Land evaluation for Land Use Planning with especial attention to sustainable fodder production in the Rouzeh Chai catchment of Orumiyeh area - Iran

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January 2003

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By

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Thesis submitted to the International Institute for Geo-information Science and Earth Observation in partial fulfilment of the requirements for the degree of Master of Science in Watershed and Environmental management

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Disclaimer

ACKNOWLEDGEMENT

At the completion of this thesis, first of all I would like to give thanks to God who provided me this academic opportunity for higher degree.

I also express my gratitude to Ir. G. r. Hennemann for his benefit guidance, useful discussions and good comments during the thesis writing.

I would like also to appreciate Dr. A. Farshad my second supervisor, for his constructive suggestions and comments about soil and ALES training.

I am also very grateful to Dr. A. Moameni my Iranian supervisor for his assistance and innumerable suggestions in the field.

I would also like to acknowledge those who were involved in my training and those who cooperated in this study.

I would like to deeply thank my family, in particular sincere gratitude to my wife for taking up all the responsibilities during my absence from home.

ABSTRACT

The study area is located in the western part of the Azarbayejan province in northwestern of Iran. The surface area is about 28,000 ha.
The study area has cold and moist winters and mild summers. The mean annual rainfall is about 367mm; the mean annual temperature is 12.2 °c. The average annual evaporation is almost 1051mm. The Rouzeh Chai river is the main river with a mean annual discharge of 1.5 m^3/s.
Lithologically, the study area includes three main groups: metamorphosed rocks, sedimentary rocks and alluvial deposits.
Geomorphologically, the catchment consists of five landscapes: Mountain, Hilland, Piedmont, Plateau and Valley.
13,087 individuals, in 2326 families, inhabit the area. Animal husbandry and farming are the main activities of people.
The soils of the area were studied using the geopedologic approach. Five landscapes and 18 landforms were distinguished. The soils were classified down to family level according to the USDA soil taxonomy system (1998).
To identify the present landuse, landsat ETM image (2000), for previous landuse TM image (1990) and aerial photographs (1956) were used. Multi - spectral classification and color density slicing for NDVI were done to classify the present landuse. Landuse changes were distinguished by comparing present and previous landuse in order to detect the causes of land degradation.
Land suitability evaluation for different Land Use Types (LUT's) was determined using ALES software.
For purpose of evaluation, 5 Land Use Types and 7 Land Qualities (LQ's) were selected to match with the list of Land Use Requirements (LUR's) prepared for the area.
To obtain physical land suitability class of map units, Land Use Requirements, severity level decision trees and physical suitability subclass decision trees were established, leading to physical suitability subclasses.
For Land Use Planning two scenarios defined and evaluated using DEFINITE software.
The predefined LUT was realized, using the ranking procedure, followed by area calculation, that is, the surface area that should be covered by each, based on land suitability in class 1 and 2.
The main problem of the area is mismanagement of agricultural systems, that is, sloping areas are plowed parallel to the slope direction, and the problem of overgrazing due to shortage of feed for animals, and converting rangelands into the agricultural lands are symptoms of unsustainability in this area. Determining suitable lands in order to increase fodder production will reduce the pressure on rangelands and consequently decrease soil erosion.
To comply with the objectives, after preparation of geopedologic map and defining LUT and doing land evaluation using ALES, finally land use options were determined using DEFINITE.

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1. INTRODUCTION

1.1 Background an problem statement

Rapidly growing population and necessity to soil in order to secure food and other demands made human being to pay more attention about soil and soil science as well. Undoubtedly, one of the ways to provide food for the human being is to increase production in area unit and to utilize the land with respect to its potentiality in an appropriate way. Land capability in production is limited. Environmental conditions (climate & soil), land use type and management, determine the production limit. Any utilization of the land, that is, over its capability will cause degradation and yield reduction in long-term duration. Therefore, to know the land production capacity and to allocate the land to the best and to the most profitable should be cared.

Global concerns about food security, the quality of life for future generations and a growing awareness about environment degradation are posing penetrating questions to the world of sciences (De Bie, Van Lanen, & Zuidema, 1996). Therefore, availability of proper land use information is required at various scales of planning.

Agriculture is one of the world's most important activities supporting human life. On a global scale, agriculture has the proven potential to increase food supplies faster than the growth of the population, a pattern to be expected in the foreseeable future (Davidson, 1992).

Projections for the year 2000 and beyond suggest that, due to population increase and income growth, demand for food and other agricultural products will continue to rise by over 3% annually (Fresco, 1989). In most countries the diet is expected to diversify in favor of higher value commodities such as livestock and horticultural products. This will have important implications for future land use.

The sound planning of changes in land use requires a thorough knowledge of the natural resources, and a reliable estimate of what they are capable of producing, so that reliable predictions and recommendations can be made. In addition to production potential, the conservation of soil and water resources for use by future generations requires consideration in planning land development.

In Iran, like many other developing countries, land use planning is not practiced on a regular basis. In many parts, rangelands are converted into rain fed agriculture. This is often the start point of degradation leading to accelerate erosion; land productivity reduction in case of fertile soil is washed away.

Undoubtedly, a proper land management decreases soil erosion and increases agricultural yield. Land evaluation is an important step in the process of land use planning where the resources are limited. Land use programming for optimum use causes the maximum profitability so that, the land will be protected for the future land users. In this frame of programming, the land is evaluated and their suitability for the possible uses will be specified. Hence, the land base on their characteristics will be determined to the most profitable use. Sustainable agriculture comes true, provided that the land based on their suitability will be classified and utilized for different uses types (FAO, 1983). Quality assessment of land suitability is to estimate land use for specific uses without taking into consideration of yield and social-economic factors (FAO, 1976,1983).

1.2 The research problem

In the Orumieh area in western Iran, rangeland has been converted on a large scale into mechanized rainfed cropland during the past two decades. Unfortunately, this conversion took place mainly on vulnerable sloping land without proper consideration of the capability and suitability of the land. As a result, accelerated soil erosion including topsoil removal has become a major threat to the livelihood of the Orumieh inhabitants. Also, the reduction of grazing land has resulted in a shortage of food for the farmers' animals (cattle, sheep and goat).

A complete list of resource problems the rural Orumieh inhabitants are faced with is as follows:

1) Low crop productivity and low farm income,
2) Indiscriminate conversion of rangeland into rainfed cropland on vulnerable sloping areas without due consideration of the suitability of the land leading to severe accelerated soil erosion,
3) Overgrazing on remaining rangeland areas leading to grassland degradation and accelerated soil erosion,
4) Lack of appropriate conservation practices on above lands has further aggravated the soil erosion situation.

Clearly, current land use developments in the area are lacking a firm sustainable basis. In addition, no systematic land suitability assessment and land use planning has been carried out in the area so far. A systematic inventory and analysis of present land resource and land use patterns is therefore required to be followed by a sound land suitability evaluation and land use planning. In this way, land use can be optimised on a sustainable basis with due consideration of government policy objectives and farmers' priorities in the area.

1.3 Research objectives

- To identify, characterize and map the major soils in the study area following a geopedologic approach.
- To identify and map the major land cover and use types in the area using RS and secondary data.

- To carry out a land suitability evaluation using ALES in order to identify economically profitable, environmentally sustainable and socially acceptable land-land use combinations with special reference to fodder production aspects,
- To establish - with due consideration of government policy objectives and farmers priorities - optimised spatial land use scenarios using DEFINIT for spatial planning decision support.

1.4 Hypotheses

Land utilization types requirements with land units' characteristics and qualities are conformed using FAO framework for land evaluation (FAO, 1976) in order to determine land suitability classes for kinds of land utilization types. If the present land use is well matched with the determined land suitability class, it may mean that there is no pressure on the land, otherwise land is improperly used, so limiting crop growth factors in the study area should be identified and rated.
Based on the results of land suitability classification, improvement of land use should be assessed.

To optimise land use, DEFFINITE software, which is a tool to support decisions with a finite set of alternatives in relation to a finite number of criteria, is used for land use planning at sub regional (local) level.

1.5 Research questions

1) What are the important land use types in the study area?
2) What are the biophysical limitations for each land utilization type (LUT) in the study area?
3) What characteristics and/or qualities of land, limit crop growth in the study area leading to highly suitable, moderately suitable, marginally suitable or not suitable land for given land utilization types?
4) Can land evaluation improve land use in the study area?
5) Do the results of land suitability classification improve the cropping system?

2. LITERATURE REVIEW

2.1. Land use planning

2.1.1. Background

Planning is a decision-making method that leads to the transformation of a current situation into a more acceptable future situation by distributing scarce resources among multiple objectives in order to minimize costs and maximize benefits under a dynamic social equilibrium (Rodriguez, 1995).

Land use planning can help decision- makers (such as government or land users) to use land in such a way that current land use problems are reduced and specific social, economic and environmental goals are satisfied (sustainability, income generation, self-sufficiency, etc.). The main objective of land use planning is to identify the uses that best satisfy specific goals for different tracts of land and the formulation of projects, programmes or management plans to implement these uses. Land use planning becomes important when the government or land users feel that there is a need for land use change. This requires not only the political will and the ability (instrument, budget, manpower) to support and implement the plan. It is also essential that the planned changes are acceptable to the people and land users involved (FAO, 1993).

The function of land use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whilst at the same time conserving those resources for the future. This planning must be based on an understanding both of the natural environment and of the kinds of land use envisaged. There have been many examples of damage to natural resources and of unsuccessful land use enterprises through failure to take account of the mutual relationships between land and the uses to which it is put. It is a function of land evaluation to bring about such understanding and to present planners with comparisons of the most promising kinds of land use (FAO 1976).

Land use planning has as its basic purpose to ensure that each area of land will be used so as to provide maximum social benefits, especially including food production, without degradation of the land resource. Planning has two aspects: the political and the rational. The political process is necessary to initiate and carry out land use planning, to set its objectives, and to arbitrate among competing interests. The rational, or technical, part of planning ensures that plans are feasible, that cost and return estimates are accurate, and that sufficient data have been collected and collated to ensure these. While the political aspect of land use planning is outside the scope of the land evaluator, clearly the expert knowledge of the agronomist, the production agriculture specialist, and other agriculturalists, must form the basis of correct land use planning in its technical aspect.

2.1.2. Importance and objectives

Land is an example of a natural resource which, when properly managed, can be used again (renewable), but of which the total quantity is limited in relation to the demand for it (scarce). Land is not uniform. It consists of unique units each with specific characteristics and qualities resulting from genesis, location and use. It is possible to grade land units according to their qualities (FAO Guidelines 1990)

Land can be used for different purposes, of which food production is just one example. As land can be used in different ways, it is important to select that way which is most studied for a particular piece of land and which best serves the interests of those concerned and involved, or at least to avoid unsuitable uses. Different land uses are often in competition with each other. Furthermore the population of an area consists of different groups and individuals, each with their own interests. Consequently, there are bound to be conflicts over the use of land (FAO Guidelines 1990).

To feed the world population adequately, as well as to generate growing incomes and increasing employment opportunities, it is necessary to increase the productivity of land, however, not at the expense of land as a resource. Land should be conserved for future generation; land use should be sustainable. In determining the best modes of sustainable land use, land use planning has an important role to play.

2.1.3. Definition and setting

Land use planning means to indicate what is possible in the future with regard to land and its use (potentials) and what should be done to go from the present situation to the future one, in other words, how to improve land and its use. In a similar sense Dent (1988:183) defines land use planning as a means of helping decision-makers to decide how to use land: by systematically evaluating land and alternative patterns of land use, choosing that use which meets specified goals, and the drawing up of policies and programmes for the use of land.

Land use planning, tries to choose the best use of resources through diagnosing land use problems, generating viable options and monitoring the implementation of proved alternatives (Dent, 1988).

Land use planning is defined as a systematic assessment of land potential. Alternatives for land use and other physical, economical and social conditions, for the purpose of selecting and adopting land use options which are most beneficial to land users without degrading the resources or the environment, together with the selection of measures most likely to encourage such land uses (FAO, 1993). It is directed at the best use of land, in view of accepted objectives, and of environmental and social opportunities and constraints (FAO, 1989).

Some techniques used in land use planning are cost/benefit analysis, optimising land use policies, linear programming, land suitability, and land use comparison (Rodriguez, 1995).

An important activity in land use planning is the selection of the preferred land use for a certain tract of land (Huizing and Bronsveld, 1994).

Land use-planning aims at improved sustainable use of land and management of resources (Muchena and Van der Bliek, 1997).

2.2. Sustainability

The concept of agriculture sustainability has been submitted to many definitions essays (Brown et al., Farshad and Zink, 1994).
Sustainability is the ability of an agricultural system to meet evolving human needs without destroying and, if possible, by improving the natural resource base on which it depends (USAID, 1988).

Sustainability concerns the long-term productive performance of systems and is primarily a function of the environmental quality, economic viability and socio-economic well being of the farming population (Conway, 1985; Dumanski, 1987; Barbier and Conway, 1998). Also Hatfield and Karlen (1994) have mentioned that based on the definition issued by the American society of Agronomy (1988) a sustainable agriculture is one that over the long term enhances environmental quality and the resources based on which agriculture depends; provides for basic human food and fibre needs; is economically viable; and enhances the quality of life for farmers and society as a whole. In general definition of sustainability indicates that there is a relationship between sustainability and suitability, stability, land degradation, and land use. Land suitability refers to use of land on a sustainable basis. It means that land evaluation should take account of the hazards of soil erosion and other types of soil degradation (FAO, 1983).

To attain sustained food production, agriculture ecosystems must be made stable (Morgan et al; 1982) otherwise land becomes degraded and its productivity declines (Blaike and Brookfield, 1987).

According to (Farhad and Zink, 1994) an average definition of sustainability would include such elements as soil fertility and productivity (rotations, integrated pes management and biological control, tillage methods, crop sequences), controlling pesticide and fertilizer pollution, management strategies) choice of hybrids and varieties, low cost input, etc.), human needs (demand for basic food and fibres), economic viability, ecological soundness, time span (long term as opposed to short term profitability), and philosophical ethics (implying satisfaction of spiritual and material goals and mankind).

2.3. Land evaluation

Burrough (1996) states that we need to look more at the interactions between how the various tools for land evaluation can be used in different circumstances, and how physical, economic and social factors can be combined. A demand driven approach to selecting a land evaluation method would help to reveal what predictions are really needed and at what level of certainty.

The process of land evaluation could be improved in several ways. Firstly, by involving local users in the plan formulation, so that their preferences and constraints are taken into account.
This would include both the assessment of the impact of interventions by market or government, for example, and of inputs (input supply, extension, credit), as well as the economic, social and environmental outputs of the implementation of the land use plans. Secondly, using existing data but changing the methods of data processing by the use of more flexible data processing methods. Thirdly, by the optimal use and better integration of the existing data like remote sensed data and field data. Finally, by a clear presentation of land evaluation and land use plans in non-technical terms (Bronsveld et al, 1994).

Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses (FAO, 1976).

Land evaluation is concerned with the assessment of land performance when used for specific purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be value in planning, the range of land uses considered has to be limited to those which are relevant within the physical, economic and social context of the area considered, and the comparisons must incorporate economic considerations.

Land evaluation is the process of estimating the potential of land for alternative kinds of use (Dent and Young, 1981).

Land evaluation can also be defined as the assessment or prediction of land quality for a specific use, in terms of its productivity, degradation hazards and management requirements (Austin and Basinski, 1978).

Ive (1985) has mentioned that agriculture land evaluation fulfils two main tasks:

- Identifying the most suitable location for a specific agriculture use (many location-single use).
- Identifying the most suitable agriculture use for a specific location (many uses-sngle location).

The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses (FAO, 1976).

Land evaluation assesses the suitability of land for specified land uses (Beek et al. 1997). In general, land evaluation is a process of matching, based on a series of selected land qualities and comparison of them with land use requirements.

Land evaluation can also be defined as the assessment or prediction of land quality for specific use. Assessment is made in terms of production, sustainability, the inputs needed to obtain that production, and (in the case of quantitative land suitability classification) economic return. This process includes: identification, selection and description of land use types relevant to the area under consideration; mapping and description of the different types of land that occur in the area and the assessment of the suitability of the different types of land for the selected land use types (FAO, 1976).

Land evaluation may be concerned with present land performance. Frequently, however, it involves change and its effects: with change in the use of land and in some cases change in the land itself. Evaluation takes into consideration the economics of the proposed enterprises, the social consequences for the people of the area and the country concerned, and the consequences, beneficial or adverse, for the environment (FAO, 1976).

Rossiter (1996) discusses a theoretical framework for the classification of land evaluation models and concludes that there is no single land evaluation modelling approach. The choice of technique affects the reliability and scope of the application, and also the predictions and purpose. Rossiter added that predictions on land performance are useful only if they are used by decision-makers to make better decisions, ‘we should take a step back, away from the question “what predictions can we make with the data we have?” i.e. a data – driven approach, to the question “ who are the decision- makers, who actually affect land use, how are they making their decisions, and how could their decision be better informed? i.e. a demand-driven approach ‘(Rossiter, 1996,P186).

Burrough (1996) states that in the top-down approach to land evaluation, the direction of reasoning is always from resource base to land utilization, a perfectly adequate approach where there is plenty of land, and the market is unconstrained. In general the conditions for agriculture will be initially created by the modification of the natural physical resources. Irrigating, fertilizing and other practices may do this; as the cost of inputs increases, however, physical land resources become less important and factors such as access to the market, infrastructure, skilled labour and organization are more important. Added to this are other aspects concerning social habits and traditions. For example in Mexico, ‘almost all farmers grow maize because their culture requires it (any maize is better than none)’(Corbett, 1995).

Land evaluation provides essential information on land resources. However this information is often not used in the planning and implementation of better land use systems or land use practices, for a number of reasons. Firstly, the information produced is frequently incompatible both to government’s objectives and/or the preferences of the local people. Secondly, data processing is in adequate, resulting in low quality information. Thirdly, land evaluation is based on a top-down approach; such an approach does not take sufficiently into account the aspirations, capabilities are constraints of the local land users. Added to which, land use plans tend not to consider sufficiently the limitations of interventions (subsidies, policy prices, input supply, extension, credit etc.) (Bronsveld et al, 1994).

Land evaluation is defined as the process of assessing the potential production for various land uses (Beek, 1978). This approach is based on the matching of qualities of different land units in a specific area, with the requirements of actual or potential land use. The results of land evaluation should be useful for rational land use planning (FAO, 1993).

The aim of land evaluation is to determine the suitability of land for alternative, actual or potential, land uses that are relevant to the area under consideration. The suitability assessment is based on the productivity, stability and sustainability of land use systems (Huizing et al, 1995).

Land suitability is assessed and classified with respect to specified kinds of use and is made in terms relevant to the physical economic and social context of the area concerned (FAO, 1984). Land evaluation surveys started in 1950 and the most important of these surveys, was land capability classification carried out by soil conservation service (S.C.S) of the United States, which major kinds of land use were determined by soil information. When human being knowledge promotion, it was specified that other factors are effective in land utilization. So, the scientists paid more attention to land characteristics and qualities.

2.4 Land and land resources

Land comprises the physical environment, including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use. It includes the results of past and present human activity, e.g. reclamation from the sea, vegetation clearance, and also adverse results, e.g. soil Salinization. Purely economic and social characteristics, however, are not included in the concept of land; these form part of the economic and social context (FAO, 1976).
Land is an area of the earth's surface, comprise the physical environment, including climate, relief, soils and underlying geology, hydrology, plant and animal population, and the results of past and present human activity (FAO, 1976, Dent and Young, 1981).

FAO (1995) defines land as : any delineable area of the earth's terrestrial surface, involving all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil, the terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), near-surface layers and associated ground water and geohydrological reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water shortage or drainage structures, roads, buildings, etc.).

As considered in the definitions of land the keyword is physical environment such as soil, climate, relief and hydrology. However FAO (1995) give a complete definition including some socio-economic aspects as well.

Land resources consist of two main categories:

- Natural land resources
- Artificial land resources including the product of human activities such as dikes and plodders (Dent and Young, 1981).

2.5 Land use

The types of use considered are limited to those, which appear to be relevant under general physical, economic and social conditions prevailing in an area. These kinds of land use serve as the subject of land evaluation. They may consist of major kinds of land use or land utilization types (FAO, 1976).
The concept of land use is often considered a relatively stable subject related mainly to the use to which the land, in a certain region at a certain time, is put.
A series of operations on land, carried out by man, with the intention to obtain products and/or benefits through using land resources is called land use (Huizing, 1993).
Land use is the result of a continous field of tension created between available resources and human needs and acted upon by human efforts (Vink, 1975).
Land use carried out in many different ways. The broadest categories include:

- Rural land use; including agriculture, forestry and wildlife.
- Urban and industrial land use including towns, villages and industrial complexes

In this study the emphasis is put on the rural and especially on the agricultural uses.

2.6 Land Utilization Type

A kind of land use described or defined in a degree of detail greater than that of a major kind of land use

2.7 Land characteristics

Attributes of land that can be measured or estimated, examples are slope, rainfall, soil texture, available water capacity, biomass of the vegetation, etc.

2.8 Land quality

A complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use.

2.9 Land mapping unit

A land-mapping unit is a mapped area of land with specified characteristics. Land mapping units are defined and mapped by natural resource surveys, e.g. soil survey, forest inventory.

2.10 Land suitability classification

The process of land suitability classification is the appraisal and grouping of specific land in terms of their suitability for defined uses. Suitability can be scored based on factor rating or degree of limitation of land use requirements when matched with the land qualities. In other words land suitability evaluation is a comparison and matching of land utilization types requirements with land units' characteristics. Land suitability classes reflect degrees of suitability. Table 2.1 shows the structure of land suitability classes.

Table 2.1: Structure of land suitability classes and subclasses

Land suitability orders	Land suitability classes	Land suitability subclasses
S	S1= highly suitable	e.g. S2m S3 e
	S2= moderately suitable	m= moisture availability
	S3=marginally suitable	e= erosion
N	N= not suitable	

Land suitability assessment was founded in 1976 by FAO and afterwards, many researches were done and are being done in land suitability evaluation for land utilization types (LUT,s) in different countries (FAO, 1984). Land evaluation surveys have been started in Iran in 1976. These surveys were founded by FAO and carried out in different phases such as land capability and resource evaluation, land classification for irrigation, land capability and land suitability determination for specific crops (Mohajer Shojaee, 1984 and Movahedee Naeeni, 1993). The basic step in the field of land suitability has been implemented as soils bulletin 32 by FAO in 1976. This bulletin and other soils bulletins 42,48,52 and 55 have been considered in different countries using different methods (FAO, 1983,1984,1985;Chinene, 1991). Young et.al (1977) has surveyed land suitability assessment in developing countries based on FAO guidlines. Ogunkunle (1993) has assessed land suitability evaluation for oil palm and has used square root of parametric method. Chinene et al. (1988) have assessed, physical land evaluation for the study area of Samfya, and five soil units have been evaluated for four main crops. Osie (1993) determined qualitative land suitability of five soil series for cultivated crops such as maize, rice and cassava under rainfed conditions using simple limitation. Embrechts et al. (1988), have assessed oil palm based on FAO framework for parts of north Somatra using parametric method.
The most parts of our country have been surveyed and the final results have been published as reports including maps. Undoubtedly, the goal of soil survey is to increase production and to help farmers for optimum use of land. Up to now the lands for general utilization such as rainfed agriculture, irrigated agriculture, grassland, forestry, or recreation have been classified however land evaluation for different agriculture crops and horticulture crops have not been employed. Thus; the concept of soil survey is only

meaningful when applied aspects are considered after carrying out a project, that is, in spite of determination of soil type and preparation of map, we should be able to present an optimum cultivated pattern to the farmers, to predict crop yield, and to conduct them in management.

In recent years, land suitability surveys have been carried out and are being carried out in agriculture research centres and universities as project or thesis respectively which is as follows:

Givee (1999) has done qualitative and quantitative land suitability for major crops of the Falavarjan of Isfehan using both simple limitation and parametric methods.

Aioobi et al. (1997) have carried out qualitative land suitability for major crops including irrigated crops, wheat, barley, maize and rice in Baraon north of Isfehan province.

Zareian (1999) has implemented land suitability semi detailed surveys for major crops in Maloosjan and Hossien abad Beiza study area of Fars province.

Sepahvand et al. (1999) have surveyed qualitative land suitability of western Plateaux of Iran for rainfed crops such as wheat, barley, and pea.

Mehnatkesh et al. (1999) have carried out qualitative and quantitative land suitability for cultivated crops such as irrigated wheat; alfalfa, potato and sugar beat for Shahreh Kord area.

Beheshtee Alaqa (1997) has done soil classification and qualitative land suitability for crops such as irrigated wheat; rainfed wheat and sugar beat for Hassan Abad of Kermanshah.

Bahmaniar (1997) has paid more attention to the land suitability evaluation role on sustainable agriculture development.

Moqeemi (1995) has surveyed resources evaluation and land suitability determination and its relation to existing erosion and soil evolution in Gaveh Rood catchment – Kermanshah province.

Movahedi Naeeni (1993) has assessed land suitability evaluation for major crops of Gorgan area.

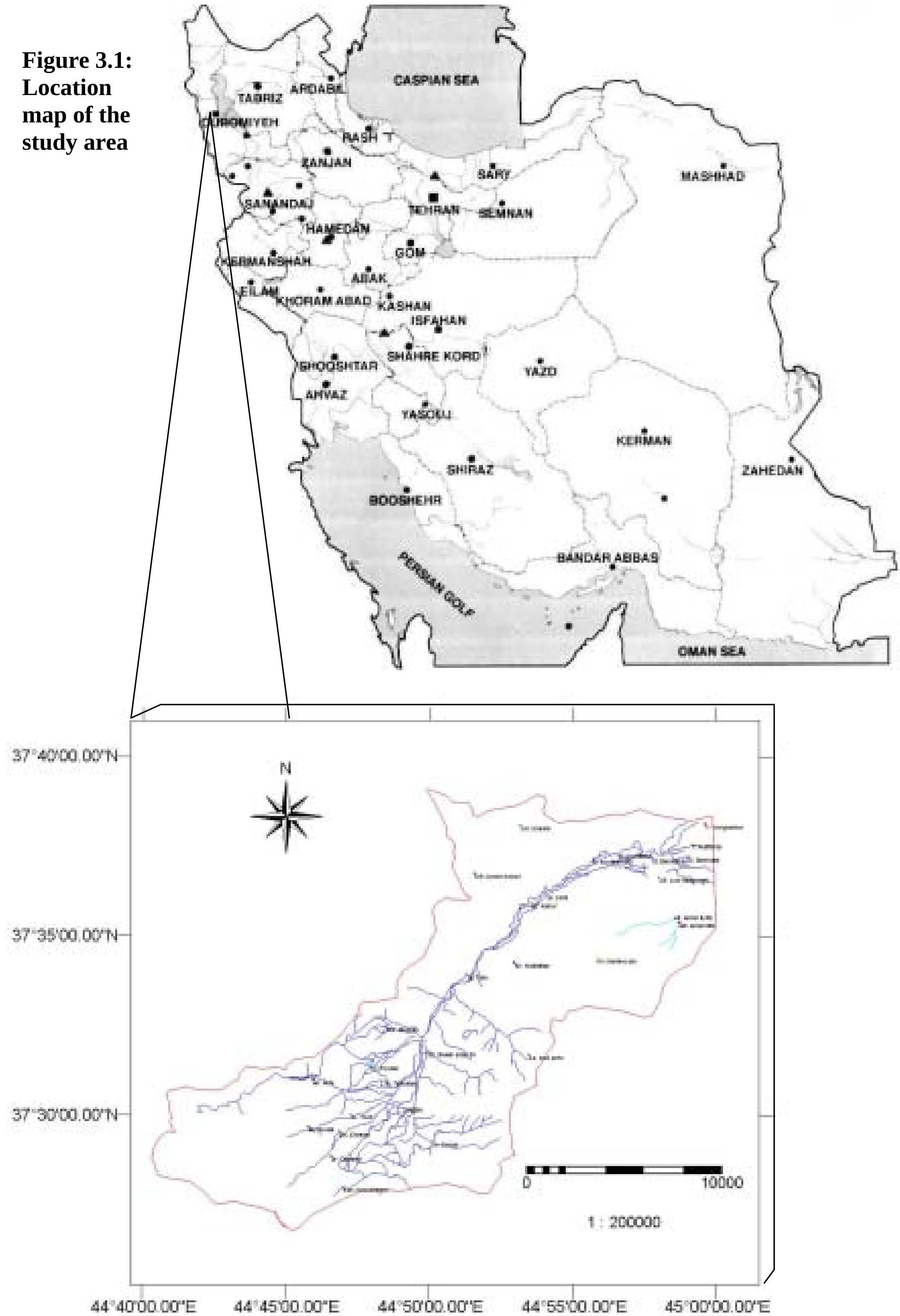
3. THE STUDY AREA

3.1 Location and extent

The study area covers the Rouzeh Chai catchment, which is located in the western part of the Azarbyejan Province in north-western Iran. The location map of the study area is illustrated in figure 3.1. It is situated just east of the Turkish border, north of Shahr Chai catchment, south of Nazloo Chai catchment and west of Orumieh city. The area is located between latitudes 37°26′ and 37° 39′ North and longitudes 44° 40′ to 45° East and covers 128 km^2 (12,800ha).

Since the study area had a limited variation of geomorphologic units, it was extended to 28,000 ha. The altitude ranges from 1,350m to more than 3,000m asl. The maximum altitude is about 3,500m asl on the Bareh Yazdeh mountain in the south-west of the catchment and the minimum elevation is less than 1,350 m asl on the eastern part of the catchment.

Figure 3.1: Location map of the study area



3.2 Climate

3.2.1 General climatic characteristics

The study area has cold and moist winters and mild summers. The Siberian cold, moist anticyclone from the North affects the area. When pressure differences between the high-pressure Siberian anticyclone and the low pressure southern air above the Persian Gulf is large, northern air comes to Azarbyjan and makes it cold causing snowfall in winter.

The meteorological data including rainfall, temperature, relative humidity, evapo-transpiration, etc, obtained from Synoptic station of Orumieh, located near the study area, are used for climatic requirements of land use types.

3.2.2 Rainfall regime

Mean annual rainfall is 367 mm. About 136 mm of the rainfall occurs in winter, 129 mm in spring, 13 mm in summer and 89mm in autumn. The rainfall data of Synoptic station is presented in Table 3.1

Table 3.1: Rainfall distribution of the Orumieh Synoptic station

Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Rainfall mm)	37	42	57	71	43	15	5	2	6	25	37	27	367
Total rainfall (season)	136			129			13			89			
% Rainfall / month	10.1	11.4	15.5	19.3	11.7	4.2	1.4	0.5	1.6	6.8	10.1	7.4	100
% Season	37			35.2			3.5			24.3			100

Table 3.1 shows the maximum monthly rainfall occurs in April which is equal to 19.3 percent of the total rainfall and the minimum monthly rainfall belongs to August with 2mm that is equal to 0.5 percent of the total rainfall. Mean monthly data of rainfall is graphically shown in Fig.3.2.

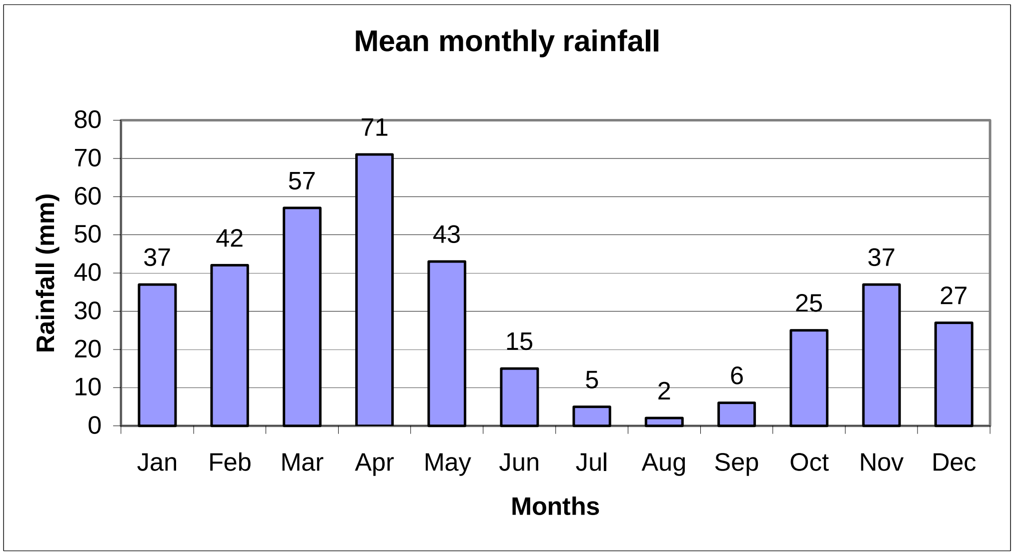


Fig. 3.2 Mean monthly rainfall (mm) from Synoptic station of Orumieh

3.2.3 Temperature regime

As shown in Table 3.2, the mean annual temperature, mean maximum temperature, mean minimum temperature of the study area are 12.2 °C, 17.9 °C and 6.4 °C, respectively.

Table 3.2: Temperature in Orumieh Synoptic station

Month Temperature	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov	Dec	Annual
Mean	-1.1	0.5	5.9	11.5	16.8	20.4	24.6	24.6	20.5	14.3	7.8	0.2	12.2
Mean max.	3.0	5.2	10.9	17.0	23.3	27.1	31.9	32.0	28.0	20.8	13.0	2.6	17.9
Mean min.	-5.2	-4.3	0.9	5.9	10.3	13.7	17.3	17.1	12.9	7.7	2.5	-2.2	6.4

The coldest month is January with –1.1 °C whereas July and August have the highest temperature, 24.6 °C. In order to determine the length of the growing season of the area, the ombrothermic curve was plotted using rainfall and temperature data (Fig. 3.3).

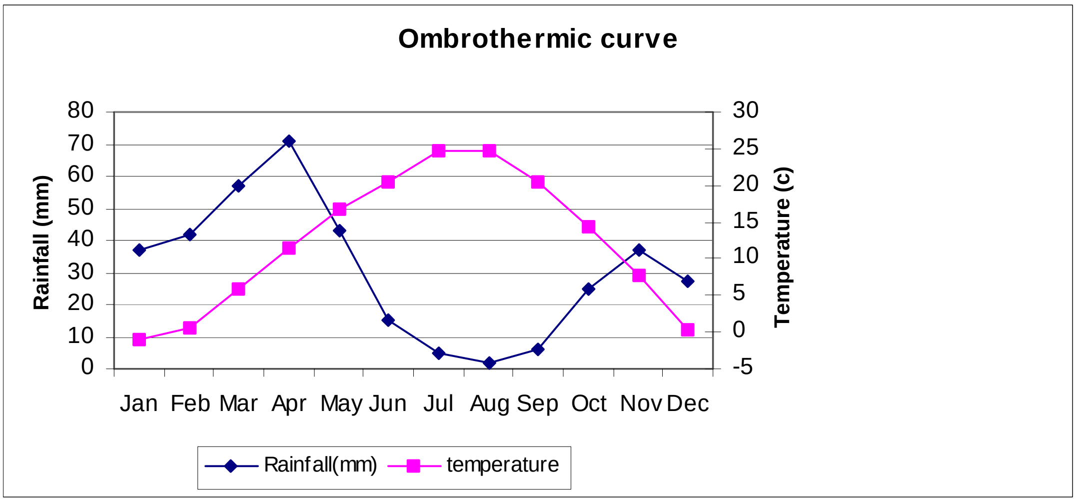


Fig. 3.3 - Ombrothermic curve of Rouzeh Chai catchment

According to the ombrothermic curve, there is a dry period of five months from the beginning of June to the end of October.

3.2.4 Evapo-transpiration

The monthly potential evapo-transpiration can be calculated from either class A pan or using following formula

$$Pet = 5.625\ (EaTmax\text{-}ed)$$

Eatmax: saturation vapour pressure that corresponds to average daily maximum. This value can be found in standard table 3 (method in land evaluation, 1991).

Ed: actual vapour pressure, this value is not always given in meteorological statistics; but it may then be computed on the basis of relative humidity and temperature:

$$Ed = EaTmean * Rhmean/100$$

EaTmean: read from standard table existed in reference book (Method in land evaluation, 1991).

Therefore, relative humidity is one of the factors that directly affects evapotranspiration. In this meteorological data evapo-transpiration measurement is carried out using class A pan records for a period of 10 years. The mean monthly evapo-transpiration and half of evapo-transpiration of Synoptic station are illustrated in table 3.3

Table 3.3: Evapo-transpiration and half evapotranspiration in the Orumieh Synoptic station

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Et	21.7	29	55.8	84	120.9	159	167.4	158.1	117	71.3	42	24.8
Et/2	10.8	14.5	27.9	42	60.4	79.5	83.7	79	58.5	35.6	21	12.4

3.3 Hydrology

The most important water resources for agricultural purposes in this region include river and springs. The main water supply is the Rouzeh Chai river, originates from Ziarat Bye Boon, Bareh Yazdeh, Setareh Lond and Bardeh Rash mountains flowing with a west-east direction into the Orumieh lake. Drainage system of the area is illustrated in Figure 3.4.

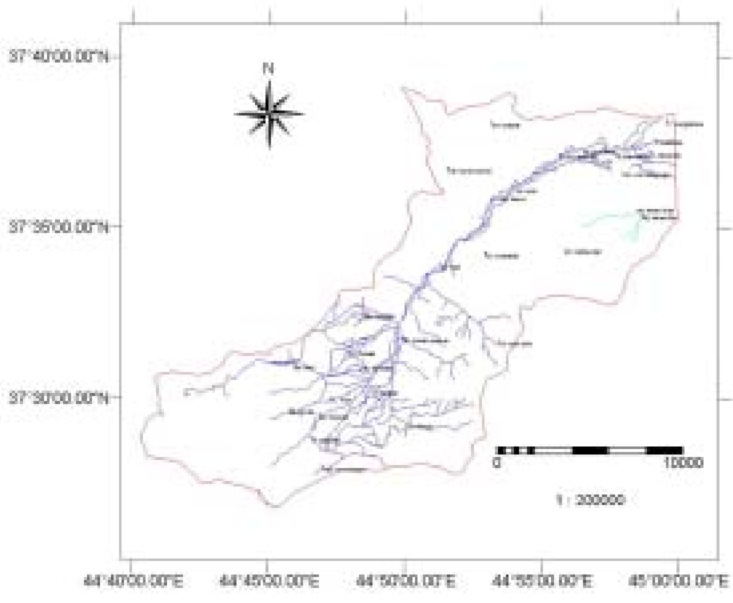


Figure 3.4 - Drainage system of the study area

Based on discharge data of the river (Figure 3.5) the minimum discharge occurs in September with 0.1 m^3/s and the maximum is in April including $3.8 m^3/s$.

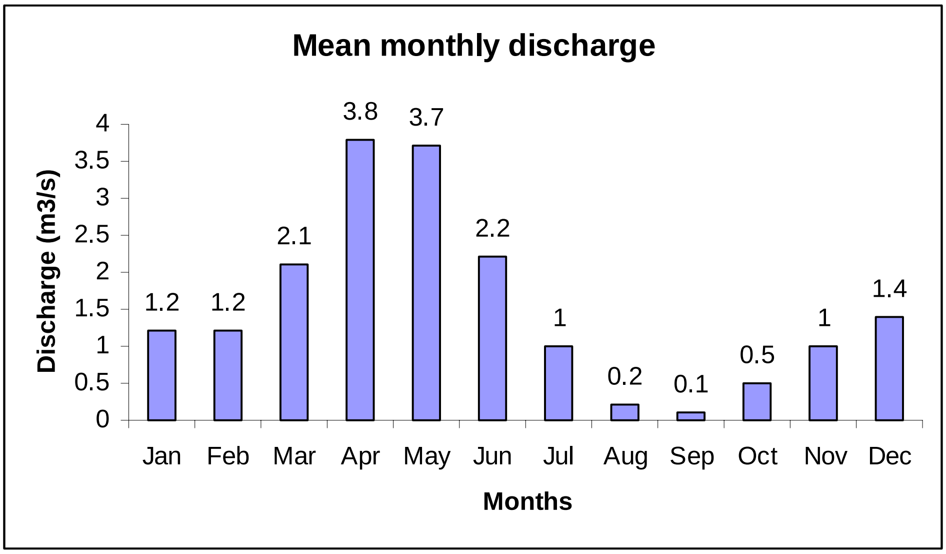


Figure 3.5 - Mean monthly discharge of Rouzeh Chai catchment

3.4 Geology

Based on the geological map at scale 1: 250,000 five geological formations have been identified in the study area as follows:

1) Pre-Cambrian

These lithological units comprise “Selvana complex” formations located on the southwest of the study area near the border line with Turkey and consists of rocks such as slate, phyllite. Other rocks are dolomite and some limestone. The age of this formation is about 1,565 million years, determined by Rubidium-Strontium method.

2) Permian

This lithology unit include “Ruteh and Dorud formations” occurred on the south-west of the study area. Ruteh formation consists of rocks such as limestone, dolomitic limestone and some dolomite. Dorud formation includes rocks such as sandstone, quartzite, red and pink, locally some shale and conglomerate at base.

3) Cretaceous

Cretaceous consists of rocks such as conglomeratic limestone and conglomerate with calcareous cement, occurred in the southwest of the study area.

4) Tertiary

Tertiary includes rocks such as sandstone, conglomerate, some marl and shale, rare limestone. These sedimentary rocks belong to Oligo-Miocene (partly Qom formation equivalent). This litho logical unit covers the most part occurred in the central part of the study area.

5) Quaternary

This litho logical unit comprises young terraces, gravel fans and old terraces, gravel fans. It also covers the piedmont (alluvial fan and glacis) in some parts of the study area. Agricultural activities occurred in this unit in case of gentle slope, deep soil and its fertility.

Table 3.4 shows geology and lithology of the area and the map is also illustrated in figure 3.6

Table 3.4: Geology of the Rouzeh Chai catchment

Geological era	Symbol	Rock type
Quaternary	Qt1	Old terraces and gravel fans
	Qt2	Young terraces and gravel fans
Tertiary	Oms	Sandstone, conglomerate, some marl and shale, rare limestone
Cretaceous	Kcl	Conglomeratic limestone and conglomerate with calcareous cement
Permian	P	Limestone, dolomitic limestone, some dolomite
	Pd	Sandstone, quartzite, red and pink, locally some shale and conglomerate at base
Precambrian	P∈s	Slate, phyllite
	P∈d	Dolomite and some limestone

Table 3.5 - Slope classes

Slope class %	Area (ha)	Percent
0-2	1,069	3.7
2-5	2,789	9.8
5-8	4,162	14.6
8-15	1,904	6.7
15-25	7,372	25.8
25-40	6,841	24
40-60	1,921	6.7
>60	2467	8.6

According to Table 3.5 more than 50 percents of the total area has a slope of more than 15 percents.

3.5 Geomorphology

1) Mountain

Mountain landscape including steep and very steep slopes subdivided into two relief types as High Hills coded Mo1 located on the southwest and moderately High Hills coded Mo2 distributed in the central part of the catchment. Since in moderately High Hills landscape, rangelands have been converted to cultivated lands, so; high amounts of erosion occur in this unit. Dominant slopes range from 40 to 60% and altitude ranges from 1,800 to more than 3,200m asl.

2) Hilland

Most part of the study area, distributed within the whole catchment including four relief types, called high level, moderately high level, low level and glacis coded as Hi1, Hi2, Hi3, Hi4 respectively. Dominant slopes range from 5 to 30% and altitude ranges from 1500 to 1800m asl.

3) Piedmont

This landscape is subdivided into five relief types such as fan, Erosional high glacis terrace, erosional mid glacis terrace, erosional low glacis terrace and glacis coded as Pi1, Pi2, Pi3, Pi4, Pi5 respectively. In this landscape the most parts of glacis are used for agricultural activities. The recognized fan in this unit is active and includes coarse materials. The slope of this landscape is about 0-10%.

4) Plateau

This unit includes very small part of the catchment located on the west part of the study area. It consists of one relief type called high glacis as Pu1. The slopes range from 2 to 5%; this landscape has been used for rainfed agriculture as well.

5) Valley

Rouzeh Chai catchment coded as Va1 has made a few small river terraces. Irrigated agriculture and tree plantation occurred on the river terraces due to their deep and productive soils. They are located in the middle of the catchment. The landscapes of the study area are shown in Fig. 3.7 and the Slope Map, which is extracted from DEM, is presented in Figure 3.8 that are grouped into 8 classes. In spite of their slope classes and their area are presented in Table 3.5.

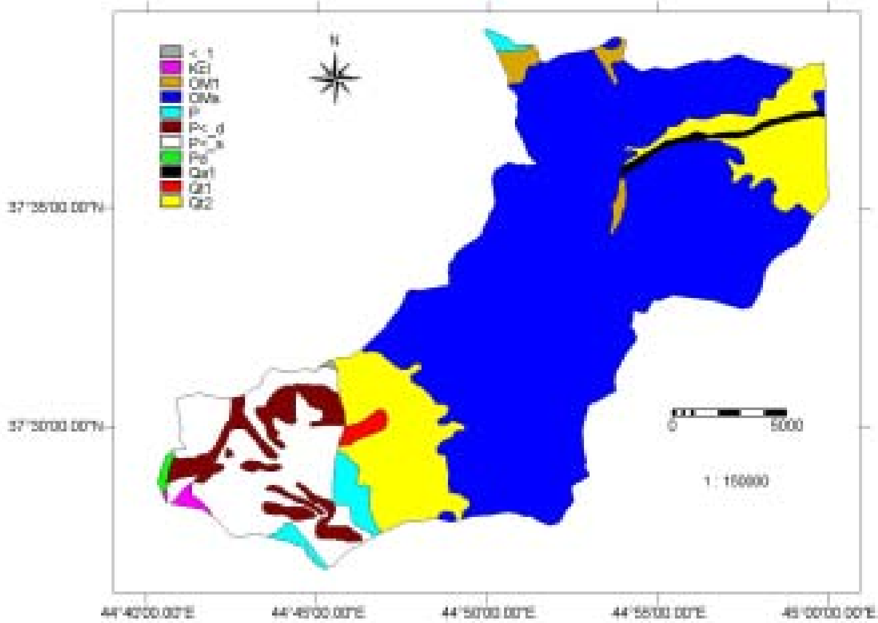


Figure 3.6 Geologic map of the study area

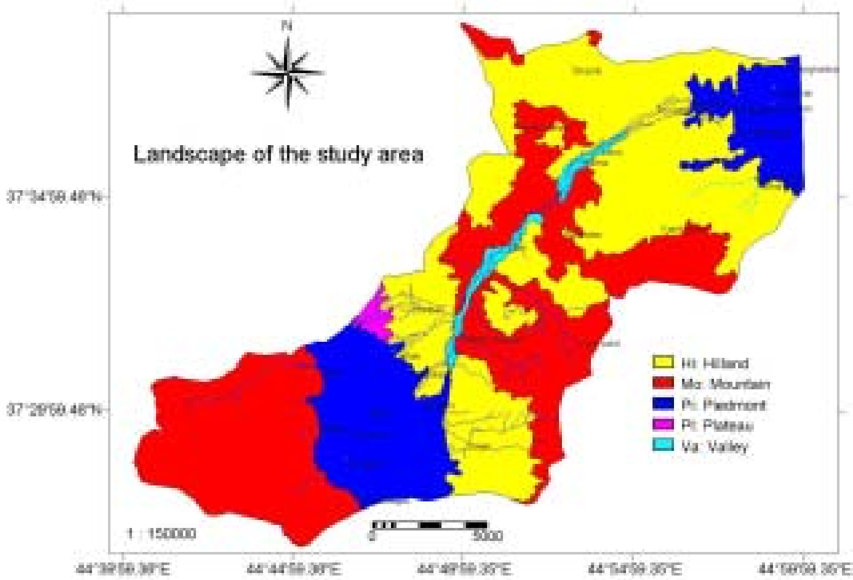


Figure 3.7 - Landscapes of the study area

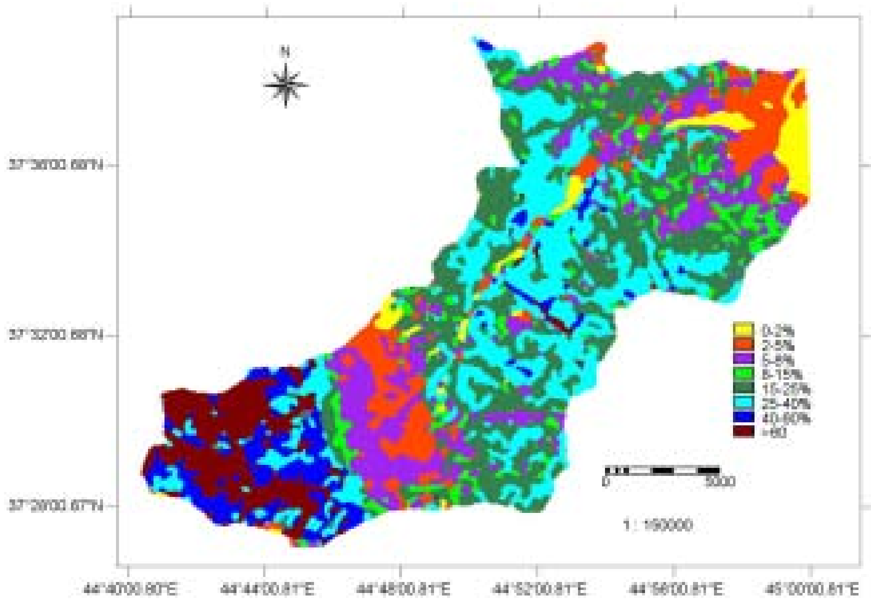


Figure 3.8 - Slope map of the study area

3.6 Vegetation

Based on annual geomorphology units, precipitation, slope, aspect, types of soil, different native vegetation as occurring in the rangeland are given below:

- *Achillea spp.*
- *Agropyron*
- *Alhagi Camellarum*
- *Althaea spp.*
- *Astragalus spp*
- *Borugo officinallis*
- *Carthamus Oxioconithus*
- *Centaurea spp.*
- *Chicurium Intybus*
- *Circium spp.*
- *Euphorbia Helioscopia*
- *Graminea*
- *Malvacea*
- *Papaver spp*

Some parts of rangeland have been converted to cultivated land due to economic conditions.

3.7 Socio-economic conditions

3.7.1. Population

A total of 13,087 people in 2,326 families inhabit the study area. This means that the average family size is 5.6 persons, which includes family labourers in agricultural activity due to socio-economic structure of the area. In total there are 27 villages in the study area (Table 3.6).

Table 3.6 - Population according to census of 2002

Village	Population	No. of family	Family size	Percent
Oshnaabad	400	80	5.0	3.1
Anharesofla-olia	900	170	5.2	6.9
Tizkharab	400	72	5.5	3.1
Tazekandeanhar	130	12	10.8	1.0
Khalifatan	420	60	7.0	3.2
Darezam	145	30	4.8	1.1
Kanikoozan	350	55	6.3	2.7
Kalhor	640	100	6.4	4.9
Goozgavand	150	30	5.0	1.1
Gardehblich	300	70	4.2	2.3
Loorbalajoogh	500	120	4.1	3.8
Larni	460	55	8.3	3.5
Yoorghanloo	400	80	5.0	3.1
Kootalan-Sabaghan	1000	120	8.3	7.6
Ghasrik	320	40	8.0	2.4
Darband	480	80	6.0	3.7
Soolak	242	44	5.5	1.8
Chaman	72	13	5.5	0.5
Tooli	650	100	6.5	5.0
Goojar	1387	190	7.3	10.6
Anbi	1600	250	6.4	12.2
Zangalan	375	50	7.5	2.9
Tayabatan	410	57	7.1	3.1
Toolaki	324	40	8.1	2.5
Sheiban	378	60	6.3	2.9
Sheikhshamzin	407	55	7.4	3.1
Talin	247	38	6.5	1.9
Total	**13087**	**2326**	**5.6**	**100**

3.7.2. Animal husbandry

Animal husbandry is the main activity of the people in the area. Table 3.7 shows the number and kind of livestock in the area.

Table 3.7: Type and number of livestock

Village	Sheep and goats	Percent	Cattle	Percent
Oshnaabad	-	0	50	1.3
Anharesofla-olia	700	2.8	290	7.8
Tizkharab	50	0.2	60	1.6
Tazekandeanhar	120	0.5	60	1.6
Khalifatan	1500	6.1	120	3.2
Darezam	10	0.1	32	0.9
Kanikoozan	700	2.8	150	4.0
Kalhor	650	2.6	250	6.7
Goozgavand	350	1.4	70	1.9
Gardehblich	600	2.4	20	0.5
Loorbalajoogh	300	1.2	165	4.4
Larni	250	1.0	60	1.6
Yoorghanloo	200	0.8	90	2.4
Kootalan-Sabaghan	340	1.4	110	3.0
Ghasrik	250	1.0	65	1.7
Darband	1100	4.5	200	5.4
Soolak	250	1.0	190	5.1
Chaman	-	0	5	0.1
Tooli	510	2.1	180	4.8
Goojar	5200	21.1	270	7.2
Anbi	2600	10.6	230	6.2
Zangalan	400	1.6	150	4.0
Tayabatan	650	2.6	300	8.1
Toolaki	1450	5.9	100	2.7
Sheiban	4100	16.7	120	3.2
Sheikhshamzin	2150	8.7	250	6.7
Talin	166	0.7	140	3.8
Total	**24596**	**87**	**3727**	**13**

Table 3.7 shows that 87% of livestock is sheep and goats; however, cattle contain low number (13%), for the catchment is a mountainous region, so the cattle can not move on the sloping area. In the on-going traditional husbandry system in the study area, animals are kept for their meat, milk, and wool production, at subsistence level. In this system approximately 88% of livestock forage depends on rangelands and their products (Haynes, 1965).

In spring (April and May) when weather allows feeding and the snow on elevation is melted, animals are taken to the rangelands for grazing. Normally, different herdsmen engage one shepherd to reduce costs. This is continued till December, so it takes about 8 months. Afterwards, some people may sale their livestock, but there are also herdsmen who keep their animals, so winter forage should be provided. Rangelands are a source of forage for free grazing domestic animals as well as wildlife and no one should use agronomic methods to alter native vegetation (Stoddart, 1975).

3.7.3. Agriculture

Both irrigated and dry farming are applied due to the specific climatic conditions prevalent. Agriculture is another economic activity in the study area while animal husbandry is done parallel with cultivation (Figure 3.9 shows a perspective of agricultural activities in the study area). As a matter of fact, it is not possible to separate these two, as they are in many traditional (subsistence) agriculture systems (Farshad and Zinck, 1995).

Except for land preparation and in some places harvesting, manual power, provided by family members, is commonly used. Management is used as semi-mechanized, that is, plowing and leveling are done by means of heavy tractors, whereas seeding and the rest of the crop-care is done manually. In case of winter wheat, these tasks are done in October and November. Spring and summer crops such as chickpea, alfalfa, are located to seeding from May to June (Figure 3.10). For cultivation of alfalfa as a dominant crop, land is ploughed by tractor followed by disking. Seeds are broadcasted by hand and harvesting is done partly mechanized in some places and manual in other places. Except alfalfa and fruit trees, others are annual crops. Alfalfa is an enduring crop, which can be cultivated once and harvested for seven successive years. Despite this, it can be harvested three times a year that makes it a profitable crop. Since alfalfa is a nitrogen fixing plant, it needs only 50 kg ammonium phosphate of chemical fertilizer at the time of plantation.

Figure 3.9 – A perspective of agricultural activities

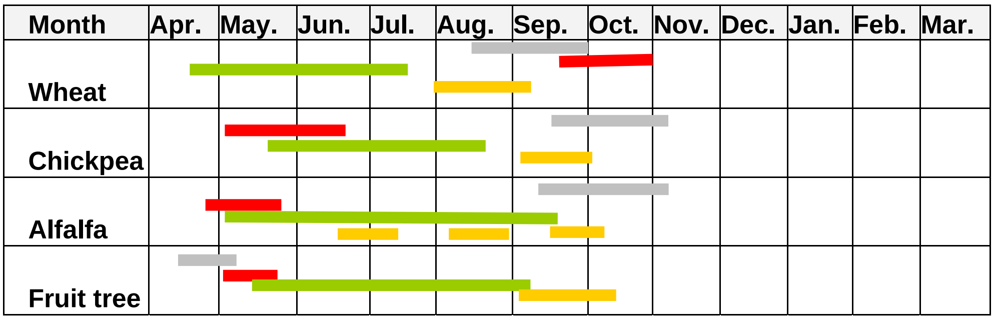


Figure 3.10 - Crop calendar of the study area

: Land preparation , : Seeding, : Crop-care, : Harvesting

The use of fertilizer and pesticides depends on the government support and normally the farmers do not use them; Table 3.8 shows the inputs for the main crops in the study area.

Table 3.8: Input used for agriculture in the area

Crop	Seed Kg/ha	Pesticide		Irrigation (Frequency)	Fertilizer (kg)		Yield (kg)	
		Kind	Amount (ltr)		Ammonium phosphate	Urea	Irrigated	rainfed
Wheat	100-150	PCNB	-	4	100	100	1800	1200
Chickpea	50-80	-	-	-	-	50	-	500
Alfalfa	25-30	Zolon Gozatun	2	4-6	50	-	2500(dry matter)	-
Fruit tree	350-400	Gozatun Zolon Akamet	2	11	-	-	20000	-

4. MATERIALS AND METHODS

4.1 Materials used

- Satellite images including 7 ETM bands (2000)
- Aerial photos with approximate scale of 1:55000
- Topographic maps of the study area at the scale of 1:50000 & 1:250000
- Geologic maps at the scale of 1:250000 & 1:100000
- Climate data
- Water resource data
- ILWIS, ALES, DEFINITE, WORD, EXCEL software packages

4.2 Methods

The methodology includes three main stages as below:

4.2.1 Prefield work stage

- Collection of all existing data including meteorological data and information about the study area from previous work.
- Study some research works, articles, theses, and etc. Through Internet or library, which are related to this project.
- Preliminary interpretation of aerial photos (applying geopedologic approach) and preparation of a photo interpretation map as a base map for fieldwork.
- Selection of sample areas for fieldwork.
- Preparation of contour lines using topographic maps.
- Interpretation of the ETM image, using digital image processing techniques, Normalized Difference Vegetation Index (NDVI) and Principal Component analysis (PC) to produce a land use/cover map.

4.2.2 Fieldwork stage

- Field checks on boundaries of the preliminary interpretation map, as a base map, using satellite images, aerial photos, geology map, topography map.
- Checking the location of sample areas in the field.
- Soil survey by means of digging pits and minipits within the boundaries of geopedologic map in the sample area to prepare soil map.
- Soil profiles description using the FAO guidelines.
- Analyzing soil samples from each horizon in the laboratory to determine the physical, chemical, and fertility parameters including Electric Conductivity (EC), PH, Organic Carbon (OC), N, P, K, particle size distribution, CaCo3, CEC and ESP.
- Soil classification down to family level using the USDA, Keys to Soil Taxonomy, 1988).

- Field checks on preliminary landuse/cover map.
- Collection of general information such as types of major crops, crop yield, rotation and socio economic data of the study area through interviewing local people and authorities.
- Determination of Land Utilization Types (LUT's) according to a set of land qualities and land characteristics relevant to the land use type and land evaluation study.

4.2.3 post fieldwork stage

It contains the following data analysis and processing:

- Preparation of final maps including LMU, soil, and landuse.
- Identification and description of Land Utilization Types (LUT's) (a land utilization type is a kind of landuse described or defined in a degree of detail greater than that of a major kind of landuse, FAO, Soils Bulletin 32).
- Determination of Land Use Requirements for each selected Land Use Types.
- Identification and description of separated land units and land qualities which contain soil and geomorphology surveys.
- Rating the limiting crop growth factors in the study area.
- Creation of a database including soil profile description data, landuse types and land qualities using ALES (the Automated Land Evaluation System).
- Determination of land suitability classes for kinds of landuse types through matching land utilization types requirements with land units characteristics and qualities.
- Socio economic data analysis
- Preparation of land suitability maps using ILWIS GIS package.
- Assessing improvement of landuse, taking into consideration the results of land suitability classification.
- Optimization of landuse, using DEFINITE program, a tool to support decisions on a finite set of alternatives in relation to a finite number of criteria.
- Selection of an appropriate method for land suitability assessment.
- Land use planning at sub regional (local) level.

It is to be noted that the emphasis in the study area is focused on fodder production hence the results of suitability will be further used to develop a plan that satisfies the amount of the fodder required. The flowchart of methodological approach is illustrated in Figure 4.1.

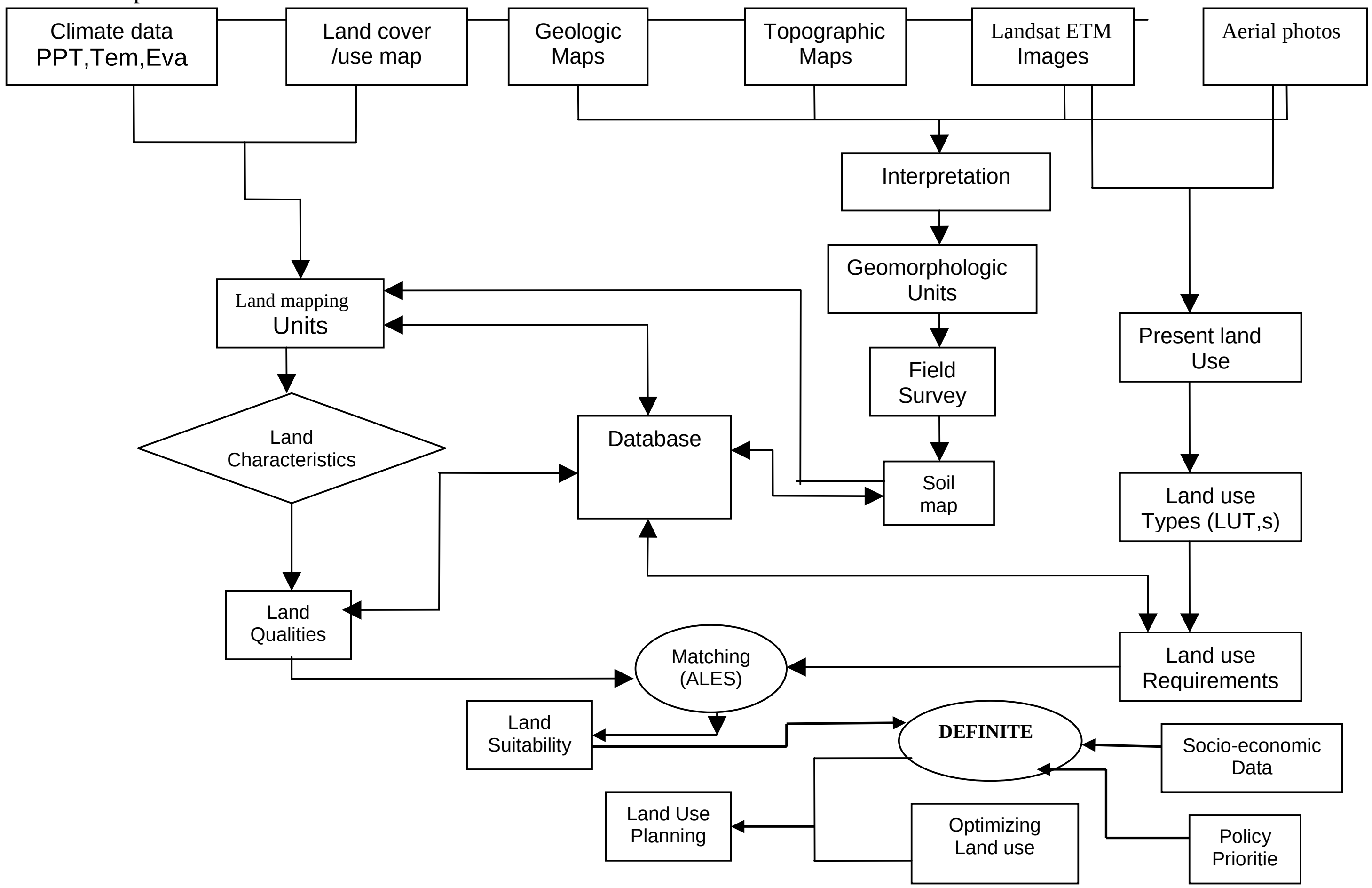


Figure 4.1 - The flowchart methodological approach

4.3 Tools applied

4.3.1 Application of Geographic Information System (GIS) and Remote Sensing (RS)

- Digitizing of existing maps such as geology, topography, catchment’s boundary and etc.
- To create DEM using digitized topographic map.
- To create slope map using DEM.
- Image processing to prepare present lanuse/cover map.
- Input attribute and spatial processed data into GIS.
- Preparing new maps by crossing, and map calculation.
- Presentation of different land suitability maps.
- Some other ranking and calculations that might be needed to prepare scenarios.

4.3.2 Application of ALES (Automated Land Evaluation System)

ALES is a computer program based on the FAO land evaluation method, developed by Rossiter and Van Wambeke (1989) that allows land evaluators to build their own expert systems, taking into account local condition and objectives. ALES is not by itself an expert system and does not include by itself any knowledge about land and landuse. ALES is not a GIS and does not itself display maps. It can, however, analyze geographic land characteristics if map units are appropriate defined.

ALES is an empty shell, that is, a framework within which land evaluators are free to generate different models and develop databases. This program has a framework where proposed land uses can be described in both physical and economic formats, and a framework for a database to describe the land areas being evaluated. It takes care of matching between the knowledge base describing the proposed landuse and the database where land units are described. The results from ALES can be exported to other data processing like ILWIS GIS that performs further manipulations.

The following steps are considered to create an land evaluation model:

Step1 - Defining a reference list

A reference list is a list of entities that can be used when defining the various land utilization types of the evaluation. These are data tables that are independent of a particular LUT, i.e., they apply equally to all LUT’s. Reference list include four options:

1- Land use requirements, are defined as codes, a short descriptive phrase, a default number of severity levels, and default severity level names. The number of severity level depends on the context of the land utilization type.
2- Output (products)
3- Inputs

4- Land characteristics (LC) are the measured or estimated properties of the land, which from the data items in the ALES database. In models, they are used in the decision trees that determine the severity level of each land quality, and ultimately, the final suitability ratings of the various LUT's. Characteristics are included in the reference list because they are useful for determining suitability levels. Land characteristics can be obtained by field survey and interviews.

Step 2 - Defining land utilization types

- Land utilization types are assigned codes and descriptive names.
- Land use requirements are defined for each LUT.
- Since they are used for determining physical land suitability, the set of LUR is basic and important in ALES.
- Four severity levels as S1 (Highly suitable), S2 (Moderately suitable), S3 (Marginally suitable), and N (Not suitable) are considered for each LUT based on FAO framework.

Step 3 - Estimating Land Qualities

Land quality can be estimated using a set of land characteristics. The relevant diagnostic factors are selected of land characteristics list. In ALES the diagnostic LC's are related with the land use requirements using decision tree.

Step 4 - Entering and editing land unit data

It covers the following:

a) <u>Defining map units including Homogenous</u>
Homogenous map units, for ALES, are LMU codes, which can have associated data, i.e. values of land characteristics. They may be mapped themselves and/ or they may be constituents of compound map units. In homogeneous map unit, ALES will assume that it has the same values of all land characteristics over all its extent. Land characteristics values are typically measured in ranges, and in a homogeneous map units, these ranges cover all the variability in the map unit.

b) <u>Defining a compound land unit.</u>
A compound map unit is made up of two or more homogenous constituents. An association of soils units has been defined. ALES will evaluate each constituent separately, and then combine the results. Compound map units are commonly used for smaller scale maps (usually at 1:50000 and smaller scale ratios), such as a general soil map of a region. At these scales the individual constituents can't be mapped separately,

however, a compound unit, which contains the homogenous soils, can be defined and mapped.

c) Data entry template
Before ALES can evaluate a map unit, it must know the data values for each land characteristic that the model builder has included in the evaluation. In other words, a database for this map unit must be filled in, so data entry template should be used to enter the data. Data values are entered using one or more data entry templates. In this model, list of the land characteristics are considered for data entry template and are included in the database. Model builders usually group related data items into templates, so that the model user can enter data separately for each group.

Step 5 - Evaluation physical suitability

Suitability can be scored based on factor rating or degree of limitation of land use requirements when matched with the land qualities. Factor rating procedure was used for determination of individual suitability classes of each land quality.

4.3.3 Application of DEFINITE

DEFINITE (decisions on a finite set of alternatives) is a decision support software package that has been developed to improve the quality of decision-making. DEFINITE is, in fact, a whole toolkit of methods that can be used on a wide variety of problems. If you have a problem to solve, and you can identify alternative solutions, then DEFINITE can weigh up the alternatives for you and assess the most reasonable.

The program contains a number of methods for supporting problem definition as well as graphical methods to support representation. To be able to deal with all types of information DEFINITE includes multi-criteria methods, cost-benefit analysis and graphical evaluation methods. Related procedures such as weight assessment, standardization, discounting and a large variety of methods for sensitivity analysis are also available. A unique feature of DEFINITE is a procedure that systematically leads an expert through a number of rounds of an interactive assessment session and uses an optimization approach to integrate all information provided by the experts to a full set of value functions.

DEFINITE supports the whole decision process, from problem definition to report generation. Its structured approach ensures that the decisions arrived at are systematic and consistent.
It includes the following steps:

a) Problem definition**:** An effect table is made, taking into consideration alternatives and criteria. In each cell of the table a value is considered based on the effect of each alternative.

b) Multicriteria analysis**:** In this module, standardization, weighs summation methods and ranking the alternatives are done based on the priorities, which are applied.
c) Cost benefit analysis**:** It includes discount, value, and indices, usually used in economic evaluation.
d) Sensitivity analysis**:** The sensitivities of the results of problem evaluation to uncertainties in scores, weights and prices, etc. are analyzed.
e) Report**:** All the results come into an assessment report, including text, graph and table.

5. PHYSIOGRAPHY AND SOILS

5.1 Geopedologic analysis

Geomorphology is a branch of geology dealing with the form of the earth, the general configuration of the earth surface, and the changes, which take place, that is, parallel with the evolution of landforms. A reconnaissance soil survey was conducted following the geopedologic approach (Zinck, 1989). The approach is based on a hierarchical system with six taxonomic levels the following of which have been used in the present study :

Level 4 – Landscape
A landscape is defined as a large portion of land characterized either by a repetition of similar relief types or an association of dissimilar relief types (e.g. Mountain, Piedmont).

Level 3 - Relief type
Geoform is determined by a given combination of topography, and geological structure, (e.g. glacis, terrace).

Level 2 - Lithology
Lithology refers to the petrographic nature of the hard rock and the facies of the soft cover formations.

Level 1 - Landform
Landform is considered here as the generic concept for the lowest level of the proposed hierarchical system. It is the elementary geomorphic unit, which can be subdivided only by means of phases.

Five different landscapes have been recognized in the study area including Mountain, Hilland, Piedmont, Plateau and Valley, which were divided into 13 relief types, each of which were further subdivided based on lithology/origin, and finally 18 landforms were distinguished in the area. Nine observations as modal profiles were determined and soils were classified at the family level according to the USDA soil taxonomy system. The geopedologic map is shown in Figure 5.1 and the legend is given in Table 5.1.

5.2. General description of the soils

5.2.1 Soils of the Mountain

Two relief types have been distinguished including high hill (Mo1) and moderately high hill (Mo2). Landform consists of mainly slope facet complex. The soils of this landscape differ, based on their relief type, lithology and landform. The dominant soils are Entisols on the steep slopes and Inceptisols on the less steep areas in some of the rather stable foot

slopes. Due to the presence of limestone and calcareous materials, Calcixerepts with k horizon occur in the map unit Mo211b. Soil depth varies from very shallow to moderately deep. Texture ranges from sandy loam to silty clay loam associated with coarse fragments more than 35% as loamy skeletal. Altitude ranges from 2300 to more than 3,200 m asl and slopes are between 25 And more than 60%. Surface stoniness varies from 10 to 30%.
Soils of this landscape are classified as Lithic Xerorthents, Lithic Haploxerepts and Typic Calcixerepts.

5.2.2 Soils of the Hilland

This landscape consists of four relief types such as high level (Hi1), moderately high level (Hi2), low level (Hi3) and Glacis (Hi4), which are subdivided into four landforms depending on lithology. The landforms are mainly slope facet complex except Hi411, which is slightly dissected. The altitude and slope range from 1500 to 1900 m asl and 5 to 40% respectively.

The soil depth is shallow to deep. Topsoil texture varies from sandy loam to silty clay loam and that of subsoil is heavy sandy clay loam to silty clay. Topsoil stoniness varies from 10-20% and coarse fragment of subsoil is 5-10%. Diagnostic horizons are Ochric, Cambic, Calcic and Petrocalcic, so soils of this landscape are classified as Lithic Haploxerepts, Typic Calcixerepts, and Petrocalcic Calcixerepts.

5.2.3. Soils of Piedmont

The Piedmont landscape includes five relief types: Fan (Pi1), Erosional high glacis terrace (Pi2), Erosional mid glacis terrace (Pi3), Erosional low glacis terrace (Pi4) and Glacis (Pi5), which are subdivided into six landforms based on lithology. The landforms are mainly Tread/riser complex and Slope/bottom complex. The altitude ranges from 1300 to 1700 m asl and slope varies from 2 to 8%.

The soil depth is shallow to very deep and topsoil texture varies from gravelly loamy sand to silty clay loam and that of subsoil is gravely loamy sand to clay. Topsoil stoniness differs from 5 to 70% and coarse fragment of subsoil is 5 to 60%. Diagnostic horizons are Ochric, Cambic, and Calcic and the soils distinguished are, Typic Haploxerepts, Calcixerepts, and Fluventic Haploxerepts.

5.2.4. Soils of the Plateau

This landscape consists of only one relief type (high glacis) and one landform (riser/backslope complex), which is considered as a consociation map unit. The plateau is a relatively elevated, flat surface, limited on one side by an escarpment. The altitude ranges from 1700 to 1800 m asl and slope varies from 2 to 5%.

The soil depth of this landscape is very deep. Topsoil texture is silty clay loam and subsoil texture is silty clay. The topsoil stoniness varies from 10-15% and coarse fragment is 5%. Diagnostic horizons are Ochric, and Calcic, the soils are classified as Calcixerepts.

5.2.5. Soils of the Valley

This landscape includes one relief type (Low terrace) and one landform (Slope/bottom complex), which is considered as a consociation map unit. Texture is sandy loam to silt loam with slope 0-2%. The soils of this landform are deep, undeveloped and well drained, which are transported from highlands including alluvial material. No diagnostic horizons are recognized, so the soils are classified as coarse loamy, typic Xerofluvents.

5.3 Effect of the soil forming factors

A soil forming process is a complex or sequence of reactions and reorganization of matter occurring under the control of a continuation of soil forming factors and leading to a given arrangement of soil material in a profile (Zinck, 1988). In an undisturbed ecosystem, the following factors play a key role in the formation of soils:
Climate (C), Vegetation (V), Topography or Relief (R), Parent material (P), and Organisms (O), over a period of time (T) (Jenny, 1941).

In the study area the most soil factors are described as follows:

- Parent material: Calcixerepts and fine textured soils have been derived due to limestone, other calcareous materials and shales respectively.
- Climate: Calcixerepts and vertic Haploxerepts that are distinguished in the study area, indicate leaching, and moving secondary visible lime, clay downward and concentration of these materials into B-horizon. This occurs due to climatic condition.
- Relief: Topographic factor has the highest effect in the formation soils and their development. The study of catena indicates the soil depth development. Lithic and Typic Xerorthents on shoulder and backslope, and Typic Haploxerepts on footslope are good examples of relief effect.
- Time

The geopedologic map is shown in Figure 5.1, accompanied by a legend in Table 5.1 showing the different landscapes that are existed in the study area.

Table 5.1 - Legend of geopedologic map

Landscape	Relief type	Lithology/ Origin	Landform	Symbol	Main soils	Association soils	Type of map unit	Slope %	Area (ha)	Percent	Map unit
Mountain	High hill	Slate, Phyllite	Slope facet complex	Mo111	Not surveyed	Not surveyed	Not surveyed	>60	4978	17.13	1
		Sandstone, Conglomerate, some marl and shale	Slope facet complex	Mo121	Rock outcrop	Lithic Xerorthents	Association	25-40	954	3.28	2
		Limestone, Dolomite limestone	Slope facet complex	Mo131	Rock outcrop	Lithic Haploxerepts	Association	15-40	223	0.77	3
	Moderately high hill	Sandstone, Conglomerate, some marl and shale	Slope facet complex, slightly dissected	Mo211a	Typic Calcixerepts	Lithic Haploxerepts	Association	15-25	1192	4.1	4
		Sandstone, Conglomerate, some marl and shale	Slope facet complex, moderately dissected	Mo211b	Lithic Haploxerepts	Typic Calcixerepts	Association	25-40	2198	7.57	5
		Sandstone, Conglomerate, some marl and shale	Slope facet complex, Highly dissected	Mo211c	Lithic Haploxerepts	Lithic Xerorthents	Association	25-40	1637	5.63	6
Hilland	High level	Sandstone, Conglomerate, some marl and shale	Slope facet complex	Hi111	Typic Calcixerepts	Lithic Haploxerepts	Association	25-40	4826	16.6	7
	Moderately high level	Sandstone, Conglomerate,s ome marl and shale	Slope facet complex	Hi211	Petrocalcic Calcixerepts	Typic Calcixerepts	Association	15-25	3950	13.6	8

Table 5.1: Legend of geopedologic map (continued)

Landscape	Relief type	Lithology/ Origin	Landform	Symbol	Main soils	Association soils	Type of map unit	Slope %	Area (ha)	Percent	Map unit
	Low level	Sandstone, Conglomerate,some marl and shale	Slope facet complex	Hi311	Typic Calcixerepts	Petrocalcic Calcixerepts	Association	5-10	2675	9.21	9
	Glacis	Alluvio/ Colluvium	Slightly dissected	Hi411	Typic Calcixerepts	------	Consociation	5-10	327	1.13	10
Piedmont	Fan	Alluvio/ Colluvium	Apex/distal complex	Pi111	Fluventic Haploxerepts	Typic Xerofluvents, Fragmental	Association	5-10	246	0.85	11
	Erosional high glacis terrace	Alluvio/ Colluvium	Tread/Riser complex	Pi211	Typic Haploxerepts	Typic Xerorthents	Association	2-5	1813	6.24	12
	Erosional mid glacis terrace	Alluvio/ Colluvium	Tread/Riser complex	Pi311	Vertic Haploxerepts	Typic Haploxerepts	Association	2-5	689	2.37	13
	Erosional low glacis terrace	Alluvio/ Colluvium	Slope/bottom complex	Pi411	Vertic Haploxerepts	Typic Haploxerepts	Association	2-5	845	2.91	14
	Glacis	Young terraces and gravel fans Alluvio/ Colluvium	High depositional glacis	Pi511	Typic Haploxerepts, Fine loamy	Typic Calcixerepts Fine loamy	Association	0-2	911	3.13	15
		Young terraces and gravel fans Alluvio/ Colluvium	Mid depositional glacis	Pi521	Typic Haploxerepts, Fine	Fine, Typic Calcixerepts	Association	0-2	900	3.1	16
Plateaux	High glacis	Sandstone, Conglomerate, some marl and shale	Riser/ backslope complex	Pu111	Typic Calcixerepts	-----	Consociation	2-5	210	0.72	17
Valley	Low terrace	Alluvium	Slope/ bottom complex	Va111	Typic Xerofluvents, Coarse loamy	------	Consociation	0-2	483	1.66	18

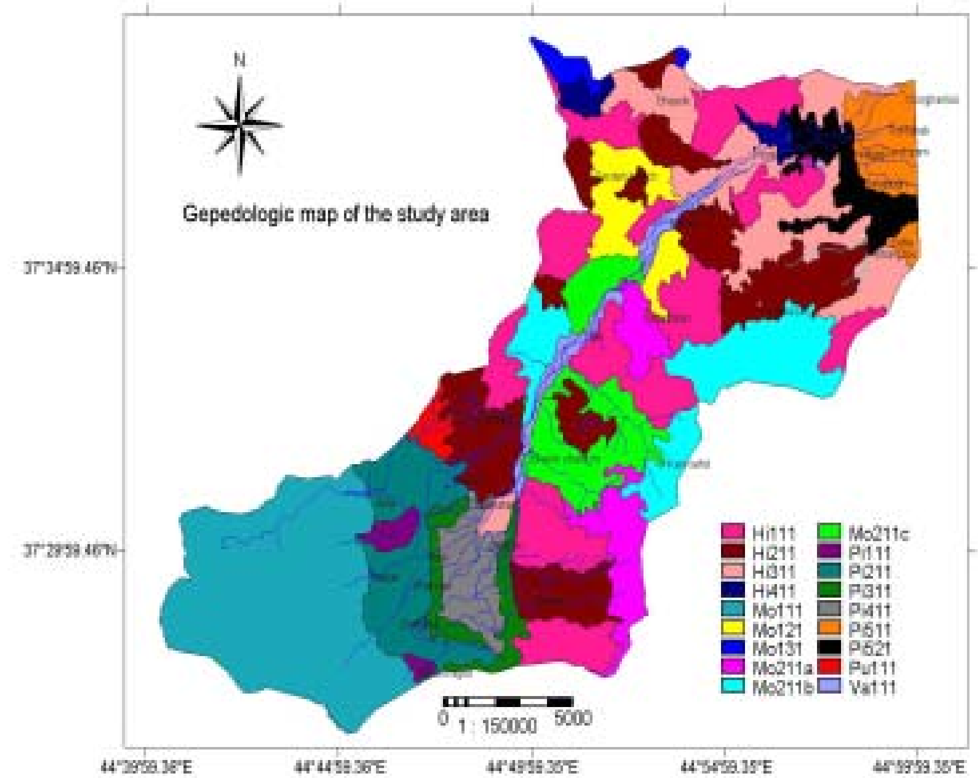


Figure 5.1: Geopedologic map of the study area

5.4 Soil climatic regime

Temperature and moisture regimes are two important soil attributes that affect chemical, biological and physical processes of soil, which are required for soil classification according to the USDA Soil Taxonomy.

5.4.1 Soil moisture regime

The soil moisture regime of the study area is Xeric. In this regime, winters are cold and moist and summers are hot and dry. The soil moisture control section, in 6 or more out of 10 years, is dry in all parts for 45 or more consecutive days in the 4 months following the summer solstice, and moist in all parts for 45 or more consecutive days in the 4 months following the winter solstice. Also, in 6 or more out of 10 years, the moisture control section is moist in some part for that half the cumulative days per year when the soil temperature at a depth of 50 cm from the soil surface is higher than 5 °c, and for 90 or more consecutive days when the soil temperature at a depth of 50 cm is higher than 8 °c.

5.4.2 Soil temperature regime

The soil temperature of the study area is mesic. In this regime, mean annual soil temperature is 8 °c or higher but lower than 15 °c, and the difference between mean summer and mean winter soil temperature is more than 5 °c either at a depth of 50 cm from the soil surface or at a lithic or paralithic contact, whichever is shallower.

5.5 Soil classification according to USDA Soil Taxonomy

In soil science, as in many other scientific disciplines, classification is used to strengthen technical communication. Similar soils are tried to put in given groups so that their correlation (of soils occurring in the different parts of the world) become possible. Among the many soil classification systems, the USDA Soil Taxonomy is considered as the most comprehensive and sophisticated system. In the USDA Soil Taxonomy, several categorical levels, such as order, suborder, great group, subgroup, family and phases of family take care of the classification.

The soils distinguished according to USDA soil taxonomy are as follows:
Most of dominant soils distinguished in mountain and valley landscapes are Entisols whereas Inceptisols are the dominant soils in Hilland and Piedmont landscapes. At subgroup level of USDA soil classification, two soils as Lithic Xerorthents and Lithic Haploxerepts have also been recognized in mountain landscape that are shallow undeveloped soil and less developed soil respectively. In hilland, at subgroup level, Typic Calcixerepts, which are soils with calcic horizon, have been distinguished, that are in association of Petrocalcic Calcixerepts. In piedmont, the dominant soils are recognized as Haploxerepts at great group level with high amount of clay, are called Vertic Haploxerepts, that are in association of Typic Haploxerepts.

<u>The following soils have been identified in the study area</u>

- Fine loamy, mixed, mesic, Typic Haploxerepts
- Fine, mixed, mesic, Typic Haploxerepts
- Fine loamy, mixed, mesic, Typic Calcixerepts
- Loamy skeletal, mixed, mesic, Typic Calcixerepts
- Fine, mixed, mesic, Typic Calcixerepts
- Fine loamy, mixed, carbonatic, mesic, Petrocalcic Calcixerepts
- Fine, mixed, carbonatic, mesic, Petrocalcic Calcixerepts
- Fine, mixed, mesic, Vertic Haploxerepts
- Fine loamy, mixed, mesic, Lithic Haploxerepts
- Fine loamy, mixed, mesic, Lithic Xerorthents
- Coarse loamy, mixed, mesic, Typic Xerofluvents
- Sandy, mixed, mesic, Fluventic Haploxerepts

The definitions for the the different soil orders, suborders, great groups and subgroups as distinguished in the study area are as below:

1) Inceptisols

Inceptisols are soils with minimal development that have a Cambic horizon and an Ochric epipedon. Inceptisols include a wide variety of soils.

Xerepts

Inceptisols that have a xeric soil moisture regime.

Vertic Haploxerepts

Haploxerepts that have cracks within 125cm of the mineral soil surface that are at least 5 mm wide with a thickness of 30cm or more and slickensides or wedge-shaped aggregates in a layer 15cm or more thick.

Lithic Haploxerepts

Haploxerepts that have a lithic contact within 50cm of the mineral soil surface.

Fluventic Haploxerepts

Haploxerepts that have an irrigular decrease in organic carbon content between a depth of 25cm and either a depth of 125cm below the mineral soil surface or a densic, lithic or paralithic contact.

Typic Haploxerepts

Inceptisols that have a xeric soil moisture regime and Cambic horizon (Figure 5.3).

Typic Calcixerepts

Xerepts that have a Calcic horizon.

Petrocalcic Calcixerepts

Calcixerepts that have a Petrocalcic horizon (Figure 5.4).

2) Entisols

Entisols are soils that have little or no evidence of the development of pedogenic horizons. Most Entisols have no diagnostic horizons other than an Ochric epipedon (soil taxonomy, 1999).

Lithic Xerorthents

Entisols that have a xeric moisture regime and a lithic contact within 50cm of the mineral soil surface.

Typic Xerofluvents

Entisols that have 1-either 0.2 percent or more organic carbon at a depth of 125cm or an irrigular decrease in content of organic carbon from a depth of 25cm to a depth of 125cm or shallower one.2- a xeric moisture regime.

Taxonomic soil map of the study area is illustrated in figure 5.2 and two soil profiles showing Haploxerepts and Petrocalcic Calcixerepts are presented in Figures 5.3 and 5.4 respectively.

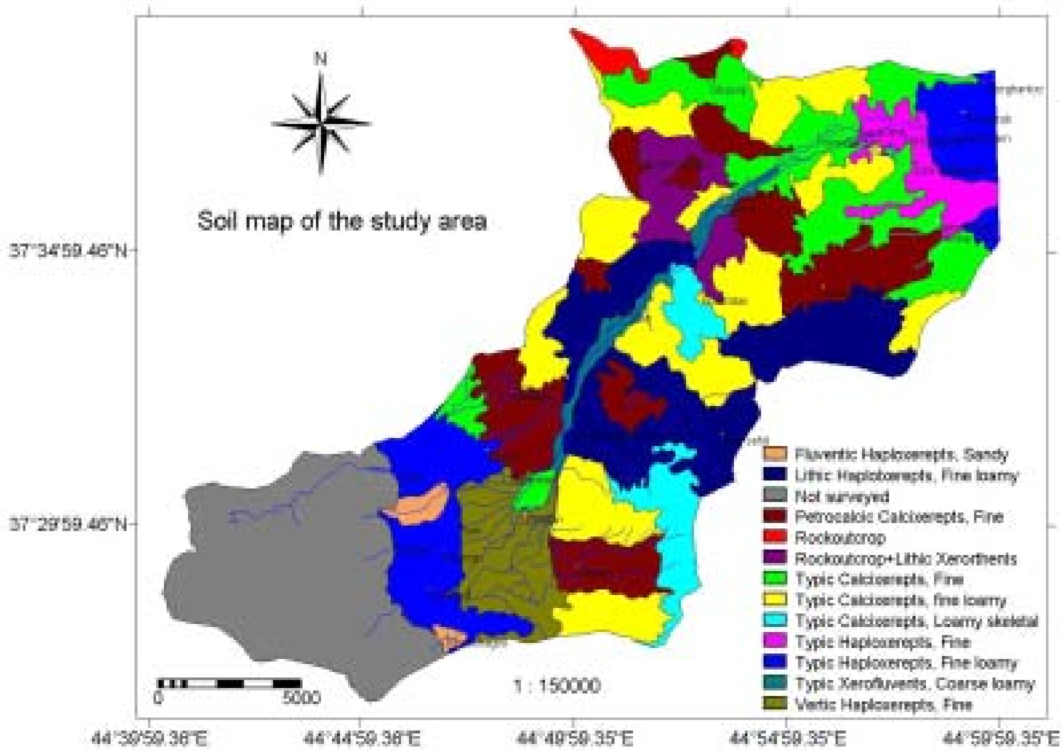


Figure 5.2: Taxonomic soil map of the study

Some of check profiles have been described in Appendix 1.

Figure 5.3 – Schematic of a Typic Haploxerepts

Figure 5.4 – Schematic of a Petrocalcic Calcixerepts

6. LAND COVER & LAND USE

6.1 Application of remote sensing

Different features such as vegetation, water bodies, rock outcrops, etc. cover land and each such a feature has a different reflection of energy that can be recorded by a sensor. The sensors produce digital images to be sent to earth's receivers. In other words, remotely sensed data are measurements of reflected solar radiation, energy emitted by the earth itself.

An image consists of an array of pixels (picture elements) including two-dimensional array of numbers, distributed in rows and columns as grid cells. Each pixel has a digital number (DN) that represents the intensity degree of reflected feature in the earth surface. The advantage of satellite images is that their data are in digital form, therefore; computer can process them. In this research, Landsat ETM images of July 2000 were used for the study area.

6.2 Methods of land use classification

There are different techniques including multi-spectral classification and image enhancement for land use classification. The following flowchart shows the image processing (Figure 6.1):

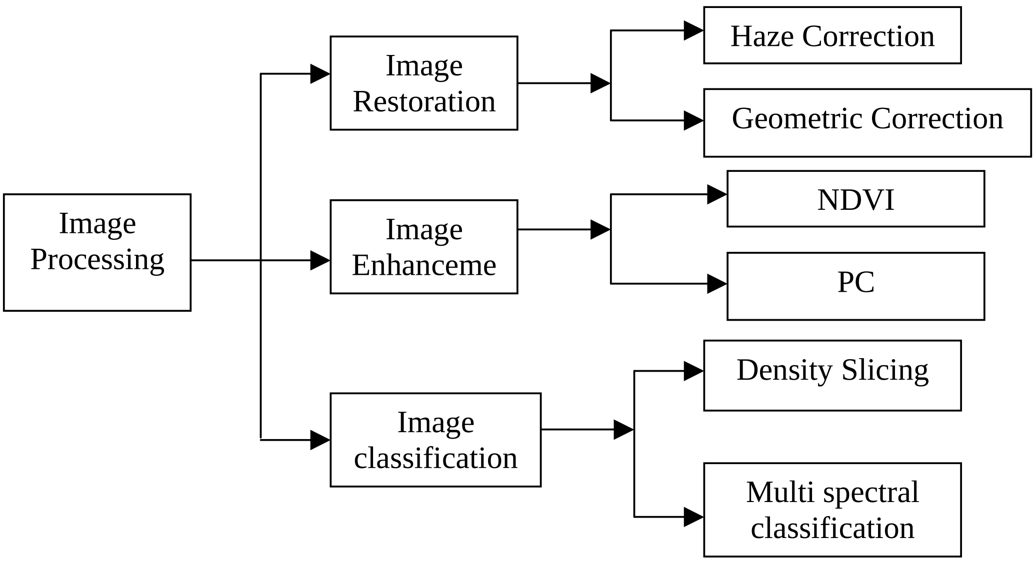


Figure 6.1 - Steps in image processing

6.2.1. Image restoration

Image restoration includes correction of data received from the satellite before classification can be made. The following correction were done:

a) Geometric correction

Remote sensing data is affected by geometric distortions due to sensor geometry, scanner and platform instabilities, earth rotation, high altitude and etc. and since the images in raw format are not georeferenced, therefore; in order to integrate these data with other data in GIS, in other word to be able to work in a GIS environment, it is necessary to georeference the image, using existing maps. A Universal Transverse Mercator projection (UTM) and affine transformation were used for correcting and georeferancing the image.

b) Haze correction

Due to water vapor and suspended particles in the atmosphere which results in a low image contrast and affect visible and infrared ETM bands, Haze correction was used using " simple haze correction" script of ILWIS (for more information see ILWIS user's guide).

6.2.2 Image enhancement

Image enhancement technique is done to make a raw image better interpretable. It improves its quality and its visual impact for the human eye. There are many techniques and methods of image enhancements used for visual interpretation, however the following techniques are the most suitable:

a) Normalized Difference Vegetation Index (NDVI)
b) Principle Component Analysis (PCA)

a) Normalized Difference Vegetation Index (NDVI)

NDVI is based on the reflectance properties of vegetated areas as compared to clouds, water and snow on the one hand, rocks and bare soil on the other. Vegetated areas have a relatively high reflection in the near infrared and a low reflection in the visible range of the spectrum. Clouds, water and snow have larger visual than near infrared reflectance. Rock and bare soil have similar reflectance in both spectral regions (ILWIS user's Guide 2001). Vegetation cover can be differentiated from the other ground cover types by NIR/Red ratio. The following simple formula was used to generate NDVI map for identification of green cover:

$$NDVI = (ETM4-ETM3) / (ETM4+ETM3) *128+127$$

Where ETM4 is ETM spectral band 4 and ETM3 is ETM spectral band 3

The numbers 127 and 128 are factors, to avoid negative index. After determination of NDVI, (Figure 6.2) the density slicing option was applied for differentiating between areas with varying vegetation densities in order to classify different vegetation covers (Figure 6.3 and Table 6.1). It is divided to four landuse / cover classes: poor rangeland, fair rangeland, good rangeland, and agriculture (which include both irrigated and rainfed lands). The result of NDVI classification showed that it was not possible to distinguish between dry land farming and the rangeland, as the reflectance between rainfed cropland and rangelands in the Mountain and Hilland are the same and it can't be used well for agricultural lands.

Table 6.1 - Landuse areas extracted from NDVI

Landuse	Area (ha)	Area %
Rockoutcrop	1,040	4
Poor range	6,549	22
Fair range	12,983	45
Good range	3,660	12
Agriculture	4,831	17

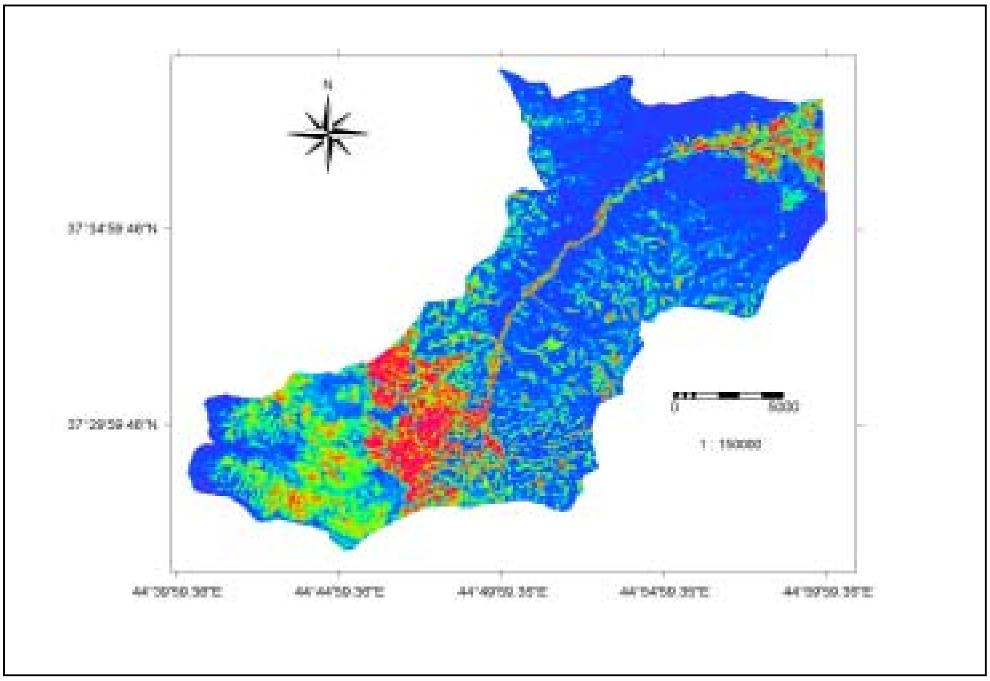


Figure 6.2 - NDVI map of the study area

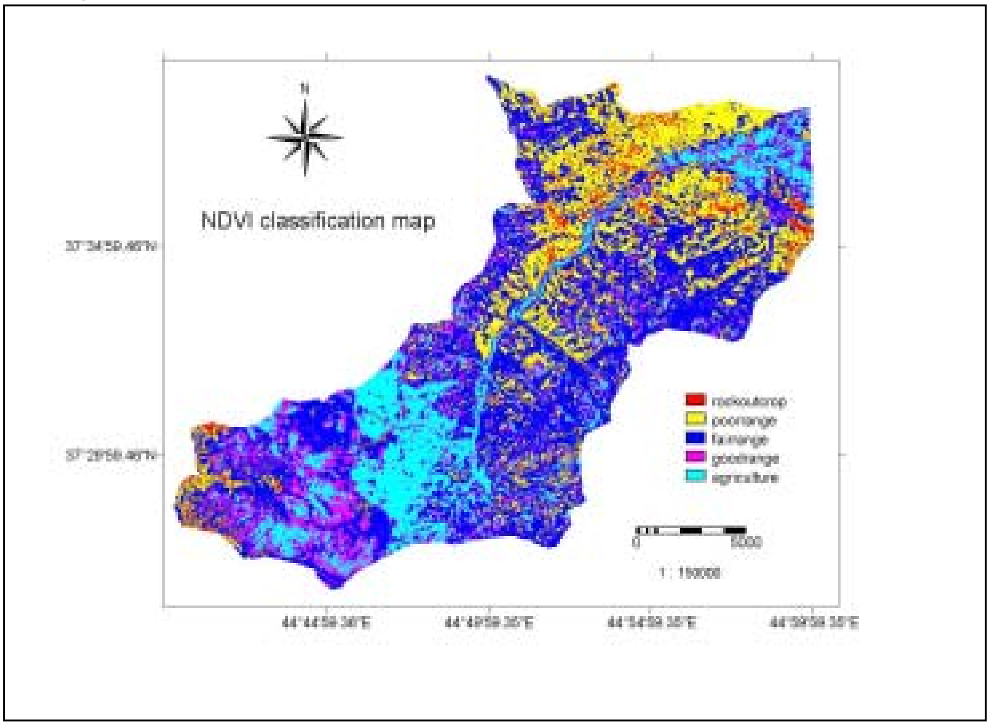


Figure 6.3 - NDVI classification map

b) Principle Component Analysis (PCA)

PCA can be applied to compact the redundant data into fewer layers and can be used to transform a set of image bands, as that the new layers (also called components) are not correlated with one another (ILWIS user's Guide 2001). High correlation between bands in multi spectral images such as Landsat image cause a lot of redundancy and finally give mixed pixels, which complicate classification.

Principal Component Analysis is a statistical method used for compressing the original data set without loosing too much information. A Principal Component Calculation is known as a method to extract or reduce the spectral noise/redundancy (Richards, 1993). Principal Component Analysis is collecting the information of the spectral bands used in a cloud of points in a multi dimensional space and calculates a new optimum set of axis through these cloud data points. The number of Principal Component equals the number of input bands. The first PC is defined by maximum variance of the original data set; the last PC defines the leftover variance (Meijerink et.al, 1994).

PC1: Useful for studies of the agricultural land and geology.
PC3: Useful for studies of the bare soil.
PC4: Useful for studies the agricultural lands.

6.2.3 Image classification techniques

1) Unsupervised classification

Classification is done automatically using only information of the digital image. In this type of classification, the computer assigns statistically spectral classes to the features.

2) Supervised classification

In the combination of multi-spectral bands, three bands including ETM4, 3 and 2 were used to supervised classification, which is based on ground data collected in the field, from training sample sites. Supervised classification is the procedure that user predefines spectral classes. Training samples are selected, where the known pixels are assigned. Within pre-selected clusters, terrain sampling was done based on field observation knowledge that is named knowledge based classification (Abkar, 1994). After construction of the training samples, the image was classified using Maximum likelihood classification with threshold 100 (Figure 6.4).

6.3 Present landuse

In the combination of multi-spectral bands, three bands including ETM4, 3 and 2 were used to present landuse classification, which is based on ground data collected in the field, from training sample sites. Supervised classification procedure was used to prepare current landuse using spectral classes (Figure 6.4). Table 6.3 shows the types of current landuse and their area. Overall accuracy of landuse classification is also shown in table 6.2.

Table 6.2 – Overall Accuracy of present land use

	Fairrange	Fallow	Goodrange	Irrigated	Irrigated+ Orchard	Rainfed	Rockoutcrop	Settlement	Accuracy
Fairrange	6	0	0	0	1	0	0	0	0.86
Fallow	0	3	0	1	0	0	0	0	0.75
Goodrange	0	1	12	0	1	0	0	0	0.86
Irrigated	0	1	1	5	1	1	0	0	0.56
Irrigated+Orchard	1	0	0	0	7	0	0	0	0.88
Rainfed	2	0	1	0	0	9	1	0	0.69
Rockoutcrop	0	0	0	0	0	1	2	0	0.67
Settlement	0	0	0	0	0	0	0	5	1
Reliability	0.67	0.60	0.86	0.83	0.70	0.82	0.67	1	

Average accuracy = 78.17 %
Average reliability = 76.77 %
Overall accuracy = 77.78%

Table 6.3 – Present land use and area

Land use/cover	Area (ha)	Area %
Fair range + Rainfed	9,347	32.2
Fallow	1,098	3.8
Good range	7,273	25.0
Irrigated	807	2.8
Irrigated+ Orchard	3,164	10.9
Poor range	6,748	23.2
Rock outcrop	507	1.74
Settlement	119	0.4

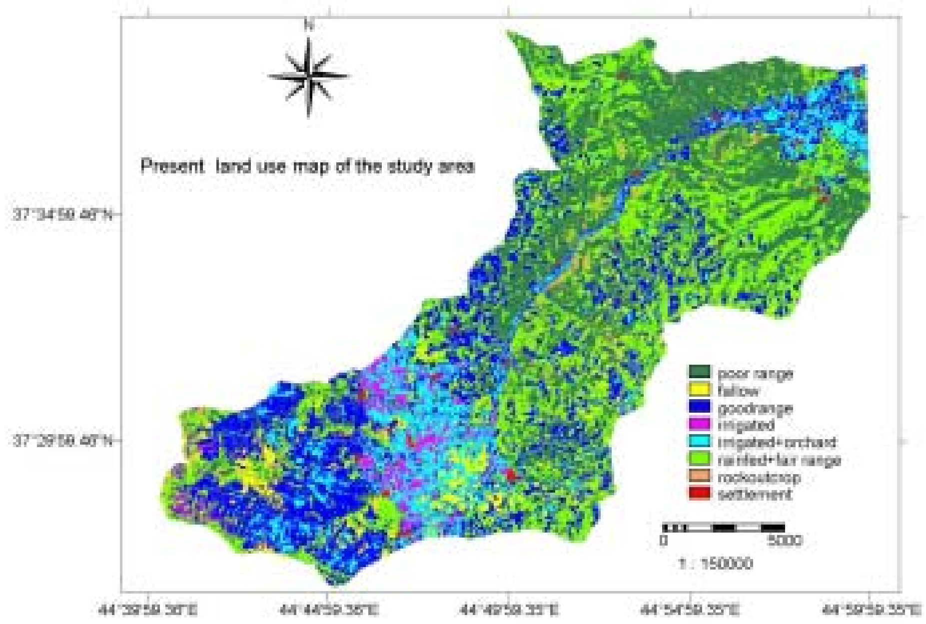


Figure 6.4 - Current land use map (2000)

6.4 Previous landuse

The previous landuse pattern is presented by two periods of time, the 1990 TM Landsat image (Figure 6.5) and the aerial photographs of 1956 (Figure 6.6).

6.4.1 Previous landuse 1990

Previous landuse was prepared for housing ministry in the Orumiyeh area by FAO (Figure 6.5). Table 6.4 shows the types of landuse and their area.

6.4.2 Previous landuse 1956

Aerial photo interpretation was conducted to produce this landuse for this period of time (Figure 6.6). The types of landuse and their area are also presented in Table 6.5.

Table 6.4 Previous land use and area (1990)

Previous land use	Area (ha)	Area %
Rangeland low density	8,233	28.33
Rangeland medium dense	7,458	25.66
Rangeland dense	3,571	12.29
Agriculture irrigated	1,518	5.22
Agriculture irrigated /orchard	2,350	8.09
Orchard	599	2.06
Settlement	35	0.12
Range land / agriculture	5,135	17.66
River bed	165	0.57

Table 6.5 Past land use and area (1956)

Past land use	Area (ha)	Percent (%)
Irrigated	3,357	11
Irrigated+ Orchard	1,817	6
Rainfed	3,810	13
Rangeland	20,080	70

6.5 Comparison and trends

In previous landuse (1956), The major landuses could only be distinguished during the mentioned period in the study area. It can be seen that the major parts of the area comprise rangeland, with a total surface area of 20,080 ha (Table 6.5). About 70 % of the total area was occupied by grazing lands. The remaining surface area was under cultivation. However, in comparison with the 1990 image (Table 6.4), the surface area of rangelands has been decreased to almost 19, 262 ha. It means that 66 % of the total area has been used for rangeland. This indicates that 4 % remaining has been converted to agricultural activities. In present landuse, since the time of image was in July, which is the growing time of the existed crops, thus it is difficult to differentiate rangeland from rainfed crops, however according to the agricultural extension services the rainfed surface area is more than 7000 ha. Hence it can be concluded that the total surface area for rangelands could be almost 16000ha (Table 6.3), meaning that about 55% of the total area are allocated to the rangeland in the current landuse. This indicates that 10 petrcents of the remaining has been changed to dry farming agriculture since 1990. The converting rangelands trends to rainfed crops can be seen during previous landuse to the present landuse, which is a problem in the study area.

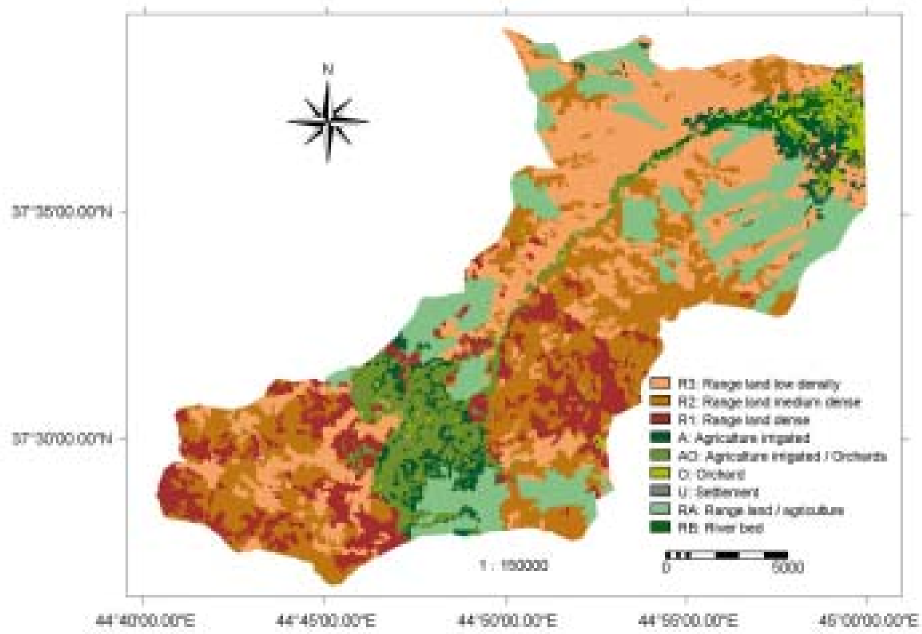


Figure 6.5 - Previous land use map (1990)

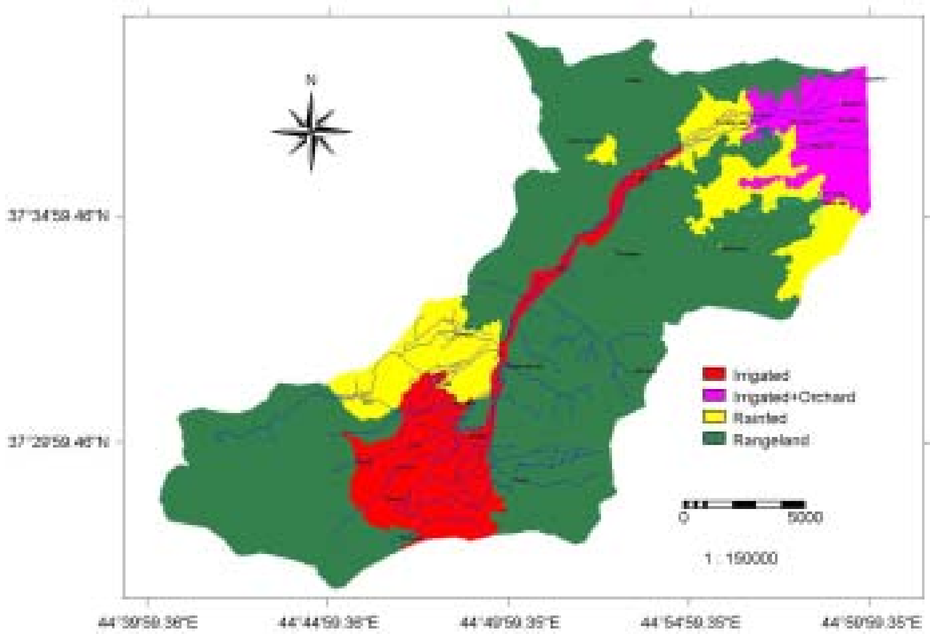


Figure 6.6 - Past land use map (1956)

6.6 Grazing capacity

The Grazing Capacity is defined as the maximum stocking that a rangeland can support without deterioration, that is, on a sustainable basis. In range management, stocking rate is defined as “Animal Unit per Month per hectare” (AUM/h). Animal unit in Iran is defined as a sheep (or goat) of 48 kg weight and is maximum animal unit that can graze a range in one month.

6.6.1 Calculation of grazing capacity

There are several methods for determination of grazing capacity. In this study, grazing capacity was calculated using rangeland classes’ method, which is common in Iran. Moghaddam (1998) has considered the following 4 classes of grazing capacity for the semi-arid area in Iran (Table 6.6).

Table 6.6 – Grazing capacity classes

Class	1 (excellent)	2 (good)	3 (moderate)	4 (poor)
AUM	>3	3 -2.5	2.5 - 1.5	<0.5

Based on the results of Sokouti Oskouei (1998) obtained in the field, rangeland of the study area can be fitted to the classes 2,3 and 4 of the Moghaddam classification. Table 6.7 shows the rangeland classes and their extents extracted from NDVI in the study area (see table 6.1).

Table 6.7 - Rangeland classes and their area

Rangeland classes	Area (ha)	Percentage %
Class 2	3,660	16
Class 3	12,983	56
Class 4	6,549	28
Total	23,192	100

According to the Table 6.7 production of the pasture in the area is enough for almost 4900 livestock. Knowing that the number of sheep and goat is 24,596 (see Table 3.7), it is easily understood that more than 19,696 heads of livestock overgraze the current rangeland.

6.6.2 Distance to water source

Distance to water source is an important factor for determination of grazing capacity and for the life of animals (Lotfollahzadeh, 1999). Animals obtain water from their food by metabolism and from open water. The need to drink depends on the amount of water present in the food. This varies seasonally on environmental conditions in particular high temperatures that affect the loss of water from their body. According to FAO (1988) in arid regions animals should not be allowed to walk more than a total distance of 10 km per day in search of food and water because, walking involves the expenditure of energy and reduces grazing time. In the study area, the perennial streams of Rouzeh Chai river and springs are used by herds. So water can not be considered as a problem. Distance to water source was computed using distance program of ILWIS (Figure 6.7).

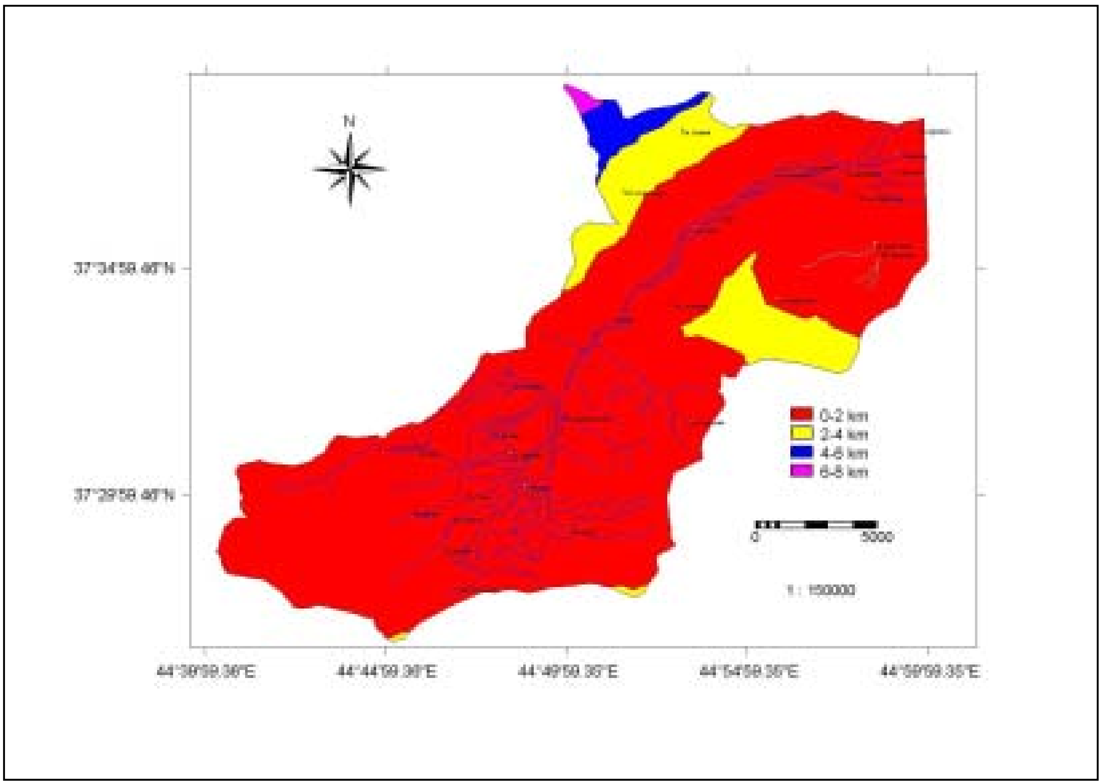


Figure 6.7 - Distance to water source

7. LAND EVALUATION

7.1 Identification and description of Land Utilization Types (LUT's)

A land utilization type is a kind of land use described or defined in a degree of detail greater than that of a major kind of land use, like production, management and socio-economic characteristics. There are two different types of agricultural activities, currently being practiced in the study area.

- Irrigated agricultural activities
- Rainfed agricultural activities

According to the kind of product and the management, five land use types (LUT1 through LUT5) have been distinguished, which are feasible and major crops in the study area (table 7.1).

Table 7.1: Current land use types

Land use types		Description
Irrigated	LUT1	Semi mechanized irrigated alfalfa
	LUT2	Semi mechanized irrigated tree plantation intercropped with alfalfa
	LUT3	Semi mechanized irrigated wheat/barley
rainfed	LUT4	Semi mechanized rainfed chickpea
	LUT5	Semi mechanized rainfed cereal (mostly wheat)

A listing of land use types description is given in table 7.2 (R. Sokouti Oskouei, 1997).

Table 7.2: Description of land use types

LUTs	Produce	Mechanization	Inputs			Market orientation	Level of technology	Yield (kg/ha)
			Seed (kg/ha)	Pesticide Lit/ha	Fertilizer Kg/ha			
LUT1	Alfalfa	Partly mechanized, (tractor), man power	25-30	2	50	Commercial with subsidiary subsistence	Low	2500 (dry matter)
LUT2	Apple fruits, alfalfa	Same as LUT1	350-400 seeding	2	100	Commercial	Low	20000 2500 (dry matter)
LUT3	Wheat/Barley	Same as LUT1	100-150 80-100		100	Subsistence with subsidiary commercial	Low	1800 1200
LUT4	Chickpea	Same as LUT1	50-80			Commercial with subsidiary subsistence	Low	500
LUT5	Wheat	Same as LUT1	80-100			Subsistence	Low	1200

7.2 summary description of Land Utilization Types

LUT1

LUT1 is mainly practiced in the Piedmont landscape close to the main river. Tractor is used to plow the land, seeding is done by hand and harvesting is either by hand or (in most case) partly mechanized. Alfalfa is sown once and harvested for six successive years.

LUT2

This multiple land use type is mostly practiced in Piedmont on slopes below 5%. Main crops planted are fruit trees (apple) and alfalfa intercropped between fruit trees. Trees occupy the land about 25-30 years and intercropping of alfalfa during this time continued (re cropped every 4-5 years). Use of machine is limited, except for land preparation before plantation, while the remaining practices are done by hand. Fruits are totally sold while a part of alfalfa is stored for own livestock as forage in winter.

LUT3

Wheat and barley are cropped in Piedmont and upper parts of the Piedmont where water supply is restricted. Generally, tractors do ploughing, but seeding and harvesting are done by hand. Cereals are mainly used for home consumption, however small part of production is sold.

LUT4

This land use type occupies a large part of the cultivated area including Glacis, Plateau and Hilland. A small product used for home consumption but a large part mainly used for selling as a cash crop. Selection of this rainfed land use type by the farmers is due to local climatic condition, easy practices and high demand. In case of mismanagement the production of this land use type is low.

LUT5

LUT5 is cropped in the same landscape as LUT4. Agricultural practices are the same as LUT3, but the yield is less than that in LUT3.

7.3 Land Use Requirements (LUR)

Generally, three groups of land use requirements can be distinguished (FAO, 1983):

1) Plant growth requirements such as moisture availability.
2) Management requirements such as soil workability.
3) Conservation requirements such as erosion hazard.

Land use requirements determine the data on land resources that is needed for land evaluation. Each land use type may have one or more land use requirements (table 7.3).

Table 7.3 Land use requirements

Land Use Types	Land use requirements
LUT1, LUT2, LUT3	Oxygen availability
	Rooting condition
	Soil workability
	Erosion hazard
	Ease of water conveyance
	Flooding hazard
LUT4, LUT5	Moisture availability
	Oxygen availability
	Rooting condition
	Soil workability
	Erosion hazard
	Flooding hazard

7.4 Description of Land qualities (LQ)

A land quality is a complex attribute of land that has a direct effect on land use. According to the land use types distinguished in the study area and their requirements, corresponding land qualities and the "diagnostic factors" i.e. land characteristics were selected in land evaluation.

The following land qualities based on land use requirements are considered.

1) Moisture availability
2) Oxygen availability
3) Rooting condition
4) Flooding hazard
5) Ease of water conveyance
6) Soil workability
7) Erosion hazard

Moisture availability

Moisture availability is an indicator for the capacity of the land to supply water and makes it available for plants. Crops growth can be badly influenced by moisture stress and ultimately die through drought. This is indeed the most important LQ for rainfed crops. Soil moisture content or water holding capacity is used to assess this land quality. Soil texture is used as an indicator due to the absence of these data.

Oxygen availability

With a few exceptions, notably rice, plants need to take in oxygen through their rooting system, and suffer restricted growth or ultimately death if deprived of this (FAO, 1984). This quality is nearly always taken into account in land evaluation. In this study, diagnostic factor drainage class is used to assess this quality.

Rooting condition
Plants need a satisfactory rooting condition in order to extract moisture and nutrients that is controlled by physical soil characteristics. In this study, rooting condition was assessed using soil depth (cm), volume percentage of stones and subsoil stoniness.

Flooding hazard
This land quality refers to flood damage that mostly occurs on the river valley landscape and some parts of the piedmont. Flood frequency was used to assess this LQ (table 7.4).

Table 7.4: flood hazard classification

Class	Flood frequency (years)
F0	>10
F1	6-10

Soil workability
Workability or ease of tillage is the ease with which the soil can be cultivated or tilled. This quality of soil depends on a number of interrelated soil characteristics including texture, slope and surface stoniness.

Ease of water conveyance
This quality was assessed using slope gradient.

Erosion hazard
All evaluations, in particular those occurred in arid/ semi arid zone, should take into account the erosion hazard. In this study present erosion hazard was used as a diagnostic factor.
All land qualities are determined by the one or more diagnostic factors (land characteristics) (table 7.5).

Table 7. 5: Diagnostic land characteristic

Land Quality	Diagnostic factor (Land Characteristic)
Moisture availability (moav)	Particle size class, soil depth
Oxygen availability (oxav)	Soil drainage class
Rooting condition (roco)	Soil depth, subsoil stoniness
Soil workability (sowo)	Soil texture, slope gradient, topsoil stoniness
Erosion hazard (erhz)	Present erosion rate
Ease of water conveyance (conv)	Slope gradient
Flooding hazard (flhz)	Flooding class

7.5 Land characteristics
Land characteristics are properties of land that can be measured or estimated. Data on relevant land characteristics are needed to determine the extent to which land conditions in the study area satisfy the landuse requirements. Land characteristics of the dominant soils of land mapping units are shown in table 7. 6.

Table 7.6: Land Characteristics

Unit code	Soil depth (Cm)	Subsoil stoniness %	Particle size class	Top soil stoniness %	Subsoil texture	Slope gradient %	Present erosion rate	Soil drainage class	Flooding
Mo111	50	30	SCL	30	SiL	>60	High	Well	F0
Mo121	40	-	SiCL	30	SiCL	25-40	v.high	Well	F0
Mo131	50	-	SL	15	SiCL	15-40	v.high	Well	F0
Mo211a	70	35	SiL	15	SiCL	15-25	Moderate	Well	F0
Mo211b	40	-	SL	10	SL	25-40	High	Well	F0
Mo211c	50	-	SiCL	15	SiCL	25-40	High	Well	F0
Hi111	130	10	SiCL	10	HSiCL	15-30	High	Well	F0
Hi211	130	5	SiL	15	SiC	8-15	Moderate	Well	F0
Hi311	130	-	SiL	-	SiC	5-8	v.l to l	Well	F0
Hi411	130	-	SL	-	SiC	5-10	v.l to l	Well	F0
Pi111	65	60	LS	70	Gravely LS	5-10	v.l to l	Well	F0
Pi211	120	10	SiCL	5	SiC	2-5	v.l to l	Moderate	F0
Pi311	120	10	CL	-	C	2-5	v.l to l	Moderate	F0
Pi411	150	10	CL	-	C	2-5	v.l to l	Moderate	F0
Pi511	130	5	SiCL	5	SiCL	0-2	v.l to l	Well	F0
Pi521	130	-	SiCL	-	SiC	0-2	v.l to l	Well	F0
Pu111	140	5	SiCL	15	SiC	2-5	v.l to l	Well	F0
Va111	140	-	SiL	-	SL	0-2	v.l to l	Well	F1

7.6 Severity levels

Severity levels of land qualities refer to the degree of limitations or hazard of a given land quality on a particular land area from level 1 (no limitation) to severe limitation, the same way as the number of physical suitability classes including S1, S2, S3 and N (table 7.7).
The severity levels can be estimated using a set of land characteristics, that is, corresponding diagnostic factors are selected out of predefined list of land characteristics and relate them with its land quality. Table 7.9 to 7.13 show factor rating for different LUTs.

Table 7. 7: Severity levels for different LURs/LQ

LURs	Code	Level1	Level2	Level3	Level4
Moisture availability	Moav	Adequate	Slight stress	Moderate stress	Severe stress
Oxygen availability	Oxav	No limitation	Slight limitation	Moderate limitation	Severe limitation
Rooting condition	Roco	Very good	Good	Moderate	Poor
Soil workability	Sowo	Easy	Moderate	Difficult	Very difficult
Erosion hazard)	Erhz	No limitation	Slight limitation	Moderate limitation	Severe limitation
Ease of water conveyance	Conv	No problem	Slight problem	Moderate problem	Severe problem
Flooding hazard	Flhz	No flood	Slight flood	-	-

In ALES land characteristics are the basis for evaluation, which is used in decision trees to estimate severity levels of land use requirements. The land characteristics classes must include all land use requirements of LUTs under consideration for entering data (table 7.8).

Table 7.8: land characteristics of reference list

LC code	Name	Unit	Class abbreviation	Class names	Class limit
Flod	Flooding	Class	F0	No flooding hazard	
			F1	Slight flooding	
Sodr	Soil drainage	Class	Well	Well drained	
			Mod	Moderately well drained	
pasz	Particle size	Class	Sil	Silt loam	
			Sl	Sandy loam	
			Sicl	Silty clay loam	
			Scl	Sandy clay loam	
			Cl	Clay loam	
			Sic	Silty clay	
			Ls	Loamy sand	
			gls	Gravely loamy sand	
pero	Present erosion rate	Class	v.l to l	Slight erosion	
			Moderate	Moderate erosion	
			High	Severe erosion	
			v.high	Very severe erosion	
Sbst	Subsoil stoniness	%	Sl	Slight limitation	0-15
			Mo	Moderate limitation	15-35
			Se	Severe limitation	35-75
			Vse	Very severe limitation	>75
Sbtx	Subsoil texture	Class	Sil	Silt loam	
			Sl	Sndy loam	
			Sicl	Silty clay loam	
			Hscl	Heavy sandy clay loam	
			Sic	Silty clay	
			Gls	Gravelly loamy sand	
			C	Clay	
			Scl	Sandy clay	
Slgr	Slope gradient	%	Nl	Nearly level	0-5
			Gs	Gently sloping	5-8
			Sl	Sloping	8-15
			Mstp	Moderately sloping	15-25
			stp	Steep	25-40
Sodp	Soil depth	Cm	Vs	Very shallow	0-25
			S	Shallow	25-40
			Md	Moderately deep	40-80
			D	Deep	80-120
			Vd	Very deep	120-150
Tpst	Topsoil stoniness	%	Sl	Slight limitation	0-15
			Mo	Moderate limitation	15-35
			Severe	Severe limitation	35-55
			Very severe	Very severe limitation	55-75

Table 7.9: Factor rating for LUT1 (Semi mechanized irrigated alfalfa)

Land use requirements			Factor rating			
Land Quality	**Diagnostic factor**	**Unit**	**S1**	**S2**	**S3**	**N**
Oxygen availability	Soil drainage class	Class	Well	Moderate	-	-
Rooting condition	Soil depth	Cm	>120	120-80	80-40	<40
	Subsoil stoniness	Vol. %	<15	15-35	35-75	>75
Flooding hazard	Flooding class	Class	F0	F1	-	-
Soil workability	Slope gradient	%	<5	5-8	8-15	>15
	Topsoil stoniness	%	<15	15-35	35-55	>55
Ease of water conveyance	Slope gradient	%	<8	8-15	15-25	>25
Erosion hazard	Present erosion rate	Class	V.low to low	Moderate	High	V.high

Table 7.10: Factor rating for LUT2 (Semi mechanized irrigated tree plantation intercropped with alfalfa)

Land use requirements			Factor rating			
Land Quality	**Diagnostic factor**	**Unit**	**S1**	**S2**	**S3**	**N**
Oxygen availability	Soil drainage class	Class	Well	Moderate	-	-
Rooting condition	Soil depth	Cm	>150	150-80	80-40	<40
	Subsoil stoniness	Vol. %	<15	15-35	35-75	>75
Flooding hazard	Flooding class	Class	F0	F1	-	-
Soil workability	Slope gradient	%	<8	8-15	15-40	>40
	Topsoil stoniness	%	<15	15-35	35-55	>55
Ease of water conveyance	Slope gradient	%	<8	8-15	15-25	>25
Erosion hazard	Present erosion rate	Class	V.low to low	Moderate	High	V.high

Table 7.11: Factor rating for LUT3 (Semi mechanized irrigated wheat/barley)

Land use requirements			Factor rating			
Land Quality	**Diagnostic factor**	**Unit**	**S1**	**S2**	**S3**	**N**
Oxygen availability	Soil drainage class	Class	Well	Moderate	-	-
Rooting condition	Soil depth	Cm	>80	80-40	40-25	<25
	Subsoil stoniness	Vol. %	<15	15-35	35-75	>75
Flooding hazard	Flooding class	Class	F0	F1	-	-
Soil workability	Slope gradient	%	<5	5-8	8-15	>15
	Topsoil stoniness	%	<15	15-35	35-55	>55
Ease of water conveyance	Slope gradient	%	<8	8-15	15-25	>25
Erosion hazard	Present erosion rate	Class	V.low to low	Moderate	High	V.high

Table 7.12: Factor rating for LUT4 (Semi mechanized rainfed chickpea)

Land use requirements			Factor rating			
Land Quality	**Diagnostic factor**	**Unit**	**S1**	**S2**	**S3**	**N**
Moisture availability	Particle size class	Class	SiCL, SCL, CL, SiC	SiL, SL	LS, GrLS	-
Oxygen availability	Soil drainage class	Class	Mod. To Well	-	-	-
Rooting condition	Soil depth	Cm	>80	80-60	60-20	<20
	Subsoil stoniness	Vol. %	<15	15-35	35-75	>75
Flooding hazard	Flooding class	Class	F0	F1	-	-
Soil workability	Slope gradient	%	<5	5-8	8-15	>15
	Topsoil stoniness	%	<15	15-35	35-55	>55
Erosion hazard	Present erosion rate	Class	V.low to low	Moderate	High	V.high

Table 7.13: Factor rating for LUT5 (Semi mechanized rainfed cereal, mostly wheat)

Land use requirements			Factor rating			
Land Quality	**Diagnostic factor**	**Unit**	**S1**	**S2**	**S3**	**N**
Moisture availability	Particle size class	Class	SiCL, SCL, CL, SiC	SiL, SL	LS, GrLS	-
Oxygen availability	Soil drainage class	Class	Mod. To Well	-	-	-
Rooting condition	Soil depth	Cm	>80	80-40	40-25	<25
	Subsoil stoniness	Vol. %	<15	15-35	35-75	>75
Flooding hazard	Flooding class	Class	F0	F1	-	-
Soil workability	Slope gradient	%	<5	5-8	8-15	>15
	Topsoil stoniness	%	<15	15-35	35-55	>55
Erosion hazard	Present erosion rate	Class	V.low to low	Moderate	High	V.high

7.7 Land suitability assessment

A physical suitability evaluation indicates the degree of suitability for a land use, without respect to economic conditions (Rositter, 1997). In ALES the evaluation results are presented in the form of a matrix, that is, a two dimensional array with rows including map units and columns consisting of the land use types for which an evaluation was computed. The intersection of the two (i.e. the cells of the matrix) is considered as the result. The overall physical suitability of a LMU or a soil component of LMU was assessed through the maximum limitation method; this means that, the suitability is taken from the most limiting land quality. The results show the physical suitability subclasses at four suitability classes 1,2,3,4 corresponding to the FAO classes; S1, S2, S3, N of each map unit for each land use type. Suitability subclasses show type(s) of limitation by subclass suffixes codes. Table 7.14 shows the land evaluation results.

Table 7. 14: Land suitability classes with limitation factors under different Land Use Types

LMU	LUT1	LUT2	LUT3	LUT4	LUT5
Mo111	4 erhz/sowo	4 erhz/sowo	4 erhz/sowo	4 erhz/sowo	4 erhz/sowo
Mo121	4 conv/erhz/sowo	4 conv/erhz/roco	4 conv/erhz/sowo	4 erhz/sowo	4 erhz/sowo
Mo131	4 erhz/sowo	4 erhz	4 erhz/sowo	4 erhz/sowo	4 erhz/sowo
Mo211a	4 roco/sowo & 4 sowo	3 conv/roco/sowo	4 roco/sowo & 4 sowo	4 sowo	4 sowo
Mo211b	4 conv/roco/sowo	4 conv & 4 conv/roco	4 conv/roco/sowo	4 sowo	4 sowo
Mo211c	4 conv/roco/sowo	4 conv & 4 conv/roco	4 conv/roco/sowo	4 sowo	4 sowo
Hi111	4 conv/roco/sowo	4 conv & 4 conv/roco	4 conv/roco/sowo	4 sowo	4 sowo
Hi211	3 roco/sowo & 3sowo	2 conv/erhz/sowo & 3 roco	3 roco/sowo & 3sowo	3 sowo	3 sowo
Hi311	3 roco	1 & 3 roco	2 sowo	2 moav/sowo	2 moav/roco/sowo
Hi411	2 sowo	1	2 sowo	2 moav/sowo	2 moav/sowo
Pi111	3 roco	3 roco	3 roco	3 moav	3 moav
Pi211	2 oxav & 2 roco	2 oxav & 2 roco	2 oxav & 2 roco	2 moav	1 & 2 moav
Pi311	2 oxav	2 oxav	2 oxav	1	1
Pi411	2 oxav	2 oxav	2 oxav	1	1
Pi511	1	1	1	1	1 & 2 moav
Pi521	1	1	1	1	1
Pu111	1	1	1	1	1
Va111	2 flhz	2 flhz	2 flhz	2 flhz/moav	2 flhz

Explanatory note: erhz = erosion hazard, sowo = soil workability, conv = ease of water conveyance, roco = rooting condition, oxav = oxygen availability, moav = moisture availability, flhz = flooding hazard

Physical land suitability maps are illustrated in figures 7.1, 7.2, 7.3, 7.4 and 7.5

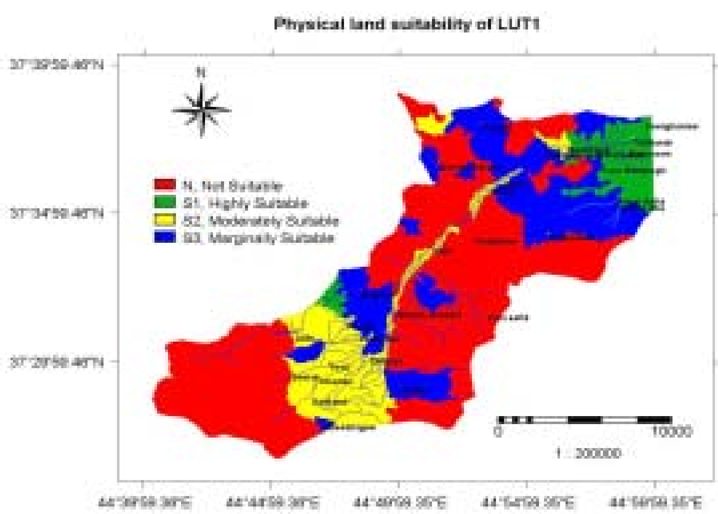


Figure 7.1: Physical land suitability for LUT1 (irrigated alfalfa)

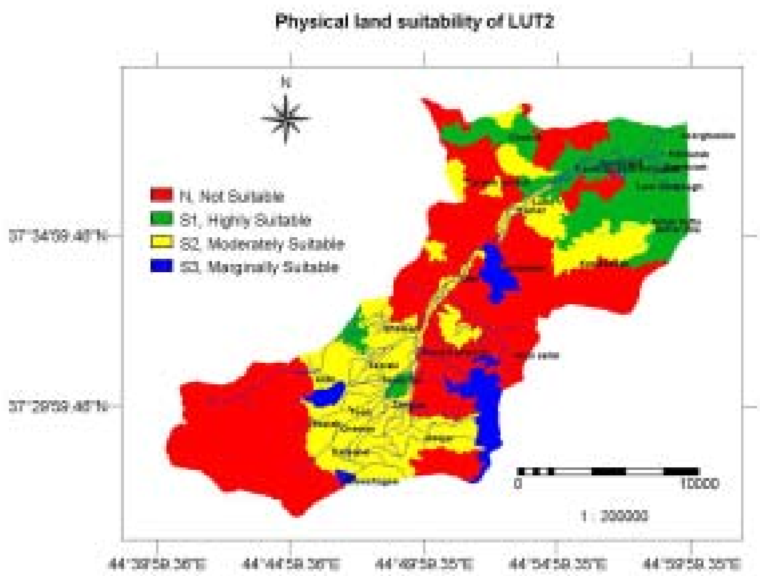


Figure 7.2: Physical land suitability for LUT2 (irrigated tree +alfalfa)

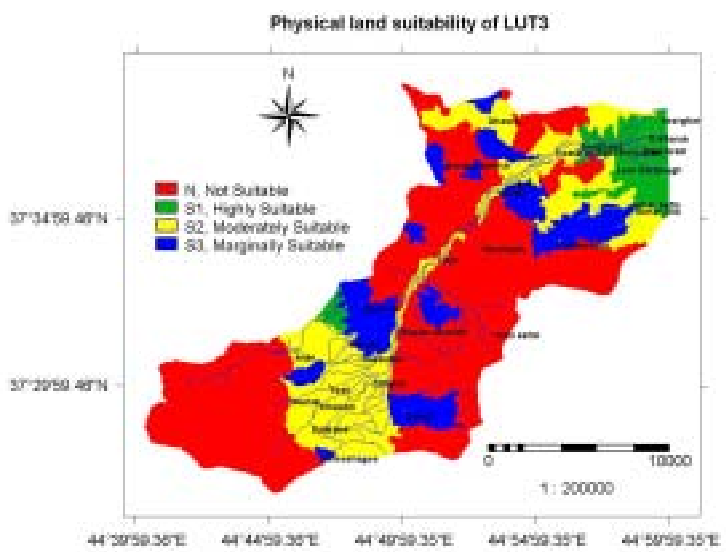


Figure 7.3: Physical land suitability for LUT3 (irrigated wheat/barley)

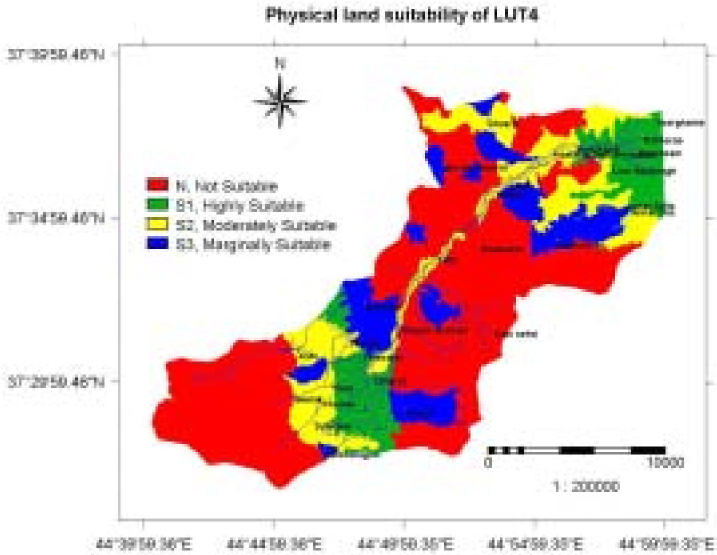


Figure 7.4: Physical land suitability for LUT4 (rainfed chickpea)

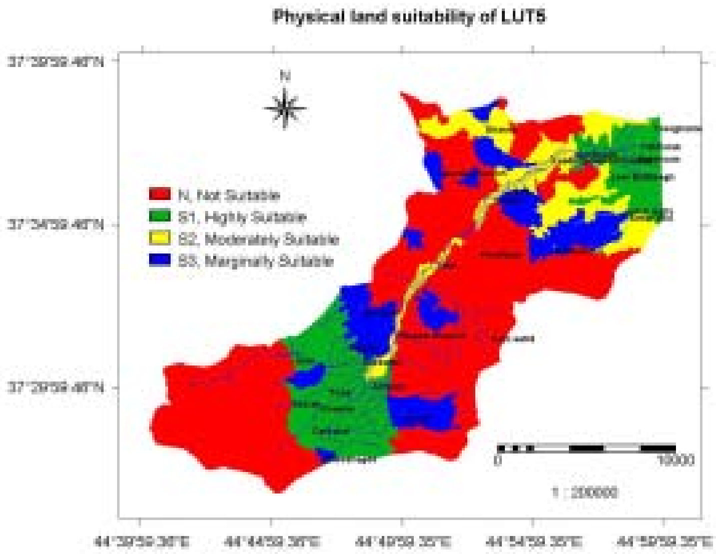


Figure 7.5: Physical land suitability for LUT5 (raifed cereal)

7.8 Discussion

Mountainous areas are found to be unsuitable for the considered LUT's because of insufficient soil depth and soil workability (steep slopes). Hilland units are mainly unsuitable and marginally suitable for the LUT's due to the same limiting factors of the Mountain landscape except of Hi311 and Glacis, which are moderately suitable in case of moisture availability and also soil workability for the different LUT's. Piedmont land mapping unit is the most suitable for different LUT's however Pi111 unit is marginally suitable for the LUT's because of rooting condition (high amount of gravels and stones) and moisture availability (particle size). Valley landscape is moderately suitable for all LUT's due to the limitation of flooding hazard.

8: LAND USE PLANNING

General

Planning is a decision-making method that analyses the problems, identifies the opportunities for change, and appraises the alternatives taking into consideration of environment, economic and social conditions that leads to the transformation of a current situation to the best option in order to minimize costs and maximize benefits.

8.1 Inputs into LUP / land use alternative assessment

8.1.1 Results from land suitability analysis

For evaluation of alternatives, the land evaluation results were used for each LUT (table 7.15) only when they were highly suitable (S1) or moderately suitable (S2). Areas which belong to marginally suitable (S3) or not suitable (N) are not considered because they are not relevant for the land use conflict analysis due to low productivity, thus the planning covers only 6 land mapping units (Hi411, Pi211, Pi311, Pi411, Pu111, Va111). Although land mapping units including Pi511 and Pi521 are highly suitable (S1), were not considered for conversion, for orchards are main crops within these units and can not be converted practically.

8.1.2 Policy priorities and weighting

Two policy priorities set have been distinguished in the study area as follows:

a) Government's policy that is more environment-oriented
b) Farmer's priorities that is more production-oriented

a) Government's policy

Extension of fodder production mainly alfalfa for developing animal husbandry industry (sheep and cattle) is supported by Agricultural Jihad Ministry. Because of this, contraction was made between Agricultural Services Centers and the farmers. The farmers receive inputs including seeds, fertilizers, etc. and also are trained for the new technology and how to come up with in an appropriate way.

b) Farmers' priorities

There is uniform consensus among the farmers about the production-oriented that there are no other rural groups involved. Based on the interviews, made during the field the farmers are interested in chickpea as a cash crop, Alfalfa as a dominant fodder for their animals feed and all kinds of crops for home consumption. In agricultural activities, the farmers are interested in production and income; therefore farmers follow the tradition if they don't obtain the benefit.

Weighting

Determining the weights is not a simple procedure, especially when it comes to assigning reliable quantitative weights. In environment-oriented policy priority, land cover, which is supported by the Government, receives high weight and the other criteria are positioned in lower one.

In production-oriented policy, economic benefit such as gross margin receives high weight and other criteria are put in lower position.

8.2 Comparative assessment of land use alternatives

8.2.1 General

For multi criteria evaluation of the alternatives, DEFINITE, software was carried out, which is a decision support system that has been developed to improve the quality of decision making. If you have a problem to solve, and you can identify alternative solutions, then DEFINITE can weigh up the alternatives and asses the most reasonable.

8.2.2 the successive steps

1) Problem definition stage
2) Multi-Criteria Analysis stage (MCA)
3) Weighting stage
4) Sensitivity analysis stage

1) The Problem definition stage

It results in an effect table, the same as LUP terminology that is called Goal Achievement Matrix, which includes the definition of alternatives (LUT's) and the effects / criteria. Table 8.1 shows the cost of cultivation, gross margin and water requirements of Land Use Types per hectare under S1 condition (highly suitable) in the study area.

It is to be noted that some of the Land Mapping Units have different land suitability classes, thus gross margin has been calculated based on the land suitability class, for instance those Land Use Types which are classified as S2 (moderately suitable) the gross margin is calculated based on 75% of the expected yield.

Table 8.1: Problem definition for assessing the different alternatives

Effects	Cost/Benefit	Unit	LUT1	LUT3	LUT4
Cost	Cost	1000R/ha	2500	1300	1200
Gross margin	Benefit	1000R/ha	8500	4550	2250
Water requirements	Cost	M^3	1400	6000	0

R = Rial 1 US$ = 8000 Rials
LUT1 = Semi mechanized irrigated Alfalfa
LUT3 = Semi mechanized irrigated wheat
LUT4 = Semi mechanized rainfed chickpea

The criteria were applied based on not only the most important natural constraints especially land degradation status but also on economic condition in particular gross margin.

2) The Multi-Criteria Analysis stage

MCA comprises standardization, weights and ranking. Since the measurement units of the criteria are not the same, therefore they cannot be compared. Standardization was made to score the effects and to make them uniform in order to be compared. Maximum method was used for standardization. The standardization scores are determined through dividing the maximum value, that is, score/highest score (table 8.3, figure 8.1 and figure 8.2).

Figure 8.1 and 8.2 illustrate standardization. Original values of the criteria are on the x-axis from 0 to the highest scores and standardized scores are placed on the y-axis.
For the benefit criteria the low original value receives low standardized value and vice versa (figure 8.1) but in cost criteria graph, on the contrary, the low original value gets a high standardize value (figure 8.2).

3) The Weighting stage

In this step DEFINITE can weigh up the alternatives and assess the most reasonable. The use of multi criteria methods requires information on the relative importance of each effect you need to assign weights. It is necessary to assign weights to the effects/criteria before applying the multi criteria method. As it is mentioned, determining the weights is not a simple procedure, in a simple cases, a good decision may be made by intuitively weighting the evidence that has been built up through steps of planning (FAO, 1993). Direct assessment method was selected to specify weights directly.

8.3 Establishment of different land use scenario's

Two main scenarios were distinguished in the study area, thus multi criteria analysis was conducted for the two following scenarios:

1. **Maximum benefit (Sc1)**
   This includes cash crop production (mainly chickpea). In this scenario, economic condition such as gross margin receives priority (high weight). Other criteria are placed in lower position (Effect table no. 8.4).

2. **Conservation scenario (Sc2)**
   This includes fodder production (alfalfa). In this scenario, land cover is the most important criterion, receiving higher weight. Other criteria are placed in lower positions (Effect table 8.5).

For each of the 2 scenario's, the problem definition, the standardization and weighting procedure have been presented for different Land Mapping Units (LMU) in tables as follows:

Table 8.2: The problem definition for Pi211 LMU

Criteria	C/B	Unit	Pi211alf	Pi211chick	Pi211wheat
Cost	**-**	1000R	4,532,500	2,175,600	2,356,900
Gross margin	**+**	1000R	11,557,875	3,060,344	6,187,769
Water requirements	**-**	M^3	2,538,200	0	10,878,000
Land cover	**+**	Ha	1632	1088	1269

C/B: Cost-Benefit
Pi211alf: LUT1 = Semi mechanized irrigated Alfalfa in Pi211 LMU
Pi211LUT3 = Semi mechanized irrigated wheat in Pi211 LMU
Pi211LUT4 = Semi mechanized rainfed chickpea in Pi211 LMU

It is to be noted that the goal of decision support system is to minimize the costs and maximize the benefits, thus it considers minus sign for cost such as water requirement and cost itself, positive sign for benefit criteria such as gross margin and land cover.

As it was mentioned Multi Criteria Analysis includes standardization and weighting method, hence the following tables are presented to show the standardization and weighting scores.

Table 8.3: Standardization results for Pi211 LMU

Criteria	Alternatives		
	Pi211alf	Pi211Chick	Pi211Wheat
Cost	0	0.52	0.48
Gross margin	1	0.26	0.54
Water requirements	0.77	1	0
Land cover	1	0.67	0.78

Table 8.4: Weighting based on maximum economic benefit for Pi211 mapping unit

Criteria	C/B	Unit	Standardization method	Minimum range	Maximum range	Weight
Cost	**-**	1000R	Maximum	0	4,532,500	0.15
Gross margin	**+**	1000R	Maximum	0	11,557,875	**0.50**
Water requirements	**-**	M^3	Maximum	0	10,878,000	0.15
Land cover	**+**	Ha	Maximum	0	1632	0.20

In table 8.4, **Weight** is based on percent; therefore the summation of the total weights should be 1.

Table 8.5: Weighting based on maximum land cover for Pi211 mapping unit

Criteria	C/B	Unit	Standardization method	Minimum range	Maximum range	Weight
Cost	-	1000R	Maximum	0	4,532,500	0.15
Gross margin	+	1000R	Maximum	0	11,557,875	0.20
Water requirements	-	M^3	Maximum	0	10,878,000	0.15
Land cover	+	Ha	Maximum	0	1632	**0.50**

The original tables of DEFINITE were used to present other Land Units including Pi411 and Pu111mapping units (Table 8.6 through 8.13). For the rest of Land Units, as the procedure of Multi Criteria Analysis is the same, therefore it is refused to repeat here, hence they are presented as tables in the appendix 2 as a few examples.
In the meantime Ranking and standardization graphs are illustrated only for one mapping unit as Pi411, as at is mentioned before the whole procedure for the remaining Land Mapping Units to present graphs are the same (figures 8.1 through 8.4).

Table 8.6: Problem definition for Pi411 LMU

	C/B	Unit	Pi411alfa	Pi411chick	Pi411wheat
cost	-	1000R	2112500.00	1014000.00	1098500.00
Gross margin	+	1000R	5386875.00	1901250.00	2883985.00
Water requirements	-	M3	1183000.00	0.00	5070000.00
Land cover	+	ha	761.00	507.00	592.00

Table 8.7: Standardization results for Pi411 LMU

Criteria	Alternatives		
	Pi411alf	Pi411Chick	Pi411Wheat
Cost	0	0.52	0.48
Gross margin	1	0.35	0.54
Water requirements	0.77	1	0
Land cover	1	0.67	0.78

Table 8.8: Weighting based on maximum economic benefit for Pi411LMU

	C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weight
cost	-	1000R	maximum	0.00	2112500.00	0.150
Gross margin	+	1000R	maximum	0.00	5386875.00	0.500
Water requirements	-	M3	maximum	0.00	5070000.00	0.150
Land cover	+	ha	maximum	0.00	761.00	0.200

Table 8.9: Weighting based on maximum land cover for Pi411LMU

	C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weight
cost	−	1000R	maximum	0.00	2112500.00	0.150
Gross margin	+	1000R	maximum	0.00	5386875.00	0.200
Water requirements	−	M3	maximum	0.00	5070000.00	0.150
Land cover	+	ha	maximum	0.00	761.00	0.500

Table 8.10: Problem definition for Pu111 LMU

	C/B	Unit	Pu111alf	Pu111ch	Pu111wh
Cost	−	1000Rials	525000.00	252000.00	273000.00
Gross margin	+	1000Rials	1785000.00	472500.00	955500.00
Water requirements	−	M3	294000.00	0.00	1260000.00
Land cover	+	Ha	189.00	126.00	147.00

Table 8.11: Standardization results for Pu111 LMU

Criteria	Alternatives		
	Pi211alf	Pi211Chick	Pi211Wheat
Cost	0	0.52	0.48
Gross margin	1	0.26	0.54
Water requirements	0.77	1	0
Land cover	1	0.67	0.78

Table 8.12: Weighting based on maximum economic benefit for Pu111 LMU

	C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weight
Cost	−	1000Rials	maximum	0.00	525000.00	0.250
Gross margin	+	1000Rials	maximum	0.00	1785000.00	0.150
Water requirements	−	M3	maximum	0.00	1260000.00	0.450
Land cover	+	Ha	maximum	0.00	189.00	0.150

Table 8.13: Weighting based on maximum land cover for Pu111 LMU

	C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weight
Cost	-	1000Rials	maximum	0.00	525000.00	0.250
Gross margin	+	1000Rials	maximum	0.00	1785000.00	0.100
Water requirements	-	M3	maximum	0.00	1260000.00	0.450
Land cover	+	Ha	maximum	0.00	189.00	0.200

After the weighting procedure was done, the preferred LUT were realized for each land-mapping units, with the ranking of the alternatives in two scenarios (table 8.14 and 8.15). Priority rank of the alternatives is also illustrated graphically in figures 8.3 and 8.4.

Table 8.14: Ranking procedure of alternatives priority

Scenario	Hi411	Pi211	Pi311	Pi411	Pu111	Va111
Sc1	**Ch**=0.74	**Alf**=0.82	**Alf**=0.82	**Alf**=0.82	**Ch**=0.72	**Alf**=0.82
	Alf=0.68	Wh=0.50	Ch=0.54	Ch=0.54	Alf=0.65	Wh=0.50
	Wh=0.29	Ch=0.49	Wh=0.50	Wh=0.50	Wh=0.32	Ch=0.49
Sc2	**Ch**=0.75	**Alf**=0.82	**Alf**=0.82	**Alf**=0.82	**Ch**=0.74	**Alf**=0.82
	Alf=0.73	Ch=0.61	Ch=0.63	Ch=0.63	Alf=0.65	Ch=0.61
	Wh=0.31	Wh=0.57	Wh=0.57	Wh=0.57	Wh=0.33	Wh=0.57

Alf= LUT1 (Semi mechanized irrigated Alfalfa), **Ch**= LUT4 (Semi mechanized rainfed chickpea), **Wh**= LUT3 (Semi mechanized irrigated wheat).

Table 8.15: Priority of land use types

LMU	Scenarios	
	Sc1	**Sc2**
Hi411	Chickpea	Chickpea
Pi211	Alfalfa	Alfalfa
Pi311	Alfalfa	Alfalfa
Pi411	Alfalfa	Alfalfa
Pu111	Chickpea	Chickpea
Va111	Alfalfa	Alfalfa

- **Sc1**: Maximum benefit
- **Sc2**: Conservation scenario

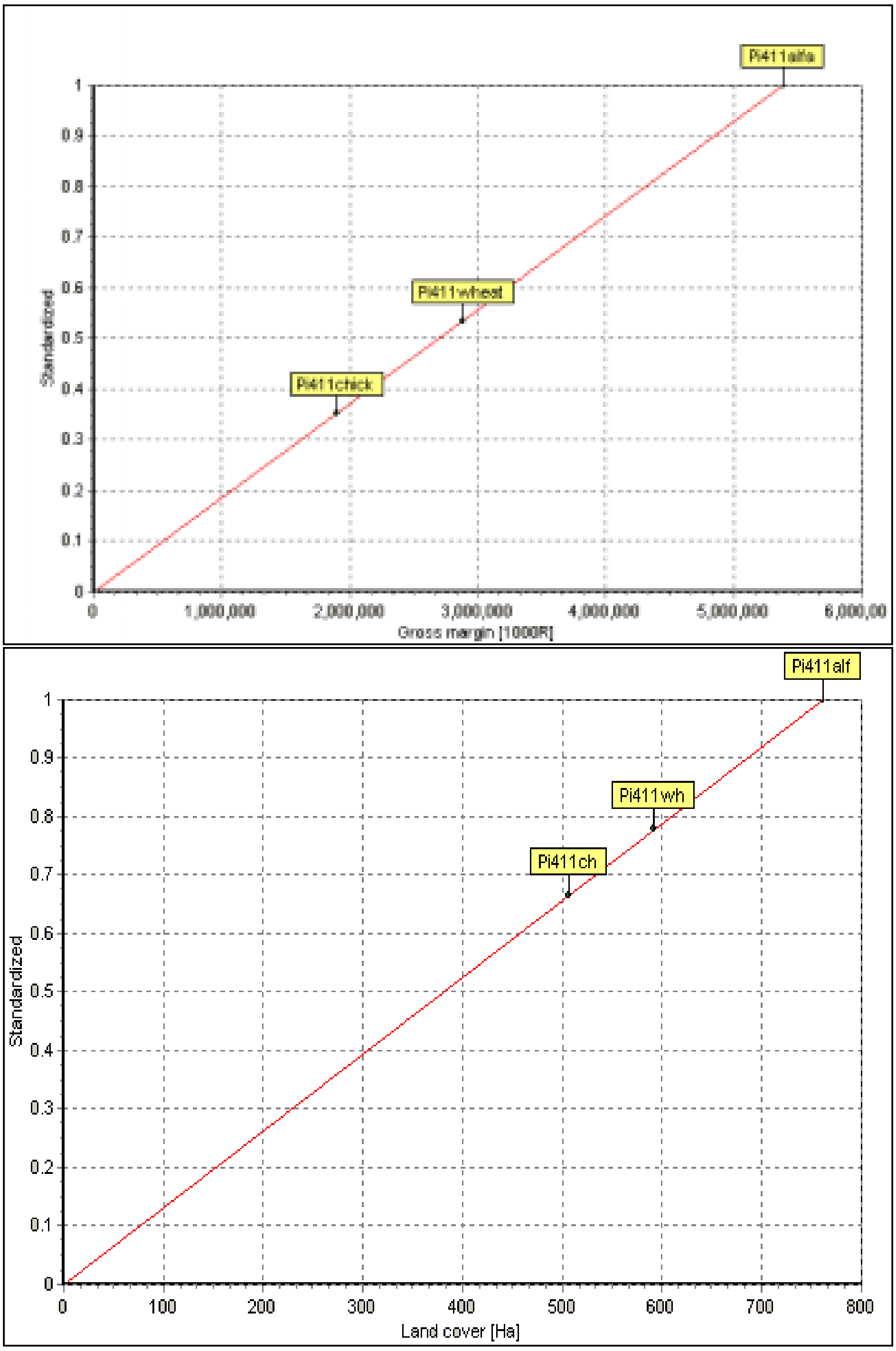


Figure 8.1: Standardization graph for two benefit criteria

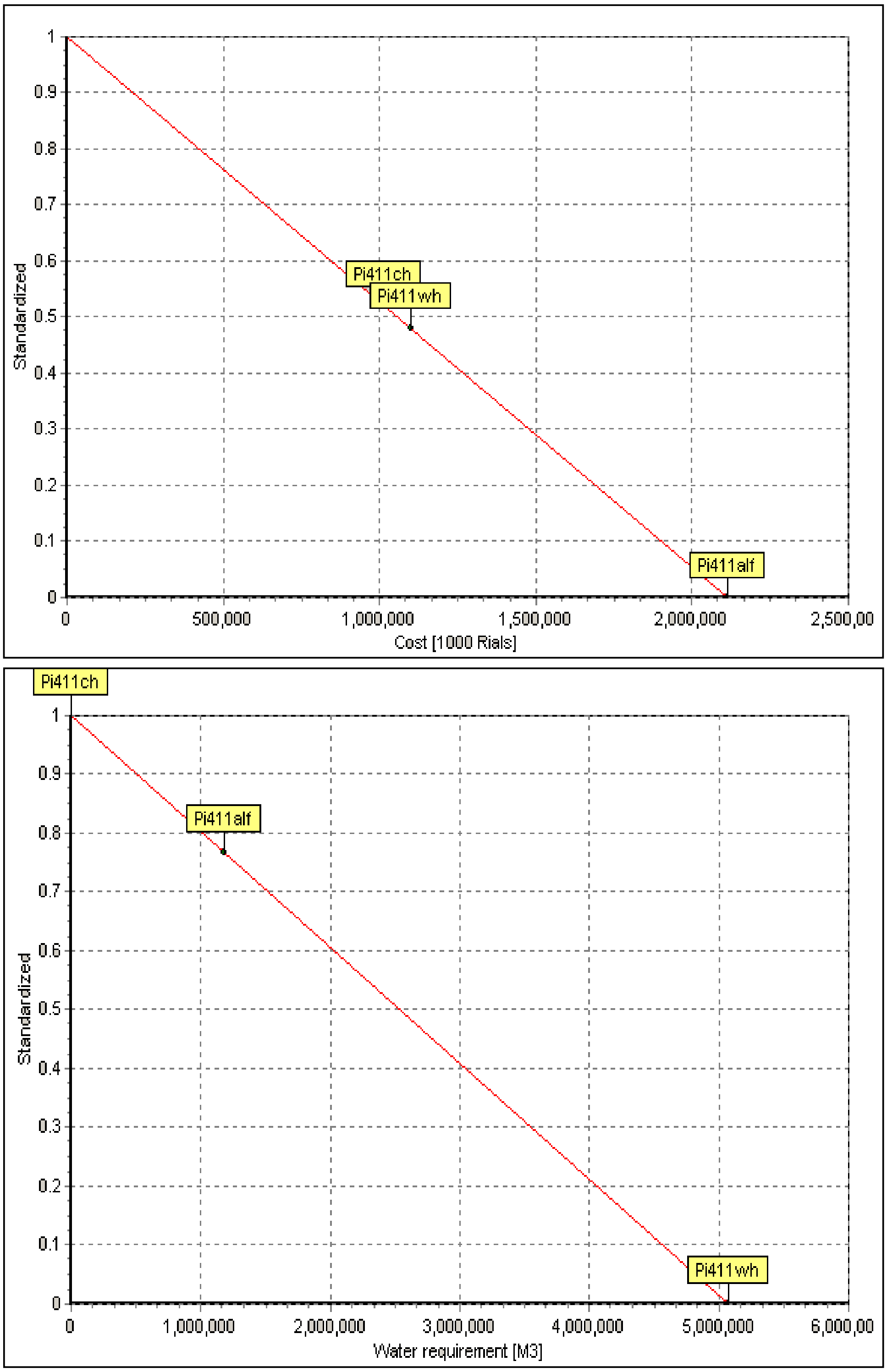


Figure 8.2: Standardization graph for two cost criteria

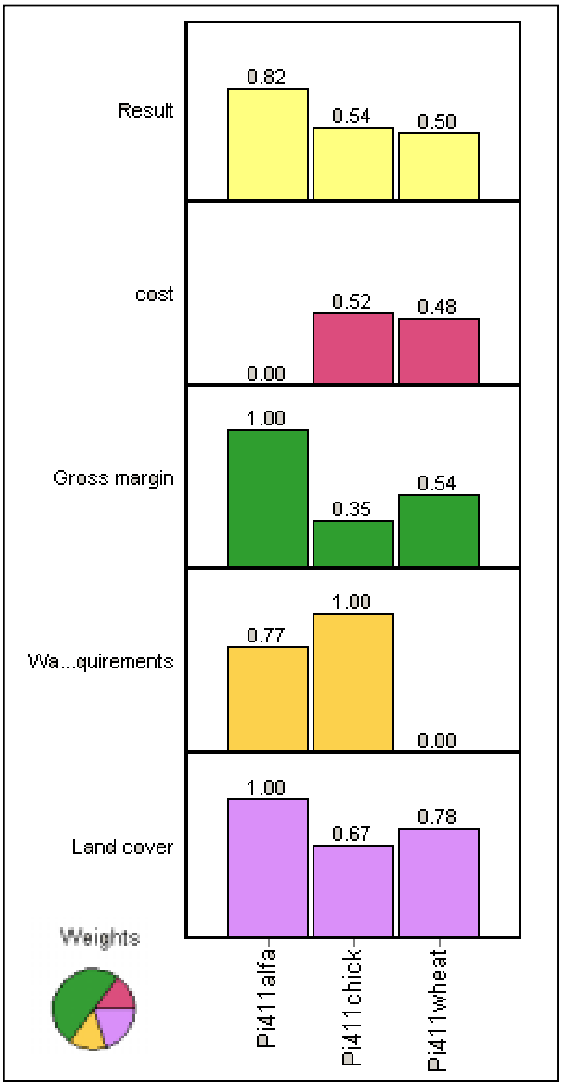


Figure 8.3: Priority rank of alternatives Considering maximum benefit Scenario For Pi411 mapping unit

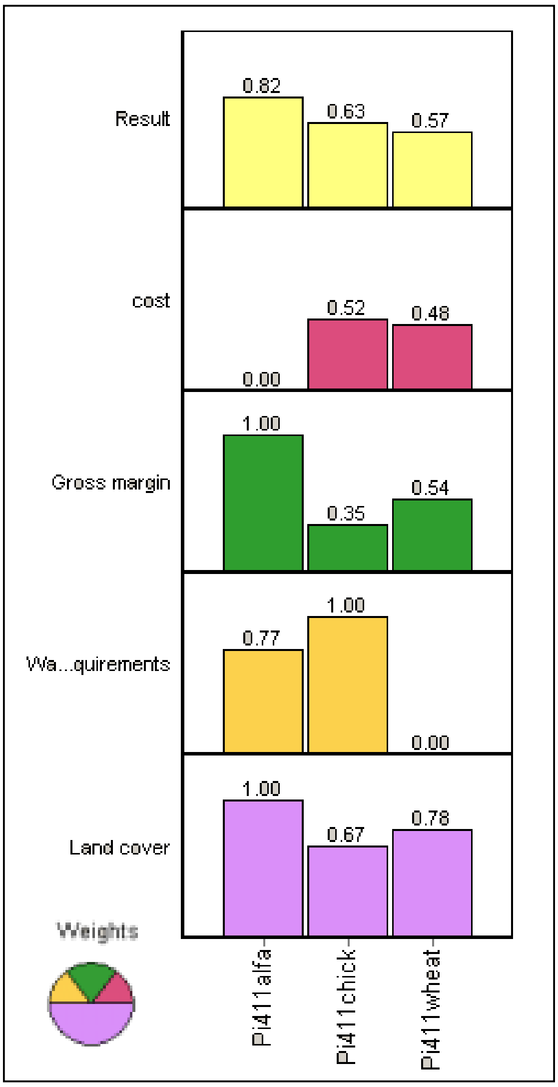


Figure 8.4: Priority rank of alternatives Considering conservation Scenario for Pi411 mapping unit

As it is shown in figure 8.3 the first priority belongs to alfalfa, the second belongs to chickpea and the third priority belongs to wheat in maximum economic benefit scenario. In the other scenario, which is conservation scenario, alfalfa is placed in the first priority; chickpea and wheat are positioned in the second and third priorities respectively (figure 8.4).

4) Sensitivity analysis

This step determines the sensitivity of a ranking for a selected score or weight. This procedure also determines a combination of weights; most similar to the original combination of weights that changes the rank order of two alternatives. Sensitivity of the ranking presents a graphic of all available rankings. These rankings are made using multi criteria method or cost benefit analysis and are presented as a graph. Sensitivity of ranking is shown for two selected weights in table 8.16, any change in weight of gross margin, will affect the change of priorities. Any change in water requirement weight also may change the priority ranking of the alternatives. Sensitivity of multi criteria evaluation is illustrated in figures 8.5 and 8.6 as a few examples for two criteria. The vertical line shows the value of the original weight, that is, 0.5 for gross margin and 0.15 for water requirements. The y-axis shows the scores of the alternatives. In these figures there are one possibility of reversal point that can cause a new priority for the alternatives (table 8.16).

Table 8.16: Sensitivity of possible ranking for two selected effects

Criteria	Original_w.	Priority	Possible changes of reversal points	
Gross margin	0.5	Alfalfa	0.1	Chickpea
		Chickpea		Alfalfa
		Wheat		Wheat
Water requirements	0.15	Alfalfa	0.61	Chickpea
		Chickpea		Alfalfa
		Wheat		Wheat

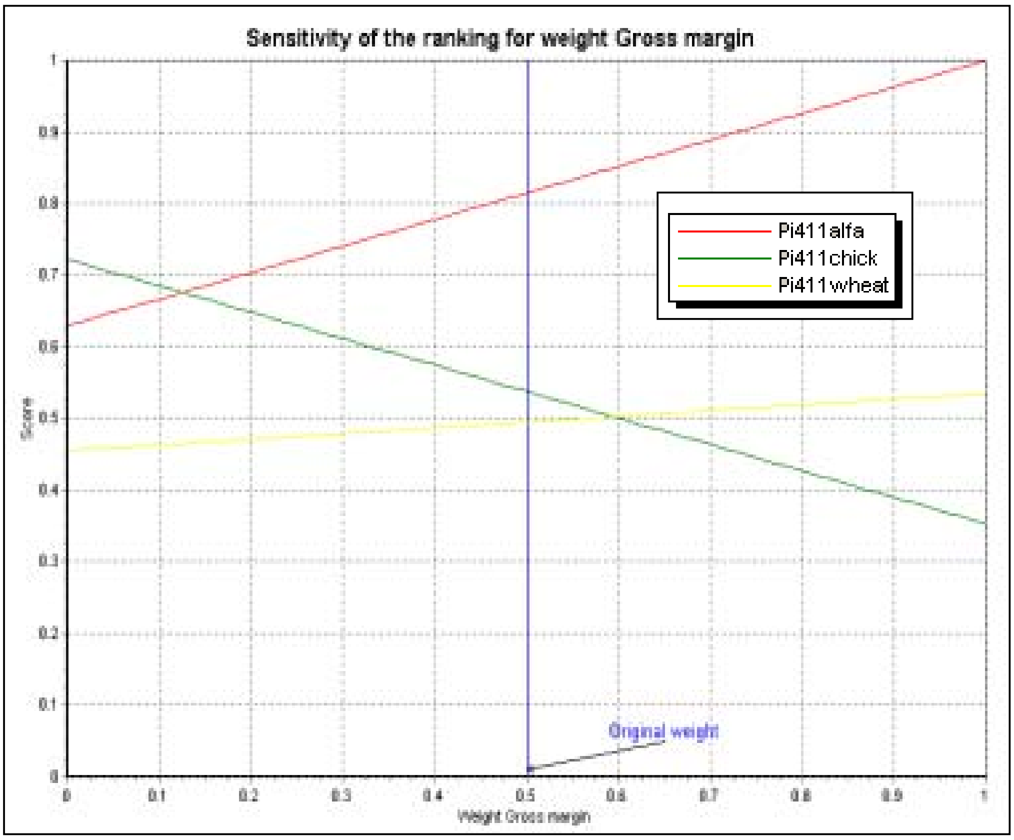


Figure 8.5: Sensitivity of the ranking for weight gross margin (Pi41 LMU)

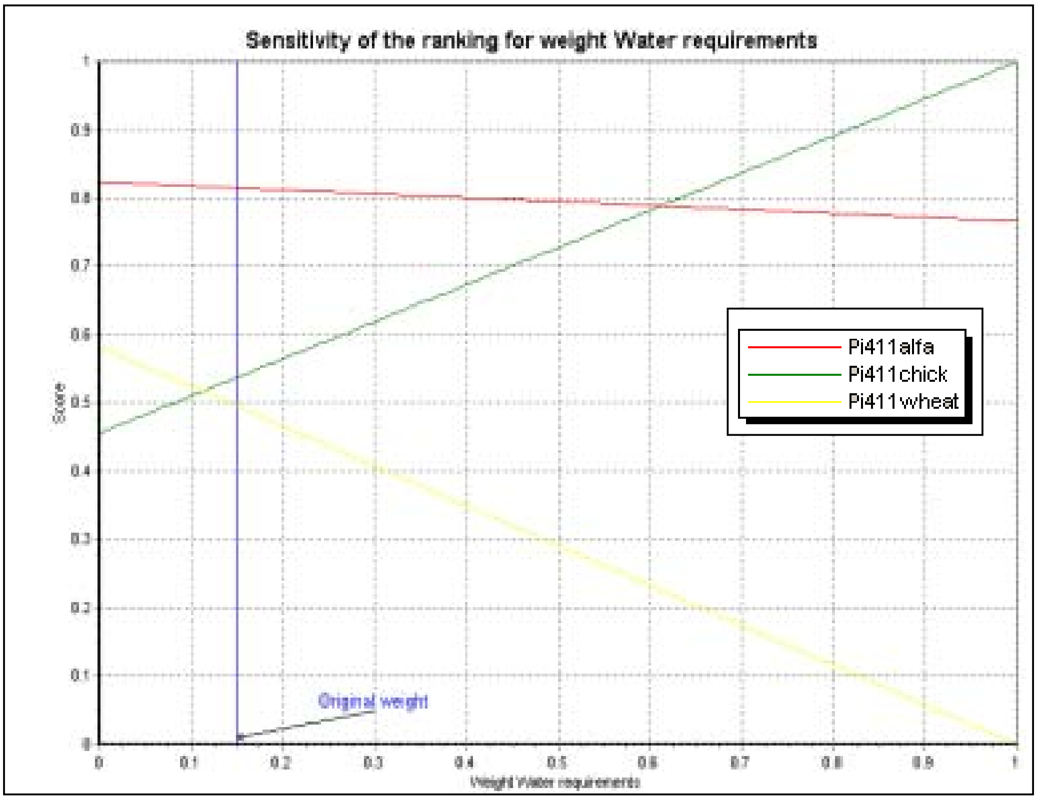


Figure 8.6: Sensitivity of the ranking for weight water requirement s (Pi41 LMU)

8.4. Conclusion and discussion

In order to realize whether the total yield of alfalfa is enough or not for livestock population, the total demand of livestock population and supply of alfalfa should be known. According to Agricultural Services Center the area that supplies alfalfa covers 1500 ha for the time being in the study area. Therefore total yield of alfalfa is about 9,000,000 kg. Total demands are shown in Table 8.17, which presents population, duration and the total need for alfalfa in the study area. It is to be noted that sheep and goat start to graze in the rangeland from May to December, so it takes about 7 months, meaning that they need to be nourished in traditional husbandry units for 150 days, however the cattle need to be nourished inside for the whole year (table 8.17).

Table 8.17: Demands for alfalfa in the study area

Livestock	Alfalfa (kg/day)	Population (heads)	Duration No. Days/year	Total need
Sheep	1.8	23,860	150	6,442,200
Goat	1.08	736	150	119,232
Cattle	7.2	3727	365	9,794,556

Through comparing total demands and supplies it will be conceived that there is more than 7,355,988 kg shortage of fodder in the study area, thus two scenarios were defined to compensate the shortage of fodder (alfalfa).
The data analysis which were done, show that the results of two scenarios seem to be more satisfactory and suitable, therefore the total area under each scenario and the total production of each crop were calculated (table 8.18).

Table 8.18: Preference crops based on sc1 and sc2

Crops	Area (ha)	Yield (kg/ha)	Total yield (kg)
Alfalfa	3,830	6000	22,980,000
Chickpea	537	500	268,500

As it is shown in table (8.18), the amount of fodder production is 22,980,000 kg. In comparison with total demands for alfalfa, which is 16,355,988 kg (table 8.17), it can be concluded that total yield which is supplied using defined scenarios is more than enough for the livestock population in the study area. Thus another scenario can be defined, so the area allocated to alfalfa in Va111 Land Mapping Unit can be replaced by wheat, which is a main crop in the study area.
The Land Mapping Units for the third scenario (Sc3), called compromise scenario are presented in table 8.19. The total area under each crop and total yield are calculated (table 8.20).

Table 8.19: LMU allocated to Sc3

LMU	Sc3
Hi411	Chickpea
Pi211	Alfalfa
Pi311	Alfalfa
Pi411	Alfalfa
Pu111	Chickpea
Va111	**Wheat**

Table 8.20: Preference crops for Sc3

Crops	Area (ha)	Yield (kg/ha)	Total yield (kg)
Alfalfa	3347	6000	20,082,000
Chickpea	537	500	268,500

9 CONCLUSION AND RECOMMENDATION

Soils

The effect of the soil forming factors on soil development and the relationship between geomorphology and soils were clear. The data obtained from soil survey indicates that except for the shallow soils of the mountains and some places of Piedmont (Pi111) with high amounts of gravels, there are not other soil-related limiting factors. Soils are generally calcareous, well-drained, non-alkaline and non-saline, with moderate to heavy texture, and organic matter of about 1%.
The information needed to carry out a land evaluation for Land Use Planning can mainly be extracted from the geopedologic map to which some information including land use, slope and agroclimatic conditions are added.

Landuse

Since ETM image was in July, which is at the time of growing crops, thus the problem of distinguishing between dry land farming and rangelands would occur. Therefore it was difficult to differentiate rangeland from rainfed crops. Classification of mixed pixels remains a problem, especially in a country like Iran where the problem of land tenure is not yet fully solved. Another serious problem is the converted rangelands into cultivated lands, which are left behind after a couple of years and used again as poor rangelands. Comparing past and the present landuse maps showed that rainfed and rangelands have been changed enormously. As it was mentioned earlier 70% of the total area in previous land use (1956) included rangelands whereas the total surface area of rangelands has been decreased to almost 55% in present landuse. It can be concluded that the converting rangelands trends to rainfed crops can be seen during previous landuse to the present landusr, which is a serious problem in the study area.
Remote Sensing data was also used to calculate rangelands capacity, which is based on the total number of sheep and goat grazing the area under natural vegetation. It was concluded that about 5000 heads of sheep and goats could graze the existing pasture.

Land evaluation

Land evaluation results can be summarized as follows:
Mountain landscape is unsuitable for the LUT’s due to limiting factors such as soil workability, rooting condition and erosion hazards.
Hilland landscape is dominantly unsuitable for agriculture LUT’s due to the same limiting factor of Mountain landscape except Glacis, which has different suitabilities for different LUT’s.
Piedmont landscape is the most suitable for different LUT’s however Pi111 mapping unit is marginally suitable due to high amount of gravels and stones.
Valley landscape is moderately suitable for different LUT’s because of the limitation of flooding hazard.

Land Use Planning

Taking into consideration that the total supply of fodder (alfalfa) does not satisfy the total demand of the study area for the livestock, hence two scenarios were defined to compensate the existing shortage of fodder using DEFINITE software. Since the total yield of alfalfa of two defined scenarios was more than enough for the livestock population, therefore another scenario was suggested, so, in spite of alfalfa and chickpea, the area can be covered by wheat, which is a major crop of the study area.
With application of the suggested scenario, total fodder (alfalfa) in the study area is about 20,082,000kg, which is enough for the total number of cattle, sheep and goats grazing in the study area.

Recommendation

In order to reach agricultural sustainability, the following suggestions are recommended:
- Rainfed agriculture should not be practiced on sloping areas and in place of poor rangelands.
- An appropriate plan to increase the fodder production and the economic income would reduce the pressure on the rangeland.
- Design a plan for increasing yield per hectare, reduce the pressure on land and consequently reduce degradation with improving the economic situation.
- To develop soil aggregate and reduce the bulk density, animal manure must be applied, especially in fine textured soils.

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