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The effects of rainfall and temperature factors on temporal and spatial distribution of malaria in the Anuradhapura District

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Abstract
In the Anuradhapura district of Sri Lanka, malaria has been a seriously risky threat over the past decades and malaria epidemic continuous to be a major public health problem, particularly in the Eastern and Northern parts of the district. The natural environmental factors that affect the spread of malaria under spatial and temporal conditions are being studied in detail the finding supports to overcome problems associated with the present and future situation in the Anuradhapura district. The aim of this study is to investigate the natural environmental factors related to the occurrence of malaria in the district. Since recent times a gradually decrease in the spatial and temporal pattern of malaria can be detected. Yet, 27 % or 448 of the total number 1,628 of malaria cases found in Sri Lanka in 2005 have been reported from the Anuradhapura district. The peak transmission season of malaria in the district occurs during October to February each year, while highest recorded in January. Seasonal rainfall created in forming breeding grounds for mosquitoes. During the Yala season, there isn't much rain when small tanks dry-up leaving puddles of water here and there forming breeding grounds of mosquitoes. Larger tanks also dry-up to a lesser extent, flow slow forming puddles intermittently which favour breeding of mosquitoes. Under these favorable conditions, *Anopheles* mosquitoes emerge from these breeding grounds and may easily suck blood from humans. There is much evidence that temperature and rainfall of Sri Lanka, has changed considered during the last century. The data collected on annual and monthly rainfall as well as on temperature of the Anuradhapura district were collecteted to malaria, incidence to understand if weather has any effects of climatic phenomena on the distribution of malaria both in temporal and spatial perspectives. These results show that monthly rainfall and the occurrence of malaria exhibits a positive relationship and the Maha season is dominated by widespread malaria cases. The temperature between 28.1-28.8 °C create the most favourable conditions for the occurrence of malaria.

Keywords: Yala season, Maha Season, rainfall

Introduction

Anuradhapura is a very large district of the central province in Sri Lanka. The district is bounded in North by the Vavuniya district, Northest by the Trincomalee district, east by the Polonnaruwa district, South and Southeast by the Matale District, Southwest by the Kurunegala District the West by the Puttalam district and Northwest by the Mannar district. Beyond this belt of prominent ridge and valley topography, notably in the North Central region, the mountain ranges become narrow and highly scattered with broad shallow valleys, transforming the ridge-valley topography into an undulating land, which becomes almost imperceptible. The study particularly tries to examine the spatial and temporal distribution of malaria occurrence in the Anuradhapura district and the impact given by climatic factors while the temporal variability refers to the inter-annual and intra-seasonal variations of malaria occurrences and their relationship to rainfall and temperature factors.

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Methodology

This study focussed on secondary data obtained from published and unpublished sources, such as books, journals articles and relevant documents. Data was related to the incidence and treatments of malaria and other related information was collected from various Government institutes such as,

1 Anti-Malaria Campaign (AMC) Head Office in Colombo
2 Regional Anti-Malaria Office (RMO) in the Anuradhapura district
3 Hospitals and Medical Officers (MOH) 19 Anuradhapura district
4 Data and information were collected from PHIs.

The data were analysed to find out the statistical significance as well as proportion of representation of the variable. The data were analysed in two stages using a bi-variable to understand regression relationship and multi variables analyses as a dependent variable and independent variable.

Annual rainfall

During the 1976-2005 periods, the Anuradhapura district received a minimum and maximum total rainfall of 608 mm and 2,650 mm, respectively, in the successive years 1977 and 1984. The maximum is more than four times higher than the minimum. The rainfall range amounts as 2,050 mm. During these 30-year observation period, significant fluctuations would be observed. The highest annual total of 2,658 mm was received in 1984 and the lowest of 608 mm in 1995. The 30 year average annual rainfall is 1,236 mm for the district. There is a magnitude of the range of annual rainfall which is smaller in the district.

Seasonal rainfall

From October to February, the northeast monsoon prevails during which time the district receives most of its rainfall while from May to September, when the Southwest monsoon prevails less rain is experienced. There are two main paddy cultivation seasons: the Maha (main) season from October-February, and the Yala (minor) season from May to September. During the Maha season, the district receives 793-1047 mm of rain making rainfed agricultural activities possible.
A considerable amount of rainfall around 1,500-2,000 mm is beneficial for agricultural activities. The Southwest monsoon experiences a lesser amount of rainfall, only around 260-700 mm. The western part of the district receives, a low rainfall that makes extremely dry climate in the eastern than in the western part of the Anuradhapura district. Fig 3 shows the seasonal rainfall pattern in the Anuradhapura district, 1976-2005.

Table 1 Distribution of rainfall during Yala and Maha seasons in the Anuradhapura district, 1976-2005

Station	Yala	%	Maha	%	Total
Padawiya	663	39	1,047	61	1,710
Nochchiyagama	263	25	793	75	1,056
Maradankadawala	704	44	896	56	1,600
Anuradhapura	359	31	800	69	1,159
Devahuwa	499	33	1,019	67	1,518

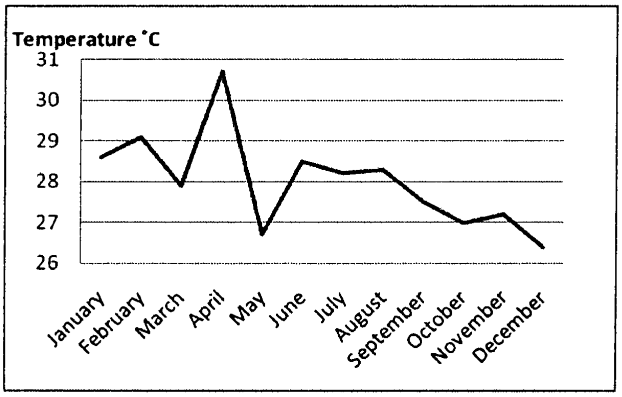
Source: Department of Meteorology, Colombo, 2005

Monthly rainfall distribution

In the Anuradhapura district, monthly rainfall fluctuations are particularly high during the rainy months. Table 3 shows monthly rainfall distribution in the Anuradhapura district for the period 1976-2005. It can be clearly observed that from October to December, during the Northeast monsoon, rainfall is above 750 mm. The Yala season during the Southwest monsoon receives low rainfall of 109 mm. Over the year, the months of February and September are mostly rainless.

Temperature

There is no significant difference in the monthly temperatures. The statistical minimum temperature is reported in December and January. The average monthly temperature is 28.5 °C. The annual maximum temperature is reported from March to May and September also temperature 29 °C-30 °C. August is even warmer temperature and average temperature is 28.3 °C in Anuradhapura district in 2005.



Source: Department Meteorology, Colombo, Sri Lanka, 2005

Fig .4. Monthly temperature in the Anuradhapura district in 2005

Mean annual temperature

Mean annual temperature during the period 1976 to 2005 is almost equal t throughout the years. Table 4 shows average annual temperature in the Anuradhapura district.

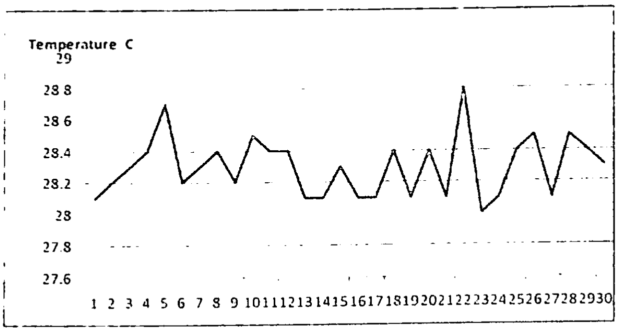


Fig 5 Annual temperatures in the Anuradhapura district, 1976-2005

Table 4. Average annual temperature in the Anuradhapura district from 1976 to 2005

Year	Temp. (°C)	Year	Temp. (°C)
1976	28.1	1991	28.1
1977	28.2	1992	28.1
1978	28.3	1993	28.4
1979	28.4	1994	28.1
1980	28.7	1995	28.4
1981	28.2	1996	28.1
1982	28.3	1997	28.8
1983	28.4	1998	28.0
1984	28.2	1999	28.1
1985	28.5	2000	28.4
1986	28.4	2001	28.5
1987	28.4	2002	28.1
1988	28.1	2003	28.5
1989	28.1	2004	28.4
1990	28.3	2005	28.3
Mean	28.3		

Source: Department of Meteorology Colombo, Sri Lanka, 2005

Spatial and temporal pattern of malaria in the district

According to the data obtained from the regional Anti-Malaria Campaign in the Anuradhapura district and Anti-Malaria Campaign in Colombo, three analyses have been employed to identify and discuss the spatial and temporal pattern of malaria in the Anuradhapura district:

1, Monthly occurrences of malaria cases from 2001 to 2005 related to the MOH (Medical Health Office) areas in the Anuradhapura district;

2, Annual data of malaria cases 2001-2005, in the MOH areas

3, Annual distribution of malaria cases from 1972 to 2005 in the Anuradhapura district.

Spatial pattern of malaria in the MOH areas in the Anuradhapura district

Anuradhapura district is a centre that transmits malaria spreads as an endemic. Malaria is a disease common among the people in the district. There has been high malaria prevalence over 35 years, with a rapidly shrinking numbers during recent years. Malaria has affected on the district for several years, in the past as annual, seasonal and monthly, with reoccurrences in all MOH areas. The spatial pattern of the prevalence of malaria can be detected clearly in the Divisional Secretary Divisions (DSDs). Data given in Table 5 show the occurrences of malaria in 2005, as officially registered in 19 MOH areas out of all 22 Divisional Secretarial Divisions, in the Anuradhapura district, see also (Fig 5).

Higher regional differences in the number of malaria cases can be observed, with the highest recorded from the northern part and the lowest number in the southern part of the district. The highest of API value 2.40 from Rambewa and lowest 0.06 from Kekirawa have been recorded. API 1.00-.50 has been recorded in Talawa, Galnewa, and Kahatagasdigiliya while in the other 11 MOH areas API is below 0.5. Accordingly, those MOH areas can be considered as low risk areas of malaria. However, the decline of the API was caused particularly by the service given by some medical institutes in malaria-affected areas. Epidemiological significance is also important during the past five years. Although it could be due to the greater incidence of malaria in the northern part of the Anuradhapura district. As for these MOH areas. Variations in recorded malaria cases are pronounced in the southern part of the district. They can be classified into three as listed in Table 5 and illustration in Fig 6.

According to Fig 6, the highest MOH risk areas are confined to the northern most part of the district except two MOH areas. The southeast part is less susceptible to malaria. The eastern most part is a moderately vulnerable to the occurrence of malaria.

Spatial pattern of malaria in API Values in MOH areas

Table 6 , and fig 7, show the MOH areas wise API values of the district from 2001-2005. In 2001, malaria is widely prevailed in all MOH areas in the district in different pattern. Malaria was an epidemic level that is indicated by API value greater than 1.02 in all MOH areas. The highest API values 34.2, found in Padawiya and lowest in Thirappane. In all the other MOH areas, it was recorded between 12.8-

Intra-monthly pattern of malaria in the district 2001-2005

To identify intra-monthly pattern of malaria in the district, the data pertaining to each month covering the period from 2001 to 2005 were collected for the whole district. Table 6 and the illustrations in fig 7 help to identify the intra-monthly patterns of malaria cases as highly monsoonal rain most likely also occurs in this period.

Table 5. Number of malaria cases by MOH in the Anuradhapura district, 2005

MOH area	Population	Malaria cases	API
Rambewa	31,340	76	2.47
Kebithigollewa	21,476	34	1.53
Horowupathana	37,400	48	1.28
Central Nuwara gam Palatha	81,918	78	0.95
Tambuttegama	37,816	40	1.08
Talawa	57,487	21	0.61
Galnewa	31,633	20	0.69
Kahatagasdigiliya	33,313	23	0.51
Nochchiyagama	41,475	13	0.46
Mihintale	33,366	13	0.30
Thirappane	32,280	13	0.32
Ipologama	36,976	12	0.30
Medawachchiya	45,543	11	0.24
Padawiya	28,910	10	0.24
Galenbidunawewa	45,018	10	0.22
Palagala	31,048	06	0.16
Rajangana	34,596	07	0.20
Nuwaragam Palatha East	85,495	07	0.08
Kekirawa	75,442	05	0.06
Total	822,802	448	0.54

Source: Anuradhapura district Regional Anti-Malaria Campaign, 2005
**CNP: Central Nuwaragam Palatha*
**ENP: Nuwaragam Palatha East*
**API: Annual Parasite Incidence means number of malaria cases per 1,000 population*

Table 5 Classification of malaria areas related to MOH areas; in the Anuradhapura district, 2005

Highly risk areas	Moderately risk areas	Low risk areas
Rambewa	Talawa	Nochchiyagama
Kebithigollewa	Galnewa	Thirappane
Horowupathana	Kahatagasdigiliya	Mihintale
Tambuttegama		Ipologama
Central Nuwaragam Palatha		Medawachchiya
		Padawiya
		Galenbidunawewa
		Palagala
		Rajanganaya
		Nuwaragam Palatha East
		Kekirawa

Based on data derived from Anti-Malaria Campaign

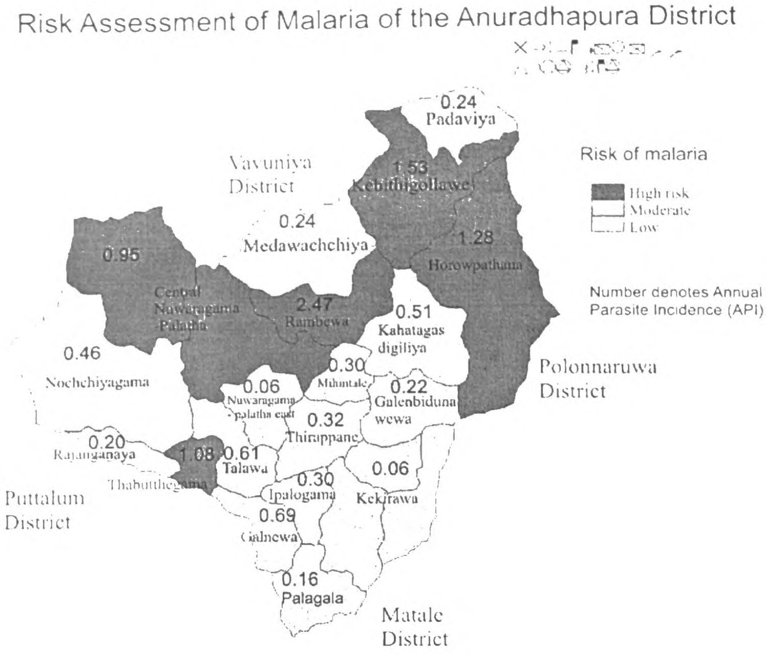


Figure 6. Occurrence of malaria in the MOH areas in 2005 in the Anuradhapura district for risk assessment

Table 6 Intra-monthly pattern of malaria cases in the Anuradhapura district, 2001-2005

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2001	676	564	326	190	272	169	118	111	117	144	184	473	3,344
2002	828	534	273	107	135	126	122	118	105	112	135	271	2,866
2003	394	251	120	45	52	33	45	54	23	54	57	85	1,213
2004	246	44	38	26	22	10	12	16	34	47	53	88	636
2005	202	66	21	8	7	7	10	20	22	25	26	34	448
Total	2,346	1,459	778	376	488	345	307	319	301	382	455	951	8,504

Source: Anti-Malaria Campaign, Regional Office, Anuradhapura district, 2005

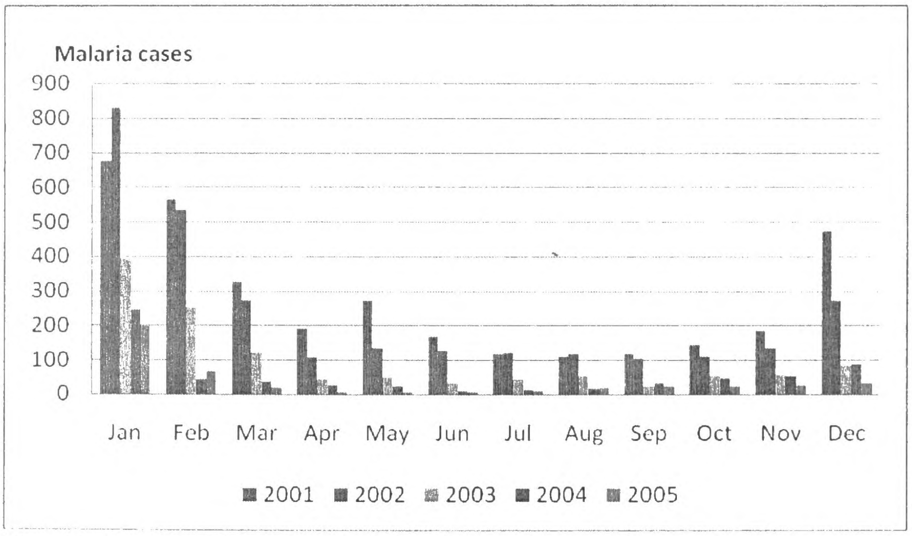


Figure 7. Intra-monthly total number of malaria in the Anuradhapura district, 2001-2005

676 (20 %) out of the total number of malaria cases (3,344) have been reported in January in 2001. In a similar pattern, 828 (28 %) out of 2,866 cases have been reported in january 2002. In this case, malaria is mostly predominated in January of the first two years 2001 and 2002 (See Fig.10).

This incident is common for the years of 2003, where 294 or 33 % out of 1,210 malaria cases have been reported in January. Again in 2004, 246 or 29 % of malaria cases have been reported in January. The same happened in 2005, too. The number of malaria cases for the whole year is 448 out of which 202 or 45 % reported in January.

Relationship between annual rainfall and occurrence of malaria

The aim to analyse the relationship between natural environmental factors and spatial and temporal patterns of malaria occurrence in the Anuradhapura district. The natural environmental factors concerned are annual seasonal and monthly rainfall, and monthly and annual temperature.

The inter-annual variability of rainfall and the total number of malaria cases in the Anuradhapura district during the period between 1976 and 2005 were investigated for studying impact of rainfall on the occurrence of malaria. Fig 8 shows that annual totals of rainfall varies greatly year to year, with showing a corresponding variability of the number of malaria cases. To study the relationship between annual rainfall and the occurrence of malaria, both variables were further statistically correlated. Fig 8shows the results and accordingly, the annual rainfall and annual total number of malaria cases are correlated slightly in a positive manner. Following the above analysis, a conclusion can be made that the rainfall factor effects on the occurrence of the malaria in the district. The reason behind this is the annual rainfall favour that spread of malaria.

The mean annual rainfall and total annual number of malaria cases in the Anuradhapura district were correlated and it shows slight negative relationship for the entire period.

Relationship between monthly rainfall and the occurrence of malaria

Data of monthly totals of rainfall and number of malaria cases are summarized in Table 6 in the Anuradhapura district, for 2001-2005. As to be seen the monthly rainfall is highly variable (varying between 396 mm and 0 mm for the whole District) in contrast to the monthly number of malaria cases varies between 828 and 7. No any correspondence with the given monthly total rainfall with malaria cases. However, the

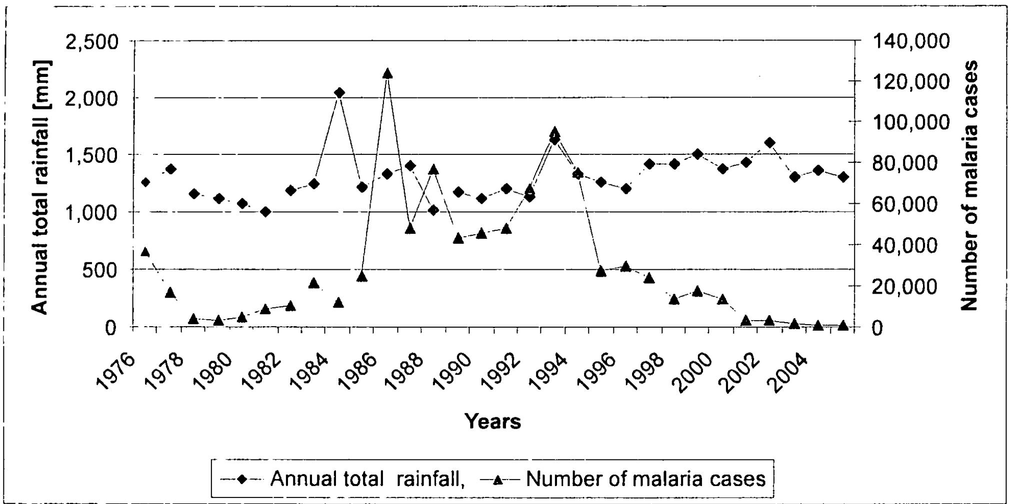


Figure 8. Relationship annual total rainfall and annual number of malaria cases 1976-2005 Annual rainfall and total number of malaria cases in the Anuradhapura district, 1976-2005)

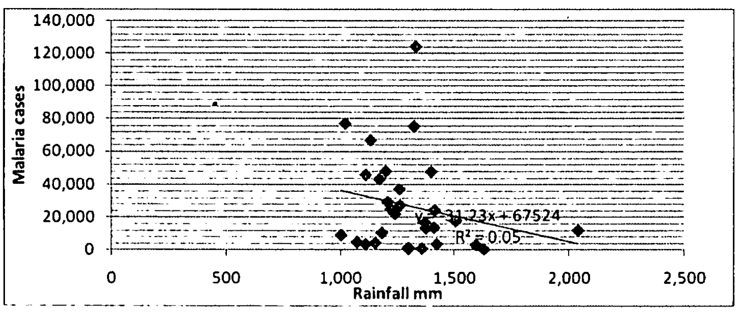


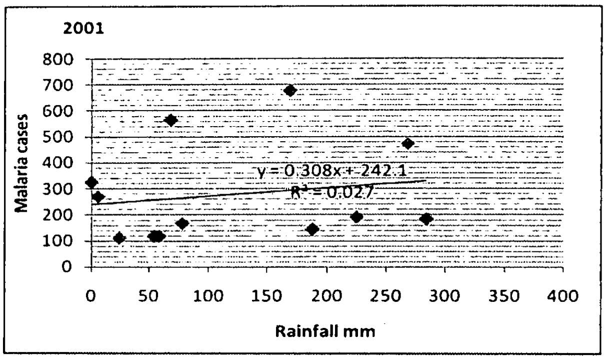
Figure 9. Correlation between mean annual rainfall and total number of malaria cases 1976-2005

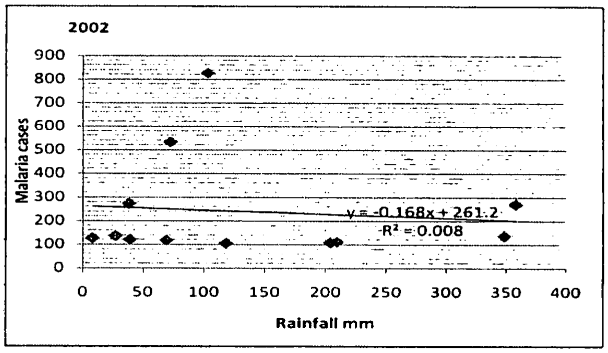
high peak season of rainfall is from October to February, and thus strongly indicates a close relationship with the occurrence of malaria during the wet (NE monsoon) season in which recorded the highest number of malaria cases. On opposite, the lower number of malaria cases corresponds with the dry (SW monsoon) period, that is from May to September.

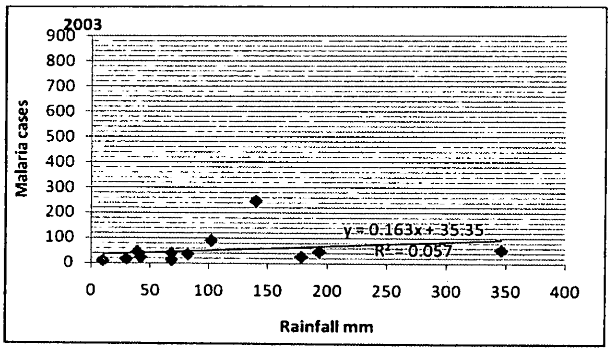
The summary, for the entire five year period (2001-2005) is that three quarters of the total rainfall in the Anuradhapura district had been received from October to March. In a similar pattern most of the malaria cases ranging from 75 % to 90 %, were recorded during the same period. The most risk and peaking months of malaria of the year is particularly in October to February, in the study period of 2001-2005 in the district. Therefore, an important natural environmental factor can be identified as the monthly rainfall that causes malaria occurrences since they have positive relationship.

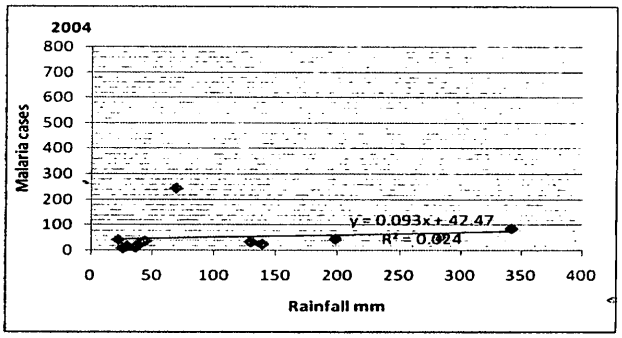
Relationship between the seasonal rainfall and the occurrence of malaria

The summarized data appear in fig 11 shows rainfall in Maha (October-March) as well as in Yala (April-September) and the number of malaria cases for the Anuradhapura district, for 2001 to 2005. Rainfall of Maha season presents a great difference as compared to Yala season. Rainfall is higher all over Maha season than that of Yala season. Maha season coincides with the NE monsoon and Yala season with SW monsoon. The maximum in Maha season rainfall during 2001-2005 has been recorded as 1,413 mm and lowest as 1,048 mm, while in Yala season it has been recorded as 300 mm and 179 mm. The rainfall ranges from 179-1,413 mm, and number of malaria cases ranges from 74-2,367. Accordingly, the number of malaria cases has been recorded as 2,367 during Maha season and 74 cases in Yala season. In every year, amount of malaria cases reported in Maha season is higher than that of Yala season. Accordingly, 71-83 % out of the recorded total number of malaria cases were in Maha season and 7-29 % in Yala season.









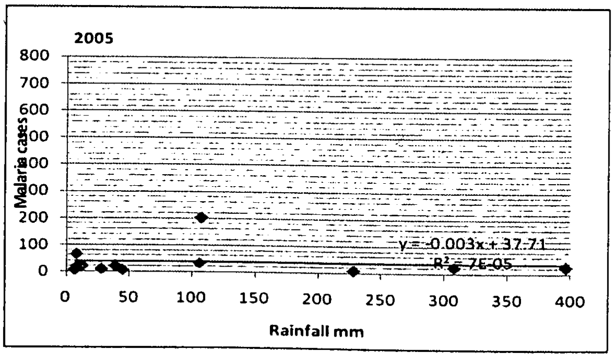
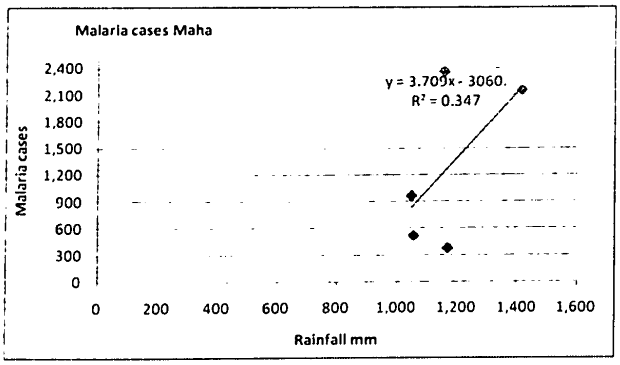


Figure 10. Correlation between monthly rainfall and monthly number of malaria cases 2001-2005



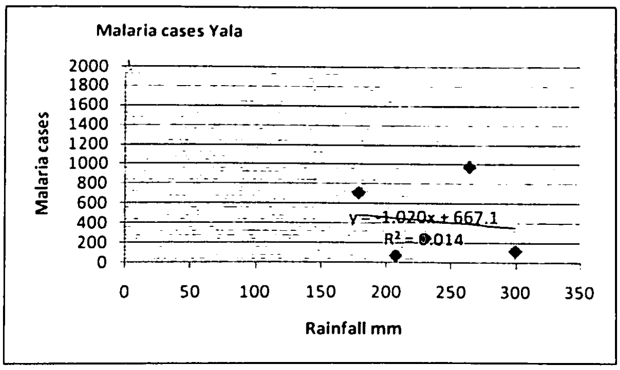


Fig 11 Correlation between seasonal rainfall and malaria cases in the Anuradhapura district 2001-2005

Relationship temperature and occurrence of malaria

The inter-annual variability of temperature and the total number of malaria cases from 1976-2005 in the Anuradhapura district was compared to understand the effect of temperature on the occurrence of malaria (Fig 12). It can be observed that the inter-annual variability of temperature is in between 28.0 and 28.8 °C. Mean annual temperature is in between 28.1 and 28.5 °C (24 out of all 30 years in the study period) has been recorded in many years. Hence, inter-annual range of temperature is little and no any major differences of temperature from year to year is observed while the number of malaria cases strikingly shows a great variability, between 124,233 (1986) and 448 (2005). However, mean annual temperature in both reference years only slightly varying, experiencing 28.4 °C (in 1986) and 28.3 °C (in 2005). It can, therefore, be deduced that there is no definite relationship between mean annual temperature and malaria occurrences. This is also proved by comparing the malaria high peak years 1993, 1988 and 1994, when the annual mean temperature was recorded at 28.4 °C, 28.1 °C and 28.1 °C, respectively.

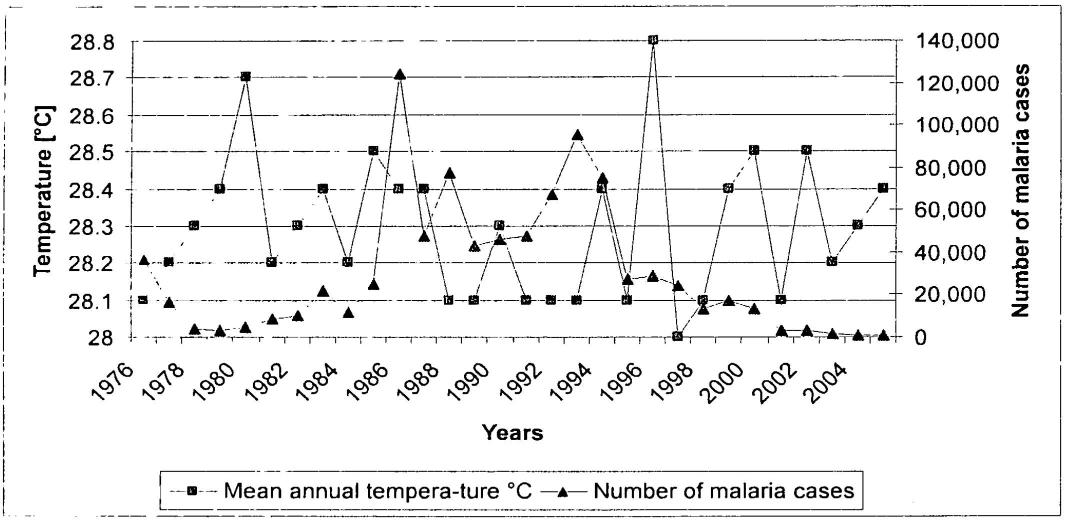


Figure 12. Correlation between annual temperature and annual total number of malaria cases in the Anuradhapura district 1976-2005

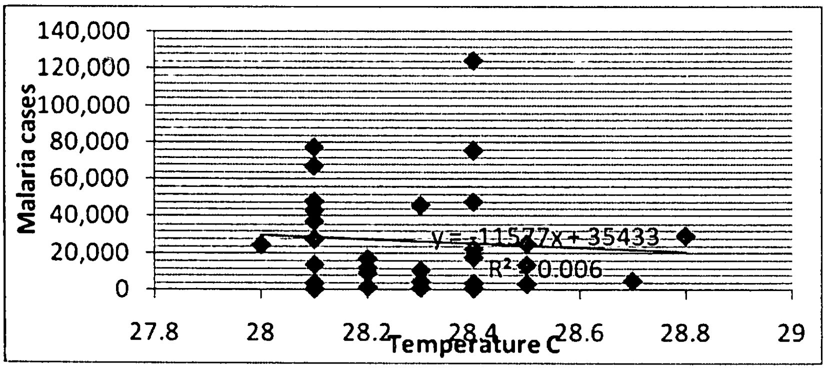
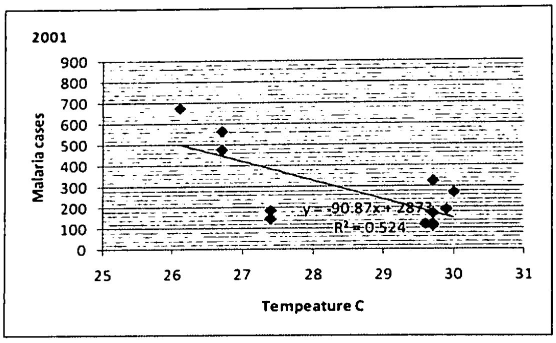
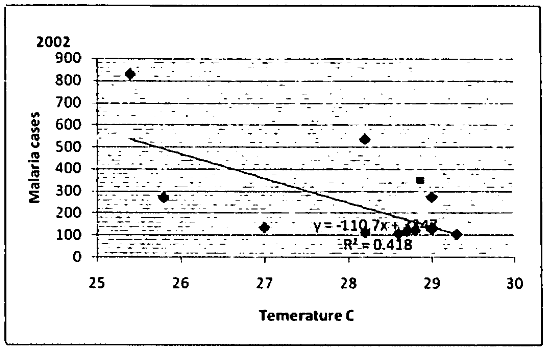
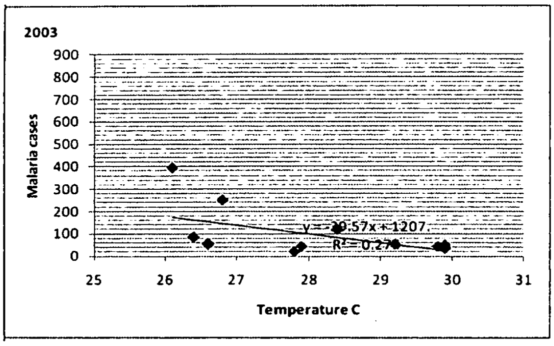


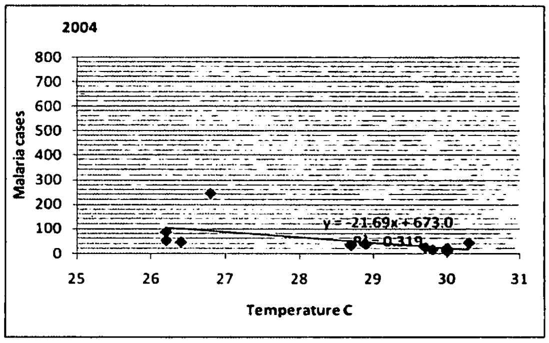
Figure 13. Corelation between mean annual temperature.

Relationship between monthly temperature and the occurrence of malaria in short-term period that is from 2001 to 2005 in order to investigate whether any relationship between monthly temperature and occurrence of malaria. Though temperatures are not significantly varying from month to month and from year to year, the number of malaria cases is, however, remarkably varying that shows a maximum number of cases in January. Over the whole year, December to February is the peak season of malaria is reported while the lowest number from July to September. It can be observed that, the maximum number of malaria cases is experienced during the slightly lesser hot and wet (Northeast monsoon) season while the minimum number of malaria cases occurs during the very hot and dry (Southwest monsoon) season.









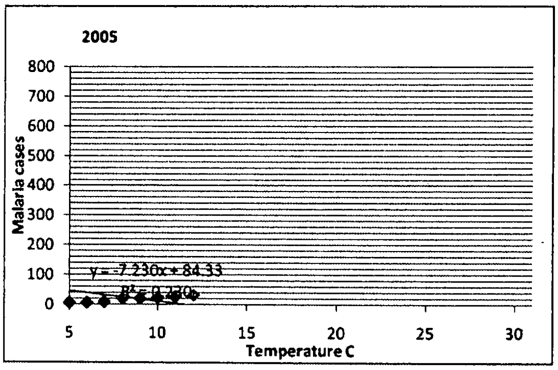


Figure 14. Correlation between monthly temperature and malaria in the Anuradhapura district 2001-2005

Conclusions

In this study analysis on the effect of natural environmental factors such as monthly rainfall, seasonal rainfall, mean annual rainfall, and temperature, monthly temperature monsoonal weather, water bodies closed to settlements and the distance of vegetation cover, on the occurrence of malaria. The most influential factors can be identified depending on the above analysis as listed below;

1. Monthly rainfall and the occurrence of malaria cases exhibit positive relationship,
2. The most of malaria incidents have been recorded during the Maha season, due to two seasons;
3. Highest rainfall that support to forms spreading grounds for mosquitoes,
4. Malaria mosquitoes are favored by optimum temperature two between 28.1-28.8 ° C. Higher the temperature, reporting malaria cases are less, and lowest the temperature the same will happen.
5. Most of malaria cases have been reported during NE monsoon rather than SW monsoon.

References

Abeysundara, N. A (1974-79) Reports of the Anti-Malaria Campaign, Administration Report, Govt. Press.

Abeyrathne, E. F. L. (1956) Dryland farming Ceylon Trop. Agricultural (Ceylon) 112-192

Abeywardana, T.A. Dilrukshi, R. K. C, Wijesuriya, S. R. E. (1996) Anopheles subpictus complex: distribution of sibling species in Sri Lanka. Indian journal of malariology 33: 53-59.

Amarasinghe, P. H. Amrasinghe, F.P, Konradsen, Fonseka K.T. Amrasinghe, P. H (1997) Anopheline (Diptere Culicidae) breeding in a traditional tank-based village ecosystem in north central Sri Lanka, Journal of medical Entomology 34: 290-297.

Amarasinghe, P. H. Amarasinghe, F.P, Konradsen, F. et al (1999) Malaria vectors traditional Dry Zone village in Sri Lanka. American Journal of Tropical Medicine and Hygiene, 60. pp 421-429.

Anti-Malaria Campaign, Regional malaria office (2001, 2002, 2003, 2004, 2005) SPR Reports, Administration reports, in Anuradhapura District.

Bruce-Chawatt, L. J (1985)_Essential Malarialogy, Heinermann Medical Books, London

Carter, H. F. (1926) "Kataragama fever its nature, causes and control" session paper 37, Government press Colombo.

Carter, H. F. and Jacoks W.P. (1929) Observation of transmission of malaria by Anophene mosquitoes in Ceylon, Ceylon of Science (D) 2: pp 67-83.

Carter, Clarke. M. (1984) Planning and Analysis in Health Care system. London Press

Department of Health Dhanapala , H, Andrah (1988) Sensitivity of malaria potential Transmission to Climate Change in Sri Lanka. Asian Profile.

Domroes, M. (1974) The Agro climate of Ceylon: A contribution towards the ecology of_tropical crops, Wiesbaden, Franz Steiner vertigo

International Research Institute for climate prediction, linking science to society (2000) Analysis of Impacts of climate variability on malaria transmission in Sri Lanka and the development of an only warning system. IRI.

IPCC International Panel on Climate Change (1992) Climate Change 1992, The Supplementary report to the IPCC Sciencetific Assessment Cambridge University Press. Cambridge.

Konradson, F. P ed all (2000) a village treatment centre for malaria: Community response in Sri Lanka. Social Science and medicine 50: pp 879-887.

Konradson, F. P ed al (2000) Malaria in Sri Lanka; Current knowledge on Transmission and Control, Colombo Sri Lanka, International Water management Institute