

A GEO-SPATIAL ANALYSIS OF ELEPHANT INTRUSION IN HUMAN SETTLEMENTS: A STUDY ABOUT THE SEASONAL TRENDS AND THE RELATIONSHIP WITH THE RAINFALL -IN SRI LANKA

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ABSTRACT: Elephant intrusion in human settlement is a top issue which has the devastating impact for humans and the elephants in Sri Lanka continue for several years, but the issue of elephant intrusion has never addressed in a national scale to see the patterns and the trends on it. And also there is no good data base available in the country about the conflict though the issue has raised as the top. The incidents of elephant caused attacks are still recording in the form of handwritten and not available in digital format. The study is focused on making a digital data base though the process of geo-coding of the place name information of the elephant caused attacks to the people and the properties which have been taken place from the year of 2004 to 2009 and made them available online as a Wiki database and in the form of Google map. The study has carried out for the entire country and analyzed the distribution, trend and the patterns based on different climatic seasons, relation with the rainfall, elevation, vegetation and the protected areas.. This paper only concludes the seasonal changes of the elephant intrusion and the relationship with the monthly rainfall. The seasonal distribution of elephant intrusion is a new approach which has analyzed the seasonal changes of the elephant intrusion. And also the intrusion of the elephant is also highly depends on the availability of the rainfall. These all criteria were considered in the national basis and distribution and the trend of the elephant intrusion has also been analyzed and mapped for whole Sri Lanka. Along with the trend analysis the Multi Linear Regression model was implemented to predict the phenomena with selected criteria of rainfall, land use and the elevation to identify the potentially risk areas of the elephant intrusion. According to the results of the Multi Linear Regression model the potential areas of the elephant intrusion has the higher relation, with where there are paddy land with low rainfall and lower elevation The prediction of the phenomenon has only been implemented for a selected area where latest land use data available.

The issue has analyzed with GIS methods and techniques which has given the wider range of application and analyzing capabilities. The relationship of the factors with elephant intrusion has analyzed with the vector and the raster data analysis methods in GIS.

INTRODUCTION

The changing natural environment by human activities creates a lot of conflict landscape for both human as well as other living organisms on the earth surface. Mainly the natural habitats were drastically converted into a cultural and fragmented landscape which is leading complex environmental, cultural and socio political consequences. The conflict between wild animal and human is one of the top issues which have been developed for longer time as a result of the expansion of human activities to wild life habitats, and also it has been recognized as a major threat to the survival of many wild species. The conflict between the man and the wild animals leads several environmental, socio economic and also political consequences with leading mortality and morbidity to both human and animals. Wildlife-human conflict is a major threat to the survival of many species on the surface of the earth. The conflict between human and the elephant or the elephant intrusion in human settlements is one of the severe issues which is coming under the conflict between human and wildlife and which has effect on both humans and elephants with morbidity and mortality. Now the conflict between the humans and the elephant is popular as Human Elephant Conflict (HEC) as well it is also known as Man and Elephant Conflict (MEC) or People Elephant Conflict (PEC). Such conflict has conservation and socio-economic significance, where potentially dangerous for the particular species that in addition to depredating resources, threaten human morbidity and mortality. Human-

elephant conflict is a case in point where elephants are mega-herbivores and commonly raid crops, causing economic losses, and death and injury to people. (Fernando et al. (2005).

Human Elephant Conflict (HEC)

The human elephant conflict can be defined as the struggle between the elephant and the humans for their survival with common use of resources. Human elephant conflict has highlighted as a major environmental and socio- economic issue in many countries where the elephant habitat are spread. The elephant habitats are mainly distributed in the two continents of Asia and Africa. Although the conflict between human and the elephants has recognized in only these two continents, the nature and the context of these two elephant habitats are varied. The conflict is more significance in the Asian region where the highest density of human population exists. The two distinct species of elephants of African (*Loxodonta Africana*) and the Asian (*Elephas Maximus*) have different habitat patterns. And also the two species has different rate of threat which caused by the conflict with humans. The Asian elephants are mostly vulnerable and recognized as an endangered species that close to extinct with the conflict between the two. Therefore the attention paid for the conservation of Asian elephant has highlighted for last few years.

The conflict between the human and the elephants has raised result of alarmingly increasing human population and the successive impact in reducing the natural forest cover and expansion of agricultural land, urbanization and expansion of the human settlements. As a result of losing the natural forest cover which is the home for the elephant make the limitation of finding their basic requirement of food, water and shelter and finally make them intrude to the human settlements and the crop fields. The conflict between human and the elephants has found in 13 Asian countries including Sri Lanka. Sri Lanka is one of the countries in the Asian region which is terribly suffering from the conflict between the human and the elephant and the country is facing a considerable amount of economic loss and loss of lives of both human and elephants. Human–elephant conflict poses a major threat to elephants in many parts of Asia, including Sri Lanka.(Fernando et al.2005).

The elephant intrusion in human settlement would not be considered as an issue unless if it is not a factor that caused human deaths, elephant deaths, crop damages, injuries or any other substantial effect for both human and elephants. There is a threat associated with the conflict for both humans and the elephant which make the both species in danger. Therefore it is necessarily required a have prompt attention in solving the issue or actions in mitigating the conflict for the survival of both in peacefully.

The elephant intrusion to the human settlement areas, property damages and the depredation of cropland by elephants is ranked as a major issue in Sri Lanka. The resent figures about elephant population in Sri Lanka say the total number of elephant is about 4000 and they only use 2% of the total land of the country. The home range size of Sri Lanka elephant is about 50-100Km² which opposed to 500-1000Km² in India. Some studies configured that the elephant population in the wild have been reduced substantially in the last 50 years. According to the information of the Department of Wild Life Conservation Sri Lanka (DWLC), there were 227 elephants and 80 people dead in 2010 because of the elephant intrusion. In 2009 alone 228 elephants and 50 people were killed due to the elephant intrusion in human settlement. And in 2008 there were 238 elephants killed (Table 1). According to the records of death of humans and the elephants there are 150-170 elephants and 50-80 people lose their lives annually because of the elephant intrusion in Sri Lanka. According to the spatial distribution 16 of 24 districts in the country face the problem of human elephant conflict figure 1. And also 58 divisional secretariat divisions of 324 also reported the issue.

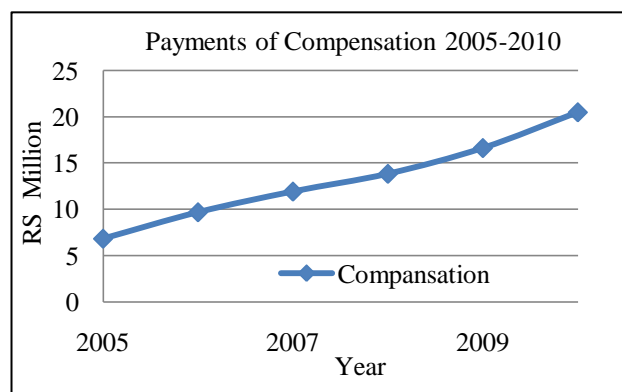
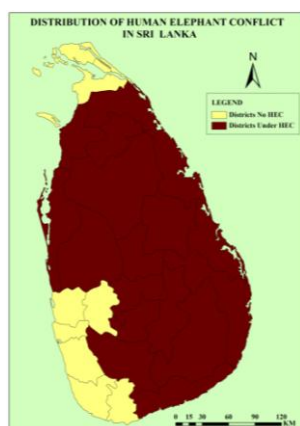


Figure 1. Distribution of HEC in Sri Lanka Figure 2. The trend of compensation payments from 2005-2010

These elephants are not killing for tusks, because the Asian elephants are not popular in carrying tusk. Less than 7% of bull elephants carry tusks in Sri Lanka. And these elephants are not killing for meat since the Sri Lankans are not eating the meats of the elephants. And these giants are not killing for their hide, because there is no

any demand or any market for elephant hide in the leather industry of Sri Lanka. The key reason behind these all deaths is the conflict between the elephant and the human. Mostly the farmers are thinking that those giants as pests and trying to kill in several ways.

The elephant intrusion is not only considered as the top issue not only because of the deaths and the damages caused by it, but also the fear of influence effect in daily activities of the people. The daily activities of the people those who are living with closer proximity to the elephant habitats are disturbed by the elephant intrusion. The intrusion normally takes place in evening when its getting darker, in the night and early morning of the following day. People are afraid to get out of their houses and pushed them to keep inside. Therefore the threat to a death has higher possibility if people move in the time once the elephant intrude to the settlement. The schooling in early morning, walking to a hospital in the night has strictly restricted by elephants.

Therefore a detailed study about elephant intrusion in human settlement is become as an urgent requirement in minimizing the threat and damage to the people and conservation of the endangered species of Asian elephant (*elephas maximus maximus*) in Sri Lanka. It is necessarily important because the problem spread about all around the country (Figure 1.2) and also it has severe impact on national income of the country. The Figure 2 shows the increasing trend of compensation payment for the victims those who lost their lives, got injured and lost properties and damaged crop lands. From 2005 to 2010 the total compensation has increased in three times. (1USD =109SLR). The amount of the money which spent on the payment of compensation badly affect in development of the country's economy.

Though the issue of elephant intrusion stands as the top issue in the country it does not have a digital database about elephant caused attack incidents. It is needed in maintaining a detailed data base and keeps it in updated for monitoring the issue and analyzes the issue in advance. And also a digital data base will facilitate the people those who are studying the issue and finding the mitigation measures.

The trend analysis of the elephant intrusion with socio environmental factors is important in make warning for the possible time of intrusion. The analysis should address with spatial context where the intrusion is intrinsically a spatial phenomena. And also the analysis should address the issue in a national level where the elephant intrusion is a Trans-boundary phenomenon.

The intensified issue of elephant intrusion caused an extinction of the elephant population in the island. According to the available sources there were 20,000 elephant at the beginning of the nineteenth (19th) century and today it dropped into 3500-4000. The extinction of the elephant population took place because of the human elephant conflict. Table 1.1 is the figures of elephant and human deaths because of the elephant intrusion. The conflict between humans and the elephant is fundamentally resulted because of the increasing population and the successive activities such as destruction of forest, conversion of forestland into agricultural lands, development, resettlement etc for the socioeconomic well being of the people. The shrinking nature of the elephant habitats and the expansion of the human habitats are overlapped together and the conflict occurred. The easiest way of managing or the controlling the conflict became as killing the jumbos in several ways.

Table **Error! No text of specified style in document.** Records of human and elephant deaths from 1991-2010

Year	Humans deaths caused by elephants	Elephant deaths caused by people
1991	32	32
1992	22	90
1993	60	103
1994	55	113
1995	57	94
1996	47	130
1997	54	164
1998	53	148
1999	81	107
2000	63	150
2001	34	162
2002	-	118

2003	-	108
2004	-	171
2005	77	123
2006	79	163
2007	72	189
2008	71	224
2009	50	228
2010	80	227

Source: The department of wild life conservation

Managing the conflict between human and elephants is a difficult and also complicated task. There are different methods that has used by the people in controlling the elephant intrusion to the crop field and settlements for a longer time. Many attempts have made in preventing the intrusion of the elephants such as firing gun shots into the air, burning chili peppers, digging larger trenches, chasing elephants with flares and crackers, erecting electric fencing etc. And some other biophysical methods also have applied in controlling the issue such as translocation the dangerous elephants and increasing the protected areas and making domesticated the wild elephants. Among them the electric fencing became as the easiest and the cheaper method as a solution for the issue. But the elephants are so intelligent in destroying the fence and keep entering to the crop field and it is impractical in erecting the fences all the areas where having the issue. Therefore it is essentially required in finding new alternative methods in controlling the elephant intrusion.

Objectives

The main objective of this study is analyzing the factors and patterns of the distribution and visualization of elephant intrusion, in Sri Lanka and development of a web published GIS database.

To fulfill the main objective there were few specific objectives as follow.

1. Creating distribution maps of elephant intrusion for Sri Lanka
2. Analyzing the relationship of elephant intrusion with seasons and rainfall

Study area

The whole Sri Lanka selected as the study area for the distribution analysis of the elephant intrusion. The migration of the elephant and the elephant caused attacks are regardless the demarcated administrative boundaries of the country. The elephant move trans-boundaries and the elephant caused attacks are also moved with them. Therefore the study was conducts for the whole country. The limited availability of selected satellite imagery data and the limited time concern, the land use maps were created only for selected area of the country.

Methodology

The methodology of the study organized under several steps as indicated in the figure 3. The primary data of elephant caused attacks were hand written and therefore it was happened me to make them in the photo format of JPG to bring it to process very easy way. But it was the very time consuming way of converting them into the digital format of excel. The data which has taken from the department of wild life conservation of Sri Lanka only recorded the address of the place but no any location information, therefore the all place name information were geo-coded and converted them into spatial data layers. The figure 4 is elaborating the process of geo-coding of the place names of the elephant caused attacks. The output results of the geo-coding finally plot in a map of Sri Lanka and the output of elephant caused attacks for all 7 years from 2003- 2010 were overlapped together as a single data layer and figured out as the figure 6. The resulted map of the elephant caused attacks show a similar pattern of distribution throughout the country where the elephant habitats distributed. Figure 5

Seasonal distribution of elephant intrusion

The seasons of Sri Lanka has defined based on the rainfall characteristic. There are 4 seasons which has two major and two minor seasons.

- South West Monsoon (SWM)- (May to September)
- North East Monsoon (NEM)- (November to February)
- Inter Monsoon 1(FIM) - (March to April)
- Inter Monsoon 2 (SIM) -(September to October)

There are two main period of the year which is getting monsoon wind and high rain called monsoon season of th South West monsoon and North East monsoon. The two monsoon seasons defined according to the direction of the wind received by the country. And the amount of the rainfall and the distribution of the rainfall are also different in two seasons. The south west monsoon coming from the south west of Indian Ocean gives higher rainfall for the south west part of the country from May to September while keeping the rest of the areas in dry. The second monsoon season occurs from November to February gives higher rainfall for entire country and more rainfall occurs especially in the eastern coast of the country. The two inter monsoons are fairly dry but evening of the day there are rainfall with thunder and lightning called the convectional rainfall. The inter monsoon gives more rain to the wet zone of the country with mountainous effect.

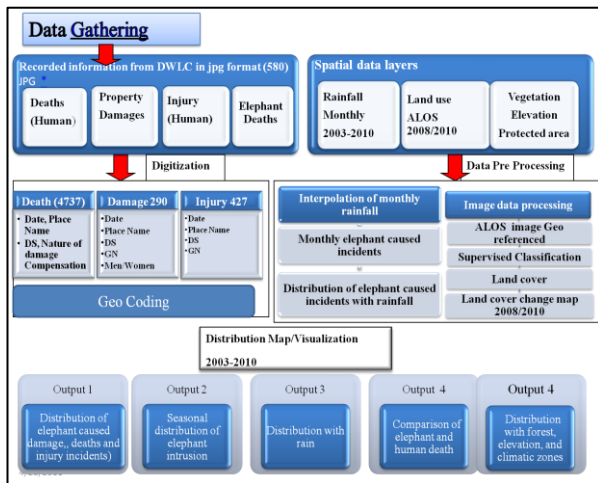


Figure 3. The methodology

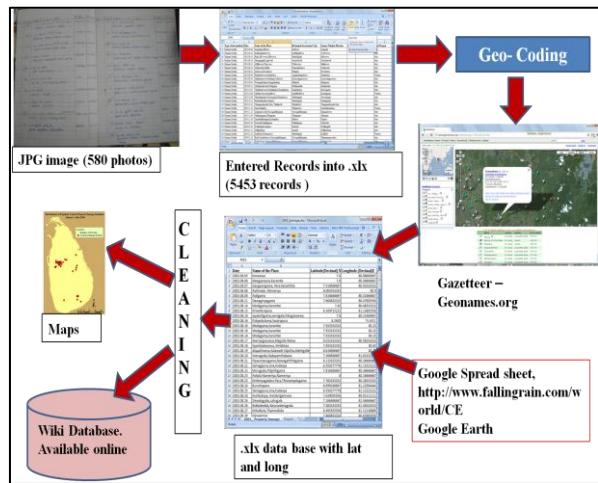


Figure 4. The process of Geo-coding

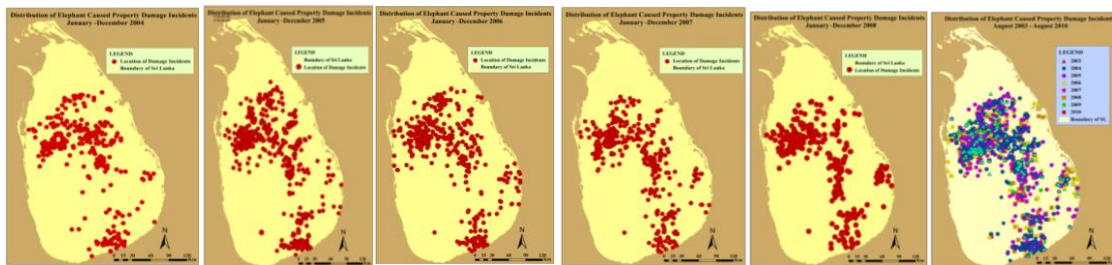


Figure 5. Distribution of elephant caused attacks 2003-2010

Figure 6: All Incidents 03-08.

The seasonal behavior of the elephant intrusions has also analyzed to understand the seasonal pattern of the attacks and the trend of the spatial distribution. The seasonal distribution maps of elephant intrusion were created after sorting the elephant caused attacks to the given season. The pattern analyses of the seasonal distribution of the elephant caused attacks were done for 8 years and the figure 7 and 8 are example for the seasonal distribution of the elephant caused attacks in seasons. The elephant caused attacks are more significance in the south west monsoon period and inter monsoon 2 and comparatively less in the North east monsoon and the inter monsoon 1. The spatial density of the elephant caused attacks is also higher in the season of south west monsoon than in other seasons and highly concentrated in the north western, central and the southern regions of the country.

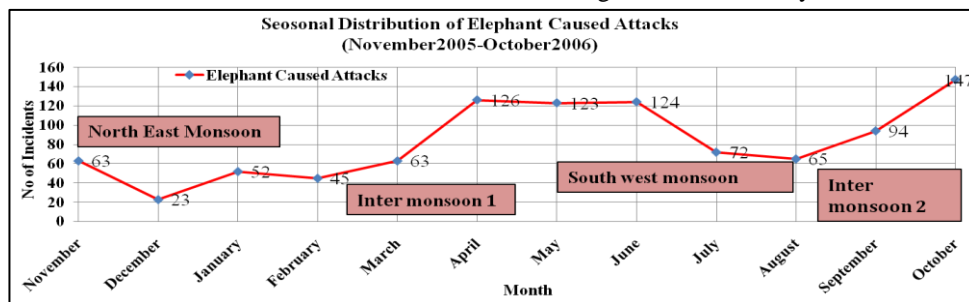


Figure 7. Seasonal Distribution of elephant caused attacks Nov 2005-Oct 2006

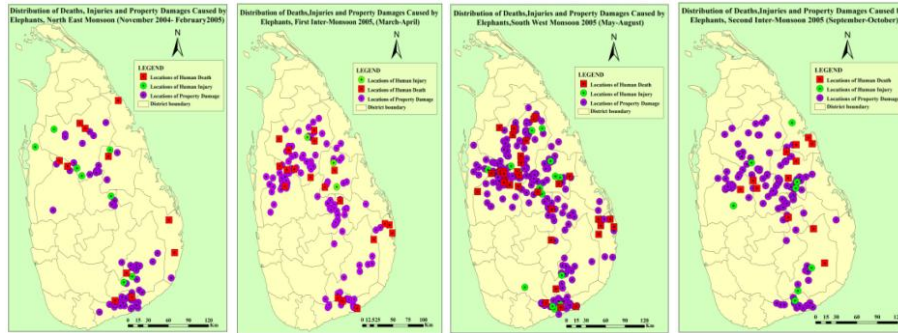


Figure 8. Seasonal Distribution of elephant caused attacks Nov 2005-Oct 2006

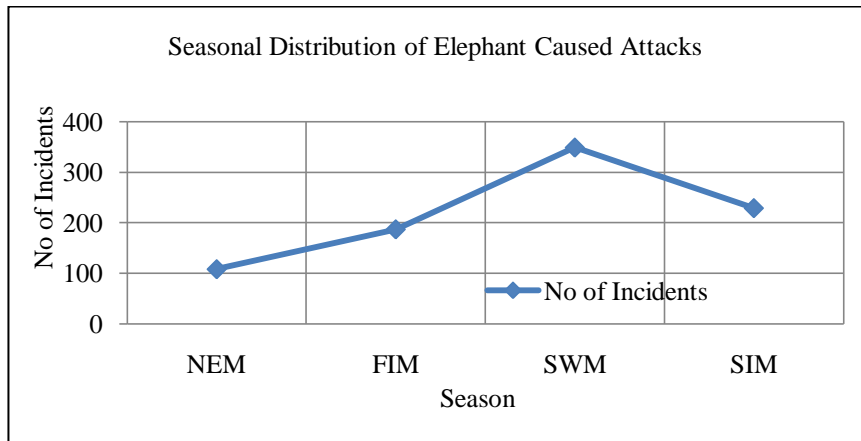


Figure 9. Seasonal distribution of elephant caused attacks

The elephant caused attacks are more high in the SWM where the dry season continue in lowland of the country for 4 months . The NEM season, the number of elephant caused attacks are getting reduced where the rainy season continue for 4 months. The climatic seasons and the agricultural seasons are coincide with each other in Sri Lanka as there are two main agricultural seasons of Yala (September- April) and Maha (May – September) totally goes together with each other. The lands preparation for the paddy cultivation occur in two intermonsoon and the elephant caused attacks are reached to the settlement areas in this two seasons where the paddy field are empty and therefore the elephants reach to the homes of the people to get the stored harvest of paddy, as a result of the intrusion to the housing areas lead ore property damages and also more deaths. The rainy season in November –February elephant not come to the human areas where the tanks are filled with rainy water and availability of enough food in the forest area. When the dry seasons advanced in May to September of the dry zone elephant move to resovior for water and also food , casued more ephant caused attacks. (Figure 9).

The elephant intrusion and rainfall

The rainfall and the elephant intrusion show a negative relationship. When the rainfall occur the number of elephant caused attacks are getting reduced. And if there is no rain or a less rainfall the number of elephant caused attack are reporting higher. This is also a considerable factor where to consider the elephant intrusion analysis. The study has analyzed the rainfall and the elephant caused attacks in basis of months to understand the relationship of the two phenomenon.

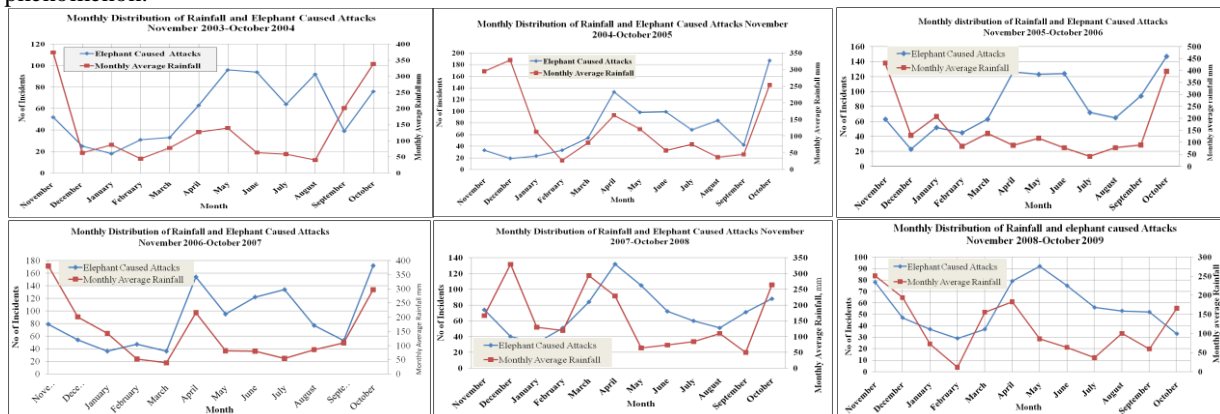


Figure 10 Elephant caused, attacks and monthly average rain fall

According to the 8 years data on monthly average rainfall and the monthly incidents of elephant attacks, the two phenomena are negatively related to each other. The higher rainfall and less number of elephant caused attacks. Specially in November to February and lower the rainfall the number of incidents getting increased from May to September. The two inter monsoons periods of March –April and September – October, the elephant caused attacks and the monthly average rainfall positively related to each other according to the graphs: the rainfall increased and also the elephant caused attacks are also increased. (Figure.10).The controversy of this pattern was taken into the consideration with the distribution of the rainfall. The rainfall data were interpolated in a monthly basis for entire country and overlapped with the elephant caused attack incidents.

The rainfall data were interpolated to visualize the distribution of elephant caused attacks with the rainfall. It shows that the rainfall in the particular time of inter monsoon mostly occur in the South West part of the country and the low land dry area is in less rainfall and have the high number of elephant caused attack. (Figure 11) The higher rainfall from November to February occur most parts of the low land dry zone and the elephant caused attacks are very less. The all rest of the months of the year continually get low rainfall in dry zone and the elephant caused attack incidents are also more prominent.

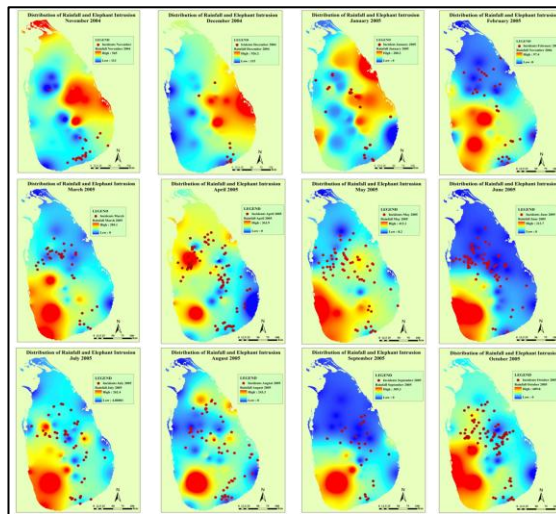


Figure .11 Monthly Rainfall interpolated map November 2004- October 2005

Conclusion

The island wide distribution analysis of the elephant intrusion provide higher advantage of understanding the spatial extent of the issue where the local boundaries not a matter for the movement of the elephant. Study of the seasonal behavior of the elephant intrusion provides the significance advance in the prior preparation for the devastated time and making the precautionary measures early. The identification of the more significance and the potential areas of elephant intrusion based on the factors such as rainfall, land provide the advantage in implementation of management strategies of controlling the issue and make it warning where possible

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