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A Review of Spatial Multi Criteria Analysis (SMCA) Methods for Sustainable Land Use Planning (SLUP)

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***Abstract*—Despite increasing necessity for considering sustainability traits in any use to which land is put as well as the proliferation of numerous decision support tools, there is a lack of appropriate guidance for decision-makers on the selection of appropriate method among these decision support tools. This study reviews existing literature on state of the art on Spatial Muilti Criteria Analysis (SMCA). Various methodological approaches of the SMCA have been analyzed with their various examples. An attempt is also made to determine the appropriate technique among the various SMCA methods for SLUP as detailed in this paper. This work was carried out on journal papers obtained through extensive literature review.**

Keywords—Sustainability; Spatial; Multi Criteria; Land Use; Abridgment; Planning.

I. INTRODUCTION

Despite increasing necessity for considering sustainability traits in any use to which land is put as well as the proliferation of numerous decision support tools, there is a lack of appropriate guidance for decision-makers on the selection of appropriate method among these decision support tools. Yet the management of a wide variety of information types, parameters and uncertainties are required for the land use sustainability assessments. Due to its dynamic nature and the possibility of facilitating dialogue between stakeholders, Spatial Multi Criteria Analysis (SMCA) has among the numerous decision support tools, been regarded as a suitable approach for sustainability evaluations [1]. This study analyzes critically the methodological approaches of the SMCA in general with their examples to determine the appropriate for SLUP.

Due to the identified advantages of the SMCA in land suitability analysis for various uses, various authors have attempted to provide an inventory of the various approaches used in SMCA [1-12]. Linkov and J. Steevens (2006) identified four approaches for optimizing algorithms namely; Multi-attribute utility theory (MAUT), multi-attribute value theory (MAVT), and the analytical hierarchy process (AHP) [8]. The fourth approach is the outranking which avoids optimization in favour of a dominance approach. The group also discussed the merits and demerits of the methods. Malczewski (2006) surveyed the SMDA approaches using a literature review and classification of articles from 1990 to 2004 using He used an electronic search and obtained over 300 articles [10]. In addition, Malczewski (2006) identified and categorized various classifications of SMCA based on the three dichotomies; the raster versus vector data models, explicitly spatial criteria versus implicitly spatial criteria, and lastly explicitly spatial alternatives versus implicitly spatial alternatives. Based on the generic elements of SMCA, Malczewski (2006) identified three dichotomies; multi-objective decision analysis (MODA) against multi-attribute decision analysis (MADA), individual against group decision-making, and decisions with certainty against decision without certainty. He also looked at the extent of integration, and the direction of integration of GIS and the MCA. Lastly, he looked at the application domains and decision problems. What was left out in his work is that he did not critically analyse the methodologies of the SMCA approaches, which is very crucial in determining the appropriate approach for Land Use Planning [10].

Furthermore, Ananda and Herath (2009) reviewed articles on SMCA but limited it to application in forest management and planning, without considering all other domains [3]. However in 2011 the group of Huang and co-workers examined the various SMCA applications in environmental domain between 2000 and 2009 [7]. They classified the articles by their environmental application area, decision or intervention type, then considered three methods of analysis namely; analytic hierarchy process, multi-attribute utility theory, and outranking. SMCA application articles using analytic hierarchy process (AHP) in land suitability analysis have been investigated by Chandio, et al., without considering other approaches of SMCA [4]. In an attempt to make SMCA more accessible Greene, et al., [6] summarized various background methods of SMCA considering that the field has not achieved widespread acceptance. IN addition, the group pf Greene covered most of the methodologies of various approaches of SMCA but did not make comparison of methods toward determining the most appropriate for land use planning.

The four sub application areas of SMCA namely; Landslide, Flood risk assessment, Site selection and Vulnerability assessment have also been outlined [2]. Ferretti (2012) carried out a review as well but his work was is extension of the Malczewski (2006) review by extending the period to 2011 [5, 10]. He highlighted the commonly used methodological approaches with reference to the MCDA components i.e. Multi-objective Decision Analysis against Multi-attribute Decision Analysis), the GIS components i.e. raster against vector data models, the degree of integration between the MCA and GIS, the decision process approach i.e. value focused thinking against alternative focused thinking, the aggregation rule used, and the type of application area. Ferretti (2012) restricted his literature source to the SCOPUS web based scientific database between 1990 and 2011. Although he found and analysed 365 articles in refereed journals, and highlighted the most commonly application area to be land suitability analysis in the context of urban and regional planning, usually based on a loose coupling approach and on a value focused thinking framework, his analysis of the aggregation rule used, which is the main methodological approaches, was not critical to determine the most appropriate for land use planning. Two review of SMCA articles were conducted in 2013 by a number of other groups in literature [11, 12]. However, Neste and Karjalainen (2013) restricted their review to SMCA articles that were applied in environmental impact assessment (EIA). Generally, familiarity and affinity with certain SMCA method seem to be the consideration of those authors for the choice of a certain procedure. Thus the reasons for choosing a certain SMCA method instead of another, have not been well defined [1]. The advantages and disadvantages of the methods they identified has also been detailed in literature [12]. They also attempted to explain how the common applications of the methods relate to their relative strengths and weaknesses. Their work assessed the more common methods of SMCA. They observed that the combination of multiple methods addresses deficiencies that may be seen in certain methods. Although, due to advancing technologies, combining of methods is becoming easier to some extent, it remains no go area for the unprofessional. Velasquez and Hester (2013) have also highlighted the appropriate application areas for the methods to some extent. However, they left the choice of methods to be open by suggesting proper assessment of the strengths and weaknesses of the methods. Cinelli, et al., 2014 review was restricted to only five SMCA methods (i.e. MAUT, AHP, PROMETHEE, ELECTRE and DRSA).

The objective of this paper is to briefly analyze the existing literature that focused on the review of the current works on the application of the SMCA in various application domain and to identify the various methodological approaches. An attempt is also made to determine the appropriate technique among the various SMCA methods for SLUP. This work was carried out on journal papers using the use of Google search engine. Google manual search engine was adopted because it provides wide platform of literature, which covers all database sources. Most authors of the existing literature resorted to it after using the automated search domains [6, 10]. The journal papers that review the ‘state of the art’ on SMCA, were briefly reviewed, while the categorization of SMCA based on their methodological approaches were analyzed in detail. Lastly the appropriate SMCA technique is determined for Land Use Planning is determined.

II. CLASSIFICATION OF SMCA

There are several techniques that have been identified under the canopy of SMCA, each involving diverse procedures for imputation, various structures for representation, alternative algorithms for the data combination, numerous processes for interpretation and selection of alternatives as well as result presentation in decision making contexts [1, 3, 5-8, 12]. Based on these diverse techniques, there are several SMCA classification method by different authors. Nevertheless the method used in classification, almost all methodologies of SMCA have some similarity of steps for organization and decision matrix development, but information is synthesized in different ways by each method). Different approaches adopt different optimization algorithms and involve different kinds of input information. Some techniques rank options, some identify a single optimal alternative, some provide an incomplete ranking, and others differentiate between acceptable and unacceptable alternatives [8].

Likewise, SMCA techniques can be categorized in ways that involve classifying alternatives or scenarios in association with various problem types. These categorization include making a single selection or recommendation referred to as choice; establishing a preference order for the alternatives, called ranking; separating alternatives in classes or groups, referred to as sorting [6]; description of the decision problem as mentioned earlier; that is developing new design or alternatives for possibly addressing the problem, and selecting a subset of alternatives called portfolio [6, 13]. Description of decision problems in SMCA, making choice and implementation are influenced by the number of decision makers, decision stage, number of objectives, number of alternatives, and existence of constraints, risk tolerance, uncertainty, measurement scales and units.

SMCA techniques are applied to achieve consensus through education, negotiation, aggregated weighting or voting [14, 15]. There are numerous methods to organise and describe decision stages i.e. stages of the decision process are supported in different ways among the problem structuring stages, the evaluation and the recommendation phase. SMCA may be carried out with single objective such as recommending the site for the cultivation of a predetermined land use [16]. In this application, the emphasis is the relevant criteria or features with measurable attributes. As highlighted previously, SMCA can also be applied for multiple objective decision-making, with few or many alternatives [6, 10, 12]. SMCA carried out for situations with few alternatives are distinct problems that usually conclude in a single selection [6, 17]. The Scenario can have multiple alternatives that signify a continuous problem involving screening, search, or suitability rating [18]. Constraints may exists in spatially continuous problems such as the need for recommended areas to have corridors of connectivity or have minimum contiguous size [17, 18]. Risk tolerance level when screening alternatives may either be flexible to accept alternatives that meet just few criteria or the risk tolerance level will be strict by accepting only alternative that meet the goal. Based on the nature of the criteria or modelling preference, the criteria and weighting should be modelled with certainty or uncertainty. In land-classification for example, the transition from shrubs to grassland could be modelled with crisp boundaries or fuzzy boundaries require similar units of measurement and scales where they differ, there may be need to convert them to common platform [6, 12].

The above discussion revealed that SMCA classification can take the following; technique or aggregation approach, level of integration between MCA and GIS, vector data versus raster data, value focused approach versus alternative focused approach, practical application versus theoretical approach, decision problems and application domain, as well as multi-attribute decision making (MADM) versus multi-objective decision making (MODM). The classification that matters in this work i.e. SLUP, is the methodology in terms of technique or aggregation approach.

III. CATEGORIZATION OF SMCA BASED ON THEIR METHODOLOGICAL APPROACHES

Due to the diverse nature of information that is required in SLUP and the fact that most agricultural land uses being carried out in most parts of the world, pose great challenges to the environment and the global economy as well, evaluation of various approaches in SMCA is required. It has become pertinent to determine which on the SMCA approaches will be most effective for SLUP. Based on their methodological approaches, SMCA are divided into non-compensatory approaches, compensatory approaches, outranking methods, mathematical programming and heuristic approach [1, 6]. SMCA that involve many objectives support criteria trade-offs because they are generally compensatory by nature. Due to the complexities and multiple phases of decision analysis, the methods are not mutually exclusive. A compensatory method could be used for preliminary screening of alternatives, followed by a non-compensatory approach to support final selection. In some cases, criteria weighting is carried out before the compensatory or outranking methods are applied, while non-compensatory methods do not require initial criteria weighting.

A. Non-Compensatory Aggregation Methods

Non-compensatory methods are usually used for screening as well as selection. Non-compensatory approaches are more direct and simpler but they require alternatives based on a firm limits. These methods include conjunctive, disjunctive, lexicographic, elimination by aspects and dominance [1, 6].

i. Conjunctive: Alternatives are accepted if they meet a cut-off value on each condition but all criteria must be fully met [6, 18]. Binary overlay are usually used in conducting spatial problems, where the objects in each layer are set to 0 if they do not pass the criterion cut-off for and 1 if the criterion cut off is attained. Logical intersection operation is used to combine layers in defining areas that met criteria.

ii. Disjunctive: This is a risk-taking method because alternatives are accepted if a cut-off value on at least one criterion is met. Binary overlay can also be used in conducting spatial problems, where union operation is used to combine the map criteria layers [6].

iii. Lexicographic: this involves ranking the criteria in an orderly manner. By comparing alternatives on the highest ranked criterion, alternatives are eliminated hierarchically [18].

iv. Elimination by aspects; this method combines the lexicographic approach and the conjunctive cut-off for each criterion [6, 18].

v. Dominance: In this method, the dominant alternatives that score at least as high as every other alternative on every criterion is selected [6, 18].

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B. Criteria Weighting for Compensatory method

In this method, relative criteria weights or order of importance are defined, before applying a compensatory aggregation method. They include ranking, rating, trade off analysis and pairwise comparison [13, 19].

i. Ranking; this involve ranking of criteria in hierarchical order followed by conversion of the ranks into weights. This is done in one of the three ways; rank sum, rank reciprocal and rank exponent.

- Rank sum; in rank sum, each rank value is divided by the sum of all rank values.

- Rank reciprocal; in rank reciprocal, 1 is divided by each rank value.

- Rank exponent; the resulting weight differences is reduced by a rank sum with the numerator and denominator raised to a power between 0 and 1.

ii. Rating: a common scale is used to rate the criteria such as any value between 0 and 1, or point allocation.

iii. Trade-off analysis: In this method, trade-offs between pairs of criteria are evaluated to define the cut-off values at which they are considered equally significant.

iv. Pairwise comparison; this is used in Analytic hierarchy process (AHP) and Analytical Network Process (ANP). Criteria pair-wisely compared on a ratio scale, followed by computing the overall relative weights based on aggregate calculations of all pairwise ratios [20, 21].

C. *Compensatory method*

In compensatory methods, loss in one criterion can be compensated for by a gain in another. Modelling of compensatory methods is delicate, but realistic because criteria outcomes are assessed against each other on a continuous scale [1, 6]. Compensatory decision rules may or may not require pairwise comparison of alternatives. The decision rules that do not require pairwise comparison of alternatives are of two types. They are the additive methods and the non-additive methods using original criteria scores.

a) Additive methods. These methods normalise criterion scores to enable comparison of performance on a common scale or platform. They include; weighted linear combination (WLC), fuzzy additive weighting (FAW) and ordered weighted averaging (OWA).

i. WLC is sometimes referred to as simple additive weighting (SAW). In this approach, normalised criteria scores are multiplied by relative criteria weights for each alternative [19, 22]. In order to aggregate each group of related criteria, such as agriculture in a rural land-management, all weighted criteria values can be summed in a single step, or proceed hierarchically, before it is combined with other groups. WLC is considered as a risk-neutral method. It falls at the middle continuum between conjunctive and disjunctive approaches on the risk tolerance, because it supports full compensation among criteria values. Estimates revealed do not always reflect the real situation; result obtained may not be logical [12, 18].

ii. FAW adapts WLC with the use of non-crisp criteria and weight values derived from fuzzy-linguistic quantifiers such as 'high', medium and low [3, 23]. The studies express lamentation that some of the irrigated districts failed to commence operation due to inappropriate site selection. The study was carried out to develop a model that would enable the selection of appropriate agricultural sites. Several influential parameters were identified with regard to economic, social, environmental and technical status to rank suitable sites for irrigation. Grouped into five main classes, namely suitable land for irrigation, cost effectiveness, resources conflicts, social acceptance and environmental impact, each criterion was subdivided into several sub-criteria, pair-wise comparison matrix was used to compare these criteria and sub-criteria, and then rank them according to their relative importance for site evaluation. A total of 11,426 hectares which is about 31% of the study area was found to be suitable area. This constitutes quite a large zone that can increase the region's agricultural production. The best sites were found to be located near the treatment plants and they were proposed to receive the surplus amount of the TWW, produced by the treatment plants of the region.

The work of Anane, et al. (2011) shows that FAW could be used to ascertain why some agricultural programs are not sustainable. Fuzzy theory enables solving of several problems involving imprecise and uncertain data. It takes into account the insufficient data and the development of available information [24]. Problems with great complexity can be resolved with few rules. However, fuzzy systems are at times difficult to develop. In some problems, numerous simulations might be required before being able to be used in the real world [12].

iii. OWA is fuzzy based method that extends WLC with the use of criteria-order weights to control the levels of criteria trade-off. This places the decision makers on a constant range of risk tolerance [10]. The group of Drobne and Lisec (2009), applied weighted linear combination (WLC) methods and ordered weighting averages (OWA) for land use suitability analysis [25]. This approach lacks complete independent weighted selection attributes, scale and methods of aggregation of attributes, error assessment, and incorporation of database and sensitivity analysis, therefore a better model is required. In an attempt to improve the OWA Greene and co-workers assessed the capability of SMCA to integrate exploration and evaluation phases in a digital format [6]. This is an improvement over the use of WLC and OWA by Drobne and Lisec (2009) because it has independent weighted selection attributes. Greene, et al. (2010) tested the validity of the work on forest-dominated landscape management with stakeholders. It was used in areas within timber harvest plan, with regard to potentials and conflict with conservation values. The short comings of this model include the involvement of tremendous computation and linear equations whose solution is at times non logical, only triangular fuzzy numbers are used and it is based on both probability and possibility measures.

b) Non-additive methods using original criteria scores including; ideal point, non-dominated set (NDS) and the reasonable goals method (RGM).

i. Ideal point. This method defines a point in criteria result space by stating the preferred value of each criterion. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is one of the methods for selecting this ideal point [19, 26]. TOPSIS identifies alternative that is nearest to the ideal resolution and farthest to the negative resolution in a multi-dimensional computing space [27]. It involves comparing a set of alternatives by identifying weights for each measurement, standardizing scores in each measurement and computing a distance between each alternative and the ideal alternative and the worst alternative throughout the weighted measurements, using one of the numerous distance measures such as Euclidean distance [7, 12]. Lastly, ratio is used to compute alternatives to describe the ratio between the distance from the worst and the sum distance from the ideal and worst alternatives is computed [7]. TOPSIS is easy to use because it has a simple process and it is programmable using only decisions required weights. The comparative distances depend on the weights and the variety of the alternatives, and the non-linear association between one measurement scores while the distance ratios produce even trade-offs. The number of steps remains the same regardless of the number of attributes and the use of Euclidean Distance doesn't consider the correlation of attributes.

The effectiveness of TOPSIS could be seen in Bakhtiarifar, et al. (2010) who developed two models using the combination of TOPSIS and two other methods; the Elimination and Choice Expressing Reality (ELECTRE) and Simple Additive Weighting (SAW), to determine land use suitability and compatibility of the changes [28]. In addition, another model was developed for new land uses allocation based on suitability, compatibility, difficulty of land use change and demand factors. In this model, land units with lower levels of suitability and compatibility were considered and evaluated with the aim of changing it to more adequate land uses. This work was robust, but besides the analysis of the present condition of land uses, there is need to evaluate future land use patterns and scenarios from the land use suitability compatibility through predictions, simulation and cellular automata and per capita levels points of view using the models. Another instance is Khosravi, et al. (2011) on application of TOPSIS in selecting rice milling system in Iran [29]. This is a developing country and one of the biggest rice importers.

The aim of Khosravi et al. (2011) study was to pave way for making Iran self-sufficient in the production of rice. TOPSIS was used to optimize this goal with the input of white rice breakage percentage; the market demand of the product; energy consumption rate; the system's capacity and system's costs as the rice milling attributes. Three alternatives of traditional and modern rice milling systems were defined as the rice milling candidate. Through this process, the most important decision making factor in selecting rice milling system actualized [29]. TOPSIS simplicity and capability to preserve similar steps irrespective of the problem size has promoted it rapid adoption for the review of other methods, or to stand on its own as a decision-making instrument. However, it is difficult to weight attributes and keep consistency of judgment, especially with additional attributes.

ii. NDS also called efficient or Pareto set, defines set of alternatives that score at least highest score of every other alternative on at least one criterion [9].

iii. RGM: This is an extension of the NDS. It assists visually in selecting an alternative using a series of two-dimensional graphs of criteria outcome space.

D. Outranking Aggregation Methods (OAM)

Based on concordance and discordance method, OAM utilizes pairwise comparison to rank discrete set of alternatives [13]. OAM assumes that, even during the SMCA process, decision makers are subject to vague and changing value judgements. The prominent methods of OAM are:

i. ELECTRE: This is an acronym for Elimination and Choice Expressing Reality. It is an outranking method of SMCA based on concordance analysis, which originated in Europe in the mid-1960s [12, 30]. ELECTRE is usually used to discard some alternatives in the problem, which are unacceptable. This application has two main phases; the first phase involves the creation of outranking relations, which compares each pair of actions in a broad way, while the second phase is a manipulation process that expands the recommendations obtained in the first phase [7, 8, 10, 12]. ELECTRE is used to analyze various problem types (choice, ranking, sorting) and approaches in decision making processes. By choosing, ranking or sorting, the nature of the recommendation depends on the problem being addressed. Thresholds are introduced for declaring preference or indifference among alternatives on a particular criterion. It supports criteria that cannot be weighted. It can be applied using another SMCA with a restricted set of alternatives saving much time. It considered uncertainty and vagueness into account in the analysis of problem [12, 31]. However, its process and outcomes requires certain degree of professionalism because it is hard to explain in layman's terms. The lowest performances under certain criteria are not represented, due to the approach of preferences are integrated. The strengths and weaknesses of the alternatives are not openly identified in the method. Likewise the results and impacts are hard to verify verified.

ii. PROMETHEE: This is an acronym for 'Preference Ranking Organization Method for

Enrichment Evaluations'. Similar to ELECTRE in terms of being an outranking method and having several iterations, PROMETHEE supports various criterion preference functions such as partial or complete ranking of the alternatives, when the set of viable solutions is continuous like U-shaped, linear and flat, problems with segmentation constraints and the human brain representation [6, 12, 22, 32]. PROMETHEE has seen much use in agricultural land use planning and related fields like environmental management, hydrology and water management. It is easy to use and does not require the assumption that the criteria are comparable. It requires the assignment of weights and values but a clear method for assigning the weights and the values are not provided.

iii. NAIADE: an acronym for Novel Approach to Imprecise Assessment and Decision Environments. It is a distinct outranking method that applies qualitative, crisp, stochastic and fuzzy information on the criteria by employing the concept of semantic distance in the pairwise comparison [33]. With the use of NAIADE, a multi-criteria analysis and conflict analysis can be carried out. Consequently, the group of Oikonomou and co-workers [34] developed a conceptual framework that provides structure of a participative decision making process, tested and ratified by applying NAIADE for ecosystem function-based planning and management. Multiple and conflicting value judgements were then treated within SMCA to facilitate decision-making process. The MCA evaluation matrix includes fuzzy measurements for performance of the alternatives with respect to evaluation criterion, thus flexible for real-world applications. The approach enables; ranking of alternatives according to the set of evaluation criteria, indications of position distance for various interest groups, possibilities of convergence of interests or coalition formations, and ranking of the alternatives according to stakeholders impacts or preferences. This has opened a wider function in SMCA beyond the limits of modelling process. The challenges of the approach include non-standard procedure for various evaluations of the performance of alternatives and comparison of fuzzy numbers methods pose problem. Information on the social stakeholder' views about comparison of the alternatives for each ecosystem service have not adequately incorporated. Outranking methods generally consider whether over performance on one criterion can make up for underperformance on another, but the procedures used in outranking are usually complex and difficult to be understood by decision makers.

E. Mathematical Programming Methods (MPM)

MPMs attempt to determine the optimal way to satisfy a decision objective by solving systems of equations, through Linear programming, Goal programming or Interactive programming. Programming is a pragmatic method able to select from an unlimited number of options [12].

i. Linear programming are used in SMCA by converting multi-objective problems to a single objective using utility functions in the case of probabilistic models or value functions in the case of deterministic models. It optimizes spatial option mathematically by minimizing or maximizing a single-criterion value using constraints, commonly employed in decision making [6].

ii. Goal programming is used to determine the alternative that minimizes overall deviation or reservation levels simultaneously for multiple objectives [35, 36].

iii. Interactive programming uses reservation levels for each objective to select a feasible alternative [37, 38].

MPM has the ability of analyzing extensive problems. Depending on the situation, the capability of MPM to yield unlimited alternatives provides a significant benefit over some methods. However, many applications have to resort to the use of other methods, such as AHP, to properly weight the coefficients because MPM is not able to weight coefficients. MPMs have been used in diverse endeavor that include environmental planning and management, water resource management, agricultural land use, planning and wildlife management problems. But most of these applications have been used in combination with other methods to achieve weighting. Where a large number of alternatives is involved like spatial modelling with raster data where every possible outcome of every raster cell is an alternative, mathematical optimization is non-attainable, due to computational limitations. It's ability to weight coefficients; typically needs to be used in combination with other MCA methods to weight coefficients.

F. Heuristic Methods

The Heuristic methods in SMCA are referred to geo-computations. They can be used in raster data sets within GIS environment to allocate cells among conflicting objectives, but with close to optimal solution [10, 39]. Geo-computations are being used to relate features of spatial decision support like time series, which are applied in predicting the future outcome of proposed alternatives that result from SMCA. These include; Multiple-objective land allocation (MOLA), Genetic Algorithms and Simulated Annealing.

i. MOLA is used to allocate each cell of the site under analysis to the objective with the closest ideal point. The purposes can optionally be weighted differently, so that a cell can be allocated to an alternative with a greater weight even if an alternative with a closer ideal point exists [6, 18].

ii. Genetic algorithms. Based on a trial-and-error process, Genetic algorithms is used to allocates cells that introduces small changes referred to as evolutionary mutations, and then tests for solution improvement [40].

iii. Simulated annealing is used to allocate cells based on an iterative random procedure, which at each step, tests the overall improvement [41].

Geo-computations such as heuristic methods are used to relate features of spatial decision support to forecast future outcome of spatial decision. This does not give significant avenue for evaluating behavioral tendencies, socioeconomic parameters and stakeholders' interests. It also has the limitation of lack of standard procedure and Information on the social stakeholder' views about comparison of the alternatives have not been effectively considered.

G. Analytic Hierarchy Process (AHP)

This is an eigenvalue system of pairwise comparisons method which works by building hierarchies that enable assessment of each lower criterion contribution to criterion at higher levels of the hierarchy [4, 42-46]. It is based on absolute natural logic, where the elements involved i.e. the qualitative and the quantitative factors in the decision issues are as much as possible classified into comparable factors, relative to their importance, then chosen through calculations based on the highest point. The principle considered in the AHP to solve problems is a structured decision making approach using expert judgments based on numerical fundamental scale, which ranges from 1 to 9 to standardize the quantitative and qualitative performances of priorities [4, 47]. In AHP, involvement of group decisions in ensured and this provides a framework for selecting the best from the various alternatives with regard to multiple priorities. AHP provides an effective framework for the decision-making process with the integrated GIS spatial analysis. It has been used in several land-use planning applications. For example, Akinci, et al. (2013) determines suitable lands for agricultural use in Artvin city, Turkey. It is a region where agricultural lands in some of the districts face the challenges of being inundated due to dams' construction. Imputes were soil groups, land use capability classes, soil depth, aspect, slope, elevation, erosion rate and other soil properties. Experts were consulted to determine the weights of the parameters, and the agricultural land suitability map generated was divided according to the land suitability classification of the FAO. Chandio, et al. (2011) used pair-wise comparison matrix in AHP and priority weights calculated with Expert Choice decision analysis software, to determine land suitability model for hillside developments [4]. Factors considered were accessibility, topography, land cover, and economic factors. This technique can also be applied to various decisions analysis fields, and there is potential application of Expert choice software widely in land use planning and management. AHP presents a powerful tool for weighting and prioritizing alternative research.

AHP is adaptable to structuring of complex weighting problems, particularly when a set of distinct options is associated with various complex set of objectives, as being the case in agricultural planning. In this regard, many works had been carried out on the application of AHP in SLUP such as Enhancing Agricultural Preservation Strategies and Agricultural land use suitability analysis carried out in Yusufeli district, Artvin, Turkey [42, 44]. In effect, the cultivation method on erosion in agricultural catchments [45] and selection of sites for agricultural product warehouses are based in Guadalajara, Jalisco, and Mexico [43]. Although these works were carried out with some degree of efficiency, there are some issues regarding the application of AHP in SLUP that include the problem of defining consistent hierarchies, the rank reversal has been an issue, the large amount of pairwise comparisons to conduct, which is it manually difficult, and aggregating opinions of different stakeholders.

H. Analytic Network Process (ANP)

In order to resolve the issues associated with AHP, Saaty (2005) introduced ANP [20]. Instead of a hierarchical order used in AHP, which is single direction relationships, the ANP based system is a network that replaces the top and bottom relationship with dependence and feedback [20]. Therefore, ANP is more powerful than AHP in the decision environment with uncertainty and dynamics. A number of studies have been carried out on SLUP using ANP. Among these works is Reig, et al. (2010) [48] who showed that in ANP, all the elements in the network can be related in any possible way. With the input of socioeconomic, cultural and environmental sustainability criteria in the study, feedback and interdependent relationships within clusters were incorporated to rank three rice cultivation tools namely; unrestricted traditional, agro-environmental and ecological, in the rice fields of Albufera Natural Park in Valencia, Spain. The work shows that the ANP methodology is perfectly suited to tackling the complex interrelations involved in land sustainability evaluation.

The group of Zhang and Wang (2011) [46], built a model on agricultural products logistics performance evaluation system using ANP. Super Decision (SD) software was used for building super-matrix of the ANP, i.e. the decision models with dependence, feedback and computing the results. The availability of packages of this kind has solved the problem of super-matrix computation. Pourkhabbaz et al., (2014) developed a framework for ecological model using ANP, SAW and customized AHP to choose suitable locations for agricultural land use in Takestan-Qazvin Plain, Iran [49]. Socioeconomic, biophysical and logical parameters were used to show that the application of decision making models could be useful in environmental capacity evaluation of agricultural land use. Targetti, et al., [50] applied ANP in agricultural landscape planning in 8 European

Countries and Turkey to show the strengths and weaknesses of that method. The results stressed the capability of ANP to cross-compare similarities and dissimilarities characterized by different Socioeconomic and biophysical factors.

Schaller, et al. (2014) assessed causal connections between stakeholders, goods provided in agricultural landscapes, socioeconomic benefits created by these goods and the contribution of such benefits to regional competitiveness in 9 European study regions [51]. The study revealed that various elements impact in different ways, on the landscape valorization system, conflicting regional conditions affect the significance of elements that play role in the system. It separates the complex causal relations that exist between agricultural landscapes development and competitiveness of rural regions. It shows that ANP is able to assess intangible assets and benefits, which characterize many components in landscape economy system. This overcomes the limits of monetary evaluation. Upon all the benefits of the ANP, it ranks reversal method and normalization is like that of AHP. As a result, it also faces some criticism as in this regard.

IV. CONCLUSION

The analysis so far has revealed various approaches and techniques for SMCA. Examples have been presented in the course of the discussions. The review revealed that there is no method that is without some limitations. Among the various decision support tools, SMCA seems to have numerous and comfortable advantages over all others. The problem with SMCA stem from the selection methods for evaluation criteria, standardization and specification of criterion weights, since methods are likely to produce disparate land-use suitability patterns, since no method for assigning the weights of relative importance to the criterion maps is inerrant. However, the analysis has revealed that ANP seems to have better advantages over the others. Future studies should consider comparative validation of methods in order to compare the practical result of the various methods.

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