Exploratory Spatial Analysis of Pavo Cristatus (Peacock) Distribution in Coimbatore District of Tamil Nadu using Local Indicators

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***Abstract**: The presence of wildlife in each forest represents the prolific eco-system, wealth and fertility of the region. The literatures on the species distribution consider the global and climatic factors, with special attention to local condition, where the species exists. This study analyzes various factors (Environmental, Social, Economic, Institutional) associated with the existence of the species (Pavo Cristatus) within the forest range of Coimbatore region in two different years (2005 and 2013). A regional level perspective is carried out by investigating the factors associated with the distribution of Pavo Cristatus and estimates the impacts on the species found during analysis. The proposed analysis makes use of Exploratory Spatial Data Analysis (ESDA) to visualize and analyze the local spatial distribution of the species. The results reveal that no exclusive single aspect, but a collection of common factors regulates the species distribution. Further the analysis indicates that the augmentation of species distribution in an area is a healthy sign of the forest regions.*

Keywords: Exploratory Spatial Data Analysis, Pavo Cristatus, K-nearest neighbor, Local Indicators of Spatial Association, multivariate spatial analysis.

I. INTRODUCTION

Tropical forests in India comprises about 0.5 per cent of the world's forest area. Western Ghats is one among the 33 recognized sensitive zones of the world, which is the home for at least 325 globally threatened flora, fauna, bird, amphibian, reptile and fish species. Every year India is losing about 1.5 million hectares of forest cover[i]. If this continues for the next 20 years, the forest value contribution of India would be zero. From the year 1951 to1976 India has lost about four million hectares of forest. Tropical deforestation is a challenging problem where forest cover is exploited in many ways emphasizing social, economic, institutional and environmental factors [9,10,24]. Many factors such as industrial expansions, road ways, fuel excavation etc. have led to the degradation of forest. The deforestation in India has affected distributions of many species around Western Ghats. The National project of interlinking rivers, if carried out without afforestation the forest value of India would be merely extinct by 2020 [9,10].

The relationship between species extinction and the associated factors, like deforestation, forest cover change and agricultural practices in the forest region have been identified and confirmed by many researches. An extensive study of literatures on species extinction has revealed that the declension of agricultural area and crops displacement has affected the distribution of species. Further this has led to the destruction of breeding sites for various species of birds and animals which is evident from the forest cover map *[11].* Illegal wildlife trafficking by poachers and urbanization are some of the reasons behind the extinction or displacement of the species. However it is found that an in-depth spatial data aggregation and analysis has not taken place to understand the factors associated with the displacement of a species *[14].* It was examined that there are many factors favor the growth of certain species of birds and animals; such factors are listed and formulated in the current study.

A study of spatial data analysis in different forest ranges of Coimbatore region for the period of 2005-2013 is designed with different objectives. First is to find the relationship between *Pavo Cristatus* and the factors that are specified in the literature. Secondly the experts are consulted and the variables available for 2005 and 2013 are identified. The analysis are made at two levels one at the global level and the other at the local level to identify the difference between them. To accomplish the above said objectives Exploratory Spatial Data Analysis (ESDA) is done to find the associated variables such as Economic, Institutional, Social, and Environmental at the municipal level *[13].*

The paper is organized as follows. Section I gives a brief introduction of the species extinction and the factors associated with it. The details of the study area are exposed in Section II. Section III describes the data extraction methodology and approaches used in computing the data. Section IV explains the results obtained from the first and the second part of the analysis. As the first step the relative change in the geographical distribution of the *Pavo Cristatus* and calculates the percentage of area under the *Pavo Cristatus* distribution, the forest cover in 2005 and 2015 is estimated. The next step of the analysis finds the key factors associated with *Pavo Cristatus* distribution using ESDA. Section V discusses the results and points some of the changes that are to be enforced to increase the area under *Pavo Cristatus* distribution/habitat. Finally the section VI contains the best available conclusions on the results obtained.

II. STUDY AREA

Coimbatore, located in the banks of Noyyal River, is the second largest districts in the state of Tamil Nadu. It has a total geographical area of 7469 sq.km *[22]*.The climate is tropical which is hot and humid with rainy season lasting from October to November. The forest cover of the district is divided in to six divisions according to the forest census 2012 as shown in map 1*[18]*. All the activities inside the range are governed based on these divisions. More than 100 species of mammals, 80 species of reptiles, 316 species of butterflies, 350 species of birds, 31 amphibians and 39 species of fishes survive in this area. The forest cover of Boluvampatty and Sirumugai range has the highest number of peafowl with a forest cover ranging around 15000 sq.Km *[26]*. The existence of different species of birds and animals are widely affected due to the human intervention and establishment of urban development into the forest regions *[18]*.

III. DATA AND METHODS

A. Data for the identification of factors associated with Species distribution:

The identification of potential factors associated with species distribution was carried out using different methods. In the first place a comprehensive and extensive search for the existing literature was done to enlist the factors. Secondly, field experts such as researchers, bird watchers, officials from NGO's were consulted and interviewed regarding the economic, social, institutional and environmental factors that affect the species distribution in the Coimbatore region. Further based on the census information a field work was carried out in the north and west Coimbatore which has experienced a rapid urbanization during the last decade *[18,19]*. Discussions with the public departments (People for animals) and the civil society (local population) were also carried out. These varied sources of information were involved the spatial analysis of the regional factors associated in the disturbance of species distribution. The analysis revealed six major and significant factor associated with species extinction. 1) Deforestation 2) Human activities 3) Ecological Imbalance 4) Non-availability of food 5) Encroachment 6) Agriculture

After identifying the key factors a detailed analysis of their association with species extinction was done. The spatial and the alphanumeric values are collected for the different forest ranges of the district. The data is organized according to the Economic, Social, Institutional and environmental factors. Table I shows the set variables which provide information at the municipal level showing the details of the whole district. The other key values (state weakness, social capital) that were identified could not be included as the information for those variables were not available. The number of birds stalked by other species was used as a substitute for the social capital. The spatial and alphanumeric data on "*Pavo Cristatus*" was obtained from Global Biodiversity Information Facility (GBIF) and from the Forest Department of Coimbatore. The percentage of *Pavo Cristatus* distribution per forest range was taken as first Variable 'A' and the other variables as 'B' to analyze the spatial association.

The best information available for spatial and the numerical values on species distribution at the forest range level in the Coimbatore region are identified for 2005 and 2013. The data was not available with complete information there were missing information for particular year. The information closest to the missing year was used. In situations where the data is available for single year alone was used for the years to be considered. The assumption is made on the basis of the fact that even though the variables tend to change over time, there prevails a spatial distribution (relation) between the other dependent variables throughout the time period. Such imputation of the values may bring inaccuracies in the results where an appropriate declaration regarding the limitations is explained in Section V.

Map 1: Forest ranges and boundaries

B. Distribution of *Pavo Cristatus* and forest cover

The analysis of *Pavo* distribution in the forest cover was based on the information collected from the Land Use Vs Land Cover (50K) map for the year 2005 obtained from NSRC/ISRO open data and product archive. The forest cover map from 2005 was overlaid with the distribution census data (provided by the forest department) of *Pavo* for two years (2005 and 2013) and the area of *Pavo* in both years that had been under the forest cover is estimated. The purpose of this analysis is to give an estimation of degree of *Pavo* distribution affected in different ecosystem due to the forest cover depletion from 2005 to 2013.

The estimation has been made from the forest cover that existed in 2005. These forests and *Pavo* distribution were grouped into three different ecosystems according to the forest cover and geographical position.

Table I: Selected Variables at the forest range level

Variable	Symbol	Category	Variable Name	Year	Source of Data	Unit	Explanation
VarA	PSD	Analysis Variable	Percentage of area under species distributed	2003-2012	Pavo distribution maps (Shape) -People for animal, Salimali centre for orinthology, Forest Department of Tamil Nadu	Percentage	Area under the distribution of particular species in comparison with the total area
VarB	GUP	Social	Growth of urban population per Square Kilometre	2005-2011	Office of the Registrar General and census Commissioner India, Ministry of Home Affairs.	Lakhs	Population growth between years
	VAAS	Institutional	Number of birds hunted due to violent activities against the species	2005-2011	The Hindu, NDTV Reports. Times of India,	Numbers	Number of peacocks killed/ Dead due to many reasons
	PFC	Environmental	Percentage of forest cover. Forest /Land cover/Land Use	2005-2013	NSRC/ISRO open data and product archive	Percentage	Percentage of hectare of forest and land cove compared with the urban growth.
	FRD	Environmental	Road density	2003	Road map shape file-created by the authors for the work	Mtrs/ha	Meters of road per hectare of scale 1:500000
	BDI	Ecological	Biodiversity Index	2007	Salim Ali Centre for ornithology	proportion	Mathematical measure of species diversity in a given community
	UBI	Social	Unsatisfied Basic Needs Index	2011	Census of India	Per Sq kilo meter	Facilities in per square kilometer

C. Exploratory spatial analysis of *Pavo Cristatus* distribution:

Two types of exploratory spatial analysis has been carried out to explore the most important factors related with the distribution of *Pavo Cristatus* in Coimbatore district, by the methods proposed in *Aselin (1995) and Patachini and Rice(2007)[7,15].*

The global multivariate spatial correlation analysis was applied to calculate municipal (forest range) level for the entire district. A measurement of the spatial correlation is made between the percentages of *Pavo Cristatus* distribution and the major factors affecting the distribution. The estimation was carried out on the basis of multivariate Moran's Coefficient*[5]* and the analysis is referred to as "global analysis" since it is based on a district wide analysis. The method analysis the factors associated with the species distribution of *Pavo Cristatus* at aggregate level.

The Exploratory Spatial Data Analysis involves a local multivariate spatial correlation analysis that lets to identify local patterns on spatial associations depending on the local indicators *[7]*. The LISA (Local Indicators of Spatial Association) approach is used to decompose the Moran's I coefficient by the identification of contributions given at local level. An extension of multivariate analysis LISA developed by Anselin et.al (2002) was used in analysis. The multivariate LISA provides an indication of degree of association between the percentage of *Pavo Cristatus* in each zonal and municipal levels and the variables of interest in the neighbouring municipalities *[5,7].*

The global and the local multivariate spatial analysis require the construction of a weight matrix, which enables to find the local nearby value around each municipality level as a geographical unit. The weight matrix is chosen as a healthier option due to the heterogeneity of the polygons and the wide variety of neighbour hoods retrieved. The neighbours are retrieved using three types of weigh matrix calculation methods (contiguity, distance and K-nearest neighbour) *[2,3].*

The global and the local multivariate spatial analysis follows Moran's I statistic which is visualized in the four quadrants of generalized scatter plot *[5,8]*, which represents the standard form of analysis in which the slope of the line represents the global Moran's I regression statistic value of the analyzed variables. The work analysis the spatial association at global level (district), the scatter plot reflects four type's local spatial correlation between municipalities and the key factors. The upper right has municipalities with high values in A variable (approximately the areas under *Pavo* distribution) covered by the municipalities with the highest values of variable B (any of the key factor selected). These could be referred to by the municipal values with High-High (H-H) association. The lower right quadrant contains the values associated with the High in the variable A and with low values in the variable B which is therefore High-Low (H-L) association. The lower left quadrant has an association between L-L ie., Low or zero values in the variable A and bounded by municipalities with low or zero values in the variable B. The Low-High quadrant on the upper adjacent to H-H quadrant contains low or zero values in the variable A with the nearest values for the variable B.

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A LISA cluster map *[3,5,7]* is been used to show the observed locations with a significance of local Moran Statistics, spatial clusters and the outliers are highlighted and the centre of the cluster are clearly classified. The spatial range of the cluster should appear within the boundary region which includes the neighbouring which is not highlighted in the map. The areas associated with H-H,L-L,H-L,L-H values in the LISA map. The level of significance with various correlation coefficient are estimated using 1000 permutations *[4,5]*.

IV. RESULTS AND DISCUSSIONS

A. Forest cover, Land Cover and Pavo Cristatus Distribution (2005-2013)

The study has revealed a remarkable change in the geographical distribution of *Pavo Cristatus* from 2005-2013. The distribution of *Pavo* has decreased in the forest range of CBE (Coimbatore)and has a considerable growth in the lower range of BOL (Boluvampatti) and SIR (Sirumugai) ranges of the district, when compared with the ecological and the forest cover changes during the year 2005- 2013.The most affected forest range of species distribution was especially found in Coimbatore and PNP (Periyanaiyakananpalayam) range during the year 2005. In 2005the distribution of *Pavo Cristatus* was found to be 12.7% in BOL has decreased the distribution of *Pavo* by 3% in 2013, which is mainly due to the displacement of *Pavo* in the lower regions of the forest range mainly towards the agricultural zone of the range. In 2005 the distribution of *Pavo* was around 9500 ha was found in the lower bed of mettupalayam range and has decreased to 8500 ha by the end of 2013. The Table II clearly reveals that in 2005, 3236 ha of the *Pavo* distribution has been increased to 3500 ha by the end of 2013 in SIR range.

The area of *Pavo* distribution has been decreased. The results clearly reveal *Pavo* habitat which has been adversely affected due to the forest cover and land cover expansion which has not been previously associated with the habitat (Map 2 and Table II).

Table II: Relative proportions of *Pavo Cristatus* in 2005 and 2013

Forest Range	Area under Pavo Distribution (Ha)	
	2005	**2013**
CBE	780	600
PNP	1230	1128
BOL	3000	4580
KAR	2378	2300
MET	9575	8453
SIR	3236	3500

B. Factors associated with Pavo Cristatus distribution (2003-2015)

The survival of *Pavo Cristatus* in a particular region of the Coimbatore is not due to the constructive environmental factors favourable for its distribution, but also it depends on the major factors that affects/favours distribution of the species, which could be analysed by the results obtained from local and global multivariate spatial analysis.

- **Multivariate global spatial analysis**

The analysis between 2005-2013a major global spatial association was identified between the percentage area under species distribution at the global level and all the major factors identified are shown in Table III. A relationship between the *Pavo Cristatus* distribution and the other variables is found to be inverse. The relation inverse is found in the variable such as number of death due to the violent activities against *Pavo*, forest density, bio diversity. A positive relation was found between the variables population growth, unsatisfied basic index, primary road density.

- **Multivariate local spatial analysis**

The key results obtained from local multivariate spatial analysis are listed below. First, in 2003 the 9 forest range with the *Pavo Cristatus* distribution showed noteworthy level of spatial correlation with the analyzed variables in global analysis, obtaining similar results in both sign and significance, except for bio diversity indices which does not show any significance at local analysis among the variables analyzed. Secondly, it is found that no variable is exclusively associated with species distribution and significant associations are found in the regions where the favourable conditions are absent. Third, between 2005 and 2013 there found a displacement of species distribution towards lower range of sirumugai and BOL ranges of the Coimbatore region. During 2005 and 2013 the species are found to be displaced to the forest, urban areas which exhibited very similar favourable conditions [Environmental, Institutional, Ecological]. It is found that no individual factor is associated with the distribution of the species, set of distinct common factors are identified (less density of forest, road density, population growth, violent activities, poisoning, unsatisfied basic index) forced and fast urban development.

Table III Multivariate global spatial analysis (Association between the percentage of area under *Pavo Cristatus* in 2005 and 2013)

Category	Variable	Association Coefficient	
		2005[@]	**2013[@]**
Social	Population growth Density	-0.092	-0.183
Social	Unsatisfied basic index	-0.086	-0.256
Economic	Primary Road Density	-0.063	-0.253
Environmental	Forest density	0.017	0.010
Environmental	Bio diversity	0.125	0.285
Institutional	Number of death	0.170	0.179

@ Degree of association (iterated from1-5) fixed as 5%

The outcomes of the analysis are presented with the maps. The LISA maps are created for all the variables selected, but those variables which exhibited a significant level of association are included. The variables that exhibited a significant level are unsatisfied basic index, growth of population and the forest cover/ landuse data.
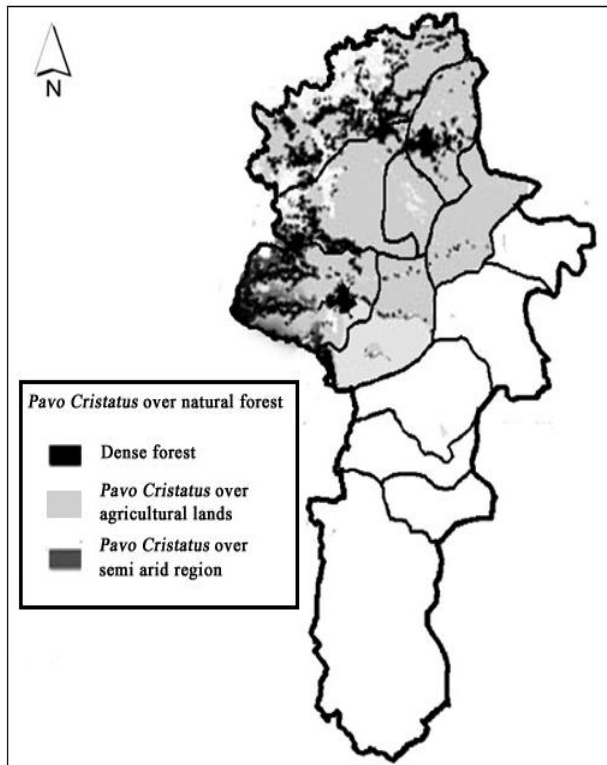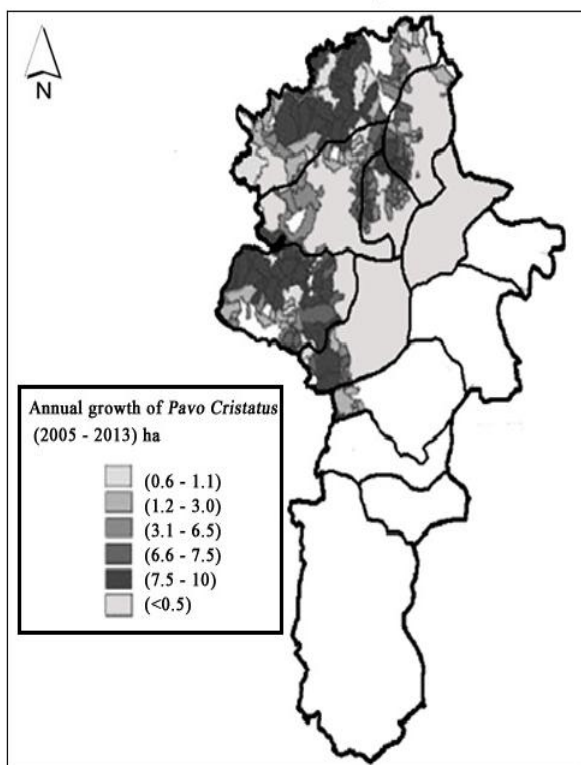
C. Environmental factors

Spatial association between the area under *Pavo Cristatus* distribution and forest land cover in Coimbatore region for the year 2005 showed a positive sign of association in H-H cluster.

The forest ranges with high density also exhibited a less prevalence of *Pavo* due to other predators destroying their habitat, ranges were also associated with the low presence area of *Pavo* distribution ie., L-H Cluster. By the end of 2011 the cluster expansion was found towards mettupalayam range indicating the displacement of the species were the semi forest density is high (Map 3)

D. Social Factors:

The *Pavo* distribution was associated with the basic needs required for the species livelihood. The clusters are found to be grouped in coimbatore, mettupalayam, boluvampatti regions, were the perch and breeding places are mainly concentrated. The forest ranges with less distribution of *Pavo* was associated with the base index. By 2011 the expansion of the H-H cluster was observed towards mettupalayam and sirumugai regions of the semi forest range. The vice versa was observed in PNP range. L-L cluster could be identified in karamadai region in 2003, the fast urbanization and population explosion exhibited a similar model of behaviour pattern in population growth variable (GUP).

Map 2: Annual growth of Pavo Cristatus and growth over the natural cover region

Spatial Association between the (H-L Cluster) *Pavo* distribution and the forest range with less population density showed a significant level of association clusters exhibiting significant relation among the low distributed *Pavo* and low populated range was also visible (Map 4). By 2013 the area under *Pavo* distribution with low populated forest ranges was found towards karamadai and boluvampatti regions.

E. Ecological factors

Different results were found at the range level regarding the association between tribal population and the *Pavo* distribution. An inverse association at the range level in 2003 and 2013 were no significant association between them at the range level. The primary road density, which contributes to the death of many species of birds and animals has showed a negative spatial association with a higher density of the *Pavo* species implying that the dense distribution of species that are isolated by the roadways (H-L) clusters. The H-L cluster region in 2003 and the same cluster by 2013 found an

expansion towards the mettupalayam and karamadai regions of the range confirms the findings.
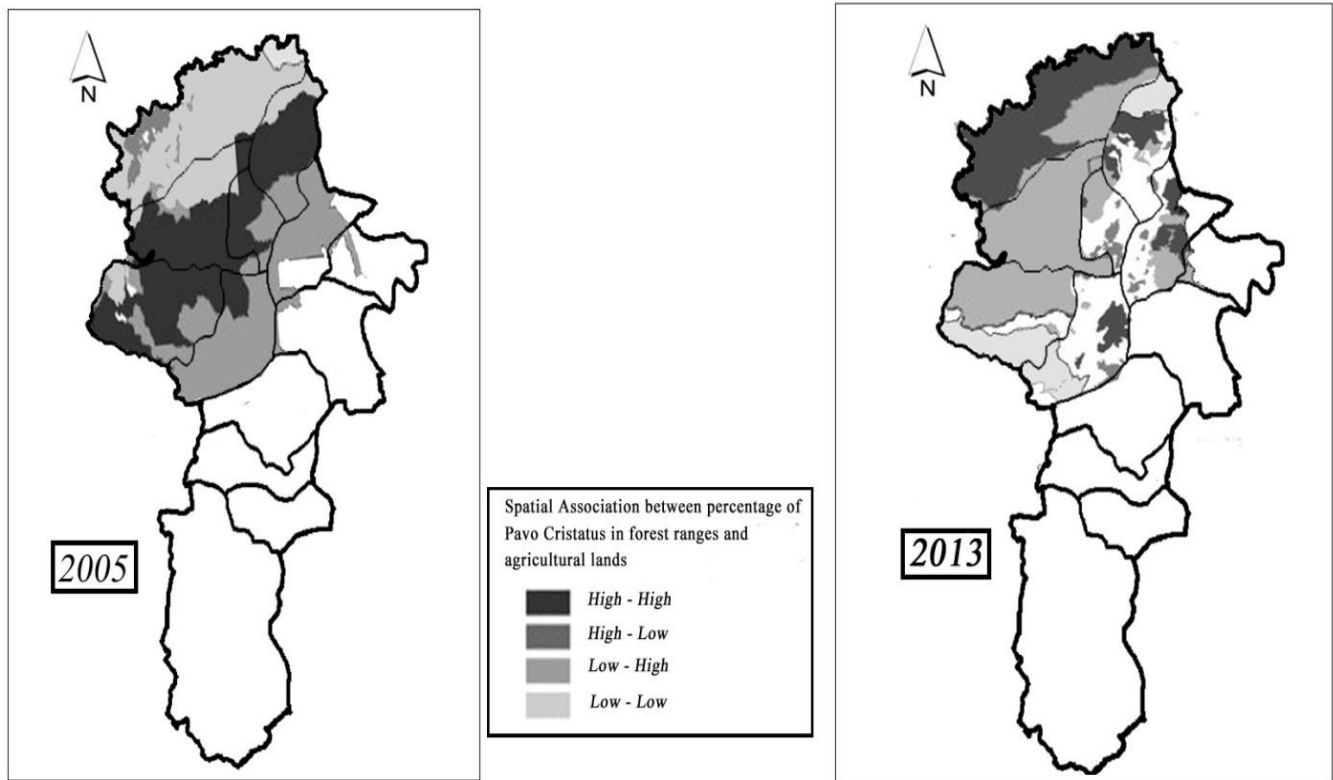
F. Institutional factors:

The municipal development co-operation has provided indexing values for the various levels of associations, showing the presence of H-L clusters in the *Pavo* distribution (Map 5) the species distribution in the municipalities were associated with the municipalities which had a higher density of forest and agricultural lands in 2003. There were also areas found to be associated municipalities and *Pavo Cristatus* was low or absent. By 2013 the H-L clusters are found to be formed towards the Coimbatore & PNP ranges, many related variables are associated with poaching and poisoning by the illegal groups (Number of violent acts) which together forms a weakness in the range level shows various results.
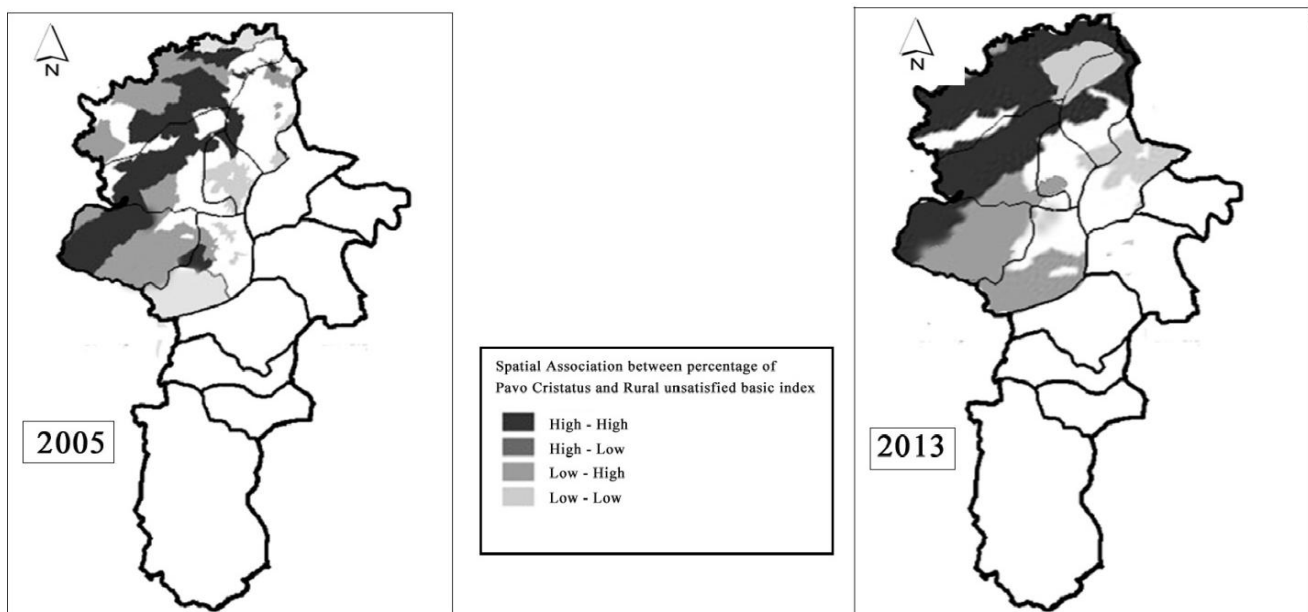
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In 2005 the forest ranges with the high density of *Pavo* associated with ranges exhibited a high level of poaching and poisoning. L-H cluster indicates that the forest range with null or low presence of the species, illegal groups were found
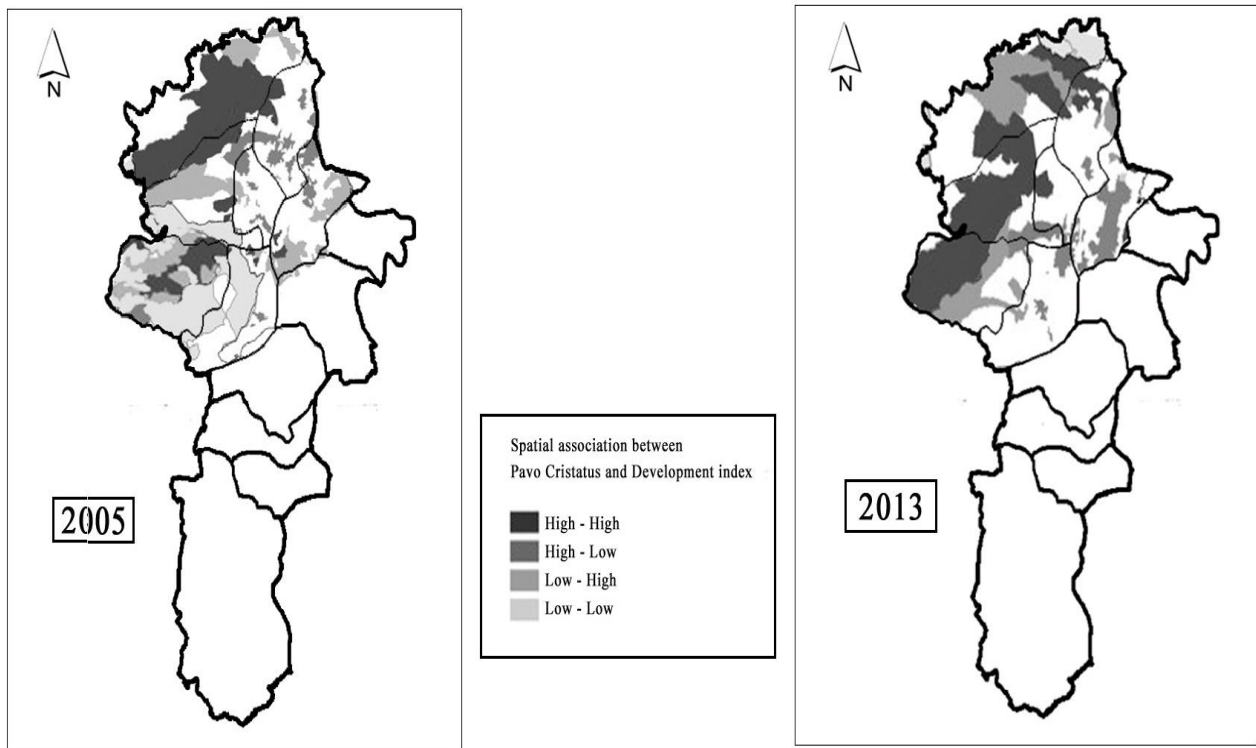
approximate results are obtained in two years 2005& 2013 in association with the significant variables. The high density variables are shifted to the boluvampatti and karamadai ranges of the district.

Map 3: LISA map for cluster expansion towards the semi forest region (Significant cluster by 0.05 sig level)

Map 4: LISA map of rural unsatisfied basic index in 2005 and 2013 (Significant cluster by 0.05 sig level)

Map 5: LISA map of municipal development (Significant cluster by 0.05 sig level)

V. DISCUSSION:

A comparison with the species distribution in 2005 and 2013 with respect to the distribution in the forest and woody in 2005 is now been replaced as the urban area with fast growth of human population. The result shows over depletion of forest region which might be transformed in to agricultural lands or other type of landuse. The results clearly reveal on depletion of species distribution area in the tropical forest which is of great ecological importance. Considering more and more specific results the semi forest cover provides a suitable region for species distribution. But previous results find a positive relation between the forest cover and the species distribution[10]. Species distribution associates the low forest cover results with less accessibility of food and shelter. This implies that the species distribution remain in the area where there is easy accessibility of food in the semi forest cover. Once when the species migrates it's a major driver for the ecological imbalance and disturbance of food chain in the food pyramid.

The foremost point to discuss is the data inconsistency found in various variables of the analysis in LISA. Complete information of the variables for both the years 2005 and 2013 could not be found, only one occurrence of certain variables (Primary road density, domestic population growth, illegal poaching of birds, unsatisfied basic index) has been recorded, the variables are normalized using the values recorded for the previous year, if the variables found to have temporal changes and maintains the spatial distribution of data[17]. The road density variable has not changed to a great extent according to

the forest department of Tamil Nadu; therefore an assumption has been made that even though there are changes in the variable the value is kept constant.

VI. CONCLUSION:

Based on Exploratory Spatial Data Analysis (ESDA) there is a correlation pattern of species (*Pavo Cristatus*) distribution associated with a different set of characteristics between 2008 and 2013. The analysis which has proved fruitful in screening that *Pavo Cristatus* is prevalent in areas which are considered to have forest area, agriculture lands were the food availability is more with forest ecosystem. The results also throw a major alarm to the ecological conservers that the distribution of *Pavo Cristatus* is mostly affected by urbanization and Human activities. These results have shown an irreversible effect on the distribution of *Pavo Cristatus*. In order to solve the migration problem of the species a policy arena need to be done by transforming the regions of species existence as the protected zone with all the facilities incurring its habitat. The posit is based on the data analyzed. The expansion migration of a species not only associated with single factor but group of factors support the migration.

The global spatial analysis reveals an inverse relation between the analysis variable and the violent activities performed against a particular species. The association is not significant, when carried at a local level.

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Pavo Cristatus are found towards the semi forest area and towards the lower forest bed, where the availability of the basic needs is at an ease. This analysis has allowed an association of global analysis between the percentage of area under species distribution at each forest range and each variable that influence the distribution of a species in Coimbatore region.

The results are analyzed at the local level as well as at the global level. The local level of spatial analysis reveals various insights of the species distribution. None of the related variables are exclusively associated with *Pavo Cristatus* distribution. An inverse relation is found towards the area under the species distribution. Although when no individual factor is associated with the *Pavo Cristatus* distribution, some common factors exists the distribution of the species such as illegal poaching of birds for medicine, unsatisfied basic index. The spatial displacement is found towards the lower / semi forest ranges, sub urban regions of sirumugai, boluvampatti and karamadai ranges between 2005 and 2015. The new displacement of *Pavo Cristatus* in 2005 and 2013 implies that the displacement occurs when similar Socio, Economic, Institutional, Environmental characteristics exists. If the causes for the displacement of such variables are not located in a controlled method. The extinction of the species will continue to a chain of action. When illegal poaching continues, the extinction of the species will be an irreversible process.

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