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Multi-criteria evaluation for sustainable horticulture

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Abstract

Multicriteria evaluation is a transparent way of systematically collecting, processing and analyzing objective information. This method integrates multiple criteria in order to combine all the relevant concerns in the decision problem as a gauge for comparison. Agricultural crop suitability is one of the interdisciplinary approaches that involve integration of criteria from different branches of science. Assessment for vegetable development in Plovdiv, Bulgaria is influenced by many parameters namely, soil and land parameters, climatic attributes, terrain and physiographic, social characteristics, cultural aspects, cultivation customs, infrastructure and human development, services available, market situations, live-hood of population, standard of living, ecology and many more. All of them can logically be classified into following categories: physical characteristics, environmental parameters and socio-economic condition. Matching all these conditions and different requirements to assess the suitability of horticulture is carried out by Analytical Hierarchy Process (AHP), developed by Saaty (1977). By calculating important indicators for sustainable vegetable cultivation, using GIS applications and digital information in the form of assessment map are the core of process.

Keywords: multi-criteria evaluation, sustainable horticulture, Analytical Hierarchy Process (AHP), GIS

Introduction

Agriculture is one of the world's most important activities supporting human life. From the beginning of the civilization man has used the land resources to satisfy his needs. The land resources regeneration is very slow while the population

growth is very fast, leading to an unbalance. On a global scale, agriculture has the proven potential to increase food supplies faster than the growth of the population (Davidson, 1992). Horticulture system analysis through improved methodology of vegetable suitability evaluation is the main aim of present research undertaken in Plovdiv region, Bulgaria.

Multi-criteria horticulture assessment of Plovdiv region is felt increasingly for the sustainable land use and better vegetable production. In this case physical land evaluation includes parameter that satisfy requirement of the vegetable crops and multi-criteria analysis evaluated social and economic indicators (Baniya, 2008). Each land mapping unit is based for the suitability analysis which collectively makes the overlaying thematic maps in GIS tool.

GIS is one of the most intensively used tool for modeling majority of real information into spatial data (Arnaudova et al., 2011). Based on INSPIRE Directives and GIS tools the volume of spatial data can be organized, operated and presented in a useful visual form for government or public level. Analytical part begins with development of environmental characteristics, which is computer aided GIS based data management. Main spatial and non spatial data were obtained through field work, literature review, expert opinions, interviews of local farmers, professional agencies and other information from the local authorities. The multi-criteria assessment is achieved by pair-wise comparison using Analytical Hierarchy Process (AHP). All aspects of spatial data can be explored and crossing each other. All collected data will be conformed to necessity of cultures development. All this kind of activities and interaction is produced on conceptual model for vegetable

production. This comprehensive overview develops a logical consequence of geographic data and its influence on vegetable development in Plovdiv region.

The multi-criteria model, which this report presents, is a framework of different conditions, which are significant for vegetable crop production. Suitability evaluation was carried out in two different phases namely:

1) Physical land suitability evaluation

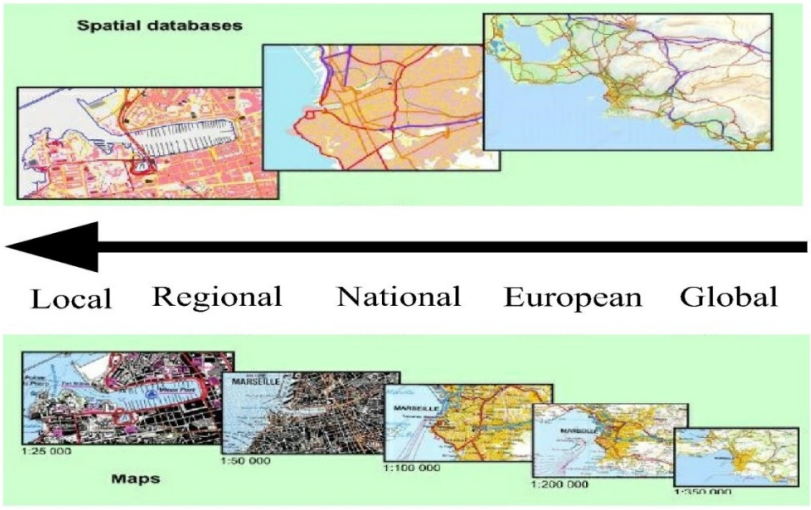
2) Socio-economic-infrastructural land evaluation (Baniya, 2008).

This report presents an integrated view of the spatial data, highlighting the main features of the environmental development. It is addressed to vegetable crop production and mainly land using for sustainable horticulture. The main objectives of this report are to explain the aspects of the framework of information and specifications about correct and continued using of land for vegetable development. The main idea of this report is laying down the multi-criteria assessment for established development of vegetable crop production. Information from environmental resources is a key to their careful and effective evaluation.

Description of the studied area

Vegetable production is an important component of agriculture and also an essential part of a balanced human diet. In recent years, vegetable production has also become an income generating enterprise for those farmers who are located close to markets and road sides (Budathoki, 2002). Vegetable farming is increasing in Plovdiv region as it has more economic returns than growing other crops, especially in the areas that have easy access to market. Vegetable farming demands intensive care and balanced nutrients input (Bileva et al., 2011).

Vegetable cultivation is traditional subsection of horticulture in Bulgaria, which is determined by good environmental conditions and increasingly qualification of the population during the years. South Central region is the main region of horticulture production, especially Plovdiv and Pazardzik region. The main live hood of the population in these locations is the horticulture. The diverse topographic features and climatic conditions in Plovdiv region permit the successful production of a large number of vegetables. The most growing vegetable plants are tomatoes and papers. Total area of Plovdiv region is 597220 ha. According to Agro-Statistical Reference book of the Ministry of Agriculture for the period 2008 to 2012 years the area with tomatoes plants are increased from 2924 ha in 2010 to 3860 ha in 2011. The results from analyses for pepper is similar. For the researched period pepper areas under cultivation change from 3013 ha in 2012 to 5013 ha in 2009. By this analytical information is made generalization for the whole vegetable areas in Bulgaria. By years and for the whole period, South - Central region is leader. The research like this has never been done before. So it is considerable to know how vegetable plan production is change during the years. This knowledge can permit us to make forecast for the future yields, to examine the strong and week points of vegetable development and to improve the environmental conditions.



Materials and methods

Cultivation is the act of making use of environmental resources to get production for livelihood of mankind. Therefore, cultivation involves both characteristics including qualities and human activities. While evaluation is purely based on the land, soil and climatic parameters, it is simply called as the physical land suitability evaluation. Incorporation of physical and climatic suitability for vegetable cultivation with the socio-economic attributes makes multi-criteria assessment of the horticulture. Examination includes information from real scientific experiences, culture practices and last analyses relevant to plan production in Plovdiv region. Suitability evaluation of vegetables is carried out considering each component separately. Physical land suitability, socio-economic suitability and environmental suitability are established ones. All necessary data about physical suitability for sustainable vegetable development is presented by the next table.

Table 1: Category of dominant and ordinary physical factors for vegetable crops in Plovdiv region

WEATHER CHARACTERISTICS	**LAND CHARACTERISTICS**	**SOIL CHARACTERISTICS**
Temperature	Land slope	Soil type
Rainfall	Surface orientation	Soil texture
Humidity	Elevation	Soil depth
Sunshine hour		Soil Fertility
Irrigation		Soil reaction (pH)
Wind speed		Organic Matter
Evapotranspiration		Water holding Capacity
Hydrography		Soil preparation
		Soil erosion

All of the dominant as well as ordinary characteristics are ranked on the basis of agronomical and physiological requirement of the selected crops. Data gathering is completed by information from The Soil Resources Agency, The Institute of Soil Science “Nikola Pushkarov”, Agro - Statistical Reference book of the Ministry of Agriculture for the period 2008 to 2012 years.

Socio-economic suitability is presented by different parameters worked on comprehensive influence over horticulture practices. Majority of spatial data about these characteristics are collected into the next table.

Table 2: Social and economic factors for vegetable crops in Plovdiv region

SOCIO-ECONOMIC ATTRIBUTES	
Marketing	Employment
Economy of the country	Existing road systems
Demography parameters	Mechanization of the working
Poverty	Education and qualification
Standard of living	Prices of the vegetable
Income and expenditure	Investments
Production transporting	

Thematic maps are the basis of the suitability analysis. The maps in present study include land use map, land capability, soil maps and map of administrative boundaries (Arnaudova et al., 2011). Those thematic maps are created and edited, overlaid and visualized. Application of GIS for overlaying thematic layers to establish land databases has to be converted into consistent coordinate system. Several maps like land capability map, land use map, road map and administrative boundary maps were collected. All spatial information is kept in the GIS framework and managed by GIS applications to create assessment map of vegetable production in Plovdiv region.

One of the most useful applications of GIS for planning and management is the land use suitability mapping and analysis. The map overlay approach has been typically applied to land-use suitability in the form of weighed linear combination (WLC). GIS-based data can be thought of as a process that combines and transforms spatial and non-spatial data (input) into a resultant decision (output) (Malczewski, 2004). These procedures define a relationship between the input maps and the output map. Matching of social-economic, environmental conditions and different requirements to assess the suitability is carried out by different methods. Analytical Hierarchy Process (AHP) is a widely used method in multi-criteria decision making and was introduced by Saaty (Saaty, 1977). AHP is a proven, effective means of dealing with complex decision making and can assist with weighting selection criteria, analyzing the data collected for the criteria, and expediting the decision-making process. By making pair-wise comparisons at each level of the hierarchy, participants can develop relative weights, called priorities, to differentiate the importance of the criteria (Hossain et.al. 2007). Development of weight in pairwise comparisons developed by Saaty (1977) is one of the appropriate decision making tool for multi-criteria assessment of vegetable cultivation.

Suitability analysis is the decision making part which is the vital of the suitability assessment job. Based on the vegetable cultivation parameters, selection of the suitable mode for the decision analysis is important part. The criteria are selected from physical environment, social and economic aspects including infrastructural aspect. The method use for the analysis is presented as follows.

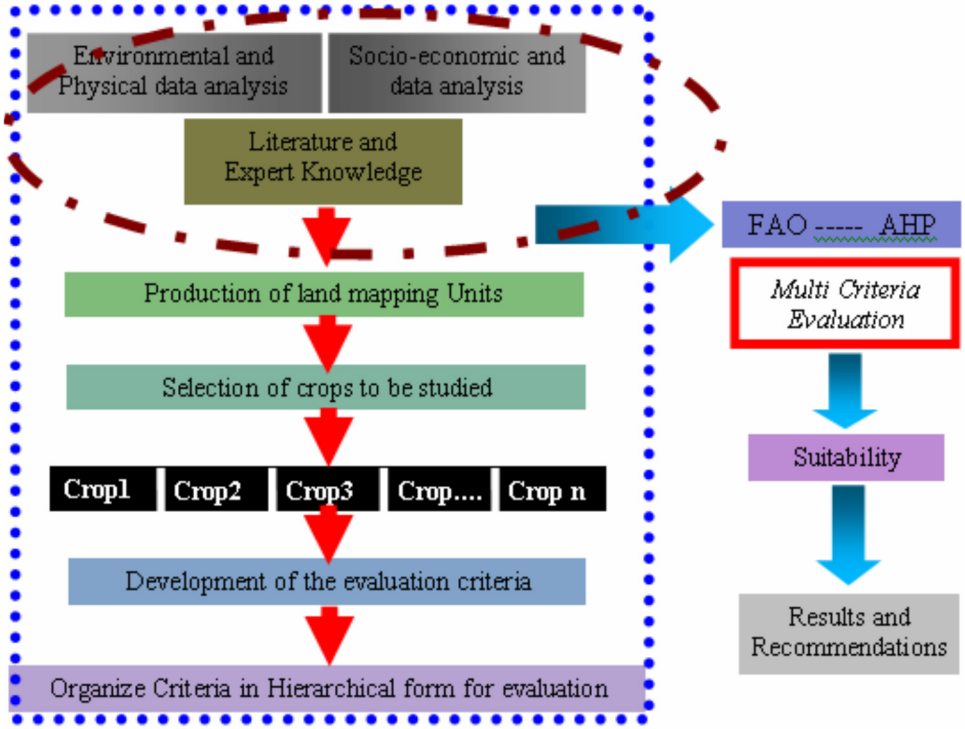


Figure 1: Conceptual flow of the research approach (Baniya, 2008)

Results

Land suitability assessment for vegetable development in Plovdiv region is influenced by many fundamental parameters namely, soil and land parameters, climatic attributes, terrain and physiographic, social characteristics, cultural aspects, cultivation customs, infrastructure development, services available, market situations and many more. All of them can logically be discussed under two categories:

- Physical and environmental parameters
- Socio-economic parameter

Almost all agronomical need of a crop is fulfilled by components of physical environment. Where as latter parameter is more likely to effects on final yield and handling of the product and post harvest handling is also depends upon same parameters. Cultivation trend in society and land use practices is social and cultural traits, which makes impacts on yield of crop. From field to kitchen (from soil to consumer) or to market is affected by the socio-economic and infrastructure attributes (Baniya, 2008).

For the development of the vegetable farming in the areas like Plovdiv needs to understand fully the land capability, which is the first and far most important aspects. This kind of research for vegetable development in this region is not done before, so it is important to understand the priority of environmental capacity. Land and soil characteristics are one of the most significant parameters, concerned to plans growing. Physiographic setting of the region allows growing of ordinary and specific crops, which are the most used in live hood and household in our country. Planning of vegetable crops begins with the selection of the suitable species based on the ecological condition of the located area.

Traditional way of cultivar improvements and selection is cultural practice in many parts of our country, on which farmers are accustomed. Understanding of soil quality and climatic condition assist to a greater cultivation of suitable species of vegetable. Infrastructure development and investment of state and central government on the horticultural sector also plays role. Road access network, setting up market place and controlling price, agricultural subsidy, etc would make impact on the yield and economic benefit from the farming. Relationship among different influencing factors should be judged properly for selection of the land area according to agronomical need of plants, capability possess by land area, farming attitude of the society and economic potentiality with infrastructure investment in land. Carry out the components of environment will generate land area which is suitable for the specific type of crop. The result will yield suitability evaluation of land area.

The dominant factors are decisive and unchangeable factors, for instance: soil type, terrain, slope, soil layer depth, etc. Other factors are ordinary ones, which hardly affect the full aspect of vegetable development. The dominant factors and ordinary factors is clearly expressed with having the presence of socio-economic conditions, infrastructure in the evaluating process. The influence of physical land, environmental condition and socio-economic lays down the framework of the suitability levels of the land mapping. Infrastructure and input availability has marked effects on the yield and economic benefits from the crop. Marketing channel, standard of living, employment, mechanization, qualification of the population, investments, government actions, etc. are very important and have significant impact on the horticultural development. Multi-criteria suitability analysis includs physical land characteristics, economic parameters and social traits. Physical parameters are prerequisite, so multi-criteria evaluation will be proceeding only if land area is physically suitable. The physical evaluation by involving climate characteristics and the development of a complete economic evaluation brings valuable results.

The research focuses on the study of land suitability evaluation of vegetables in Plovdiv region. Research methods include collection of available and new field work data, data analysis using various tools and techniques. The research needed data on climate, hydrology, topography, soil, land cover and land use. In addition to these, data were collected to assess indicators of land utilization in various ranges. Data gathering included field surveys, laboratory analysis and secondary data collection from various organizations and individuals (Bileva et al., 2011). The main purpose of the Multi-criteria evaluation techniques is to investigate a number of alternatives in the light of multiple criteria and conflicting objectives (Voogd, 1983). Multicriteria decision making could be understood as a world of concepts, approaches, models and methods that aid an evaluation according to several criteria (Barredo, 1996). This method enables the combination of many criteria into a one model of suitability. It is a transparent way of systematically collecting and operating heterogeneous information.The main goal

of multicriteria evaluation is to generate a gauge to compare possible alternatives or solutions.

Suitability assessment of agricultural development is one of the interdisciplinary approaches that involve integration of criteria from different branches of science. Criterion may be both qualitative as well as quantitative. Therefore, multicriteria analysis can be used to define the most suitable areas for agricultural crops. Multi-criteria decision making, combined with GIS data, is a powerful approach to systematically and comprehensively analyze a problem.

Social and cultural characteristics influence horticulture cultivation in developing countries like Bulgaria is also effected by social attributes. Importance of social parameter for suitability assessment should be raised from the opinion of individual and corresponding weight can be given for analysis purpose. The flowchart of social, economic and environmental land suitability analysis is presented as follows.

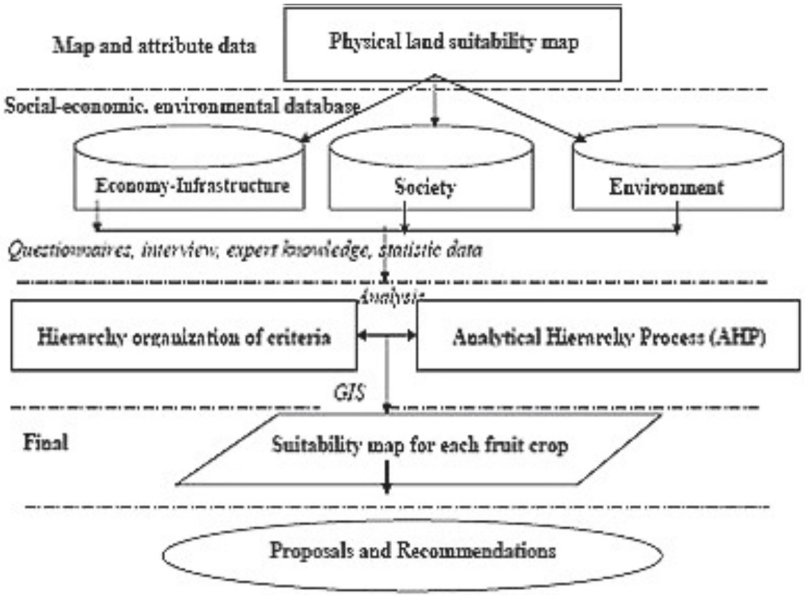


Figure 2: flow chart showing application of GIS and AHP for physical environment, social and economic-infrastructure suitability evaluation (Baniya, 2008)

Socio-economic, environmental suitability evaluation is carried only on those areas which are physically suitable. If land unit show degree of unsuitability in physical suitability assessment, they are further not taken for the suitability assessment.

To achieve the full assessment of horticulture in Plovdiv region is used GIS tools and Analytic Hierarchy Process (AHP), introduced by Saaty (1977). This theory on analytical hierarchy process (AHP) is the backbone of the pairwise comparison of criteria. The AHP is a practical and effective method for solving multi-criteria decision problems (Guo et al., 1998) which uses hierarchical structures to represent a problem and then develop priorities for alternatives based on the judgment of the user (Saaty, 1980). Suitability analysis consists of multiple criteria and alternatives which must be useful to decision-maker in order to achieve a goal. At the same time, this model can also be expanded in other parts of our country for better land management purpose. It is recommended from the research to set a panel for gathering and updating reliable and consistent data, both spatial and attribute data. With usually used weighted linear combination, factors are combined by applying a weight to each followed by a summation of the results to yield a suitability map. GIS have emerged as useful computer-based tools for spatial description and manipulation. All spatial data related to economy-infrastructure, society and environment is converted into thematic maps. Then all suitability maps are overlayed and the results appeared-assessment map of sustainable horticulture.

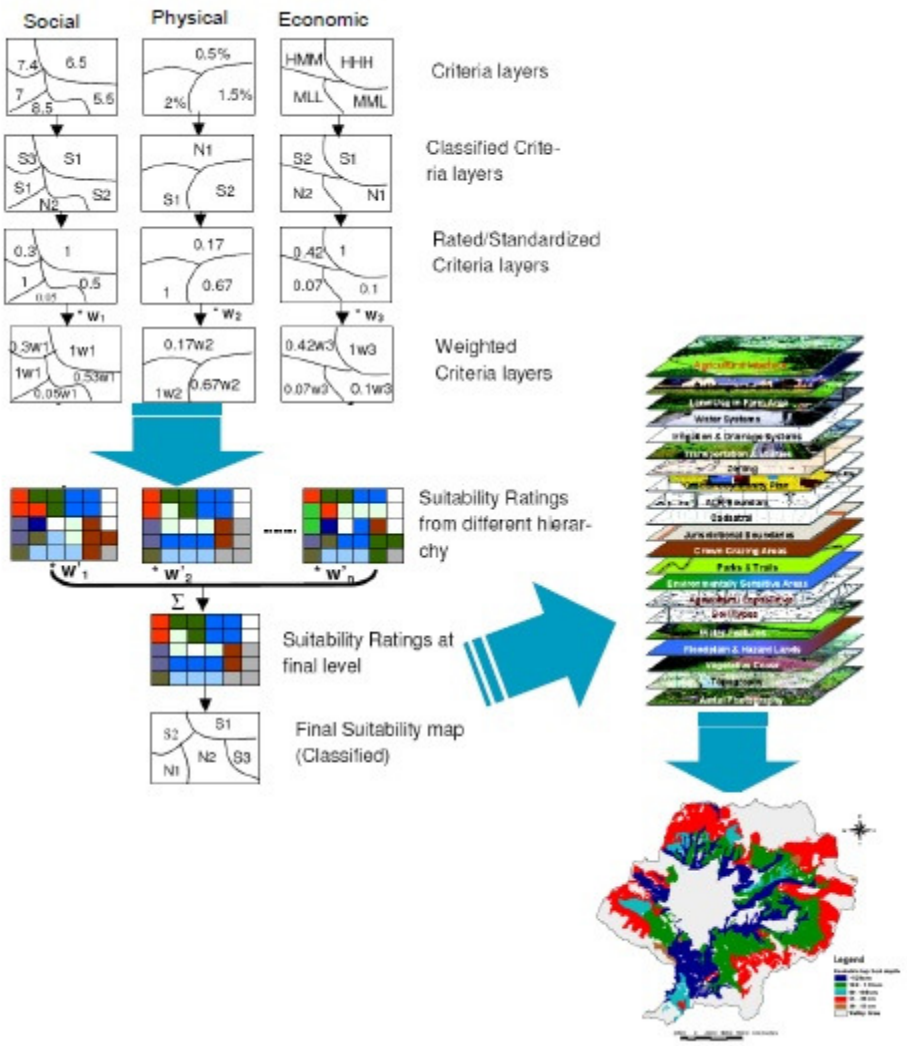


Figure 3: GIS based model for multi-criteria land suitability evaluations for agriculture (Baniya, 2008)

Classifying and evaluating all suitability criteria are valuable proposals for effective and profitable horticulture planning. All researches satisfy the idea of significantly improving the growth, development and productivity of vegetable crops.

Conclusion

Multi-criteria evaluation for sustainable horticulture in this study uses physical and environmental parameters, social attributes and economic indicator as necessary factors for best possible outcome consulting both with farmers and experts. Spatial information like maps and attributive characteristics are incorporated into GIS based data as a system. Use of social and economic parameters through AHP analysis provides reflection of real situation of study area. Therefore social and economic attribute together with land quality information in present work are combined to have useful, comprehensive, systematic, easyto- use and easy-to-update information system (Baniya, 2008).

Vegetable sector is one of the important components of Bulgaria agriculture where diversity in vegetable cropping is presented by different agro-ecological regions of the country. Results from the physical land suitability are combined with socioeconomic land suitability evaluation. The total out put is portrayed in the thematic map of the Plovdiv region. Result of multi-criteria evaluation is used to determine the investment requirement. Horticulture suitability evaluation is one of the best alternatives and multicriteria evaluation further gives

best suitability classification considering wide range of multi-disciplinary alternatives. The goal of assessment map is to present the best appropriate and lucrative development of vegetable plants, workable to further forecasts and substantial investments.

Acknowledgement

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