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GIS ASSISTED SUITABILITY ANALYSIS FOR URBAN AGRICULTURE; AS A STRATEGY FOR IMPROVING GREEN SPACES IN COLOMBO URBAN AREA

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Abstract

Present world urbanization and urban growth are increasing at the alarming rate. Its ultimate result indicates to conversion of environmentally sound land for built environment. Improvement of urban green spaces in perfect manner is one of the best options for mitigating negative environmental effects exists on the urban expansion. In the developing country context only open green spaces cannot be considered; upgrading these green areas for urban agriculture is the best solution for that. Identification of suitable land for best agricultural practices need to identify a proper scientific manner. Present GIS analysis functions provide better insight for that. Integration with Multi-Criteria Evaluation (MCE) with the Analytic Hierarchy Process (AHP) is one of the best methods for that. This research aims to develop possible methodologies integrated GIS with multi criteria evaluation. In this case Analytic Hierarchy Process used for giving weights. Final classification developed based on the result map of the above application. It provides a better guideline for different urban agriculture suitabilities in the study area.

Key words: Suitability Analysis; Urban Agriculture; Multicriteria Evaluation; Analytic Hierarchy Process

Introduction

Urbanization and urban expansion are a common global phenomenon; in 2011 world urban population accounts 53% of the total population [32]. Another important feature of this trend is ½ the population in the developing countries can be taken as urban. Therefore, accommodating this population with sustainable living is an enormous challenge for all over the world. In the 21st Century the urban expansions of the Asia push up the overspill population in the wilderness areas and the rural hinterland. Above urban transition, causes to create high land demand and its pressure on agriculture and wetlands in the immediate surroundings of urban centers. It has the further effect to balance sustainable urban development [1]. In 1996 Kaiser et al., mentioned that without balancing three sets of land values means market value, social use value and ecological value of the land parcel any country cannot achieve the sustainable development [15]. Therefore ecological value is the most important concept we need to concern. Land conversion has affected not only prime agricultural land , but also areas which have been designated as conservation areas. Then, any country need to concern protecting green areas for balancing their urban environment. Then, they need to focus this green area for getting highest and best use of the land. With the rapid increase of population Asian countries will be a very high demand for a continuous supply of food, especially fresh nutrient-rich food. From the long history of the urban age, farms and forests have been integrated within cities and it was given a hand to promote their sustenance [31] In present development trends, are paying less attention to this, because, the economies are mainly diverting throughout market mechanism. Now this is the time to pay significant attention to overcome the situation. Otherwise, will create critical pollution and nutritional problems.

Green spaces and urban agricuture

Considering the sustainable living, urban green space plays a major role as the lungs of the urban areas. It provides for an environmentally sustainable life of the masses, who are living in this congested urban area. But, urbanization result to replace natural green features such as vegetation and marshes to the built matter for residential, commercial, roadways etc. Along with these structural changes, urbanization too influences the negative consequences, such as, concentration of human activities, increases the emissions of heat, environmental pollution etc. Increase of the vegetated surfaces or green spaces in the urban landscape helps to minimize negative effects of structural changes [28]. Healthy natural ecosystem is supported to prevent life long system of the urban community. Hence the present fast urban system require to change with natural ecosystems not only focuses on parks and walkways; concern on urban agriculture practices. Present city planners concern the urban agriculture and urban forestry combine with the urban environment as green spaces. Foster and Rosenzweig (2007) stated “the first time in modern history there is an understanding by global thinkers and city managers of the important role that agriculture and forestry can play in the creation of modern, dynamic, ecologically, sustainable cities” [7] Further he was stated that the indigenous socioeconomic and ethnic structures of an urban area are the foundation stones upon which to construct a strategic superstructure of urban agriculture and urban forestry.

Although urban agriculture is a relatively simple solution, in many cities, which is, formal recognition and integration of agriculture into city planning and city growth has hardly changed. In the city planning, urban agriculture can be recorded as one of the best models for sustainable urban growth can take place. In present, developed countries, mix-up this concept to their city plans. But, in the context of Asian countries, there are absences of meeting this green space concept, because their urban scenario is much different.

The urban agriculture has played an important role for sustainable exploitation of urban environments and makes a substantial contribution to many cities for self-reliance in food. It also stands to increase the green spaces in cities to maintain the lifelong system. Foster in 2007 defined that, Urban Agriculture are any and all enterprises, commercial and non-commercial, related to the production, distribution, sale or other consumption of agricultural and horticultural produce or commodities in a metropolitan / major urban center. The amount of land available for urban agriculture is continuing to minimize but, the need for food in the cities is becoming more pressing due to the large-scale migration. On the other hand, urban agriculture contributes to local economic development, poverty alleviation and social inclusion of the urban poor. However, land scarcity is, one of the major obstacles for the growth of this sector. Hence, finding of possible agriculture developments for different part of the city is important because it will be added value to sustain cities. With the limited land urban agriculture practices cannot be done in traditional way and need to identify different alternative methods for different regions of the city; not only fringe congested areas as well. Hence land suitability analysis for different urban agriculture practices is a possible solution and it should be done in a scientific way. GIS provides a tool in integrating and analyzing of land resources to assure the suitability for a land use or several land uses [12].

Land Suitability Analysis

Spatial data analysis is the process of extraction of useful information distributed over the space. Therefore it is seeking out patterns and associations on maps that help to characterize, understand and predict spatial phenomena. It includes a "variety of activities that serves in the descriptions, understanding, and prediction of patterns and associations along the map" (Carter, 1994). Land suitability analysis is one of the important components of spatial data analysis. It can be described as a process to determine suitability factors for some specific uses to determine its suitability level [8];[29]. Land suitabilities mostly related to different criteria like physical, socioeconomic and environmental. The evaluation result of those multiple criteria assist to take better decisions about the suitable areas. Therefore, recent researches identified on it as a method named multi-criteria evaluation in spatial analysis.

Multi-criteria Evaluation

Multi-criteria Evaluation is primarily concerned with how to combine the information from several criteria to form. It is numerical algorithms that define the suitability of a particular solution on the basis of the input criteria and a weight together [24] with some mathematical or logical means of determining trade- offs when conflicts arise [9]. Combination of GIS and MCE process of transformed geographical data (input) into a result decision (output) [4]; [9]; [10];[4]. In the earlier stages GIS techniques played the major role, while in the later stages, MCE techniques are of major importance. Hence with this combination GIS provide the capabilities until analysis of the data to obtain information for making decisions (because the GIS has limited capacity to examine the value structure). The MCE techniques provide the tools for aggregating the geographical data and the decision maker's preferences into the usefulness of alternative decisions. Over the last 10 years or so, researchers attempted to find solutions for land-use suitability problems using GIS-based multi-criteria evaluation procedures. (e.g. [30]; [2]; [19] [20]; [24]; [14]; [18]; [19]). Within this MCE process, determination of criterion weights are important task and Analytic Hierarchy Process is one of the best methodologies to be used.

Analytic Hierarchy Process (AHP)

The AHP is a powerful and flexible decision making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of decisions need to be considered. AHP was developed in the 1970's by Thomas Saaty as the most highly regarded and widely used decision-making theory. The most prominent character of this theory is using the pairwise comparison matrix for value judgement. The criteria pairwise comparison matrix takes the pairwise comparisons as an input and produces the relative weights as output and the AHP provides a mathematical method of translating this matrix into a vector of relative weights for the criteria [17]; [18]; [19] It is the procedure by which criteria are combined to arrive at a particular evaluation and by which evaluations are compared and acted upon [6]. The following table shows the Saaty defined pairwise comparison scales in the AHP.

Table 1 the AHP scales for paired comparisons

Intensity of Importance	Definition
1	Equal importance
2	Equal to Moderate importance
3	Moderate importance
4	Moderate to strong importance.
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to Extremely strong
9	importance
	Extreme importance

Source: Adapted by Saaty

In recent years many researchers used multi-criteria evaluation to various disciplines. In demarcation boundary in the city and National Park [27], public decision making for buffer zone demarcation [23], find the best location for housing [17], ulti-functional forestry [16], Urban land evaluation [30];[33], root alignments developments [26], flood vulnerability analysis [2].

Problem

Colombo is the capital city of Sri Lanka and it is the highly urbanized city in the country. During the last two decades, its growth expands throughout the whole Colombo district [22] Therefore many of the agricultural lands within the Colombo district converted to build up purposes [5] like fragmentation of highland agricultural land and filling low-lying agricultural lands such as paddy fields. As a result of that Colombo and surrounding suburban areas has to depend on other cities in the country for vegetables, fruits and meats. To overcome the above issues it is proposed to discourage fragmentation of the agricultural lands and filling of low lying lands but not a proper solution for avoiding underutilization of above lands. Although there are several agricultural lands those are cannot used for agricultural purposes rest of the other lands which are suitable for urban agriculture, still vacant or underutilization. But these lands essential to protect as green spaces to balance the environment. To better solution for that is to introduce urban agriculture as a major land use/function and commercial activity for these lands; self survival method for avoiding these under utilization. Several studies concerned about urban agriculture in Sri Lanka but never paid attention to how to combine it with urban planning. With less technology, as a developing country needs to pay attention to that with way to maximize our limited resources. At first, identification of suitable land for suitable urban agriculture practices are significant task and this research intend to provide basic guideline for that.

Objectives of the study

The main objective of this study is to develop a methodology for identification of land for urban agriculture suitabilities in the Colombo Urban Area. To achieve this main objective following specific objectives were outlined.

- To identify several indicators to measure urban agriculture suitability
- To combine these indicators to GIS platform and evaluate it using MCE and AHP methods.
- To perform suitability analysis in the case study area.

Methodology

Analytical method

A Geographic Information System (GIS) is a powerful tool for land use planners in their effort to make land development processes more efficient and attractive. Urban land evaluation is a very complex process, which requires significant consideration of many socioeconomic, and physical factors. Therefore this study attempt to integration of GIS with Multi-Criteria Evaluation and Analytic Hierarchy Process (AHP) to develop suitable decision scenarios to define, land for different urban agriculture practices.

Data

Data collected from several primary and secondary sources. Two types of primary sources used for that. In first thematic maps used as primary data and obtained 1:2000 scale digital maps prepared by the survey department of Sri Lanka. A second category of data includes agriculture experts and farmers opinions obtained from unstructured interviews. It used for decision making stage of the research; AHP weights calculated based on this outcome.

Methodological process of identifying the suitable land areas for urban agriculture based on four steps. First, the factors affecting the agricultural were set up as criterion maps. Second all of the factors were scored in the suitability range based on expert opinion. Third the weights of all factors were determined using the Analytic Hierarchy Process through a experts's and farmer's opinions. Finally GIS operations to generate the final urban agricultural suitability map.

Determining Criteria

The identification of the relevant parameters for the multiple criteria has been considered several factors in ecologically and socially. An important criterion for defining relevant parameters is that they may be conveniently quantified in a geographic framework. In this study, six parameters namely Land use, slope, water table depth, flood retention areas, population density and housing density have been identified.

Classification of final map

The final suitability map was based raster classification map based on 10X10 pixel range. Raster data layer in GIS can be defined as a specific character with composite weights. In this way each grid cell in the raster file can be developed with value for certain attributes. There are multiple data layer for each attribute and these layers can be overlapped for getting final value map using GIS.

$$CL_i = CL_1, CL_2, CL_3, \ldots\ldots CL_n \ldots\ldots (1)$$

Where C***Li, I = 1, 2 , ……. n,*** represents each individual data layer considered in the suitability process. The weight of each individual data layer is different in the cartographic modeling process, it needs to give weights to another set:

$W_i = (W_1, W_2, \ldots\ldots W_n)$……(2)

Where ***Wi, i = 1,2, ... n,*** represents the weight of each individual data layer. Finally there should be a set containing the decision space or evaluation scale:

$V_k = V_1, V_2, \ldots\ldots V_m$……(3)

Where ***Vk, k = 1,2, . . ., m,*** represents each individual decision space scale like highly suitable, more valuable, moderately suitable & less suitable. All of the grid cells in the i^{th} data layer can be represented as a subset of V, that is RDL_i

$RDL_i = rijk$

Where RDL_i show in the raster matrix as follows

$$RIDL\ I = \begin{pmatrix} ri11 & ri12 & --- & ri1m \\ ri21 & ri22 & --- & ri2m \\ --- & --- & rijk & ---- \\ rit1 & rit2 & & ritm \end{pmatrix} \quad 4$$

Where **rijk** is the membership grade of j-th grid cell in the i-th data layer to k-th class. For the cells with the same location in all the data layers considered (same location but different attributes), they can also be represented as a subset on V, that is:

$Cj = rijk$

Therefore Matix form like as follows

$$Cj = \begin{pmatrix} r1j1 & r1j2 & --- & r1jm \\ r2j2 & ---- & --- & r2jm \\ --- & ---- & --- & rijk \\ mj1 & mj2 & --- & mjm \end{pmatrix} \quad 5$$

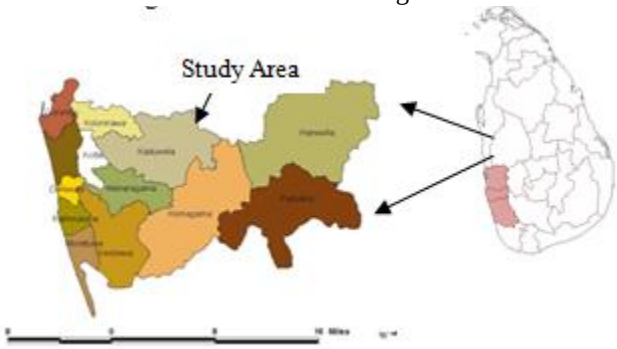
Calculated final composite weights were used for developing suitability criterion such as highly suitable, more suitable, moderately suitable and less suitable. The final suitability map was developed based on the above mentioned different suitability levels. Similar to matrix (4), **rijk** is also the membership grade of j-th grid cell in the i-th data layer to k-th class. Matrices (4) multiply by weights of each layer and **rijk** can be calculated by specific membership functions in a particular application context. Combined with the weight set, the cartographic modeling procedure, which is a process of overlaying multiple data layers in GIS, is actually an operation of set W and Cj, or in algebraic mapping from Cj to Bj through W:

Where Bj is the j-th grid cell in the result data layer and "x" represents the operator when performing cartographic modeling. The following algebraic multiplication operator is used in this paper:

$$Bj = \sum_{i=1}^{n} Wi * rijk$$

Application

One of the congested Municipal Council area located in the Colombo district, named Kaduwela Municipal Council (KMC) area was identified as an application area. KMC is situated about 11 miles away from the city of Colombo. The area of the KMC is 87.69 sq.km. The study area is located within the Wet Zone. This experiences a rainy, humid and hot climate. The topography of the project area is a gradual slope from high elevation in the south to low elevation in the north. The Kelani River flows from east to west along the northern boundary of the KMC Area. There are highly valued resources, which can be added in terms of density of ecosystems along with their flora and fauna in KMC. During the two decades from 1981 – 2001 average annual growth rate is 2.6 %. Thus an increasing trend of population growth could be seen in the KMC for the last two decades and it is still continuing.



Source: urban development authority, sri lanka
Figure 1 location of study area

Important features of land uses of the study area indicated in following table 2

Table 2 land use distribution

Land use	Nature	%
Built-up area	All built-up areas including commercial, residential, administrative etc.	74.1
Water bodies		3.5
Paddy	Existing paddy and all uncultivated paddy land	12.2
Marshy land	Marshy land and abandon paddy land	2.3
Other agriculture	All other existing agriculture including coconut, rubber	8.1
Hilly forests	Valuable forests.	0.8

According to the above table in this area more than 28% of the area was non built-up area. Then planners responsible for maintaining appropriate green spaces of this area, those are built-up area or not. Therefore, preparing an urban agriculture suitability plan is important to take planning decisions.

Experts are given some priorities for factors which are importance of selecting suitable lands for different agriculture uses. Those factors concern to given weights for criterion maps using AHP ranks.

According to that, six criterion maps, namely Land use, slope, water table depth, flood retention areas, population density and housing density were identified as criterion maps for concern different agriculture suitability. After that above calculated composite weights were given to each criterion maps; overlaying this criterion maps final suitability map was classified and figure 2 shows it.

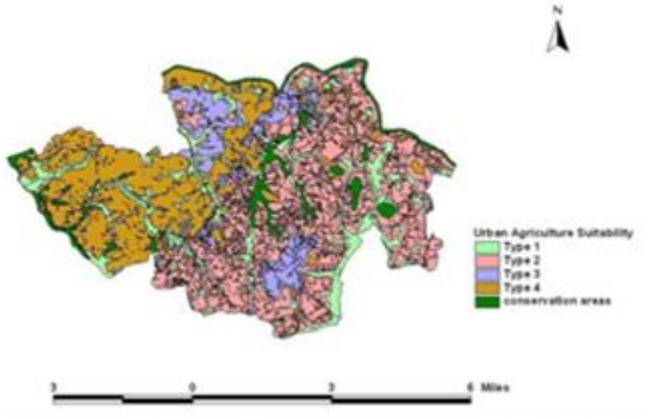


Figure 2 Final Suitability Map

Final suitability Map

The following map shows different agriculture suitabilities in different areas. Percentages of different land suitabilities indicated table 2. It indicated percentages of different land allocations in the area.

Table 2 result map classification

Land classification type	% of the land
Type 1- Highly suitable	13%
Type 11- More suitable	41%
Type 111 - Moderately suitable	15%
Type 1V - Least suitable	25%
Conservation areas	6%

Different land classifications indicated different uses of urban agriculture and it can be classified as follows.

Type 1 - Highly Suitable

Most of the lands in this area are underutilization and need to develop it as in novel concepts. These areas consist most of the paddy fields and marshes and presently most paddy fields are not used for paddy or any type of agriculture. Most of these areas are water logging areas. Some of the areas close to the city is already identified as a green recreation area and other areas far from the city, and ability to pay attention to developments in areas for growing leafy vegetables. In the present there are high demands for leaf vegetables from urban dwellers. Then these areas can be used for profitable use in maintaining green spaces.

Type 11 - More suitable

These areas are not lowlands, it consists of agriculture like coconut and other agriculture. For avoid fragmentation of that land for profitable purposes can be introduce more profitable way of organic farming practices. The organic agriculture is one of the best solutions for minimizing the negative consequences of the agriculture. These products have strong demand due to high consumer preference. Hence it will be caused to uplift income of the people who are engaging this agriculture. Then these more suitable areas can be used for that and can be proposed some subsidies for farmers for uplift that.

Type 111 - Moderatly Suitable

These areas suitable for developing home business gardens (HGB). The concept allows urban people to work on environmental and/or commercial agriculture with a viable mix of resource utilization and sustainable management at the homestead level. The main theme of the concept of the HBG is to stress the need in converting simple form of home gardening or kitchen gardening into the entrepreneurship development venture on the long-term basis.

Type 1V - Less Suitable

Family nutrition gives high priority so as to address issues of imbalance food intake by advocating cultivating some important nutritious crops (earth-beds or pots) for urban communities. For instance, use of vertical space of the homestead by adopting low cost methods such as "cultivation tower", cultivations in empty containers, plastic bottles and tires are also can be advocated for that.

Conservation Areas

These areas presently allocate as green spaces utilize for recreational areas and forest areas. These areas can be protected as existing use. This areas fulfil the green space concept and it add better living environment for people.

As a result of the evaluations and the application of agricultural suitabilities in study Area, is used as guidelines for urban planning studies. Therefore it is easily applied to every part of suburban area with little improvements. These guidelines can be considered to certain aspects of the development plan and zoning plan.

Conclusions

This research aimed to develop suitable methodology for identifying suitable land for different urban agricultural practices in the scientific manner. GIS and multi-criteria integrated methodology used for finding out different agriculture suitability areas in terms of protecting green spaces. In the context of application, the analysis indicates that 4 different areas suitable for different urban agriculture practices like highly suitable, more suitable, moderately suitable and less suitable. Final analysis map, illustrates 13% of the area consist of highly suitable or type 1 category. This is an extremely important area need to pay planner's attention. Presently these areas are under utilized water logged areas and it need to focus on development with active participation of farmers in the particular area without harming green environment. This is the imperative point to extract from this study to planner's to preparation of their development plans. More suitable areas indicated large area and development potential areas with high population growth. Hence this area is most suitable for organic farming. This classification is very useful for implementing an awareness program for improving green spaces in urban areas. When the analysis used in other urban areas it can be formed in different forms depend on its local features by limiting the user's requirements, differentiations the rules used in the criteria and weighted parameters. It is important that the analysis provides an interactive means of dynamically testing the feasibility of the physical urban pattern in terms of broad social, economic and environmental goals of sustainability. In this way, the analysis can be a useful tool in an active approach to urban pattern control.

In general GIS based analysis offer a powerful tool for suitability analysis due its capability to process and analyze different layers of spatial data. Further, the paper demonstrates, the application of GIS for identifying ecologically sound lands for green space development with some maximum benefit to the society.

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