Study on the Application of Information Technologies on Suitability Evaluation Analysis in Agriculture

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Abstract. It is expounded the suitability evaluation research in agriculture in three aspects: land suitability, climatic suitability and crop ecological suitability in this paper. The suitability evaluation methods in agriculture are summarized systematically, which including of traditional mathematic model methods (fuzzy comprehensive assessment analysis, AHP etc.) and modern information technologies (GIS, RS and ES etc.). The future development trends of suitability evaluation in agriculture is pointed out that GIS etc. other information technologies and systems can be used and developed for impact assessments of agricultural practices and for studying the effects of land, climate and ecology etc. change.

Key words: Suitability, evaluation, agriculture, information technology

1 Introduction

The original study of suitability evaluation in agriculture was mainly focused on land suitability for land use planning and city planning et al. Along with the development of suitability evaluation theory and method, the meteorologists and ecologists were also referring to the suitability evaluation analysis in their research. Most suitability evaluation was discussed in three aspects in agriculture: farming land suitability, climatic suitability and ecological suitability.

In the past, many mathematic-based methods have been used for the evaluation of the suitability in agriculture, which mainly concluded mathematic model, fuzzy comprehensive assessment analysis [1, 2], AHP [3, 4], grey correlation degree

analysis and cluster analysis et al. Then artificial neural network (ANN)[5] and information technologies, such as GIS[6], RS[7,8], ES[9], SOTER database[10], AEZ (Agro ecological Zone) and ARC/INFO software[11] et al. were also wildly application. The combination of qualitative and quantitative methods, information technology and mathematical methods combining the integrated use of research methods, making suitability evaluation results more scientific and precision[12,13,14,15].

The research of suitability is not only limited on land, climatic and ecology et al. science area but also combined with economy and society. LiJing in her master dissertation evaluated the eco-economic adaptability and development potential of crops production by using the theory of ecology and economic. They put forward the concept of the apparent eco-economic adaptability of crop-region. They calculated 6 crops' apparent eco-economic adaptability indexes (AEEA) in31 regions by using synthesis scale level and relative output level and scale stability and yield stability. They compartmentalized the adaptability grades of 6 crops in 31 regions, comparatively analyzed the AEEA of crops in each region, and got 5 adaptability grade areas of each crop and dominant crops in each region. Based on the theory of three critical points in ecology and comparative advantage in economics, they put forward the evaluation of eco-economic adaptability of crop production along with the mind of combining the ecology, economics and social background [16]. That extended the ecological suitability evaluation to economy and society which making agricultural suitability evaluation more comprehensive and integrated.

1.1 Traditional mathematic methods

As we all know, some scientists have done a lot of research work on land, climatic, ecological suitability evaluation, but we can also find out that their studies were often limited in one or several factors, which were almost the climatic factors. On the other hand, we know that many other factors can influence the crop growth and develop. Taking into account these factors, they are very complex and numerous even impossible if we continue to use the previous ways and the routine means. With development of the computer, especially rapid progress of GIS, it is possible to consider so many factors to evaluate the suitability [17].

On the one hand, the analysis of great deal of spatial data is needed for the eco-suitability evaluation and planting regionalization of the crop, on the other hand,

the comparison of all kind of the evaluation project is also needed in order to support the establishment of reasonable project. The work is heavy and complicated if using the routine appraisement method. Therefore, by using the important factors to the evaluation objects, the comprehensive evaluation model of suitability was set up. The method of comprehensive assessment analysis was wildly used in the evaluation of the suitability of agriculture. The evaluation index system was established according to the factors selection principle and the actual condition of agricultural region [18]. Actually most of the factors selection principle was subjective and empirical, even by using the Delphi methods to quantify in some degree the experts' subjective conclusion. They selected the factors from professional books, literatures and some experts' experience, such as the light intensity, temperature and precipitation et al. some crop living factors' data. At the same time they will combine with the practical production situation data in the research region, such as more than 20 years climatic data from meteorological stations and crop production data from statistical yearbook et al., then finally the important factors which using in the index system will be determined.

The evaluation factors were selected empirically for each evaluation target. Thus, each evaluation target has its own evaluation factors, and then each evaluation factors should be given its rating values. Weight determination is also a difficult points and key problem in the evaluation system. The grey relational analysis (GRA) was combined with the analytic hierarchy process (AHP) to address the uncertainties during the process of evaluation, especially of the fuzzy comprehensive suitability evaluation [15]. The growing areas of natural sweet wine material were studied by Song Yuyang et al., using of the method of AHP and multi- factors evaluation, and the mathematics model was established [4]. Li Baoguo et al. chose different red Fuji apple growing areas in Hebei , Shandong , Shanxi , Henan in their study , the index which determined fruit qualities in these areas were collected, ecology environment data were gathered at the same time, and then the evaluation equation of red Fuji apple suitable cultivation area were established [19]. Zhan Xiangwen et al. based on black-box theory, a lot of work on data processing and regression analysis had been done, then the parameters required in the evaluation model were got [20]. ZhangJing et al. on the basis of limitation law of ecological factors, variable weight principle and method were introduced into establishing a systemic approach of crop ecological adaptability evaluation to avoid the disadvantages induced by subjective weighting method [21].

In the fuzzy synthetically judgment for suitability evaluation, different type of factors organizational state, each factors importance and main limited factors are different, therefore weight vector to fuzzy weight matrix were extended and rebuilt by Lu Enshuang et al. According to the theory, they found the positive method of fuzzy weight matrix and applied it to Kiwifruit suitability synthetic judgment in mountain area of South Shaanxi, the consequence showed that the method can correctly reflect short-factor's constraint function and the conclusion is in accordance with practice [1]. Wu Kening et.al due to fuzziness in adaptability assessment, established tobacco eco-adaptability assessment models by applying fuzzy comprehensive evaluation [2]. Luolin et al. used the annual mean temperature, annual precipitation, and soil pH which are vital to the fruit tree growth and development to set up the fuzzy evaluation model of ecological suitability. A comprehensive evaluation was carried out for the chestnut grown in Bijie in western Guizhou Province, and a designation of the most favorable region, favorable region, suitable region, and undesirable region was generated [3].

1.2 Information technologies

Since 1900s, modern new and high technology which concludes space, remote sensing(RS), geographical information system(GIS), computer, et al. and modern scientific method which includes systematology, informationism, cybernetics et al. are got extensive and deep application. In developed countries, the application of GIS technology in ecological suitability evaluation could be ascended to 1960s. At that time, overlay aerial image had been applied on urban land use suitability evaluation by the planning designers in American and West European, and fast developed to agriculture planning and urban construction. With the improvement of image resolution of GIS and spatial analysis technology, the land and ecological suitability evaluation methods have been greatly expanded in agriculture [22].

In China, the deep and systemic research in this respect started in the late 1970s, and the rapid development focused on evaluation index system, evaluation methods and evaluation technology. In the beginning of 1990s, Huang Xingyuan et al. [23] first used the theory and method of GIS to land evaluation. Until the late of 1990s, most land evaluation was all had GIS technology application [24].

On the basis of mathematic method, many researchers combined GIS et al. modern information technologies in the suitability evaluation in agriculture. Based on

GIS-fuzzy comprehensive evaluation method, the land, climatic or ecological suitability of the crop in some region was evaluated. The comprehensive consideration was taken on the climatic, soil, and topographic factors related to crop growth. The spatial data of the factors were organized and computed with GIS method; the weights of the factors were derived by using AHP method; and the proper membership function and fuzzy arithmetic operators were selected to conduct the comprehensive ecological suitability evaluation. Compared with traditional evaluation methods, the GIS-fuzzy comprehensive evaluation method had the advantages of short-term,more fine and detailed, and more suitable for small spatial scale areas [24]. GIS technology and fuzzy mathematics methods were used on studying the relationship between eco-physiological features and environment, selecting evaluating indexes of ecological adaptability and constructing evaluation mode1 [25]. Li Qifeng et al. selected single pollution index and comprehensive pollution index to analysis the three bases of non-pollution food, green food and organic food, and then the evaluation unit with GIS technology was built. On this basis, considering of the surrounding environmental conditions, road conditions, farmland soil quality, industrial development conditions, economy and society level et al. factors, the evaluation system of three bases was constructed [26].

In order to establish a framework of quantitative evaluation method and implement a universal tool (software) for evaluating crop ecological suitability based on the framework. Three improvements were made by Lu Zhou et al. [27] in quantitative evaluation method. With the improved method, they had developed a universal evaluation tool implementing a quantitative evaluation, which can help agriculture experts without IT engineering knowledge. Song Ruhua et al. built land source management information system for land suitability evaluation and land use planning[28], Cheng Jianquan summarized the space analysis methods by using GIS to quantified spatial indicators, and applied to optimize the urban dimensional development[29]; otherwise, GIS also be widely applied in tourism land evaluation[30], Land reclamation[31] et al. aspects.

Not only information technology could combine with mathematic method, but also different information technologies could combined. Expert system and Geographic information system are both new high-technology. Xie Yu et al. probed into the study on the application of the integration of ES and GIS in the rice cultivated adaptability analysis. They applied system science, mathematics, crop planting science and rice weather ecology, established an expert system of rice cultivated adaptability analysis,

accordingly added space database and space knowledge base which realized by GIS to its database and knowledge base systems, integrated the managing function of space information of GIS into the ES, which made the expert system have the deductive and ratiocinative ability in space. That realized the integration of ES and GIS, successfully used in the rice cultivated adaptability analysis [9]. Remote sensing(RS) also be applied in land evaluation, Fang Linna et al. based on SPOT multispectral remote sensing image and data using in cultivated land fertility survey, the cultivated land quality assessment study was carried out. Cultivated land quality assessment indicators were abstracted from SPOT multispectral image, e.g. NDVI, DVI and RVI, which represented soil fertility, water availability and soil degradation respectively. The assessment indicator system was constructed using the indicators mentioned above. By virtue of PSR framework, the assessment model was developed in order to explore the feasibility of RS technology in cultivated land quality assessment [33].

2 Suitability evaluations in agriculture

2.1 Farming land suitability evaluation

Land suitability evaluation is the appraisal of the suitability and its extent of land for a purpose, it is the basis for land-use decision-making and using direction, it is also the content of the land resource research in the near past 20 years [34]. The Food and Agricultural Organization (FAO) [35] recommended an approach for land suitability evaluation for crops in terms of suitability ratings from highly suitable to not suitable based on climatic and terrain data and soil properties crop-wise, in which the procedures and methods of land suitability evaluation were explained. However, the framework is basically a qualitative one and it is difficult to make a direct connection of evaluation results with decision-making on land use planning [6].

Recently years, the integration of GIS and assessment model have been a new trend, Xie Shuchun et al. based on VB and MapX to expounded how to make use of the mighty special analysis function of GIS to realize the suitability evaluation of testing land[36]. The whole evaluation course regards GIS and RS as the technologies platform of the work, has realized greatly, formed a set of intact technological routes of evaluation, at the same time automation basically from beginning to the output of

the achievement pictures. Relatively traditional method, this method, which improved the working efficiency and evaluating precision, has certain reference value to the suitability evaluation of other land [37]. Wang Dacheng etc. employed artificial neural network (ANN) analysis to select factors and evaluate the relative importance of selected environment factors, and the spatial models were developed and demonstrated their use in selecting the most suitable areas for the winter wheat cultivation. Satellite images, top sheet, and ancillary data of the study area were used to find tillable land. These categories were formed by integrating the various layers with corresponding weights in GIS. An integrated land suitability potential (LSP) index was computed considering the contribution of various parameters of land suitability [38]. Xia Min et al. studied on the components and their realization of farmland suitability evaluation spatial support system (FSESDSS), probed into all methods and their suitable area used in land suitability evaluation [39].

The suitability evaluation for farming land is one of the most major content of land suitability evaluation. By grading the appropriate level of the farming land into several levels and opening out the suitability for faming land, it can provide basis for adjusting and optimizing the land-use structure and making rational land exploitation layout. The research is focused on two aspects of farming land in suitability evaluation: cultivated land quality evaluation and cultivated land fertility.

2.1.1 Cultivated land quality evaluation

Cultivation land is an important base of grain production, in order to protect the farmland, the overall investigation and analysis about the present status of it is required.

Nong Xiao-xiao et al. [40] based on the spatial analysis model of ArcGIS, evaluated the cultivation land quality with the method of multi-factor comprehensive judgment, which basis data were the topographic map, land use map, soil type map. Shi Changyun et al. pointed out that a quantitative and scientific evaluation method of land quality based on GIS was made. Mathematical models, such as correlation analysis, hierarchical analysis, fuzzy evaluation, were applied in their study [41]. Kou Jinmei had set up the information system for comprehensive evaluation of farmland quality which takes Microsoft SQL Server 2000 as the backstage database, edited under the condition of Delphi which was new visual editorial environment and supported by GIS software (Map/Info) [42]. Nie Yan et al. by using the new and high

technology as computer, ComGIS, UML, workflow, expert system, combining such multidisciplinary theory as soil, land, landscape, ecology, information and modern mathematics, they carried out the information system of classification, graduation and evaluation on cultivated land (ALEIS). Under the support of AELIS, the quantitative appraisal models and methods were developed [43].

All the cultivated land quality evaluation result is almost rational and provided the reference for the farmland protection.

2.1.2 Cultivated land fertility evaluation

Recent years, cultivated land fertility evaluation is developing toward quantitative and practical direction, especially the wildly application of GIS, including of complicated mathematic model combined with GIS, RS technology combined with GIS and expert system (ES) combined with GIS etc.

Wang Ruiyan etc. took Qingzhou City as their study area, intended to research for quantitative methods for cultivated land fertility evaluation. Based on the plentiful information that obtained by remote sensing technique, field-survey and lab analysis, the automatic and quantitative evaluation procedure was realized by adopting various mathematical models and methods such as system-cluster, analytical hierarchy program, fuzzy math, etc. and supported by GIS techniques [44]. In Niu Yanbin's study, farmland evaluation in Quzhou county of Hebei Province based on GIS was made, mathematical models, such as analytical hierarchy process (AHP), fuzzy evaluation, were applied in this study. The productivity of farmland is evaluated rapidly and exactly, with the powerful functions of GIS software [45]. Chen Haisheng etc. based on the analysis of the physical and chemical properties of soil samples collected from Henan tobacco plantation area, established the index system of soil fertility adaptability of tobacco. The fertility level was evaluated and classified by fuzzy and analysis. And the fertility map of Henan tobacco plantation area was drawn with GIS software MapGIS [46].

The approach of combination of GIS, RS, and ES etc. was feasible and effective in cultivated land fertility assessment, and the results of evaluation were almost in accorded with the real circumstances.

2.2 Agriculture climatic suitability evaluation

In climatic suitability evaluation, the maximum entropy (MaxEnt) model was introduced in recently two or three years. Many researchers combined it with GIS to establish the relationship between climate and climatic suitability regionalization and potential cultivation distribution.

He Qijin etc. [47] based on the potential climate indices at national and annual scales influencing maize cultivation distribution from the references, together with the maximum entropy (MaxEnt) model as well as ArcGIS spatial analysis technique, the relationship between potential spring maize cultivation distribution and climate and the climatic suitability regionalization of potential spring maize cultivation in China were studied. Based on published data, geographical information, national climate data, and the MaxEnt model, the relationship between the distribution of the winter wheat cultivation zone and climate was established by Sun Jing-Song etc [48].

For the crop suitability zoning, the concept of growing period was introduced into the traditional approach by Araya etc. [49], to produce agro-climatic zones. This method could be used to develop agronomic strategies to cope with the anticipated increase in drought in the semi-arid tropics under climate change. Accordingly, quick maturing and drought-resistant varieties of teff and barley can be grown in the center and in the east, while medium-maturing cultivars should do well in the south-west. The method requires limited input data and is simple in its use.

An agro-climatic suitability library for crop production was generated by using climatic data sets from 20 to 33 years for 41meteorological stations in the Bolivian Altiplano by Sam Geerts [50]. Four agro-climatic indicators for the region were obtained by validated calculation procedures. The reference evapotranspiration, the length of the rainy season, the severity of intra-seasonal dry spells and the monthly frost risks were determined for each of the stations. To get a geographical coverage, the point data were subsequently entered in a GIS environment and interpolated using ordinary Kriging, with or without incorporating anisotropy.

The actual distribution of crop cultivation depends not only on climate, socio-economic conditions, and local production technologies, but also on soil type, geographic characteristics, crop varieties,human activity and so on, especially in relation to its yield and economic value. All the above research provided scientific support for planning crop production and designing the countermeasures against the effects of climate change on crop.

2.3 Crop ecological suitability evaluation

In the crop ecological suitability evaluation, there were many researchers using the Analytical Hierarchical Process (AHP) technique and combining with GIS etc. information technologies.

Chen Haisheng et al. [51] based on the principal of hierarchy analysis and fuzzy mathematics and the technique of GIS, the comprehensive evaluation of tobacco ecology suitability were studied according to the actual circumstances of the whole Henan tobacco planting regions. The evaluation index system of tobacco ecology suitability of Henan tobacco planting regions was established by choosing 17 evaluation indexes from 3 respects of climate, soil and landform with Delphi method. Furthermore, the membership function was set up according to the effects of each ecology factors on the growth and quality of tobacco suitability. And the AHP was used to determine the weight of indexes by using quantitative analysis. Then the tobacco ecology suitability map of Henan tobacco plantation was drawn with GIS software MapGIS. Li Bo etc. [19] using a geographic information system (GIS), there nine factors were quantitatively analyzed. The grey relational analysis (GRA) was combined with the analytic hierarchy process (AHP) to address the uncertainties during the process of evaluating the traditional land ecological suitability, and a modified land ecological suitability evaluation (LESE) model was built. Mo Jingjing et al. [52] by using Delphi method and based on the ecological conditions of eight tobacco planting counties of Nanyang, 6 ecological factors related to the tobacco ecological suitability evaluation were established. According to the 6 various factors which affect the tobacco growth and quality, the corresponding membership degree function was established, and the original values of the factors were transformed into degree of membership, the weight of the factors were confirmed through Analytic Hierarchy Process (AHP), and overlaid into a raster map through using the spatial overlay analysis of GIS. Finally, the tobacco cultivation ecological suitability classification map of Nanyang was gained.

The study objective of Chavez, MD et al. [53] is to develop useful criteria for assessing diversification activities and to provide a ranking of different diversification activities on these criteria. The Analytical Hierarchical Process (AHP) technique is applied to get consistent assessments of criteria and activities from experts and stakeholders. Next, goal programming methods are used to aggregate individual assessments in order to arrive at the final ranking of farming activities for

diversification. The results of this research can be used in optimization models for determining the optimal mix of farming activities in combination with tobacco production. Such models can provide further insights into factors determining diversification.

The software component suitability presented herein implements several published approaches for computing crop suitability, based on available climate, soil and crop information. Users can access the suitability software component via two application programming interfaces for single- and multi-cell estimations, the latter based on multiple regression methods. The component, extensible by third parties, is released as .NET 3.5 DLL, thus targeting the development of .NET clients [54].

An integrated indicator-based system was established to map the suitability of spring soybean cultivation in northeast China by He Yingbin [55]. The indicator system incorporated both biophysical and socioeconomic factors, including the effects of temperature, precipitation, and sunshine on the individual development stages of the spring soybean life cycle. Spatial estimates of crop suitability derived using this indicator system were also compared with spring soybean planting areas to identify locations where there was scope for structural adjustment in soybean farming. It is anticipated that this study will provide a basis for follow-up studies on crop cultivation suitability.

3 Conclusions and future perspectives

The theoretical foundation of suitability evaluation is building suitable analysis model by the statistical relationship between research targets and each variables. The support of technology is combining GIS etc. technologies with mathematic model effectively, which based on the multi-criteria analysis function of GIS. By the software of GIS to deal with the original data and derived data to send command which is ordered and interactional, to simulated the spatial decision-making process, for achieving the aim of analysis and evaluation on the research object.

The scientific and reliable of the evaluation result depends on the integrality of the basic data and the rationality of the evaluation method. It can be conducted rapidly and correctly by combining AHP and multi-factor fuzzy comprehensive evaluation method which also supported by GIS. That could overcome and avoid the drawbacks

of empirically determined classification and reflect crop areas climate, ecological suitability level difference accurately.

In the future, by redefining query limits and incorporating other data, the GIS etc. other information technologies and systems can be used and developed for impact assessments of agricultural practices and for studying the effects of land, climate and ecology etc. change.

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