Identifying Suitable Areas for Plantation of Organic Products Using GIS and AHP

J C Mohd Zaini\(^1\), N Mohamed Saraf*\(^1\), N Naharudin\(^1\), A R Abdul Rasam\(^1\) and N Hashim\(^1\)

\(^1\)Centre of Studies for Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

noraainms@uitm.edu.my

Abstract. Organic farming is a technique, which involves cultivation of plants in natural ways. In Malaysia, because the organic food industry is still small-scale, over 60% of organic foods are still imported and it is not possible for the availability and output of organic goods to meet the local demand and need. This study was intended to utilize the GIS and AHP technique to identify suitable areas for organic farming in Sabak Bernam, Malaysia. The study was conducted based on the objectives where criteria for organic farming were identified through background research. Pair-wise comparison (PWCM) method using questionnaires answered by experts were used to determine the weights for each of the parameters used. For this study, seven (7) criteria were considered. The criteria were then weighted according to importance and those weighted criteria were combined to produce a suitability map. A site suitability model was built using the Modelbuilder tool in Arcmap. The model used the AHP and Weighted Overlay basis which provides promising result for the analysis of finding suitable sites for organic farming. Results obtained showed that the majority of land within the Sabak Bernam district is suitable to carry out organic cultivation where the land is far from road networks, contains high organic matter content, gentle slopes with flat aspects low elevation and less than 10 meters from drainages. While land deemed not suitable involves land in dense urban area. This simultaneously means that the land is too close to road networks where underground contamination is a major possibility.

1. Introduction
As the Food and Agriculture Organization (FAO) has said, "Organic or natural cultivation is an environmentally friendly method of cultivation because the input of chemical-filled substances is eliminated." This approach helps increase crop yields without damaging the surrounding ecosystem. This also refers to the people in the environment who live and work [1]. The environmental benefits of organic farming include the strengthening of the local food market, the growth of biodiversity, the enhancement of soil quality, the reduction of contamination due to biological agents and packaging waste, and the use of water [2]. The primary objective of organic farming is to supply agricultural products, particularly food that is safe for consumption for the general public and does not cause harm to the environment [3]. This specific preference by consumers and economic development drives towards the rise in the demand for products from organic agriculture [4].
There is a standard set in Malaysia for it to be certified as an organic product. It is based on an accurate and precise standard of production of organic crops. The standard is the Skim Organik Malaysia (SOM), which is issued by the Malaysian Agriculture Department (DOA). As we are still importing more than 60% of organic foods, the supply and production of organic products are not able to be at par with the demand and need for organic products by locals. Next, it is understood that organic food, relative to conventionally manufactured goods, has a substantially high price tag. The price differential in Malaysia can be as high as 100% to 300% relative to the United States (USA) and the European Union (EU), while the price disparity in the USA and the European Union (EU) is just 25% to 30% [5]. This research will hopefully be able to provide a map as a guide for farmers on suitable locations to begin organic farming that adheres with the SOM set by DOA.

2. Background of study
The Analytical Hierarchical Process (AHP) is also used as a decision-making tool for selecting appropriate organic farming locations. AHP was created and developed by Saaty (1988) [6]. AHP defines a hierarchical model based on alternatives and criteria [7]. The chosen factors controlling the site suitability are weighted using the analytical approach which is supported by pairwise comparison matrix (PWCM) that utilizes the scale of relative importance [8].

A research done by Baroudi (2016) is highlighted in developing a spatial model for identification of land suitability analysis for crops, wheat specifically, using the technique of Geographic Information System (GIS) [9]. Next, GIS aids in spatiotemporal analysis of different types of technique of production of crops by computation of assessment factors [10]. Multicriteria decision analysis (MCDA) incorporating GIS gives the advantage of aiding the process of decision-making in an organized and efficient manner and then represent the data on a map. This interdisciplinary technique has various applications in spatial analysis for complex planning involving land use. A wide range of MCDA methods under the GIS setting can be incorporated. This includes Boolean overlays, weighted linear combinations (WLC), analytical hierarchy process (AHP), ordered weighted averaging and multiple objective land allocation [11].

3. Methodology
In this study, on the basis of different parameters and constraints, multi-criteria site suitability analysis was performed to classify suitable locations for organic agriculture. Seven different parameters have been selected on the basis of their value and relevance in organic agriculture. The selection of different criteria was based on conditions that affect the product yield from organic farming and standards that have been established by Department of Agriculture (DOA) which includes distance from roads drainages, soil fertility, slope, elevation, aspect and land use land cover (LULC). Weights for each criterion were calculated using Analytical Hierarchical Process (AHP). The weight value analyses the relative significance of each criteria and therefore has to be calculated carefully as to reflect real life situation [12]. Next, Weighted Overlay analysis was done to generate the suitability map. The summary of the methodology was shown in Figure 1.
3.1. Study area
Sabak Bernam is a district located at Selangor, Malaysia. Figure 2 shows the enlarged area of Sabak Bernam district. The area lies between Latitude 3°46'10.56" N and Longitude 100°59'01.32" E. Regarding the economic development, almost 50 percent of the land is utilized for agricultural activities such as palm oil, cocoa, coconut, rice, fruits and vegetables. The primary income sources are rice, cocoa and coconut. Tropical climate is the type of weather condition in Sabak Bernam. The district receives heavy rainfall throughout the year. The average temperature is recorded at 27 °C and rainfall normally has a mean of 2130mm [13].

3.2. Criteria
The criteria were chosen with reference to Malaysian Organic Scheme (SOM) [14][15]. These criteria were required to be obeyed so that products farmed can be labelled as “organic”. Table 1 show the suitability classes and requirements for an organic farm where the criteria listed were based on the criteria chosen for this particular study [16][17].
Table 1. Requirements for an organic farm

| Criteria                      | Rating Ranges          |
|-------------------------------|------------------------|
|                               | S1 | S2 | S3 | N1 |
| Suitability Classes           |    |    |    |    |
| Roads (m)                     | >40| 21–40| 11–20| 5–10 |
| Drainage (m)                  | 5–10| 11–20| 21–40| >40 |
| Slope (°)                     | 0–5| 5–10 | 14–24| 24–34 |
| Soil Fertility/Organic Matter (%)| >1.5| 0.8–1.5| 0.4–0.8| <0.4 |
| Aspect                        | Flat, N, W | NE, SE, SW, NW | S | E |
| Elevation (m)                 | 2–11| 11–20| 20–36| 36–77 |

3.3. Analytical Hierarchical Process (AHP)
AHP was based on the rating obtained from the questionnaire, a pair wise comparison (PWCM) between the criteria were made [6]. Then, the rating was applied within AHP to check the consistency ratio (CR) of the ratings. To obtain CR, consistency index (CI) was calculated first. The formula to obtain CI was shown in Equation 1.

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\]  

3.3.1. Consistency Index (CI). Principal Eigen value (denoted as \(\lambda_{\text{max}}\)) was calculated where it was obtained from the sum of products between each weightage elements obtained earlier and the sum of diagonal values of the reciprocal matrix. The equation shows the formula to obtain consistency index where \(\lambda_{\text{max}}\) is the Principal Eigen value and \(n\) is the number of comparisons.

3.3.2. Random Consistency Index (RI). Next, knowing the CI, this index is suggested to be compared with the appropriate CI which is called Random Consistency Index (RI) [6]. The table of random consistency index is as shown in Table 2.

Table 2. Table of random consistency index

| Number of criteria (n) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|------------------------|---|---|---|---|---|---|---|---|---|----|----|
| Random consistency     | 0 | 0.0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 |

3.3.3. Consistency Ratio (CR). CR was done to check the consistency of ratings obtained from the questionnaire. A CR below 0.10 is regarded as acceptable [18]. A value higher requires the ratings to be re-examined. After obtaining the CI and RI, CR was calculated. The formula is shown as in Equation 2 where CI is the Consistency Index while RI is the Random Consistency Index.

\[
CR = \frac{CI}{RI}
\]

3.4. Determination of weights using AHP and PWCM
The scale rating was analyzed in the EasyAHP plugin. The plugin uses the AHP formula (Equation 3) where \(n\) is the number of comparisons, R1 is the Rating 1 and Sn1 is the sum of rating 1 to obtain
weightages for each criterion. The value (λ), CI and CR were calculated. Only the rankings with CR of below 0.10 will be considered to ensure the reliability of criteria’s weightage.

\[
W_A = \frac{1}{n} \left[ \frac{R_1}{S_{n_1}} + \frac{R_2}{S_{n_2}} + \ldots + \frac{R_n}{S_{n_n}} \right]
\]

(3)

3.5. Data processing

The raster maps and tools were stringed together through the ModelBuilder tool in ArcMap. From the ratings obtained from experts’ opinions, the calculations of weightage for each criterion were done by utilizing the EasyAHP plugin in QGIS. The weightage or influence for each designated parameter in percentage (%) and scores for each sub-criterion were summarized in Table 3. After inserting weightage for each criterion and sub-criteria’s scores, the model was verified, run and a suitability map for organic agriculture in Sabak Bernam district was generated.

| Table 3. Ranks and score for each criterion |
|--------------------------------------------|
| **Main criteria** | **Weight** | **Influence (%)** | **Sub-criteria** | **Score** |
| Road (km) | 0.17 | 17 | 0 - 0.00932 | 1 |
| | | | 0.00932 – 0.001863 | 3 |
| | | | 0.001863 – 0.00280 | 4 |
| | | | 0.002780 – 0.00373 | 4 |
| LULC | 0.12 | 12 | Water body | Restricted |
| | | | Urban area | Restricted |
| | | | Oil palm plantation | 4 |
| | | | Forest | 4 |
| | | | Paddy field | 4 |
| | | | Rubber plantation | 3 |
| | | | Bare Soil | 4 |
| Drainage (km) | 0.14 | 14 | 0 - 0.00932 | 4 |
| | | | 0.00932 – 0.001863 | 4 |
| | | | 0.001863 – 0.00278 | 3 |
| | | | 0.00278 – 0.00373 | 1 |
| Aspect | 0.04 | 4 | Flat | 4 |
| | | | North | 4 |
| | | | Northeast | 3 |
| | | | East | 1 |
| | | | Southeast | 3 |
| | | | South | 2 |
| | | | Southwest | 3 |
| | | | West | 4 |
| | | | Northwest | 3 |
| Elevation (m) | 0.06 | 6 | -13 – 9.5 | 3 |
| | | | 9.5 – 32 | 4 |
| | | | 32 – 54.5 | 1 |
| | | | 54.5 – 77 | 1 |
| Soil Fertility, SOC (kg/m²) | 0.44 | 44 | 0 – 1.75 | 1 |
| | | | 1.75 – 3.5 | 1 |
| | | | 3.5 – 5.25 | 4 |
| | | | 5.25 – 7 | 4 |
| Slope (°) | 0.03 | 3 | 0 – 4.7 | 4 |
| | | | 4.7 – 9.5 | 4 |
| | | | 9.5 – 14.2 | 3 |
| | | | 14.2 – 18.9 | 1 |
3.6. Ground truthing
Accuracy assessment is the comparison between final map (output) and reference data. Google Earth was used to verify the land at Sabak Bernam corresponds similarly to the final map produced. The accuracy assessment method was not only used for knowing accuracy levels but also for enhancing the accuracy of output map. Hence, 30 ground reference points were selected from study area using Google Earth and verified using ArcMap’s Imagery base map. Utilizing Google Earth’s Street View that provides 360° view of the study area, pictures were taken where the verification points were placed on the final suitability map.

4. Results and Discussion
According to the classification of Food and Agricultural Organization, FAO [19], land suitability for agriculture were classified according to four levels of FAO’s classification (Table 4).

| Suitability Class | Class Name               | Rating Range (1-100) | Class Description                                      |
|-------------------|--------------------------|----------------------|--------------------------------------------------------|
| S1                | Highly Suitable          | 95-100               | Land having no significant limitations or only minor limitations |
| S2                | Moderately Suitable      | 85-95                | Land having limitations which in aggregate are moderately severe |
| S3                | Marginally Suitable      | 65-85                | Land having limitations which in aggregate are severe |
| N1                | Currently Not Suitable   | 40-65                | Land having so severe limitations which may be surmountable in time |

4.1 Suitability map for Organic Farming in Sabak Bernam, Selangor.
The area according to FAO’s classification framework and coverage percentage of the suitability map (Figure 3) were summarized in Table 5.

Figure 3. Final suitability map for Organic Farming
Table 5. Summary of area and percentage of each suitability classes

| Suitability Classes       | Area (ha) | Percent (%) |
|---------------------------|-----------|-------------|
| Not Suitable (N1)         | 4,202.32  | 3.84        |
| Marginally Suitable (S3)  | 1,144.56  | 1.05        |
| Moderately Suitable (S2)  | 101,443.00| 92.67       |
| Highly Suitable (S1)      | 2,672.84  | 2.44        |

4.2 *Highly Suitable*
About 2.44% of land was classified into the class, ‘Highly suitable’ for organic farming (Table 5). The lands classified into this class have a distance of more than 40 meters from road networks, high organic matter content where the soil comprises of sufficient minerals, possesses good structure of soil and are excellent in keeping the soil’s moisture. Next, very gentle slopes with flat aspects influence agricultural land suitability due to temperature changes. Moving on, the land is deemed suitable if it is less than 10 meters from drainages. Drainage permits the removal of excess water and materials from the farm to enhance growth of crops [20]. Moreover, land facing the North and West direction receives the most sunlight during the afternoon which enhances photosynthesis process [21].

4.3 *Moderately Suitable*
Moderately suitable lands for agriculture make up the majority of land at 92.67%. This is due to the large area of Sabak Bernam in the Southeast region is covered by forest where the distance from nearest roads is at the range of 20 to 40 meters which is suitable to avoid debris and dust from motorized vehicles. This is also considered as a buffer zone. Distance of buffer zones between organically produced crops and potential contaminants must be of sufficient distance and structure to avoid drift or runoff of forbidden substances [22]. Moreover, the underground elements of roads such as heavy traffic emissions, lead and oil or petroleum leaks could absorb to the nearby organic farm hence contaminating the farm [23]. Moreover, since agriculture covers up 41% of the district, drainages are already within close proximity to each other. Next, with gentle slopes and aspects facing the NE, SE, SW and NW direction, this helps in optimizing the growth of organic plants.

4.4 *Marginally Suitable*
Areas deemed marginally suitable (1.05%) to conduct organic farming are more evident at the Northwest region. The areas here have aspects that faces South with elevation at an average of 28 meters above sea level. This area in general is quite close to small roads and hence, makes land here have less access to drainages. Finally, the most important criteria for organic cultivation, the soil fertility is low in the Northwest region. A fertile soil comprises of sufficient minerals, organic matter in soil, possesses good structure of soil and excellent in keeping the soil’s moisture where in general, a fertile soil naturally requires less to none fertilizers for crops to grow on [24].

4.5 *Not Suitable*
About 3.84% of land is in the ‘Not Suitable’ region. This is mostly seen in the West and Southwest region (refer to Figure 3) where there is a dense urban area. This simultaneously means that the land is too close to road networks where underground contamination is a major possibility. In the east region, the sun would be blocked in the afternoon which limits the growth of organic plants. Finally, areas covered in water body and urban areas are deemed permanently not suitable. Urban areas are regarded as non-suitable due to the limited space and environmental pollution. According to Parveen S., Basheer J. and Praveen B., to optimally make use of land, it is required to have information on existing land use/land cover [25].
5. Conclusion

This study was mainly focused on highlighting criteria and land conditions to consider for starting the organic farming. This study was also done to identify suitable land for organic agriculture in the Sabak Bernam district where seven criteria were studied. Analytical hierarchal process (AHP) with the integration of Geographic information system (GIS) was utilized and it was effective in identifying suitable lands for organic farming. The major advantages of this method were the possibility to combine quantitative and qualitative criteria [26]. Ranks and weightages of each criteria were determined based on academician’s and expert’s opinions, literature survey and correlation analyses (PWCM).

At the end of the evaluation, it was computed that 2.44 % (2,672.84 ha) of the study area be highly suitable (S1) for organic agricultural production, 92.67 % (101,443.00 ha) is moderately suitable (S2), 1.05 % (1,144.56 ha) is marginally suitable land (S3), and 3.84% (4,202.32 ha) is permanently not suitable (N1). The final map obtained from this study can be adopted for the process of decision making to start establishing organic farming within the study area, as it gives insight in pinpointing the suitable areas to increase productivity of land [27]. This promotes toward an environmentally sustainable method of agriculture where it is predominantly dependent on its surrounding ecosystem [28] [29].

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