**UNIVERSITI PUTRA MALAYSIA**

# *USING GENETIC ALGORITHMS TO OPTIMISE LAND USE SUITABILITY*

**SAEID PORMANAFI**

**ITMA 2012 14**

# USING GENETIC ALGORITHMS TO OPTIMISE LAND USE SUITABILITY

**BY**

**SAEID PORMANAFI**

**Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia in fulfilment of the Requirement for the Degree of Doctor of Philosophy**

**February 2012**

**DEDICATION**

**Dedicated:**

**To my beloved wife** **To my dearest parent**

**Thank you all for your unwavering love, encouragement and support**

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

**USING GENETIC ALGORITHMS TO OPTIMISE LAND USE SUITABILITY**

By

**SAEID PORMANAFI**

**February 2012**

**Chairman: Professor Shattri B. Mansor, PhD**

**Faculty: Institute of advanced Technology**

Land-use planning is defined as the most appropriate utilization that would achieve the paramount benefit of protecting the resources. In this study, under environment-friendliness objective, based on multi-agent genetic algorithms, was developed a geospatial model for the land use allocation. The model applied to solve the practical multi-objective spatial optimization allocation problems of land use in the core region of Menderjan Basin in Iran. The first task was studying the dominant of crops and economic suitability evaluation of land with the land evaluation framework developed by FAO, (1976-2007) using GIS. Second task is to determine the fitness function for the genetic algorithms. The third objective is to optimize the land use map using economic benefits. In the socioeconomic assessment of the Menderjan watershed; consultation with experts and the interview with local residents implemented. Different scenarios then arranged according to the land suitability classes. The Erosion Potential Method (EPM) used in erosion estimation and sediment yield of the study. The highest annual erosion rate belongs to the potato agricultural land use. Third scenario suggested in comparison to the economic views.

In this research, based on both irrigation managements of the crops and water demands' model of crops would be developed and calculated which they integrated in RS and GIS environment. In the GAs Model, parent selected among the initial population. In fact, the initial population includes the land suitability analysis, land use/ land cover, which is extracted from RS and scenarios of land evaluation and crop suitability. To sum up, coding is remarkably based on objective function, which it has been great in cost/ benefit from all cultivating activities and obtained costs of land erosion. After calculating the fitness function, which it includes, cost and benefit matrix, cost of changing land uses together, offspring (the next generation) which are importantly generated. Selecting the offspring during the research has been based on their capability of elitism. This selection implemented according to the percentage of progressing, comparison and replacing in GAs programming. Finally, the land use and defined scenarios obtained as optimized output, which is a dynamic model in this study. The results shows; the major limitations regarding to wheat in this region is related to the topography. 28.6% of the land has severe topographic limitations. The most suitable class is $S_2$ for Potato. The limitation of this suitability class majorly is soil properties. Results of Almond land suitability analysis shows, the most extensive land is in the moderate limitation class. The main limitation is properties of the soil and climate. After doing the related analyses, it has been achieved that the water consumption (water demand) for wheat in May had the most consumption of water and April and June comes afterward. Potato in July has more water consumption and after that August, September, June and May. The erosion potential categories determined that heavy and severe class covered 35% of the area. Land use/ Land Cover is obtained by satellite image processing that the overall kappa of the classification is 87.4% and the overall accuracy is 89.6%. As it has mapped, the

Irrigated area is 4689 ha. According to the results of the GAs Programme and the produced graphs in evaluating the best solutions, it has been recognized that after 25 frequencies there is not any intensify change, which it happened in the optimized beneficial value, so, extra reiteration has not influence in the possible better answer. The final optimized benefit is $12*10^{11}$.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan Ijazah Doktor Falsafah


**GENETIK UNTUK MENGOPTIMUMKAN KESESUAIAN PENGGUNAAN TANAH**

Oleh

**SAEID PORMANAFI**

**Februari 2012**

**Pengerusi: Profesor Shattri B. Mansor, PhD**

**Fakulti: Institut Teknologi Maju**

Perancangan penggunaan tanah didefinisikan sebagai pendayagunaan yang paling wajar yang dapat mencapai faedah yang paling berkesan bagi melindungi sumber. Dalam kajian ini, disebabkan oleh objektif mesra alam persekitaran, berdasarkan algoritma genetic multiagen, model geospatial bagi alokasi penggunaan tanah telah dihasilkan. Model ini diaplikasikan bagi menyelesaikan maaslah pengalokasian optima spatial multiobjektif yang praktikal terhadap penggunaan tanah di daerah utama di Lembangan Menderjan di Iran. Tugas pertama ialah mengkaji tanaman yang dominan dan penilaian kesesuaian ekonomi tanah yang dimajukan oleh FAO, (1976-2007). Tugas kedua adalah untuk menentukan fungsi fitness bagi algoritma genetik. Objektif ketiga adalah untuk mengoptimumkan peta penggunaan tanah menggunakan faedah ekomomi. Dalam penilaian sosioekonomi legeh Menderjan; konsultasi dengan pakar dan temubual dengan penduduk. Senario yang berbeza telah diatur berdasarkan kelas kesesuaian tanah. Kaedah Potensi Hakisan (EPM) digunakan dalam menganggarkan hakisan dan hasil sedimen dalam kajian ini. Dari sudut ekonomi, kos penggunaan tanah yang efektif ialah. Senario ketiga dicadangkan

untuk membandingkannya dengan sudut pandangan ekonomi. Dalam penyelidikan ini, berdasarkan kedua-dua pengurusan pengairan tanaman dan model permintaan terhadap air bagi tanaman pada musim pertumbuhan, sepatutnya dihasilkan dan dikira yang diintegratasikan dalam persekitaran RS dan GIS. Dalam model GAs, Sebenarnya, populasi awal termasuk penilaian kesesuaian tanah, penggunaan tanah/ permukaan tanah, yang diekstrak daripada RS dan senario penilaian tanah dan kesesuaian tanaman. Ringkasnya, koding berdasarkan fungsi yang objektif ,yang di dalam kos/manfaat daripada semua aktivit penanaman dan kos hakisan tanah.. Selaepas mengambil kira fungsi fitnes yang termasuk kos dan matrik faedah, kos penukaran penggunaan tanah bersama, keturunan (generasi seterusnya) yang penting dijana. Pemilihan keturunan ketika penyelidikan berdasarkan kapabiliti elitisme mereka. Pemilihan ini dilaksana berdasarkan peratusan dari segi kemajuan, perbandingan dan penggantian dalam program GA. Akhirnya, penggunaan tanah dan senario yang telah dikena diperoleh sebagai output yang merupakan model yang dinamik dalam kajian ini. Keputusan menunjukkan; limitasi utamaberkaitan dengan gandum di daerah ini ialah yang berkaitan dengan topografi. 28.6% tanah mempunyai limitasi topografi yang teruk. Kelas yang paling sesuai ialah $S_2$ untuk kentang. Limitasi kesesuaian kelas yang paling utama ialah sifat tanih. Keputusan analisis kesesuaian tanah untuk badam menunjukkan tanah yang paling ekstensif ialah kelas limitasi yang sederhana. Limitasi utama ialah sifat fizikal tanih dan iklim. Selepas menjalankan analisis keputusan, didapati bahawa konsumsi air (permintaan untuk air) bagi gandum dalam bulan Mei menunjukkan konsumsi air yang paling ketara dan April dan seterusnya bulan Jun. Kentang pula menunjukkan konsumsi air yang banyak pada bulan Julai dan diikuti bulan Ogos, September, Jun dan Mei. Kategori potensi hakisan menerntukan  kelas berat dan teruk meliputi 35% kawasan.

Penggunaan tanah/ permukaan tanah diperoleh melalui pemprosesan imej satelit yang menunjukkan bahawa keseluruhan klasifikasi kappa ialah 87.4% dan keseluruhan ketepatan ailah 89.6%. Disebabkan pemetaan, kawasan berpengairan ialah 4689 hektar. Berdasarkan keputusan yang diperoleh daripada Program GAs dan graf yang dihasilkan dalam menilai penyelesaian yang terbaik, didapati bahawa selepas 25 frekuensi tidak terdapat perubahan ketara yang berlaku pada nilai bermanfaat yang optimum, oleh itu, tambahan reiterasi tidak mempengaruhi jawapan yang lebih baik setakat ini. Faedah optimum terakhir ialah $12*10^{11}$.

**ACKNOWLEDGEMENTS**

**In the name of God, the merciful and compassionate**

First, Worthy of praise to the Merciful Allah, who has qualified me to complete this thesis and given me sound health. I wish to thank my Supervisor of studies Professor Dr. Shattri Bin Mansor, for his well-considered advice and constructive supervision over my research. I would also like to thank Associate Professor Dr. Ahmad Rodzi Mahmoud for his specialist assistance.

I am thankful to Dr. Saied Pirasteh and all staff of UPM, especially those at the Faculty of Engineering and ITMA, who directly and indirectly contributed my learning process. I would also like to thank staffs of jihad-e- Agriculture organization of Isfahan province, Ali Sarhadi and Dr. Nasri for their specialist assistance.

Friendship makes my life in Malaysia more enjoyable. I would also like to thank my friends in UPM, especially Ahmad ShakerArdakani, Ahmad Davoudvandi and Hosseinali Livani.

I feel a deep sense of gratitude for my dear wife, Mozhdeh, and her kind parent and family for their patient and assist. Finally, I would like to thank my parent and sisters for “occasionally" asking when my PhD would be finished! Then also thankworthy for their patient and support.

**Saeid Pormanafi**

**APPROVAL**

I certify that a Thesis Examination Committee has met on (**24 February 2012**) to conduct the final examination of (SAEID PORMANAFI) on his (or her) thesis entitled "**Using Genetic Algorithms to Optimise Landuse Suitability**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the (Doctor of Philosophy).

Members of the Thesis Examination Committee were as follows:

**Helmi Zolhaidi Mohd Shafri, PhD**
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

**Abdul Rashid bin Mohamed Sharif, PhD**
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

**Biswajeet Pradhan, PhD**
Institute of Advanced Technology
Universiti Putra Malaysia
(Internal Examiner)

**Alexis Comber, PhD**
Department of Geography
University of Leicester
UK
(External Examiner)

**SEOW HENG FONG, PhD**
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Doctor of Philosophy**. The Members of the Supervisory Committee were as follows:

**Shattri Bin Mansor, PhD**
Professor
Institute of Advanced Technology
Universiti Putra Malaysia
(Chairman)

**Ahmad Rodzi Mahmoud, PhD**
Associate Professor
Institute of Advanced Technology
Universiti Putra Malaysia
(Member)

**Saied Pirasteh, PhD**
Senior Research Fellow
Institute of Advanced Technology
Universiti Putra Malaysia
(Member)

**BUJANG BIN KIM HUAT, PhD**
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

## DECLARATION

I declare that thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

______________________________

**SAEID PORMANAFI**

Date:

## TABLE OF CONTENTS

Page

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| GIS | Geographical Information System |
| MCDM | Multi Criteria Decision Making |
| MCA | Multi Criteria Analysis |
| GA | Genetic Algorithm |
| GPS | Global Positioning System |
| LADSS | Land Decision Support System |
| DSS | Decision Support System |
| FAO | Food and Agriculture Organization |
| LUT | Land Utilization Types |
| LESA | Land-Evaluation and Site Assessment |
| AEZ | Agro-Ecological Zoning |
| ALES | Automated Land Evaluation System |
| AI | Artificial Intelligence |
| RS | Remote Sensing |
| ET | Actual Evapotranspiration |
| ETo | Reference Evapotranspiration |
| ETc | Crop Eevapotranspiration |
| WBM | Water Balance Model |
| USLE | Universal Soil Loss Equation |
| MUSLE | Modified Universal Soil Loss Equation |
| WEPP | Water Erosion Prediction Project |
| RUSLE | Revised Universal Soil Loss Equation |
| PSIAC | Pacific Southwest Interagency Committee |
| EPM | Erosion Potential Method |

| | |
|---|---|
| MQCE | Method for the Quantitative Classification of Erosion |
| EA | Evolutionary Algorithms |
| ES | Evolutionary Strategies |
| GP | Genetic Programming |
| LADSS | Land Allocation Decision Support System |
| LP | Linear Programming |
| AWEC | Available Water Exchange Capacity |
| PH | Soil Reaction |
| CEC | Cation Exchange Capacity |
| EC | Exchange Capacity |
| ESP | Soil Alkalinity |
| CaCo3 | Carbonates |
| LQ | Land Qualities |
| LC | Land Characteristics |
| U.S.D.A | United State of Drainage and Agriculture |
| AWHC | Available Water Holding Capacity |
| ISODATA | Interactive Self-Organizing Data Analysis |
| MLC | Maximum Likelihood Classifier |
| RMS | Root Mean Square |
| GCP | Ground Control Points |
| RMSE | Root Mean Square Error |
| DN | Digital Number |
| DOS | Dark Object Subtraction |
| UTM | Universal Transverse Mercator |
| OIF | Optimum Index Factor |

| | |
|---|---|
| PCA | Principle Component Analysis |
| ER | Effective Rainfall |
| WSP | Waste Special |
| IRS | Indian remote sensing |
| DEM | Digital Elevation Model |
| OM | Organic Matter |
| SOM | Soil Organic Matter |
| GCP | Ground Control Point |
| ANN | A Neural Network |
| CA | Cellular Automata |
| EAs | Evolutionary Algorithms |
| IP | Integer Programming |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

With the increase in population, as well as human activities, pressure on land has been intensified (Bandyopadhyay, Jaiswal, Hegde, & Jayaraman, 2009).

Degradation of farmlands is happening with farming activities in the watersheds without proper management practices, such as measures to reduce soil losses due to the soil erosion, rainwater harvesting, the replacement of nutrients using organic matter the applications, etc. Different approaches of land evaluation have been developed, and each has a particular methodological procedure (FAO, 1976; Storie, 1933). The factor based land evaluation uses either single or multiple parameters converted to an integrated index (Guo et al., 2005). The (FAO, 1976) has recommended a framework for land suitability evaluation for crops in terms of suitability ratings ranging from highly suitable to not suitable based on climatic and terrain data and soil properties which is used in the methodology of current research. The success of the FAO framework (1976) and subsequent guidelines for application in diverse types of land uses and land areas (FAO, 1983, 1984, 1985a, 1991; Rossiter, 1996) is an encouraging development.

Land suitability is the fitness of a given type of land for a defined use. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defining uses (FAO, 1976). Land suitability could be assessed for present condition or after improvement (Potential Land Suitability). In land and crop suitability, information is based on physical environment data generated from soil or land resources surveys. The information is based on soil characteristics and climate data related to the growth requirements of crops being evaluated.

## 1.2 GIS Methods for Land Suitability Evaluation

Improvements in information and communication technology that have caused to develop decision support models by the computer for land evaluation. Geographical information system (GIS) is one of the tools to implement to improvement land evaluation through the map analysis techniques. In land suitability evaluation, geospatial data (GIS layers, Global Positioning System (GPS) data and Remote Sensing (RS) imagery) and analysis significantly help in facilitating the decision-making process. GIS can be used in specific applications, ranging from the evaluation of land resource assessment and land-use planning using tools (FAO, 2007), such as components (GIS functions, data models and sources), software, operations (Malczewski, 2004) and evaluation of scenarios. Researchers can build geographic databases and GPS or other source such as RS technology (FAO, 2007) can import new research data. According to (Malczewski, 2004), there are three main groups of methods for the GIS land-use suitability analysis: 1- computer-assisted overlay, 2- multi-criteria assessment and; 3- Artificial intelligence (soft computing or Geo-computation) methods.

The computer-assisted techniques are developed as one the greatest response toward the manual method's limitations of mapping and combining of large datasets. Rather than manually mapping the values of a series of suitability factors in gray or colour scales, the models stored in a numerical forms as matrices in the computer. The integration of MCDM techniques with GIS has significantly been progressed the conventional map overlay approaches to the land-use suitability analysis (Malczewski, 2004). GIS-based MCDA can assumed of as a process that combines and transforms spatial data (input) into a resultant decision (output). The MCDM procedures (or decision rules) define a relationship between the input maps and the output map. The procedures heavily consisted the utilization of geographical data, the decision maker's preferences and the manipulation of the data and preferences according to specified decision rules (Malczewski, 2006).

## 1.3 Artificial Intelligence Methods

Developments in spatial analysis showed that Artificial intelligence (AI) offers new opportunities to land use suitability analysis and planning (Fotheringham, Openshaw, & Abrahart, 2000) includes modern techniques of calculation that may help the modeling and description of complex systems for inference and decision making (Malczewski, 2006). AI is a generic term that covers several methods such as Evolutionary Algorithms (EAs), Genetic Programming (GP), Artificial Neural Networks (ANN), Cellular Automata (CA) and Fuzzy systems (Zadeh, 1994). The scope of Geo-Ccomputation got sometimes used to cover these new computer-based techniques for analysis and modelling geographic data and solving spatial problems (De Smith, Goodchild, & Longley, 2007; Fotheringham et al., 2000). Table 1.1 shows comparative characteristics of the components of Soft Computing.

### 1.3.1 Genetic Algorithms (GAs)

GAs is a search method, originally developed by John Holland in the 1970s (Holland, 1975) and one part of the intelligence and evolutionary computation.

**Table 1.1. Comparative characteristics of the components of Soft Computing, after,(Kennedy & Krouse, 1999; ogly Aliev & Aliev, 2001).**

| Strategy | Fuzzy Sets | Artificial Neural Networks | Evolutionary Computing, GAs |
|---|---|---|---|
| **Weaknesses** | • Knowledge Acquisition<br>• Learning<br>• needs a set of rules to be devised which can be difficult<br>• rules can conflict with each other | • Black Box Interpretability<br>• not tolerant of missing data<br>• can be 'overtrained'<br>• can be inappropriately applied<br>• duplicate results not dealt which well | • Coding<br>• Computational speed |
| **Strengths** | • Interpretability<br>• Transparency<br>• Plausibility<br>• Graduality<br>• Modeling<br>• Reasoning<br>• Very tolerant of noisy or highly variable input data and missing data.<br>• Tolerance to imprecision | • Learning<br>• Adaptation<br>• Fault tolerance<br>• Curve fitting<br>• Generalization ability<br>• Approximation ability | • Computational Efficiency<br>• Global optimization<br>• medium steadily improves<br>• new medium automatically selected |
| **Concept** | Multivalued logic which executes a series of rules | Model that mimics the learning ability of the brain | Uses evolutionary natural selection process |

Figure 1.1 shows the division of into Artificial Intelligence vs. Computational Intelligence (Fotheringham et al., 2000). GAs are optimization methods inspired by the biological processes of natural selection and survival of the fittest that allows a population composed of many individuals to evolve under specified selection rules to a state that maximizes the "fitness" (i.e., Minimizes the cost function) (Haupt, Haupt, & Wiley, 2004; Koomen & Stillwell, 2007; Malczewski, 2004). It is based on the principles of Darwin's evolutionary theory (Koomen & Stillwell, 2007).

### 1.3.2 Linking a Geographic Information System and GAs

GAs have been applied to spatial optimization problems (Aerts & Heuvelink, 2002; Matthews, 2001; (K. Matthews, Buchan, Sibbald, & Craw, 2002) By representing each geographical feature as a "layer" which it has been using in a different GIS software so as to perform various sorts of spatial analysis of huge bulk number of geographic accurate data.

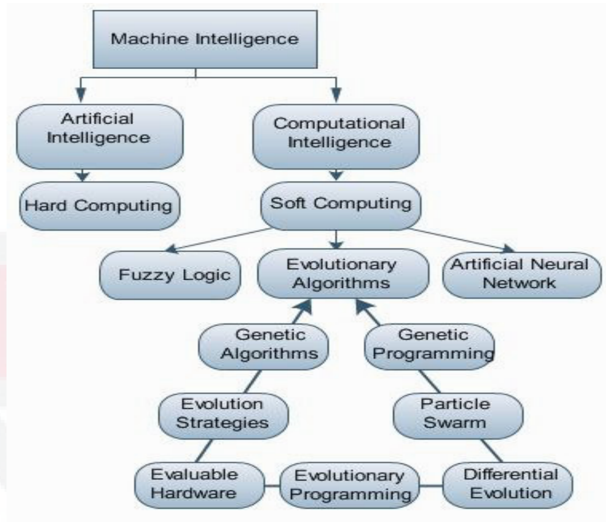


**Figure 1.1. Artificial Intelligence vs. Computational Intelligence**

All databases that come out from descriptive data will link to the GAs as an input and GAs population (Park, Choi, Wang, & Park, 2006). However, by combining GIs and integer programing (IP) with each other, they can significantly solve complexity in decision-making, and increase participation of stakeholders (Datta, Deb, Fonseca, Lobo, & Condado, 2007).

## 1.4 Problem Statement

Majority geographical problems are not directly solvable through the straightforward application of a specific methodology. Such these problems often require the participation of a variety of stakeholders with Varity and often conflicting objectives (Branke, Deb, & Miettinen, 2008; Xiao, Bennett, & Armstrong, 2007). Allocating the Land evaluation at land use planning; for instance, requiring decision makers minimize its economic cost, and minimize negative environmental effects. In the land use management, the incorporation of multiple objectives into decision-making and the search for suitable land use policies are known as the critical to the sustainable regional development. These and other types of multi-objective problems present a significant challenge to researchers for three main reasons. First, they are combinatorial optimization problems that often require a large amount of computation time to solve. Second, the search for solutions to these problems often involves the participation of stakeholders who have different backgrounds and view the problem from different perspectives. Finally, a solution that meets all criteria may not exist. Instead, stakeholders are required to examine trade-off among competing alternatives before a final solution can be reached (Xiao, Bennett, & Armstrong, 2007). As a consequence, it is important to develop some solution approaches that are (1) efficient in terms of their time complexity, (2) effective in terms of their ability to find a variety of high quality solutions, and (3) interactive so that decision makers can experiment with criteria, visually explore alternatives, and learn about a problem as they search for its solution.

Recognizing the links among agricultural/environmental policies, human decision making through land use choices, and environmental outcome can help design policies that directly affect incentives pertaining to land use and management. Consequently, in this study an agent-based model within a watershed-planning context is used to analyse the trade-off involved in producing a number of ecosystem services and agricultural commodities given a number of price and policy scenarios while assuming three different types of scenarios in terms of their goals. Most of the previous simulation studies used traditional mathematical programming methods lack the capability of modelling complex, human-decision- making process of feedback and interaction of agents with the environment and among themselves, and they also lack in spatial specificity (Berger, Schreinemachers, & Woelcke, 2006).

In this research a multi-agent-based model that capture land suitability scenario, current land use and economic issues are developed by using a historic search and optimization technique called genetic algorithms (GAs) (Holland, 1975), which belongs to a broader class of Evolutionary Algorithms (EA).

To investigate regional scale and watershed, this required to collect the data and information from library resources and fieldwork. GIS has made a robust help in storing and analysing the data, as data layers. Using GIS and RS in evaluating and suitability of land and crop, not only improve the accuracy of the study, but also decrease the cost of evaluating by accelerating the investigation. In addition, majority of the GIS analysis is based on the overlade layers. By developing various sciences and increasing applications of the other sciences in GIS have been advancing the integrating of layers in this system and science relegated GIS, or inverse. Boolean Method was one of the popular methods. Boolean method observes zero and one value only. This method and the others such as index overlay, weight overlay, Multi Criteria Decision Making (MCDM) are one of the fundamental new developing methods in Geo-statistic and mathematic methods which they have been utilizing in GIS. Nowadays those mentioned methods indicate more accurate and precise results to users. New scientific methods in GIS and land-use suitability analysis have their origin backed in applications from hand-drawn overlay technique that used by landscape architects in the United State in the late nineteenth century and the beginning of modern 20th.

The important limitation of the classical overlay methods is lackness as to define mechanisms to judge (e.g. the decision-makers preference) the GIS, which, based on legal procedures. This limitation is able to remove by integrating GIS and MCDM methods. The main problems related to the choice of method to combining different evaluation criteria, standardization of criterion maps, and the specification of criterion weights. MCDM depends on the experts and has some limitations in the numbers of the criteria, while the number of factors increase, the management and comparisons of the factors would be difficult, and may influence results. Different methods may produce different type results of in expert systems methods, different weighting methods would result in different overall land-use patterns. Some researchers suggested that these problems could be, at least partially, resolved by using the AI based methods (Malczewski, 2004).

All traditional artificial intelligence systems have been implemented using the Hard Computing technology, which restricts considerably the abilities of those systems. Moreover, the traditional artificial intelligence, does not accept the numerical methods, which are important for accounting for uncertainty and imprecision. Due to the above limitations, the Machine Intelligence Proportion for traditional artificial intelligence systems is not sufficiently high. Soft Computing methodology implies cooperative activity rather than autonomous one for such new computing paradigms as fuzzy logic, neural networks, evolutionary computation and others. This approach allows solving many important real-world problems, which were impossible to solve using traditional artificial intelligence methods (ogly Aliev & Aliev, 2001).

A number of optimization techniques have been proposed for the computation of the optimal allocation of land use within an area. However, most of these techniques are aimed at selecting optimal sites for a single land use type within an area. Heuristic algorithms have also been applied to predominantly single site allocation problems (T. J. Stewart, Janssen, & van Herwijnen, 2004).

Therefore, the AI methods have been used to eliminate possibility of enigmatic gaps and to improve results considerably. However, mentioned methods, (Overlay methods, Expert systems, etc) also used in AI methods in GIS environment. AI methods consist of Fuzzy, ANN, GA, and CA that used in set of spatial data complex, which eluded as “Geo-Computation”. Therefore, Geo-computation is an innovative research area within the field of GIS and geospatial analysis. For this reason, it is strongly influenced by recent developments in programming, data processing and interface design. Nowhere is this more obvious than in the concern for modelling of dynamic process (De Smith et al., 2007).

As comprehended before, it is worth mentioning that all previously mentioned methods have some gaps, which caused some restrictions for users. Accordingly, it is possible to integrate GAs with GIS and apply them as matrix base in solving related problems in the real world. In this method, mathematical and spatial analysis used in related to GAs analysis and its operators. It seems that integration of GA and GIS can remarkably decrease those gaps among previously mentioned methods. GIS are as the efficient and effective way of storing and presenting geo-referenced information. Both vector-based and grid-based systems can provide the input for optimization algorithms and can be used to present the results generated by these algorithms. If, however, the planning problem involves a large area and/or activities need to be allocated to small spatial units, then the amount of data to be used can be enormous. This requires that the algorithm be able to handle a large amount of data and that there be good communication between the algorithm and the GIS (T. J. Stewart et al., 2004). A few studies have done in land use planning by using of GA all around world. Specifically, according to the Iranian educational organization, there have not done any research thesis in related subject so far. To sum up, this method attempts to use, more capabilities of the land suitability evaluation. Table 1.2 presents a comparison of their abilities at different fields of application, along with those of control theory and AI.

**Table 1.2. comparison of some methods (Xiaoli, Chen, & Daoliang, 2009)**

| Method | **Control Theory** | **Neural Network** | **Fuzzy Logic** | **Artificial Intelligence** | **Genetic Algorithm** |
|---|---|---|---|---|---|
| Mathematical Model | Good | X | Fair | Need | X |
| Learning Data | X | Good | X | X | Good |
| Operator Knowledge | Needs | X | Good | Good | X |
| Real Time | Good | Good | Good | X | Needs |
| Knowledge representation | X | X | Needs | Good | X |
| Nonlinearity | X | Good | Good | Needs | X |
| Optimization | X | Fair | X | X | **Good** |

Explanation of Symbols: Good=Good or suitable, Needs=Needs some other knowledge or techniques, X=Unsuitable or does not require.

Based on the aim of research, important and strategic crops (wheat, potato and almond) investigated. Land evaluation in this current study includes; land (irrigated and rein-fed) and crops suitability evaluation, in both rain-fed and irrigated land type use, and crop type, which has the capability to implant, regarding environmental and ecologic land potential. Reviewing related literatures revealed that, in the most aspects of them, only evaluation of land use or sort of crops was being considered.

In this study, the experts and residents' attitudes considered using the FAO framework in the field of land evaluation and land suitability for implanting each kind of rain-fed and irrigated crops. Therefore, it is hopeful to achieve, considered goals in the conservation of the soil and other ecological potential of the region, and lead them to an economic benefit to all residents. Socioeconomic assessments remarkably have been considered in the majority of land suitability investigations and biophysical land evaluation model. This fact is a gap in the results. On the other word, evaluating of the crop evaluation without socioeconomic assessments is a problem for planners and decision makers. In land evaluation FAO model (1976), the socioeconomic assessments are considered. According to this research, both land suitability and crop suitability evaluations considered.

## 1.5 The objectives of research

This study analyzes the multi-functional-based model, in the decision making process, on the possible economic and environmental outcome for policy scenarios and change in agricultural/ environmental policies such as soil conservation. This study tests the robustness of the developed agent-model in accurately capturing the variations in the decision-making process of various scenario defined and three main crop (wheat, potato and almond) due to variations in endogenous (e.g. agents value) and exogenous factors (e.g. market price) compared to the actual land use land cover map. This research has to provide an overview of recent developments in multi-objective problem solving. This believed that borrowing ideas from other fields will benefit research on spatial decision-making. Evolutionary algorithms such as GAs are particularly important because they can be used to solve multiobjective geographical problems efficiently, effectively, and often interactively. In this study uses the GAs codding to optimizing land use/ land cover obtained from remote sensing processing of the study area and determining the best current economic benefit of the region.

The main purpose of this research is; to optimizing the developed FAO‘s Evaluation Model (1976) and land use/ land cover in Menderjan Watershed using GIS, RS and GAs; These Objectives are mentioned as follows:

- To determine Land Suitability Analysis for three main crops (wheat, potato and almond).

- To determine Fitness Function by Presenting Water Erosion spatial Pattern and estimating economical amount of cost/ benefit crops and soil loss.
- To investigation the use of GAs to optimize land use allocation.

## 1.6 Significance of the Study

The most significant part of this research divided into two paramount aspects, firstly matters of great moments, which are existed in the case study from different points of economical and agricultural issues which all have to meticulously consider important in the study, and secondly using different methods both technical or skilful procedures to solve above problems. It is valuable to state that the land potential and agriculture in Menderjan basin, which it is one of the important catchments in "Zayandeh Rood" Watershed, is vital for residents and planners. Further comprehensive study has not implemented in Menderjan Watershed yet. Therefore, this is an innovative study and it will be both significant for sustainable development of Menderjan and planners. The technical and methodological significant in this study uses of the FAO model (1976-2007) as basic. Author attempts to contribute the expert's advice using GIS and RS to optimize the FAO framework for Menderjan Basin. In addition, in this research, the mathematical methods, statistical and spatial analysis, and programming used to achieve technical significant. GAs as an optimization method, which is using in this study has widely used to solve one or more problems of optimization goals (Câmara, Monteiro, 2001). As the result of surveys in this research we can include that the significant current research method, which is a matrix based in terms of using capabilities of GAs, operators and elements of GAs in a dynamic ambiances is being innovated; meanwhile these GIS layers introduce as an input of GAs. The contributions and novelity of current research are as below:

- According to the literature review, most GAs studies have been done in both the industries and electronics fields, and in the Geomatic fields also; surveys toward GAs studies has an enormous worth of further researching and studying as a novelty issue.

- Capability in handling the great numbers of pixels.

## 1.7 Study Area

"Zayandeh Rood" river is one of the most important rivers of Iran which is vital for the city of Esfahan as drinking water and the alluvial plain for agriculture. The river has a very vast watershed and extends over Esfahan and Charmahal& Bakhtiari Provinces.

According to the Isfahan Directorate of Watershed Management of Jihad Agriculture Organization reports, more than 100 families have left their village for the cities. Insufficient income was found to be the main reason for immigration. Isfahan, Gom and Tehran are attracted cities for the immigrants. The most important problem of Menderjan Basin is land destruction whereas the most principle economic activities are agriculture and ranching. Consequently, superfluity to agriculture lands and natural resources has destructed the soil and its fertility and has decreased the economic benefits of the residents. In the long time, residents have been engaged in irrigated and rain-fed agriculture to crop wheat, barley, potato and almond, grazing have been a long history in this region. The watershed has been divided into 28 basins or sub-catchments; each of them is called a parcel. The research area is one of these parcels, named B2 or Menderjan, which is selected. Zayandeh Rood Dam is located above the Zayandeh Rood River in Chadegan City in Isfahan Province and is important in terms of agriculture. Figure 1.2 shows the location of Menderjan watershed. A considerable amount of information is available for the area and therefore the research can be run more fluently. It is located west of Esfahan, on the western side of Chadegan city and north of the Zayandeh Rood dam. It's geographic location is 50° '7' 16" to 50° 40' 34" E and 32° 45' 12" to 32° 56' 48" N. The slope of thirty percent of the area is between 30 to 60 percent and nearly half of the area is located between 2200 to 2400 meters elevation. The most important physical characteristics of the study area are defined in Table 1.3. According to Coppen's method, the area falls in the continental moderate or cold agro-ecological zone with cool summers and very cold winters. The average monthly maximum temperature is 10°C and the average monthly minimum temperature minus 5°C, with the absolute maximum temperature of 38.5°C. The area has a Mediterranean type rainfall, characterized by rainy winters and dry summers. Annual rainfall concentrated in winter is about 332 mm. The rainy season starts in October and ends in March. Fifty percent of the precipitation is snowy; and the other scope is rainy which falls in winter and spring. Stats Total Days of Ice Station Chadegan months of that December, January and February in all those days of the freezing order freeze the average number of days in a year is 103 days. Agricultural practices in Menderjan can be divided into two sectors, irrigated and rain-fed.

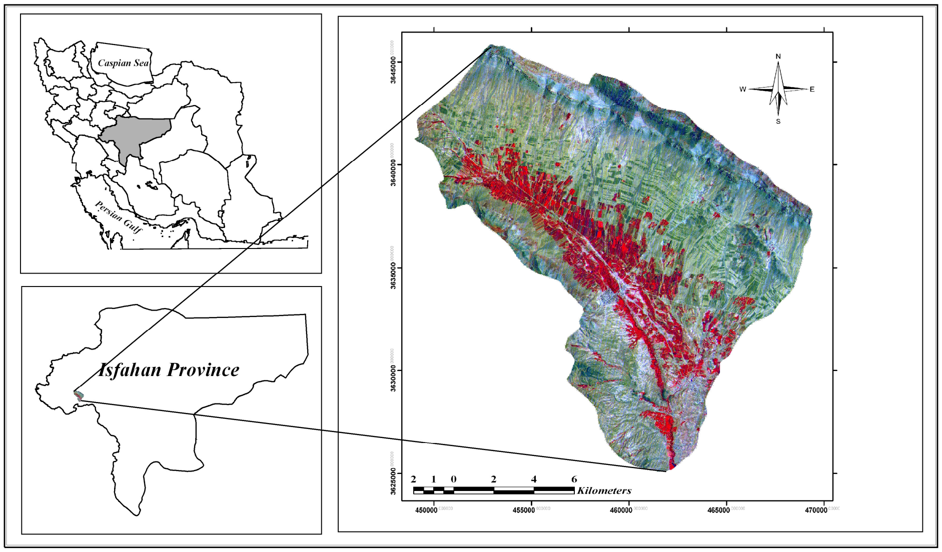


**Figure 1.2. Location of the study area (Color Composite RGB 432, IRS- P6 )**

**Table 1.3. Physical characteristics of the study area**

| **Land Characteristic** | **Description** |
|---|---|
| General Aspect of Slope | South |
| Area | 226.8 $km^2$ |
| Perimeter | 69.5 km |
| Mean altitude | 2430 m |
| Maximum altitude | 3642 m |
| Minimum altitude | 2100 m |
| Length of the longest channel | 22.8 km |
| Rough slope of the main channel | 2.2% |
| Net slope of the main channel | 14.3% |
| Average slope of the basin | 13.3% |
| Compactness coefficient | 1.51 |
| Gravellus coefficient | 1.29 |
| Form factor | 0.436 |
| Time of concentration | 4.67 hr |
| Stream frequency | 1.87 $km/km^2$ |

**Rain-fed agriculture**: is a cause of erosion in the study area. Fertile soil washed away rapidly, and land productivity decreases because of rain-fed agriculture. Principal crops are winter wheat and winter barley. Crops harvested in good years and grazed in bad years.

**Irrigated agriculture**: The principle-irrigated crops are wheat, barley, potato and forage such as alfalfa. Sources of water are rivers, wells and small streams. The Esfahan Water Organization reports that 121 wells, 35 streams, and 66 Ghanats are available in the Menderjan watershed. The Province Agricultural Organization has reported that the surface areas occupied by gardens are 1036.3 hectares, and other crops 7680 hectares.

## 1.8 Layout of the Thesis

This thesis organized into five chapters. The first chapter is the introduction, which gives a background of the Land Evaluation, Land Use Planning, Land Crop Suitability, GIS and Genetic Algorithms. It also brings forward the idea of Genetic Algorithms that is one of the parts in Geo-computation, Artificial Intelligence and Water Demand Model. The objectives and significance of the study mentioned in this chapter. Chapter 2 is the literature review, which gives an overview of the FAO Land Evaluation, Land Use Planning, Land Crop Suitability and GIS and Genetic Algorithm. A water demand model discussed, as it is the important aspect of the research work. Chapter three present discussions of Land Evaluation, Land Use Planning, Land Crop Suitability in the Menderjan basin using GIS, RS and Genetic Algorithms. The study area and the used method and material highlighted. The results and discussion presented in Chapter 4. In chapter five, summaries of the work presented, suggestions of possible areas of improvement are given and the research concluded.

## REFERENCES


Abd El-Kawy, O., Rød, J., Ismail, H., & Suliman, A. (2011). Land use and land cover change detection in the western Nile delta of Egypt using remote sensing data. *Applied Geography, 31*(2), 483-494.

Aerts, J. C. J. H., & Heuvelink, G. B. M. (2002). Using simulated annealing for resource allocation. *International Journal of Geographical Information Science, 16* (6), 571-587.

Ahmadi, H., & Mohammadi, A. (2010). Evaluation Of Sediment Estimation Of Epm And Psiac Models Using Geomorphology Method (Case Study: Dehnamak Watershed). *Iranian Journal of Range and Desert Research.*

Akinbile, C., & Sangodoyin, A. (2010). Estimating crop coefficient model for upland rice (NERICA) under sprinkler irrigation system. *African Journal of Agricultural Research, 5*(6), 436-441.

Ali, A., Sato, Y., & Shimizu, N. (2001). Exploration and analysis of socio-economic potentials for sustainable development in rural Egypt using GIS technology. *Journal of Rural Planning Association, 20.*

Allen, R. G., Pereira, L., Raes, D., & Smith, M. (1998). FAO irrigation and drainage paper no. 56. *Rome, Italy.*

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *FAO, Rome, 300*, 6541.

Amini, S., Rafiei, B., Khodabakhsh, S., & Heydari, M. (2010). Estimation of erosion and sediment yield of Ekbatan Dam drainage basin with EPM, using GIS. *IRANIAN JOURNAL OF EARTH SCIENCES (IJES).*

Andrade Benítez, O. C. (2007). *Generating information for land evaluation in Tocuyo River basin (Venezuela) by means of GIS and Remote Sensing: environmental parameters, land cover, and erosion hazard.* Niedersächsische Staats-und Universitätsbibliothek Göttingen.

Anonymous. (2000). Soil and water Conservation *No 3, Soil Report* (pp. 102). Isfahan Iran.

Armstrong, M. P., Xiao, N., & Bennett, D. A. (2003). Using genetic algorithms to create multicriteria class intervals for choropleth maps. *Annals of the Association of American Geographers, 93*(3), 595-623.

Aronoff, S., & Petrie, G. (2005). Photographic cameras, digital cameras, and videography. *Remote sensing for GIS managers*, 111.

Arora, V., & Gajri, P. (2000). Assessment of a crop growth-water balance model for predicting maize growth and yield in a subtropical environment. *Agricultural Water Management, 46*(2), 157-166.

Ayoubi SH, Jalalian A, & AM., A. (2002). Quantitative land suitability in northern Braan region in Esfahan Province of Iran for agricultural crops such as irrigation wheat, barley, maize and rice. *Iran J Sci Technol Agr Nat Resourc, 3*, 105–118.

Bäck, T., & Schwefel, H. P. (1993). An overview of evolutionary algorithms for parameter optimization. *Evolutionary computation, 1*(1), 1-23.

Badenhorst, J., de Lange, M., Mokwena, M., & Rutherfoord, R. (2000). 51st International Executive Council WATSAVE Workshop, Cape Town, South Africa.

Baja, S., Chapman, D. M., & Dragovich, D. (2007). Spatial based compromise programming for multiple criteria decision making in land use planning. *Environmental Modeling and Assessment, 12*(3), 171-184.

Bandyopadhyay, S., Jaiswal, R., Hegde, V., & Jayaraman, V. (2009). Assessment of land suitability potentials for agriculture using a remote sensing and GIS based approach. *International Journal of Remote Sensing, 30*(4), 879-895.

Berger, T., Schreinemachers, P., & Woelcke, J. (2006). Multi-agent simulation for the targeting of development policies in less-favored areas. *Agricultural Systems, 88*(1), 28-43.

Bini, C., Gemignani, S., & Zilocchi, L. (2006). Effect of different land use on soil erosion in the pre-alpine fringe (North-East Italy): Ion budget and sediment yield. *Science of the total environment, 369*(1), 433-440.

Bolstad, P. V., & Lillesand, T. (1992). Improved classification of forest vegetation in northern Wisconsin through a rule-based combination of soils, terrain, and Landsat Thematic Mapper data. *Forest Science, 38*(1), 5-20.

Booker, L. B., Goldberg, D. E., & Holland, J. H. (1989). Classifier systems and genetic algorithms. *Artificial intelligence, 40*(1-3), 235-282.

Brady, N. C., & Weil, R. R. (2004). *Elements of the nature and properties of soils*: Prentice Hall.

Branke, J., Deb, K., & Miettinen, K. (2008). *Multiobjective optimization: Interactive and evolutionary approaches* (Vol. 5252): Springer-Verlag New York Inc.

Burrough, P., Van Gaans, P., & Hootsmans, R. (1997). Continuous classification in soil survey: spatial correlation, confusion and boundaries. *Geoderma, 77*(2), 115-135.

Cai, J., Liu, Y., Xu, D., Paredes, P., & Pereira, L. (2009). Simulation of the soil water balance of wheat using daily weather forecast messages to estimate the reference evapotranspiration. *Hydrology and Earth System Sciences, 13*(7), 1045-1059.

Campbell, J. B. (2002). *Introduction to remote sensing* (third edition ed.): Guilford Press.

Chapman, S. R., & Carter, L. P. (1976). *Crop production: Principles and practices*: WH Freeman.

Chaudhuri, D., & Agrawal, A. (2010). Split-and-merge Procedure for Image Segmentation using Bimodality Detection Approach. *Defence Science Journal, 60*(3), 290-301.

Chavez, P. S. (1996). Image-based atmospheric corrections-revisited and improved. *Photogrammetric engineering and remote sensing, 62*(9), 1025-1035.

Chen, X., Vierling, L., & Deering, D. (2005). A simple and effective radiometric correction method to improve landscape change detection across sensors and across time. *Remote Sensing of Environment, 98*(1), 63-79.

Chubey, M. S., Franklin, S. E., & Wulder, M. A. (2006). Object-based analysis of Ikonos-2 imagery for extraction of forest inventory parameters. *Photogrammetric engineering and remote sensing, 72*(4), 383.

Collingwood, A. (2008). *Satellite image classification and spatial analysis of agricultural areas for land cover mapping of grizzly bear habitat.*

Collingwood, A., Franklin, S. E., Guo, X., & Stenhouse, G. (2009). A medium-resolution remote sensing classification of agricultural areas in Alberta grizzly bear habitat. *Canadian Journal of Remote Sensing, 35*(1), 23-36.

Correa, E. S., Steiner, M. T. A., Freitas, A. A., & Carnieri, C. (2004). A genetic algorithm for solving a capacitated p-median problem. *Numerical Algorithms, 35*(2), 373-388.

Darvishian, M. (2000). *Almond Planting and Producing* (Vol. First Edition). Mashhad Publication, Persian Text.

Datta, D., Deb, K., Fonseca, C. M., Lobo, F., & Condado, P. (2007). Multi-objective evolutionary algorithm for land-use management problem. *International Journal of Computational Intelligence Research, 3*(4), 1-24.

De Jong, K. (1980). Adaptive system design: a genetic approach. *Systems, Man and Cybernetics, IEEE Transactions on, 10*(9), 566-574.

De Smith, M. J., Goodchild, M. F., & Longley, P. (2007). *Geospatial analysis: a comprehensive guide to principles, techniques and software tools*: Troubador Publishing.

De Vente, J., Poesen, J., Verstraeten, G., Van Rompaey, A., & Govers, G. (2008). Spatially distributed modelling of soil erosion and sediment yield at regional scales in Spain. *Global and planetary change, 60*(3), 393-415.

De Wit, C., Van Keulen, H., Seligman, N., & Spharim, I. (1988). Application of interactive multiple goal programming techniques for analysis and planning of regional agricultural development. *Agricultural Systems, 26*(3), 211-230.

Debaeke, P., Faci, J. M., Cavero, J., & Farre, I. (2000). Simulation of maize yield under water stress with the EPICphase and CROPWAT models.

Delorite, R., & Ahlgren, H. (1967). Crop production. Printice-Hall. *Inc., Englwood Cliffs, New Jersy*, 34-35.

Dengiz, O., Bayramin, I., & Yüksel, M. (2003). Geographic Information System and Remote Sensing Based Land Evaluation of Beypazarı Area Soils by ILSEN Model. *Turk. J. Agric. For, 27*, 145-153.

Dent, D., & Young, A. (1981). *Soil survey and land evaluation*: George Allen & Unwin.

Diamond, J., & Wright, J. (1988). Design of an integrated spatial information system for multiobjective land-use planning. *Environment and Planning B, 15*(2), 205-214.

Doorenbos, J., & Pruitt, W. O. (1984). Guidelines for predicting crop water requirements, Irrigation and Drainage Paper 24. *Land and Water Development Division FAO Rome*.

Dorigo, M., & Gambardella, L. M. (1997). Ant colony system: A cooperative learning approach to the traveling salesman problem. *Evolutionary Computation, IEEE Transactions on, 1*(1), 53-66.

Du, Y., Teillet, P. M., & Cihlar, J. (2002). Radiometric normalization of multitemporal high-resolution satellite images with quality control for land cover change detection. *Remote Sensing of Environment, 82*(1), 123-134.

Dumanski, J., & Onofrei, C. (1989). Techniques of crop yield assessment for agricultural land evaluation. *Soil Use and Management, 5*(1), 9-15.

Ehlers, M., Kaufmann, H. J., & Michel, U. (2004). *Remote sensing for environmental monitoring, GIS applications, and geology III: 9-11 September 2003, Barcelona, Spain* (Vol. 5239): Society of Photo Optical.

Elaalem, M., Comber, A., & Fisher, P. (2011). A Comparison of Fuzzy AHP and Ideal Point Methods for Evaluating Land Suitability. *Transactions in GIS, 15*(3), 329-346.

Er-Raki, S., Chehbouni, A., Guemouria, N., Ezzahar, J., Khabba, S., Boulet, G., & Hanich, L. (2009). Citrus orchard evapotranspiration: comparison between eddy covariance measurements and the FAO-56 approach estimates. *Plant Biosystems, 143*(1), 201-208.

Erskine, W. D., Mahmoudzadeh, A., Browning, C., & Myers, C. (2003). Sediment yields and soil loss rates from different land uses on Triassic shales in western Sydney, NSW. *Soil Research, 41*(1), 127-140.

Fanetti, D., & Vezzoli, L. (2007). Sediment input and evolution of lacustrine deltas: The Breggia and Greggio rivers case study (Lake Como, Italy). *Quaternary International, 173*, 113-124.

FAO. (1976). A framework for land evaluation. FAO Soils Bulletin Rome: FAO Publication, 72 pp.

FAO. (1978-81). Report on the Agro-ecological Zones project. Vol. 1. Methodology and results for Africa. Vol.2. Results for southwest Asia; Vol.3. Methodology and results for South and Central America; Vol. 4, Results for Southeast Asia *FAO World Soil Resources Report, 48/1, 4*. FAO, Rome.

FAO. (1979). Land evaluation criteria for irrigation, Soils Bulletin 50. Food and Agriculture Organization of the United Nations (FAO), Rome, pp: 219.

FAO. (1983). Guidelines: Land Evaluation for Rainfed Agriculture. FAO Soils Bulletin No 52 FAO, Roma, Italia. 229 pp.

FAO. (1984). Land evaluation for forestry. FAO Forestry ,Paper 48. FAO Forestry Paper FAO, Rome, 123 pp.

FAO. (1985a). Guidelines:Land Evaluation for Irrigation. FAO Soils Bulletin nº 55 FAO, Rome. 123 pp.

FAO. (1990a). The Conservation and Rehabilitation of African Lands: An International Scheme.. *ARC/90/4*. Rome, 38 pp.

FAO. (1991). Guidelines: land evaluation for extensive grazing. FAO Soils Bulletin 58. FAO, Rome, 158 pp.

FAO. (1993a). Guidelines for land use planning . *FAO Development Series 1*. FAO, Rome, 96 pp.

FAO. (2007). Land evaluation: towards a revised framework *Land and Water Discussion, Paper 6*. FAO, Rome, 108 pp.

Farahpour, M., Van Keulen, H., Sharifi, M., & Bassiri, M. (2004). A planning support system for rangeland allocation in Iran with case study of Chadegan Sub-region. *The Rangeland Journal, 26*(2), 225-236.

Feyznia, S. (1995). Rocks strength against erosion factors in different climates of Iran. J. *Natural Res. Iran, 47*, 95-116.

Fotheringham, A. S., Openshaw, S., & Abrahart, R. (2000). *GeoComputation analysis and modern spatial data*.

Franklin, S., & Wulder, M. (2002). Remote sensing methods in medium spatial resolution satellite data land cover classification of large areas. *Progress in Physical Geography, 26*(2), 173.

Gavrilovic, Z. (1988). *The Use of an Empirical Method (Erosion Potential Method For Calculating Sediment Production and Transportation in Unstudied or Torrential Streams*. Paper presented at the International Conference on RIVER REGIME, Wallingford, England.

Gavrilovic, Z., Stefanovic, M., Milojevic, M., & Cotric, J. (2004). Erosion potential method: an important support for integrated water resource management. *Institute Development of Water Resources, 14p*.

Gaw, S. K., & Council, A. R. (2002). *Pesticide residues in horticultural soils in the Auckland region*: Auckland Regional Council.

Gen, M., & Cheng, R. (2000). *Genetic algorithms and engineering optimization* (Vol. 7): Wiley-interscience.

Givi, J. (1997). Qualitative Evaluation of Lands for Orchard and Farming Crops (pp. 100). Tehran, Iran.

Globevnik, L., Holjevic, D., Petkovsek, G., & Rubinic, J. (2003). Applicability of the Gavrilovic method in erosion calculation using spatial data manipulation techniques. *IAHS PUBLICATION*, 224-233.

Guo, X., Wang, J., Xie, J., He, T., Lian, G., & Lv, C. (2005). *Land degradation analysis based on the land use changes and land degradation evaluation in the Huan Beijing area*.

Hall, G., Wang, F., & Subaryono, J. (1992). Comparison of Boolean and fuzzy classification methods in land suitability analysis by using geographical information systems. *Environment and Planning A, 24*(4), 497-516.

Haupt, R. L., Haupt, S. E., & Wiley, J. (2004). *Practical genetic algorithms*: Wiley Online Library.

Holland, J. H. (1975). Adaptation in natural and artificial systems. *Ann Arbor: University of Michigan Press, 2*.

Holzkämper, A., & Seppelt, R. (2007). A generic tool for optimising land-use patterns and landscape structures. *Environmental Modelling & Software, 22*(12), 1801-1804.

Hutchinson, M. J., & Veenendaal, B. (2011). An agent-based framework for intelligent geocoding. *Applied Geomatics*, 1-12.

ILACO.(1989).Agricultural Compendium for Rural Development in The Tropics and Subtropics.*Elsevier Science Publishing Company Inc.,Second Edition ed. New York*.

Imagine, E. (2005). Erdas Imagine Field Guide. *ERDAS Inc., Atlanta, Georgia*.

Issar, A. S., & Adar, E. (2010). Progressive development of water resources in the Middle East for sustainable water supply in a period of climate change. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 368*(1931), 5339-5350.

Izzi, G., Farahani, H., Bruggeman, A., & Oweis, T. (2008). In-season wheat root growth and soil water extraction in the Mediterranean environment of northern Syria. *Agricultural Water Management, 95*(3), 259-270.

Jain, A., & Zongker, D. (1997). Feature selection: Evaluation, application, and small sample performance. *Pattern Analysis and Machine Intelligence, IEEE Transactions on, 19*(2), 153-158.

Jang, M. W., Choi, J. Y., & Lee, J. J. (2007). A spatial reasoning approach to estimating paddy rice water demand in Hwanghaenam-do, North Korea. *Agricultural Water Management, 89*(3), 185-198.

Jansen, H. G. P., Bouman, B. A. M., Schipper, R. A., Hengsdijk, H., & Nieuwenhuyse, A. (2005). An interdisciplinary approach to regional land use analysis using GIS, with applications to the Atlantic Zone of Costa Rica. *Agricultural economics, 32*(1), 87-104.

Jenerette, G. D., & Wu, J. (2001). Analysis and simulation of land-use change in the central Arizona–Phoenix region, USA. *Landscape Ecology, 16*(7), 611-626.

Jensen, J. (1996). Introduction to digital image processing of remotely sensed data. *Introductory digital image processing: a remote sensing perspective. Prentice-Hall, Inc., New Jersey*, 1-2.

Jensen, J. (2005). Remote sensing and digital image processing. *Introductory Digital Image Processing. A Remote Sensing Perspective*, 1-34.

Jensen, J. (2007). Remote Sensing of the Environment an Earth Resource Perspective, person prentice Hall: Pearson Education. Inc. Upper Saddle River, NJ07458.

Jones, J. W., Hoogenboom, G., Porter, C., Boote, K., Batchelor, W., Hunt, L., . . . Ritchie, J. (2003). The DSSAT cropping system model. *European journal of agronomy, 18*(3-4), 235-265.

Katerji, N., & Rana, G. (2008). Crop evapotranspiration measurement and estimation in the Mediterranean region. *CRA-SCA. Italy*.

Katerji, N., & Rana, G. (2011). Crop reference evapotranspiration: a discussion of the concept, analysis of the process and validation. *Water resources management, 25*(6), 1581-1600.

Kennedy, M., & Krouse, D. (1999). Strategies for improving fermentation medium performance: a review. *Journal of industrial microbiology & biotechnology, 23*(6), 456-475.

Kester, D. E., Gradziel, T. M., & Grasselly, C. (1991). Almonds (Prunus). *Genetic Resources of Temperate Fruit and Nut Crops 290*, 701-760.

Kirkpatrick, S., Gelatt Jr, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. *science, 220*(4598), 671-680.

Koomen, E., & Stillwell, J. (2007). Modelling land-use change. *Modelling Land-Use Change*, 1-22.

Kuo, S. F., Ho, S. S., & Liu, C. W. (2006). Estimation irrigation water requirements with derived crop coefficients for upland and paddy crops in ChiaNan Irrigation Association, Taiwan. *Agricultural Water Management, 82*(3), 433-451.

Landon, J. R. (1991). *Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics*: Longman Scientific & Technical.

Lascano, R. J. (2000). A general system to measure and calculate daily crop water use. *Agronomy Journal, 92*(5), 821-832.

Le Bissonnais, Y., Montier, C., Jamagne, M., Daroussin, J., & King, D. (2002). Mapping erosion risk for cultivated soil in France. *Catena, 46*(2-3), 207-220.

Li, X., & Yeh, A. G. O. (2005). Integration of genetic algorithms and GIS for optimal location search. *International Journal of Geographical Information Science, 19*(5), 581-601.

Ligmann-Zielinska, A., Church, R. L., & Jankowski, P. (2008). Spatial optimization as a generative technique for sustainable multiobjective land-use allocation. *International Journal of Geographical Information Science, 22*(6), 601-622.

Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2004). *Remote sensing and image interpretation*: John Wiley & Sons Ltd.

Lim, H., MatJafri, M., & Abdullah, K. (2009). High spatial resolution land cover mapping using remotely sensed image. *Modern Applied Science, 3*(5), P82.

Lobell, D. B., Asner, G. P., Ortiz-Monasterio, J. I., & Benning, T. L. (2003). Remote sensing of regional crop production in the Yaqui Valley, Mexico: estimates and uncertainties. *Agriculture, ecosystems & environment, 94*(2), 205-220.

Lombardo, S., & Petri, M. (2008). The Simulation of Spatial Change: What Relation Between Knowledge and Modeling? A Proposal and Its Application. *The Dynamics of Complex Urban Systems*, 335-356.

Lu, D., Mausel, P., Brondizio, E., & Moran, E. (2002). Assessment of atmospheric correction methods for Landsat TM data applicable to Amazon basin LBA research. *International Journal of Remote Sensing, 23*(13), 2651-2671.

Lu, D., & Weng, Q. (2007). A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing, 28*(5), 823-870.

Lufafa, A., Tenywa, M., Isabirye, M., & Majaliwa, M. (2003). Prediction of soil erosion in alake victoria basin catchment using a GIS-based universal soil loss model. *Agri. Systems, 76*, 883-894.

Makhdoum, M. (2007). Fundamental of land use planning: University of Tehran Press.

Malano, H. M., George, B. A., & Davidson, B. (2004). *A framework for improving the management of irrigation schemes in Vietnam. Proceedings of a workshop, Ho Chi Minh City, Vietnam, 28 November 2003*.

Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning, 62*(1), 3-65.

Malczewski, J. (2006). GIS-based multicriteria decision analysis: a survey of the literature. *International Journal of Geographical Information Science, 20*(7), 703-726.

Maniee, A. (1990). *Scientific Principles of Fruit Horticulture* (Vol. First Edition). Iran, Theran: Iran Technical publication, pp 297.

Manna, P., Basile, A., Bonfante, A., De Mascellis, R., & Terribile, F. (2009). Comparative Land Evaluation approaches: An itinerary from FAO framework to simulation modelling. *Geoderma, 150*(3-4), 367-378.

Martin, D., & Saha, S. (2009). Land evaluation by integrating remote sensing and GIS for cropping system analysis in a watershed. *Current Science, 96*(4), 569-575.

Martin, J. H., W.H., Leonard., D.l., Stamp. (1976). *Principles of Field Crop Production* (Vol. 3nd edition). New York: MacMillan.

Matthews, K., Buchan, K., Sibbald, A., & Craw, S. (2002). *Using soft-systems methods to evaluate the outputs from multi-objective land use planning tools*.

Matthews, K. B. (2001). *Applying genetic algorithms to multi-objective land-use planning*. The Robert Gordon University.

Michalewicz, Z., & Schoenauer, M. (1996). Evolutionary algorithms for constrained parameter optimization problems. *Evolutionary computation, 4*(1), 1-32.

Micke, W. C. (1996). *Almond production manual* (Vol. 3364): ANR Publications.

Miller, C. L., & Laflamme, R. A. (1958). *The Digital Terrain Model-: Theory & Application*: MIT Photogrammetry Laboratory.

Moradi, H. (2001). Qualitative and Quantitative of Almond Varieties (pp. P:12). Agricultural Centre of Chahar Mahal of Bakhtiari: Persian Research Report of the Investigation Projects., Agricultural Centre of Chahar Mahal of Bakhtiari.

Morgan, R., & Duzant, J. (2008). Modified MMF (Morgan–Morgan–Finney) model for evaluating effects of crops and vegetation cover on soil erosion. *Earth Surface Processes and Landforms, 33*(1), 90-106.

Nasri, M., Feiznia, S., Jafari, M., & Ahmadi, H. ( 2009). Using Field Indices of Rill and Gully in order to Erosion Estimating and Sediment Analysis (Case Study: Menderjan Watershed in Isfahan Province, Iran). *International Journal of Humanities and Social Sciences, 3*(3), 230- 236.

Neameh, B. (2003). Land evaluation for Land Use Planning with especial attention to sustainable fodder production in the Rouzeh Chai catchment of Orumiyeh area–Iran. MS unpublished Thesis. *International Institute for Geo-information Science and Earth Observation., Nederland*.

Neelam, A., Cassol, T., Mehta, R. A., Abdul-Baki, A. A., Sobolev, A. P., Goyal, R. K., Mattoo, A. K. (2008). A field-grown transgenic tomato line expressing higher levels of polyamines reveals legume cover crop mulch-specific perturbations in fruit phenotype at the levels of metabolite profiles, gene expression, and agronomic characteristics. *Journal of experimental botany, 59*(9), 2337-2346.

Nelson, C., & Rasele, Y. (1989). Evaluating the debris flow potential after a wild fire, rapid response using the PSIAC method, Salt Lake County, Utah. *Geolog.* Soc. Am. Abstracts Programs, 121.

Nunez, Q., & Ferrer, E. (2010). A Hybrid Genetic Algorithm for the Student-Aware University Course Timetabling Problem.

Ogly Aliev, R. A., & Aliev, R. R. (2001). *Soft computing and its applications*: World Scientific Pub Co Inc.

Park, S. Y., Choi, J. H., Wang, S., & Park, S. S. (2006). Design of a water quality monitoring network in a large river system using the genetic algorithm. *Ecological Modelling, 199*(3), 289-297.

Parolo, G., Ferrarini, A., & Rossi, G. (2009). Optimization of tourism impacts within protected areas by means of genetic algorithms. *Ecological Modelling, 220*(8), 1138-1147.

Parsopoulos, K. E., & Vrahatis, M. N. (2002). Recent approaches to global optimization problems through particle swarm optimization. *Natural computing, 1*(2), 235-306.

Patil, A., Annachhatre, A., & Tripathi, N. (2002). Comparison of conventional and geo-spatial EIA: A shrimp farming case study. *Environmental Impact Assessment Review, 22*(4), 361-375.

Paulinas, M., & Ušinskas, A. (2007). A survey of genetic algorithms applications for image enhancement and segmentation. *Information Technology and control, 36*(3), 278-284.

Penev, K., & Ruzhekov, A. (2011). Adaptive intelligence applied to numerical optimisation. *Numerical Methods and Applications*, 280-288.

Qaid, A. M., & Basavarajappa, H. (2008). Application of Optimum Index Factor Technique to Landsat-7 Data for Geological Mapping of North East of Hajjah, Yemen. *American-Eurasian Journal of Scientific Research, 3*(1), 84-91.

Quanta, & Engineers, C. (1977). Guidelines for Requirements and Constrains of the Agricultural Meteorology for 15 major Crops of Iran *Iran Meteorology Organization and Romani Meteorology Institute*.

RAES, D. (2009). ETo calculator Evapotranspiration from a reference surface (Land and water digital media series N 36) CD-ROM. *Recherche, 67*, 02.

Refahi, H. (2007). *Water erosion and consevation*. Tehran-Iran: Tehran University Press. 671.

Refahi, H., & Namati, M. (1995). Using EPM for study erodibility and sediment yield in Alamout watershed. *Iranian Journal of Agriculture Science, 26*(2), 32-45.

Riveira, I. S., & Maseda, R. C. (2006). A review of rural land-use planning models. *Environment and Planning B: Planning and Design, 33*(2), 165-183.

Rockström, J., Barron, J., & Fox, P. (2003). Water productivity in rain-fed agriculture: challenges and opportunities for smallholder farmers in drought-prone tropical agroecosystems. *Water productivity in agriculture: Limits and opportunities for improvement, 85199*(669), 8.

Rodríguez, M. A., & Jarur, M. C. (2005). A genetic algorithm for searching spatial configurations. *Evolutionary Computation, IEEE Transactions on, 9*(3), 252-270.

Rossiter, D. G. (1996). A theoretical framework for land evaluation. *Geoderma, 72*(3), 165-190.

Rossiter, D. G., & Van Wambeke, A. R. (1997). Automated land evaluation system ALES version 4.65 user's manual. *Management, 6*(1), 7-20.

Rudas, I. J., & Fodor, J. (2008). Intelligent systems. *International Journal of Computers, Communications & Control, 3*, 132-138.

Sahin, U., Kiziloglu, F., Anapali, O., & Okuroglu, M. (2007). Determining crop and pan coefficients for sugar beet and potato crops under cool season semiarid climatic conditions. *Journal of agronomy and crop science, 193*(2), 146-152.

Sanchez, P. A., Palm, C. A., & Buol, S. W. (2003). Fertility capability soil classification: a tool to help assess soil quality in the tropics. *Geoderma, 114*(3), 157-185.

Sarkar, D., & Modak, J. M. (2005). Pareto-optimal solutions for multi-objective optimization of fed-batch bioreactors using nondominated sorting genetic algorithm. *Chemical Engineering Science, 60*(2), 481-492.

Sarra, A. P. (2000). *Crop Water Requirement of Micro Irrigated Crops RS WIJESEKARA Subject matter specialist (Micro Irrigation).* Paper presented at the workshop on Micro Irrigation, p 1-7, India.

Sathiyan, S. P., & Lins, A. W. (2011). Soft Computing Based Adaptive Cruise Control. *Indian Journal of Computer Science and Engineering, 2*(1), 68-76.

Seixas, J., Nunes, J. P., Lourenço, P., & Corte-Real, J. (2007). GeneticLand: modelling land-use change using evolutionary algorithms. *Modelling Land-Use Change*, 181-197.

Shad, R. (2004). *Evaluation of Indexing Overlay, Fuzzy Logic and Genetic Algorithm Methods for Industrial Estates Site Selection in GIS Environment*.

Shanmugam, P., Ahn, Y. H., & Sanjeevi, S. (2006). A comparison of the classification of wetland characteristics by linear spectral mixture modelling and traditional hard classifiers on multispectral remotely sensed imagery in southern India. *Ecological Modelling, 194*(4), 379-394.

Sharifi, M., & Van Keulen, H. (1994). A decision support system for land use planning at farm enterprise level. *Agricultural Systems, 45*(3), 239-257.

Shayesteh, A. (2008). Land use planning for sediment minimizing Master of Science, Isfahan University of Technology.

Singh, R., Semwal, D., Rai, A., & Chhikara, R. S. (2002). Small area estimation of crop yield using remote sensing satellite data. *International Journal of Remote Sensing, 23*(1), 49-56.

Sivanandam, S., & Deepa, S. (2007). *Introduction to genetic algorithms*: Springer Publishing Company, Incorporated.

Smith, M. (1992). CROPWAT, a computer program for irrigation planning and management by M. *FAO Irrigatin and Drainage Paper. Rome*.

Solaimani, K., Modallaldoust, S., & Lotfi, S. (2009). Investigation of land use changes on soil erosion process using geographical information system. *International Journal of Environmental Science and Technology, 6*(3), 415-424.

Soman, S., Misgna, G., Kraft, S., Lant, C., & Beaulieu, J. (2008). *An agent-based model of multifunctional agricultural landscape using genetic algorithms.* Paper presented at the American Agricultural Economics Association, 2008 Annual Meeting, July 27-29, 2008., Orlando, Florida, 35pp.

Stewart, B. A., Nielsen, D.R. (1990). Irrigation of Agricultural Crops. *Agronomy, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, 30*, 1218.

Stewart, G. A., & Scientific, C. (1968). *Land evaluation*: Macmillan Melbourne.

Stewart, T. J., Janssen, R., & van Herwijnen, M. (2004). A genetic algorithm approach to multiobjective land use planning. *Computers & Operations Research, 31*(14), 2293-2313.

Storie, R. E. (1933). An index for rating the agricultural value of soils *California Agricultural Experiment Station Bulletin 556, 44 pp*. Berkeley: California Agricultural Experiment Station.

Sys, C., Van Ranst, E., & Debaveye, J. (1991). Land Evaluation. Part. II. Methods in land evaluation. *Agricultural publication*(7), 247.

Sys, C., Van Ranst, E., Debaveye, J., & Beernaert, F. (1993). Land evaluation, part III: Crop requirements. *Agricultural publication*(7).

SYS, C. (1979). Evaluation of the physical environment for irrigation. *Land evaluation criteria for irrigation. FAO. Roma.*

Tangestani, M. H. (2006). Comparison of EPM and PSIAC models in GIS for erosion and sediment yield assessment in a semi-arid environment: Afzar Catchment, Fars Province, Iran. *Journal of Asian Earth Sciences, 27*(5), 585-597.

Tanji, K. K., Kielen, N. C., Food, & Nations, A. O. o. t. U. (2002). *Agricultural drainage water management in arid and semi-arid areas* (Vol. 61): FAO.

Tesfaye, K., & Walker, S. (2004). Matching of crop and environment for optimal water use: the case of Ethiopia. *Physics and Chemistry of the Earth, Parts A/B/C, 29*(15-18), 1061-1067.

Turker, M., & Arikan, M. (2005). Sequential masking classification of multi-temporal Landsat7 ETM+ images for field-based crop mapping in Karacabey, Turkey. *International Journal of Remote Sensing, 26*(17), 3813-3830.

Turner, R. K. (2004). *Economic valuation of water resources in agriculture: From the sectoral to a functional perspective of natural resource management* (Vol. 27): Food & Agriculture Organization of the UN (FAO).

Van Diepen, C., Van Keulen, H., Wolf, J., & Berkhout, J. (1991). Land evaluation: from intuition to quantification. *Advances in soil science, 15*, 139-204.

Van Ranst, E., Tang, H., Groenemam, R., & Sinthurahat, S. (1996). Application of fuzzy logic to land suitability for rubber production in peninsular Thailand. *Geoderma, 70*(1), 1-19.

Vermeiren, I., & Jobling, G. (1995). Localized irrigation. Rome: FAO, 1980. 203p. *Irrigation and Drainage Paper, 36*.

Wahyunto, W., Rintung, S., Wahdini, W., & Agus, F. (2008). Alternative tree crops for reconstruction of the green infrastructure post-tsunami in the coastal areas of Aceh Barat District. *Indonesian Journal of Agricultural Science, 10*(1), 1-12.

Wang, Y., Traore, S., & Kerh, T. (2009). Applying Evapotranspiration Reference Model and RainfallContribution Index for Agricultural Water Management Plan in Burkina Faso. *African Journal of Agricultural Research, 4*(12), 1493-1504.

Winch, T. (2007). *Growing food: a guide to food production*: Springer Verlag.

Wischmeier, W. S. (1978). Predicting Rainfall Erosion Losses. A Guide to Conservation Planning. *US Department of Agriculture. Washington DC*.

Wright, L. E., Zitzmann, W., Young, K., & Googins, R. (1983). LESA—agricultural land evaluation and site assessment. *Journal of Soil and Water Conservation, 38*(2), 82-86.

Wulder, M., Skakun, R., Kurz, W., & White, J. (2004). Estimating time since forest harvest using segmented Landsat ETM+ imagery. *Remote Sensing of Environment, 93*(1), 179-187.

Xiao, N., Bennett, D. A., & Armstrong, M. P. (2007). Interactive evolutionary approaches to multiobjective spatial decision making: A synthetic review. *Computers, Environment and Urban Systems, 31*(3), 232-252.

Xiaoli, L., Chen, Y., & Daoliang, L. (2009). A spatial decision support system for land-use structure optimization. *WSEAS Transactions on Computers, 8*(3), 439-448.

Yialouris, C. P., Kollias, V., Lorentzos, N. A., Kalivas, D., & Sideridis, A. B. (1997). An integrated expert geographical information system for soil suitability and soil evaluation. *Journal of Geographic Information and Decision Analysis, 1*(2), 89-99.

Zadeh, L. A. (1994). Fuzzy logic, neural networks, and soft computing. *Communications of the ACM, 37*(3), 77-84.

Zander, P., & Kächele, H. (1999). Modelling multiple objectives of land use for sustainable development. *Agricultural Systems, 59*(3), 311-325.

Zhang, H., & Oweis, T. (1999). Water-yield relations and optimal irrigation scheduling of wheat in the Mediterranean region. *Agricultural Water Management, 38*(3), 195-211.