Contents

Plant selection matrix for classifying elephant forage plants in Sri Lanka using metadata: A Cluster and Classification -and- Regression Tree Approach

U D Tharangi[1*], R U Halwathura[1] and S Somaratne[2]

[1]Department of Civil Engineering, Faculty of Civil Engineering, University of Moratuwa, Sri Lanka.

[2]Department of Botany, The Open University of Sri Lanka, Nawala, Nugegoda, Sri Lanka.

ABSTRACT

The elephant, the largest terrestrial herbivore in the world, requires a higher amount of plant material for survival. The degradation and shrinking of forests on the island resulted due to anthropogenic activities, drive to deplete the habitats and niches of elephants migrating towards new habitats and food sources. Identifying the preferences of plant species is imperative in enhancing habitat enrichment endeavours to mitigate Human-Elephant Conflict (HEC). There was a scarcity of in-depth knowledge available on the feeding behavior and dietary patterns of Asian elephants grazing on rangelands and secondary forests. The work carried out on the elephant forage, in general, indicated that most of the Sri Lankan elephants preferred grasses over the other plants, the preferences vary with the seasonal availability of forage plants during dry/wet seasons. The establishment of forages could be considered one of the remedial measures for wildlife conservation. The objective of the study was to develop a plant selection matrix using plants and ecological characters from metadata analyzed using Cluster analysis (CA) and, Classification and Regression Tree (CART). CA produced three clusters at 80% phenon level and characterized by plant height ($p < 0.05$), soil pH ($p < 0.05$) and habitat type ($p < 0.05$). CART recognized the type of lifecycle, soil type and method of pollination as decisive features. Both cluster and classification and regression tree analyses identified the important character /character state that helped to group elephant forage. These characters were used to construct a forage plant section matrix for identifying proficient forge plants with minimum effort.

Keywords: *Elephant conservation, elephant forage grass establishment, cluster analysis, Classification and Regression tree analysis.*

Corresponding author - Email: tharangi.uyanahewa90@gmail.com

INTRODUCTION

Human-Elephant Conflict (HEC) is one of the most controversial topics that receive a -wide range of attention due to the increased rate of threats to both humans and wildlife -species today, and conservation biologists receive more attention. Conflict starts from a series of both direct and indirect negative interactions between humans and animals, whereas HEC is a well-known major challenge to enhance the chances of the existence of elephants within their ranges since these are places where many development projects are implemented for human well-being (Mmopelwa & Mpolokeng, 2016) . Thus, human and elephant communities have to share the space for the fulfilment of their requirements. In Sri Lanka, the intensity of HEC in many rural areas adjacent to -elephants' habitats has been increasing fast, whereas, in the dry zone, this problem prominently occurs over access to water and the competition for resources. It is a renowned fact that a majority of low-income subsistence farming communities often reside close to the forests and protected areas due to the limited availability of arable lands, inaccessible irrigation access, and cultural affinities in the protected areas (Sajla & Famees, 2022). A greater number of farming and pastoral areas are changing ecological dynamics and habitat patterns through agricultural production and management of important natural resources (McHale et al., 2018). The land clearance for agricultural extension and enhancing forage land for new vegetative growth for farming animals led to the move of elephants into refugees (Shaffer et al., 2019). Human activities significantly impact the nearby forestland and their activities restrict -the elephants' home range and their population density through direct and indirect competition for natural resources such as water, food, and space (The Department of Wildlife Conservation, 2013). There are several migratory measures in practice, including the introduction of electric fences as well as trenching to restrict the movement of elephants. However, HEC remains persistent as most existing prevention strategies are driven by site-specific factors -only offer short-term solutions, while mitigation strategies transfer conflict risk from one place to another (Shaffer et al., 2019). For a sustainable solution for the HEC, a holistic approach to the problem is essential, and the factors of basic needs such as water, food, and -breeding sites are of importance in such endeavours (Skitka et al., 2011). As far as feeding behaviour such as fodder palatability, availability, and nutrient requirement, is concerned, it provides indispensable factual evidence for finding migratory measures for the HEC (Nakano et al., 2020). Therefore, it is necessary to focus on the increase in the availability of grass fodder. It is a well-known fact that forage -palatability is associated with physical characteristics such as fiber content, level of maturity, toughness, succulence, and leafiness, which are determined through the observation of the forage intake of elephants. Food plays an important role in the elephant movement and is considered to be one of the factors leading to Human-Elephant Conflict (HEC). Asian elephants consume a wide variety of vegetation, as many as 165 species of plants belonging to 56 families (Schwarz et al., 2020).

The within-range enhancements of the elephant forage availability led to within-range confining of the elephant and reduced the gravity of the HEC. Further, forage grass availability and the preference of an animal were the major factors influencing the relative preference made (Stubbs & Blundell, 2013). Therefore, identifying the preferences of each plant species is important in enhancing the habitat enrichment endeavors to mitigate human-elephant conflict (HEC) by avoiding the implementation of fences, including biological and electric, with unsustainable pressure on elephant behavior (Bhatt et al., 2011). There are a considerable number of studies carried out in Sri Lanka on the number of elephant -behavioral aspects. The work carried out on the elephant forage, in general, indicated -that most of the Sri Lankan elephants preferred grasses over other plants, the -preferences vary with the seasonal availability of forage plants during dry/wet seasons (Sirimewan et al., 2018). Thus, the majority of elephants feed on the grassland established in reservoir beds as -well as drained natural water bodies on the island (De Silva et al., 2013; Samansiri & Weerakoon, 2007). One of the major -concerns over the availability of elephant forage grasses which have been addressed by -wildlife authorities is that illegal grazing by cattle and buffaloes during the dry season -and encroachment of the grassland by invasive plant species such as *Lantana camara* (Sirimewan et al., 2018). Therefore, an increase in forage availability would lead to minimizing the HEC, and -in this regard, it is worthwhile attempting to identify the plants that could be -introduced into the inaccessible elephant ranges. The grasses possess higher -adaptability and regenerative capacity and thrive well in varying climatic conditions. Therefore, it is appropriate to increase the abundance of grazing forage availability to minimize the elephant movement from the protected areas, which in turn reduces the chances of human-elephant confrontations. As far as feeding behavior is concerned, fodder palatability, availability, and nutrient requirement play a crucial role in planning mitigatory measures for the HEC (Nakano et al., 2020).

Hence, identifying suitable plants and elephants' preferences for each plant species is important in enhancing the habitat enrichment endeavors to mitigate HEC, avoiding the current conventional methods, with unsustainable pressure on elephant behavior (Krishnan & Braude, 2014). A comprehensive literature survey on the preference of wild range elephants for each grazing forage in Sri Lanka revealed that there was a scarcity of in-depth studies available on feeding behavior and diets of Asian elephants grazing on rangelands and secondary forests (Samansiri & Weerakoon, 2007). However, mitigation of EHC through wild elephant management and enhancing habitat enrichment techniques require a crucial understanding of feeding behavior and ecology (Krishnan & Braude, 2014). For the survival of wild-range Asian elephants in fragmented landscapes through a habitat enrichment approach and co-existence strategy, in-depth research is required to fill the gaps of knowledge about the relative preference of Farage plants of the Asian elephants in the ranging forests in Sri Lanka (Kumar et al., 2010). Before making an attempt to establish the forage plants in an elephant range, it is essential to select the plant based on the vegetative, reproductive and environmental characteristics.

This study has overviewed the value of Elephant forages, developed a 'plant selection matrix' tool, and identified plant species suitable for extensive forages in forest restoration for elephant conservation in Sri Lanka as a tropical country aimed at conveying findings to policymakers and identifying consensus priorities for future work. In the research context, it has also demonstrated that substantial forage increment can be achieved with forage securing considering its external and internal factors.

Therefore, the objective of the study was to develop a plant selection matrix using the outcomes of the cluster analysis and CART, a machine learning algorithm (De'ath & Fabricius, 2000). This report is targeted at researchers, wildlife conservationists, ecologists, and policymakers in the field of wildlife and forest conservation, who will benefit the most from this research. Hence, this report is useful in developing guidelines and policies that promote the implementation of securing and restoring forage availability.

METHODOLOGY

Preprocessing of Data

An extensive literature survey was carried out on the elephants' forage plants and information related to growth performance, ecological provenance, reproduction, resistance to abiotic and biotic stress, etc., was identified. A total of 12 variables and 22 forage plant species (Table - 01 and - 02) were extracted from *ca.*150 articles published in the literature and also verified through wildlife experts and a survey using piloted and validated questionnaire. Information on the elephant forage plants gathered through metadata from the literature survey was placed in a database and used to prepare a Plant matrix. Before analyzing data, preprocessing was carried out on parametric data to convert them into categorical data to be compatible with the categorical data obtained from the literature survey.

The database was analyzed using two statistical methods which were commonly used in the classificatory problem (Cluster analysis and Classification and Regression tree analysis (CART). The dataset included 22 forage plant species representing six plant families and three plant types. In addition, the Sinhala vernacular names were used throughout the study (Table - 01).

Table 1: List of selected Elephants' forage plants in Sri Lanka.

Scientific name	Plant family	Common name	Plant type
Achyranthes aspera	Acanthaceae	Gas Karalheba	
Alysicarpus vaginalis	Fabaceae	Aswenna	Herb
Bacopa monnieri	Scrophulariaceae	Lunuwila	
Cyperus haspan	Cyperaceae	Hal pan	
Cyperus iria	Cyperaceae	Thunessa	
Cyperus rotundus	Cyperaceae	Kalanduru	Sedge
Fimbrisstylis miliacea	Cyperaceae	Mudu hal pan	
Schoenoplectus grossus	Poaceae	Thun hiriya	
Dactyloctenium aegyptium	Poaceae	Putu tana	
Echinochloa colona	Poaceae	Gira tana	
Echinochloa crusgalli	Poaceae	Wel marakku	
Echinochloa glabrescens	Poaceae	Bajiri	
Eleusine indica	Poaceae	Bela tana	
Imperata cylindrica	Poaceae	Illuk	
Isachne globosa	Poaceae	Batadella	Grass
Ischaemum rugosum	Poaceae	Gojarawalu	
Ischaemum timorense	Poaceae	Rila rat tana	
Leersia hexandra	Poaceae	Layu	
Panicum maximum	Poaceae	Guinea thana	
Panicum repens	Poaceae	Etora (Atawara)	
Pennisetum purpureum	Poaceae	Ali maana	
Sacciolepis interrupta	Poaceae	Beru grass	

The detail of the plant and ecological characters used in the study are summarized in the Table 02. The parameters measured in scales were treated as the parametric data and further converted into separate classes. Meanwhile, plant characters of non-parametric nature were coded with suitable classes.

Table 2: Codes used for denoting forage plant and ecological characteristics

Plant character	Character class
Plant type	1. Herb 2. Grass 3. Sedge
Habitat	1. Aquatic 2. Marshy 3. Dry Open Grassland 4.Cosmopolitan
Annual dry yield (t per ha)	1. Low (≤ 11 ton/ha), 2. Medium (11 ≤ Medium ≤ 21), 3. High (High ≥ 21)
Method of propagation	1. Vegetative, 2. Seed, 3. By both vegetative and seed
Height of plant (m)	1. Low (≤ 0.75 m), 2. 0.75m ≤ Medium ≤ 1.5m, 3. High ≥ 1.5m
Resistance or tolerance capacity	1. Law/ None 2. Abiotic 3. Biotic 4. Abiotic and biotic
Method of pollination	1.Self-pollination 2. Cross-pollination 3. No or less pollination 4. Both self and cross-pollination
Life cycle	1. Annual 2. Perennial 3. Both annual and perennial, biannual
Altitude (m)	1. 0 to 600 (low), 2. 600 to 1500 (medium), 3. 1500 to up (high), 4. All types
Soil type	1. Loamy 2. Alluvial 3. Clay 4. All soil types
pH	1.pH 6.5 2. pH 6.5 to 7.5 3. pH ≥7.5
Growth rate	1. Low 2. Medium 3. High
Rainfall	1. Wet (2500up), 2. Intermediate (1750 -2500mm), 3. Dry (less than 750 mm), 4. All

ANALYSIS OF DATA

a) Cluster analysis

Cluster analysis is a technique in which the object is grouped into categories according to the similarity or dissimilarity between the pairs of objects., in this study, the hierarchical classificatory method was used and the following steps involved the calculation of the similarity or the dissimilarity matrix was performed according to Man Hatton distance (Equation 1), and Ward method was used as an agglomeration method (Drennan, 2009).

$D_m(x,y)=\sum i=1D|xi-yi|$ **Equation 1**

D_m = measured distance

X_i = i^{th} value of the character X

Y_i= i^{th} value of the character y

In addition, the Kruskal Wallis (KW) test was carried out on the cluster memberships (categorical) and the original variables (nominal) in order to find out the contributions made by each variable in the grouping of patterns of forage plants in cluster analysis. In particular, non-parametric statistical analyses were carried out on the non-parametric measurements used in the clustering efforts of the data.

b) Classification and Regression Tree analysis (CART)

Classification and Regression Tree (CART) modelling is an exploratory technique based on uncovering structure in data (De'ath & Fabricius, 2000) that has recognized the importance of tree-based regression in effective modelling of the relationships between species and environment and many methods have been employed for this purpose (Guisan & Zimmermann, 2000). CART explains the variation of a single response variable by one or more explanatory variables and this shift towards a predictive ecology is profound in both philosophy and method (Draper, 1995). CART explains the variation of a single response variable by one or more explanatory variables. The response variable is usually either categorical or numerical, and the explanatory variable can be categorical and/or numeric. The tree is constructed by repeatedly splitting the data, defined by a simple rule based on a single explanatory variable. At each split, the data are partitioned into two mutually exclusive groups, each of which is as homogenous as possible. The splitting procedure is then applied to each group separately. The objective is to partition the response variable into homogenous groups, but also to keep the tree reasonably small. The size of a tree equals the number of final groups. Splitting is continuous until an over-large tree is grown, which is then pruned back to the desired size. Each group is typically characterized by either the distribution or mean value of the response variable, group size, and the values of the explanatory variables that are defined (Daniya et al., 2020).

The way that explanatory variables are used to form splits depends on their type. For categorical explanatory variables with two levels, only one split is possible, with each level defining a group. For categorical variables with more than two levels, any combination of levels can be used to form a split, and for *k* levels, there are 2^{k-1}-1 possible splits. For numeric explanatory variables, a split is defined by a value less than, and greater than, some chosen values. Thus only the rank order of numeric variables determines a split, and for *p* unique values there are *p-1* possible splits. From all possible splits of all explanatory variables, it is selected the one that maximizes the homogeneity of the two resulting groups. Homogeneity can be defined in many ways, with the choice depending on the type of response variable (De'ath & Fabricius, 2000). Trees are represented graphically, with the root node, which represents the undivided data, at the top, and the branches and leaves (each leaf represents one of the final groups) beneath. Additional information such as summary statistics of nodes, or distributional plots can be displayed on the tree (Marc et al., 2000).

All partitions resulting from all variables are compared with the reduction in heterogeneity that they provide. In CARTs the heterogeneity in a group is measured by computing mean squared error. According to (De'ath & Fabricius, 2000; Guisan & Zimmermann, 2000; Marc et al., 2000) relative mean squared errors (R(d)) is defined for a group of observed values y as,

$$R(d) = \frac{1}{N}\sum_{n}(y_n - \bar{y})^2 \qquad \textbf{Equation 2}$$

in which $\bar{y}$ is the mean value across all observations y_i.

Each partition of CART generates left $R(d)_L = \frac{1}{N}\sum_{n}(y_n - \bar{y})^2$ and right $R(d)_R = \frac{1}{N}\sum_{n}(y_n - \bar{y})^2$ MSE values where subscript L and R indicates an assignment of a number of samples in branches in a partition. The partition that minimizes the change in mean square error, is the partition to be selected.

$$\Delta R(d) = R(d) - R(d)_L - R(d)_R \qquad \textbf{Equation 3}$$

The performance of the CART model is usually accesses by risk estimate and the associated standard error, a measure of the tree's predictive accuracy. However, in case of categorical dependent variables, the risk estimate presents the proportion of cases incorrectly classified and subsequently adjustment for prior probabilities and misclassification costs. The CART has been gained wider acceptance in variety of field of studies (Daniya et al., 2020). The literature review on the application of CART in Sri Lankan context, there were a number of studies carried out using CART (Daniya et al., 2020; Marc et al., 2000; Somaratne et al., 2014). Therefore, an attempt was made to classify the forage plants using CART analysis. All statistical analyses were performed using SPSS PC Ver. 25, IBM Statistics (Surf Spot, 2018).

RESULTS AND DISCUSSION

The descriptive statistics of the variables included in the study if shown in Table 03. In the dataset is dominated with grasses (63.6%) whereas the rest of the plants types followed by the sedges (22.7%) and herbs (13.6%) respectively. The soil pH varied from the 6.5 to < 7.5 and the majority of plants (81.8%) chosen were from the marshlands. The perennial is prominent (50%) in the data set and the plants survives annual to perennial and annuals are represented with 27.3% and 22.3% respectively.

The distribution of plants across the soil types indicated that the majority of plants were well-distrusted in all the types of soils (45.5%). The majority of plants were cross-pollinated (72.7%) and distributed in medium altitudes (45.5%). The growth rate of the plants varies from Low to high with percentages of 13.6, 40.9 and 45.5, respectively. A majority of plants were occurred in the all zones (50%) and the of 8 % and 3 % of plants were confined to the dry and intermediate zones. The distribution of plants across the height class indicated that a considerable percentage of plants (68.2%) were included in the low category. Similarly, the yields of the plants were also fallen with the category of low (77.3%) and resistance/tolerance classes were represented by abiotic (58.2%). The majority of plant were vegetative propagated (40.9%).

The result of the CA illustrated group combining similar species in a dendrogram (Tree diagram) (Figure – 1), which indicated a particular grouping tendency of the plant species included in the dataset and three groups such A, B1 and B2 were recognized at 80% phenon level. The benchmark species (*Sacciolepis interrupta*, *Imperata cylindrica*, *Panicum maximum, Pennisetum purpureum)* recognized and mostly preferred by elephants were well separated in to different groups presenting their ecological preferences.

Table 3: Frequency distribution of plant character, character class with their median and modal value.

Character	Character Class	No. plant species	Percent	Median	Mode
Plant type	Herbs	3	13.6	2.00	2
	Grass	14	63.6		
	Sedge	5	22.7		
pH class	Less than 6.5	9	40.9	2.5	3
	>= 6.5 - < 7.5	2	9.1		
	All	11	50.0		
Habitat class	Aquatic	1	4.5	2.00	2
	Marshy	18	81.8		
	Cosmopolitan	3	13.6		
Life Cycle	Annual	5	22.7	2.00	2
	Perennial	11	50.0		
	Annual and Perennial	6	27.3		
Soil requirement	Loamy	2	9.1	3.00	4

	Alluvial	6	27.3		
	Clay	4	18.2		
	All	10	45.5		
Pollination	No pollination	1	4.5	3.00	3
	Self-pollination	2	9.1		
	Cross-pollination	16	72.7		
	Both	3	13.6		
Altitude class	Medium	10	45.5	3.00	2
	High	4	18.2		
	All	8	36.4		
Growth rate	Low	3	13.6	2.00	3
	Medium	9	40.9		
	High	10	45.5		
Rainfall	Intermediate zone: 1750- 2500 mm	3	13.6	3.50	4
	Dry zone: Less than 1750	8	36.4		
	All areas	11	50		
Height class	Low	15	68.2	1.00	1
	Medium	4	18.2		
	High	3	13.6		
Yield class	Low	17	77.3	1.00	1
	Medium	4	18.2		
	High	1	4.5		
Propagation	By seed	9	40.9	2.00	1
	By vegetative	7	31.8		
	Both Seed and Vegetatively	6	27.3		
Resistance or tolerance capacity	Low/ None	2	9.1	1.00	1
	Abiotic	15	68.2		
	Both Abiotic and biotic	5	22.7		

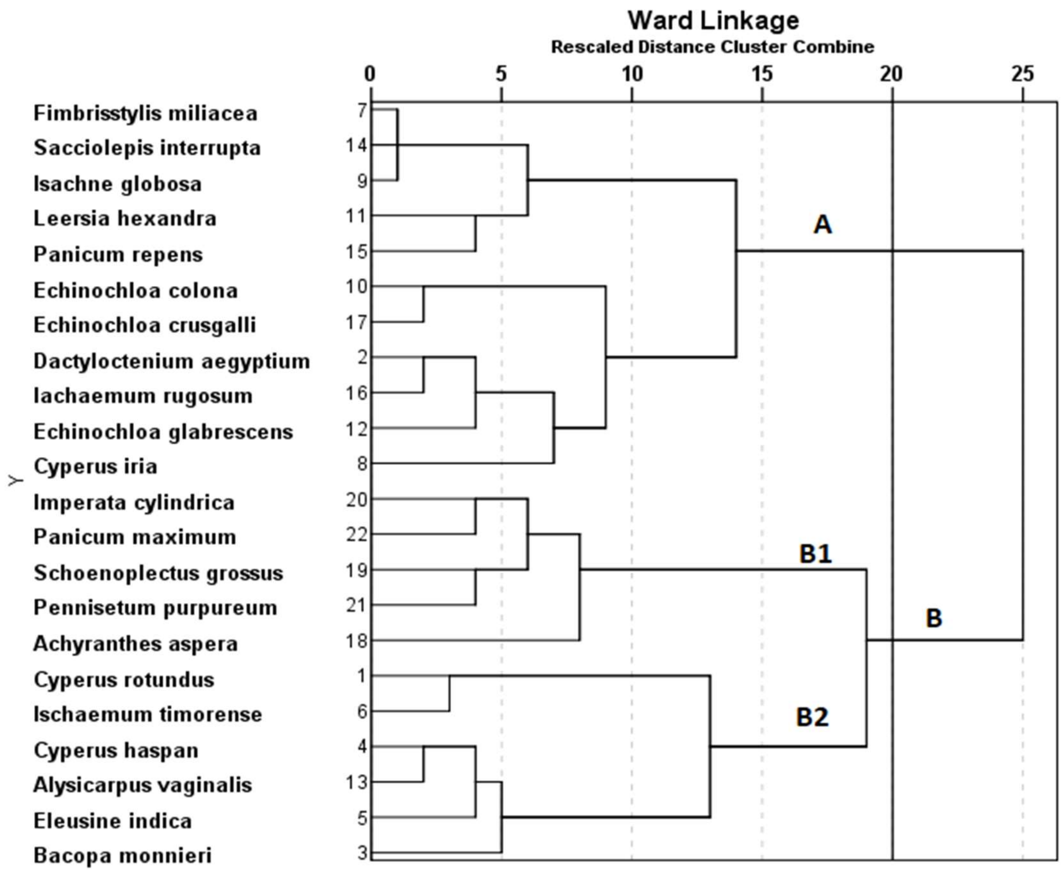

Figure - 1: Dendrogral produced by the cluster analysis of the datase

Table -4: Kruskal-Wallis test of association between the plant type and variables chosen.

Variable	Chi-Square	df	Significance
Height class	17.659	2	0.000
Yield class	3.021	2	0.221
Propagation class	1.56	2	0.458
pH class	10.517	2	0.005
Habitat class	7.231	2	0.027
Tolerance /adaptation capacity	0.53	2	0.767
Life cycle	5.185	2	0.075
Soil requirements	3.384	2	0.184
Pollination	1.995	2	0.369
Altitude class	0.163	2	0.922
Growth rate	3.16	2	0.206
Rainfall	4.039	2	0.133

The results of the non-parametric Kruskal-Wallis test depicted the contribution made by Height class, pH class and Habitat class were statistically significant ($p < 0.05$) (Table – 04).

The results of the CART obtained from the dataset is presented in a tree (Figure -02). The parental nodes and their subsequent splits indicated that there certainty variables play critical roles. The list of 22 plants were grouped into two child nodes based on the nature of the life cycle and the perennials separated from the annuals as well as the plants possessing survival capability from annual to perennial. Therefore, the nature of the life cycle is the one of the important characters in the separation of plants. The perennial plant group further separated by the soil requirement of the plants and resulted two child nodes; the plants grow in all the soil types and alluvial, loamy and clay. The plant grown in all soil types were further split based on pollination which yield child nodes with *Pennisetum purpreum*, *Imperta cyndrica*, and *Shoenopletus grossius*. The group of plants which lacks pollination or both pollination types included *Achyranthes aspera*, *Echinocloa glabrencens*, and *Panicum repens.* The group of plants included in the child node resulted from split based on soil types of alluvial, loamy and clay was further separated into two child nodes by soil types and resulted two terminal nodes as plants occurs in alluvial soils, and loam and clay soils. The terminal node characterized by alluvial soils composed of *Bacopa monnieri*, *Isachne globosa* and *Leersia hexandra*. The other terminal node of formed by loamy and clay soil included *Cyperus rotundus*, and *Panicum maximum*. Similarly, the child node with annual and both annual and perennial further split into four terminal nodes based on the soil requirement (Figure – 02).

The developed database and the results of the analyses were used to construct a forage plant selection matrix as a field tool for the selection of elephant forage plants (Table - 05). Further, priority was given to the character of easy accessed with minimum parsimony. The questions and their answers are presented in a dichotomous key. The key provided a rapid method to identify the elephant forage plants using characteristics of their life cycles and ecological provenance. From the study, it is clear that long-term evaluation of a wider range of plant species, substrate conditions and irrigation regimes is required to support increasing confidence in forage restoration for inaccessible range forests in Sri Lanka.

Twenty-two plant species identified by the selection matrix as being suitable for forage restoration in tropics were included in the evaluation trial. A list of the most important plant growth factors that was obtained from the prepared database for the elephant forage plants with the aid of literature, was taken to construct a key referred as a “Plant Selection Matrix” in terms of qualitative approach (Perkins & Joyce, 2012). To provide continuous long term vegetation cover, the forage planting should be mixed predominantly herbaceous perennials with annuals. The abiotic/biotic tolerance or resistance of plant is also an important plant feature since habitat with shallow substrate of non-irrigated grasslands or forestlands can regularly dry out and drought tolerant species can better maintain adequate vegetation cover during these periods. The ability of self-propagation can be used for ranged forest where fluctuation seasonality is prevailed (Barua et al., 2012; Schaedler et al., 2015)

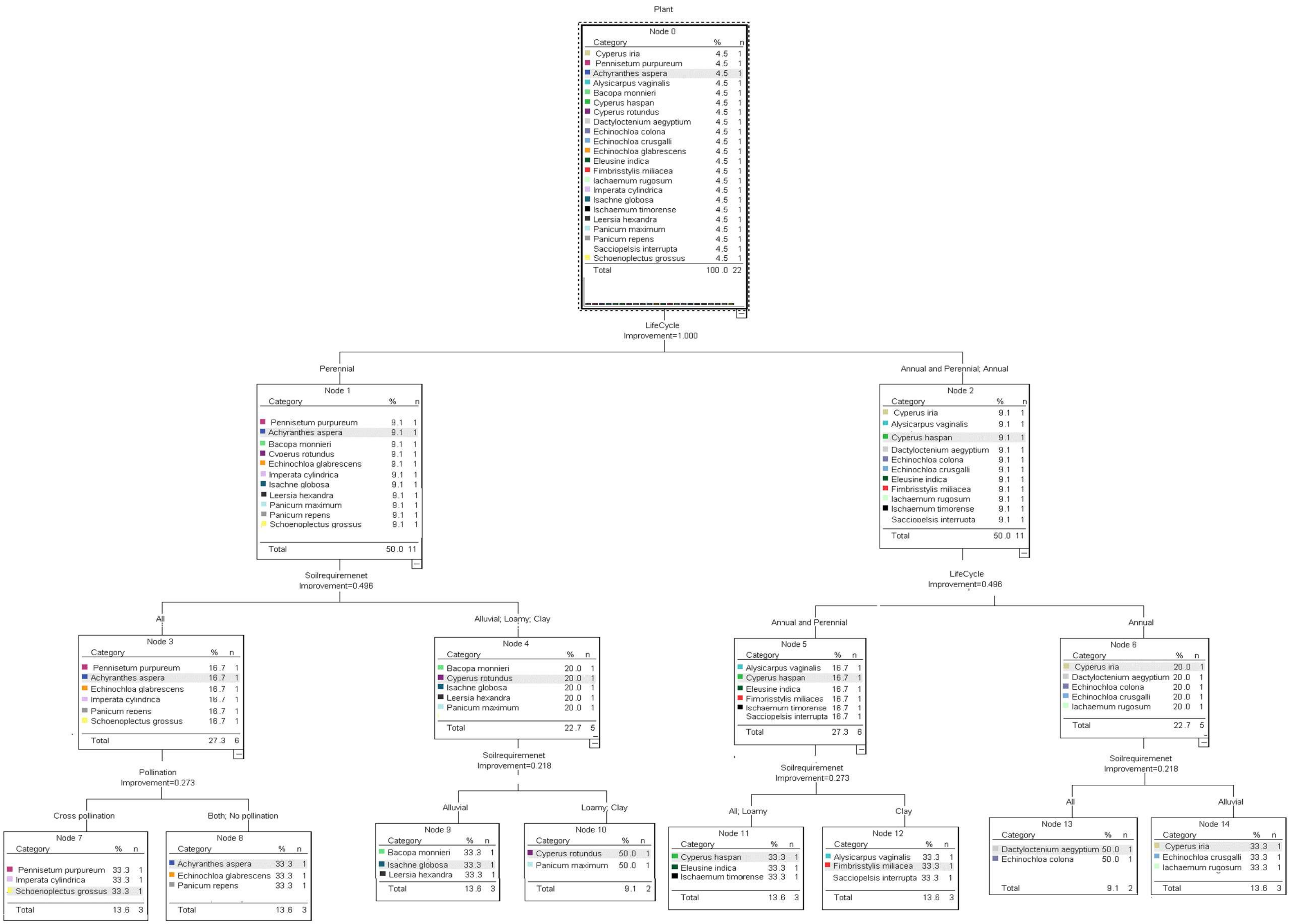

Figure - 2: Classification and regression tree produced from the dataset.

Table -5: Elephant-forage plant selection matrix

Question No.	Question	Response	Instructions
1	Is the plant palatable to elephants?	Yes No	Go to Question 2 Unsuitable
2	Is the plant type a grass/sedge or herbaceous?	Yes No	Go to Question 3 Unsuitable
3	Is the plant type suitable for the tropical region?	Yes No	Go to Question 4 Unsuitable
4	Is the plant available in the natural ecosystem?	Yes No	Go to Question 5 Unsuitable
5	Does the plant possess considerable ecological tolerance characteristics for survival in natural environment?	Yes No	Go to Question 6 Unsuitable
6	Does the plant have considerable yield?	Yes No	Go to Question 7 Go to Question 7
7	Does the plant have a rapid propagation method?	Yes No	Go to Question 8 Go to Question 8
8	Does this plant display a vigorous growth rate?	Yes No	Go to Question 9 Unsuitable
9	What is the life-cycle of the plant?	Perennial Biennial Annual	Highly suitable Suitable Slightly suitable

This study is intended to provide them with greater confidence to conserve wildlife in forage restoration and elephant conservation projects, thereby introducing the importance of securing elephant forage plants in Sri Lanka. It is also advocated that local and state government authorities will find this study useful in developing guidelines and policies that promote the implementation of forage restoration. The study is concentrated in elephant ranging areas, particularly in the dry zone and intermediate zones of Sri Lanka. An overview of available literature, internet sources and industry/research contacts identified forage plants and essential factors for the selection criteria used in both local and overseas whereas critically analyzed their relevance in the context of Sri Lankan climate. However, plant of proven suitability for use in harsh Sri Lankan environments are needed. This is particularly so for elephant ranging forests, tank beds and grasslands in larger scale with usually expansive and ideally low maintenance is ideally low. With careful planning, management and maintenance, forage establishment can be a useful element of sustainable wildlife conservation strategy in this country. A progression of the successful mitigation methods in HEC further yet to be identified.

CONCLUSIONS

This study is intended to provide elephant conservation with greater knowledge of plant selection for forage restoration and forest resilience in Sri Lanka's challenging climate. The many environmental, economic and social benefits of correct forage selection have resulted in food security in elephants. However, a lack of proven plant species suited to Sri Lankan conditions has deterred the growth of forests in this country. By comparison, local native plant species exhibited superior performance in terms of plant survival and vegetative coverage. However, this species could not sustain a high level of vegetation cover during the dry period under limited irrigation regimes. Plant selection has received less attention for forage restoration in wildlife conservation than it has for animal husbandry. Development of a selection matrix for forage plants should ideally encompass the substantial amount of plant selection information that exists for forage restoration. Several of the traits mentioned in literature as being desirable for forage plants also apply to plants in the forage management context. For example, ensuring that plants are palatable or don't have heavy wood can be important for a rapid vegetative cover. From the study, it is clear that long-term evaluation of a wider range of plant species, substrate formulations and irrigation regimes is required to support increasing confidence in forage restoration for inaccessible range forests in Sri Lanka.

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