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Seasonal Changes in Home Range and Habitat Use of Elephants in Southern and North-central Provinces of Sri Lanka

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ABSTRACT: *Elephants generally require a large area of habitat, and usually avoid human settlements and agricultural lands. However, less protected agricultural lands such as Chenas are vulnerable during droughts where food is scarce. If available, grasslands are highly preferred by elephants, and forest lands are less preferred compared to scrub lands. According to past research, it was estimated that Sri Lankan female elephants have home ranges of about 29.6 – 160.7 km^2. The objective of this study was to access the seasonal changes of home ranges and the habitat selection of elephants in Southern and North-Central Provinces of Sri Lanka. This study also attempted to estimate the size of the home range using satellite telemetry data collected for two study sites with minimum convex polygon approach. Seasonal home ranges and home range core areas were derived using 95% and 50% Nonparametric Kernel Utilization Distribution. The land use selection was analysed using the Jacob's Index and the expected proportional usage of habitats were calculated. The estimates were evaluated against the Bonferroni's simultaneous confidence intervals. The results identified that average size of the home range of female herds during the dry season is about 73 km^2. The seasonal fluctuation of elephant home range lies within 12.12- 73.07 km^2. As identified by the present study, the maximum size of the core of the home range where elephants spend more time is 25.76 km^2. It suggests that preferences and spatial requirements highlighted by this study should be taken into consideration when the interventions are made on manipulation of the home range of elephants for management requirements. The geo-informatics approach used in the study could also be used effectively in implementing such interventions.*

Keywords: *Asian elephant, home range, seasonal habitat preference, geo-informatics*

INTRODUCTION

The elephant survey conducted in 2012 suggests that, more than 5,879 wild elephants exist in Sri Lanka (Department of Wildlife Conservation, 2013). Sri Lanka holds an important position with regard to Asian elephant conservation as a country with the highest density of elephants (Fernando ***et al.,*** 2011).

Elephants are highly mobile and have large home ranges (Jakson ***et al.,*** 2005). Fragmentation and loss of the natural habitats of elephants (Desi, 1998) are considered to be the main cause of Human Elephant Conflict in Sri Lanka (Bandara, 2005). According to Baskaran ***et al.*** (1995) home ranges of Sri Lankan elephants are relatively small compared to that of

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Southern India. Home ranges of Sri Lankan male elephants vary from 53.6-346 km^2 and in the case of females, it ranges within 29.6-160.7 km^2 (Weerakoon *et al*., 2003). According to Weerakoon *et al.* (2003) Sri Lankan elephants show a high fidelity to home ranges.

The African elephants concentrate their movement to areas where the water is available during dry season and they expand their ranges (Western *et al.,* 1984). However, Weerakoon *et al.* (2003) argues that the Asian Elephants in Sri Lanka shows no distinct seasonal range differences during wet and dry seasons. The same author has also noted that there is a trend of increasing home range size with increasing fragmentation of land by the elephants inhabited in landscapes with high level of human activity (Weerakoon *et al.,* 2003). However, in another view, the water scarcity in the dry season is considered to be one of the reasons for elephants to come out of the protected areas (Santiapillai *et al.*, 1994). In other words, the elephants are moving out of the core area during the dry season. The escalated level of human elephant conflict during dry season justifies this view as elephants' raid human habitats mostly during dry season. However, the research suggests that monthly distribution of human elephant conflict incidents were strongly negatively correlated with rainfall, but not with the availability of water (Campos-Arceiz *et al.*, 2009).

The occurrence of dry seasons in between the two rainy seasons is a well-recognized character for the dry zone of Sri Lanka (De Silva and Punyawardena, 2006). The main rainy season of the dry zone of Sri Lanka comes from September to December (Campos-Arceiz *et al.,* 2009). The dry season runs from June to mid-September, with the maximum drought occurring in August and early September. In April and May, there is a shorter period of rains (Campos-Arceiz *et al.*, 2009).

The habitat usage of elephants is influenced by many factors including vegetation quality and biomass (Natumi *et al.,* 2005) vegetation cover, water availability (Natumi, 2002) and human disturbance in response to crop damages (De Boer and Baquete, 1998). Since the seasonality of Sri Lanka and the above mentioned factors depend on rains, the seasonality should have an impact on the movement and the habitat use of the elephants.

Objectives

In this context, the objective of this study was to examine the home ranges and to explore the seasonal changes of habitat used by two selected herds of elephants. The specific objectives of the study were;

- to examine the home range sizes and the seasonal changes of selected elephant herds using geo-informatics tools.
- to investigate the habitat selection and use patterns in the study sites.

METHODOLOGY

The study was carried out in two sites located in the North-Central and Southern Regions. Two elephant herds selected were monitored using satellite telemetry for almost 2 years from 2009 to 2011. One elephant herd was roaming in Palugasdamana, Hingurakgoda, Dambulla and the boundary of Kekirawa Divisional Secretariat Divisions (Site 1 – North-Central) and the second heard was roaming in Lunugmavehera, Hambantota, Sooriya Wewa and Tanamalwila Divisional Secretariat Divisions (Site 2 – Southern). The location of the two

sites is shown in Fig. 1. Location data of herd 1 was collected from 05/11/2009 to 30/09/2012 and of herd 2 data were collected from 18/09/2009 to 30/09/2012. Data have been recorded at four hour intervals in both cases.

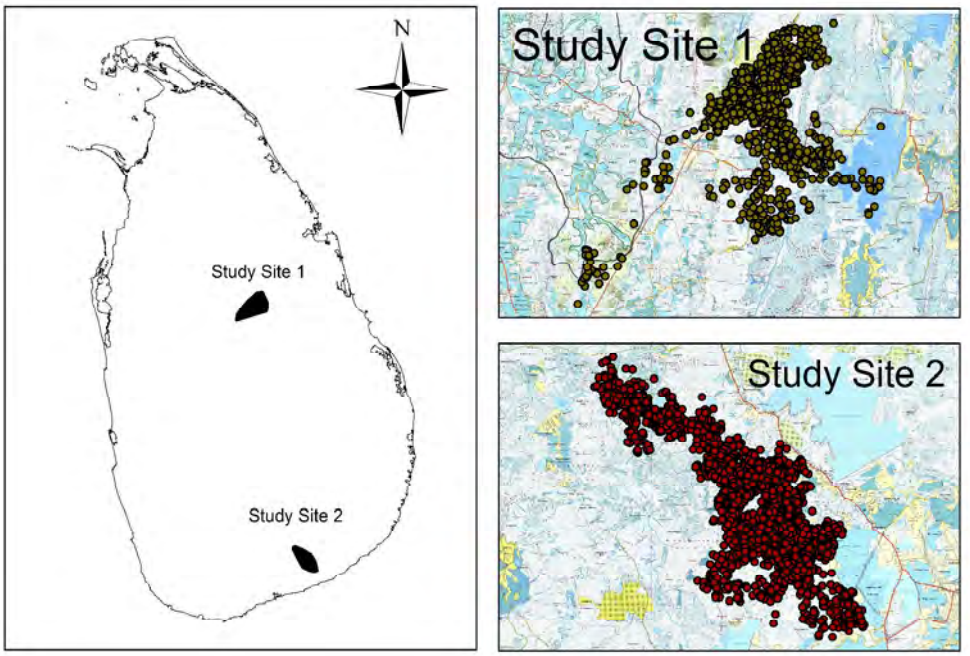

Fig.1. The study sites

Range size and the seasonal spatial changes

Using the location data set of each elephant herd, maximum area where they have moved during the study period was determined using the Minimum Convex Polygon (MCP) approach (Natumi *et al.*, 2005). A buffer of 1000m was added to the derived MCP and considered as the area of interest (AOI) for that elephant heard. Then the location data was grouped according to the dry and wet periods (Campos-Arceiz *et al.*, 2009) of the dry zone of Sri Lanka (De Silva *et al.*, 2006).

Table 1. Rainfall seasons of the day zone of Sri Lanka

Season	Duration	Remarks
1st Dry Season	February to March	
1st Wet season	April to May	
2nd Dry Season	June to September	Acute dry season
2nd Wet Season	October to February	Main wet season

Source: Campos-Arceiz *et al.* (2009) and De Silva *et al.* (2006)

Generally, the minimum convex polygon approach is used in the home range area calculations. In this approach, areas that elephants have never visited are also included. However if one needs to identify the actual area where elephants really visited, the nonparametric kernel Utilization Distribution (UD) provides more rational outcomes. Within the home range, elephants tend to spend more time in certain areas and such areas are called core areas. Such core areas could also be identified using the same approach.

The seasonal home range of each elephant herd was derived using 95% nonparametric kernel Utilization Distribution (UD) and the core area of the home range was derived using the same method at 50% UD (Borger *et al.,* 2006). The Least Square Cross Validation (LSCV) was used to determine the smoothing factor (Worton, 1989).

From the perspective of humans, Human-Elephant Conflict has two dimensions; human deaths and the crop/property damages. The male elephants tend to invade the human habitats as single individuals and most of the human deaths and property damages are caused by them. The females are generally move as herds and often responsible for crop damages (Arceiz *et al.,* 2009). The study focused on the behaviour of the herds comprising females, juveniles and calves.

Habitat selection and use

The elephants are generally not restricted to legally protected areas. Hence the selection of the land use types available in the area by elephant was assessed. The digital land use data prepared by the Survey Department of Sri Lanka was used in the analysis. The land use selection was analysed using the Jacob's Index; JI (D). JI (D) is defined (Jacobs, 1974) as (r-p)/(r+p-2rp) where r is the proportion of considered land use class in the home range (95% UD) and p is the proportion of that land use class in the AOI of the herd. JI (D) is a value ranging from -1 to +1 and the values > 0.3 are considered as preferred while values < -0.3 are considered as avoided land use types (Kriegler *et al.,* 1969).

The occurrence of a particular vegetation type in a space used by an animal does not necessarily indicate that it is preferred (Roux *et al.,* 2007). Hence the habitat use preferences were evaluated using the method described by Neu *et al.* (1974) and Byers *et al.* (1984). First the area under each land use class in the AOI (AHC_{AOI}) was calculated and the relative area (RA_{AOI}) was calculated using the formula $RA_{AOI}=AHC_{AOI}/A_{AOI}$ .Then the expected usage (U_E) was calculated by multiplying the total number of GPS fixes (TFX) within the AOI by the RA_{AOI} (U_E = TFX . RA_{AOI}). The actual usage (U_A) was considered as the total number of GPS fixes within the considered habitat class (TFX_{HC}).The expected proportional usage (U_{PE}) and the observed proportional usage (U_{OE}) were calculated as U_{PE} = U_E/TFX and UPA= U_A/TFX. Finally the expected usage was evaluated against the Bonferroni's (Byers *et al.,* 1984) simultaneous confidence intervals. Chi-Square goodness of fit test was also performed on the expected and actual usage values (Byers *et al.,* 1984).The confidence interval (CI) was calculated using Equation 1.

$$CI = U_{PA} \mp Z_{\alpha/2k}\sqrt{\frac{U_{PA}(1-U_{PA})}{TFX}} \qquad (1)$$

Value of α is the probability at which the CI is calculated and k is the number of land use classes. If the CI falls below the expected proportional usage (U_{PE}), the habitat is avoided. If

the CI falls above the U_{PE} the habitat is preferred. If the U_{PE} is within the CI habitat is used according to the abundance in the area (Roux ***et al.,*** 2007*).*

In the analysis, ABODE V5.1, a free software developed for ArcMap V10.1 by the Department of Fisheries and Wildlife Sciences of Virginia Tech University, USA was used in generating home ranges. Python scripts were used in calculating the JI (D) and CI values.

RESULTS AND DISCUSSION

Home range size and seasonal spatial changes

The area of the entire landscape where the elephant roam during the study period was 326.57 km^2 in the study site 1 (North-Central Region) whereas it is only 217.03 km^2 in the site 2 (Southern Region). Site 1 comprises of eight land use types including grasslands. But in study site 2, seven land use types were observed but grasslands. The seasonal home ranges and core areas were generated for four seasons for both sites as shown in Fig. 2. The calculated area of home ranges is shown in Table 2. The seasonal home range of the site 1 elephants herd vary from 12.12 to 72.97 km^2 whereas in site 2 it is ranging from 49.34 to 73.07 km^2. The seasonal core area of the site 1 herd varied from 3.24 to 16.04 km^2 whereas for the site 2 herd, it varied from 21.62 to 25.76 km^2. The maximum size of the seasonal home range was generally shown during the dry season. In North-Central herd (site 1), the maximum seasonal home range was observed in the 2nd Dry Season (June– Sept.). Maximum seasonal home range was observed for the Southern Region herd (Site 2) in the 1st Dry season (Jan-Mar). Even though the total area at the dispose (the total area where the herd has explored during the study period) of site 1 herd was higher than the site 2, the seasonal home range and the seasonal core home ranges of the site 2 elephants are high. When the overall situation in both sites is considered, elephants were roaming in area less than 73 km^2. However, in both cases, they have concentrated in an area of 25.76 km^2 at most of the time.

Table 2. Variation of the extent of seasonal home ranges

Season	North-Central Region (Site 1)			Southern Region (Site 2)		
	Area Available	Seasonal Home Range	Core Home Range	Area Available	Seasonal Home Range	Core Home Range
1st Dry (Feb-Mar)	326.57	12.12	3.24	217.03	73.07	23.76
1st Wet (Apr-May)	326.57	30.78	8.12	217.03	65.99	21.62
2nd Dry (Jun-Sep)	326.57	72.97	16.04	217.03	49.34	13.64
2nd Wet (Oct-Jan)	326.57	33.25	7.71	217.03	71.82	25.76

*All areas are in km^2

Habitat selection and use

In the study site 1 grasslands were available but not in the study site 2. The grassland available in site 1 falls within Hurulu Forest Reserve. The calculated Jacob's Indexes for each land use type for both study sites are shown in Table 3 and Table 5. The preference and avoidance derived from Jacob's index is shown in Table 4 and Table 6.

In site 1, human habitats and paddy cultivations have been avoided by the elephants. Forest lands and the Scrub lands were indifferent. *Chenas* have been avoided in the dry season and indifferently used during rainy seasons. However in the overall picture, *Chenas* have been avoided by the elephants. Grasslands were preferred in dry seasons and indifferently preferred in rainy seasons. Rocks were generally indifferent but in dry seasons they have avoided such areas. Water bodies were mostly avoided except in the acute dry seasons but have been visited for a shorter period for drinking and wallowing purposes.

Table 3. Jacob's Index values for the 1st site

Habitat	1st Dry Season	1st Rainy Season	2nd Dry Season	2nd Rainy Season
Chena and Rain Fed Vegetables	-0.9186	-0.1496	-0.8476	-0.2283
Forest	-0.2480	-0.0234	0.2209	0.2029
Grassland	0.9970	-1.0000	0.4549	-1.0000
Human Habitats	-1.0000	-0.9498	-0.8860	-0.3154
Paddy Cultivations	-1.0000	-0.6975	-0.9187	-0.6437
Rocks	-1.0000	0.2812	-0.6977	-0.2000
Scrub Land	-0.0612	0.2911	0.2221	0.0663
Water bodies	-1.0000	-0.9254	-0.0454	-0.4975

Table 4. Selection of habitats by elephants in the 1st site

Habitat	1st Dry Season	1st Rain Season	2nd Dry Season	2nd Rain Season
Chena and Rain Fed Vegetables	Avoid	Indif	Avoid	Indif
Forest	Indif	Indif	Indif	Indif
Grassland	Pref	Avoid	Pref	Avoid
Human Habitats	Avoid	Avoid	Avoid	Avoid
Paddy Cultivations	Avoid	Avoid	Avoid	Avoid
Rocks	Avoid	Indif	Avoid	Indif
Scrub Land	Indif	Indif	Indif	Indif
Water bodies	Avoid	Avoid	Indif	Avoid

Note: Avoid = Avoiding, Indif = Indifferent, Pref= Preferred

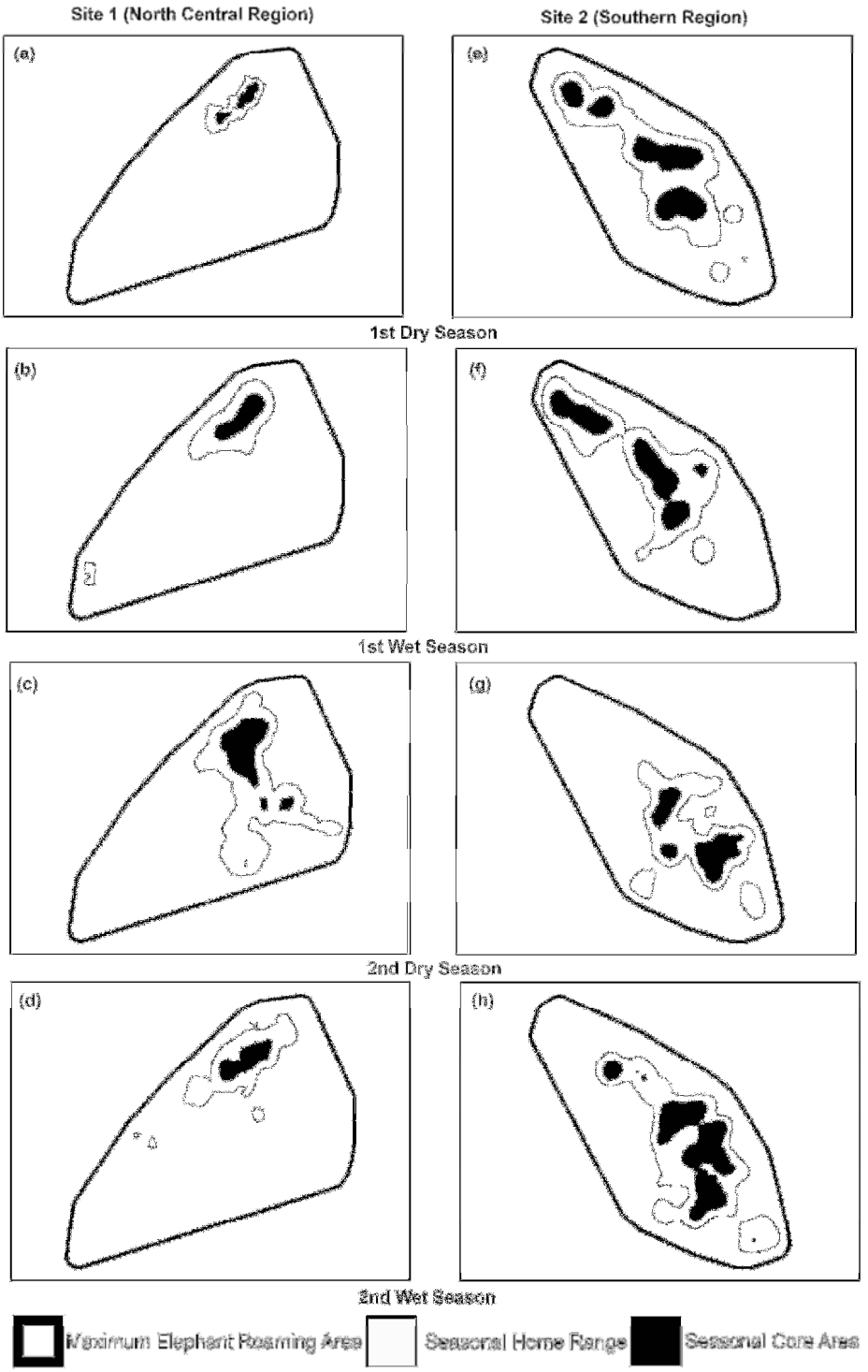

Fig. 2. Seasonal change of the home ranges of elephants in two study sites

Table 5. Jacob's Index values for the 2nd site

Habitat	1st Dry Season	1st Rain Season	2nd Dry Season	2nd Rain Season
Chena and Rain Fed Vegetables	-0.0761	-0.0692	-0.0001	-0.0171
Forest	0.0878	0.1042	-0.0671	-0.1095
Grassland	NA	NA	NA	NA
Human Habitats	-0.6560	-0.4184	-0.4569	-0.5556
Paddy Cultivations	-0.4318	-0.3889	-0.3834	-0.3777
Rocks	-0.3529	-1.0000	0.1216	-0.3308
Scrub Land	0.1541	0.0944	0.1875	0.2204
Water bodies	-0.3691	-0.1833	-0.4220	-0.3610

Table 6. Selection of habitats by elephants in the 2nd Site

Habitat	1st Dry Season	1st Rain Season	2nd Dry Season	2nd Rain Season
Chena and Rain Fed Vegetables	Indif	Indif	Indif	Indif
Forest	Indif	Indif	Indif	Indif
Grassland	*NA*	*NA*	*NA*	*NA*
Human Habitats	Avoid	Avoid	Avoid	Avoid
Paddy Cultivations	Avoid	Avoid	Avoid	Avoid
Rocks	Avoid	Avoid	Indif	Avoid
Scrub Land	Indif	Indif	Indif	Indif
Water bodies	Avoid	Indif	Avoid	Avoid

Note: Avoid = Avoiding, Indif = Indifferent, Pref= Preferred, *NA*= Not Available

Table 7. Attributes and calculated values for the 1st site

Habitat	TFX	AHC_{AOI}[1]	RA_{AOI}	U_E	U_A	U_{PE}	U_{PA}
Chena and Rain Fed Vegetables	67	56.23	0.172	480.5	67	0.18	0.02
Forest	643	96.17	0.294	821.7	643	0.29	0.23
Grassland	3	0.32	0.001	2.7	3	0.00	0.00
Human Habitats	1	11.27	0.034	96.3	1	0.04	0.00
Paddy Cultivations	3	7.74	0.024	66.1	3	0.02	0.00
Rocks	0	0.30	0.001	2.6	0	0.00	0.00
Scrub Land	2047	139.08	0.425	1188.4	2047	0.46	0.73
Water bodies	32	16.12	0.049	137.7	32	0.05	0.01
Total	2796	327.2					

[1] Area in hectares, χ^2 Calculated =1253.3, χ^2 Table = 14.07 (α = 05, df = 7)

Table 8. Expected values and confidence intervals of the 1st site

Habitat	U_{PE}	U_{PA}	Confidence Interval (CI)	
			Left	Right
Chena and Rain Fed Vegetables[1]	0.18	0.02	0.01604	0.03189
Forest[1]	0.29	0.23	0.20817	0.25178
Grassland[2]	0.00	0.00	-0.00062	0.00277
Human Habitats[1]	0.04	0.00	-0.00062	0.00134
Paddy Cultivations[1]	0.03	0.00	-0.00062	0.00277
Rocks[0]	0.00	0.00	0.00000	0.00000
Scrub Land[2]	0.46	0.73	0.70917	0.75507
Water bodies[1]	0.05	0.01	0.00593	0.01696

Note: 1= CI is below U_{PE} – the habitat is avoided, 2 = CI is above the U_{PE} – habit is preferred, 0 = U_{PE} is within CI _ Indifferent.

Table 9. Attributes and calculated values for the 2nd site

Habitat	TFX	AHC_{AOI}[1]	RA_{AOI}	U_E	U_A	U_{PE}	U_{PA}
Chena and Rain Fed Vegetables	602	32.11	0.148	558.2	602	0.15	0.16
Forest	720	32.88	0.151	571.6	720	0.15	0.19
Grassland		NA	NA	NA	NA	NA	NA
Human Habitats	20	9.78	0.045	170.1	20	0.05	0.01
Paddy Cultivations	38	6.09	0.028	105.9	38	0.03	0.01
Rocks	1	0.18	0.001	3.1	1	0.00	0.00
Scrub Land	2203	124.99	0.576	2173.0	2203	0.58	0.58
Water bodies	191	11.11	0.051	193.1	191	0.05	0.05
Total	3775	217.14					

[1] Area in hectares 1253.346, χ^2 Calculated =219.8, χ^2 Table = 12.59 (α = 05, df = 6)

Table 10. Expected values and confidence intervals of the 2nd site

Habitat	U_{PE}	U_{PA}	Confidence Interval (CI)	
			Left	Right
Chena and Rain Fed Vegetables[0]	0.15	0.16	0.14338	0.17556
Forest[2]	0.15	0.19	0.17346	0.20799
Grassland	NA	NA	NA	NA
Human Habitats[1]	0.05	0.01	0.00211	0.00849
Paddy Cultivations[1]	0.03	0.01	0.00568	0.01445
Rocks[0]	0.00	0.00	-0.00045	0.00098
Scrub Land[0]	0.58	0.58	0.56191	0.60524
Water bodies[0]	0.05	0.05	0.04096	0.06023

Note: 1= CI is below U_{PE} – the habitat is avoided, 2 = CI is above the U_{PE} – habit is preferred, 0 = U_{PE} is within CI _ Indifferent.

The outcome of the Bonferroni's CI procedure was used to compare two sites (Table 11). According to the outcome, *Chena* is an avoided land use in the North-Central herd and it was used indifferently in the Southern Region elephants. Forest was an avoided land use in the North-Central Region and it was a preferred landscape in the Southern Region. Grassland was a preferred land use in North-Central Region. However, such grasslands were unavailable in the Southern region site. Human habitats and paddy cultivation are avoided land uses. Rocky terrains are indifferent in both cases.

Table 11. Comparison of study sites using Bonferroni's CI procedure

Habitat	North-Central Region	Southern Region
Chena and Rain Fed Vegetables	Avoided	Indifferent
Forest	Avoided	Preferred
Grassland	Preferred	*NA*
Human Habitats	Avoided	Avoided
Paddy Cultivations	Avoided	Avoided
Rocks	Indifferent	Indifferent
Scrub Land	Preferred	Indifferent
Water bodies	Avoided	Indifferent

According to the analysis (Table 4 and Table 6), even though grasslands are available only in the site 1 they are preferred in dry season and avoided in the wet season. According to this behaviour it is apparent that the grasslands area capable in providing necessities for elephants even in dry season compared to other habitat types. In site 2 no grasslands were present and there is no specially preferred land use type in the site. Therefore, grasslands can assume to be a preferred land use type in general. The avoidance of grasslands in the wet season may be due to increased food availability in the other land use type during wet season making elephants to stay in the areas such as forests where safety is high. According to Bonferroni's CI Procedure (Table 11) it was shown that Grasslands and Scrub Land area preferred land use types. Forests were not preferred in the site 2 where no grasslands available. In this context, developing management interventions on human elephant conflict mitigation, grasslands and scrublands are the primary areas to be focused on and conservation of forests is the next.

According to the results of the study, human habitations and paddy cultivations are avoided by the elephants (Table 11). However, Human Elephant Conflict occurs mostly when elephants invaded into such areas. Past studies (Campos-Arceiz ***et al.***, 2009) suggested that Human Elephant Conflicts increase during dry seasons. The results of this study have shown that the extent of the core use area does not change much with the seasons. However, the seasonal habitats increase in extent during dry seasons. Hence, one can infer that the elephants try to invade into human habitations and cultivations during dry seasons although it is an avoided area. The food availability both in quality and quantity is higher in human habitations and paddy cultivations and the harvesting is also relatively easy compared to other land use types. In such a context the reason/s for avoiding human habitations and paddy cultivations during any season, is an important question to be answered. Except all other habitats, human habitations and cultivations are heavily guarded by the community and

the government organizations. In this scenario, movement in to such other habitats is purely voluntary while movement in to human habitation is affected by the protective measures and management interventions of the people and the government.

CONCLUSIONS

According to the results of the study it can be concluded that, although elephants tend to move in larger areas ranging from 29.6 – 346 km^2 as reported earlier, the studied two herds use relatively small home range of about 75 km^2 (72.97 - 73.07). Further, the two herds use relatively small core area of 21.62-25.76 km^2 compared to the reported size of 40 km^2 in earlier studies.

The maximum seasonal home range was shown during the dry season although water bodies were not the preferred land use types of the elephants. Water is a vital factor for life, but elephants do not spend much time in the water. Even during the dry season, water bodies are not preferred land use class. Therefore, the main problem for elephants in long and stronger dry season may be the inadequacy of food comparative to the scarcity of water. Therefore, if the home range of the elephants needed to be restricted to a small area for management requirements such as minimizing elephant human conflict, constructing water bodies inside the forests would not be an ideal solution. In this context, habitat enrichment to make food available is the most viable option. Out of the total area of the home range, the core area should be given priority.

The total area explored by the elephant in the North-Central herd (327.2 km^2) was higher than the Southern herd (217.1 km^2). However, the seasonal home range and the seasonal core home ranges of the Southern region elephants are high. The most possible reason may be the quality of the habitat. When examine the quality of the habitat of the North-Central herd, the area is rich in food compared to the area of the Southern herd. The area of the Southern herd is more disturbed and degraded than that of the North-Central herd.

The study has shown the ability of geo-informatics in evaluating the preference of different habitat types during different seasons by the elephants. In planning elephant related management activities, these findings and the procedures could be used effectively. Managed elephant reserves are the most recent management intervention to minimize the human elephant conflict. Management of “Managed Elephant Reserves”, enrichment of the elephant habitats, and “protection-infrastructure” (i.e. Electric fences) establishment which restrict the movement of elephants should be done after identifying the core use areas as presented in this paper.

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