Application of Self Organizing Map, SAHN clustering and spatial analysis on the diversity of plant resource in homegardens: Case study in Perak, Malaysia

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Abstract

Homegardens are defined as less complex agroforests which look like and function as natural forest ecosystems but are integrated into agricultural management systems located around houses. Study on the factor effecting on diversity of plant resource in homegardens is paramount important to improve productivity and sustainability. Previous studies related to homegradens analysis are conducted using ordination techniques (e.g. Principal Component Analysis, Correspondence Analysis). In this study we introduced the application of Self-Organizing Map (SOM) a type of Artificial neural networks (ANNs) to analyze the effects of socioeconomic variable and homegardens characteristic toward diversity of plant resource, and to investigate the spatial configuration occurring within homegardens. The inter-relationships among the socioeconomic variable and homegardens characteristic were extracted and interpreted using the pattern analysis visualized in component planes. Sequential agglomerative hierarchical non-overlapping (SAHN) clustering techniques was also used to verify results obtained from SOM by using the unweighted pair grouping method with arithmetic-mean (UPGMA). Ten homegardens were identified from SOM U-Matrix and each of the homegardens was investigated for their horizontal and vertical profile. Inspection of SOM indicates that the region with high d-values for size of homegardens coincides with those of food, ornamental, and medicinal plants. Region of high d-value in Shannon index coincides with region of high d-value in Evenness index. Region of low d-value in income coincides with high d-values in both the Shannon and Evenness indices. Region of high d-value in age of household also coincides with high d-values in both the Shannon and Evenness indices. Combination of SOM, SAHN and spatial analysis techniques has a potential to analyst and monitor not only the factors affecting homegardens biodiversity but also their development and improvement which to our best knowledge has yet been reported in literature.

Keyword

Homegardens, Self-Organizing Map, Spatial Analysis

Introduction

Homegardens (also spelled "home gardens") are defined as less complex agroforests which look like and function as natural forest ecosystems but are integrated into agricultural management systems located around houses (*Mapongmetsem et al., 2012*). Homegardens are also classified as a small type of agrobiodiversity (also known as agricultural biodiversity) but highly diversified ecological niches (*Galluzzi et al., 2010*), which comprises of variability and varieties of plants, animals and microorganisms that are important in maintaining critical functions of the agricultural ecosystem (*FAO, 1999a*). The varieties of the plants are composed by trees, shrubs and herbs in association with annual and perennial agriculture crops (*Fernandez & Nair, 1986*), which all of the plants are located and organized in different vertical structure and configuration (*Mustafa et al., 1996*; *Akinnifesi et al., 2010*; *Carvalho et al., 2013*; *Abebe et al., 2010*; *Gbedomon et al., 2016*). Homegardens are mainly intended to grow and produce food items for family consumption (*Galhena et al., 2013*) but also were regarded as a staple crop production base (*Maroyi, 2009*; *de la Cerda and Mukul., 2008*; *Alam, 2011*; *Coomes and Ban, 2004*), besides contribute to household economic well-being through additional income generated from the sale of homegardens products (*Eyzaguirre & Linares, 2010*; *Torquebiau, 1992*; *Trinh et al., 2003*). Homegardens consist of variety of plant species that have some medicinal value which can be used to treat various illnesses and diseases besides to improve health conditions in a cost effective manner (*Millat-e-Mustafa et al., 2002*; *Rugalema et al., 1994*; *de Clerck and Negreros-Castillo, 2000*; *Ramli et al., 2015*).

The resemblance of homegardens to forests incur that they provide multiple environmental and ecological benefits. Homegardens serve as sink of carbon that contributes to climate change mitigation through enhanced carbon sequestration (*Verchot et al., 2007*). The rich diversity and the dense distribution of plant resource denote extraordinary features of homegardens ecology. Homegardens provides an ideal environment for small mammals, birds, reptilies and insects (*Christanty, 1990*)), besides contributes to a highly efficient nutrient cycling (*Gajaseni and Gajaseni, 1999*; *Seneviratne et al., 2010*) and protect the soil from erosion (*Hochegger, 1998; Karyono, 1990*). Due to the importance and benefits provided by these systems, several studies have been undertaken to investigate homegardens. The early studies are started on 1930s by the Dutch scholars Ochse and Terra on mixed gardens in Java, Indonesia (*Ochse and Terra, 1934*). Then, the studies are expanding to the other tropical areas in Central and South America (*Mendez et al., 2001*; *Aguilar-Stoen et al., 2009*), South and South-East Asia (*Ali, 2005*; *Abdoellah et al., 2006*), Africa (*Faber et al., 2002*; *Thompson et al., 2010*) and also in temperate region (*Bassullu and Tolunay, 2010*; *Reyes-Garcia et al., 2012*) focusing on species inventories (*Sujarwo and Caneva,2015*; *Mekonen et al., 2015*; *Milow et al.,2013*, *Srithi et al., 2012*), its functions (*Ijinu et al, 2011*; *Tanjang and Arunachalam, 2009*), structural

characteristics (*Gbedomon et al., 2016*;*Thompson et al., 2010*), management (*Ferdous et al., 2016*; *Mekonen et al., 2015*), socio-economic aspect (*Motiur et al., 2006*; *Mohan et al., 2006*), ecological aspect (*Junqueira et al., 2016*; *Mattsson et al., 2013*) and cultural relevance (*Alam et al., 2010*; *Howard, 2006*).

Apparently, most of the studies in homegardens are using multivariate method. The most well-known and widely-used are including Principal Component Analysis, Correspondence Analysis and Cluster Analysis (e.g., *Blanckaert et al., 2004*; *Albuquerque et al., 2005*; *Huerta and Wal, 2012*; *Parra et al., 2012*; *Gbedomon et al., 2015*). Conventional multivariate methods are somewhat limited for interpreting the non-linear and complex dynamic nature (*Wang et al., 2014*). Artificial neural networks (ANNs) are essentially a mathematical model constructed by simulation of the structure and function of human brain neural networks (*Erb 1993; Agatonovic--Kustrin and Beresford, 2000*) should be a convenient alternative tool to traditional statistical methods. Artificial neural networks have been carried out in an effectively manner in the fields of pattern recognition, modeling, and control (*Haykin, 1999*). ANN has found applications in fields like medicine, biology, engineering, economics, and agriculture.

Developed by Teuvo Kohonen (*Kohonen,2001*), Self-Organizing Map (SOM) is one of the most popular unsupervised neural network models, which simultaneously performs a topology-preserving projection from the data space onto a regular two-dimensional grid (*Kohonen, 1990*). The main computing steps of SOM include construction of data set, data preprocessing, initialization and training of input data and visualization and analysis of the correlated results. SOM been applied to handle high dimensional data including engineering, agriculture, health, environment management and remote sensing image classification. In agriculture, SOM has been applied for detection of potential alien pests (*Vanninen et al., 2011*), land cover identification (*Tasdemir & Wirnhardt, 2012*), soil analysis (*Merdun, 2011*) and predicting losses of agriculture induced by typhoon (*Chiang et al., 2012*). It also reported that SOM been used to assess the importance of farm ponds to the aquatic biodiversity *(Ruggiero et al., 2008*; *Cereghino et al., 2008*), detection and identification of plant species (*Tyystjarvi et al., 1999*), detection of apple mealiness (*Moshou et al., 2003*) and detection of 'yellowrust' disease in wheat (*Moshou et al., 2004*). In Malaysia, SOM has been used in agricultural rice pest management (*Hasan and Sap, 2010*). However, to our best knowledge application of SOM in the study of homegardens are not reported.

Spatial analysis is concerned with the geographic space, that is, observations that correspond to locations in space that capture their proximity in the real world and the visualization data in the form of maps (*Freitas et al., 2012*). The emphasis of spatial analysis is to measure properties and relationships, taking into account the spatial localization of the phenomenon under study in a direct way (*Camara et al., 2004*). These analysis has gain a lot of attention when the availability of Geographic Information System (GIS) and been used in many field of study including medicine, environmental, biology, economic and agriculture. The application of spatial analysis also been reported in the study of homegardens focusing on

vertical and horizontal structure. Several studies have paid special attention to the variation of plant species in different layer and configuration constituting home gardens (e.g., *de Clerck and Negreros-Castillo, 2000*; *Fernandes and Nair, 1986*; *Gajaseni and Gajaseni, 1999*; *Abebe et al., 2010*; *Méndez et al., 2001*).Understanding the spatial distribution of plant resource in homegardens is essential for their developing models as sustainable agriculture and better management.

The aim of this study is to explore the structure and spatial configuration of tropical homegardens in Malaysia, to understand the effect on socioeconomic feature and homegardens characteristics to the diversity of plants resource using SOM and SAHN clustering method. To our best knowledge the combination application of SOM, SAHN and spatial analysis have not been reported in literature and can be considered novel.

Method

Location

Tropical homegardens of a village in Peninsular Malaysia was selected to carry out this study. The village, known as Kampung Masjid Ijok, is located in Selama District, in the state of Perak (Figure 1). The climate is tropical with temperature between 28^{o}C to 32^{o}C. The village is accessible by road and the nearest town, Batu Kurau, is only 20 km away and Taiping town as about 35 km. The village area is occupied by forests (hills and reserve forest), rubber and oil palm small holdings and homegardens. Surrounding with three hills (Bukit Chop to the southwest is 320 meter high, Bukit Ganding to the southeast is 680 meter and Bukit Panji to the northwest is 300 meter) and Bintang Hijau reserve forest to the northeast is 1520 meter high are made this village a strategic location for homegardens research. The average annual rainfall is about 2,000mm -2,500mm. The main economic activities in the village are rubber tapping, petty trading, and collection and selling of homegarden products such as mango, durian, mangosteen and rambutan besides forest products such as *Parkia speciosa* Hassk., *Pithecellobium bubalinum* (Jack)Benth., *Archidendron jiringa* (Jack)I.C.Nielsen and *Baccaurea motleyana* Hook. f. These products are usually sold to middle-men who subsequently sold them to buyers in larger towns such as Taiping, Ipoh and Penang. This village has several public facilities such schools, mosque, playgrounds, an agricultural office, sub-district office and a clinic.

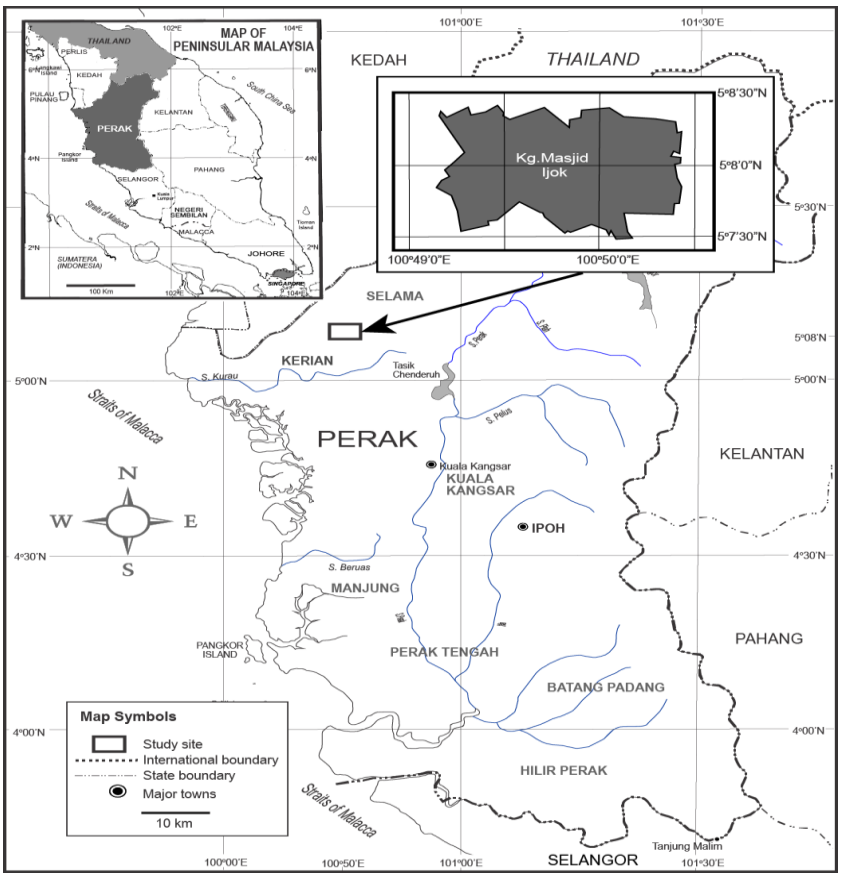


Figure 1 - Map of Peninsular Malaysia showing the location of study site

Data and Data Analysis

Data in this study was obtained through inspections and semi-structured interviews with 40 homegarden owners from 2013 to 2014 which were selected randomly. During the visits, useful plant species in homegardens were recorded and photographed. Also recorded were local names, habits, uses, number of individuals of each useful plant species. The data were used to calculate Shannon Index and Evenness Index.

The Shannon index was calculated based on the following formula.

$$H = \sum_{i=1}^{S} - (Pi * \ln Pi)$$

where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species. Evenness index is the distribution of individuals among species.

The index is calculated based on the following formula.

$$\text{Evenness Index} = \frac{H}{LogS}$$

where H is the number derived from the Shannon index. S is the number of species in the homegarden. The usage of plants species in homegardens were classified into three main categories: food plants, medicinal plants and ornamental plants. Food plants are those yielding products that are consumed as fruits, vegetables and spices. Medicinal plants those known as to villagers as having healing or health enhancing properties to the villagers. Ornamental plants are those aesthetically important to households. Even though some of the plants are having multiple uses, however in this study only their primary use has been recorded by the homegardens owner are noted.

Besides continuous variables, categorical variables used in this study are size of homegardens and socioeconomic information. Homegarden boundary of homegarden areas that was used to calculate areas was as told by their owners. Homegarden perimeters were obtained manually with a measuring tape. Homegarden shapes were polygonal and the formula used to calculate homegarden areas depended on their shape. When necessary a homegarden was divided into several polygons and its area was calculated as the sum of its polygon areas (*Brouwer et al., 1992*). Socio-economic information of the homegardens owners were gathered during the semi-structured interviews. Socio-economic information that were gathered were the age of the homegardens owner, gender, highest level of education attained, main source of income, total income and number of members of the household. Other information homegarden that were also obtained from the interviews were ownership status (on traditionally inherited land, on land acquired through purchase, as part of rented property). Summary statistics of the continuous variable and categorical variable are used in this study given in Table 1 and Table 2 respectively.

Table 1
Summary statistic of continuous variable used in SOM development and SAHN clustering

Variable	Min	Max	Median	Standard deviation
Shannon diversity index	2.14	3.61	3.024	0.33910
Evenness Index	0.774	0.96902	0.77412	0.04487
Total Species of Food Plants	10	43	24.5	8.5816
Total Species of Medicinal Plants	2	23	9	4.651
Total Species of Ornamental Plants	0	12	5.5	4.357

Table 2
Summary of categorical variable used in SOM development and SAHN clustering

Variables	Categories
Gender	(1 = Male,2 = Female)
Age	(1 = Young,2 = Middle-age,3 = Old-age)
Highest level of education attained	(1 = Non formal,2 = Primary school,3 = Secondary school)
Monthly income (RM)	(1 = Less, 2 = Medium-less,3 = Medium-high,4 = High)
Job	(1 = Rubber tapper,2 = Government retired,3 = Employment,4 = Small business)
Total member(s) in household	(1 = Low,2 = High)
Do they have other land properties	(1 = Yes, 2 = No)
Status of homegardens	(1 = Inherited,2 = Self-owner,3 = Rent)
Size of homegardens (m2)	(1 = Small, 2 = Medium,3 = Large)

SOM Development

The present study has utilized the Self Organizing feature Maps (SOM) to ordinate socioeconomic and homegardens input variables with respect to diversity of plant resource based on the Shannon diversity index and Evenness index. The distance between the inputs variables were calculated through Euclidean distance and were visualized as distance matrix (U-matrix). SOM analysis reduces dimensions by producing a 2D map and the data will be grouping together based on their similarity. The SOM consists of two layers: an input layer formed by a set of nodes or neurons, and an output layer formed by nodes arranged in a two-dimensional grid (Figure 2). Every node in the input layer is represented as vector (x_i) and is connected to each neuron (j). The connections between neuronal layers are represented by weights (w_{ij}), whose values represent the strengths of the connections. When an input vector is sent through the network, each neuron in the network computes the distance between the weight vector and the input vector. Among all the output neurons, the one having the minimum distance between the weight and input vectors is chosen and known as winner neurons. The weights of both this winner neuron and its neighboring neurons are then updated to further reduce the distance between the weight and the input vector according to the SOM learning rules as follows:

$$w_{ij}(t+1) = w_{ij} + \alpha(t)\, h_{jc}(t)\, [\, x_i(t) - w_{ij}(t)]$$

where $w_{ij}(t)$ is a weight between a node i in the input layer and a node j in the output layer at iteration time t, $\alpha(t)$ is a learning rate factor which is a decreasing function of the iteration time t, and $h_{jc}(t)$ is a neighborhood function (a smoothing kernel defined over the lattice points) that defines the size of neighborhood of the winning node (c) to be updated during the learning

process. This learning process is continued until a stopping criterion is met, usually, when weight vectors stabilize or when a number of iterations are completed. After the learning process, a SOM configures the output neurons into a topological representation of the original data using a self-organization process (*Kohonen, 1990*).

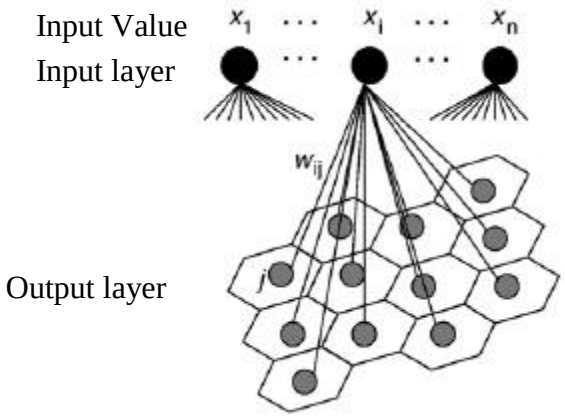


Figure 2- SOM architecture updated from Park et al., 2006

In this study, a data matrix was created using data on 15 variables (including Shannon and Evenness index) in each homegarden. The matrix contained 40 columns (representing 40 homegardens) and 15 rows (representing 15 variables). SOM was run by Neural Network Toolbox in MATLAB Ver. (R20013, MathWorks) (*Matlab Release 2013a*). Unified distance matrix (U-matrix) and Component Plane (CP) are two types of SOM visualization in 2-D hexagonal grid nodes map. The distance between the adjacent neurons is calculated and presented with different colorings between the adjacent nodes (*Kohonen, 1989*). Dark area in the U-matrix represent a frontier region between clusters, and light areas represent a high degree of similarities among neurons on that region, clusters. Individual component plane maps provide clear visualization of the different input variables and correlations among variables can be detected by viewing the colored pattern for each component planes. A darker shade corresponds to larger ordinal values, a grey shade represents a medium ordinal value and a lighter shade represents a low ordinal value of operation sequence. Quality of the result map of SOM can be determined through quantization error (QE) and topographic error (TE). QE exhibits the average distance between each data vector and its 'best matching unit' (BMU), and thus measures map resolution. TE represents the proportion of all data vectors for which 1st and 2nd BMUs are not adjacent, and is used for the measurement of topology preservation (*Céréghino and Park, 2009*). The best map is expected to be yield the smallest average quantization error (*Malek et al., 2018*).

SAHN Clustering

The Sequential agglomerative hierarchical non-overlapping clustering techniques (SAHN) is a prominent example of hierarchical cluster analysis (*Day & Edelsbrunner, 1984*; *Murtagh & Contreras,2012*). These approaches start with singleton clusters and iteratively merge two

clusters with minimum dissimilarity until only one cluster remains (*Kriege et al 2014*). The inter-cluster dissimilarity is determined by a linkage strategy and based on the dissimilarity of the objects contained in the clusters (*Kriege et al 2014*). The single, complete, average, median, centroid, and Ward linkage methods are well-studied and widely used (*Murtagh, 1985*). Introduced in 1958 (*Sokal & Michener, 1958*), average linkage analysis, usually referred to as UPGMA (Unweighted Pair Group Method with Arithmetic Mean), is arguably the most popular hierarchical clustering algorithm among other linkage strategy been used by many researchers (*Milow et al., 2013*; *Srithi et al., 2012*; *Blanckaert et al., 2004*; *Singh et al 201*; *Gehre et al., 2016; Esposito et al., 2016*). This method uses the mean similarity across all cluster data points and is a particularly practical algorithm owing to the stability of the arithmetic mean (*Loewenstein et al., 2008).* The present study has utilized the SAHN and UPGMA linkage strategy to clustering homegardens based on the socioeconomic and homegardens input variables. It receives as input a set of elements and a dissimilarity matrix which contains pairwise distances between all elements, and returns a hierarchy of clusters on this set. It starts by initializing a singleton-cluster for each element in the set, and then follows the closest-pair hierarchical clustering scheme. In each such iteration the distances from the new cluster to all other clusters are computed via the reduction formula. The distance between the input variables were calculated through Euclidean distance and the result were presented by leaf-labeled tree structures known as dendrograms or rooted phylogenetic trees. SAHN cluster analysis was performed using statistical program NTSYSpc version 2.02 (*Rohlf, 1998*)

Spatial Analysis

Ten homegardens were selected from SOM and SAHN cluster analysis. Spatial data recorded were; a) coordinates of the homegardens from geographical positioning system (taken within 1 m from the front door of each house), b) horizontal and vertical profile of homegarden plants and the identity of homegarden plants. Certain house features (e.g. height, lay-out) were also taken to facilitate in the homegarden illustrations. Plant heights were obtained either by direct measurement using measuring tape or calculated using trigonometry. The former method was only possible for shrubs. The latter method has to be used for trees and the readings for the calculation were obtained using SNDWAY Laser Distance Meter or clinometer. The horizontal profile or spatial configuration of homegardens was determined by mapping out the plant species based on four locations namely house front (HF), house rear (HR), house side (HS), and pot (POT).

Result

A total of 207 species of useful plants distributed among 169 genera and 78 families were recorded from homegardens in Kampung Masjid Ijok. Detailed information of these plants are shown in Table 3. *Musa paradisiaca* L. recorded the highest frequency of 85%. This was followed by *Cocos nucifera* L. (80%), *Nephelium lappaceum* L. (77.5%), *Capsicum frutescens* L. (75%), *Carica papaya* L (75%), *Cymbopogen citratus* (DC.) Stapf (72.5%), *Mangifera indica* L (72.5%), *Curcuma domestica* Valeton (67.5%), *Garcinia mangostana* L (62.5%), *Manihot esculenta* Crantz (62.5%), *Lansium domesticum* Corrêa (55%) and *Areca catechu* L (52.5%). Twelve species of useful plants in the homegardens have been also to occur in the wild such as nearby forests. These are *Scorodocarpus borneensis* (Baill) Becc, *Eurycoma longifoli* Jack, *Calamus manan* Miq, *Garcinia cambogia* (Gaertn.) Desr, *Aquilaria malaccensis* Benth, *Nepenthes gracilis* Korth, *Zingziber zerumbet* (L.) Smith, *Baccaurea macrocarpa* Müll.Arg, *Etlingera megalocheilo* (Griff.)A.D.Poulsen, *Parkia speciosa* Hassk, *Pithecellobium bubalinum* (Jack) Benth and *Archidendron jiringa* (Jack)I.C.Nielsen. At the family level, Euphorbiaceae, Araceae, Fabaceae, Arecacea, Malvaceae, Zingiberaceae and Rutaceae demonstrated the highest species composition of useful plants in homegardens with 13 species, 11 species, 10 species, 9 species, 8 species (Malvaceae & Zingiberaceae) and 7 species respectively. In term of habit, shrubs dominated the plant resource found in all homegardens with 42.03%, followed by tree (29.47%), herb (23.67%) and climber (4.83%). 43.3% of the useful plant species are exclusively used as food. 27.8% and 24% of the species were respectively used exclusively as ornamental and medicine. The remaining 4.9% of the plant species have other uses apart from food, medicine, and ornamental. These are grouped under the category miscellaneous.

Summary statistics of homegarden attributes and the household head socio-economic data that were used as input variables to construct SOM and SAHN are shown in Table 1 and Table 2. Figure 3 illustrates SOM component planes generated using input variables from Table 1 and Table 2. The SOM component plane map provides a graphic representation of relationship between each input variable with the diversity of plant species in the homegardens. The quantization error of the map was recorded as 0.00 and the topographic error 0.04. Inspection of SOMs indicates that the region with high d-values for size of homegardens coincides with those of food, ornamental, and medicinal plants. Region of high d-value in Shannon index coincides with region of high d-value in Evenness index. Region of low d-value in income coincides with high d-values in both the Shannon and Evenness indices. Region of high d-value in age of household also coincides with high d-values in both the Shannon and Evenness indices. The Shannon and Evenness indices of homegarden useful plants range from 2.16 to 3.61 and 0.782 to 0.965 respectively (Table 1).

SAHN clusters generated from input variable (Table 1 and Table 2) produced two big clusters where 38 of the homegardens falls into either one of the two clusters. SAHN clusters are made to match with the SOM U-matrix by cutting the former at Euclidean coefficient 4.301. The SOM U-matrix (Figure 5) generated using input variables from Table 1 and Table 2 indicate at

least seven clusters. The boundary of each of the seven clusters is colored red in Figure 5 that corresponds to clusters from SAHN clustering method (Figure 4) in which Cluster 1 (HG2-HG16-HG33-HG18-HG35-HG38-HG20-HG25-HG28-HG32), Cluster 2 (HG6-HG11-HG22), Cluster 3 (HG4-HG27-HG14-HG39), Cluster 4 (HG19-HG26-HG29-HG34-HG40), Cluster 5 (HG3-HG7-HG15-HG13-HG31), Cluster 6 (HG8-HG21-HG12-HG9-HG10-HG37-HG23) and Cluster 7 (HG24-HG30). Homegardens (HG1, HG5, HG17, and HG36) do not fit into the seven clusters in the U-matrix and SAHN.

Homegardens were polygonal in shape with four to five sides. Each homegarden area can be spatially distinguished by its location relative to the side of the house that faces it. Hence, each homegarden area are distinguished into (1) house front (HF) which is facing the house main door; (2) house rear (HR) which facing the opposite end of house front; (3) house side (HS)-which facing either the left or right of the house. Homegarden plants were either grown on landed ground or in pots (POT) (4). Most of the ornamental plants are grown in pots in house front (HF), while food and medicinal plants are found in house rear and house side.

All ten homegardens selected from SOM and SAHN clustering showed layer ranging from two to five layers (strata). Although the numbers of layer are varied, three out of ten homegardens namely HG13, HG17 and HG37 contained five layers that started at ground level and rose to 20m or more to the dominant tree stratum. The herbaceous stratum or ground stratum started on the homegardens floor rose to 1m and was comprised of annual and perennial herbs, creepers and lower shrub. The second stratum, the shrub stratum, was from 1m to 5m and was comprised of shrub. The third stratum, the understory stratum (5m- 10m), was dominated by fruit tree. The canopy layer was the tall tree stratum which rose from 10 to 20m. The fifth layer namely emergent layer was the last stratum and only contained two species of plants such as *Durio zibethinus* and *Melia excelsia.*

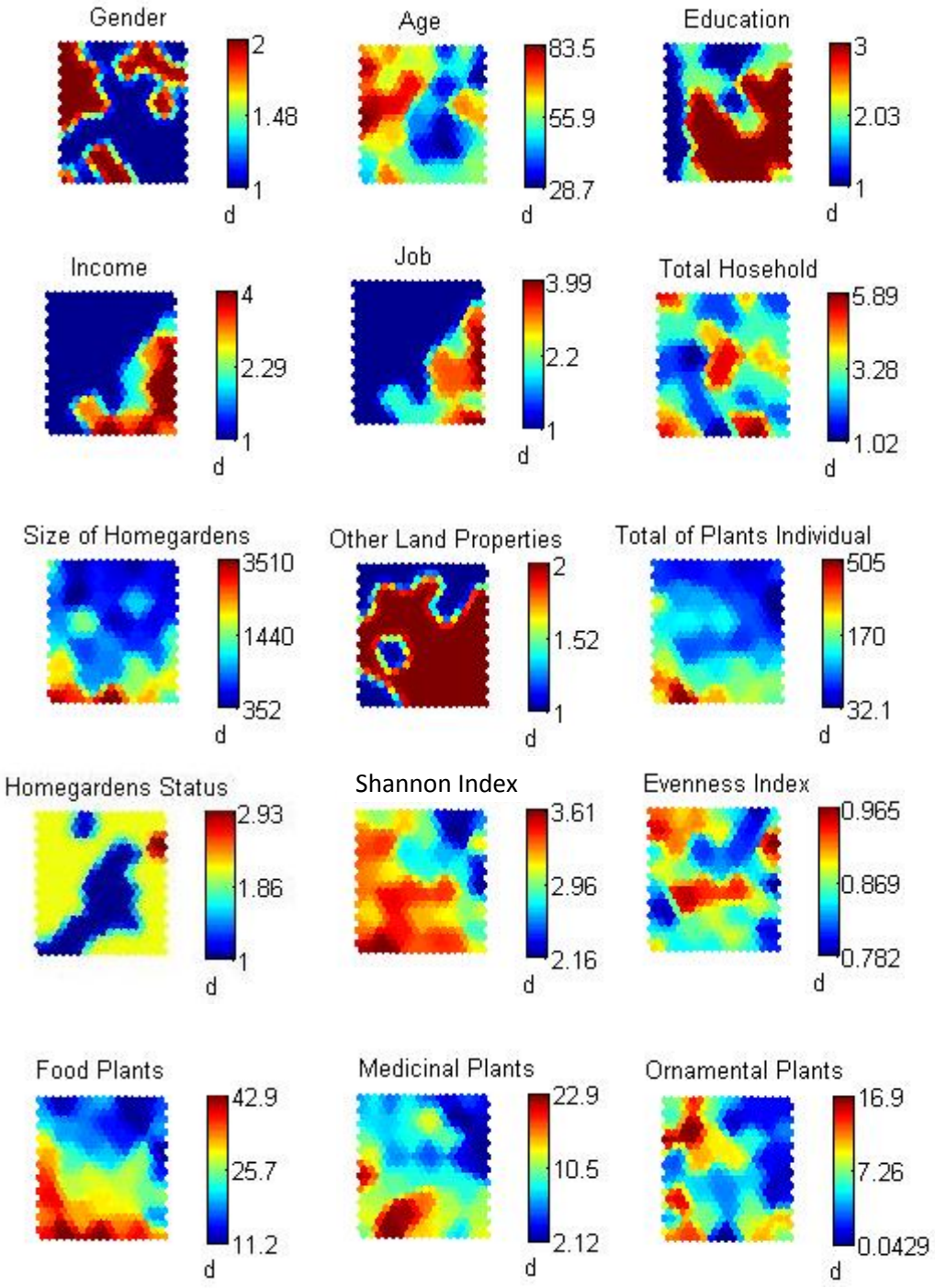


Figure 3 - SOM maps representing the relationship between 15 variables

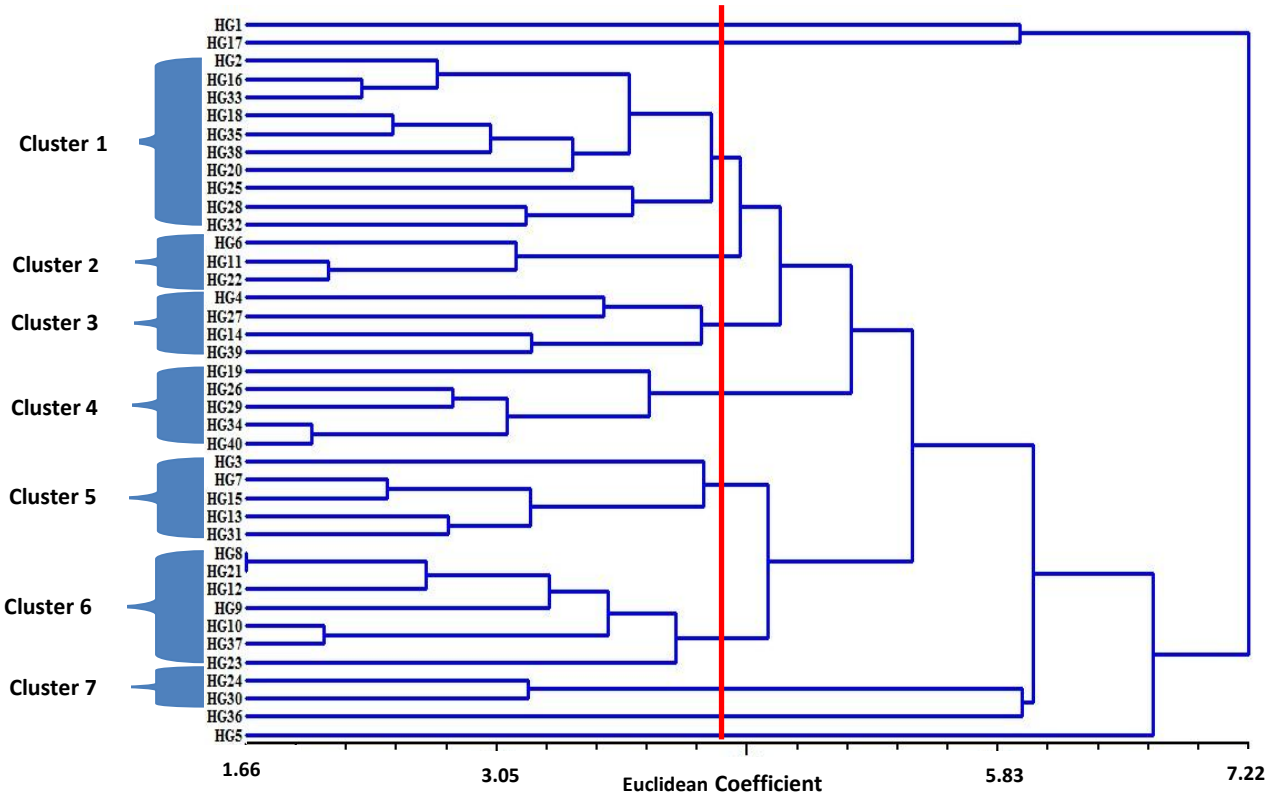


Figure 4 - SAHN Cluster Analysis shows seven clusters of homegardens

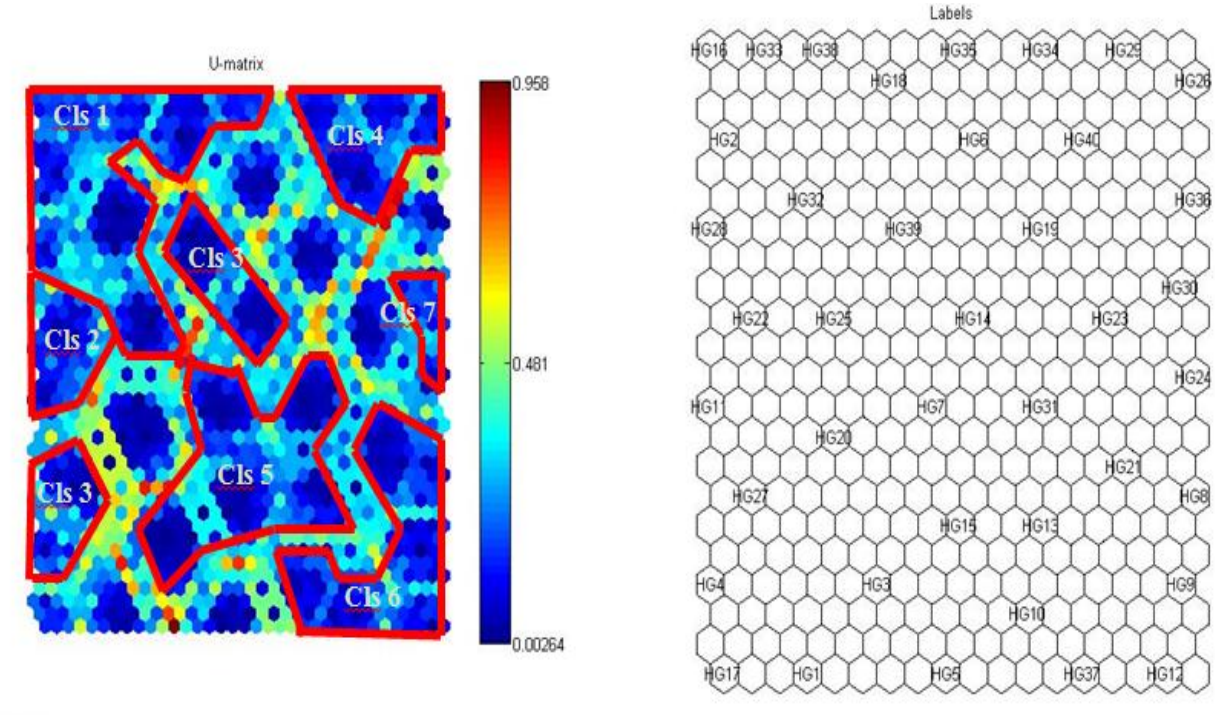
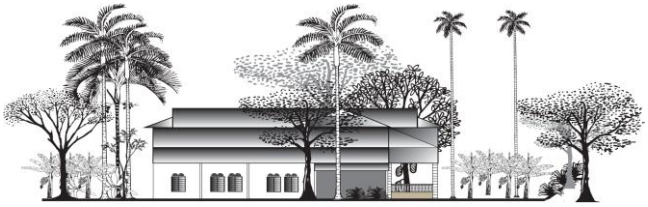


Figure 5- U-Matrix for self-organizing maps shows seven clusters of homegardens

Homegarden 1

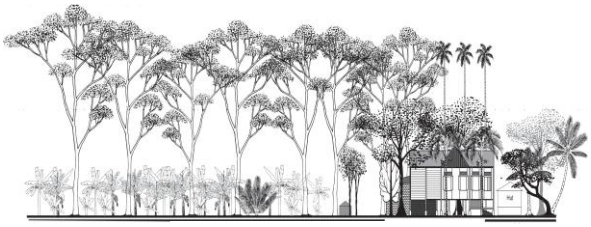
Homegarden 4



Homegarden 7

Homegarden 11

Homegarden 13



Homegarden 17

Homegarden 18

Homegarden 27

Homegarden 28

Homegarden 37

Figure 6- Illustration for vertical structure of the ten tropical homegardens in Malaysia

Discussion

The total of species recorded in the present study is higher than recorded by similar study by Milow et al., (2011) on plant resource of another village in the state of Perak where the villagers are mostly paddy farmers. The number of species in families of plants found in homegardens in the present study showed an agreement with the species diversity in family reported for other tropical homegardens. *Milow et al.,* (2013) indicates that Euphorbiaceae, Leguminosae and Zingiberaceae are three most diverse families of plants in homegardens of the Orang Asli in Negeri Sembilan. *Saikia et al.,* (2012) also noted that Euphorbiaceae had the highest number of species followed by Moraceae and Poaceae in homegardens of Upper Assam, India. *Akinnifesi et al.,* (2010) reported that the most common plant families in urban homegardens of a city in Northern Brazil were Arecaceae, Caesalpinaceae, Anarcadiaceae, Poaceae, Bignoniaceae, and Mimoseae. The highest Shannon diversity index recorded in this study was in agreement with other tropical homegardens. The Shannon diversity index also known as Shannon-Wiener index (H) (Shannon and Weaver 1949) is the most common measures of biodiversity, which is derived from information theory (Mendes et al, 2008). The index has been widely used in the last fifty years and they are appealing because they summarize, in a single number, a partial description of species richness (S) and species evenness (E) (Mendes et al, 2008).Thus, they make simple comparisons of samples possible (*Hubalek, 2000*). The value of Shannon Weiner Diversity Index usually falls between 1.5 and 3.5, only rarely it surpasses 4.5 (*Bibi and Ali, 2013*). Comparison of Shannon Index value of useful plants in homegardens between different localities is summarized in Table 4. It shows species diversity of useful homegarden plants varies between localities regardless of their proximity. Homegarden size and soil property are suspected to be the contributing factors. Nonetheless, the Shannon Index value for useful homegarden plants of Kampung Masjid Ijok lies well within the index value range for useful homegarden plants in other localities.

Evenness is a measure of the relative abundance of different species making up the richness of an area. It may be defined as 'the degree to which the abundances are equal among the species present in a sample or community' (*Molinari, 1989*). The evenness index is typically on a scale ranging from near 0, which indicates low evenness or high single-species dominance, to 1, which indicates equal abundance of all species or maximum evenness (*Routledge, 1980*; *Alatalo, 1981*). The present study shows the evenness index ranging from 0.774 to 0.96902 indicated homegardens in Kampung Masjid Ijok is species richness and the individuals over species are equally distributed. According to *Fernandes and Nair (1986)* the species distribution in homegardens is determined by a few factors, including socio-economic factor, market demands as well as environmental factors and dietary habits.

This study shows that SOM, with the aid of SAHN clustering technique, can be used to visualize relationships between socioeconomic factor and homegarden variables with respect to diversity of plant resource based on the Shannon diversity index and Evenness index. Results of SOM techniques prove its ability to visualize these relationships with lowest quantization and

topographic errors approximately were 0.00 and 0.04. SOM result showed that the size of homegardens is one of the main factors affecting the diversity of plant resource in homegardens. The large homegardens (indicated in light colour in component planes), coincides with high values of Shannon diversity index and average value of evenness index. This indicates that large homegardens contains high species of plant resource and the individuals over the species are averagely distributed. Moreover, the large homegardens are also contained high species of food, medicinal and ornamental plants as per visualized in SOM component planes. This finding is also in agreement with the report by *Mekonen et al., (2015)* which indicated that useful plant species diversity is high when the size of homegarndens is increases. The Brazillian homegardens also shows higher species diversity associated with large homesteads (*Albuquerque et al., 2005*). A study conducted in southern Ethiopia (*Abebe, 2005*) also revealed that the size of homegardens is correlated with the diversity of plant resource, whereby the increases size of homegardens, so does the diversity of plant species.

Locality (Province/State, Country)	Shannon Index range or average	References
Kampung Masjid Ijok (Perak, Malaysia)	2.16 – 3.61	present study
Bali Aga villages (Bali, Indonesia)	0.92 – 1.13	*Sujarwo et al.*, 2015
Several villages of Andaman and Nicobar islands (Andaman and Nicobar, India)	1.3	*Pandey et al., 2007*
Villages within Thrissur district (Kerala, India)	1.15 – 1.42	*Mohan et al., 2007*
Nibujon village, El Recreo village (both in Alexander von Humboldt National Park) and Baitiquirí village (all in eastern Cuba, Cuba)	1.63 – 1.79	*Wezel and Bender, 2003*
Selected homegardens (4 provinces (Sukhothai; Srisatchanalai; Ayudhaya; Nonthaburi) Thailand)	1.9 – 2.7	*Gajaseni and Gajaseni, 1999*
Three villages (Hoa Bac, Phong Thu and Hung Thai) (Thua Thien Hue, Vietnam)	0.54 – 0.78	*Vlkova et al., 2011*
Homegaredens in two Chibchan Amerindian Reserves) (Lower Talamanca, Costa Rica)	3.17 – 3.82	*Zaldivar et al., 2002*
Villages of Gazipur Sadar subdistrict (Gazipur, Bangladesh)	3.43	*Rahman et al., 2005*
Homegardens in Sebeta-Awas District (Oromia Region, Ethiopia)	2.8 – 3.5	*Mekonen et al., 2015*
Homegardens in three Hmong and three Mien villages (Nan province, Thailand)	4.56 – 5.06	*Srithi et al., 2012*
Homegardens in nine villages in 3 subdistricts (Gazipur Sadar, Kaliakair and Kapasia,) (Gazipur, Bangladesh)	6.63 – 7.34	Ahmed and Rahman, 2013

Table 4 - A comparison of Shannon Index values for homegardens from various localities

Socioeconomic status and livelihood conditions may impact the species composition in the homegardens. Results obtained from SOM in this study indicate that income and source of income of homegarden head of household is negatively correlated to the diversity index. Homegardens owner who were work as a rubber tapper and get less income (indicated in dark color in component planes) shows high values of both Shannon diversity index and evenness index (indicated in light color in component planes). They planted their homegardens with diverse of food and medicinal plants and *Musa paradisiaca* (Banana) is the most dominant plant found in their homegardens. The bananas are sold to the middle man as an extra source of income. Studies in other region also indicated the same finding which reported that homegardens be able to support food system (*Buchmann, 2009*; *Cabalda et al., 2011*; Kumar and Nair, 2004), mitigate economic hardship and provide additional income for households (*Drescher et al., 2006*; *Méndez et al., 2001*; *Schupp and Sharp, 2012*; *Smith et al., 2013*). Level of educations among homegardens owner irregularly distributed with no obvious trend as shown in component planes. *Whitney et al., (2017)* also reported that farmers' education had no significant effect on homegarden crop diversity.

Results obtained from SOM in this study indicates that gender, total member in a household, homegarden status and other land properties did not shows an obvious pattern to the diversity of plant resource in homegardens. However, in the literature it has been reported that gender have an important role in the management of homegardens and thus affecting its biodiversity. *Ahmad et al., (1980)* reported that certain group of plants, especially commercial crops which including fruit trees and coconut are managed by men, while other groups (tubers, spices, vegetables, ornamentals) are managed by women. Moreover, it has been reported that women have much role in the cultivation of medicinal plants, use and herbal preparation. In Nicoya, Costa Rica, it was noted that although men and women had equal knowledge of the part used, women had greater knowledge of medical species, the forms of preparation and application than men (*Ochea et al, 1999; Howard, 2006*). In Tanzania, men harvest fuel and fodder tree, while women harvest fodder grasses and herbs (*Fernandes et a.l, 1984*). Besides, SOM component planes also indicates that homegardens owner who aged more than 50 years old show high diversity of plant resource compared to the younger owner. This trend also been reported by other studies (*Gbedomon et al., 2015*; *Avohou et al., 2012*). Young people tend to be selectively use and manage plants of interest (*Gbedomon et al., 2015*) and produce plants with attractive market value and the diversity of plant within their homegardens would continuously be adapted to local market demand (*Avohou et al., 2012*).

An application of SOM techniques prove its suitability to be an extremely powerful tool for identification the effect of socioeconomic factors and homegardens variable towards diversity of plant resource. Number of clusters identified from SOM Umatrix and SAHN clustering method were consistent with each other proved that computing method and traditional conventional method produced the same result but different visualization output. Both of them have their own strength and it is evident from this work that it is possible to combine them for

better understanding in the study of homegardens. SOM U-matrix has an ability to view the cluster in hexagonal color code but SAHN output display in dendogram unit. SAHN has an advantage of resolving any obscure clusters produced from SOM.

Even though the maximum layered (emergent layer) was measured in this study, but only two species of plants can reached this layer. It has been reported by the homegardens owner that both the *Durio zibethinus* and *Melia excelsia* are located in the gardens before the current homegardens owner took place from their ancestors. It is learnt that the age of the plants to be more than 90 years old. *Aziz et al., (2017)* reported that height of *Durio zibethinus* tree or also known as *Durian* among local community are ranged from 10 to 25 meter. Likewise, *Melia excelsia* can reach up to 50 meter as per recorded by *Joker (2000)*. The multi-layered vegetation structure among the homegardens studied offers many benefits and advantages as been reported by other researchers. Among the benefits were including favorable microclimate, reduced risk of pests and diseases, efficient use of resources, year-round availability of products and soil fertility maintenance. Thus, plant species diversity in homegardens considered as contributing substantially to the sustainability of the system (*Soemarwoto and Conway, 1991*; *Torquebiau, 1992*). All the 10 homegardens studied spatially distinguished by its location into four configurations relative to the side of the house that faces it. Ornamental plants are mostly concentrated close to the house especially in front and the side of the house, while edible and medicinal plants are found at rear of the house. This finding is an agreement with the homegardens in other tropical country (Blanckaert et al., 2004)

Conclusion

This study provides insight about the feasibility of combining SOM, SAHN and spatial analysis to study on homegardens. SOM can be used for analyzing the effect on socioeconomic factors and homegardens variables towards diversity of plant resource. A conclusion can be drawn that using such method may be useful tools to get better insight for the homegarden study. However, application SOM seems has not been developed to its full potential especially in homegardens research. More studies are required to further improve its performance in field of homegardens.

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Competing Interests

The authors declare that they have no competing interest**.**

Declarations

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Table 3 - Floristic information on plants resource surveyed in 40 homegardens

Family	Scientific Name	Local Name	Habit	Use	Part Used	Frequency in all homegardens (%)
Acanthaceae	*Acanthus ebracteatus* Vahl	Jeruju Hitam	Herb	Medicinal	Root	7.5
	Andrographis paniculata (Burm.f.) Wall. ex Nees	Hempedu Bumi	Herb	Medicinal	Whole Plant	2.5
	Clinacanthus nutans (Burm. fil.) Lindau	Belalai gajah	Shrub	Medicinal	Leaves	5
	Rhinacanthus communis Nees	Ubat Kurap	Herb	Medicinal	Leaves	2.5
	Ruellia tweediana Griseb.	Bunga Ungu	Shrub	Ornamental	-	17.5
Agavaceae	*Agave americana* L.	Kelumpang Telur	Shrub	Ornamental	-	5
	Cordyline terminalis Linn.Kunth	Jenjuang Merah	Shrub	Ornamental	-	2.5
Alismataceae	Limnocharis flava (L.) Buchenau	Keladi itik	Herb	Vegetable	Leaves /Stem	2.5
Amaranthaceae	*Amaranthus gangeticus* L.	Bayam	Herb	Vegetable	Leaves	2.5
	Gomphrena globosa L.	Bunga Butang	Herb	Ornamental	-	2.5
Amaryllidaceae	*Allium cepa* L.	Bawang	Herb	Spice	Leaves /Tuber	2.5
	Allium tuberosum Rottler ex Spreng.	Kucai	Herb	[1]Vegetable/ [2]Medicinal	[1,2]Leaves	30
	Crinum asiaticum L.	Tembaga Suasa	Shrub	Ornamental	-	10

	Crinum pedunculatum R.Br.	Spider lily	Shrub	Ornamental	-	15
Anacardiaceae	*Anacardium occidentale* L.	Gajus	Tree	Food	Fruit/Seed	12.5
	Bouea macrophylla Griff.	Setar	Tree	Food	Fruit	25
	Mangifera foetida Lour.	Machang	Tree	[1]Food/ [2]Medicinal	[1]Fruit/ [2]Leaves	17.5
	Mangifera indica L.	Mempelam	Tree	Food	Fruit	72.5
	Spondias pinnata (L. f.) Kurz	Ambra	Tree	Food	Fruit	10
Annonaceae	*Annona muricata* L.	Durian Belanda	Tree	[1]Food/[2]Medicinal	[1]Fruit/ [2]Leaves	22.5
Apiaceae	*Oenanthe javanica* (Blume) DC.	Selom	Herb	Vegetable	Leaves /Stem	27.5
Apocynaceae	*Allamanda cathartica* L.	Bunga Loceng	Shrub	Ornamental	-	17.5
	Catharanthus roseus (L.) G. Don	Kemunting Cina	Shrub	Ornamental	-	10
	Ervatamia coronaria (Jacq.) Stapf	Melur	Shrub	Ornamental	-	22.5
	Plumeria rubra L.	Kemboja Merah	Tree	Ornamental	-	2.5
Araceae	*Alocasia denudata* Engl.	Keladi udang	Shrub	Vegetable	Stem/Tuber	15
	Alocasia macrorrhiza (L.) G.Don	Keladi Gajah	Shrub	Ornamental	-	2.5
	Alocasia macrorrhiza Black Stem	Keladi Hitam	Shrub	Vegetable	Stem/Tuber	10
	Alocasia sanderiana (W.Bull) Engl.	Kris Plant	Herb	Ornamental	-	2.5

	Caladium bicolor (Aiton) Vent.	Keladi Hiasan	Herb	Ornamental	-	17.5
	Caladium humboldtii Vent.	Keladi hiasan	Herb	Ornamental	-	2.5
	Caladium lindenii (André) Madison	Angel's Wing	Herb	Ornamental	-	2.5
	Colocasia esculenta (L.) Schott.	Keladi Minyak	Shrub	Vegetable	Stem/Tuber	40
	Colocasia gigantea (Blume ex Hassk.) Hook.f.	Keladi Lambut	Shrub	Vegetable	Stem	10
	Dieffenbachia maculata (Lodd.) G. Don.	Keladi hiasan	Shrub	Ornamental	-	7.5
	Xanthosoma sagittifolium (L.) Schott.	Keladi Telur	Shrub	Food	Tuber	30
Arecacea	*Areca catechu* L.	Pinang	Tree	[1]Food/ [2]Medicinal/ [3]Miscellaneous	[1,3]Seed/ [2]Root	52.5
	Calamus manan Miq.	Rotan Manau	Tree	Ornamental	-	2.5
	Cocos nucifera L.	Kelapa	Tree	[1]Food/ [2]Miscellaneous/[3]Medicinal	[1,3]Fruit/ [2]Leaves/ [3]Root	80
	Dypsis lutescens (H.Wendl.) Beentje & J.Dransf.	Pinang hiasan	Tree	Ornamental	-	17.5
	Elaeis guineensis Jacq.	Kelapa Sawit	Tree	Miscellaneous	Fruit	5

	Licuala peltata Roxb. ex Buch.	Pokok Kipas	Shrub	Ornamental	-	2.5
	Licuala spinosa Roxb.	Palas	Shrub	Miscellaneous	Leaves	20
	Metroxylon sagu Rottb.	Rumbia	Tree	Food	Stem/Fruit	2.5
	Salacca zalacca (Gaertn.) Voss.	Salak	Shrub	Food	Fruit	40
Asparagaceae	*Sansevieria cylindrica* Bojer ex Hook.	Lidah Jin Tajam	Shrub	Ornamental	-	10
	Sansevieria trifasciata Prain	Lidah Jin	Shrub	Ornamental	-	25
Asteraceae	*Ageratum conyzoides* L.	Pokok Tahi Babi	Herb	Medicinal	Leaves	2.5
	Blumea balsamifera (L.) DC.	Capa	Shrub	Medicinal	Leaves	2.5
	Cosmos caudatus Kunth	Ulam Raja	Herb	Vegetable	Leaves	30
	Vernonia amygdalina Delile	Ketum Cina	Shrub	Medicinal	Leaves	10
	Vernonia cinera (Linn). Less.	Sawi Langit	Herb	Medicinal	Root	2.5
	Wedelia trilobata (L.) A.S. Hitchc.	Yellow dots	Herb	Ornamental	-	10
Balsaminaceae	*Impatiens balsamina* L.	Keembung	Herb	Ornamental	-	30
Begoniaceae	*Begonia venosa* Skan ex Hook.f	-	Herb	Ornamental	-	2.5
Bignoniaceae	*Oroxylum indicum* (L.)	Beka	Tree	[1]Vegetables/ [2]Medicinal	[1,2]Leaves	32.5

	Kurz					
Bromeliaceae	*Ananas comosus* (L.) Merr.	Nanas	Shrub	Food	Fruit	35
	Ananas nanus (L.B.Sm.) L.B.Sm.	Nanas Batu	Shrub	Medicinal	Fruit	7.5
Cactaceae	*Hylocercus undatus* (Haw.) Britton & Rose	Pokok Buah Naga	Shrub	Food	Fruit	7.5
Campalunaceae	*Laurentia longiflora* (Linn) Paterm.	Tangkai Ular	Herb	Medicinal	Leaves	5
Caricaceae	*Carica papaya* L	Betik	Shrub	[1]Food/[2]Vegetable	[1]Fruit/ [2]Male flower	75
Clusiaceae	*Garcinia cambogia* (Gaertn.) Desr.	Gelugur	Tree	[1]Spice/[2]Traded	[1,2]Fruit	10
	Garcinia mangostana L	Manggis	Tree	[1]Food/[2]Traded	[1,2]Fruit	62.5
Compositae	*Gynura sarmentosa* (Blume) DC.	Sambung nyawa	Herb	Medicinal	Leaves	2.5
Convolvulaceae	*Ipomoea aquatica* Forssk.	Kangkong air	Herb	Vegetable	Leaves/ Stem	10
	Ipomoea batatas (L.) Lam.	Ubi Keledek	Herb	[1]Vegetable/ [2]Food	[1]Leaves/[2] Tuber	7.5
Costaceae	*Costus speciosus* (J.Konig) C.Specht	Setawar Putih	Shrub	Ornamental	-	2.5
	Costus spiralis (Jacq.) Roscoe.	Spiral Ginger	Shrub	Ornamental	-	5
Crassulaceae	*Kalanchoe pinnata* (Lam.) Pers.	Setawar	Herb	Medicinal	Leaves	7.5

Cucurbitaceae	*Cucurbita moschata* Duchesne ex Poir.	Labu	Climber	Food	Fruit	17.5
	Cucumis sativus L.	Timun	Climber	Food	Fruit	5
	Momordica charantia L.	Peria	Climber	Food	Fruit	5
Cycadaceae	*Cycas macrocarpa* Griff.	-	Shrub	Ornamental	-	7.5
Cyperaceae	Cyperus alternifolius L	Nerung	Shrub	Medicinal	Root	10
Dilleniaceae	*Dillenia suffruticosa* (Griff.) Martelli.	Simpoh Air	Tree	Ornamental	-	2.5
Dioscoreaceae	*Tacca integrifolia* Ker Gawl.	Keladi murai	Herb	Medicinal	Root	5
Euphorbiaceae	*Acalypha hispida* Burm.f.	Ekor Kucing	Shrub	Ornamental	-	10
	Claoxylon longifolium (Blume) Endl. Sx Hassk	Pokok Salang /Chapa Batu	Shrub	Vegetable	Leaves	42.5
	Codiaeum variegaantum (L.) A. Juss.	Puding	Shrub	Ornamental	-	37.5
	Euphorbia hirta L.	Ara Tanah	Herb	Medicinal	Whole Plants	10
	Euphorbia mili Des Moul.	Crown of Thorns	Shrub	Ornamental	-	22.5
	Euphorbia neriifolia L.	Pokok Sesudu	Shrub	Ornamental	-	5
	Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Getah	Tree	Miscellaneous	Latex	12.5
	Mallotus barbatus	Pokok Tapu	Tree	Medicinal	Root	7.5

	Müll.Arg.					
	Manihot esculenta Crantz	Ubi kayu	Shrub	[1]Food/ [2]Vegetable	[1]Tuber/ [2]Leaves	62.5
	Pedilanthus titymaloides (L.) Poit.	Lelipan	Shrub	Ornamental	-	15
	Phyllanthus pulcher Wall.ex Mull.Arg.	Naga Buana	Shrub	Medicinal	Leaves	2.5
	Ricinus communis L.	Pokok Jarak	Shrub	Medicinal	Leaves	2.5
	Sauropus androgynus (L.) Merr.	Sayur manis	Shrub	Vegetables	Leaves	27.5
Fabaceae	*Archidendron jiringa* (Jack)I.C.Nielsen	Jering	Tree	[1]Food/[2]Medicinal	[1,2]Fruit	37.5
	Cassia alata L.	Gelenggang kecil	Shrub	Medicinal	Root	5
	Cynometra cauliflora L.	Nam nam	Tree	Food	Fruit	40
	Leucaena leucocephala (Lamk) De Wit	Petai Belalang	Tree	[1]Vegetables/ [2]Medicinal	Fruit	12.5
	Mimosa pudica L.	Semalu	Herb	Medicinal	Root	7.5
	Pachyrhizus erosus (L.) Urb.	Ubi sengkuang	Climber	Food	Tuber	5
	Parkia speciosa Hassk.	Petai	Tree	[1]Food/[2]Medicinal	[1,2]Fruit	32.5
	Pithecellobium bubalinum (Jack)Benth.	Kerdas	Tree	Food	Fruit	15
	Psophocarpus tetragonolobus (L.) D.C.	Kacang sirih	Climber	Vegetables	Fruit	10

	Vigna sesquipedalis (L.)Fruwirth	Kacang Panjang	Climber	Vegetables	Fruit	15
Gesneriaceae	*Chrysothemis pulchella* (Donn ex Sims) Decne.	Black Flamingo	Herb	Ornamental	-	7.5
Heliconiaceae	*Heliconia bicolor* Benth.		Shrub	Ornamental	-	2.5
	Heliconia psittacorum L.f.	Pokok Sepit Udang	Shrub	Ornamental	-	15
Huperziaceae	*Huperzia carinata* (Desv. Ex Poir) Trevisan	Seri Gading Jantan	Herb	Ornamental	-	5
	Lycopodium phlegmaria A. Cunn.	Clubmoss	Herb	Ornamental	-	5
Hypoxidaceae	*Molineria latifolia* (Dryand. ex W.T.Aiton) Herb. ex Kurz	Remba	Herb	[1]Medicinal/ [2]Food	[1]Root/ [2]Fruit	15
Labiatae	*Ocimum gratissimum* Forssk.	Selasih	Shrub	Medicinal	Leaves	5
	Orthosiphon aristatus (Blume) Miq.	Misai Kucing	Shrub	Medicinal	Leaves	7.5
Lamiaceae	*Coleus blumei* Benth.	Ati-Ati	Herb	Medicinal	Leaves	15
Lamiales	*Episcia cupreata* (Hook.) Hanst.	-	Herb	Ornamental	-	5
Lauraceae	*Cinnamomum iners* Reinw. ex Bl.	Medang Teja	Tree	Medicinal	Bark	2.5
Lecythidaceae	*Barringtonia racemosa* (L) Spreng	Putat	Tree	Vegetable	Fruit	7.5
Lythraceae	*Lawsonia inermis* L.	Inai	Shrub	[1]Medicine/[2]Miscellaneous	[1,2]Leaves	35

	Punica granatum L.	Delima	Shrub	Food	Fruit	5
Malvaceae	*Abelmoschus esculentus* (L.) Moench	Kacang bendi	Shrub	Food	Fruit	10
	Ceiba pentandra (L.) Gaertn.	Kekabu	Tree	[1]Miscellaneous	[1]Fruit	7.5
	Durio zibethinus Murr	Durian	Tree	Food	Fruit	42.5
	Hibiscus rosa-sinensis L.	Bunga Raya	Shrub	Ornamental/ [1]Medicinal	[1]Leaves	27.5
	Hibiscus sabdariffa L.	Roselle	Shrub	Ornamental	-	10
	Sida rhombifolia L.	Senanguri	Herb	Medicinal	Leaves	2.5
	Theobroma cacao L.	Koko	Tree	Food	Fruit	7.5
	Urena lobata L.	Pulut Pulut	Shrub	Ornamental	-	2.5
Marantaceae	*Calathea metallica* Planch. & Linden	-	Shrub	Ornamental	-	2.5
	Calathea zebrina (Sims) Lindl.	Zebra Plant	Shrub	Ornamental	-	2.5
Melastomataceae	*Clidemia hirta* (L.) D. Don	Senduduk babi	Shrub	Medicinal	Root	25
	Melastoma decemfidum Roxb.	Senduduk	Shrub	Medicinal	Root	22.5
Meliaceae	*Lansium domesticum* Corrêa	Langsat	Tree	Food	Fruit	55
	Melia excelsa Jack	Setang	Tree	Vegetable	Leaves	30
Moraceae	*Artocarpus altilis* (Parkinson)	Sukun	Tree	Food	Fruit	12.5

	Fosberg					
	Artocarpus heterophyllus Lam.	Nangka	Tree	Food	Fruit	45
	Artocarpus integer (Thunb.) Merr.	Cempedak	Tree	Food	Fruit	25
	Ficus schwarzii Koord	Kelempong	Tree	[1]Food/[2]Medicinal	[1,2]Fruit	7.5
Musaceae	*Musa paradisiaca* L.	Pisang	Shrub	[1]Food/[2]Traded/ [3]Vegetable/ [4]Miscellaneous	[1,2]Fruit/ [3]Flowers/[4] Leaves	85
Myrtaceae	*Eugenia aquea* Burm. f.	Jambu air	Tree	Food	Fruit	37.5
	Psidium guajava L.	Jambu biji	Tree	[1]Food/ [2]Medicinal	[1]Fruit/ [2]Leaves	17.5
	Syzygium jambos L. (Alston)	Jambu Mawar	Tree	Food	Fruit	5
	Syzygium malaccense (L.) Merr. & L.M.Perry	Jambu Belacan	Tree	Food	Fruit	25
Nepenthaceae	*Nepenthes gracilis* Korth.	Periuk kera	Herb	Ornamental	-	2.5
Nyctaginaceae	*Bougainvillea formosa* W.Bull	Bunga Kertas	Shrub	Ornamental	-	32.5
	Mirabilis longiflora L.	-	Herb	Ornamental	-	2.5
Olacaceae	*Scorodocarpus borneensis* (Baill.) Becc.	Pokok kulim	Tree	Medicinal	Fruit	22.5
Orchidaceae	*Arundina graminifolia* (D.Don) Hochr.	Orkid buluh	Shrub	Ornamental	-	7.5
	Spathoglottis	Lumbah	Shrub	Ornamental	-	15

	plicata Blume	Tikus				
Oxalidaceae	*Averrhoa bilimbi* L.	Belimbing buluh	Tree	Food	Fruit	32.5
	Averrhoea carambola L.	Belimbing besi	Tree	Food	Fruit	12.5
	Oxalis barrelieri L.	Belimbing tanah	Herb	Medicinal	Leaves	2.5
	Oxalis triangularis A.St.-Hil.	Pokok Rerama	Herb	Ornamental	-	12.5
Pandanaceae	*Pandanus amaryllifolius* Roxb.	Pandan	Shrub	Spice	Leaves	45
	Pandanus caricosus Spreng.	Mengkuang	Shrub	[1]Medicinal/ [2]Miscellaneous	[1]Root/ [2]Leaves	10
Passifloraceae	*Passiflora edulis* Sims	Markisa	Climber	Food	Fruit	5
Phyllanthaceae	*Baccaurea macrocarpa* Müll.Arg.	Larah	Tree	Food	Fruit	2.5
	Baccaurea motleyana Hook. f.	Rambai	Tree	Food	Fruit	17.5
	Phyllanthus niruri L.	Dukung Anak	Herb	Medicinal	Leaves	2.5
Piperaceae	*Peperomia pellucida* Kunth	Ketumpang air	Herb	Vegetable	Whole Plant	5
	Piper betle L.	Sireh	Climber	Medicinal	Leaves	27.5
	Piper sarmentosum Roxb.	Kadok	Herb	[1]Vegetable/ [2]Medicinal	[1,2]Leaves	32.5
Poaceae	*Cymbopogen citratus* (DC.) Stapf	Serai	Shrub	Spice	Stem	72.5
	Cymbopogon nardus (L.) Rendle	Serai wangi	Shrub	Medicinal	Stem	7.5
	Gigantochloa albociliata	Buluh Madu	Tree	Vegetable	Shoot	2.5

	(Munro) Kurz					
	Saccharum officinarum L.	Tebu	Shrub	Food	Stem	30
	Zea mays L.	Jagung	Shrub	Food	Fruit	2.5
Polyganaceae	*Persicaria hydropiper* L.	Kesum	Herb	Spice	Leaves	12.5
Polypodiaceae	*Platycerium coronarium* (D. König ex O.F. Müll.) Desv.]	Tanduk rusa	Shrub	Ornamental	-	17.5
	Pyrrosia piloselloides (L.) M.G.Price	Duit-Duit	Herb	Medicinal	-	2.5
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms	Water hyacinth	Herb	Ornamental	-	2.5
Portulacaceae	*Portulaca grandiflora* Hook.	Kembang Pagi	Herb	Ornamental	-	12.5
	Talinum paniculatum (Jacq.) Gaertn.	Ginseng	Shrub	Medicinal	Root	2.5
Primulaceae	*Ardisia crenata* Sims.	Mata Ayam	Shrub	Food	Fruit	5
Pteridaceae	*Pteris ensiformis* Burm.	Silver Lace Fern	Herb	Ornamental	-	5
Rosaceae	Rosa L.	Bunga Ros	Shrub	Ornamental/ [1]Medicinal	[1]Leaves	17.5
Rubiaceae	*Chassalia curviflora* (Wall.) Thwaites	Beberas	Shrub	Medicinal	Root	7.5
	Coffea canephora Pierre ex A.Froehner	Kopi	Shrub	Food	Fruit	2.5
	Morinda citrifolia L.	Mengkudu	Tree	Medicinal	Fruit/ Leaves	17.5
	Ixora javanica	Jenjarum	Shrub	Ornamental	-	30

	(Blume) DC.					
Rutaceae	*Citrus aurantiifolia* (Christm.) Swingle	Limau nipis	Tree	[1]Spice/[2]Miscellaneous	[1,2]Fruit	47.5
	Citrus hystrix DC.	Limau purut	Tree	[1]Spice/ [2]Miscellaneous	[1,2]Fruit	22.5
	Citrus maxima (Burm. f.) Merr.	Limau Bali	Tree	Food	Fruit	25
	Citrus medica (Christm. & Panzer) Swingle	Limau Kapas	Tree	Spice	Fruit	2.5
	Citrus suhuiensis Hayata	Limau manis	Tree	Food	Fruit	12.5
	Citrus x microcarpa	Limau kasturi	Tree	Spice	Fruit	25
	Murraya koenigii (L.) Spreng.	Pokok kari	Tree	Spice	Fruit	40
Sapindaceae	*Dimocarpus longan* Lour	Mata kucing	Tree	Food	Fruit	7.5
	Lepisanthes rubigibosa (Roxb.) Leenh	Terajang	Tree	Food	Fruit	22.5
	Nephelium lappaceum L.	Rambutan	Tree	Food	Fruit	77.5
	*Nephelium mutabil*e Bl.	Pulasan	Tree	Food	Fruit	7.5
Sapotaceae	*Manilkara zapota* (L.) P.Royen	Ciku	Tree	Food	Fruit	7.5
Simaroubaceae	*Eurycoma longifolia* Jack	Tongkat ali	Tree	Medicinal	Root	10
Smilacacaceae	*Smilax myosotiflora* A.DC.	Ubi gadut	Climber	Medicinal	Tuber	2.5

Solanaceae	*Capsicum frutescens* L.	Cili	Shrub	Spice	Fruit	75
	Physalis minima L.	Letup-Letup	Climber	Medicinal	Leaves	2.5
	Solanum ferox L.	Terung Asam	Shrub	Food	Fruit	5
	Solanum lasiocarpum Dunal	Terung satuk	Shrub	Food	Fruit	5
	Solanum melongena L.	Terung	Shrub	Food	Fruit	40
	Solanum torvum Sw.	Terung Pipit	Shrub	[1]Medicinal/ [2]Vegetable	[1,2]Fruit	25
Thymelaeaceae	*Aquilaria malaccensis* Benth.	Gaharu	Tree	Miscellaneous	Stem	2.5
Turneraceae	*Tunera ulmifolia* L.	Bunga Lidah Kucing	Shrub	Ornamental	-	2.5
Verbenaceae	*Clerodendron paniculatum* L.	Pepanggil	Shrub	Medicinal	Root	5
	Stachytarpheta jamaicensis (L.) Vahl	Cabai Tali	Shrub	Medicinal	Leaves	10
	Vitex pubescens Vahl.	Halban	Tree	Medicinal	Bark	2.5
Xanthorrhoeaceae	*Aloe vera* (L.) Burm.f.	Lidah Buaya	Shrub	Ornamental/ [1]Medicinal	[1]Leaves	12.5
Zingiberaceae	*Alpinia officinarum* Hance	Lengkuas Ranting	Herb	[1]Spices/ [2]Medicinal	[1,2]Rhizome	2.5
	Curcuma domestica Valeton	Kunyit	Herb	[1]Spices/[2]Medicinal	[1,2]Rhizome	67.5
	Etlingera coccinea (Blume) S.Sakai & Nagam.]]	Kapur Kesing	Herb	Medicinal	Leaves	7.5
	Etlingera elatior (Jack)	Kantan	Shrub	Spices	Flowers	40

	R.M.Sm.					
	Etlingera megalocheilos (Griff.) A.D.Poulsen	Tepus Gajah	Shrub	Food	Stem	12.5
	Languas galanga (L.) Stuntz	Lengkuas	Shrub	Spices	Rhizome	45
	Zingiber efficinale Roscoe	Halia	Shrub	Spices[1]/ Medicinal[2]	[1,2]Rhizome	20
	Zingziber zerumbet (L.) Smith	Lempoyang	Shrub	Medicinal	Rhizome	7.5