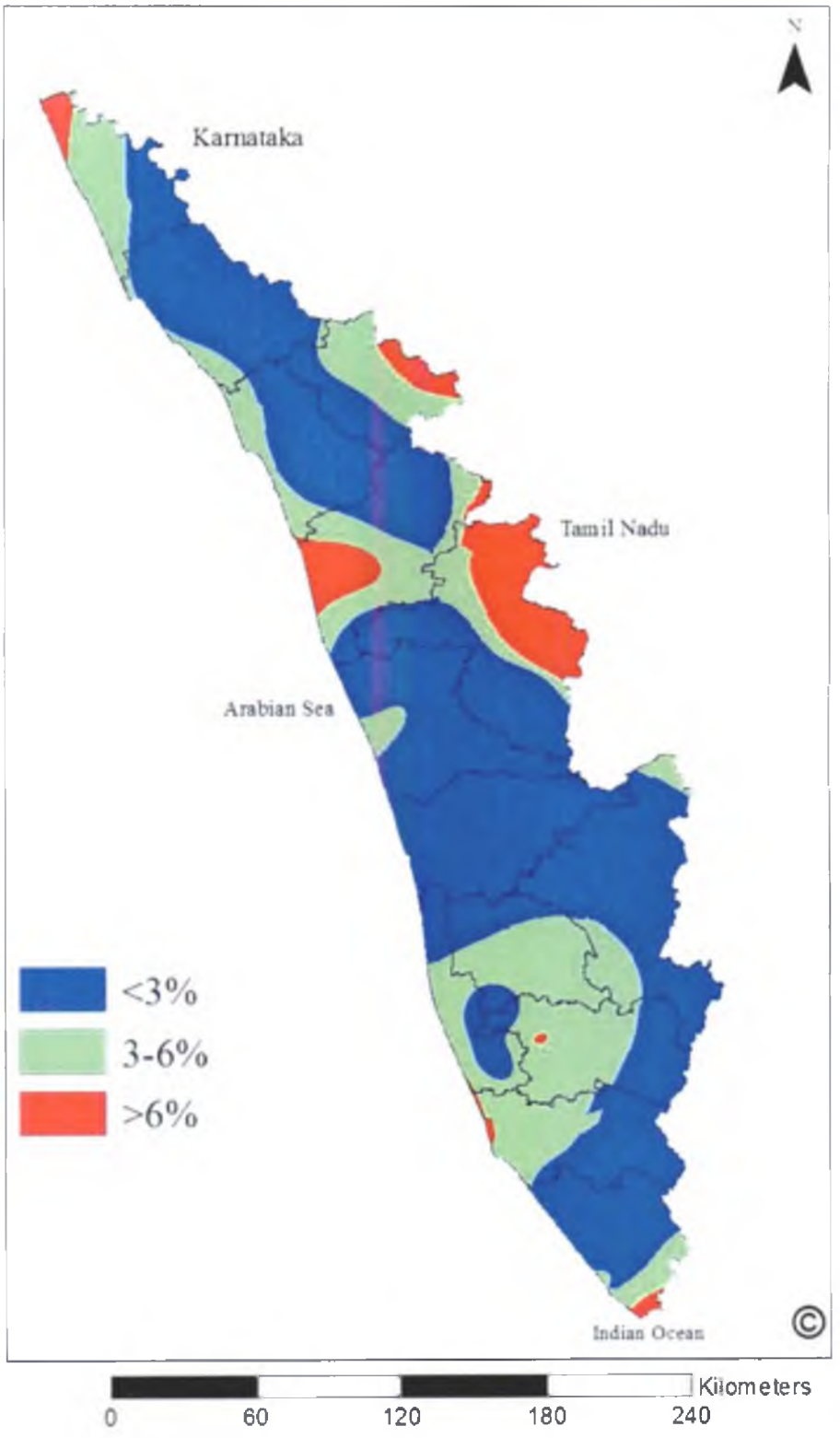


Fig. 85(d): Probability of extremely dry rainfall during Northeast monsoon (SPI less than -2.0) in Kerala

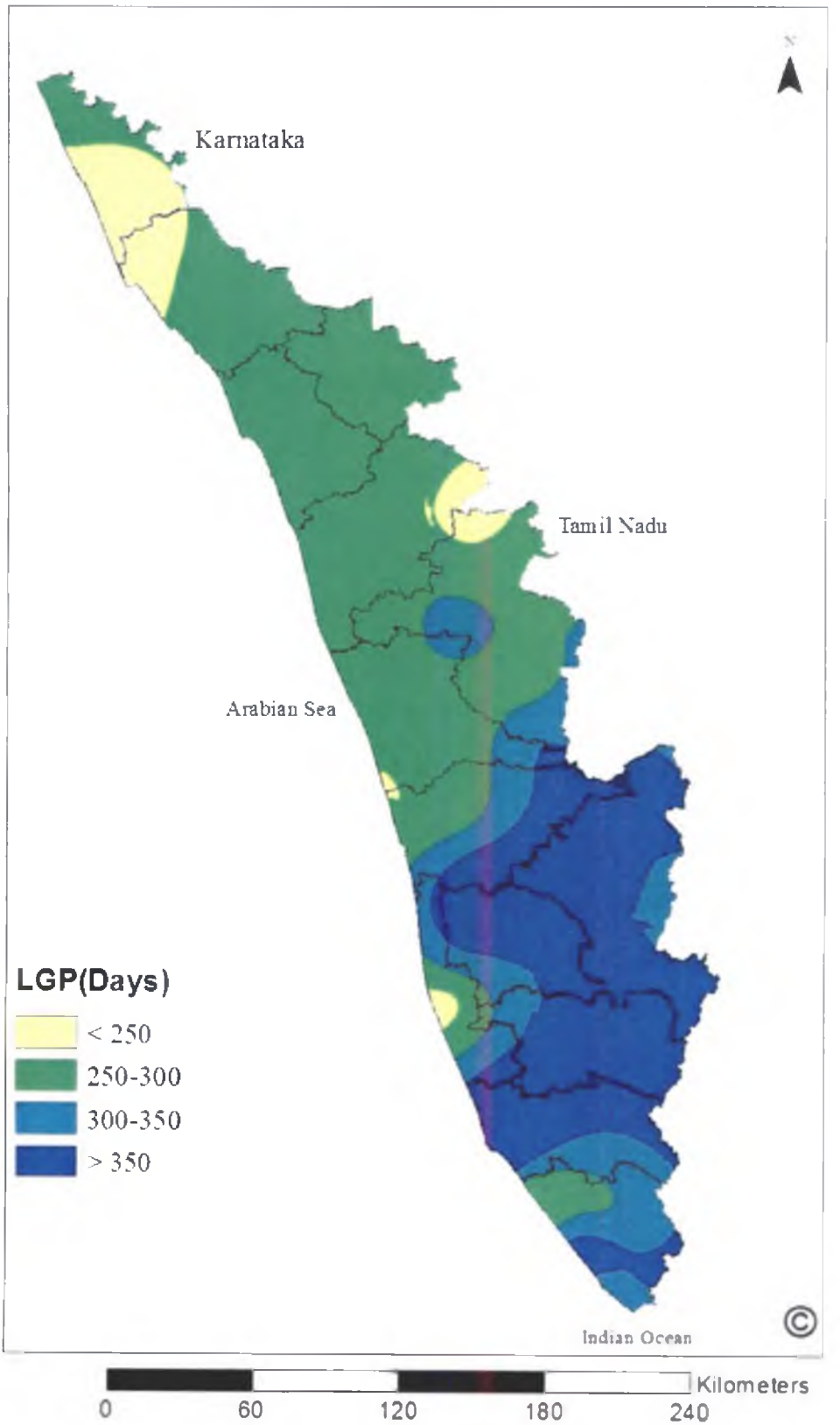


Fig. 86: Length of growing period (LGP) in Kerala

Table 17: Start, end and duration of crop growing season in soils with different water holding capacities in various districts in Kerala

Districts	50mm			100mm			150mm			200mm		
	Start	End	Duration	Start	End	Duration	Start	End	Duration	Start	End	Duration
Alappuzha	21	1	33	21	9	41	21	22	54	21	39	71
Kannur	21	50	30	21	2	33	21	4	36	22	9	40
Kasargode	21	51	31	22	3	34	21	28	60	21	15	47
Kozhikkode	21	51	31	21	3	34	21	6	37	21	8	39
Kottayam	22	49	28	22	52	31	22	5	36	22	11	42
Malappuram	21	49	28	21	52	31	21	2	34	21	5	37
Wayanad	21	50	30	21	1	33	22	4	35	22	6	37
Idukki	22	1	32	22	8	39	22	12	43	21	22	2
Ernakulam	21	52	32	21	5	37	21	11	43	21	19	51
Palakkad	22	50	29	21	1	33	21	4	35	22	7	39
Thrissur	21	50	30	21	1	33	21	5	37	21	7	39
Thiruvananthapuram	21	3	35	21	10	42	21	19	51	21	33	65
Kollam	21	52	32	21	8	40	21	14	46	21	19	51

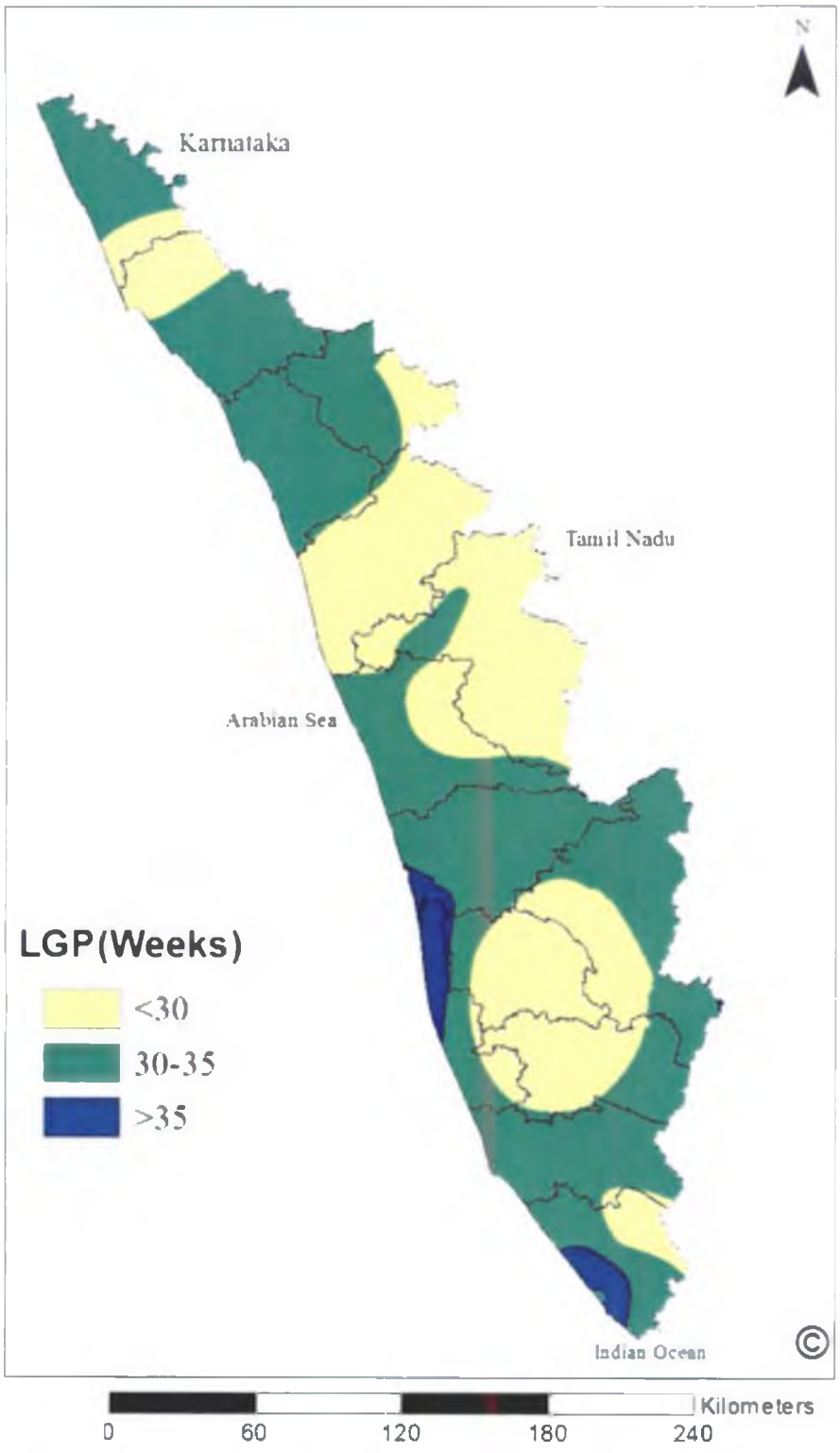


Fig. 87(a): LGP (weeks) soils having water holding capacity of 50 mm in Kerala

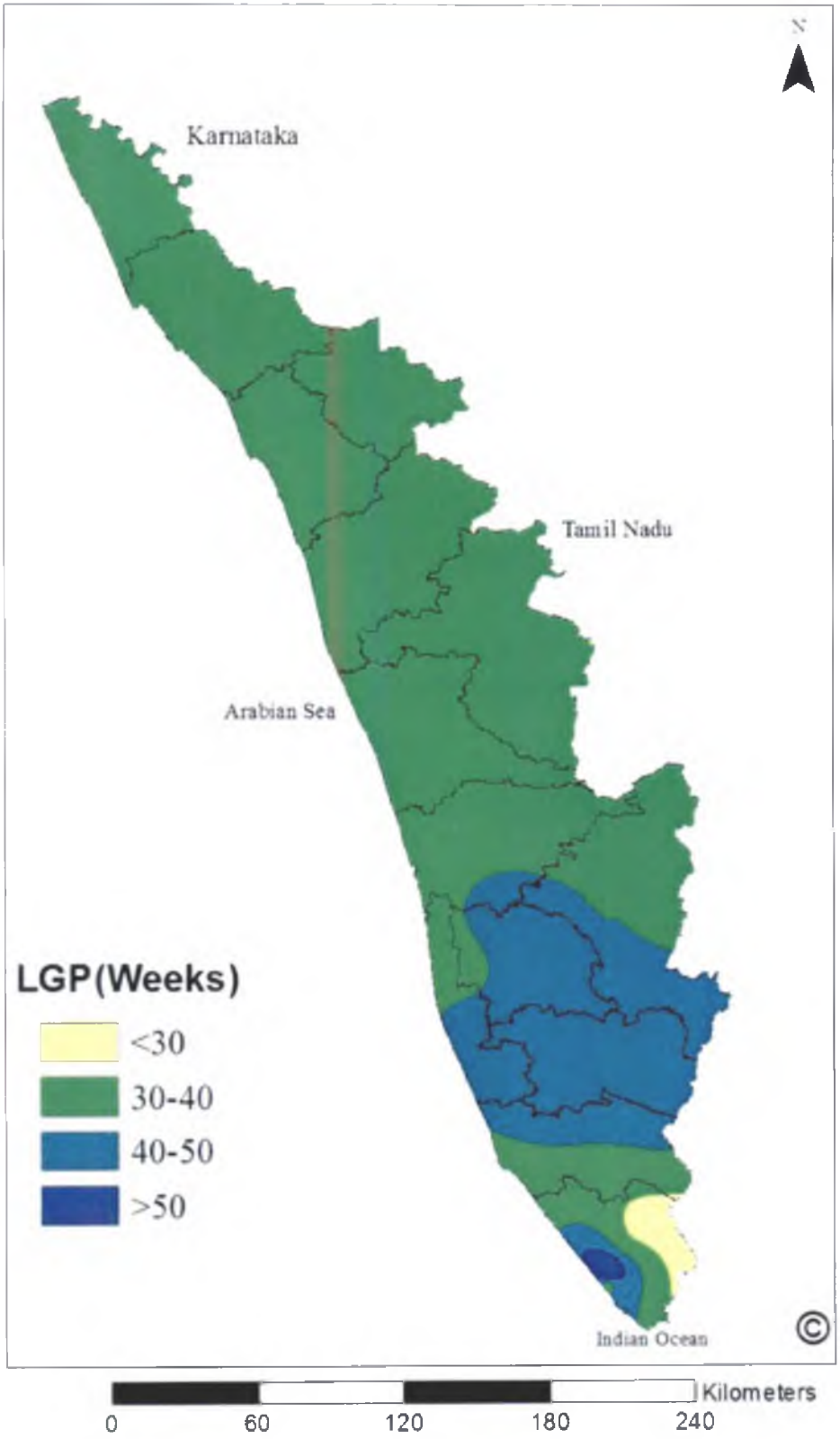


Fig. 87(b): LGP (weeks) soils having water holding capacity of 100 mm in Kerala

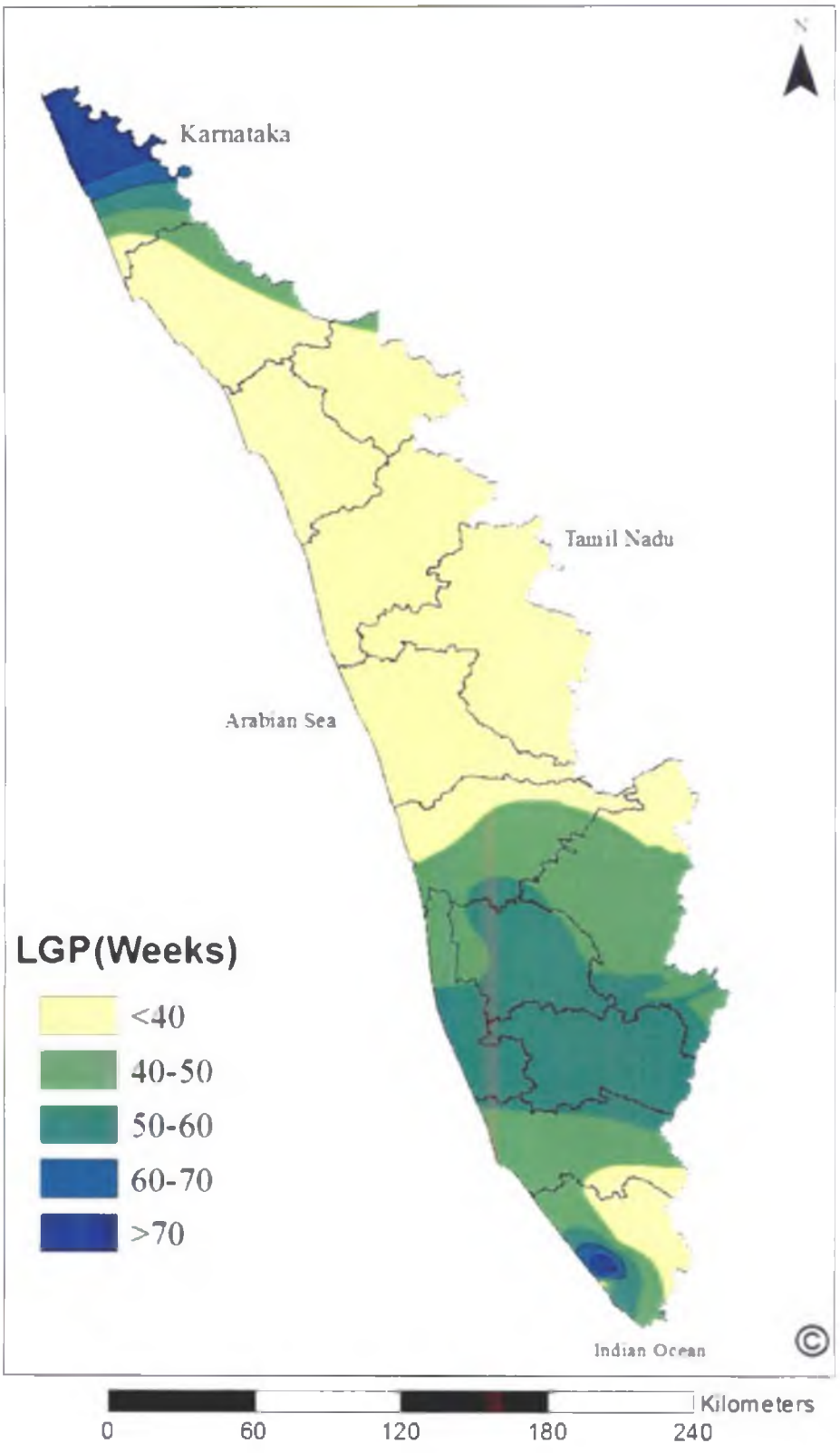


Fig. 87(c): LGP (weeks) soils having water holding capacity of 150 mm in Kerala

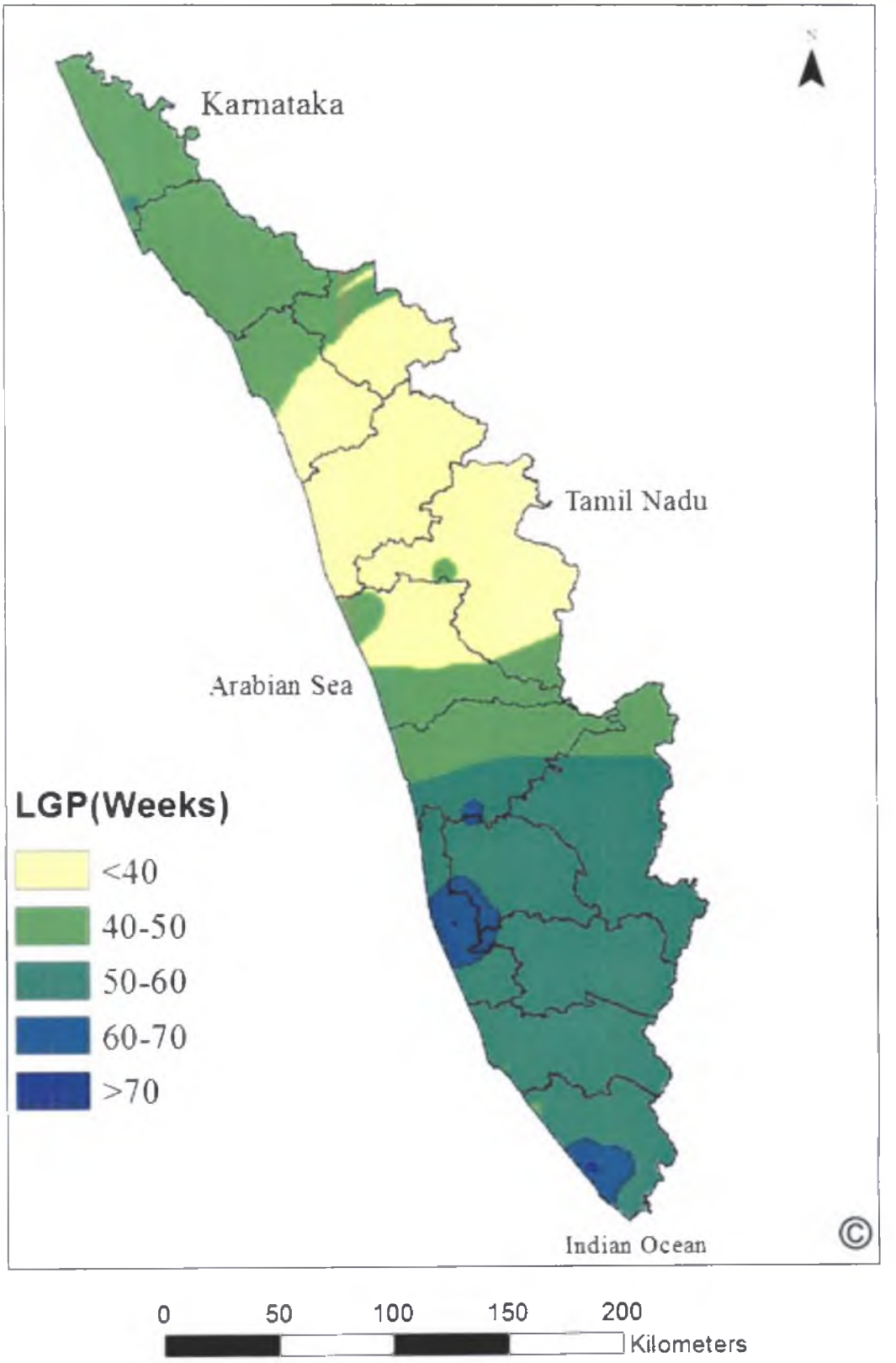


Fig. 87(d): LGP (weeks) soils having water holding capacity of 200 mm in Kerala

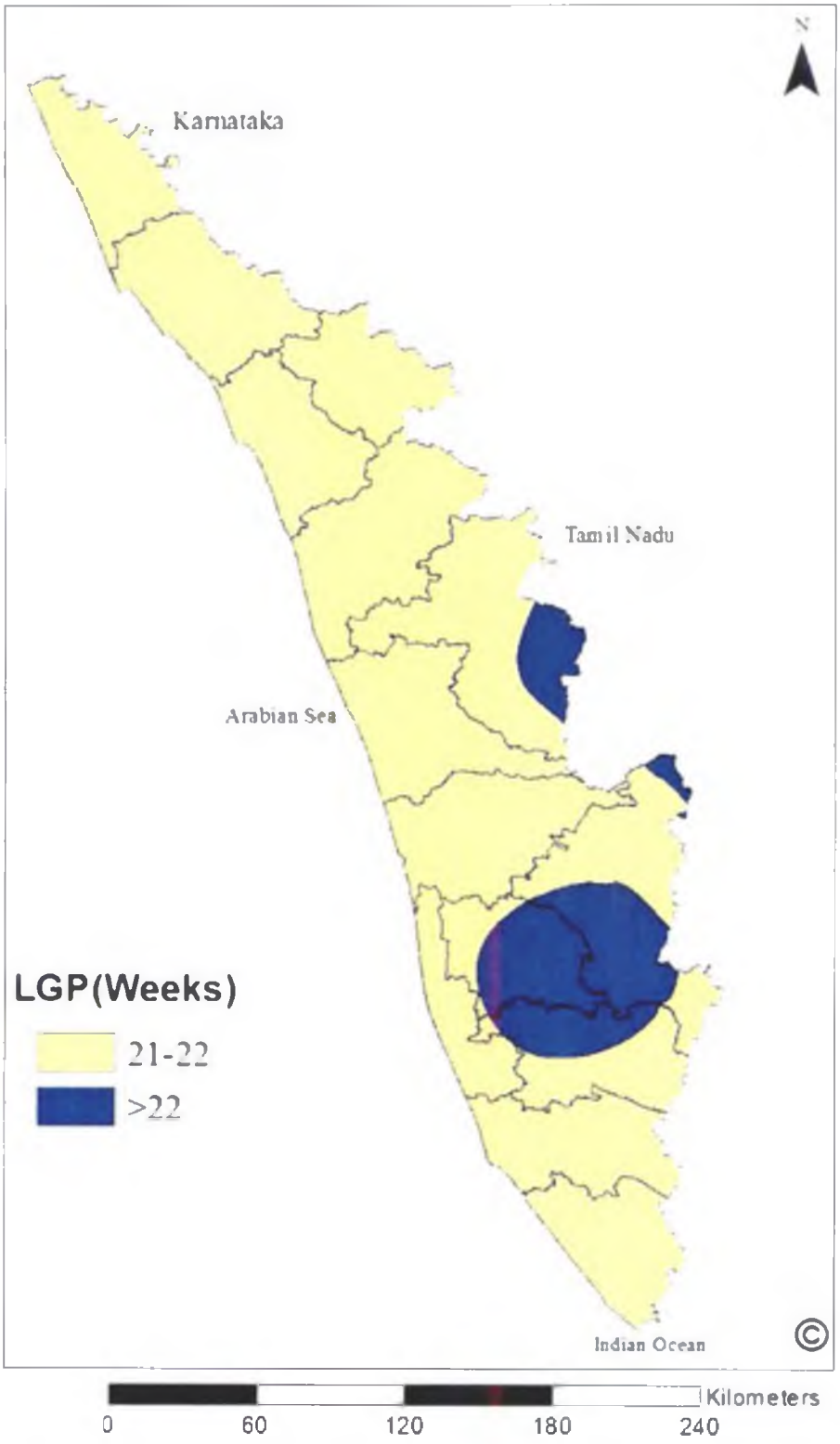


Fig. 88(a): Commencement of growing season (SMW) for soils having water holding capacity of 50 mm in Kerala

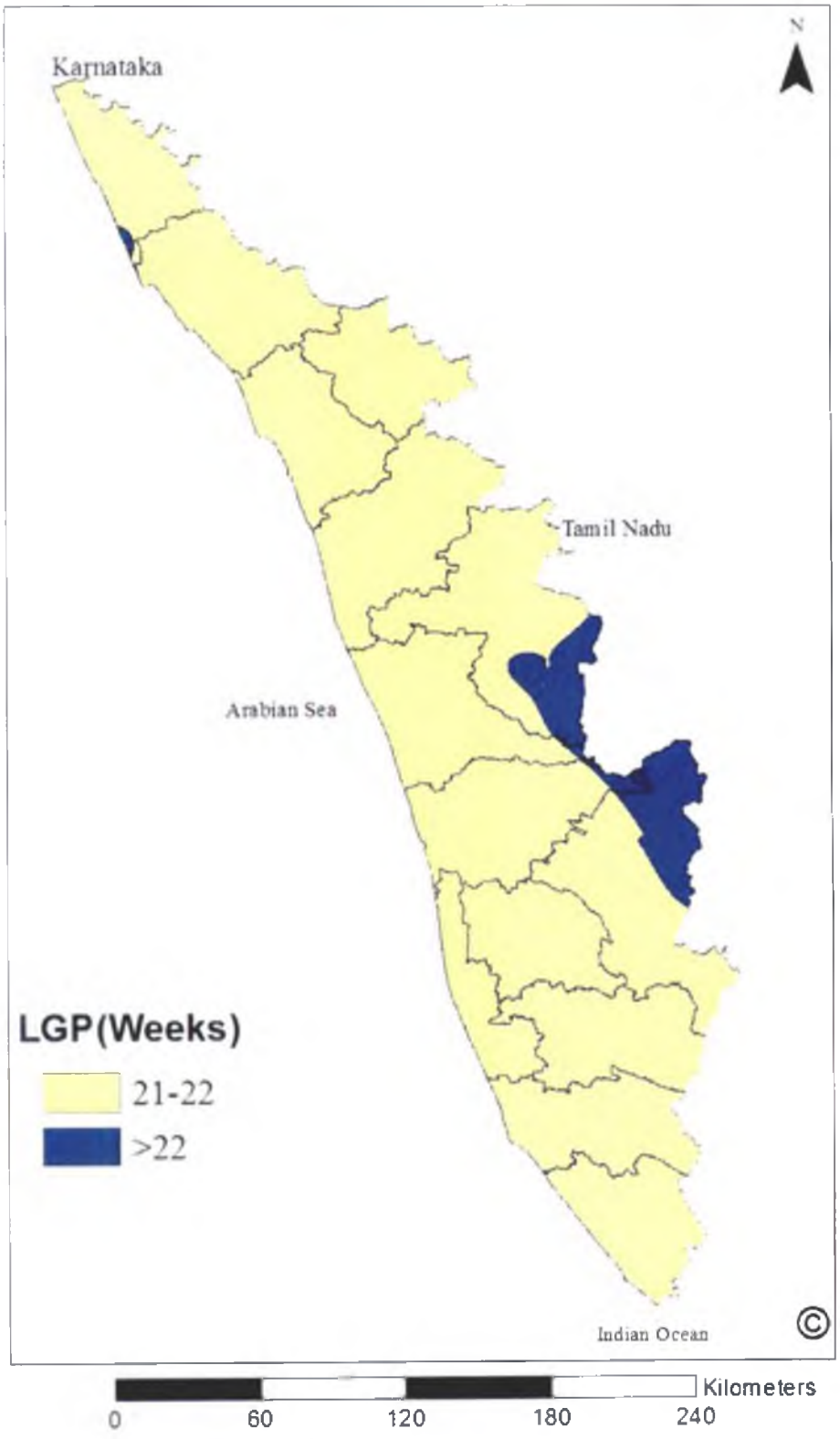


Fig. 88(b): Commencement of growing season (SMW) for soils having water holding capacity of 100 mm in Kerala

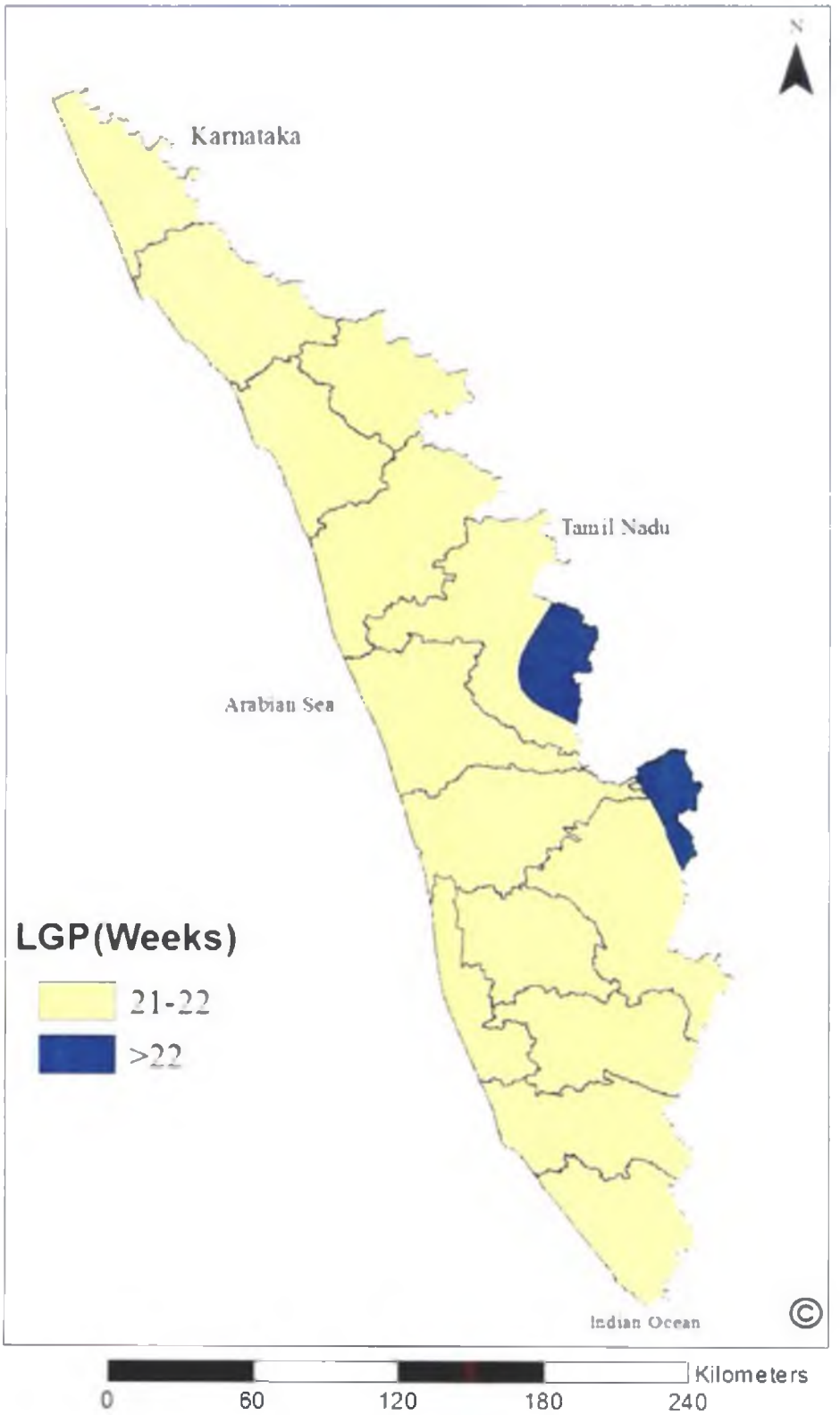


Fig. 88(c): Commencement of growing season (SMW) for soils having water holding capacity of 150 mm in Kerala

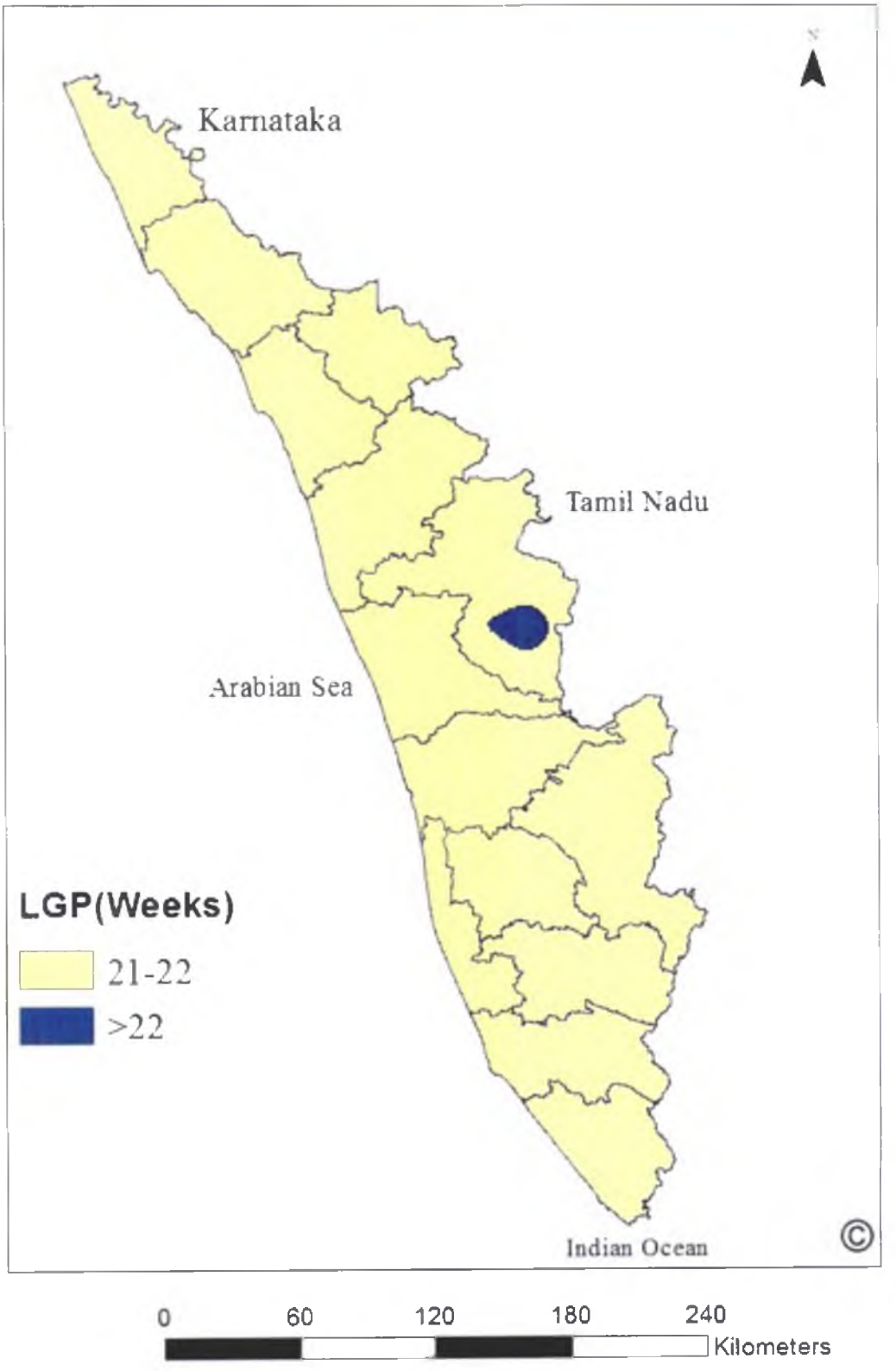


Fig. 88(d): Commencement of growing season (SMW) for soils having water holding capacity of 200 mm in Kerala

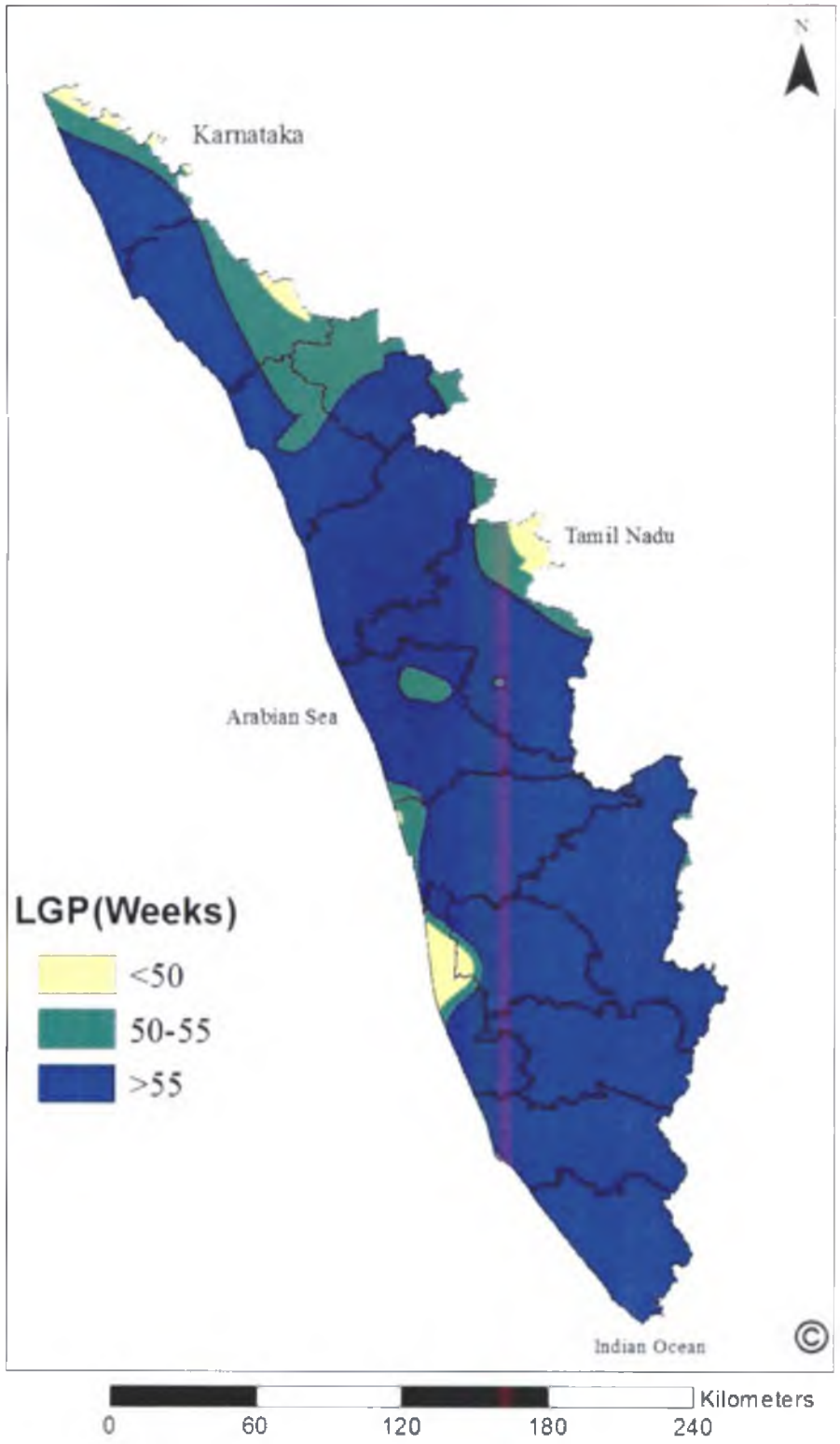


Fig. 89 (a): Termination of growing season (SMW) for soils having water holding capacity of 50 mm in Kerala

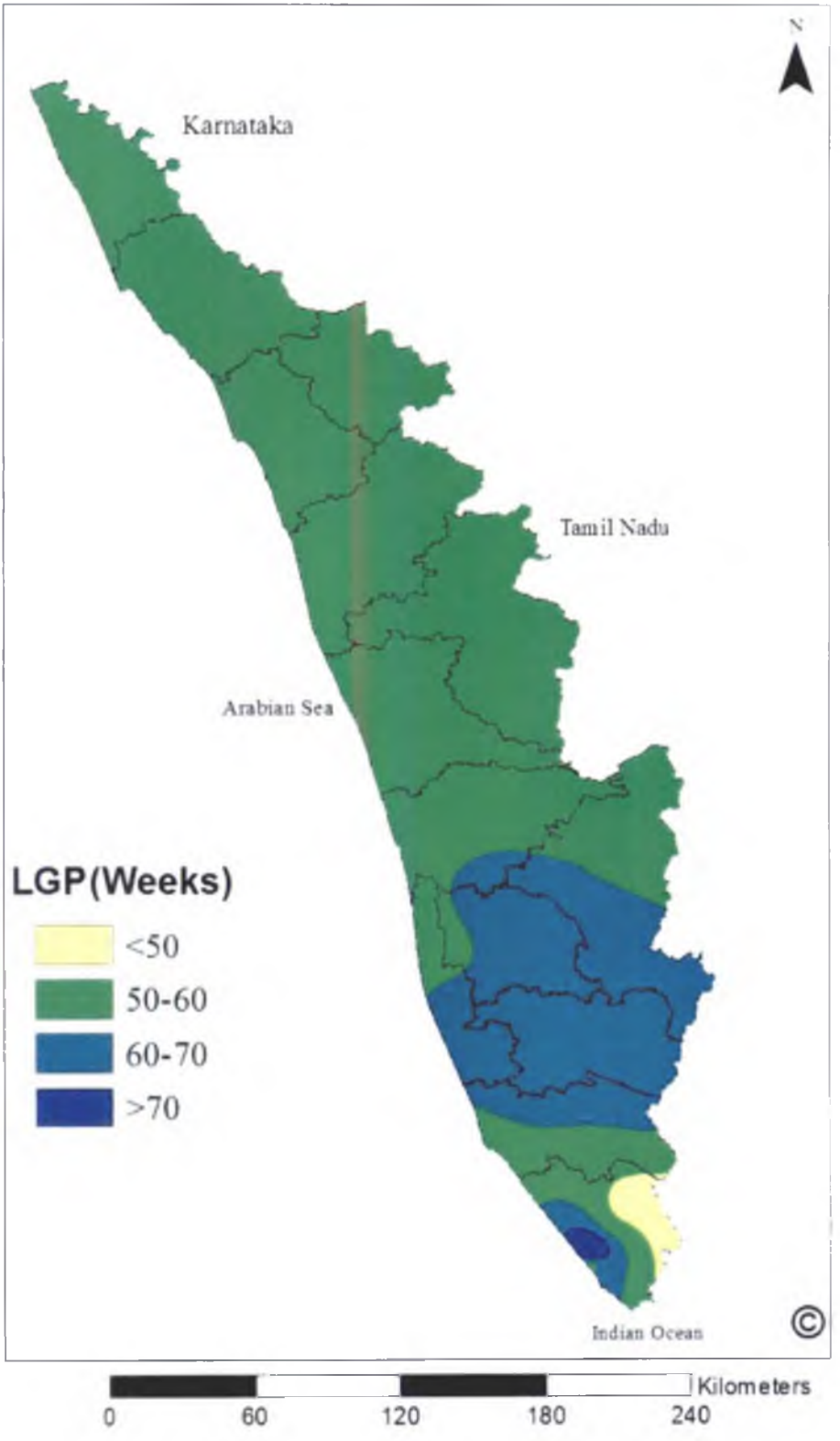


Fig. 89 (b): Termination of growing season (SMW) for soils having water holding capacity of 100 mm in Kerala

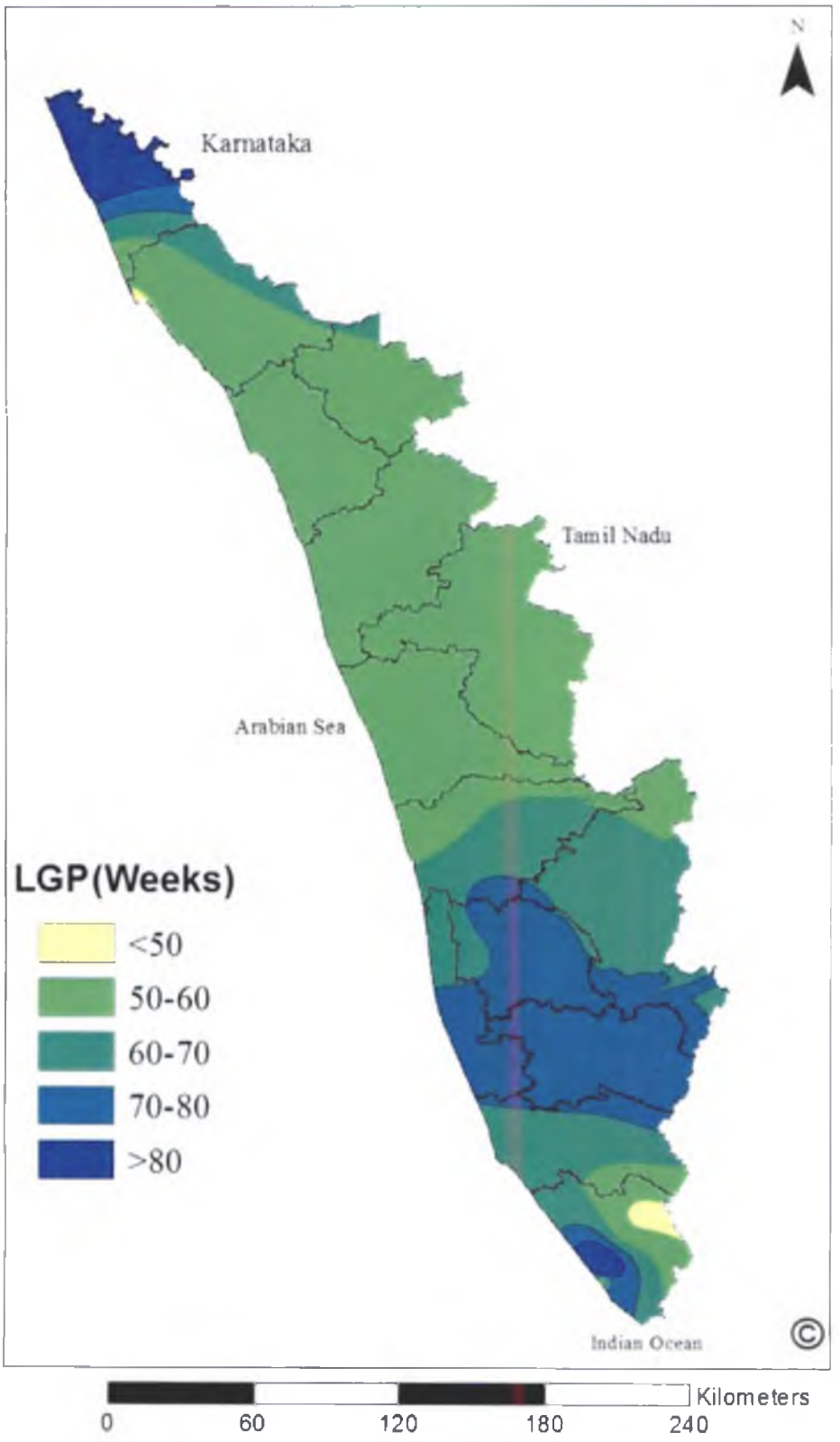


Fig. 89 (c): Termination of growing season (SMW) for soils having water holding capacity of 150 mm in Kerala

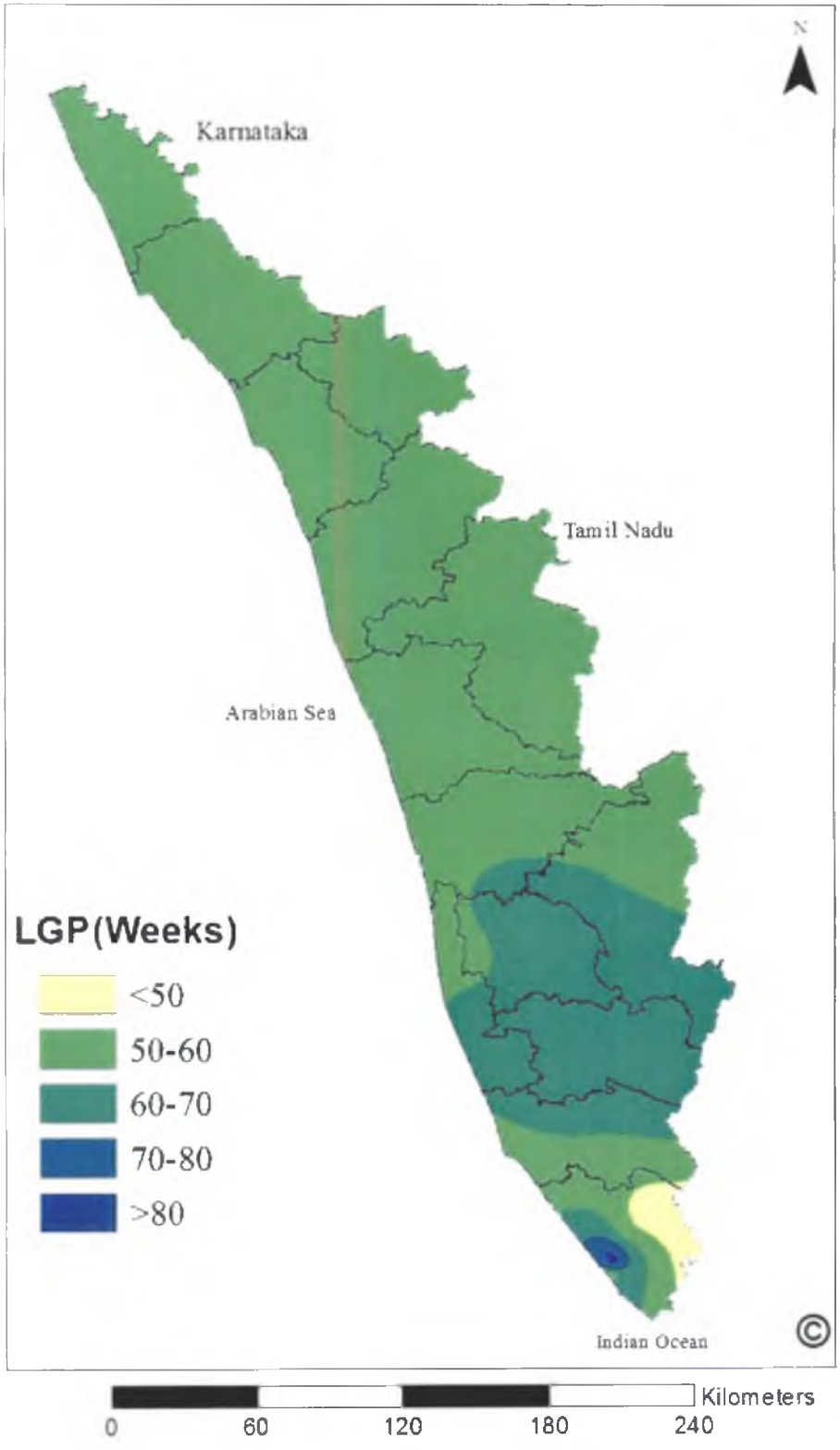
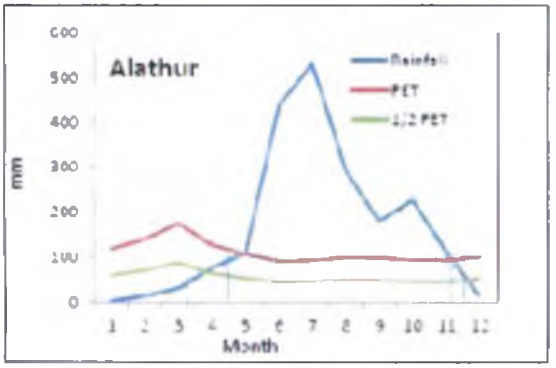
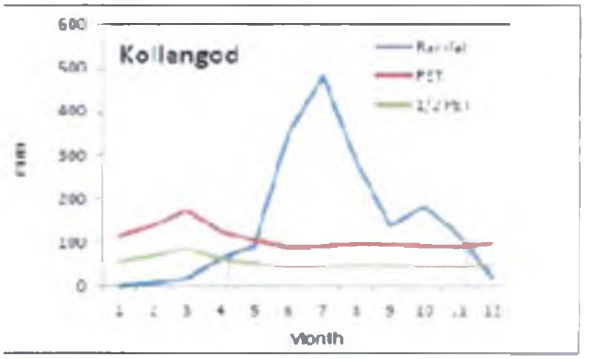
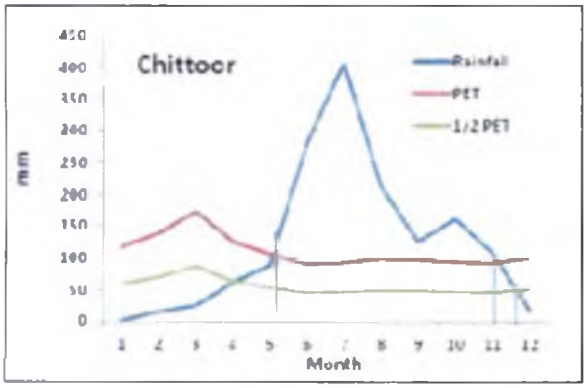
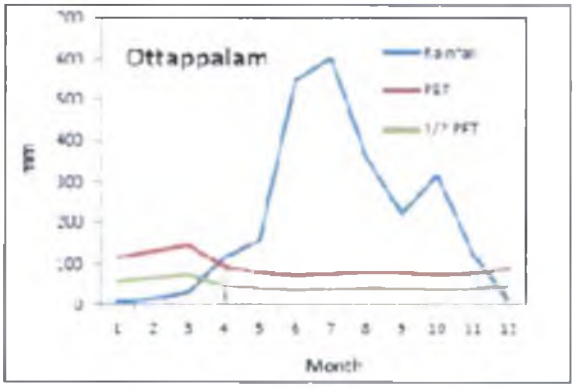


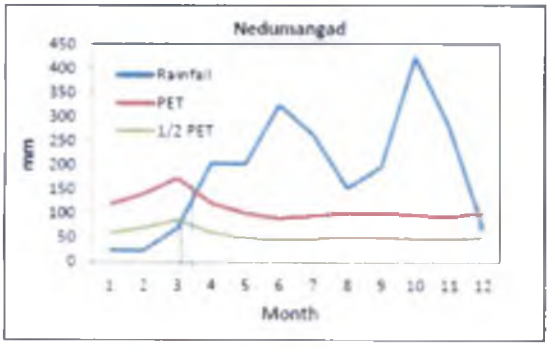
Fig. 89 (d): Termination of growing season (SMW) for soils having water holding capacity of 200 mm in Kerala

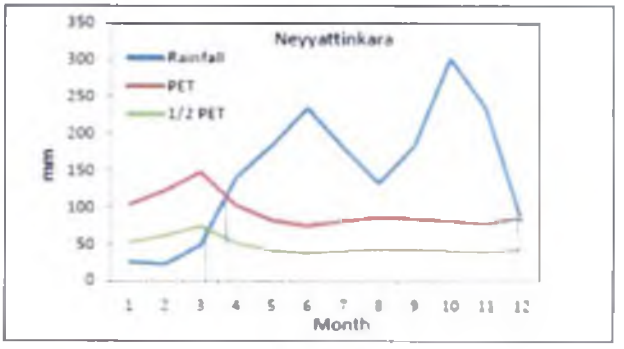

Alathur
Rainfall
PET
1/2 PET
mm
Month

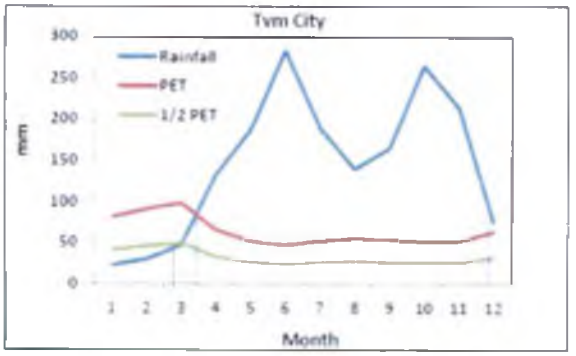

Kollangod
Rainfall
PET
1/2 PET
mm
Month

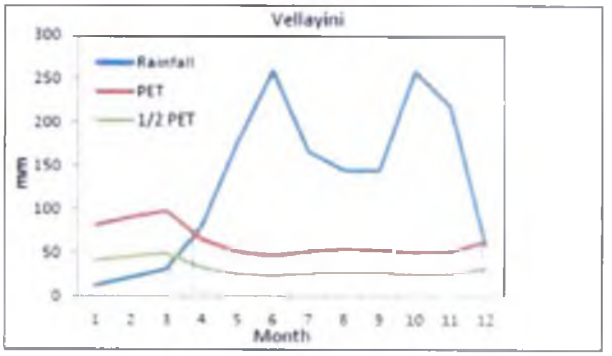

Chittoor
Rainfall
PET
1/2 PET
mm
Month

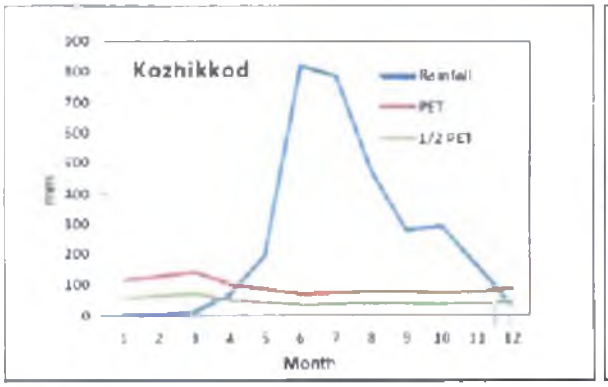

Ottappalam
Rainfall
PET
1/2 PET
mm
Month

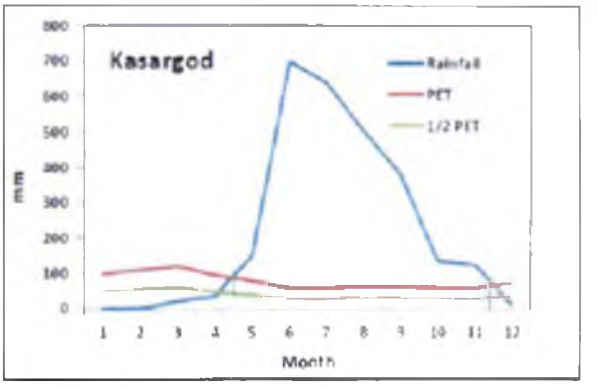

Nedumangad
Rainfall
PET
1/2 PET
mm
Month

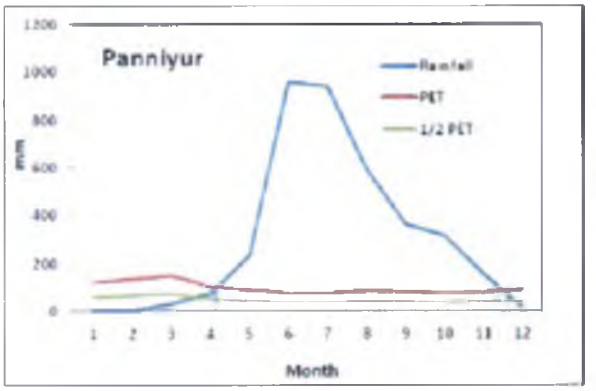

Neyyattinkara
Rainfall
PET
1/2 PET
mm
Month

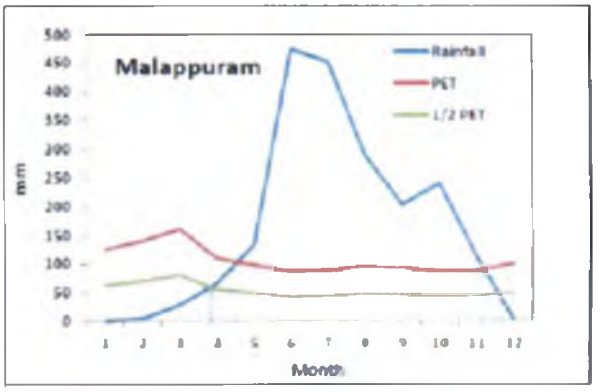

Tvm City
Rainfall
PET
1/2 PET
mm
Month

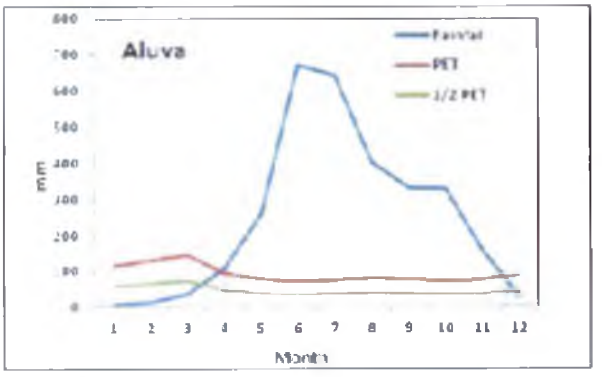

Vellayini
Rainfall
PET
1/2 PET
mm
Month

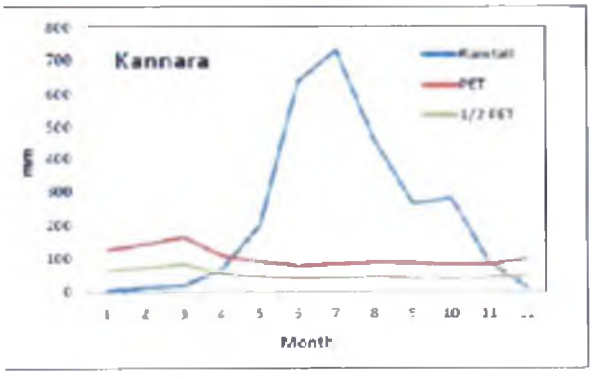

Kozhikkod
Rainfall
PET
1/2 PET
mm
Month

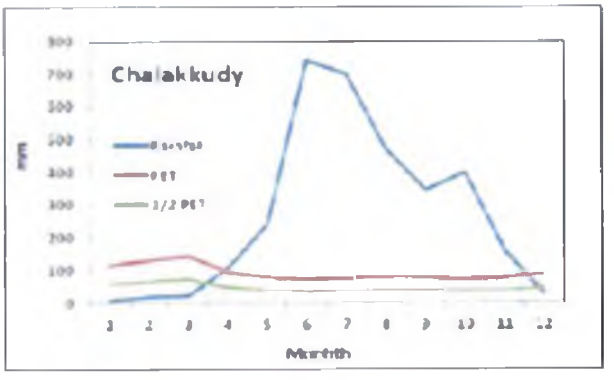

Kasargod
Rainfall
PET
1/2 PET
mm
Month

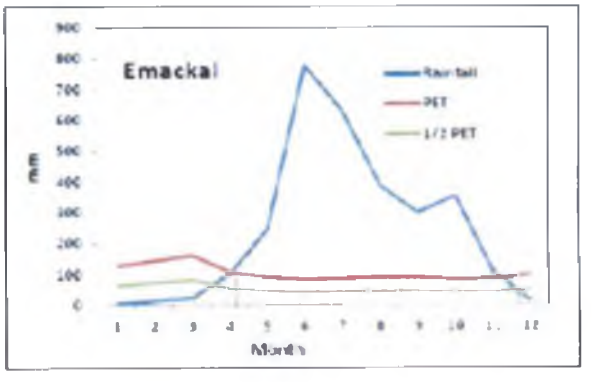

Panniyur
Rainfall
PET
1/2 PET
mm
Month

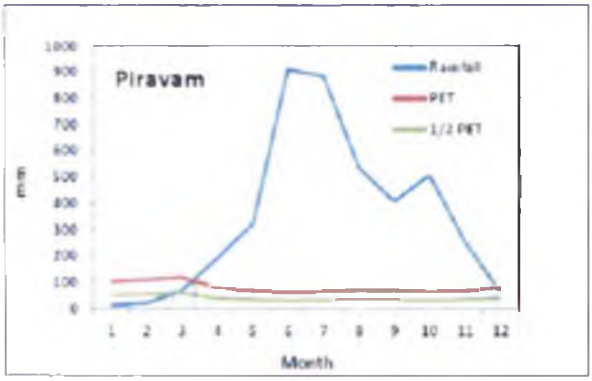

Malappuram
Rainfall
PET
1/2 PET
mm
Month

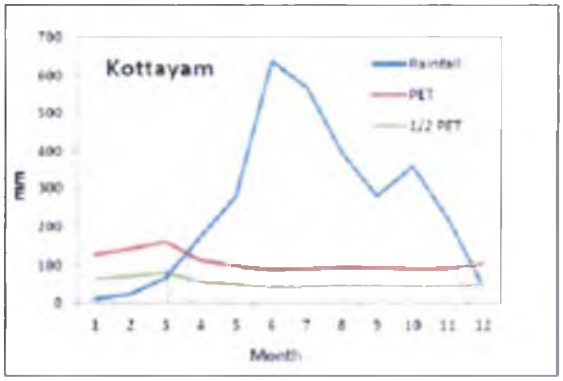

Aluva
PET
1/2 PET
mm
Month

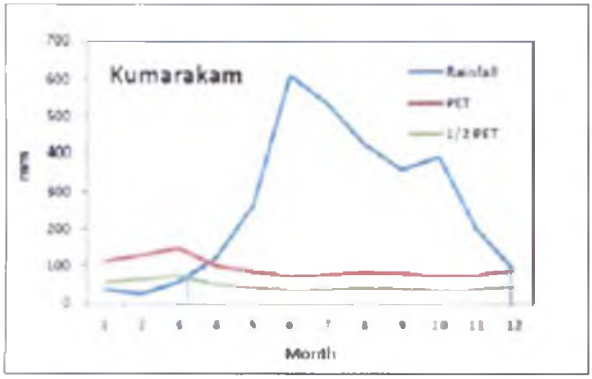

Kannara
PET
1/2 PET
mm
Month

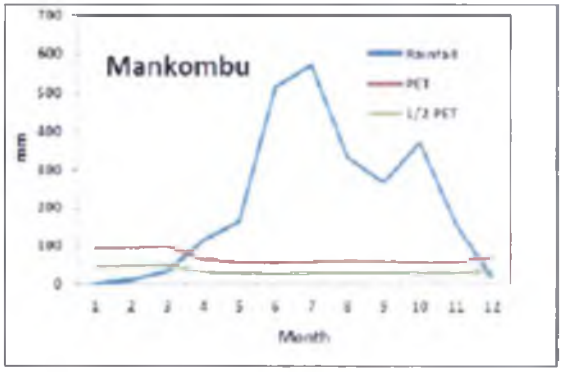

Chalakkudy
1/2 PET
mm

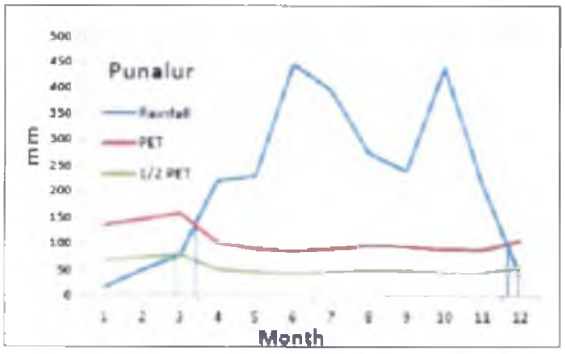

Emackal
Rainfall
PET
1/2 PET
mm
Month

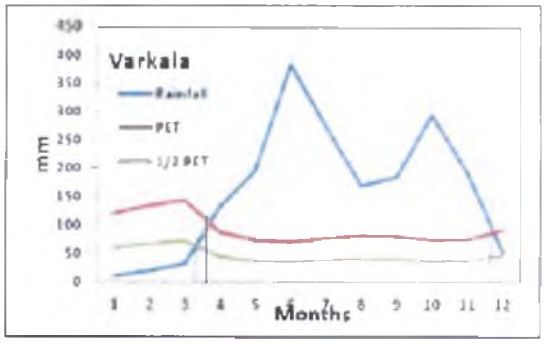

Piravam
Rainfall
PET
1/2 PET
mm
Month

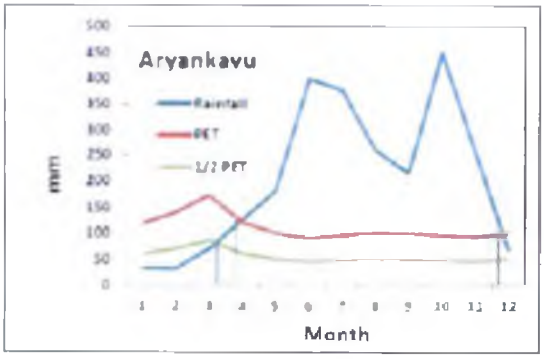

Kottayam
Rainfall
PET
1/2 PET
mm
Month

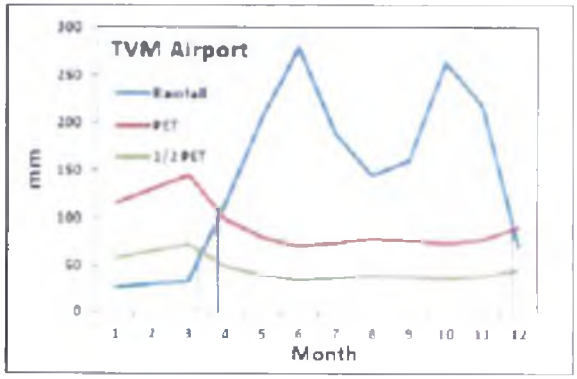

Kumarakam
Rainfall
PET
1/2 PET
mm
Month

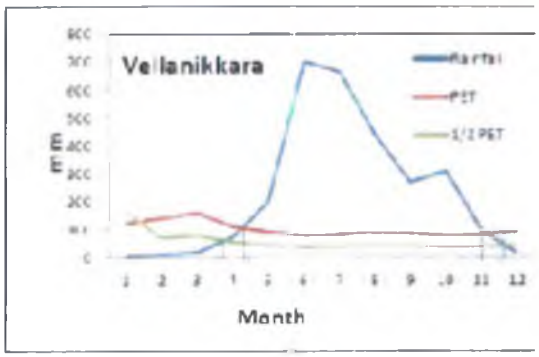

Mankombu
Rainfall
PET
1/2 PET
mm
Month

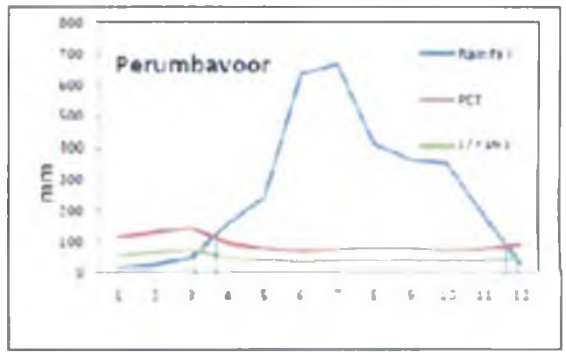

Punalur
Rainfall
PET
1/2 PET
mm
Month

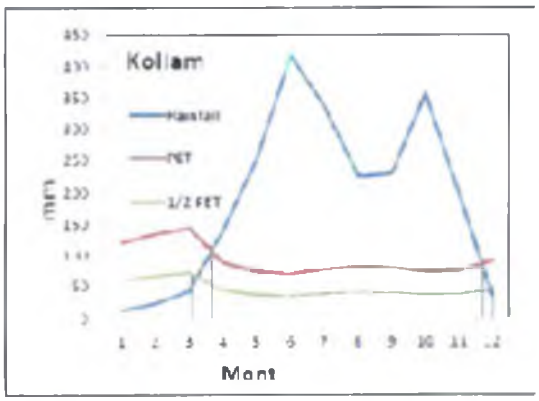

Varkala
Rainfall
PET
1/2 PET
mm
Month

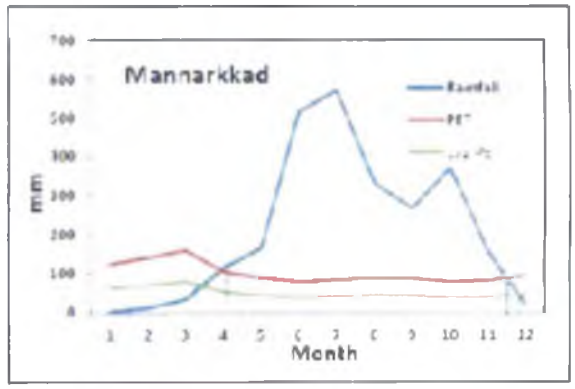

Aryankavu
Rainfall
PET
1/2 PET
mm
Month

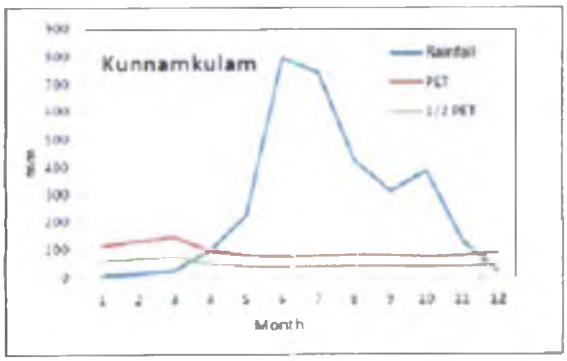

TVM Airport
Rainfall
PET
1/2 PET
mm
Month

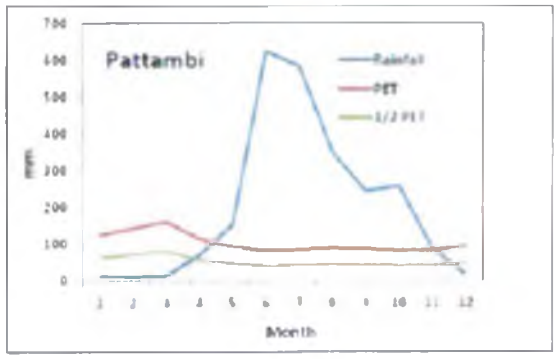

Vellanikkara
Rainfall
PET
1/2 PET
mm
Month

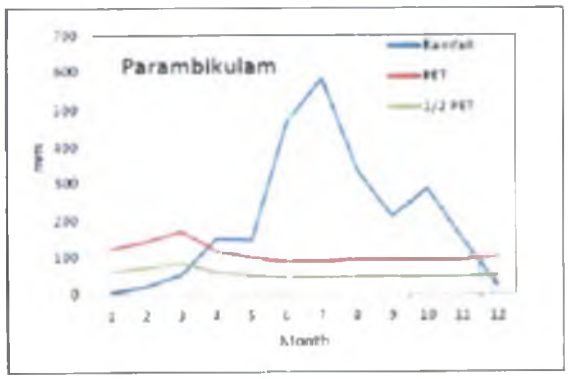

Perumbavoor
Rainfall
PET
1/2 PET
mm

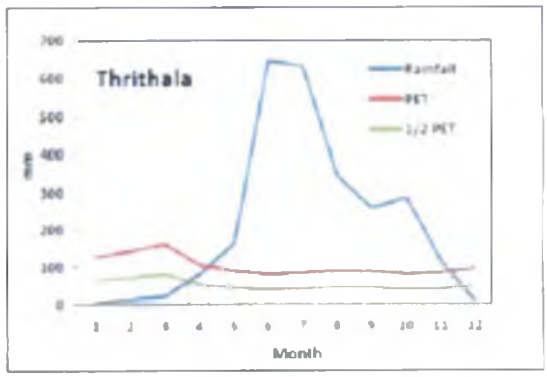

Kollam
Rainfall
PET
1/2 PET
mm
Month


Mannarkkad
Rainfall
PET
mm
Month


Kunnamkulam
Rainfall
PET
1/2 PET
mm
Month


Pattambi
Rainfall
PET
1/2 PET
mm
Month


Parambikulam
Rainfall
PET
1/2 PET
mm
Month


Thrithala
Rainfall
PET
1/2 PET
mm
Month

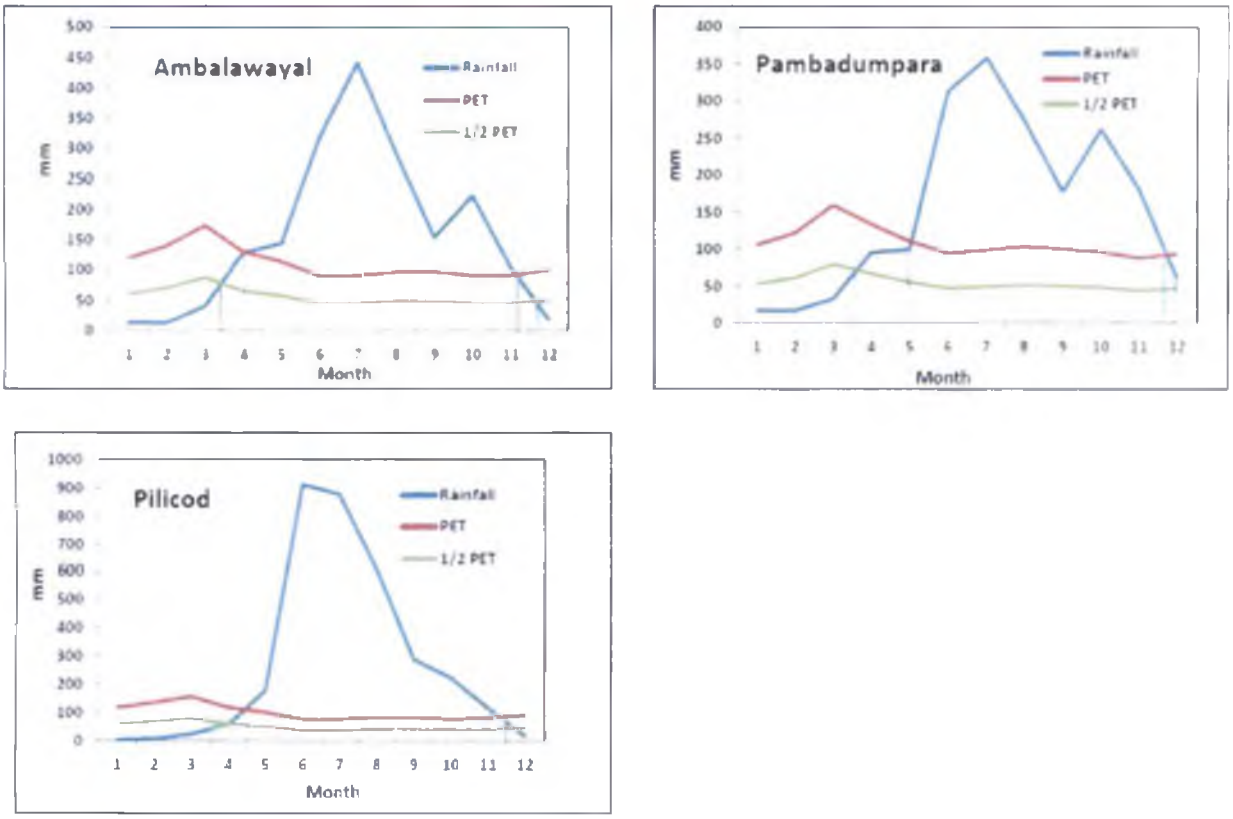


Fig. 90: Water balance for different stations in Kerala

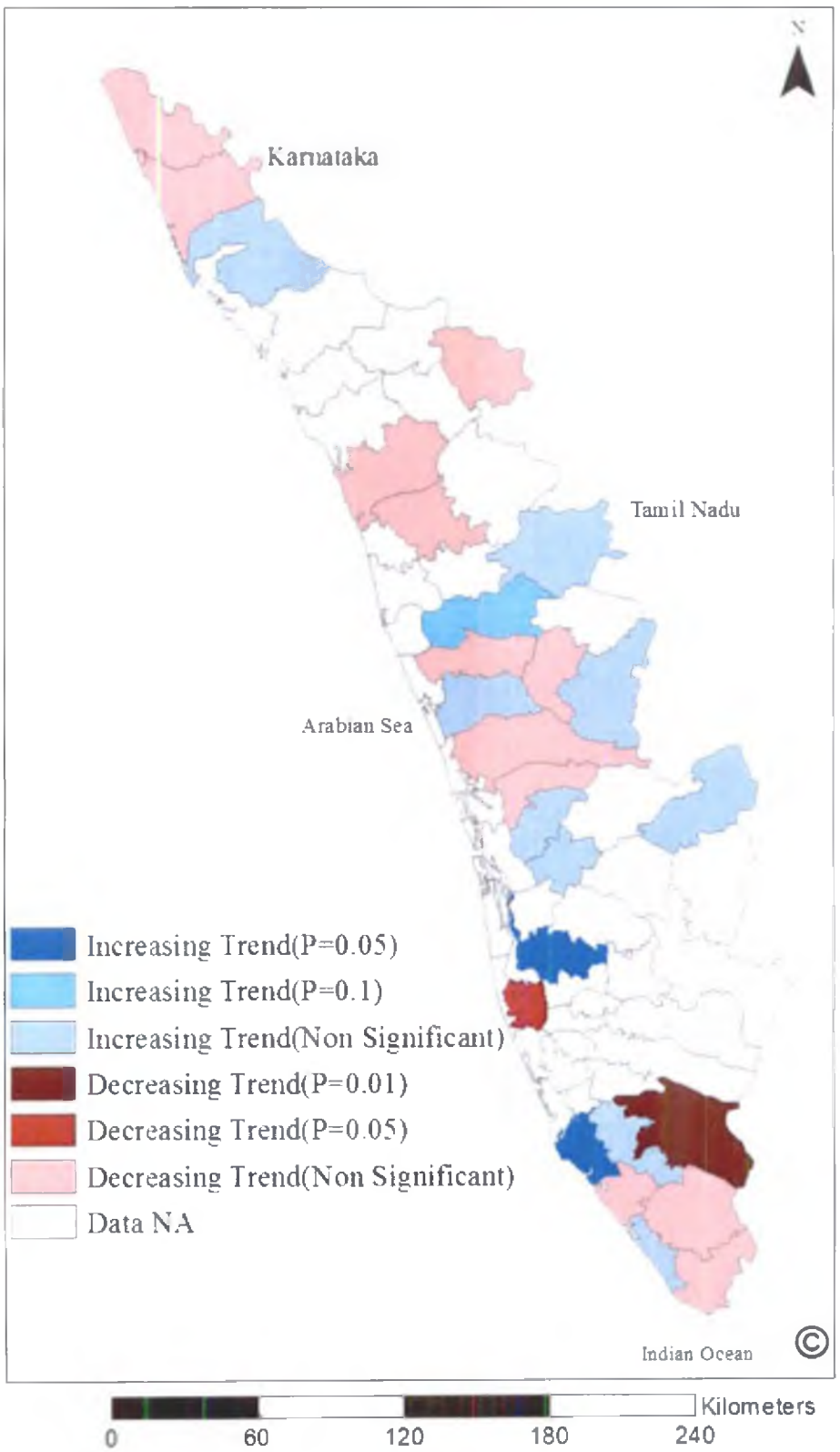


Fig. 91: Taluks showing changes in maximum one-day rainfall episodes in Kerala

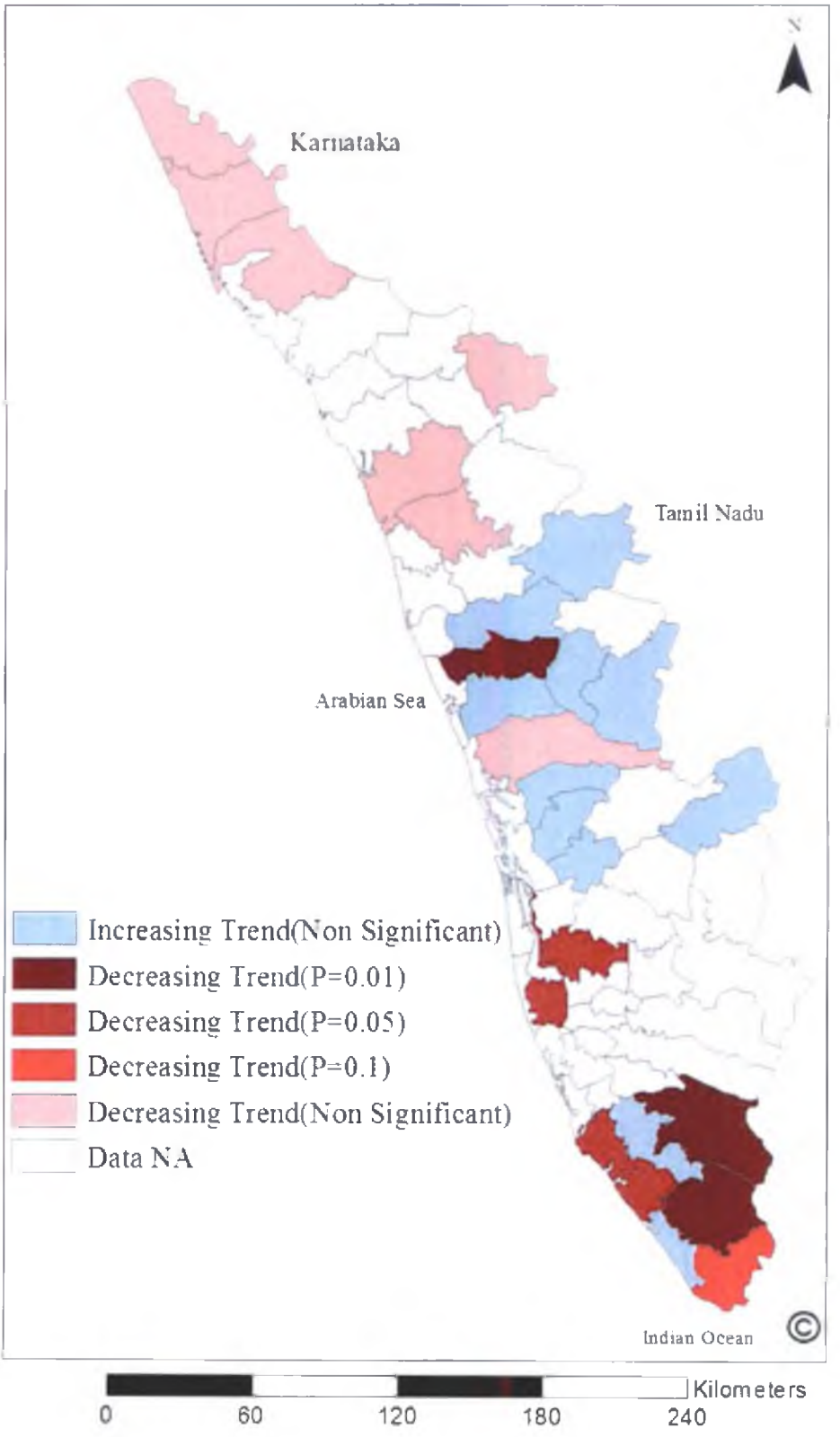


Fig. 92: Taluks in Kerala showing changes in maximum five-day total rainfall

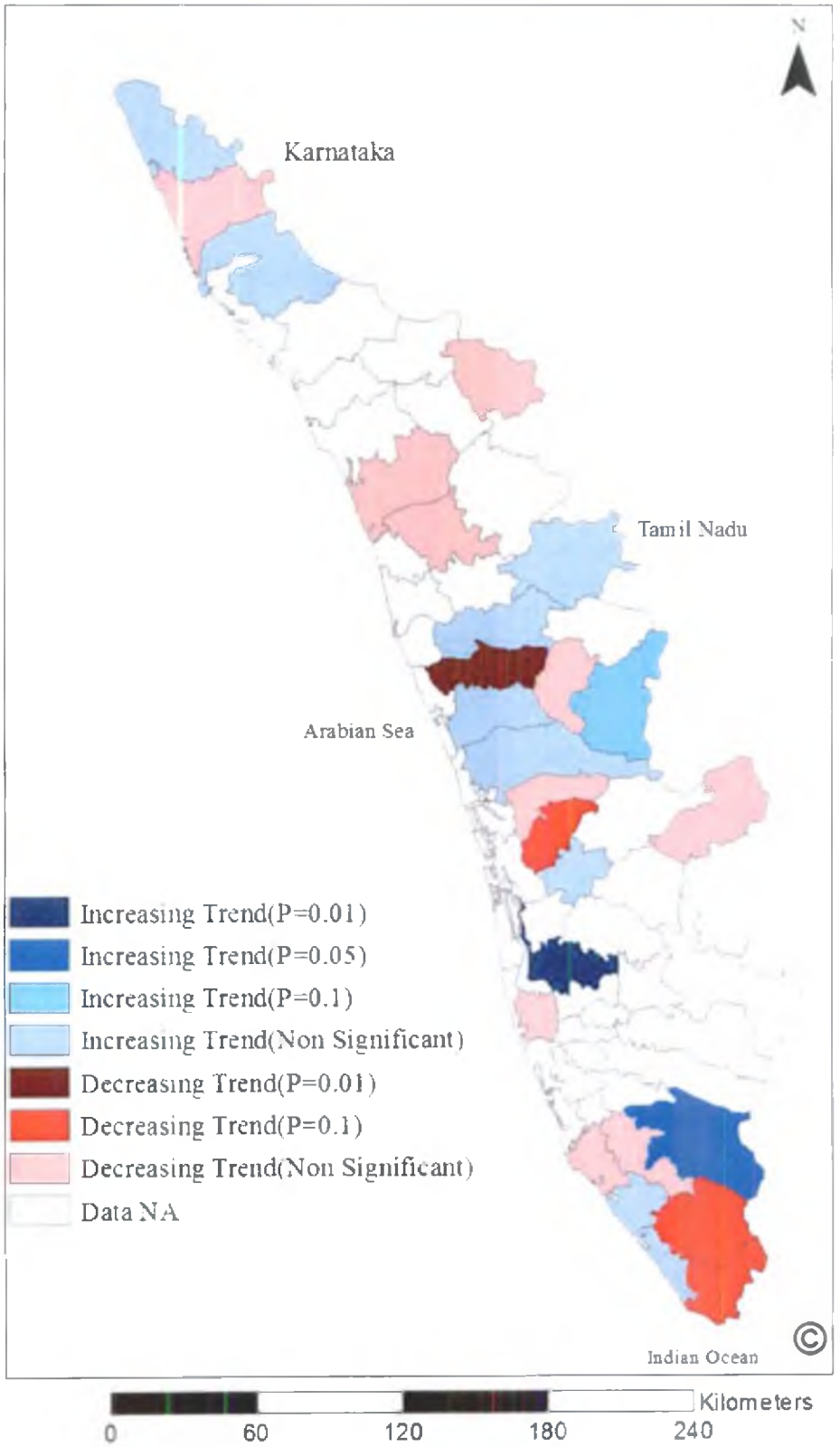


Fig. 93: Taluks in Kerala showing changes in mean daily rainfall intensity

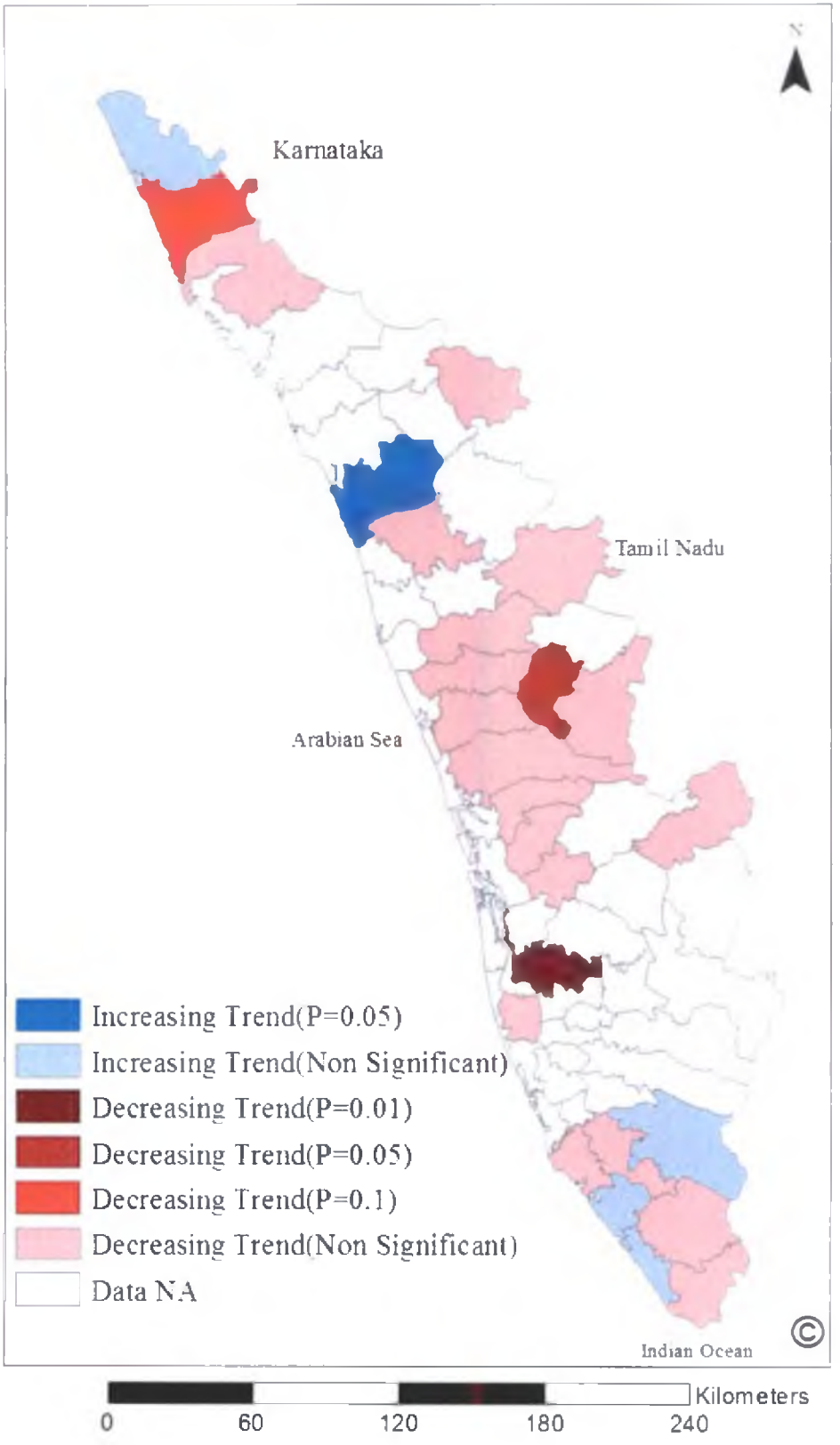


Fig. 94: Taluks showing changes in maximum length of dry spell in Kerala

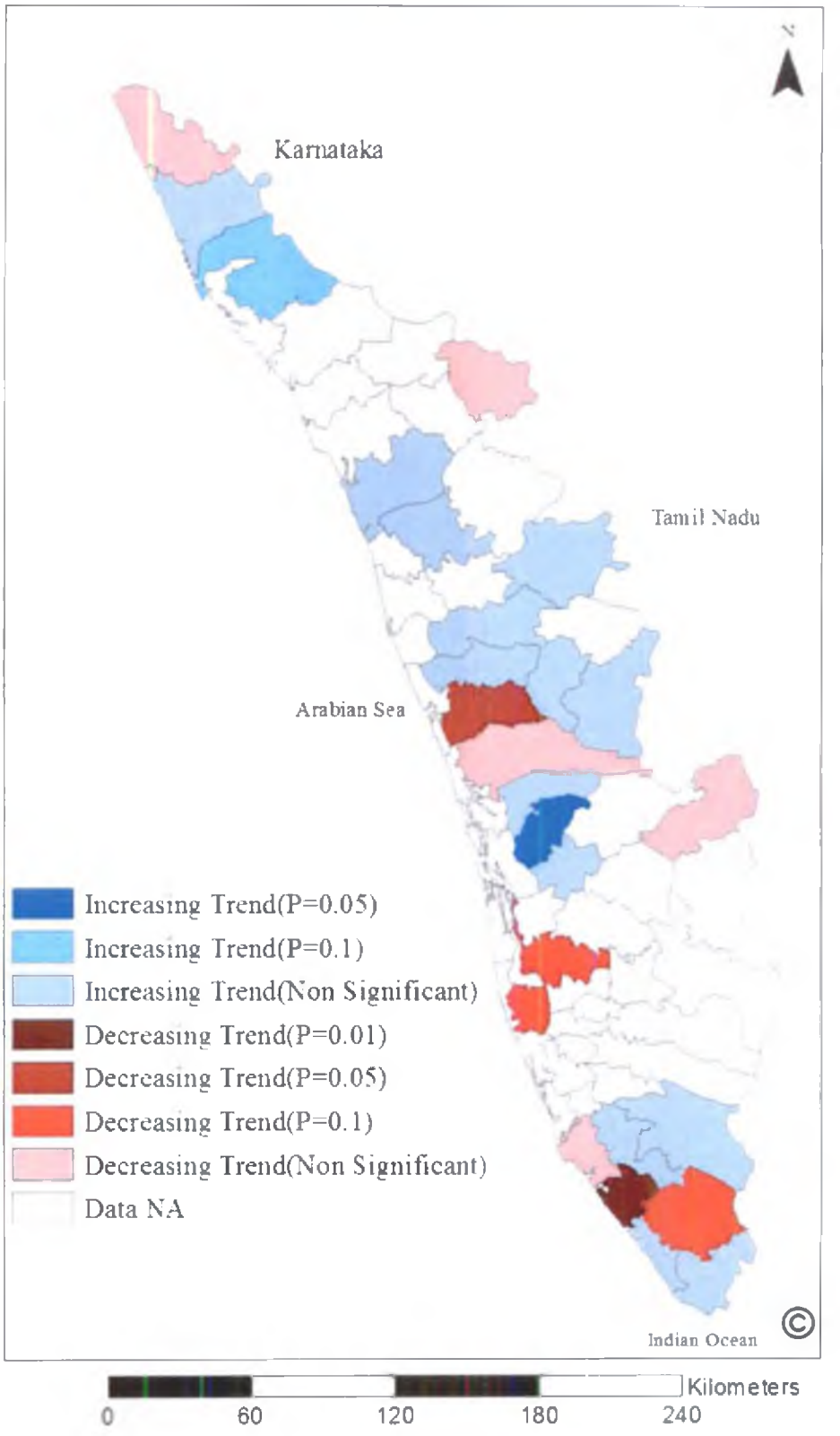


Fig. 95: Taluks showing changes in maximum length of wet spells in Kerala

5. Temperature

5.1. Maximum temperature

The mean annual maximum temperature over Kerala is 31°C. The highest mean maximum temperature is observed during summer season 33°C and lowest is SWM season (29°C). Average maximum temperature over the state in NEM season is 31°C and in winter season is 32°C. The central zone has recorded highest seasonal mean maximum temperature (34°C) at both winter and summer season. High range zone experiences lowest maximum temperatures among the zones during all the season (Table.19).

Palakkad and Kollam district show highest annual mean maximum temperature (33° C). Idukki district is coolest district in Kerala on a mean annual temperature 25°C followed by Wayanad district (27°C) Over the seasons Palakkad district recorded highest maximum temperature 36°C during summer and Idukki district observed lowest temperature (23°C) in SWM (Table.18). The highest monthly maximum temperature is observed over Palakkad district in March & April (37°C) and lowest is over Idukki district (22°C) in July (Fig.96)(Table.18)

5.2 Minimum temperature

The Kerala state as a whole experiences a mean minimum temperature 23°C on an annual basis. The highest mean minimum temperature is observed during summer season 24°C and lowest is 21°C during winter season. In zone wise highest minimum temperature observed in northern zone (24°C) and lowest minimum temperature observed in high range zone (18°C). In the case of mean annual minimum temperature data Malappuram, Kannur, Kozhikode, Eranakulam, Thiruvananthapuram, Pathanamthitta and Alappuzha recorded high temperature (24°C for these districts) (Table. 21).

Over the seasons lowest minimum temperature recorded at Idukki district 16°C during winter season and high temperature observed at Malappuram district(26°C) during summer season (Fig.101 and Table.20).

Kerala state having very low temperature at both January and December month (21°C) .Lowest minimum temperature in Kerala is observed in during winter season having mean 21°C.

Table 18: District wise average mean monthly maximum temperature (^{0}C) in Kerala

Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Summer	SWM	NEM	Annual
Kannur	34	35	36	36	35	31	29	30	31	32	33	34	35	35	30	33	33
Kasargode	33	33	33	34	34	30	29	30	30	31	32	32	33	34	30	32	32
Kozhikkode	32	33	34	34	33	30	29	29	30	31	32	32	33	34	30	32	32
Malappuram	33	34	34	34	34	30	29	30	31	32	32	33	34	34	30	32	32
Ernakulam	32	32	33	33	32	30	29	29	30	31	31	32	32	32	30	31	31
Palakkad	34	36	37	37	34	30	29	30	31	32	33	33	35	36	30	32	33
Thrissur	33	35	35	35	33	30	29	30	30	31	32	32	34	35	30	32	32
Thiruvananthapuram	32	33	33	33	32	31	30	30	31	31	31	32	32	33	30	31	31
kollam	34	35	36	35	34	31	30	31	32	32	32	33	35	35	31	32	33
Pathanamthitta	32	35	35	31	29	28	28	28	28	28	29	29	33	32	28	29	30
Alappuzha	33	33	34	34	33	30	29	29	30	31	32	32	33	33	30	32	32
Kottayam	33	34	35	34	33	30	30	30	31	31	32	33	34	34	30	32	32
Wayanad	28	30	31	30	29	26	24	26	27	26	26	27	29	30	26	26	27
Idukki	24	27	29	29	28	24	22	23	25	25	24	23	25	29	23	24	25
State mean	32	33	34	33	32	29	28	29	30	30	31	31	32	33	29	31	31

Table 19: Zone wise average mean monthly maximum temperature (^{0}C) in Kerala

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Summer	SWM	NEM	Annual
Northern zone	33	34	34	35	34	30	29	29	30	31	32	33	33	34	30	32	32
Central zone	33	34	35	35	33	30	29	29	30	31	32	32	34	34	30	32	32
Southern zone	33	34	35	33	32	30	29	30	30	30	30	31	33	33	30	31	31
Problem area zone	33	33	34	34	33	30	29	30	30	31	32	32	33	34	30	32	32
High range zone	26	28	30	30	28	25	23	24	26	26	25	25	27	29	24	25	26

Table 20: District wise average mean monthly minimum temperature (^{0}C) in Kerala

Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Summer	SWM	NEM	Annual
Kannur	22	23	25	26	26	24	24	24	24	24	24	23	22	25	24	23	24
Kasargode	20	21	23	25	25	24	23	23	23	23	22	21	21	25	23	22	23
Kozhikkode	22	23	25	26	25	24	23	23	24	24	23	22	22	25	24	23	24
Malappuram	23	24	25	26	26	24	23	24	24	24	24	23	23	26	24	24	24
Ernakulam	23	24	25	26	25	24	24	24	24	24	24	23	23	26	24	24	24
Palakkad	21	22	24	25	25	23	23	23	23	23	23	22	22	25	23	23	23
thrissur	21	22	24	25	25	23	23	23	23	23	23	21	22	24	23	22	23
Thiruvananthapuram	22	23	24	25	25	24	24	24	24	24	23	22	23	25	24	23	24
Kollam	20	21	23	24	24	23	23	23	23	22	22	21	21	23	23	22	22
Pathanamthitta	22	23	25	26	26	25	24	24	24	24	24	22	22	25	24	23	24
Alalppuzha	22	23	25	25	25	24	24	24	24	24	24	23	23	25	24	24	24
Kottayam	21	22	24	24	24	23	23	23	23	23	23	22	22	24	23	22	23
Wayanad	15	17	18	19	20	19	18	18	18	18	17	15	16	19	18	17	18
Idukki	15	16	18	19	19	18	17	18	18	18	17	16	16	19	18	17	17
State mean	21	22	23	24	24	23	23	23	23	23	22	21	21	24	23	22	23

Table 21: Zone wise average mean monthly minimum temperature (^{0}C) in Kerala

Zones	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Summer	SWM	NEM	Annual
Northern zone	22	23	24	26	26	24	23	24	24	24	23	22	22	25	24	23	24
Central zone	22	23	24	25	25	24	23	23	23	23	23	22	22	25	23	23	23
Southern zone	22	23	24	25	25	24	23	23	23	23	23	22	22	24	24	23	23
Problem area zone	22	23	24	25	25	24	23	23	23	23	23	22	22	25	23	23	23
High range zone	15	16	18	19	19	18	18	18	18	18	17	15	16	19	18	17	18

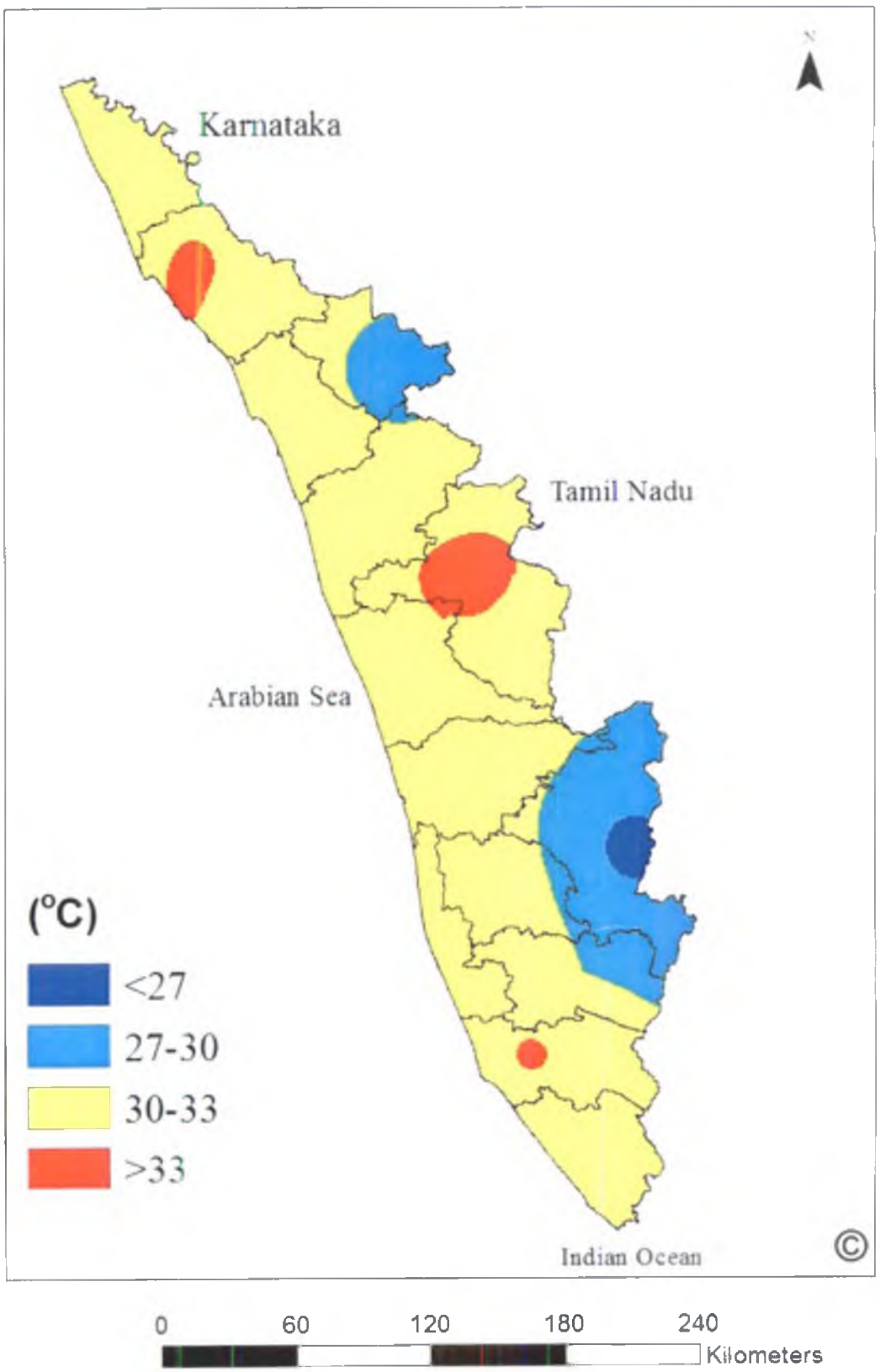


Fig. 96: Spatial distribution of annual mean maximum temperature in Kerala

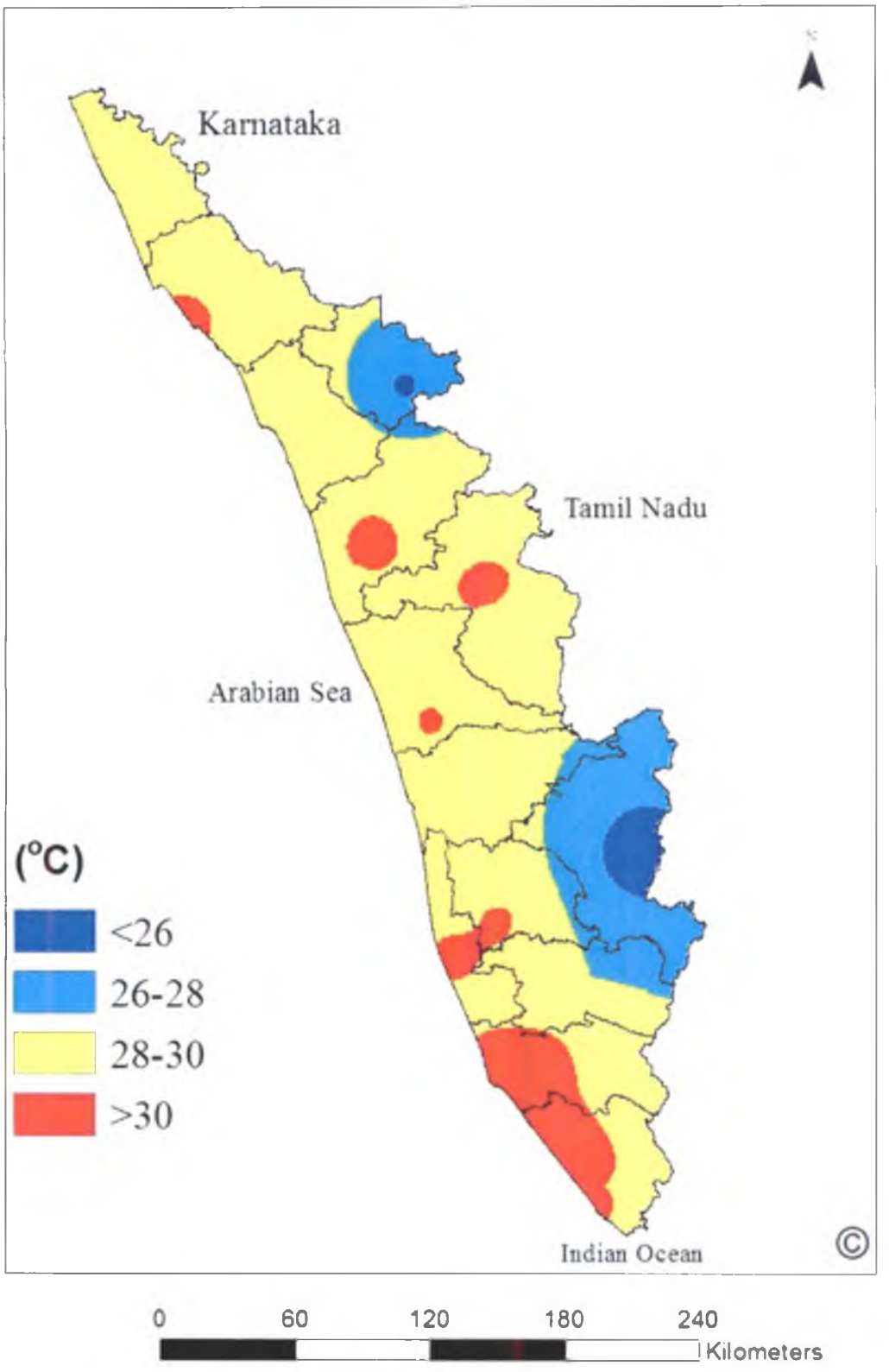


Fig. 97: Spatial distribution of mean Southwest monsoon season maximum temperature in Kerala

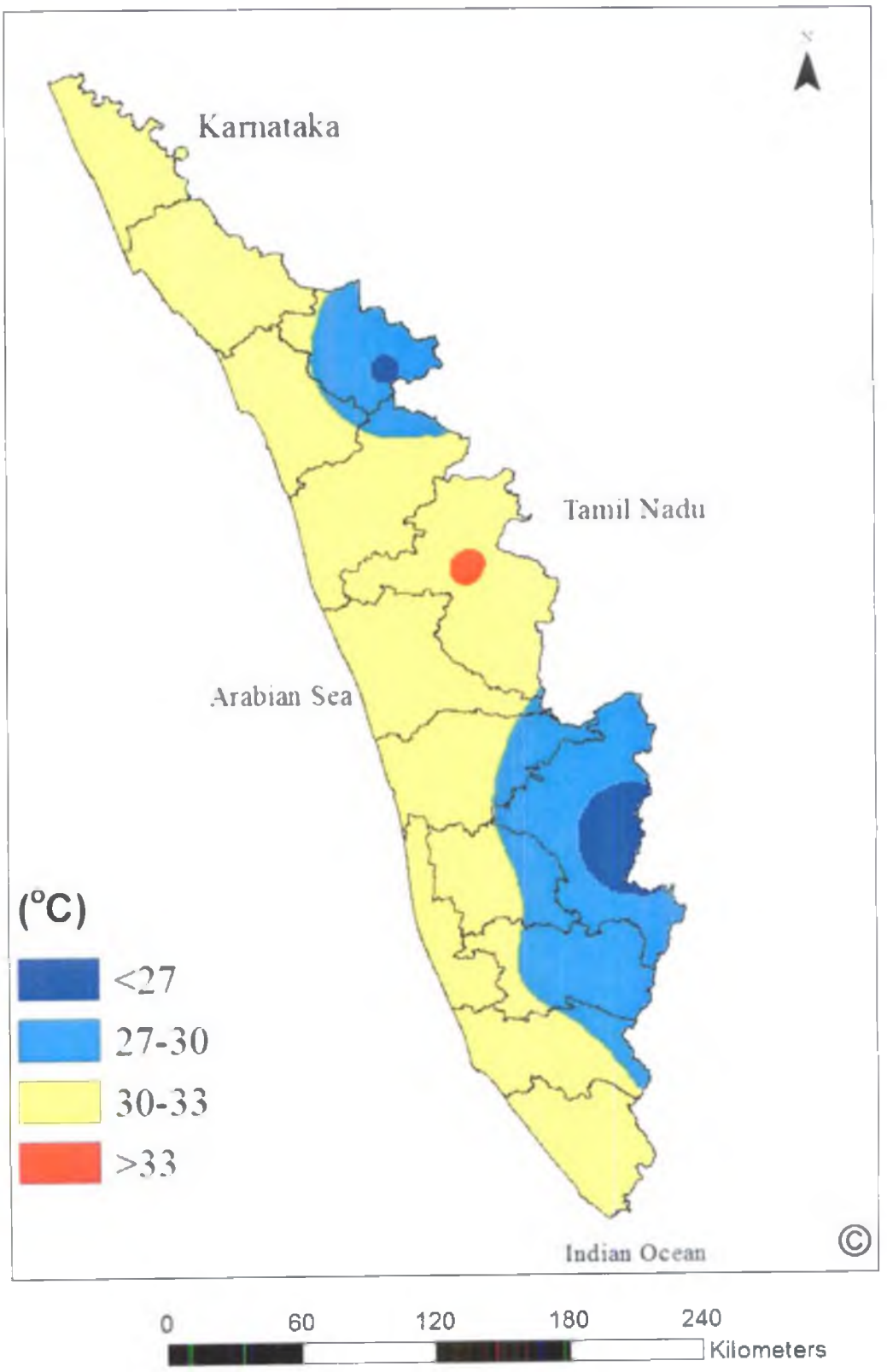


Fig. 98: Spatial distribution of mean Northeast monsoon season maximum temperature in Kerala

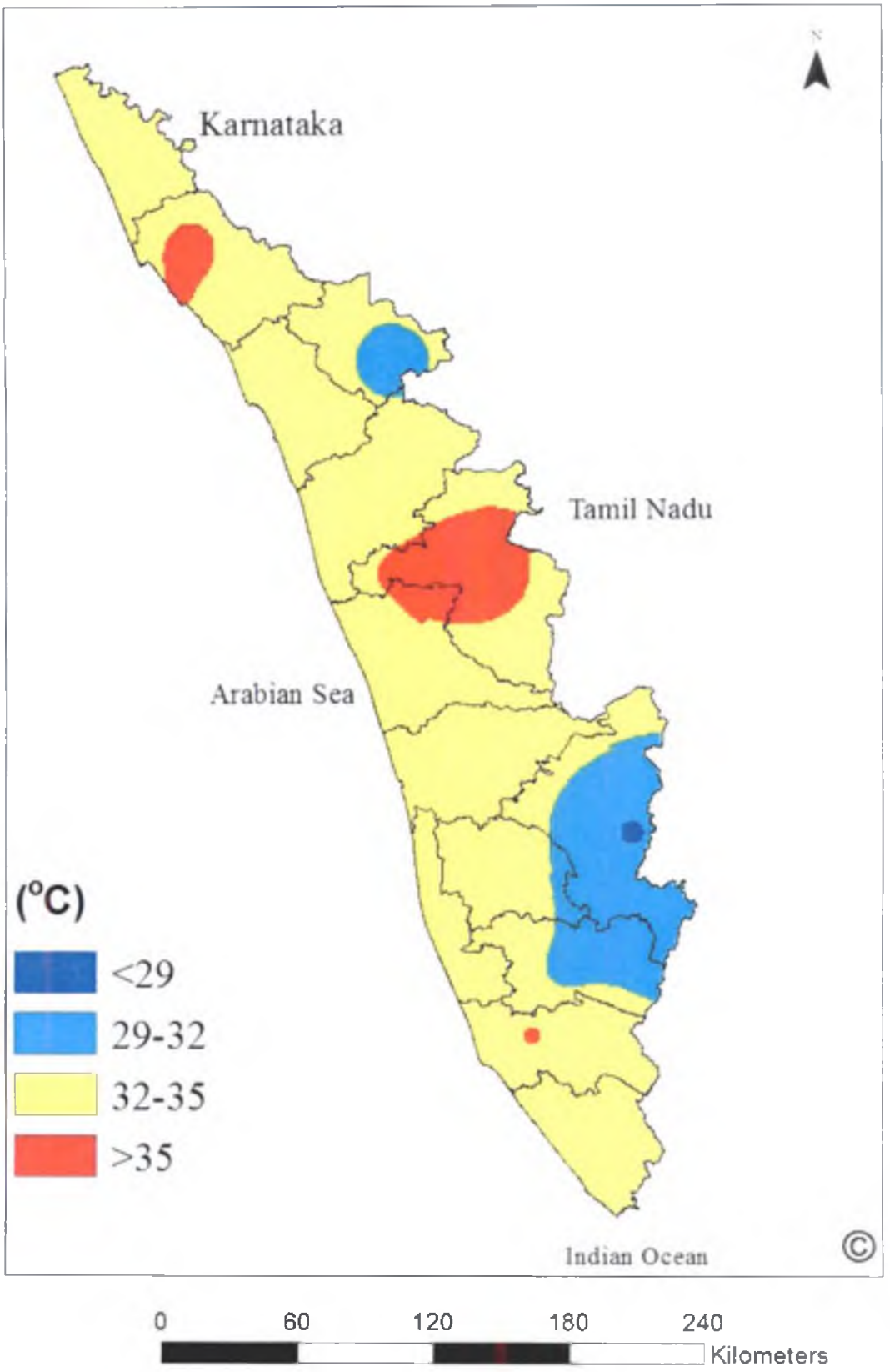


Fig. 99: Spatial distribution of mean Summer season maximum temperature in Kerala

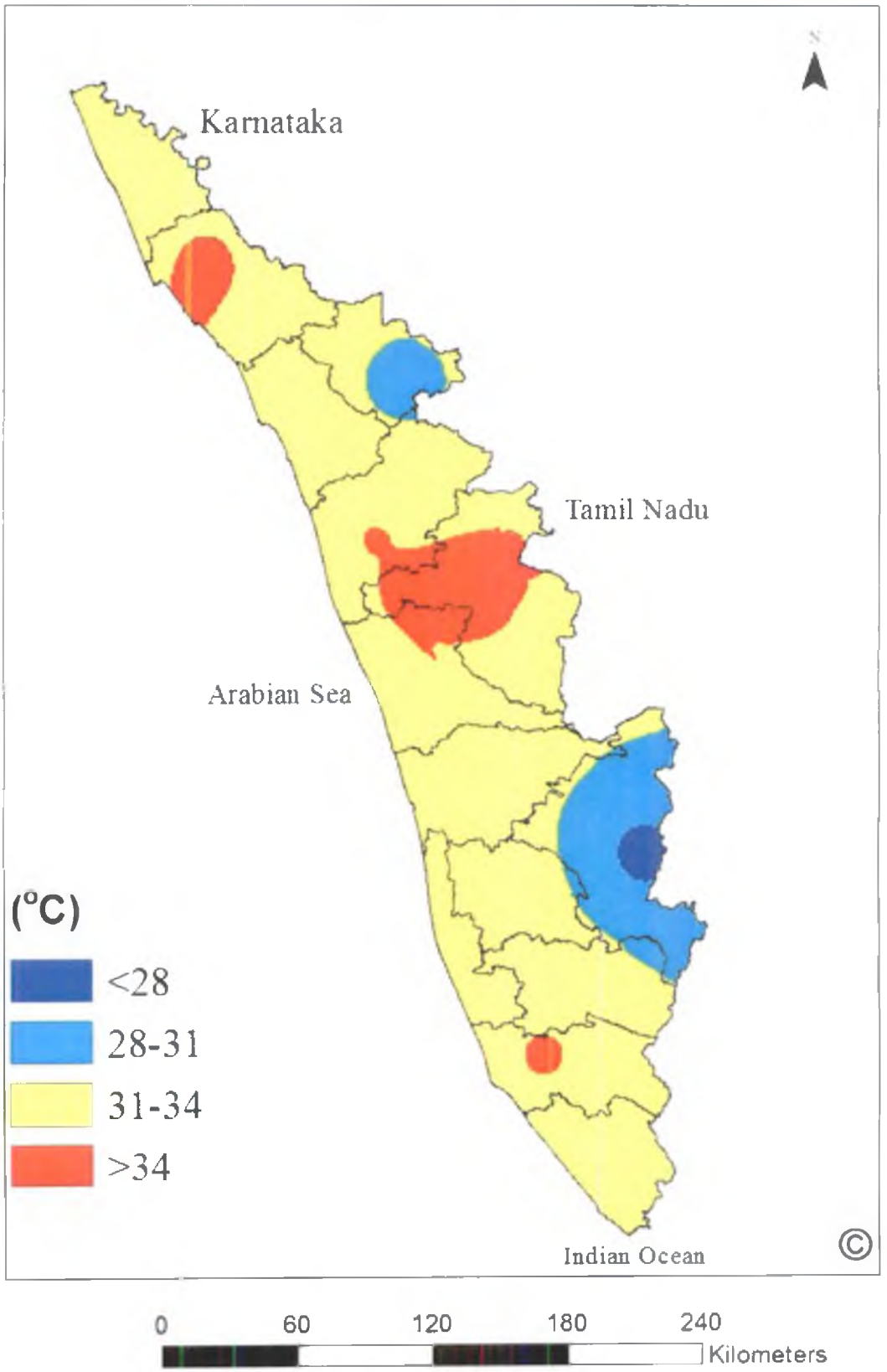


Fig. 100: Spatial distribution of mean Winter season maximum temperature in Kerala

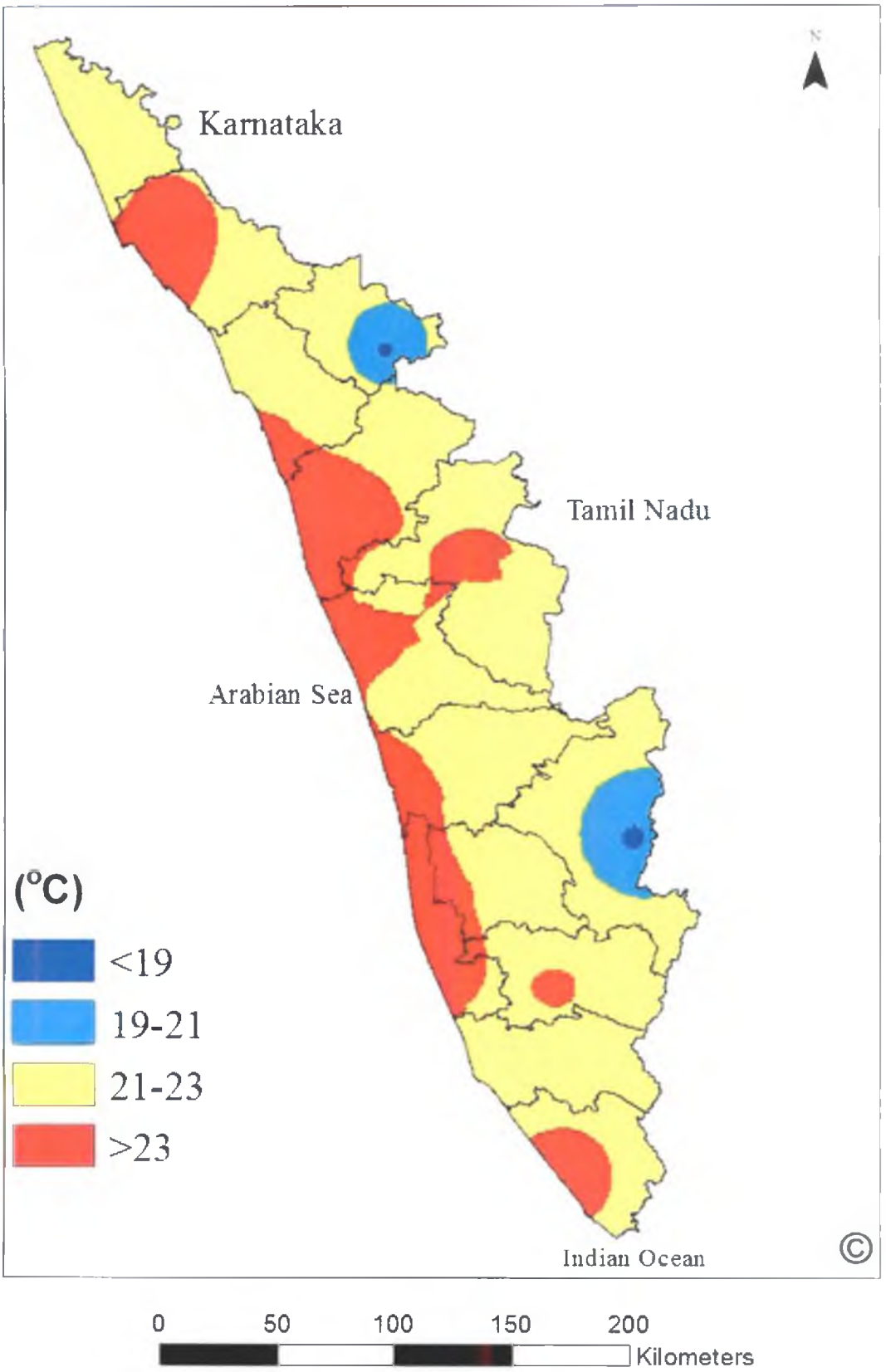


Fig. 101: Spatial distribution of annual mean minimum temperature in Kerala

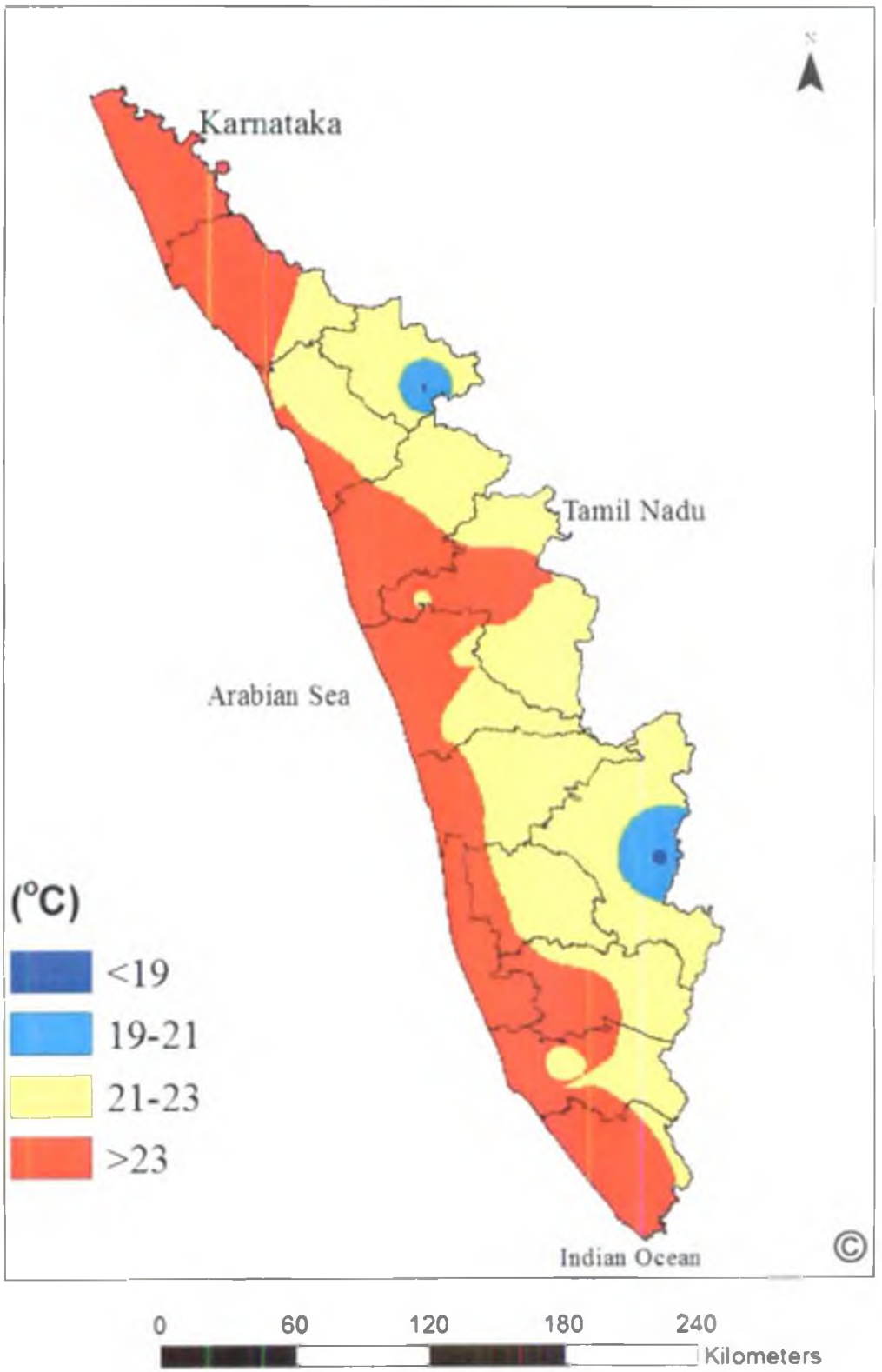


Fig. 102: Spatial distribution of mean Southwest monsoon season minimum temperature in Kerala

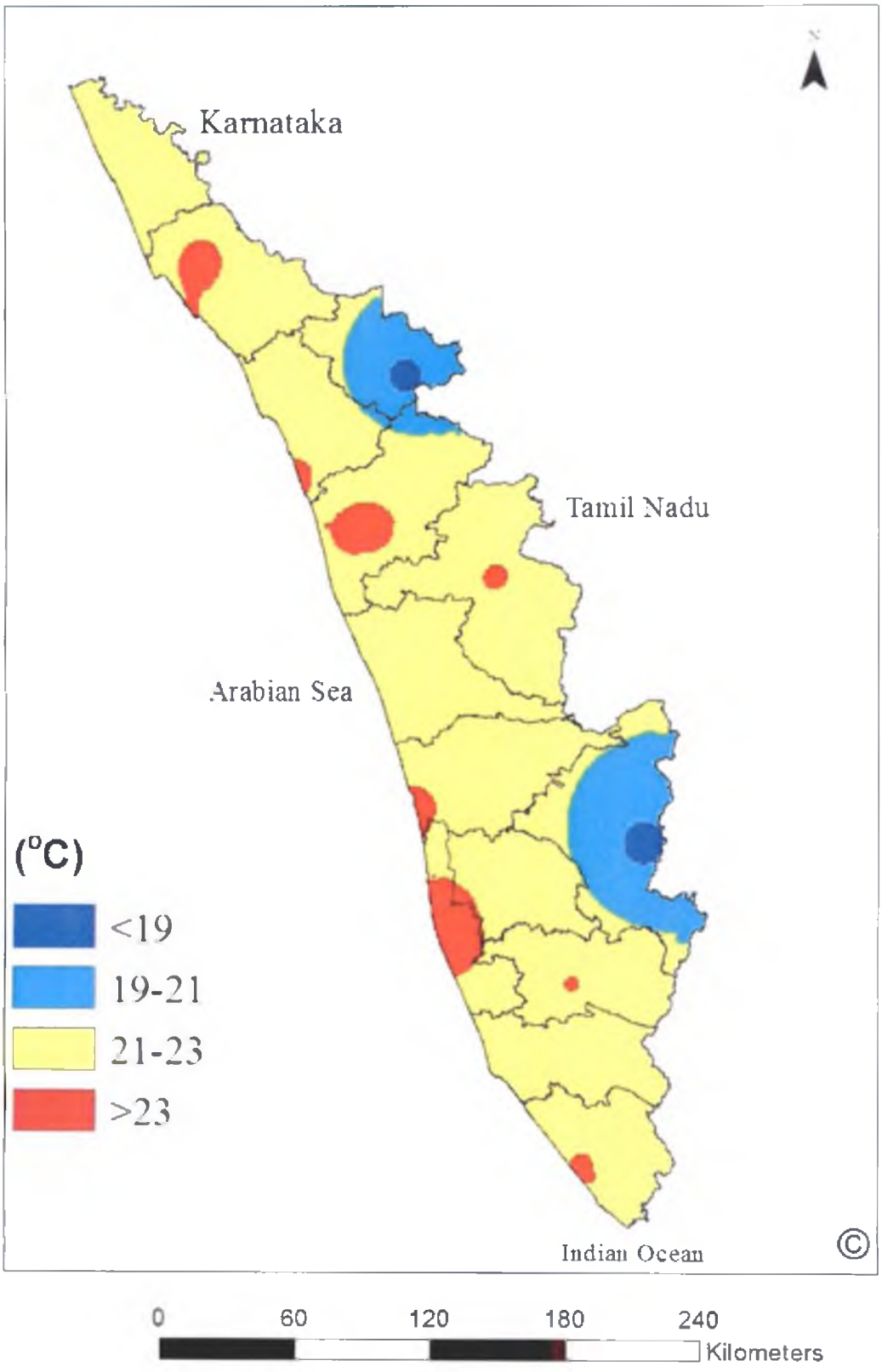


Fig. 103: Spatial distribution of mean Northeast monsoon season minimum temperature in Kerala

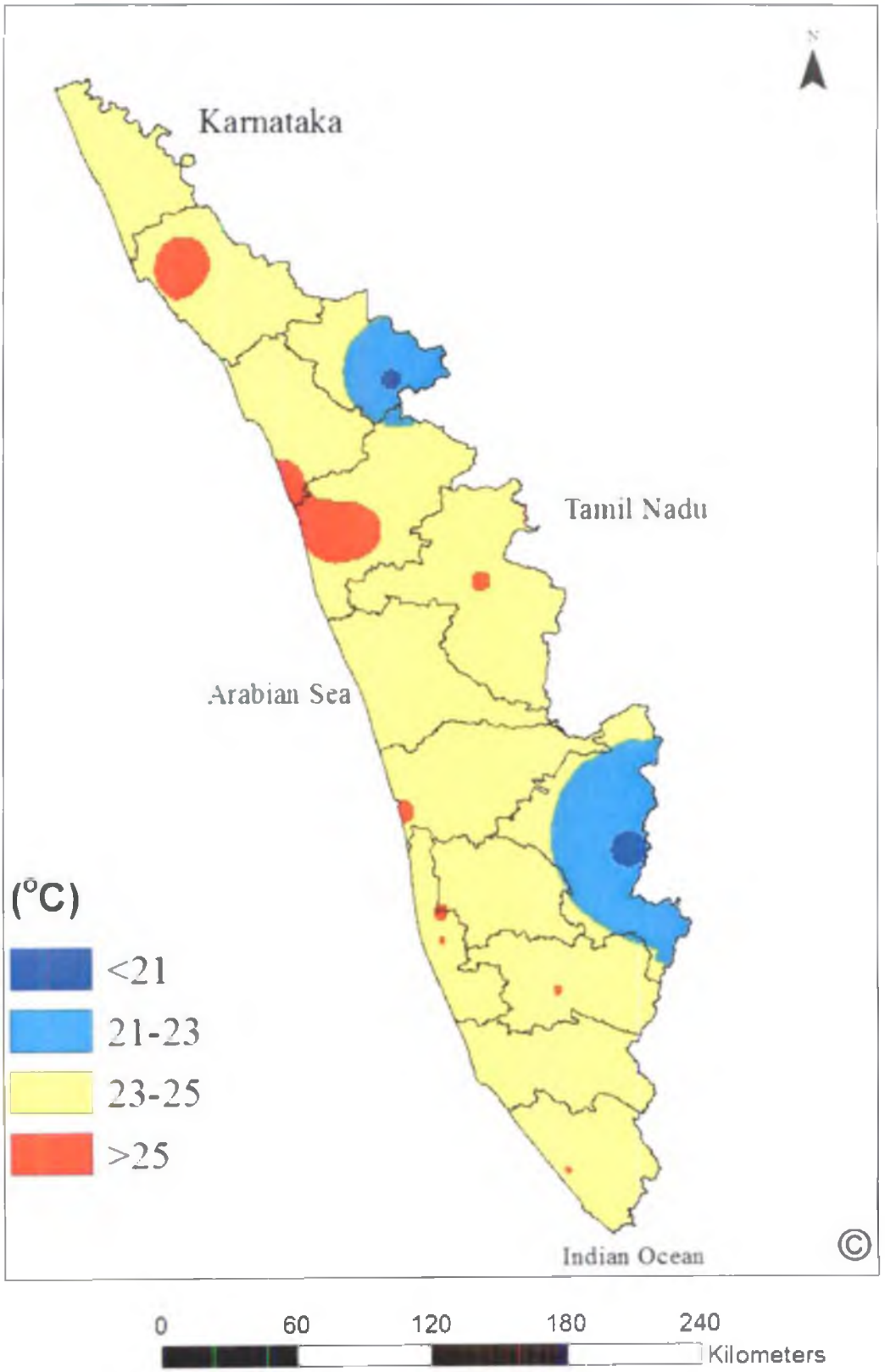


Fig. 104: Spatial distribution of mean Summer season minimum temperature in Kerala

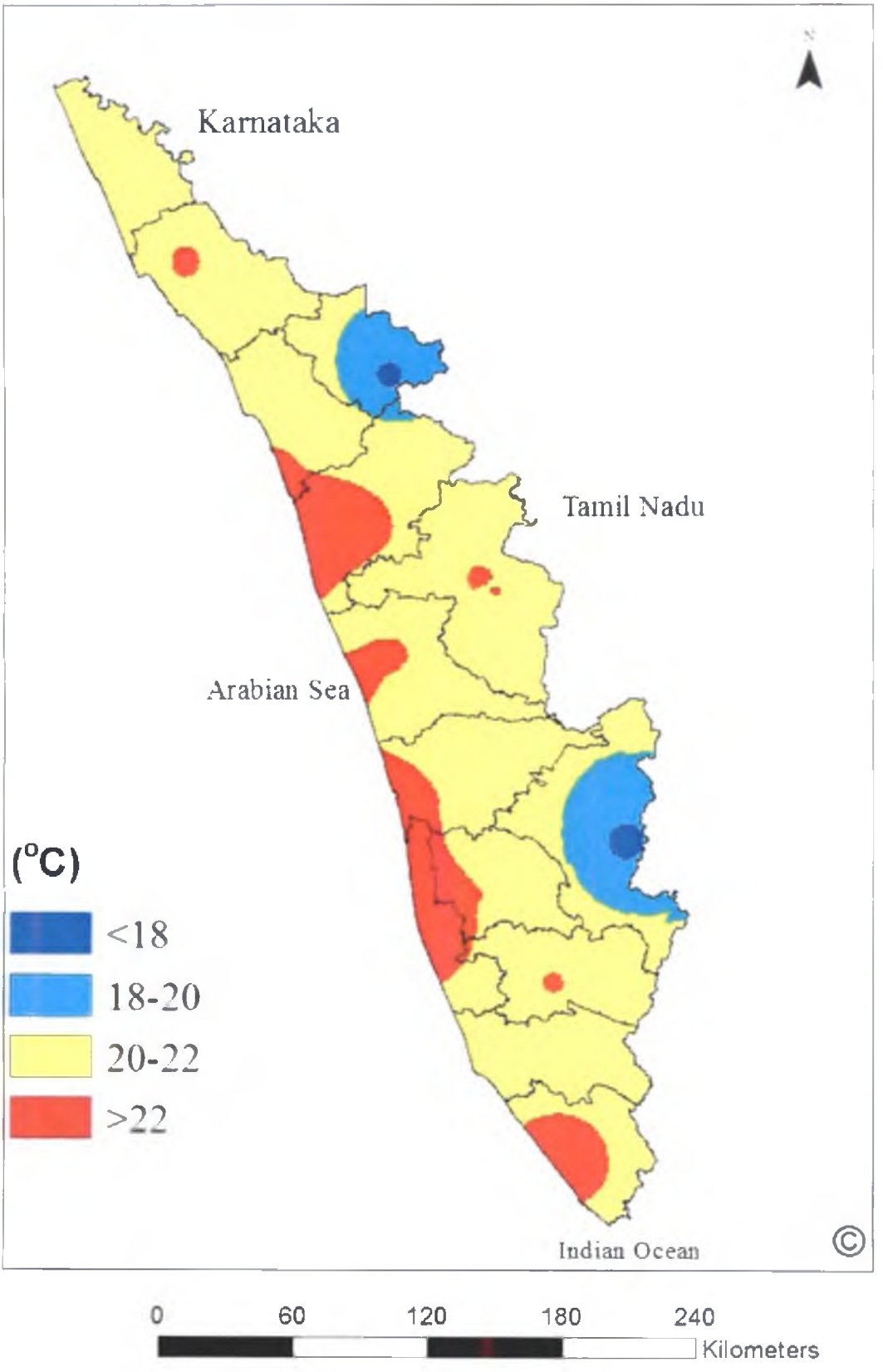


Fig. 105: Spatial distribution of mean Winter season minimum temperature in Kerala

6. Relative Humidity

6.1. Morning Relative Humidity over the state of Kerala

On annual basis the Kerala state experiences 87% morning relative humidity. However zone to zone, relative humidity is varying. Relative humidity is found to be highest in High range zone (93%) and lowest in Northern zone (85%). During SWM season the morning relative humidity is highest as compared to all other season with an average 93% and lowest morning relative humidity is found in winter season with an average 81%. During SWM season morning relative humidity is highest in Idukki district (97%) and lowest in Malappuram district (89%). Annual average of morning relative humidity is highest in Idukki district (94%) and lowest in Malappuram district 80% (Table.22).

On a monthly basis the state as whole experiences high morning humidity during July month (94%) and least morning humidity is recorded in January month(81%). (Table 22-23). The spatial distribution of annual and seasonal morning and evening relative humidity is presented in the figure .106 -110.

6.2. Afternoon Relative Humidity over Kerala

On annual basis the Kerala state experiences 70% afternoon relative humidity, zone wise relative humidity almost similar except central zone it has percentage of relative humidity 66% which is lowest relative humidity. Problem zone having highest relative humidity 72%. During SWM relative humidity is highest at a percentage 81% and lowest value shown by Palakkad district (74%). In all season Alappuzha district shows high afternoon relative humidity (77%) as compared to all other districts (Table 25-26, Fig.111-115). Annual average of afternoon relative humidity is highest in Alappuzha district(79%) followed by Kannur district(76%) and lowest in Palakkad district.

On a monthly basis the state as a whole experiences high afternoon relative humidity during July month (83%) which is similar observation got in the case of morning relative humidity. Afternoon relative humidity is lowest in the month of February (55%). (Table 24-25)

Table 22: District wise average mean monthly morning relative humidity (%) over Kerala

Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
Alappuzha	79	82	83	82	85	93	93	92	90	87	87	84	92	86	81	84	87
Kannur	69	71	76	77	76	91	94	94	89	84	77	69	92	76	70	76	81
Kasargode	85	83	82	80	81	92	94	93	91	88	85	83	92	85	84	81	86
Kozhikkode	86	87	86	86	87	94	95	94	93	91	91	88	94	90	87	86	90
Kottayam	83	85	87	88	89	93	93	93	92	92	90	85	93	89	84	88	89
Malappuram	71	73	76	76	79	88	90	90	87	85	79	70	89	78	72	77	80
Wayanad	89	87	90	92	92	94	94	94	93	93	92	89	94	91	88	91	92
Idukki	93	89	89	93	94	97	98	97	96	96	94	93	97	94	91	92	94
Ernakulam	78	80	79	81	84	91	92	91	88	86	84	78	90	83	79	81	84
Palakkad	82	85	89	89	90	95	95	94	94	94	90	84	95	89	84	89	90
Thrissur	73	77	83	86	88	94	95	94	93	91	83	74	94	83	75	86	86
Thiruvananthapuram	77	78	81	82	84	89	91	88	88	87	84	78	89	83	78	82	84
Kollam	85	86	90	93	93	95	94	96	95	94	94	88	95	92	86	92	92
State mean	81	82	84	85	86	93	94	93	91	90	87	82	93	86	81	85	87

Table 23: Zone wise average mean monthly Morning relative humidity (%) over Kerala

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
Northern zone	80	80	81	81	82	92	94	93	90	88	85	80	92	84	80	81	85
Southern zone	79	80	83	84	86	90	92	90	89	89	86	81	90	85	80	85	86
Central zone	77	80	83	84	87	93	93	93	91	90	85	78	92	84	78	85	86
High range	91	88	89	92	93	96	96	96	94	94	93	91	95	93	90	92	93
Problem area zone	82	84	86	86	88	93	93	93	91	90	89	85	93	88	83	87	88

Table.24: District average mean monthly afternoon relative humidity (%) over Kerala

Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
Alappuzha	67	70	75	76	80	87	87	87	83	80	78	73	86	77	69	77	79
Kannur	64	64	67	69	69	85	89	88	85	82	76	68	86	76	64	68	76
Kasargode	59	60	64	66	68	82	85	84	80	77	71	62	83	70	60	66	71
Kozhikkode	58	58	61	64	68	81	83	81	76	74	70	61	80	68	58	64	69
Kottayam	55	54	58	66	71	79	79	78	75	74	71	61	77	69	55	65	68
Malappuram	57	57	63	67	71	82	83	81	78	79	73	61	81	71	57	67	71
Wayanad	51	50	50	62	69	81	84	83	79	76	71	58	82	68	51	60	68
Idukki	63	55	50	63	73	85	90	86	81	80	78	71	86	76	59	62	73
Ernakulam	58	61	66	71	72	82	83	81	79	77	74	64	81	71	60	70	72
Palakkad	42	36	41	52	59	76	77	75	69	68	58	48	74	58	39	51	58
Thrissur	40	38	44	55	62	77	79	76	70	69	60	49	76	59	39	54	60
Thiruvananthapuram	55	54	58	65	68	76	77	75	72	72	69	61	75	67	54	63	67
kollam	52	52	59	75	73	82	81	83	81	78	79	65	82	74	52	69	72
State mean	56	55	58	65	70	81	83	81	77	76	71	62	81	70	55	64	70

Table.25: Zonal wise average mean monthly afternoon relative humidity (%) over Kerala

Zones	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
Northern zone	58	59	62	65	69	81	84	82	78	76	71	61	81	69	58	65	71
Southern zone	54	53	58	67	69	77	78	77	74	74	71	62	77	69	54	65	68
Central zone	50	49	54	62	66	79	80	78	74	73	66	56	78	65	49	61	66
High range	57	52	50	63	71	83	87	85	80	78	75	64	84	72	55	61	70
Problem zone	59	59	63	69	74	81	82	81	77	76	73	65	80	72	59	69	72

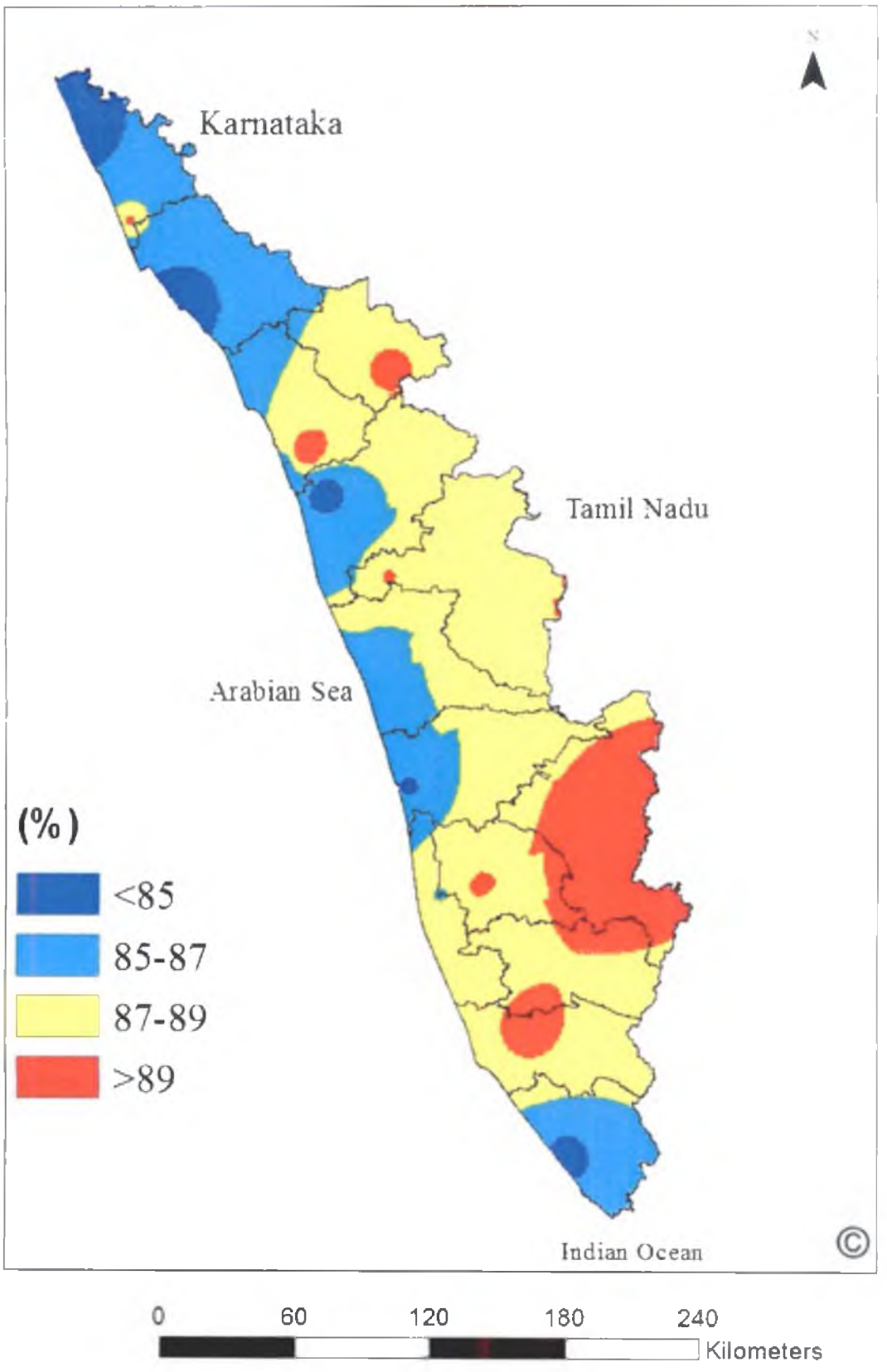


Fig. 106: Mean annual morning relative humidity in Kerala

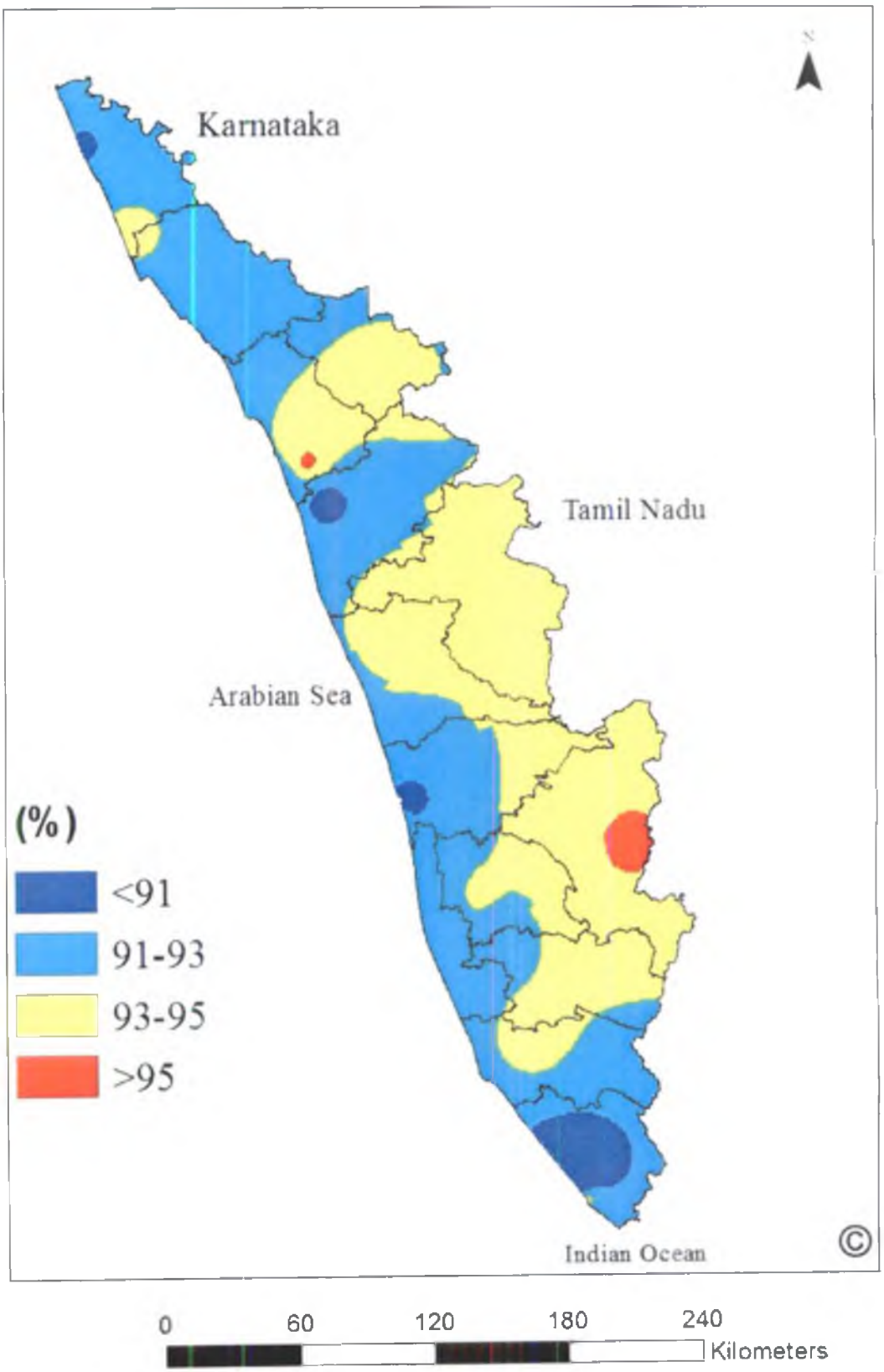


Fig. 107: Mean morning relative humidity during the Southwest monsoon season in Kerala

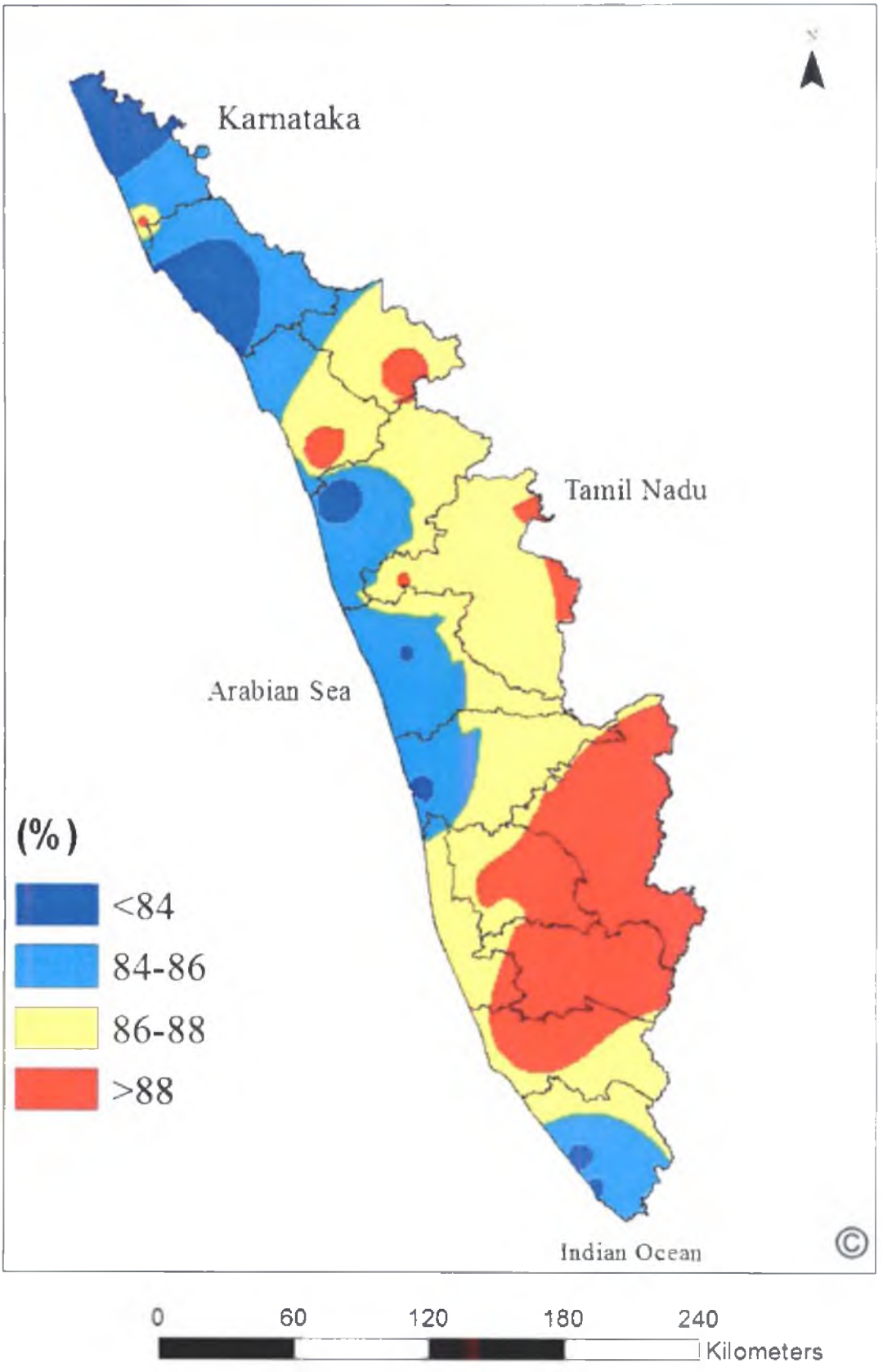


Fig. 108: Mean morning relative humidity during the Northeast monsoon season in Kerala

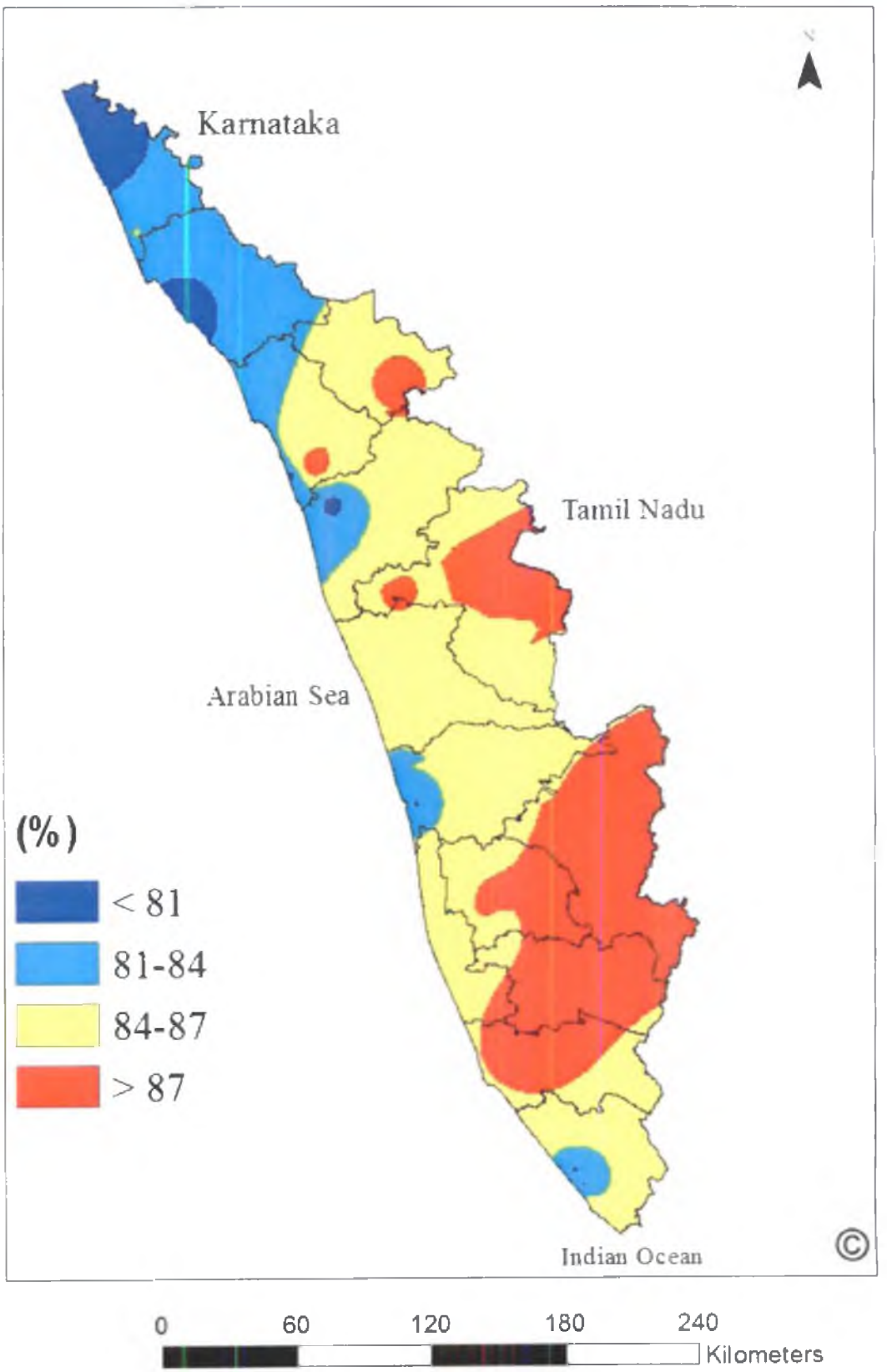


Fig. 109: Mean morning relative humidity during the Summer season in Kerala

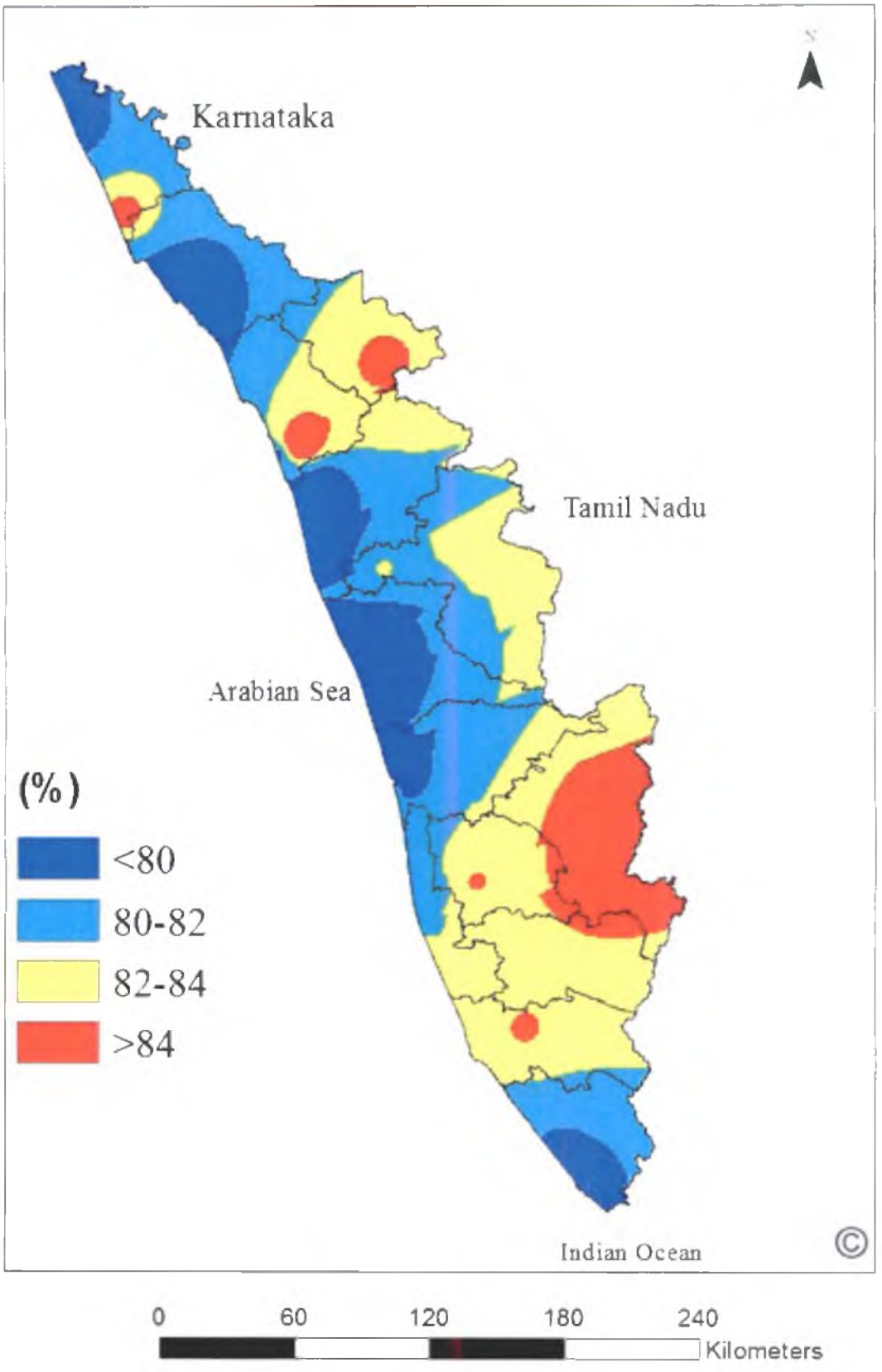


Fig. 110: Mean morning relative humidity during the Winter season in Kerala

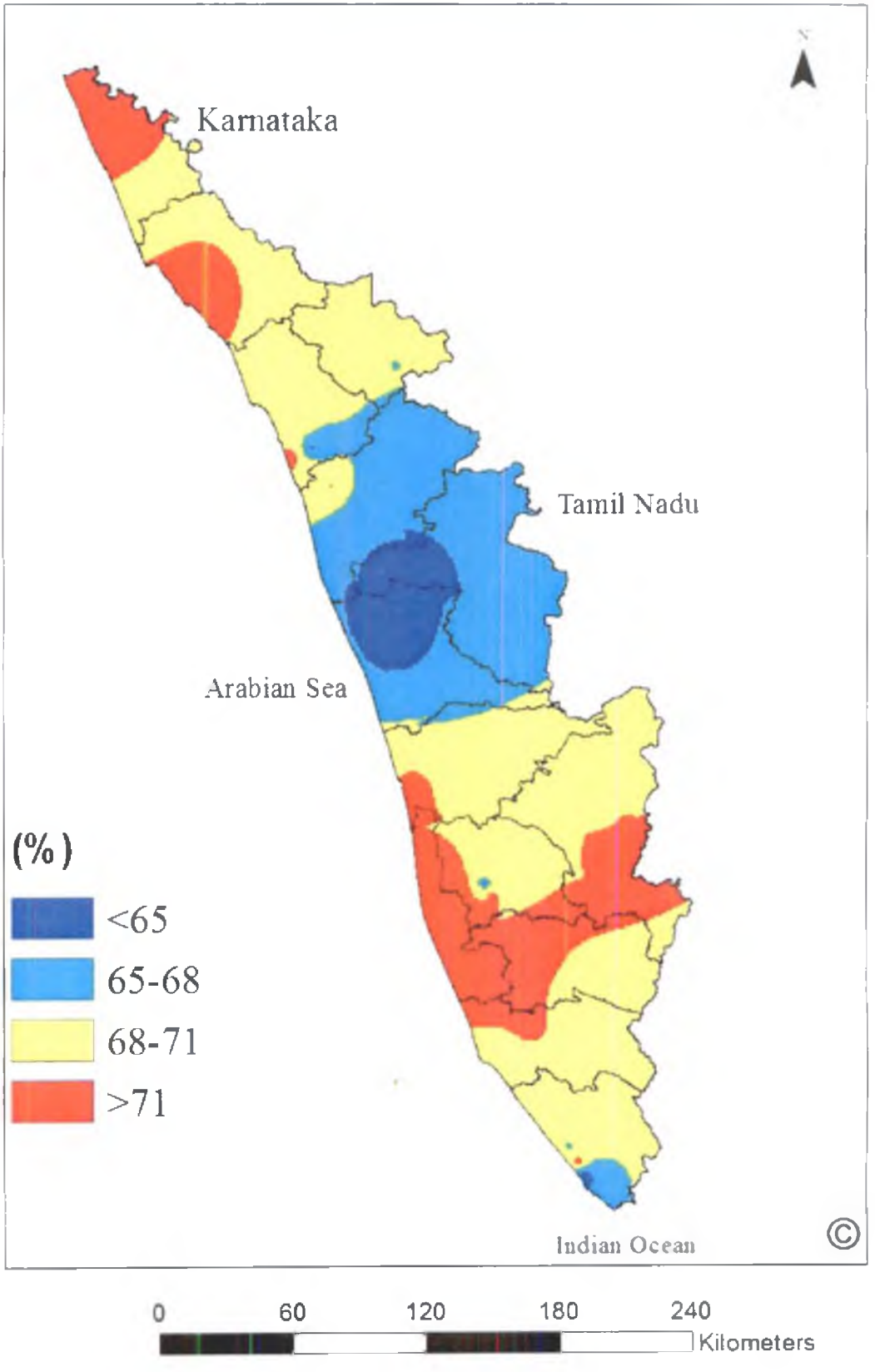


Fig. 111: Annual mean relative humidity (afternoon) over Kerala

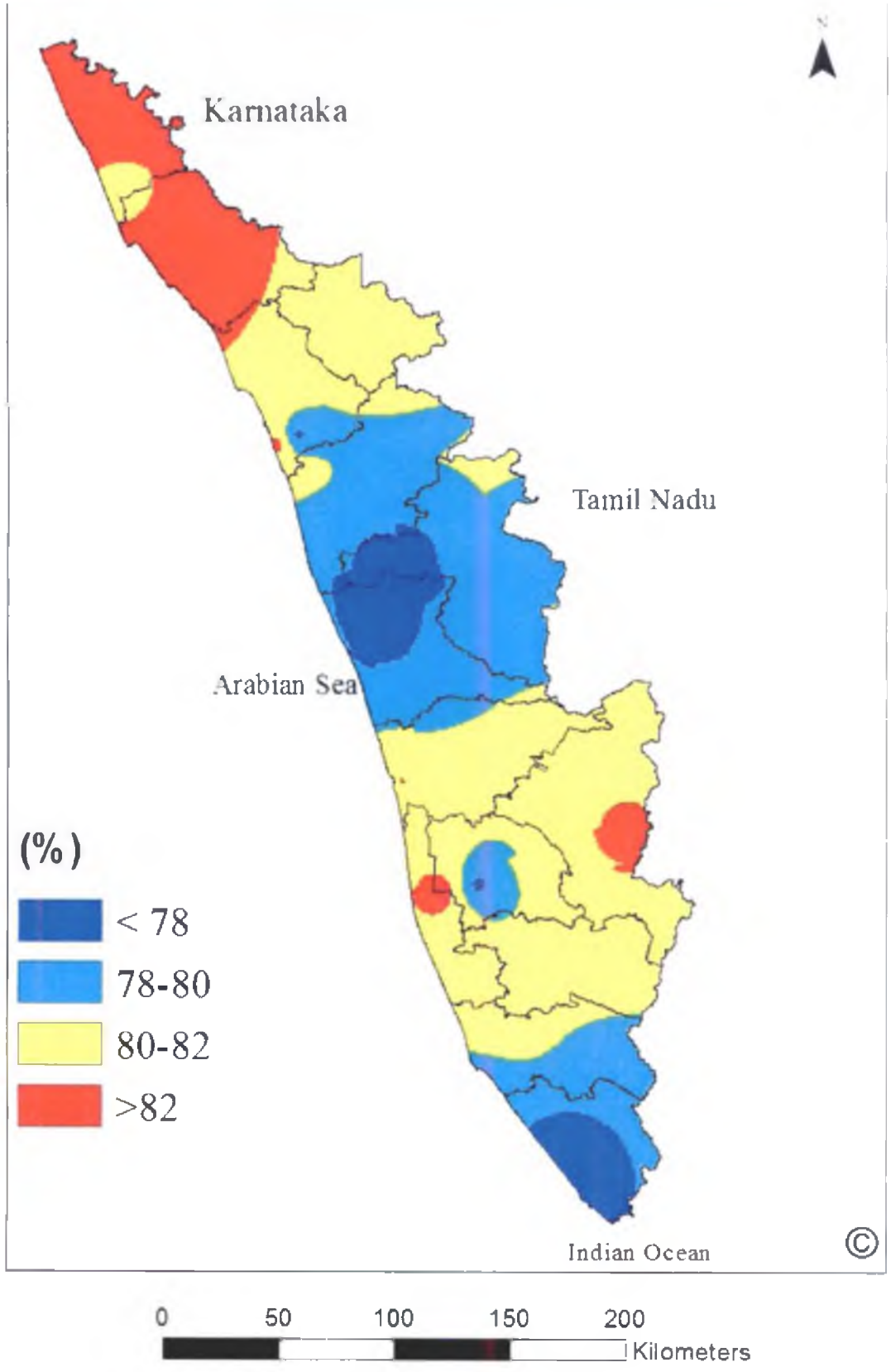


Fig. 112: Mean Southwest monsoon season relative humidity (afternoon) over Kerala

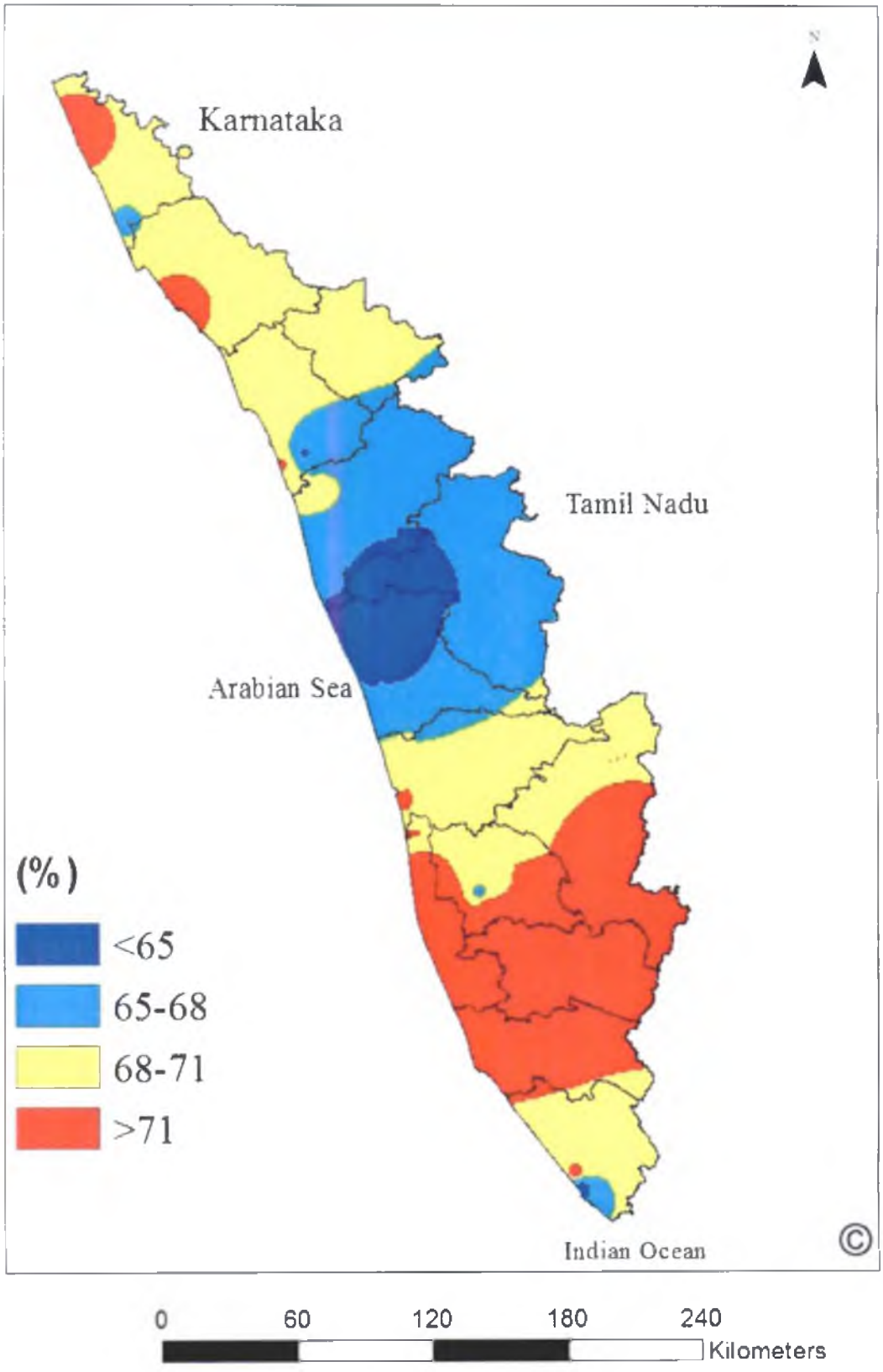


Fig. 113: Mean Northeast monsoon season relative humidity (afternoon) over Kerala

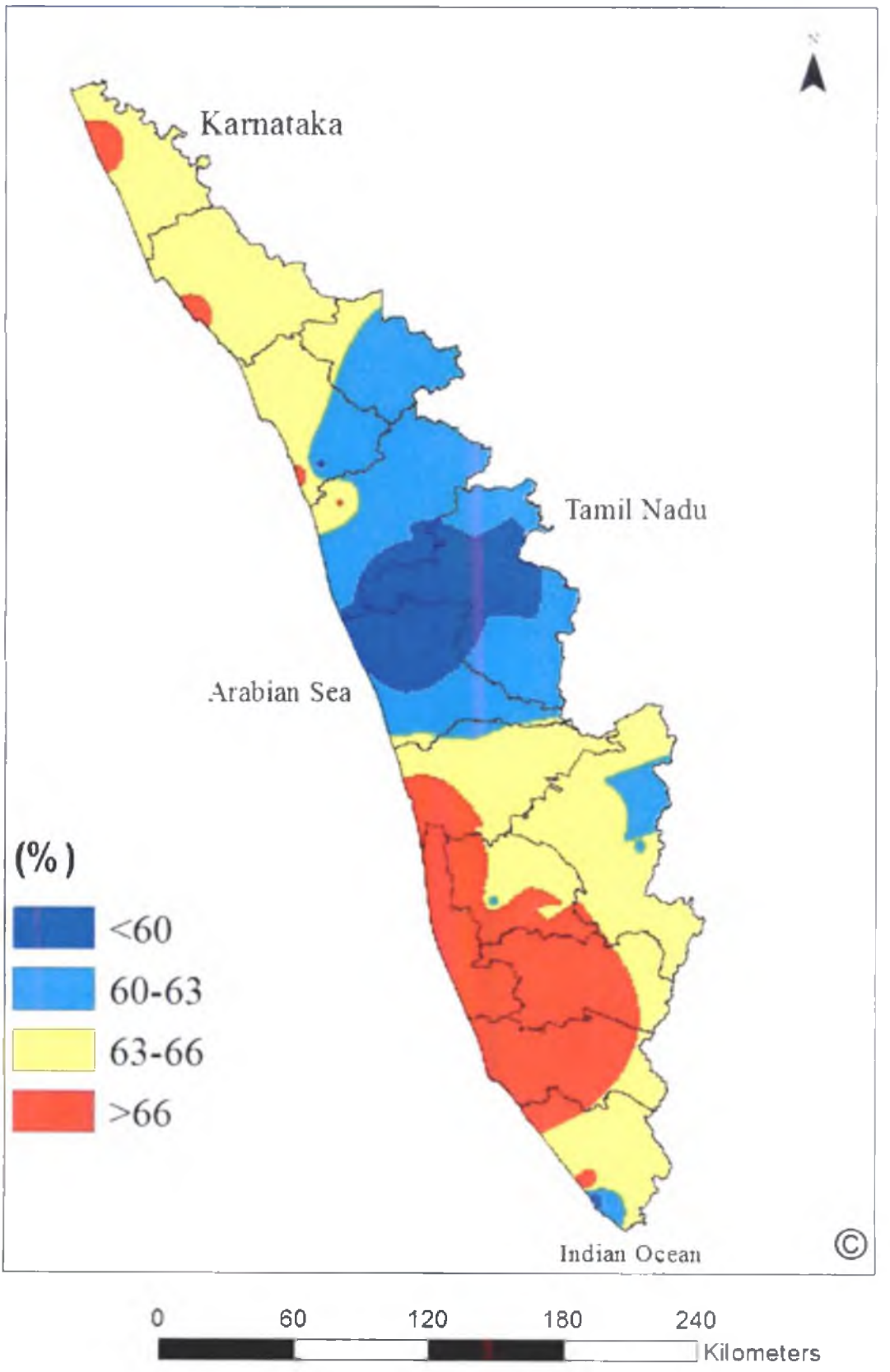


Fig. 114: Mean Summer season relative humidity (afternoon) over Kerala

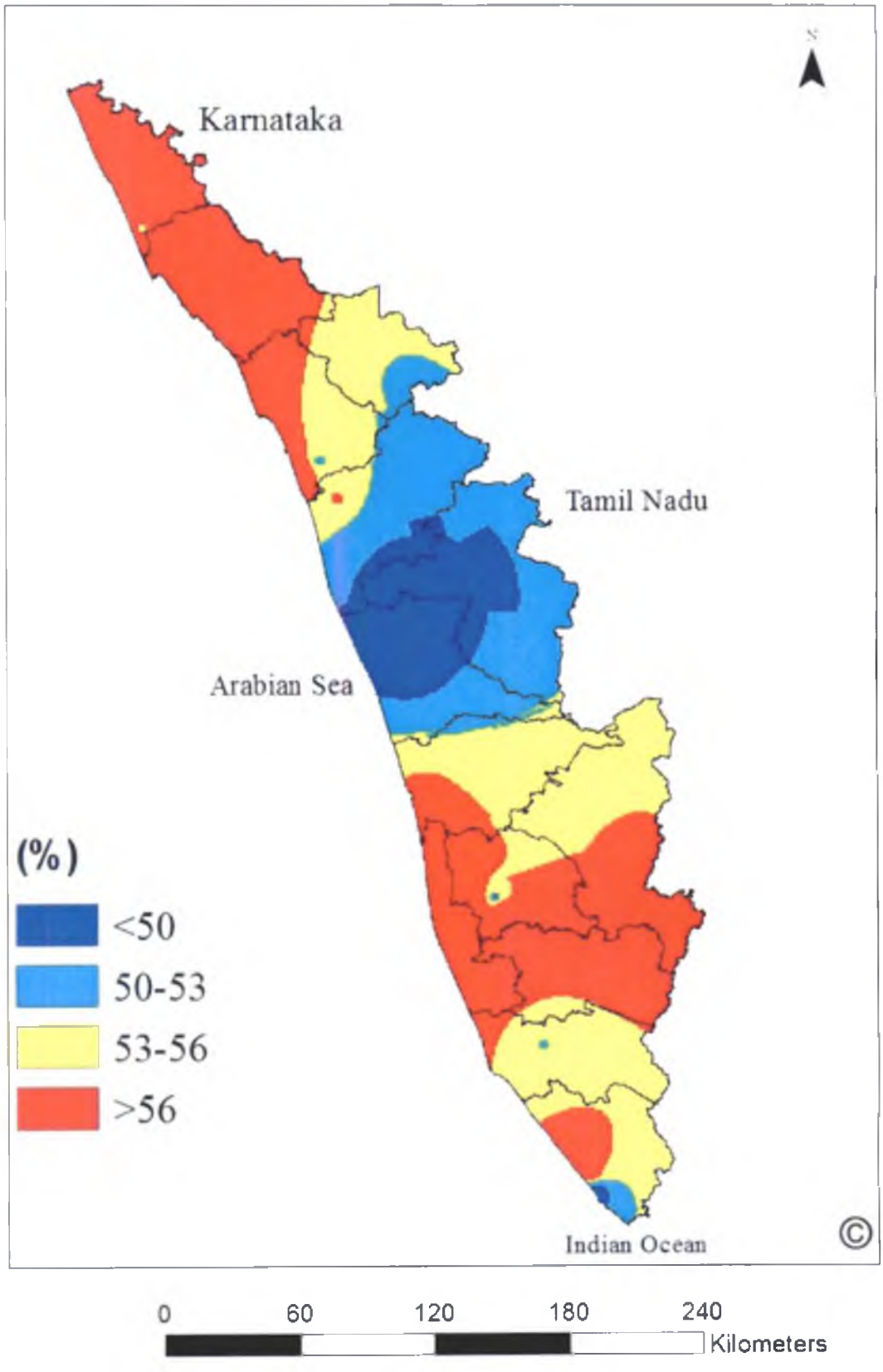


Fig. 115: Mean Winter season relative humidity (afternoon) over Kerala

7. Wind speed

The mean annual wind speed for the entire state is 2.8 m/s. Southern zone shows highest wind speed (3.4 m/s) on an annual basis. Lowest wind speed experiences in High range zone (2.1 m/s). On an annual basis highest wind speed recorded in Thiruvananthapuram district with a speed of 4.4 m/s followed by Kozhikode district having a speed (3.1 m/s). Lowest wind speed recorded at Wayanad district with a speed 1.8 m/s

July is the month with highest wind conditions for the entire state having average wind speed 4.5 m/s followed by June month 4.3 m/s. November is the month with lowest wind speed 1.9 m/s. Wind speed during SWM season is 4.1 m/s. During SWM season highest wind speed recorded in Thiruvananthapuram district 6.2 m/s followed by Kollam district (4.7 m/s) (Table 26-27).

Winds during SWM season are stronger than as compared to other seasons. High range zone and problem zones relatively calm zones having an average wind speed 1.6 m/s. (Fig.116-120).

Table.26: District wise average mean monthly wind speed (m/s) in Kerala

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
Alappuzha	2.0	2.0	2.2	2.4	3.5	4.9	4.9	4.6	3.8	2.6	1.9	2.1	4.6	2.2	2.0	2.7	3.1
Kannur	1.8	2.1	2.4	2.4	2.9	4.1	4.5	4.1	3.2	2.2	1.8	1.9	4.0	2.0	2.0	2.5	2.8
Kasargode	1.9	2.3	2.5	2.4	2.9	4.1	4.6	4.2	3.2	2.2	1.9	2.0	4.0	2.0	2.1	2.6	2.8
Kozhikkode	2.1	2.3	2.5	2.6	3.4	4.8	5.0	4.7	3.7	2.5	2.0	2.2	4.6	2.2	2.2	2.8	3.2
Kottayam	1.6	1.5	1.6	1.7	2.6	3.7	3.7	3.5	2.8	1.9	1.4	1.7	3.4	1.6	1.5	2.0	2.3
Malappuram	2.2	1.9	2.0	2.1	2.9	4.1	4.3	3.9	3.1	2.1	1.8	2.3	3.9	2.1	2.0	2.3	2.7
Pathanamthitta	1.8	1.5	1.6	1.8	2.8	3.9	4.0	3.8	3.1	2.1	1.6	1.9	3.7	1.9	1.7	2.1	2.5
Wayanad	1.4	1.2	1.2	1.1	1.7	2.9	3.1	2.9	2.0	1.3	1.3	1.6	2.7	1.4	1.3	1.3	1.8
Idukki	1.8	1.6	1.4	1.4	2.4	3.6	3.8	3.5	2.7	1.7	1.6	2.0	3.4	1.8	1.7	1.7	2.3
Ernakulam	2.1	2.0	2.2	2.4	3.4	4.7	4.7	4.3	3.6	2.5	1.9	2.2	4.3	2.2	2.1	2.7	3.0
Palakkad	2.1	1.8	1.7	1.7	2.6	3.7	3.9	3.5	2.8	1.9	1.8	2.2	3.5	1.9	1.9	2.0	2.5
thrissur	2.4	2.0	2.1	2.2	3.1	4.4	4.5	4.1	3.3	2.2	2.0	2.5	4.1	2.2	2.2	2.5	2.9
Thiruvananthapuram	3.7	2.9	2.8	3.1	5.0	6.6	6.5	6.2	5.4	3.9	3.0	3.8	6.2	3.6	3.3	3.6	4.4
kollam	2.6	2.1	2.1	2.3	3.7	5.0	5.0	4.8	4.1	2.8	2.2	2.7	4.7	2.6	2.4	2.7	3.3
state mean	2.1	1.9	2.0	2.1	3.1	4.3	4.5	4.2	3.4	2.3	1.9	2.2	4.1	2.1	2.0	2.4	2.8

Table.27: Zone wise average mean monthly wind speed (m/s) in Kerala

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
Northern zone	2.0	2.2	2.3	2.4	3.0	4.3	4.6	4.2	3.3	2.2	1.9	2.1	4.1	2.1	2.1	2.6	2.9
Southern zone	2.7	2.2	2.2	2.4	3.8	5.2	5.2	4.9	4.2	2.9	2.3	2.8	4.9	2.7	2.4	2.8	3.4
Central zone	2.2	1.9	2.0	2.1	3.0	4.3	4.4	4.0	3.3	2.2	1.9	2.3	4.0	2.1	2.1	2.4	2.8
High range	1.6	1.4	1.3	1.2	2.0	3.3	3.4	3.2	2.3	1.5	1.5	1.8	3.1	1.6	1.5	1.5	2.1
Problem area zone	1.8	1.7	1.9	2.1	3.0	4.3	4.3	4.1	3.3	2.3	1.6	1.9	4.0	1.9	1.7	2.3	2.7

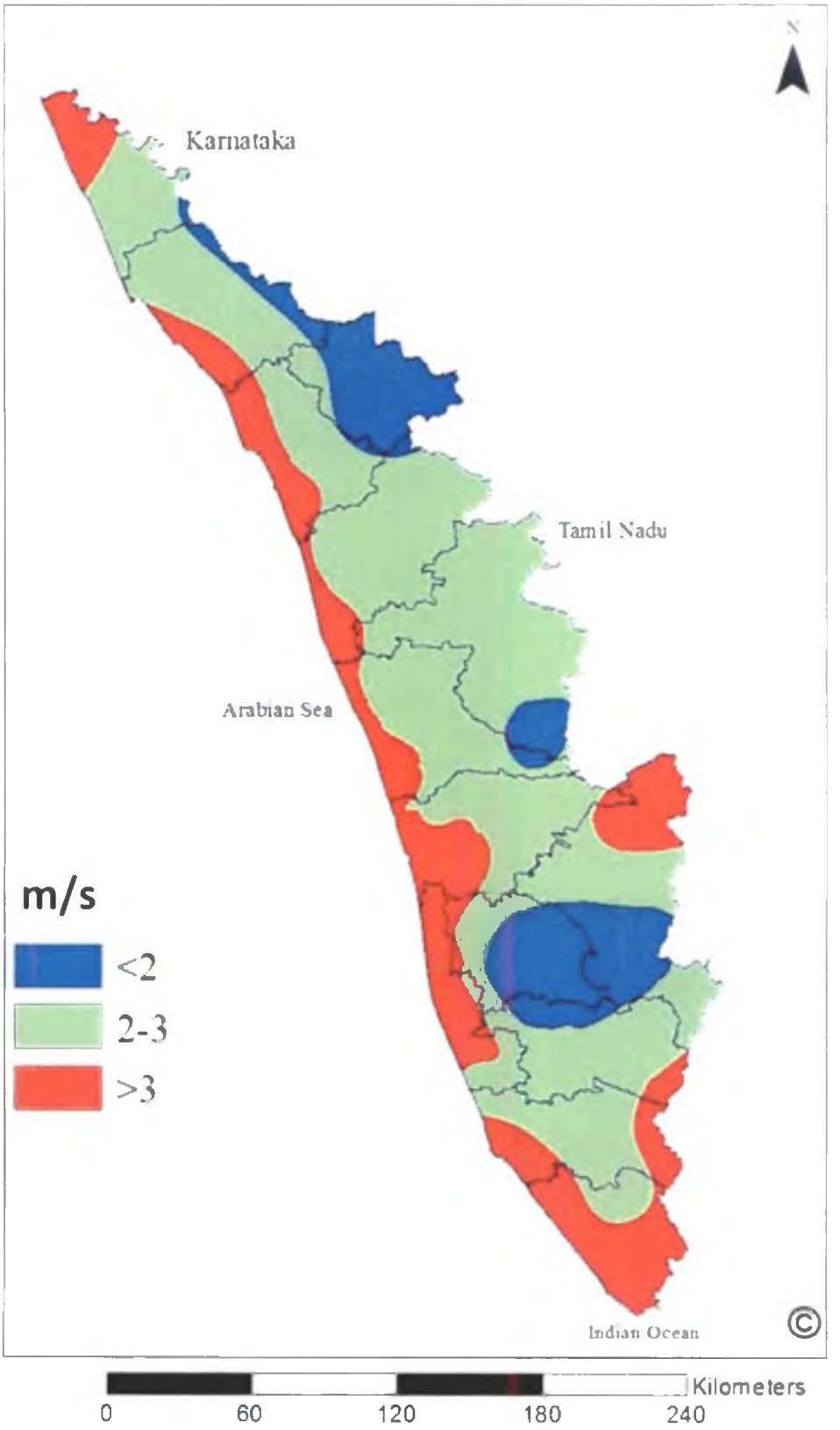


Fig. 116: Annual mean wind speeds over Kerala

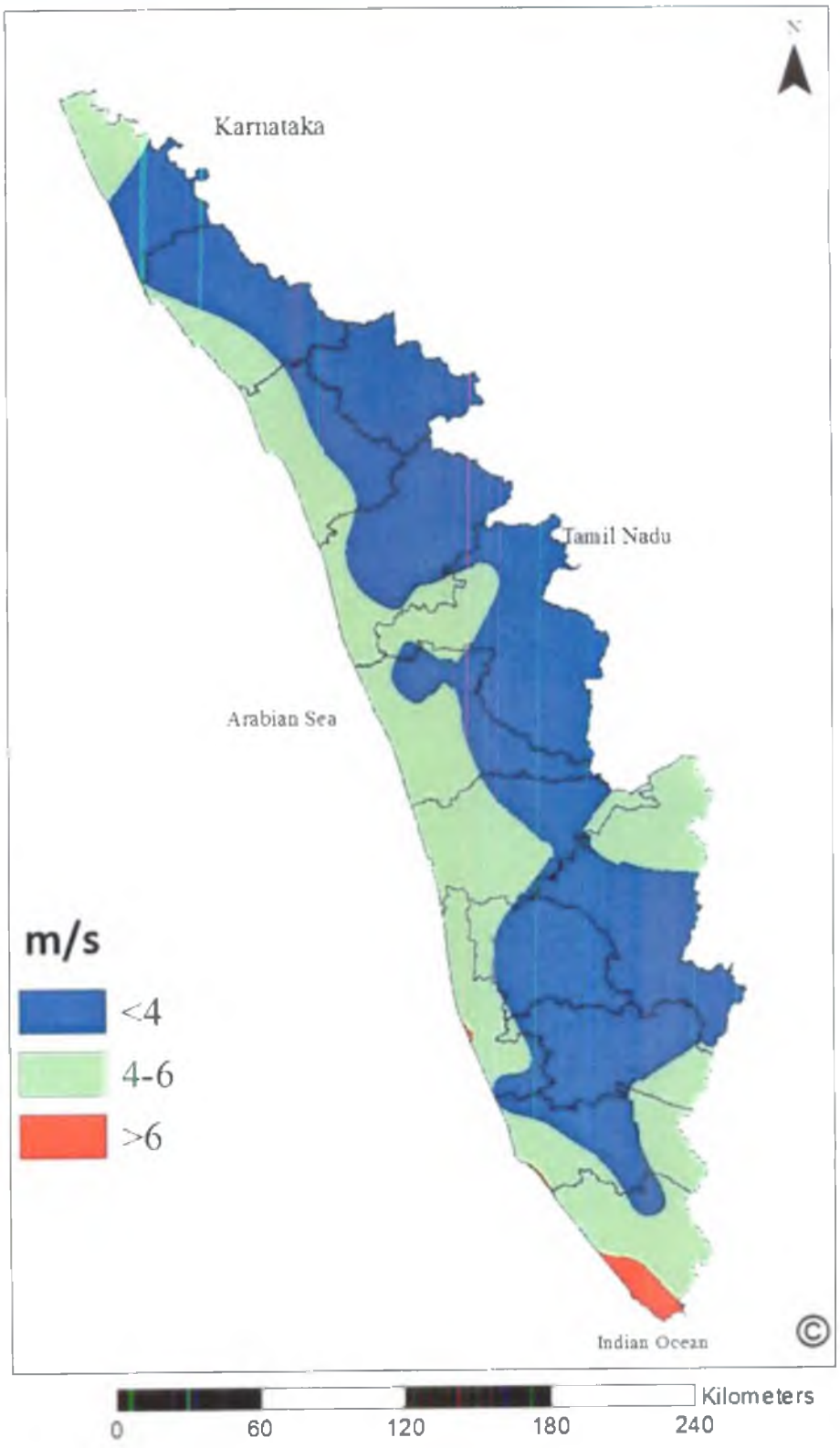


Fig. 117: Southwest monsoon season mean wind speeds over Kerala

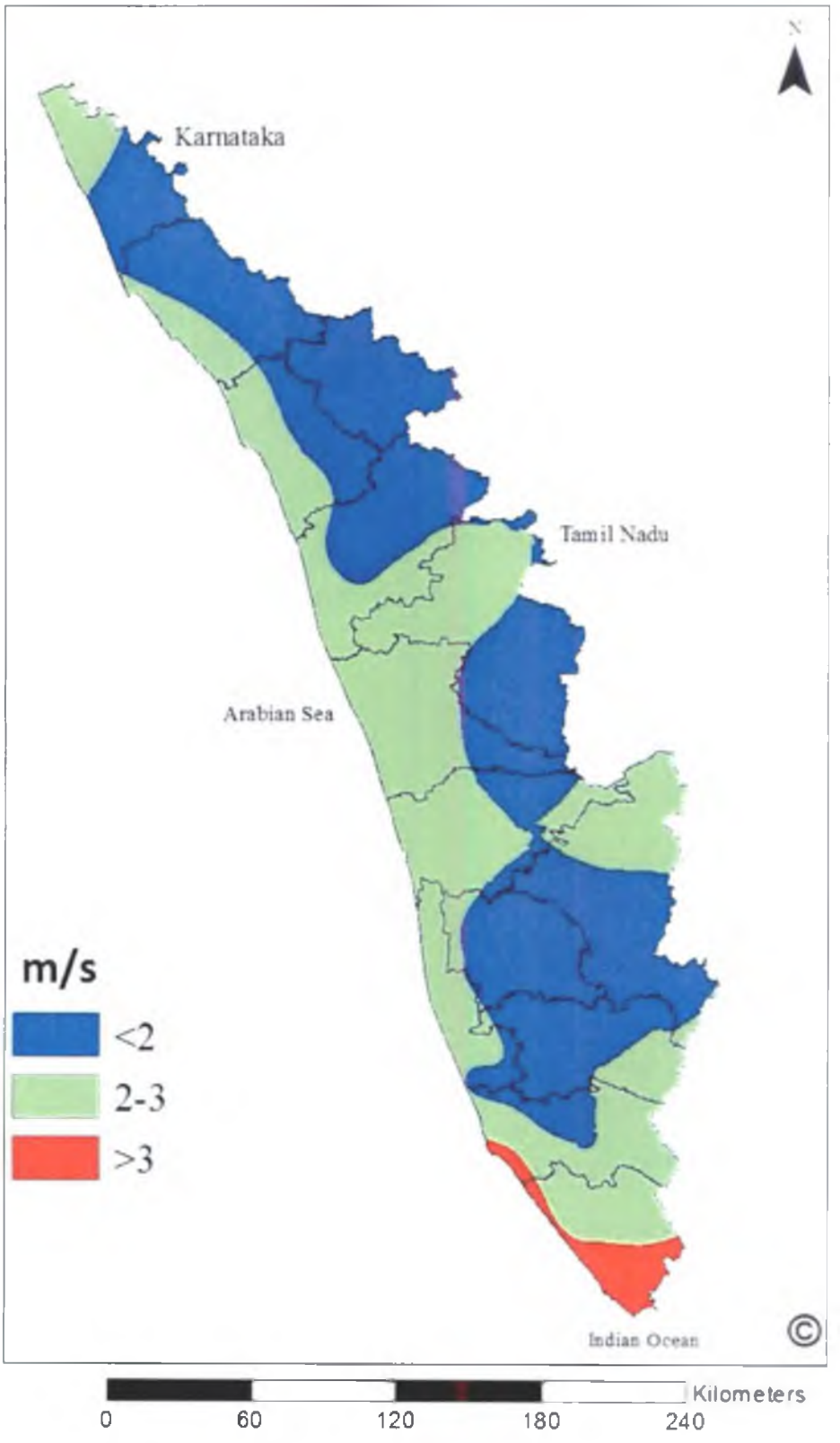


Fig. 118: Northeast monsoon season mean wind speeds over Kerala

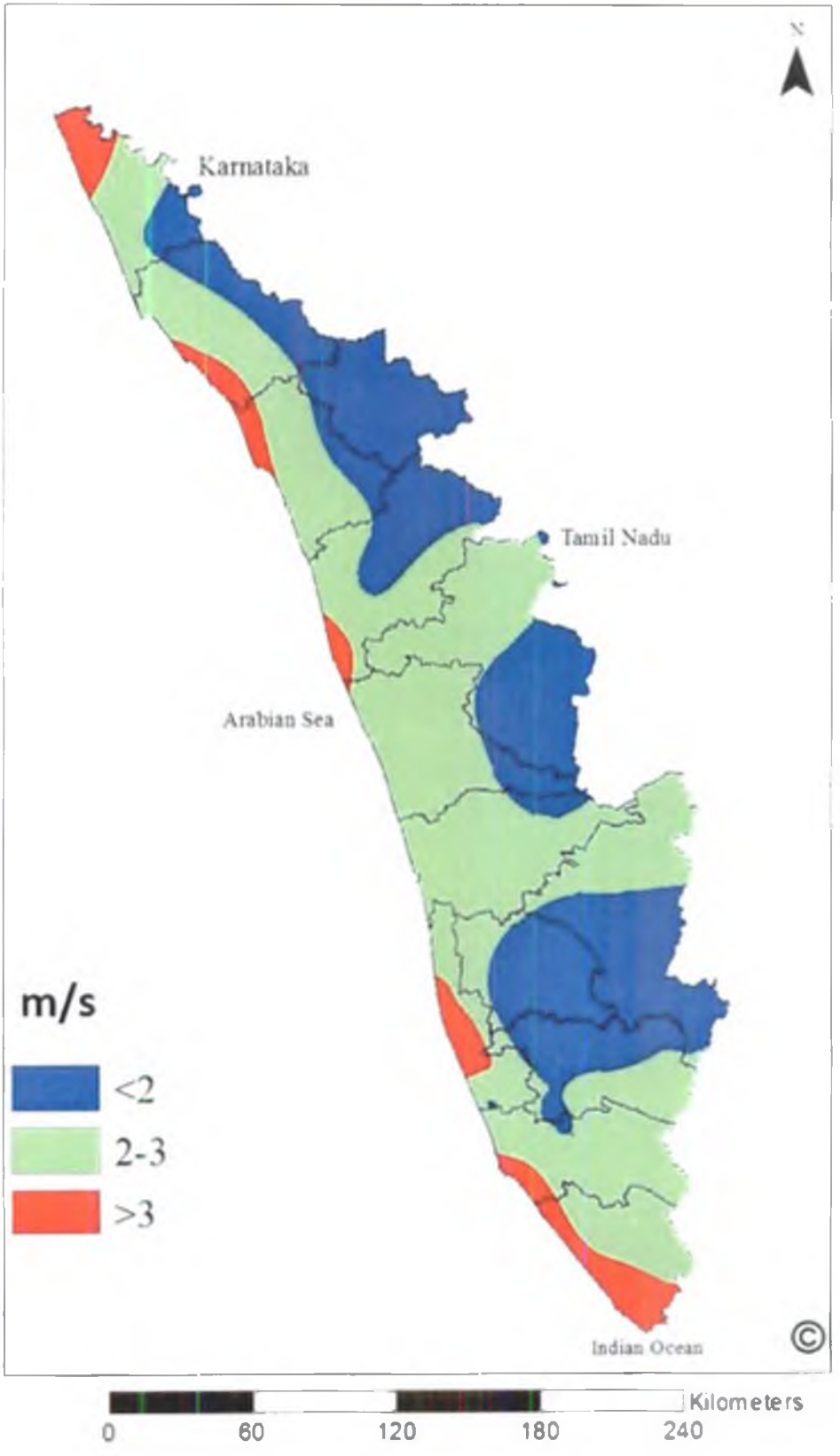


Fig. 119: Summer season mean wind speeds over Kerala

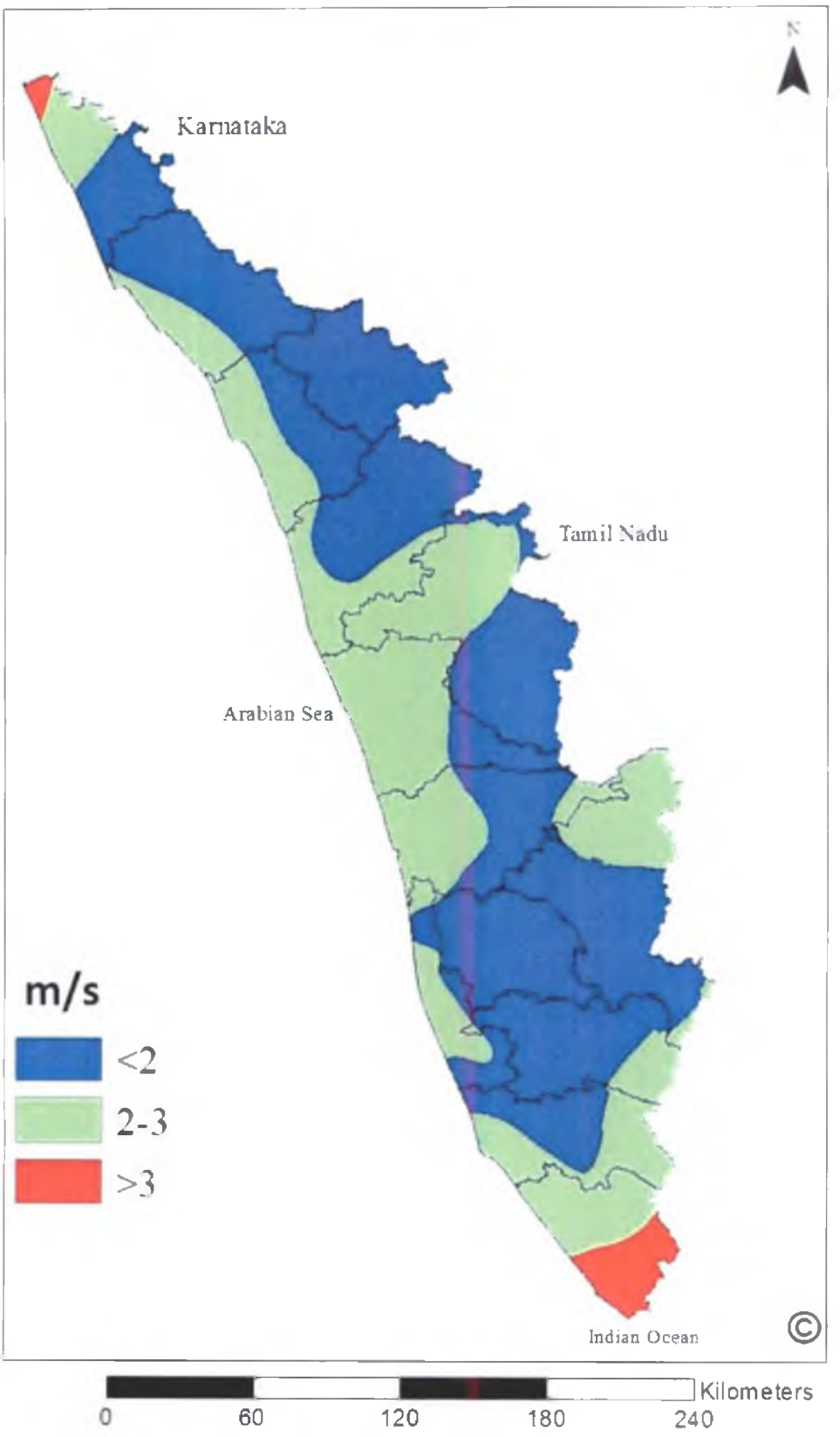


Fig. 120: Winter season mean wind speeds over Kerala

8. Sunshine hours

Mean annual number of hours of bright sunshine for the state are 7.0 hr / day with Southern zone receiving mean annual sunlight for a longer period (8.0 hr/day). Thiruvanathapuram district (8.0 hr/day) is the brightest district and Idukki is the dimmest (6.1 hr/day). February is the month with longest days (8.9 hr/day) and July is the month of days with shorter day length (3.8 hr/day). Kasaragode district receives day light for the longest period (9.6 hr/day) and this occurs in the month of February. Idukki district receives day for shortest period (2.2 hr/day) in the month of July (Table 28-29).

Out of all four seasons SWM receives sunlight for the shortest period on an average (4.7 hr/day).During SWM season High range zone records the lowest number hours/day of bright sunlight (3.5 hr/day) and Southern zone receives highest number hours/day of bright sunlight (7.5 hr/day) followed by central zone and Problem zones(4.0 hr/day).In NEM season Kasargod district receives highest number of sunshine hours (7.4 hr/day) followed by Thiruvananthapuram district (7.3 hr/day) and Idukki receives lowest number of sunshine hours (5.6 hr/day) followed by Alappuzha district (5.8 hr/day) (Fig.121-125).

In winter season Kasargod district is the brightest district (9.4 hr/day) followed by Thrissur district having 9.1 hr/day sunshine hours. Idukki district receives dimmest district during winter season having 8.10 hrs/day. During summer season also Southern zone receives highest number of sunshine hours (8.6 hr/day) and lowest in Problem zone (7.1 hr/day). Among the districts Thiruvanathapuram receives highest number of sunshine hours (8.6 hr/day) and Alappuzha district receives lowest number of sunshine hours (5.7 hr/day).

Table 28: District wise average mean sunshine hours/day

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
kozhikkod	8.2	8.6	8.5	8.2	6.8	3.5	2.6	3.7	5.5	5.5	6.1	7.6	3.8	6.4	8.6	7.8	6.7
Thiruvananthapuram	8.5	9.1	9.1	8.2	8.3	7.3	7.6	7.7	7.6	6.9	7.1	7.8	7.5	7.3	8.8	8.6	8.0
palakkad	8.8	9.1	8.6	8.0	7.3	3.7	3.2	4.4	5.8	5.8	6.7	8.2	4.3	6.9	8.9	8.0	7.0
thrissur	8.9	9.2	8.7	7.8	6.4	3.2	2.6	3.8	5.5	5.7	6.6	8.2	3.8	6.8	9.1	7.6	6.8
kottayam	8.0	8.6	8.3	7.3	6.3	3.9	3.2	4.5	5.3	5.3	5.5	6.9	4.2	5.9	8.3	7.3	6.4
Idukki	7.7	8.5	8.1	7.4	6.4	2.8	2.2	3.5	5.3	4.8	5.0	6.9	3.5	5.6	8.1	7.3	6.1
Kasargod	9.2	9.6	9.0	8.8	7.7	3.3	2.5	3.8	5.8	6.2	7.4	8.7	3.9	7.4	9.4	8.5	7.3
Alappuzha	8.5	8.6	7.6	7.1	6.1	3.6	3.0	3.9	4.3	5.3	5.5	6.7	3.7	5.8	8.6	6.9	6.2
State mean	**8.5**	**8.9**	**8.6**	**7.9**	**7.1**	**4.3**	**3.8**	**4.8**	**5.9**	**5.8**	**6.3**	**7.6**	**4.7**	**6.6**	**8.7**	**7.8**	**7.0**

Table 29: Zone wise average mean sunshine hours/day

Zones	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
Northern zone	8.7	9.1	8.8	8.5	7.2	3.4	2.6	3.7	5.6	5.9	6.8	8.1	3.8	6.9	9.0	8.2	7.0
Southern zone	8.5	9.1	9.1	8.2	8.3	7.3	7.6	7.7	7.6	6.9	7.1	7.8	7.5	7.3	8.8	8.6	8.0
Central zone	8.9	9.1	8.7	7.9	6.9	3.5	2.9	4.1	5.6	5.7	6.7	8.2	4.0	6.9	9.0	7.8	6.9
High range	7.7	8.5	8.1	7.4	6.4	2.8	2.2	3.5	5.3	4.8	5.0	6.9	3.5	5.6	8.1	7.3	6.1
Problem zone	8.3	8.6	8.0	7.2	6.2	3.8	3.1	4.2	4.8	5.3	5.5	6.8	4.0	5.9	8.4	7.1	6.3

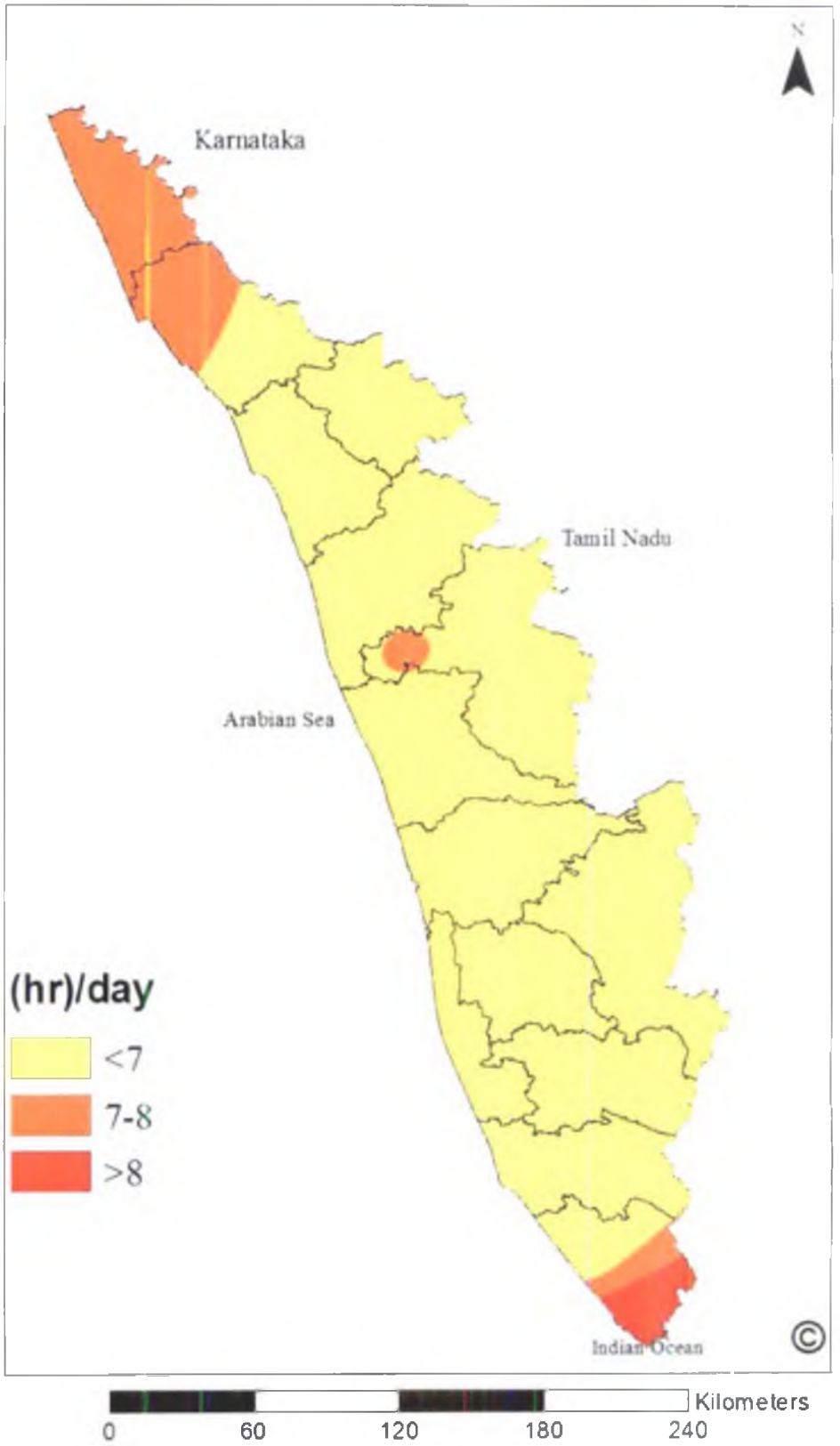


Fig. 121: Annual mean sunshine hours over Kerala

9. Open pan evaporation

The analysis showed that the mean annual evaporation of the state is 4.0 mm. Among the districts Kozhikode has maximum evaporation of mean value 5.1 mm followed by Thrissur district (4.5 mm) and lowest mean value recorded at Thiruvananthapuram (3.5 mm). Central zone shows highest annual mean evaporation value (4.5 mm). In SWM season Kerala state recorded an average of mean value of evaporation 2.8 mm. During NEM the state average becomes 3.3 mm. During summer season Kerala state has an average mean value 4.9 mm.

March is the month of maximum mean evaporation; the mean evaporation value of March is 4.9 mm followed by February having 4.7 mm. July is the month of minimum mean value of evaporation of 2.6 mm. Kozhikode district data shows that the mean value of evaporation on its peak in the month of March having mean evaporation value 7.2 mm (Table 30-31). The spatial distribution of annual and seasonal mean evaporation is presented in the figure.126 -130.

Table 30: District wise average mean monthly open-pan evaporation of districts of Kerala (mm)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	summer	Annual
Kottayam	4.3	4.8	5.3	4.6	3.9	2.7	2.5	2.8	3.1	3.0	3.0	3.6	2.8	3.2	4.6	4.6	3.6
Thiruvananthapuram	3.2	3.6	4.0	3.6	3.3	2.7	2.9	3.2	3.3	2.8	2.7	2.8	3.0	2.8	3.4	3.6	3.2
Kasaragode	3.2	4.0	4.0	4.2	3.9	1.9	1.8	2.1	2.5	2.6	2.7	2.9	2.0	2.7	3.6	4.0	3.0
Thrissur	6.4	6.3	6.2	5.3	4.5	3.1	2.8	3.1	3.4	3.2	3.8	5.4	3.1	4.1	6.4	5.3	4.5
Malappuram	2.8	3.0	3.1	3.3	3.0	4.4	3.4	2.3	2.7	2.8	2.8	2.6	3.2	2.7	2.9	3.1	3.0
Palakkad	5.3	5.7	5.8	5.2	4.7	2.8	2.6	2.9	3.3	3.1	3.3	4.4	2.9	3.6	5.5	5.2	4.1
Alappuzha	3.8	4.1	4.4	4.3	3.6	3.5	2.4	2.9	2.8	3.1	3.2	3.6	2.9	3.3	4.0	4.1	3.5
Kozhikode	5.3	6.3	7.2	7.0	6.3	4.1	3.6	3.9	4.5	4.1	4.0	4.7	4.0	4.3	5.8	6.8	5.1
Idukki	3.6	4.6	4.8	3.9	3.0	2.1	1.3	1.9	2.1	2.1	2.1	2.8	1.9	2.4	4.3	3.4	2.9
Kerala mean	4.2	4.7	5.0	4.6	4.0	3.0	2.6	2.8	3.1	3.0	3.1	3.6	2.9	3.2	4.5	4.5	3.6

Table 31: Zone wise average mean monthly open-pan evaporation of districts of Kerala (mm)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	NEM	Winter	Summer	Annual
Northern zone	3.8	4.4	4.8	4.8	4.4	3.5	2.9	2.7	3.2	3.2	3.2	3.4	3.1	3.2	4.1	4.7	3.7
Southern zone	3.2	3.6	4.0	3.6	3.3	2.7	2.9	3.2	3.3	2.8	2.7	2.8	3.0	2.8	3.4	3.6	3.2
Central zone	5.8	6.0	6.0	5.3	4.6	2.9	2.7	3.0	3.4	3.1	3.5	4.9	3.0	3.9	5.9	5.3	4.3
High range	3.6	4.6	4.8	3.9	3.0	2.1	1.3	1.9	2.1	2.1	2.1	2.8	1.9	2.4	4.3	3.4	2.9
Problem area zone	4.1	4.5	4.9	4.5	3.8	3.1	2.5	2.9	3.0	3.1	3.1	3.6	2.8	3.3	4.3	4.4	3.6

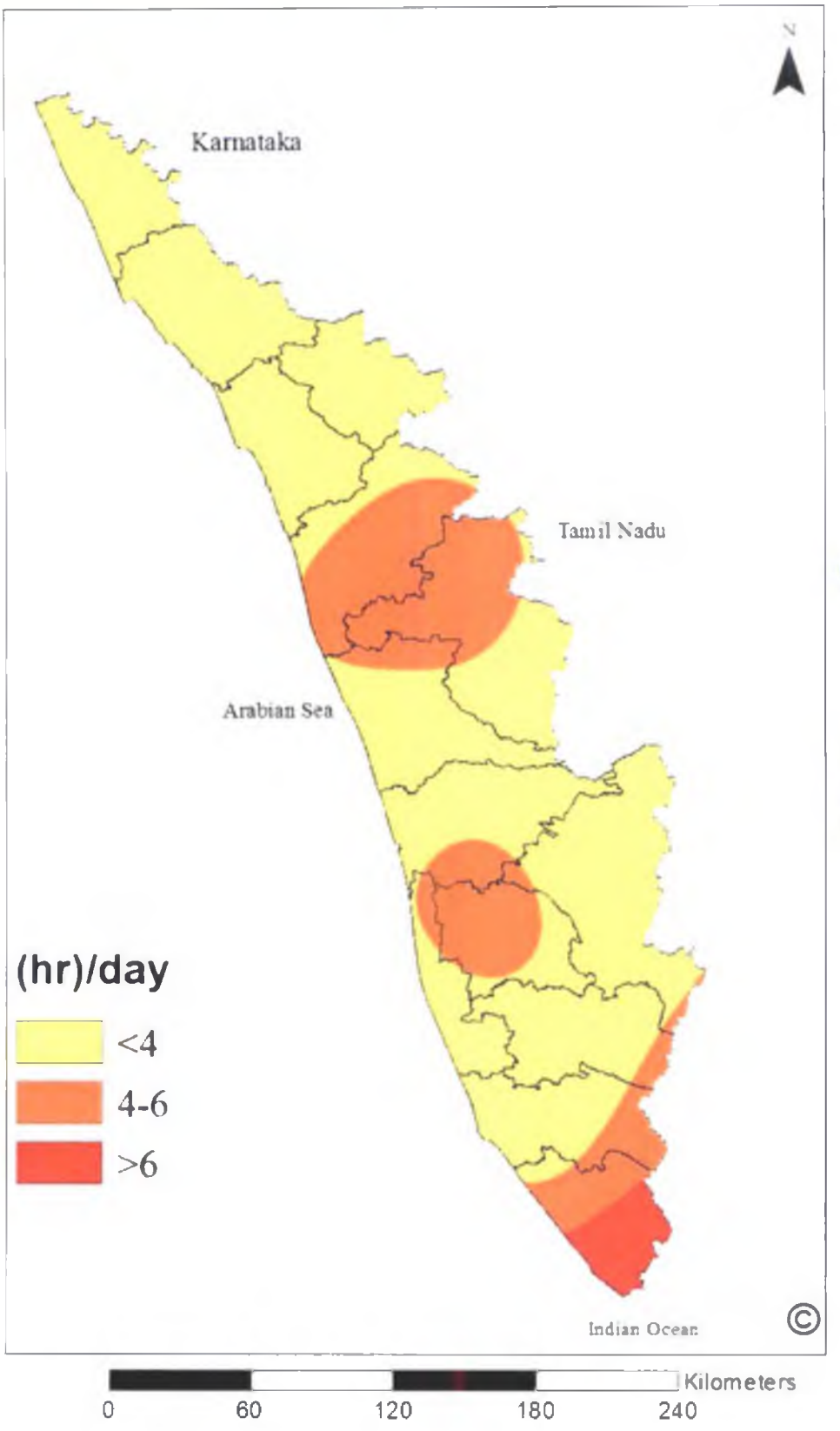


Fig. 122: Southwest monsoon season mean sunshine hours/day over Kerala

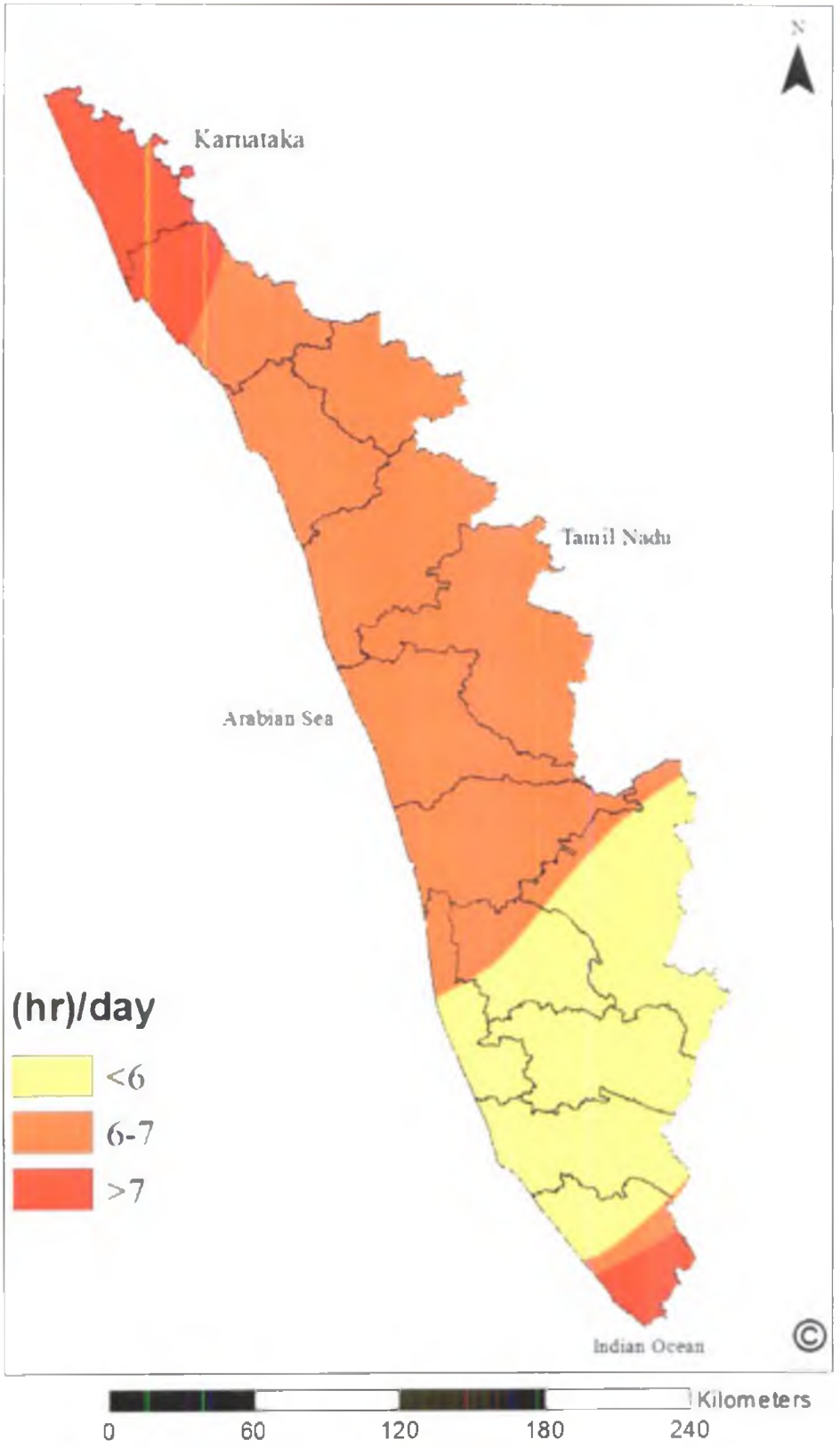


Fig. 123: Northeast monsoon season mean sunshine hours/day over Kerala

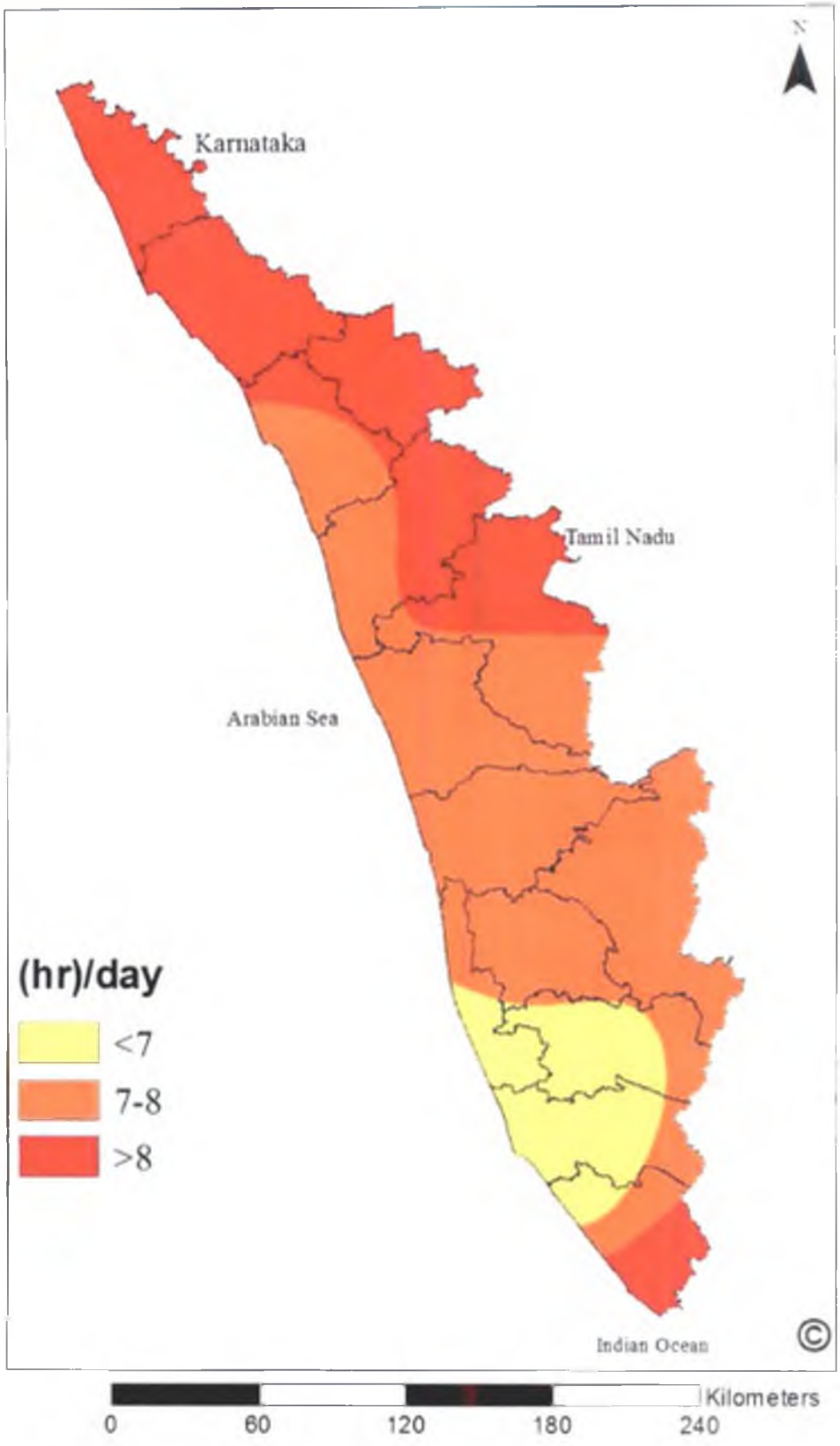


Fig. 124: Summer season mean sunshine hours/day over Kerala

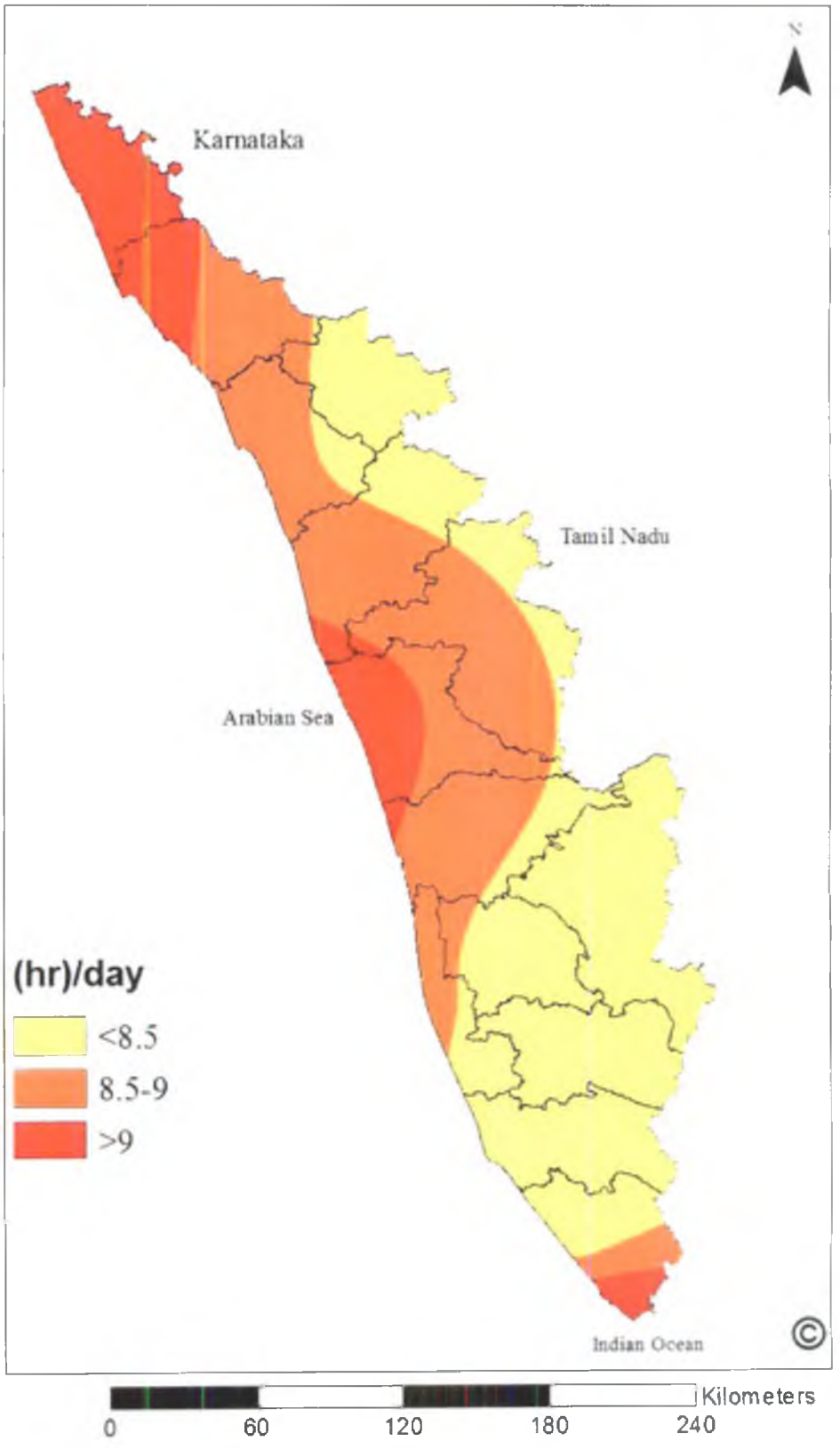


Fig. 125: Winter season mean sunshine hours /day over Kerala

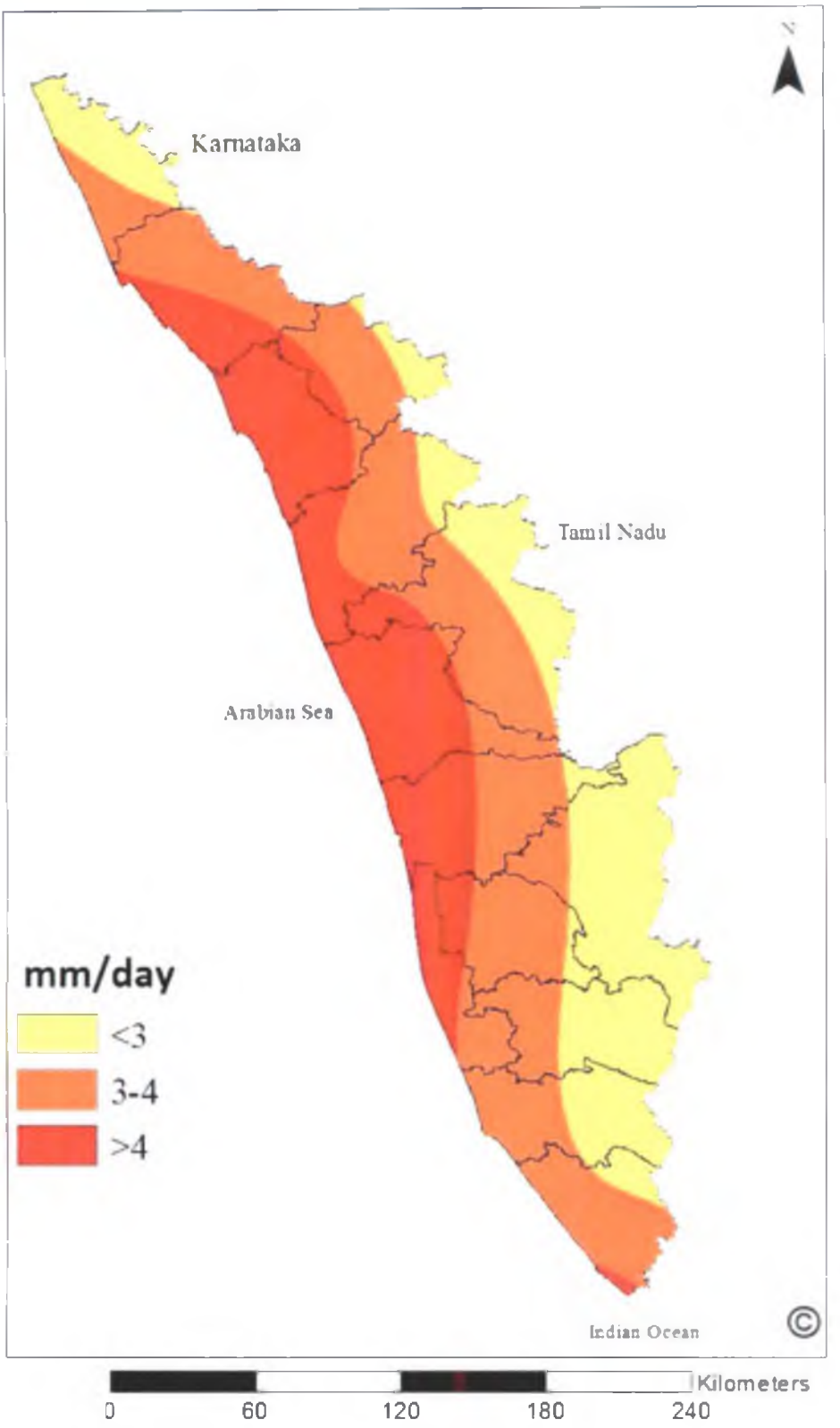


Fig. 126: Annual mean open-pan evaporation over Kerala

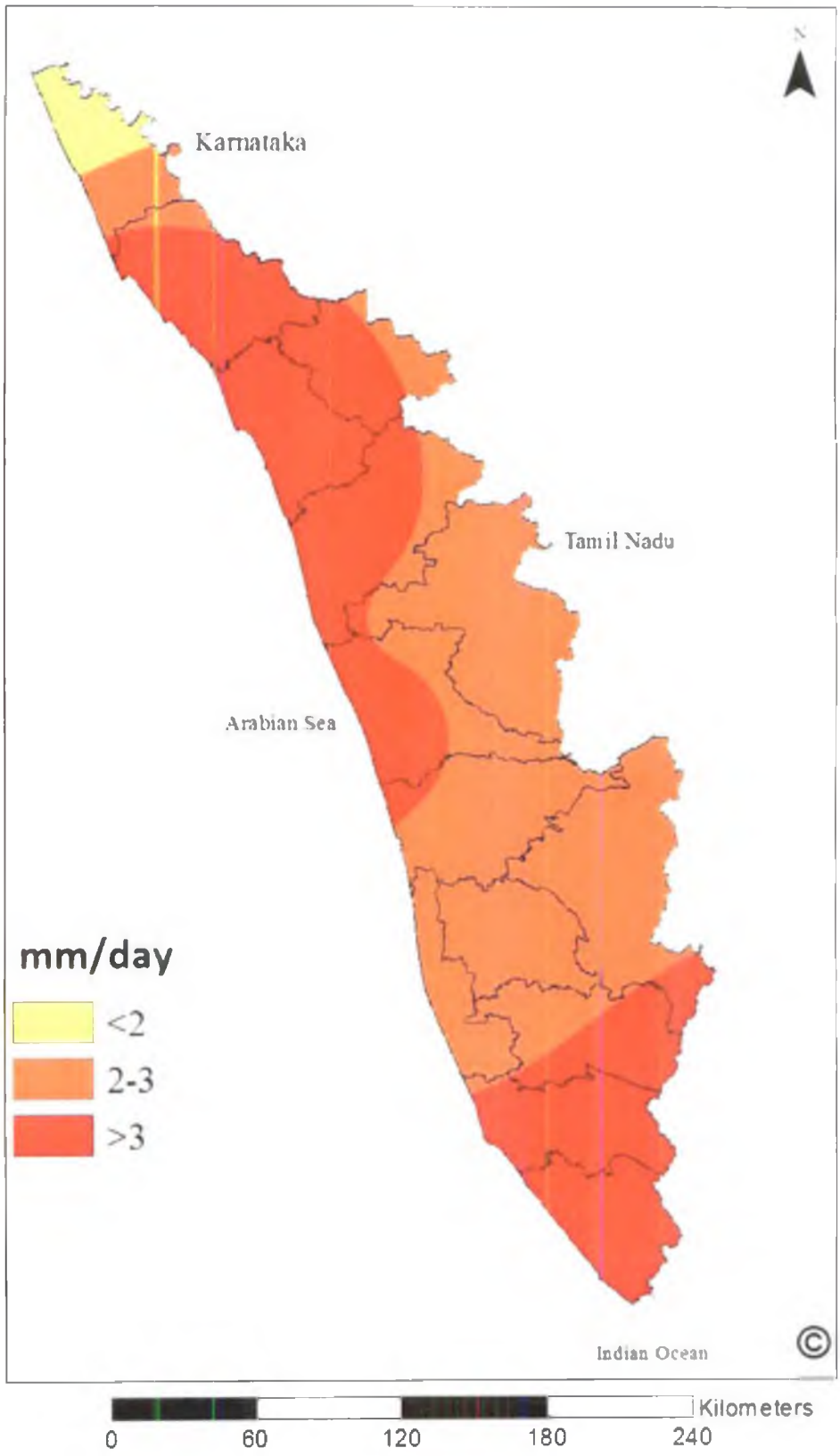


Fig. 127: Southwest monsoon season mean open-pan evaporation over Kerala

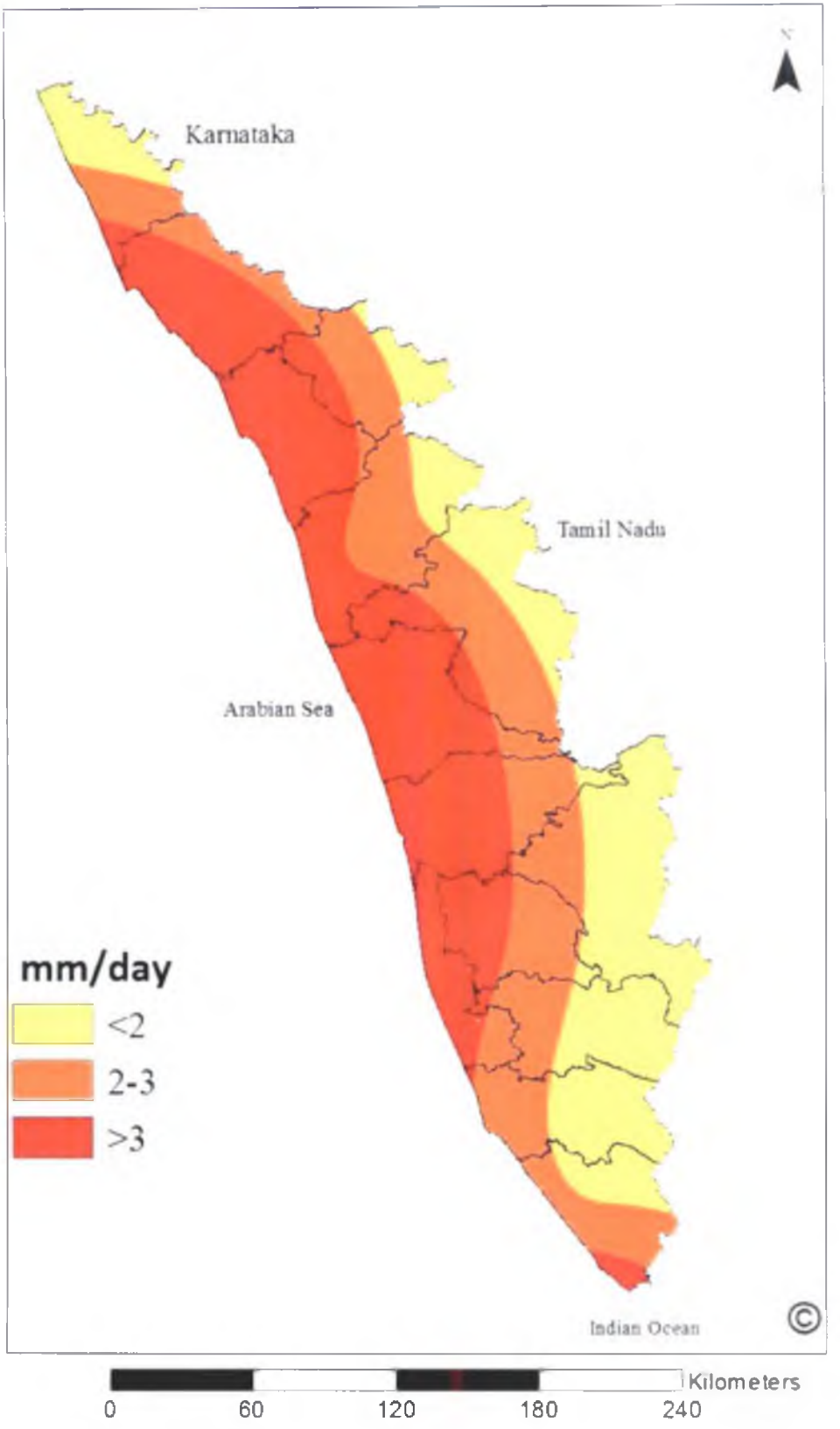


Fig. 128: Northeast monsoon season mean open-pan evaporation over Kerala

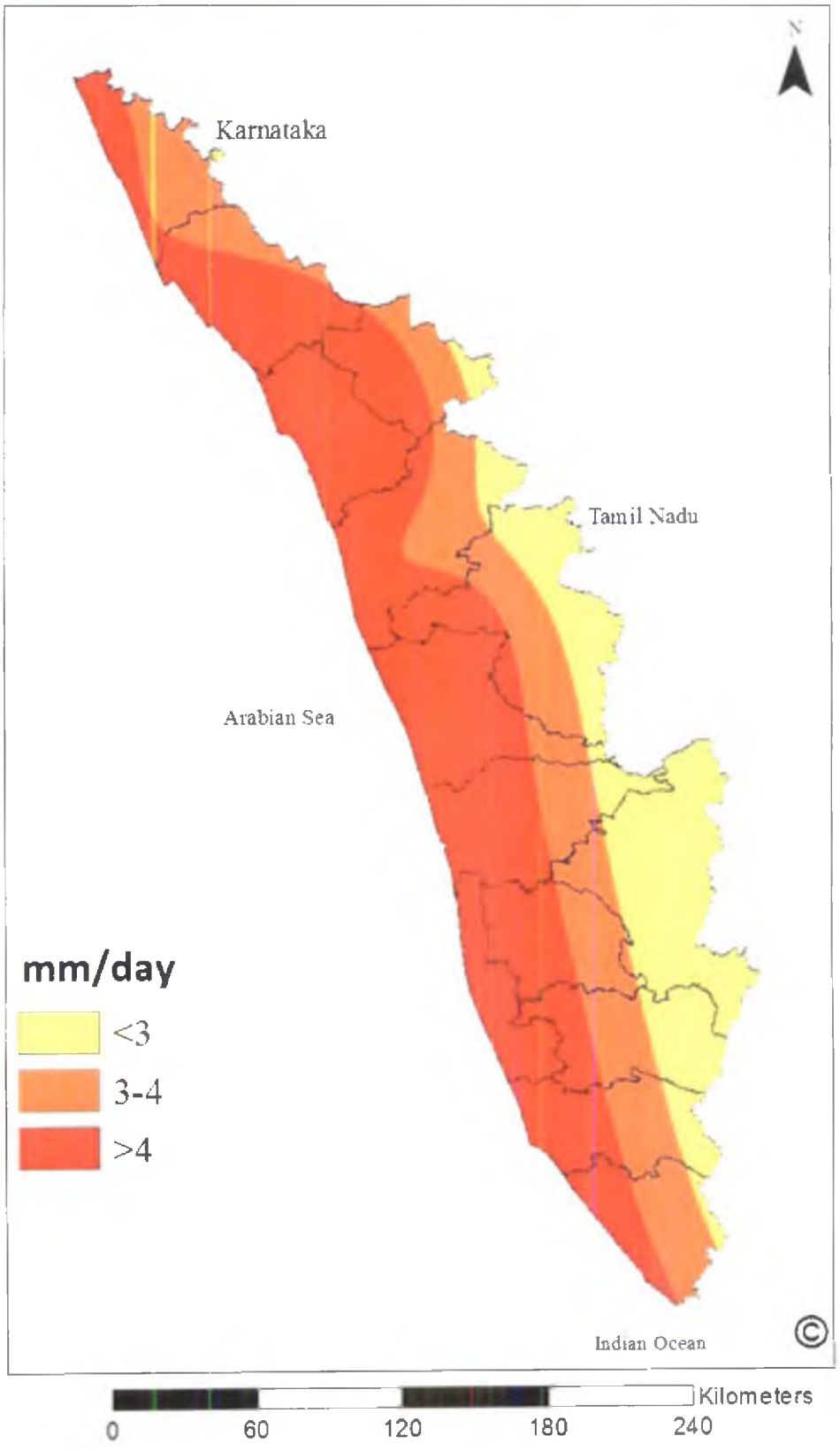


Fig. 129: Summer season mean open-pan evaporation over Kerala

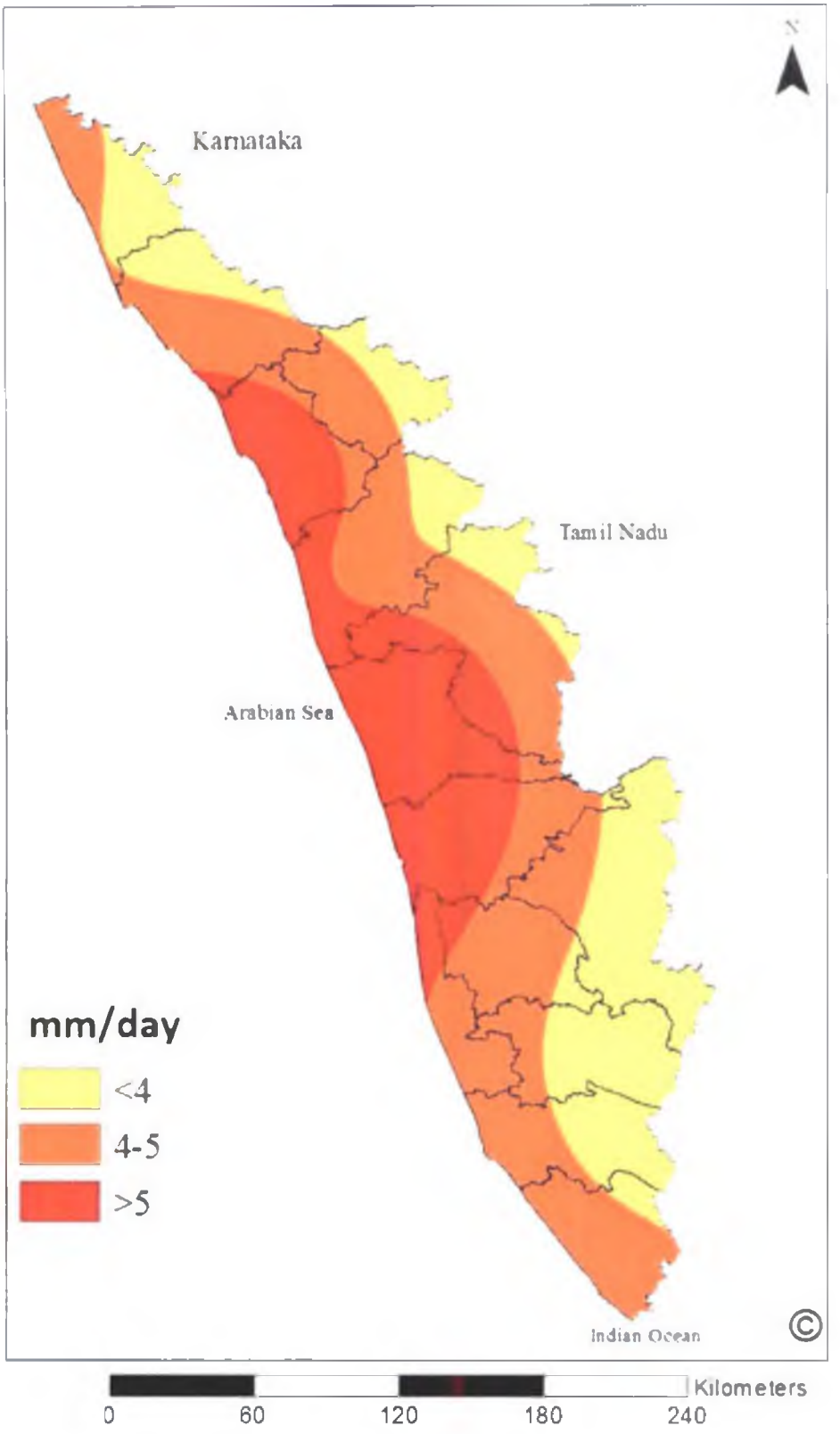


Fig. 130: Winter season mean open-pan evaporation over Kerala

Annexure-I

Details for stations and length of data used for rainfall analysis

Rainfall Daily data

Sl. No:	District	Stations	Data Period	Missing data period
1	Alappuzha	Mankombu	1990-2014	
2	Kannur	panniyur	2001-2013	
3	Kasargode	pilicode	1983-2014	1999, 2000, 2001, 2002
4		Kasargod	2005-2012	
5	Kozhikkode	CWRDM	1980-2014	
6	Kottayam	RRI	1985-2014	1988,90,99
7		kumarakam	1991-2013	
8	Malappuram	Malappuram, Civil station	2001-2014	
9	Wayanad	Ambalawayal	1991-2012	
10	Idukki	pambadumpara	1991-2012	
11	Ernakulam	Aluva	1991-2013	
12		perumbavur	1991-2013	2002,03,04
13		piravam	1991-2013	2002
14	Palakkad	Alathur	1991-2013	
15		chittoor	1991-2013	
16		thrithala	1991-2013	
17		mannarkkad	1991-2013	
18		kollengode	1991-2013	
19		parmbikulam	1991-2013	2002 , 2007
20		ottappalam	1991-2013	2002
21		pattambi	1983-2013	
22	Thrissur	chalakkudy	1991-2013	
23		Emackal	1991-2013	
24		kannara	1991-2013	
25		kunnamkulam	1991-2013	
26		vellanikkara	1983-2014	
27	Thiruvananthapuram	Nedumangad	1991-2013	
28		Neyyattinkara	1992-2013	2002, 2003, 2005, 2009
29		varkala	1991-2012	2002
30		tvm city	1983-2012	1995, 1996, 1997, 1998
31		tvm AP	1983-2012	1995, 1996, 1997, 1998
32		Vellayini	1983-2014	
33	Kollam	Aryankavu	1991-2012	
34		kollam	1991-2012	
35		punalur	1991-2013	

Rainfall monthly data

Sl. No.	District	Stations	Data Period
1	Alappuzha	Alappuzha	1951-2012
2		Chengannur	1991-2012
3		Cherthala	1991-2012
4		haripad	1991-2012
5		Kayamkulam	1991-2012
6		Mavelikkara	1991-2012
7	Kannur	Irikkur	1991-2012
8		Thalassery	1991-2012
9	Kasargode	Hosdurg	1991-2012
10	Kozhikkode	kozhikkode OBSY	1991-2012
11	Kottayam	Vaikom	1991-2009
12		kottayam	1998-2009
13	Malappuram	Nilambur	1991-2012
14		Manjeri	1991-2012
15		Ponnani	1991-2012
16		Perinthelmanna	1991-2012
17		Angadippuram	1991-2012
18	Pathanamthitta	Konni	1991-2012
19		Thiruvalla	1991-2009
20	Wayanad	Vythiri	1991-2012
21		Mananthawadi	1991-2012
22	Thiruvananthapuram	CTCRI	1998-2014
23	Idukki	Munnar	1991-2012
24		Pirumed	1991-2012

Temperature – Daily data

Sl.No:	District	Stations	Data Period	Missing data
1	Aiappuzha	Mankombu	1990-2014	
2	Kannur	Panniyur	2003-2013	
3	Kasargod	Kasargod	2005-2012	
4		Pilicod	1991-2014	
5	Kottayam	RRI	1985-2014	1988, 1990
6	Malappuram	Malappuram Civil station	2001-2013	
7	Wayanad	Ambalawayal	1991-2012	
8	Idukki	Pambadumpara	1990-2007	1991,92,93
9	Thrissur	Vellanikkara	1983-2014	
10		Chalakkudy	1996-2011	
11	Thiruvanathapuram	Vellayini	1983-2014	
12	Palakkad	Pattambi	1983-2013	

Temperature – Monthly data

Sl. No:	District	Stations	Data Period	Missing data
1	Aiappuzha	Aiappuzha	1956-2012	
2	Kozhikkod	Kozhikkod	1956-2012	
3	Cochin	Cochin	1956-2012	
4	Kottayam	kottayam	1998-2012	
5	Kannur	Kannur	2008-2012	
6	Malappuram	Karipur	1993-2012	
7	Palakkad	Mundur	2005-2014	
8	Kozhikkod	CWRDM	1984-2014	
9	Kollam	Punalur	1956-2012	
10	Trivandrum	CTCRI	1998-2014	2008-2011
11		Trivandrum	1956-2012	

Relative humidity

Sl. No:	District	Stations	Data Period	Daily/monthly	Missing data
1	Alappuzha	Alapuzha	2008-2012	Monthly	
2		Kannur	2008-2012	Monthly	
3	Kasargode	pilicode	1983-2014	Daily	
4		kasargode	2005-2010	Daily	
5	Kozhikkode	Kozhikkode AP	2008-2012	Monthly	
6		CWRDM	1984-2014	Daily	
7	Kottayam	Kottayam	1998-2012	Daily	
8	Kottayam RRI	RRI	1985-2014	Daily	1988, 1990
9	Malappuram	Karipur Airport	1993-2012	Monthly	
10	Wayanad	Ambalavayal	1991-2012	Daily	
11	Idukki	pampadumpara	1994-2007		
12	Ernakulam	Cochi	2008-2012	Monthly	
13		NAS, Cochi	1974-2013	Daily	1982, 2003, 2007, 2008
14	Palakkad	Pattambi	1983-2013	Daily	
15	Thrissur	vellanikkara	1983-2014	Daily	
16	Thiruvananthapuram	Vellayini	1983-2014	Daily	
17		Trivandrum	2008-2012	Monthly	
18		ctcri, tvm	1998-2014	Monthly	2008,2009,2010, 2011
19	kollam	Punalur	2008-2012	Monthly	

Sunshine hours

Sl. No:	District	Stations	Data Period	Monthly/Daily	Missing data
1	Alappuzha	Mankombu	2006-2014	Daily	
2	Idukki	Pambadumpara	2000-2007	Daily	2006
3	Kasargod	pilicod	1984-2014	Daily	
4	kottayam	kottayam rri	1991-2014	Daily	
5	kozhikkod	CWRDM	1987-2014	Daily	2005,06,07,08
6	palakkad	pattambi	1983-2012	Daily	
7	Thiruvananthapuram	CTCRI	1998-2007	Monthly	
8		Vellayini	2012-2014	Daily	
9	thrissur	Vellanikkara	1983-2014	Daily	

Evaporation

Sl. No:	District	Stations	Data Period	Daily/monthly	Missing data
1	Alappuzha	Mankombu	2006-2014	Daily	
2	Idukki	Pambadumpara	2000-2007	Daily	2006
3	Kasargod	pilicod	1984-2014	Daily	
4	kottayam	kottayam rri	1991-2014	Daily	
5	kozhikkod	CWRDM	1987-2014	Daily	2005,06,07,08
6	palakkad	pattambi	1983-2012	Daily	
7	Thiruvananthapuram	CTCRI	1998-2007	Monthly	
8		Vellayini	2012-2014	Daily	
9	Thrissur	Vellanikkara	1983-2014	Monthly	
10	Malappuram	Malappuram	2001-2014	Daily	

Annexure-II

Rainfall Daily data

Sl. No:	District	Stations	Data Period
1	Alappuzha	Mankombu	1990-2014
2	Kannur	panniyur	2001-2013
3	Kasargode	pilicode	1983-2014
4		Kasargod	2005-2012
5	Kozhikkode	CWRDM	1980-2014
6	Kottayam	RRI	1985-2014
7		kumarakam	1991-2013
8	Malappuram	Malappuram, Civil station	2001-2014
9	Wayanad	Ambalawayal	1991-2012
10	Idukki	pambadumpara	1991-2012
11	Ernakulam	Aluva	1991-2013
12		perumbavur	1991-2013
13		piravam	1991-2013
14	Palakkad	Alathur	1991-2013
15		chittoor	1991-2013
16		thrithala	1991-2013
17		mannarkkad	1991-2013
18		kollengode	1991-2013
19		parmbikulam	1991-2013
20		ottappalam	1991-2013
21		pattambi	1983-2013
22	Thrissur	chalakkudy	1991-2013
23		Emackal	1991-2013
24		kannara	1991-2013
25		kunnamkulam	1991-2013
26		vellanikkara	1983-2014
27	Thiruvananthapuram	Nedumangad	1991-2013
28		Neyyattinkara	1992-2013
29		varkala	1991-2012
30		tvm city	1983-2012
31		tvm AP	1983-2012
32		Vellayini	1983-2014
33	Kollam	Aryankavu	1991-2012
34		kollam	1991-2012
35		punalur	1991-2013

Rainfall monthly data

Sl. No.	District	Stations	Data Period
1	Alappuzha	Aiappuzha	1951-2012
2		Chengannur	1991-2012
3		Cherthala	1991-2012
4		haripad	1991-2012
5		Kayamkulam	1991-2012
6		Mavelikkara	1991-2012
7	Kannur	Irikkur	1991-2012
8		Thalassery	1991-2012
9	Kasargode	Hosdurg	1991-2012
10	Kozhikkode	kozhikkode OBSY	1991-2012
11	Kottayam	Vaikom	1991-2009
12		kottayam	1998-2009
13	Malappuram	Nilambur	1991-2012
14		Manjeri	1991-2012
15		Ponnani	1991-2012
16		Perinthelmanna	1991-2012
17		Angadippuram	1991-2012
18	Pathanamthitta	Konni	1991-2012
19		Thiruvalla	1991-2009
20	Wayanad	Vythiri	1991-2012
21		Mananthawadi	1991-2012
22	Thiruvananthapuram	CTCRI	1998-2014
23	Idukki	Munnar	1991-2012
24		Pirumed	1991-2012

Temperature – Daily data

Sl.No:	District	Stations	Data Period
1	Alappuzha	Mankombu	1990-2014
2	Kannur	Panniyur	2003-2013
3	Kasargod	Kasargod	2005-2012
4		Pilicod	1991-2014
5	Kottayam	RRI	1985-2014
6	Malappuram	Malappuram Civil station	2001-2013
7	Wayanad	Ambalawayal	1991-2012
8	Idukki	Pambadumpara	1990-2007
9	Thrissur	Vellanikkara	1983-2014
10		Chalakkudy	1996-2011
11	Thiruvanathapuram	Vellayini	1983-2014
12	Palakkad	Pattambi	1983-2013

Temperature – Monthly data

Sl. No:	District	Stations	Data Period
1	Alappuzha	Alappuzha	1956-2012
2	Kozhikkod	Kozhikkod	1956-2012
3	Cochin	Cochin	1956-2012
4	Kottayam	kottayam	1998-2012
5	Kannur	Kannur	2008-2012
6	Malappuram	Karipur	1993-2012
7	Palakkad	Mundur	2005-2014
8	Kozhikkod	CWRDM	1984-2014
9	Kollam	Punalur	1956-2012
10	Trivandrum	CTCRI	1998-2014
11		Trivandrum	1956-2012

Relative humidity

Sl. No:	District	Stations	Data Period	Daily/monthly
1	Alappuzha	Alapuzha	2008-2012	Monthly
2		Kannur	2008-2012	Monthly
3	Kasargode	pilicode	1983-2014	Daily
4		kasargode	2005-2010	Daily
5	Kozhikkode	Kozhikkode AP	2008-2012	Monthly
6		CWRDM	1984-2014	Daily
7	Kottayam	Kottayam	1998-2012	Daily
8	Kottayam RRI	RRI	1985-2014	Daily
9	Malappuram	Karipur Airport	1993-2012	Monthly
10	Wayanad	Ambalavayal	1991-2012	Daily
11	Idukki	pampadumpara	1994-2007	
12	Ernakulam	Cochi	2008-2012	Monthly
13		NAS, Cochi	1974-2013	Daily
14	Palakkad	Pattambi	1983-2013	Daily
15	Thrissur	vellanikkara	1983-2014	Daily
16	Thiruvananthapuram	Vellayini	1983-2014	Daily
17		Trivandrum	2008-2012	Monthly
18		ctcri, tvm	1998-2014	Monthly
19	kollam	Punalur	2008-2012	Monthly

Sunshine hours

Sl. No:	District	Stations	Data Period	Monthly/Daily
1	Alappuzha	Mankombu	2006-2014	Daily
2	Idukki	Pambadumpara	2000-2007	Daily
3	Kasargod	pilicod	1984-2014	Daily
4	kottayam	kottayam rri	1991-2014	Daily
5	kozhikkod	CWRDM	1987-2014	Daily
6	palakkad	pattambi	1983-2012	Daily
7	Thiruvananthapuram	CTCRI	1998-2007	Monthly
8		Vellayini	2012-2014	Daily
9	thrissur	Vellanikkara	1983-2014	Daily

Evaporation

Sl. No:	District	Stations	Data Period	Daily/monthly
1	Alappuzha	Mankombu	2006-2014	Daily
2	Idukki	Pambadumpara	2000-2007	Daily
3	Kasargod	pilicod	1984-2014	Daily
4	kottayam	kottayam rri	1991-2014	Daily
5	kozhikkod	CWRDM	1987-2014	Daily
6	palakkad	pattambi	1983-2012	Daily
7	Thiruvananthapuram	CTCRI	1998-2007	Monthly
8		Vellayini	2012-2014	Daily
9	Thrissur	Vellanikkara	1983-2014	Monthly
10	Malappuram	Malappuram	2001-2014	Daily