A planning support system for rangeland allocation in Iran

Case of Chadegan sub-region

Promotor: Prof. dr. ir. H. van Keulen
Hoogleraar bij de leerstoelgroep Plantaardige productiesystemen

Co-promotor: Prof. dr. A.M. Sharifi
Associate professor Decision Support Systems and Land Us
Planning Social Sciences Division
International Institute of Geoinformation Science and Earth Observation, ITC Enschede

Samenstelling promotiecommissie:
Prof. dr. ir. J. Bouma (Wageningen Universiteit)
Prof. dr. W. H. van den Toorn (ITC)
Dr. ir. H. Udo (Wageningen Universiteit)
Dr. N. de Ridder (Wageningen Universiteit)

A planning support system for rangeland allocation in Iran

Case of Chadegan sub-region

Mehdi Farahpour

Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
Prof. dr. ir. L. Speelman
in het openbaar te verdedigen
op vrijdag 19 april 2002
des namiddags te half twee in de Aula

Mehdi Farahpour (2002)

A Planning Support System for Rangeland Allocation in Iran
Case of Chadegan sub-region
Farahpour, M. – [S.L.: s.n.]. Ill.
PhD Thesis Wageningen University. – With ref. –
With summaries in English and Dutch
ISBN: 90-5808-629-1
Subject headings: multi-criteria decision support, IMGLP

Propositions

1- In the current practise of Iranian range management, much technical and socio-economic information is collected but not used in management decisions (this thesis).
2- Rangeland systems as any other natural resource systems are in constant state of change and evolutions, with socio-economic and ecological impacts (this thesis).
3- Good management and effective decision-making process should be supported by planning/decision support systems that is based on the application of existing knowledge, and supports analysis of the existing information to understand the behaviour of the systems and assess the impacts of different actions (this thesis).
4- Planning Support Systems should be based on the existing information and knowledge, should support, resource analysis, policy/plan formulation, impact assessment, and multiple criteria evaluation of evaluation of various policy/plans (this thesis).
5- Land ownership does not make sense, if the right of trading is not granted to the landowners (this thesis).
6- For poor people sustainable range management is a remote target. Design of alternative land use systems should shorten the distance (this thesis).
7- It is very tempting to do research behind a computer, but it is important to find out exactly what happens in the field (Louise Fresco, FAO Assistant Director-General for Agriculture).
8- New technology can help us hold back the desert. But land degradation is also a people problem, and people must be part of the solution (http://www.fao.org/news/2002/020205-e.htm).
9- The potential for utilizing the world's supply of poor quality roughage cannot be gauged merely from its total production; it depends much more on the opportunities for creating situations in which ample supplies of roughage coincide with supplies of suitable supplementary feeds and with possibilities for efficient management (http://www.fao.org/DOCREP/003/X6503E/X6503E00.HTM).

Propositions belonging to the PhD thesis of Mehdi Farahpour, A Planning Support System for Rangeland Allocation in Iran. Case of Chadegan sub-region. Wageningen, April 2002.

Abstract

Farahpoor M., 2002. A planning support system for rangeland allocation in Iran. Case of Chadegan sub-region. PhD Thesis, Wageningen University, The Netherlands, 180 pp., with English and Dutch summaries.

Rangelands, like other natural resources are subject to many changes. In Iran, one of the changes is the land tenure reform, that may have significant effects on both the land and the land user. Land tenure changes not only affect the life of the present, but also that of next generations, and involve very complex decision-making. This decision should lead to a sustainable use of the land and contribute to the livelihood of the present and future generations. In this context, a planning support system has been developed for rangeland allocation in Iran to support its rangeland tenure reform. The system consists of three modules: land evaluation module, district planning module and local planning module.

The land evaluation module works in a GIS environment and uses the FAO methodology for land evaluation. It is mainly based on biophysical characteristics of the land use system. However, socio-economic factors, in terms of the effect of human intervention on the current status of the land, have also been taken into account.

The district planning module comprises three sub-modules: the planning sub-module, the grazing sub-module and the multicriteria evaluation (MCE) sub-module. The planning sub-module is an optimisation model that allows examination of the degree of realisation of the various objectives of stakeholders, and generates alternative solutions. For each alternative, the grazing capacity of the land is assessed through the grazing sub-module, which translates the forage production into grazing capacity. The MCE module ranks all alternatives, taking into account their advantages and disadvantages, and provides a platform for decision makers to judge the trade-offs between alternatives and supports rational decision-making. This leads to a land use pattern, in line with the existing government policies and satisfying the needs and desires of the population in the district.

The local planning module also comprises three sub-modules: Land allocation, economic enterprise and land improvement. The land allocation sub-module transforms the district land use pattern into a local land use plan. The economic enterprise sub-module determines the appropriate size of the land holding for each household on each land mapping unit. Finally, the land improvement sub-module provides information on the status and impact of the programme at each specified point in time and space.

Keywords: land evaluation; FAO; planning support; multi-criteria decision making; multi-objective optimisation; IMGLP; extensive grazing; rainfed agriculture; participatory planning

Acknowledgement

This study would never have materialized without the help and support of many individuals and organizations to whom I have the honor of expressing my appreciation and gratitude. I will never forget the help and support of my promotor, professor H. van Keulen, my co-promotor Dr. M.A. Sharifi and my supervisor Dr. M. Basiri.

What I learned from Dr. M.A. Sharifi was far beyond my imagination and for that I greatly owe him. Words are not enough to express my gratitude to him, for his keen interest in the subject and his unfailing willingness to support me and engage in discussions that have added to the quality of the study. His many lessons not only enriched my professional career, but also my personal life. I feel the way in which he treated me as I felt characterized by endless hospitality and brotherhood. I thank God, who put him on my path and let me enjoy the pleasure and honor of working under his supervision.

I am also gratefully indebted to professor Herman van Keulen, whose scientific knowledge and experience in the field of land use planning and modeling are well known. I take great pleasure in thanking him for his invaluable guidance and his patience in coaching and supervising me. His scientific support, constructive comments and the time he has spent on successive revisions of the manuscript are only some of his many elegant characteristics. I learned very much from him and I wish him continued success in his personal and scientific life.

Dr. Basiri, has taught me a lot in field of range management. He came to the field many times and showed me the way problems of range tenure could be dealt with. I owe him a lot for all he has done for me during the study.

This study was conducted under the auspices and with a scholarship of the Ministry of Jihad-e-Sazandegi. First, I would like to express my gratitude to Mr. T. Amanpoor, the ex-deputy minister of Jihad, for providing me with the opportunity to engage in the study. Among many other friends within the Ministry, I would like to thank especially Mr. Rajabbigi and Mr. Meissami for their support and assistance. The study was conducted with full co-operation of many colleagues in the Esfahan Research Center for Animal Science and Natural Resources, I take this opportunity to thank them all, but specially Mr. Marandi, Mr. Shams, Mr. Aghaei and Mr. Akhbari.

The thesis has been published by the Research Institute of Forests and Rangelands. I would like to thank Dr. A. Jalili, Director and Dr. A. Ghamarizare, Head of the Office of Education of the Institute for their positive attitude and support. I also thank Mr. A.R. Mosavi, my colleague who helped me in reviewing the text.

In the course of the study, I spent various time periods at ITC, the International Institute for Geo-information Science and Earth Observation in Enschede, the Netherlands, where I have profited from the support and guidance offered by many of its scientific and administrative staff members. Especially, I want to express my gratitude for the scientific support of professor W. van den Toorn and the administrative support of Ms. B. Geerdink, Ms. Carla Gerritsen and Mr. G.H. Leppink.

Finally, I would like to thank my family members for their patience, help and support. They have had to cope during the periods of my absence. All of my domestic obligations during those days were put on the shoulders of my wife. I thank her very much for all she did to run the family affairs as well as she did.

To my wife

For Hengameh, Hamed and Hoda

Contents

List of figures

List of tables

1 General introduction

1.1 *Importance of the rangelands*

Although Iran is the second largest country in the Middle East, limited natural resources, particularly fertile soil and water restrict the possibilities for expansion and/or intensification of arable farming (Sheidaei & Nemati, 1978). Extensive animal husbandry, on the other hand, including nomadic, transhumant and sedentary forms, is widespread over the rangelands of the country. Rangelands and animal husbandry have been of great importance in Iran for a very long time, as witnessed by the teachings of Zoroaster[1] (Bavari, 1980; Seraj, 1970). More recently, many people have died in defense of their rangelands, even after land nationalization, and when only the right of use was at stake (Alimolaei, 1984). The degree of importance attached to rangeland in a particular situation, is the reflection of its productivity, land scarcity and the availability of alternative sources of income.

In Iran, as in other parts of the world, animal husbandry is the most productive use of the semi-arid zones bordering the desert (Reed & Berk, 1995; Breman & de Wit, 1983). As Niknam and Kyne (cited by Sheidaei & Nemati, 1970) have calculated, 80 to 90% of the livestock production of Iran, equal to 168,000 to 180,000 ton y^{-1} of meat (M.P.B, 1998), is associated with the rangelands. Annual dry matter production of rangelands is estimated at more than ten million tons (Fazilati & Eraghi, 1984). In addition to forage production, mining, fuel wood collection, industrial use of rangeland by-products, e.g. medicinal plants and recreation are other functions of the rangelands in Iran (Kardavani, 1995).

Estimates of the total rangeland area are not consistent, e.g. there is a very wide gap between the ten million hectares of Bavari (1980) and the one hundred and six million of Sheidaei & Nemati (1978). This difference, by an order of magnitude, is most likely due to inconsistent and vague definitions of the term rangeland (see Chapter 2). Probably, the first reliable estimate of the area of rangelands (one hundred million hectares) is the work of Niknam (cited by Sheidaei & Nemati, 1970), in which a map of Iran's rangelands was prepared on the basis of the definition given in the Forest and Rangeland Utilization Act in 1967.

[1] An ancient prophet of Iran, living around 660 B.C. (Le petit Larousse, 1996. Dictionnaire Encyclopèdique Larousse, France).

For the first time in 1974, satellite images were used by an American company, FMC, leading to an estimate of Iran's rangelands of 90 million hectares (Fazilati & Eraghi, 1984). In addition to fallow lands, i.e. abandoned crop land, rangelands include lands located on mountains, hillsides or plains covered by natural vegetation during the grazing season and traditionally recognized as range (M.P.B., 1998). Of the 90 million hectares, covered by this definition, 43 million hectare have been classified in poor, 37 million in fair and 10 million in good condition (M.P.B., 1998).

1.2 Animal husbandry systems in Iran

Nomadic animal husbandry

Nomadism is defined as: A type of pastoralism in which livestock owners follow the irregularities of the weather, in search of drinking water and pasture for their herds and flocks (FAO, 1991). Such animal husbandry systems have typically developed in regions with seasonal rainfall, i.e. arid and semi-arid regions. The vegetation density of semi-arid and arid rangelands is low, and the temporal and spatial variability in forage supply and quality is enormous. These large fluctuations, combined with periodic lack of drinking water and very high temperatures, force the herdsmen to continuously move with their herds. Nomads generally, do not own any specific area, they live at subsistence level and their products are mostly absorbed by the family, so that their contribution to the meat or other animal product market is small (De Ridder et al., 1982). This type of animal husbandry is rare in Iran, though it is practiced by a small group of people referred to in Farsi as "Koly".

Transhumant animal husbandry

Transhumance is defined as: A type of pastoralism in which pastoralists regularly graze their herds in two or more geographically separated grazing orbits within a year (FAO, 1991). This animal husbandry system takes advantage of the temporal and spatial variability associated with typically alternating rainy and dry seasons. In Iran, annual migrations take place from mountainous cold rangelands towards the warmer plains at the beginning of fall, with the reverse movement in spring, when temperatures increase. In the Iranian system of transhumant animal husbandry, two range sites are allocated to a family, one in the cold and the other in the warm region, the route between the two sites is fixed, and the right of grazing of available forage along this route is recognized by the local farmers and tribes. Transhumant animal husbandry is practiced in Iran predominantly in the Zagross Mountains. Pastoralist households of several tribes, e.g. "Chahar Lang e Bakhtiyari" or "Haft Lang e Bakhtiyari" move between the cold regions located in the East and Northeast of the mountains and the warmer region in the South and Southwest. Most commonly, households move with their herd, however settled families may hire a herdsman or entrust their animals to other members of the tribe. For security reasons, members of a tribe used to move together, however, with the improvement in infrastructure and means of transport, single family migration is developing. Research in the Zagross region has shown that 84% of the households migrate in family groups consisting of 45 members at maximum (Bagheri, 1994). The government owns the land, the pastoralists however, are granted the usufructuary[2] grazing rights on both sides of the mountains. To avoid conflicts, a grazing usufruct (or Grazing Licence) is usually issued for the same land that was used by the family's ancestors. In this system of animal husbandry, the total stock comprises on average 48% sheep, 47% goats, 3% cattle and 2% draught animals, such as donkeys and horses (Bagheri, 1994).

Sedentary animal husbandry

Sedentary animal husbandry, a common system in Iran, is mostly practiced by arable farmers in a system of mixed farming, with animals in support of arable farming. Herds are taken out from the village to adjacent communal rangelands in the summer grazing season. Crop residues, weeds, wheat and barley stubble are other sources of animal feed in this system. A herd usually comprises goats and sheep, while this system as a whole consist of 35% sheep, 58% goats, 5% cattle and 2% donkeys and horses (Bagheri, 1994) . Cattle, when present, are rather kept on the farms or graze on the plains adjacent to the village, as they cannot move very far from the village, because of the topography of the rangelands and because they have to be milked regularly. Meat is the main output of the system and milk directly or in processed forms is mainly consumed by the household. Manure is used for the farms and usage of draught animal is gradually replaced by machines and tractors. Herds are grazing the rangelands in one of the following forms:

- Households, owning small numbers of animals combine them to form a herd kept by a herdsman. Each household contributes to the salary of the herdsman in proportion to its number of animals. There is no individual grazing right for the households.

[2] The right to use the resource of an area; for example the grazing, drinking water, access routes and fuel-wood, without an ownership title to the land (FAO, 1991).

- For households owning bigger herds, that should graze individually, the size of the herd is used as criterion for identification of the grazing right period of a household (Bagheri, 1994).

1.3 Floristic regions of Iran

In terms of vegetation composition, the following regions can be distinguished in Iran (Mobayen & Tregubov, 1970; Figure 1.1):

The Hircanian region, comprising the area from the Caspian coast to the northern slopes of the Alborz Mountains. Annual rainfall varies between 600 and 2000 mm, minimum precipitation is in June and maximum in October-November. There is no distinct dry season. The vegetation type of areas between sea level and 1000 m altitude is characterized by *Quercus castaneaefolia,* from 1000 to 2000 m by *Carpinus betulus* and *Fagus orientalis*, and from 2000 to 2700 m by *Quercus macranthera.*

The Iran-o-Touranian region, comprising the entire centre of Iran with boundaries extending from Azerbayejan to Zahedan and from Khorassan to the Zagross region. It is further sub-divided in (Sheidaei & Nemati, 1978): semi-desert characterized by *Halocnemum strobilaceum, Seidlitzia rosmarinus* and *Artemisia sieberi,* steppe in which *Artemisia sieberi* and *Stipa barbata* are dominant species, semi-steppe characterized by *Astragalus spp.* and *Bromus tomentellus,* dry forest dominated by *Quercus persica, Pistacia atlantica, Crataegus spp.* and *Amygdalus spp.* and elevated mountains with *Onobrychis cornuta, Acantholimon spp., Astragalus adscendens* and *Ferula ovina*. Annual rainfall ranges from 40 to 500 mm and is seasonal, with a distinct dry season varying from 5 to 9 months in length, starting in mid-spring (May) and extending till mid-winter (December).

The Zagross region, encompassing the Zagross Mountains in western Iran. This region comprises semi-steppe to elevated mountains of the Iran-o-Touranian region and the study area is located in this region. Annual rainfall varies between 200 and 500 mm, however in elevated zones, it may exceed 1000 mm (Karimi, 1987). Minimum precipitation occurs in August and maximum in February. Temperature variation is very large, e.g. in July it may go up to 33 °C and in December it may drop to -30 °C. The vegetation in this region is very diverse. As an illustration, the list of woody plants comprises 191 trees and bushes (Javanshir, 1976).

The Khalidj-o-Ommanian region, comprising all of the southern coastal area of Iran, is sub-divided in two parts, Khalidjian and Ommanian. The most striking feature of this region is warm and humid weather from March to December. Annual precipitation ranges from 100 to 300 mm. This region is characterized by *Acacia arabica, Acacia nubica, Ziziphus spina-chirsti* and *Prosopis spicigera.*

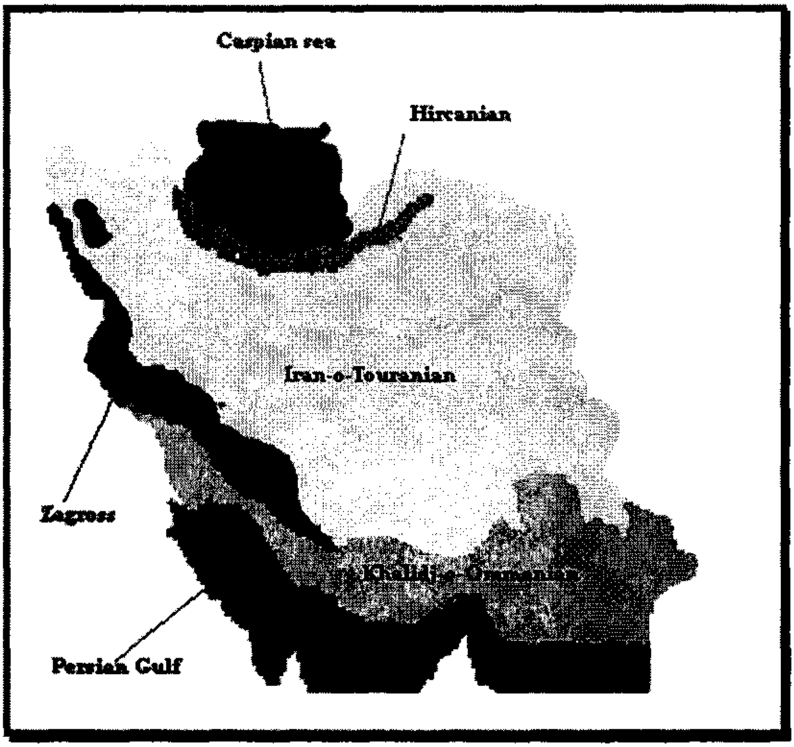


Figure 1.1 Floristic map of Iran (Source: Javanshir, 1976).

1.4 Rangeland problems in Iran

Schematically, two types of problems can be distinguished: biophysical and socio-economic.

1.4.1 Biophysical problems

A large part of Iran is located in the arid and semi-arid region, where, by any criterion, low and erratic rainfall is the most outstanding characteristic of the land (van Keulen, 1975). Average annual rainfall in the arid part of the country is as low as 40 mm, and in the semi-arid regions and elevated mountains up to 1600 mm (Karimi, 1987). Since the climate is Mediterranean, annual precipitation is concentrated in winter. In terms of availability of water to the vegetation, in addition to the amount of rainfall, distribution is of prime importance (de Wit & Seligman 1992; van Keulen, 1975). Very often, in the growing season (late April to late June), when temperatures are favorable for plant growth, rainfall is insufficient to provide the required moisture. Maintenance of perennials, that form part of the climax vegetation, has been emphasized in Zagross range improvement programs, while annuals, because of their low productivity and very strong annual yield fluctuations, have received relatively little attention. Regrowth of perennial plants starts during March – April, and flowering between April and May. Short growing periods, associated with late onset or early cessation of rains, may prevent perennials from completing their annual life cycle, which leads to gradual depletion of their carbohydrate reserves and the associated loss of vigour (Cissé & Breman, 1980). Under a rather heavy grazing regime, these species can therefore easily disappear from the vegetation.

1.4.2 Socio-economic problems

Annual population growth in Iran averaged 3.1% over the period 1980-1994 and is now estimated at 2.1%. As a consequence of population growth of the pastoralists, which even exceeded the national average, rangelands have to support increasing numbers of users. As a consequence, alternative land use systems, such as dryland farming, are practiced by households as a way toward land ownership (Fazilati & Eraghi, 1984).

Dryland farming

Cereal dryland farming, involving repetitive plowing, is a most destructive practice on rangelands: Natural vegetation vanishes and fertile surface soil is subject to erosion and may wash away. In addition to the action itself, the prevailing method of cultivation, whereby furrows are made parallel to the slope aspect, aggravates the situation. Expansion of dryland farming is strongly related to the cultural and economic status of the population. The process is accelerated by inappropriate government policies.

Cultural reasons: Land reclamation in Iran is not merely an economically guided practice, but is religiously driven. Zoroaster has said, "bare lands are occupied by evils", and commanded that "this is the duty of the young to cultivate and reclaim the bare lands" (Azadeh & Ahmadian, 1993). The Holy Quran also contains many commandments with respect to land

reclamation. Land reclamation becomes relevant when the productivity of rangelands declines to such low levels, that they may be described as "bare lands" by those that want to take advantage of this misinterpretation, in order into transform them to other unsuitable land uses.
Ownership: There has always been serious controversy between arable farmers and pastoralists over control and use of the rangelands. Transhumant pastoralists have always complained that their rights were not being respected by farmers, and that in their absence from the area, their ranges were used. Heavily overgrazed areas around the villages and on adjacent rangelands present proof for this claim. Even within families tensions arise on communally used rangelands.
Arable farming represents one way of legally establishing land ownership, and when water for irrigation is not available, no other choice is left but dryland farming. Policies, encouraging these practices, such as provision of subsidized chemical fertilizers and/or tractors on the basis of farm size (irrespective whether rainfed or irrigated farming is practiced), are an additional cause for expansion of dryland farming.
Economics: Cereals are cultivated with the objective of producing grain for food, if the year is good and distribution of rainfall is favourable, otherwise they are used for grazing. It is not economically viable to grow cereals in most of the Zagross region, even if labour and transportation are provided by members of the household, and thus for free. In the context of the current study, many farmers have been interviewed and it was evident that they are also of the opinion, that currently rainfed agriculture to produce grain is not economically viable.

Overgrazing

Dashlyboron (1986) suggests that only 25% of the required animal feed of the country can be obtained from rangelands, if sustainability is a boundary condition. It has been calculated that the livestock population in Charmahal province, located in the Zagross region, exceeds its carrying capacity by more than a factor three (Basiri, 1987). Various reasons exist for overgrazing, of which ownership and authority seem the most important.

Overgrazing seems almost inevitable when rangelands are used communally. Every user tries to take as much as possible from this 'open access' resource, since the attitude is that all other users behave similarly (Hardin, 1968). Rangelands of local farmers are not clearly separated from those of pastoralists, and neither have been specifically allocated to members of a tribe or a village. In such a situation, no one takes responsibility for maintenance of the productive capacity of the land that is not privately owned. Before Iran's land nationalization (1962), in which ownership of all rangelands and forests was transferred to the government, land belonged to the tribe that had vested authority in a leader, who effectively acted as range manager. Within this system, specific range management practices were applied. For instance, "Rest Rotational Grazing" was the most common practice, i. e. traditionally allocated grazing land was divided in two parts: each part was grazed under control of herdsmen every other year, while the other part was allowed to recover. Each member of the tribe had the right of use, for grazing or a place to settle, however, the regulations set by the range manager aimed at the prevention of land misuse. As a consequence of the land nationalization, the authority of these leaders diminished or vanished, and there was no replacement for these grazing managers. The process of land nationalization was implemented too early and in too short a time span, because the government lacked qualified personnel, the required instruments and authority, to play an influential role in grazing programming, as part of rangeland management, and the consequence was that pastoralists became self-ruled (Basiri, 1984). Moreover, early grazing, a common practice among farmers in sedentary animal husbandry systems, is becoming routine behaviour for the pastoralists, under the influence of 'modernization' and development of infrastructure, i.e. roads. Currently, three types of migration are practiced, traditional, motorized, and semi-motorized. In motorized systems, animals and people move in trucks and cars; in semi-motorized systems, people move in cars and herds travel on foot directed by a herdsman; and in the traditional system some individuals move on draught animals, including women and children, and the herdsmen and herds on foot. As a result of this change in migration pattern, the destinations are reached within a short time, and grazing starts very early, which is detrimental to the sustainability of the rangelands (Noy-Meir, 1978a; b; 1976). Another consequence is that grazing can continue for a longer period, thus allowing higher exploitation pressure.

1.5 Rangeland reforms

Before the 1978 revolution

The origins of animal husbandry in Iran can not be traced back, but there is evidence that Iran's rangelands have been grazed for more than ten thousand years (Dashlyboron, 1986). Before the rangeland nationalization in 1962, traditional patterns of pastoralism were based on a tribal management system for the rangelands. When all rangelands and forests were placed under government authority, all existing land ownership certificates were revoked, hence the existing land management system could no longer be enforced (Azadivar, 1991). Indeed, as a consequence of the removal of local managers, 'land lost its master and man lost his property'. This chaotic situation, characterized by 'cut-and-go' practices, was not created intentionally. The third article of the Land Nationalization Act stipulated that "preparation of range management plans and issueing of grazing licences should preceed land utilization" (Salmasi, 1995). It was obvious, however, that the government was not well prepared for implementation of the program (Azadivar, 1991), with the results as indicated. Some time later, governmental grazing licences were introduced, as remedial action against land degradation, but that did not basically change the situation, because conditions for awarding grazing licences were (Taghian, 1988):

- Long records of pastoralism.
- Testimony of neighboring pastoralists.
- Determination of the herd size and appropriate stocking rate of the range (grazing usufruct is determined on the basis of livestock ownership).

For determination of the appropriate number of livestock, identification of the carrying capacity of the given area is an essential step. For that the range was supposed to be fully inventorized and evaluated. However, because of lack of time and money this process has not been executed adequately. Consequently, the permitted number of livestock exceeded the carrying capacity of the range. Moreover, pastoralists are not likely to comply with the regulations and may keep any number of animals, especially since it is almost impossible for the government to maintain control in such a vast and remote area. Since Article 7 of the Act states that "the grazing licence is issued to a household or households", and in most cases was issued to a group of households, without specific boundaries for individual households, the rangelands for all practical purposes, were still used communally (Mosavi Nejat, 1996).

In 1967, the first range management plan in Iran was formulated by students of Gorgan[3] College of Natural Resources, for 2000 hectares of Firozkoh rangelands, located in the Alborz mountains (Moeinodiny, 1993). The methodology developed in the Gorgan College of Natural Resources was used as a prototype by the Technical Range Office of

[3] A city in the north of Iran close to the Caspian Sea.

Iran's Forest and Range Organization[4] for the formulation of several range management plans to be implemented all over the country. These plans were given to the pastoralists as a guideline for range management. In 1975, implementation of the range rehabilitation guidelines, included in the range management plans, was introduced as a condition for granting rights of grazing usufruct. In first instance, grazing licences to the pastoralists were issued for a period of ten years. In year eleven, the land was evaluated and when range conditions had indeed improved, the licence was renewed for a period of thirty years. The overall result of the process seemed satisfactory, because despite all difficulties associated with its application, a basis for periodic evaluation of the land and land use was established.

After the 1978 revolution

Following the 1978 revolution, ownership of the land was considered the key issue to sustainable land management (Kardavani, 1995; Babakhanlo, 1985). Hence, the land deed program was one of the main policy measures of the revolutionary government. A committee of seven members was established to deed the so-called "non-cultivated" or "bare" lands. Hence, this committee was not explicitly supposed to deal with rangelands, unless, because of low productivity, they were described as "bare lands".

The rangeland deed program started in 1985 under the auspices of the Forest and Range Organization, comprising the following stages:

- Range inventory and analysis;
- Preparation of a range management plan;
- Conditional land allocation for a period of 30 years. At this stage, accompanying the 'long-term lease contract' certificate, the plan is presented to the pastoralists. They must agree to implementation of the plan, and its suggested management measures;
- Governmental loan is granted to the pastoralists;
- Government experts monitor the range;
- The range management practices will be evaluated in year 30 , and if satisfactory results have been achieved, the lease contract is extended for another period of 60 years;
- Fragmentation of the range is not allowed: only one of the family members becomes heir to the grazing licence.

[4] Organization responsible for control and management of national lands, consisting of rangelands and forests.

1.6 Justification of the land deed program

In almost all relevant Iranian publications, lack of land ownership is identified as the most severe constraint to range rehabilitation (Kardavani, 1995; Sheidaei & Nemati, 1970), e.g. whenever land is owned and has been managed by an individual family, regardless of the animal husbandry system practiced, productivity of the range has increased (Bagheri, 1994). Communal ownership, formerly considered equivalent to underexploitation, is currently reason for overexploitation and degradation. Ownership and transfer rights are considered necessary conditions to improve both farmers' welfare and aggregate growth rate of agricultural production (Platteau, 1996).

Comparative research on deeded rangelands in Zagross and communally used neighboring land (Mosavi Nejat, 1996) has shown that annual production of the privately owned land is significantly higher. Similar results have been reported from another site in Zagross, i.e. Khoy province (Dadafarid, 1994). Answers to 102 questionnaires, distributed among transhumant pastoralists in Ilam province, indicate that 84.3% believe that privatization is a positive action against land degradation (Pazireh, 1994), 72.6% responded that they were not prepared to reduce their livestock numbers in the current situation. However, they also indicated that they would be prepared to follow the instructions in the range management plans and adapt the number of their livestock to the carrying capacity of the range, once the land would be 'given' to them (Pazireh, 1994).

1.7 Stakeholders and decision makers

Stakeholders in range management comprise both governmental and non-governmental entities. Governmental stakeholders include the Local Office of Natural Resources, Agricultural Bank, Office of Animal Affairs, Office of Extension and People's Participation, Veterinary Office, Organization for Nomad Affairs, Environmental Protection Organization, Governor, Planning and Budget Organization, Directorate of Watershed Management, Agricultural Research Organization, Research Center for Natural Resources and Animal Science, and judges. Non-governmental stakeholders include local farmers, pastoralists and NGOs.

Decision makers, having a direct influence on the decision making process with respect to range management include Local Offices of Natural Resources (LONR) from the governmental side and local public

institutions, village councils or pastoral cooperatives from the side of the land users.
Planning is the task of LONR and in the planning process objectives, aspirations, possibilities and limitations expressed by the stakeholders should be taken into account.

1.8 Rationale and objectives of the study

The required size of an economically viable pastoral enterprise is determined by the environmental conditions, governing the productivity of the land and of the animals, and the interactions with the prevailing social and economic conditions. Within the ongoing land deed program, land ownership certificates are issued without attention for the economically acceptable size of the property. The areas within traditional boundaries of the rangelands between tribes or villages, called Saman-e-Orfi (SO), are first established. Such a SO is deeded communally, to the population of the village or the members of the tribe. Thus, there is no allocation for individual households and communal use of the range is still prevalent. Many arguments may be put forward for ignoring determination of the size of the economically viable enterprise in rangeland allocation, such as scarcity of land and a growing population or disagreements among stakeholders, that make it difficult to decide to whom the land should be allocated. Moreover, a suitable methodology to support the process of planning is lacking.

Current land use on the rangelands is faced with problems related to overgrazing, either through overstocking or untimely grazing, as a consequence of population growth and economic pressures. In addition, rangeland is converted to other land uses, regardless of its biophysical suitability, by the local population, in search of poverty alleviation and/or ownership. In the light of these problems, there is need for development of a methodology that allows definition, appraisal and analysis of alternative land uses as a basis for formulation of a decision support system for land allocation.

In the current land deed program the different goals and aspirations of the various stakeholders are not considered, with the consequence of dwindling support for and doubtful success of the program. Moreover, the goals of the decision makers are not adequately and quantitatively defined. Future evaluation of the land improvement program, an important policy objective of the government, remains subjective and at odds with the purpose of the land deed program.

To reach a compromise solution on land allocation, on the basis of all relevant information, and taking into account the interests of the various stakeholders, an integrated and interactive methodology is required, that allows explicit consideration of the goals of all stakeholders. Such a methodology should allow identification of multiple options (depending on the weight attached to the various, often partially conflicting, goals) and could serve as a support system to help the decision-makers to decide on what is 'more acceptable'.

The aim of this study is to develop a support system that could contribute to planning a sustainable future for Iran's rangelands. This tool can be used by planners to address all inputs and outputs associated with the use of the land, current or alternative, to identify a window of opportunities and its associated constraints (van Ittersum et al., 1998). Application of this planning support system should allow explicit determination of the benefits and costs associated with a particular type of use of a tract of land. That forms the basis for the decision on the area and quality of land to be allocated to each land user(s) (household or households). The system should be flexible, and easily adaptable to different conditions, prevailing at the moment of implementation of a specific land deed program. The content of such a system should be based on a methodology which allows the analysis of rangeland resources, demand and supply analysis for animal feed, generation of alternative land use plans, appraisal and comparison of various alternatives at district and local level. It should include enough analytical facilities to support answering to the following types of questions:

- What is the suitability of a specific tract of the land for extensive grazing and rainfed agriculture?
- What is the current land use and what are alternatives?
- What is the required management at tactical and operational levels?
- What are the inputs and outputs associated with suggested alternative land uses?
- What is the suitable land use for an area, given the objectives of the local (or national) decision-makers?
- What are the consequences of the selected district policy for implementation at the local level?
- What is the required land area for an individual animal, and for a household?
- What is the impact of selection of a tract of land on family budget in terms of inputs required and outputs expected?

1.9 Outline of the thesis

The basic concepts and structure of the system are described in Chapter 2, that outlines the way in which a planning support system can be constructed and may be used in the process of decision making. Issues, such as sustainability, land use planning; decision support systems, and planning support systems are discussed to provide a basis for identification of required functions and overall design of the system.
The system includes three main components, mainly, land resource evaluation, district and local planning modules. The development and operationalization of each module is described in separate chapters. Chapter three covers land evaluation. The FAO methodology for land evaluation (FAO, 1991; FAO, 1983) is discussed and concepts and definitions of the land evaluation component of the current methodology are explained. The land evaluation methodology is operationalised for the study area and land suitability classes for rainfed agriculture and rangeland (rehabilitated) are identified.
The district-planning module is described in Chapter 4 that deals with multi-objective and multi-attribute decision-making processes. These processes and the tools applied are explained. Furthermore, application of an interactive multiple goal linear programming technique (IMGLP) in the district planning module is explained, in relation to the inputs and outputs of the various land uses. The operationalization of the methodology for generation of the scenarios and their assessment are also explained in this chapter.

The local planning module is treated in Chapter 5. Application of the results of the district module (outcome of Chapter 4) in local land use planning is illustrated. Subsequently, a sub-model, developed for determination of the required size of a grazing enterprise, is explained. The methodology is implemented for the study area and the results for one grazing usufruct area are explained and discussed.
Chapter 6 is devoted to a general discussion, conclusions and suggestions for application of the methodology.

2 Planning support system for land allocation in Iran: Framework and Methodology

2.1 Introduction

Evolving perceptions of planning, in combination with the evolution of computer-based information and communication technology provide the basis for a new perspective on computer-aided planning (Klosterman, 1997). Planning for sustainable use or development of natural resources has basically been pursued by FAO (FAO, 1993; 1991). The FAO system that has been widely applied in various contexts has its merits, although criticism has been voiced (Beek et al., 1997; Pieri, 1997). Identification of the best or optimal land use or combination of land uses is in most cases not a simple straightforward procedure, because of the many (agro-) technical, economic and social factors involved. Techniques, such as multi-criteria evaluation methods, have been applied in procedures for land use planning (Van Keulen et al., 1998), to allow decision-making in an interactive participatory process.

Major developments in the information science, from data to information and from information to knowledge, have resulted in the development of Decision Support Systems in the 1980s (Klosterman, 1997). These developments continued as knowledge moved toward intelligence, and Planning Support Systems (PSSs) evolved as the next step in planning tools.

In this chapter, a methodology is introduced for development of such a PSS for sustainable land use planning at district and local levels, based on the FAO procedure, with the ultimate objective of providing a solution to the problem of land allocation.

2.2 Concepts in Management Information Systems

2.2.1 *Sustainability*

Sustainability, that has become one of the most frequently used concepts in connection with development and natural resources management during the past two decades, is a subjective notion (Herrero, 1997), and has been defined in many ways (MacRae et al., 1990; Francis & Youngberg, 1990; American Society of Agronomy, 1989; WCED, 1987). Olembo (1994) argues that sustainability is confusing, when it is used interchangeably in the terms sustainable use, sustainable development and sustainable growth. He even suggests that sustainable growth is a contradiction in terms, because physically nothing can grow forever.

In literal English usage, quoted by Hansen (1996), sustainability is the ability to "keep in existence; keep up; maintain or prolong". Herrero (1997) has expressed his preference for the use of the definition of WCED (1987): "development that meets the needs of the present population, without compromising the ability of future generations to meet their needs".

To explicitly define the concept of sustainability, as used in this study, it is postulated that:

- Sustainability refers to sustainable use, which applies to renewable resources (Olembo, 1994).
- Sustainability expresses the ability of a system to continue into the future; therefore it cannot be applied to static systems (Hansen & Jones, 1996).
- Sustainable use mostly derives its meaning from the observation that the present system can not be maintained or prolonged, and to avoid collapse of the system, alternatives are introduced that, in contrast can remain operational in the future (O'Connel, 1992; Dobbs & Becker, 1991; Hauptli et al., 1990; Lockeretz, 1988).
- Sustainable alternatives are economically viable, socially acceptable and ecologically sound (Yanuariadi, 1999).

Taking into account these criteria, the definition of the American Society of Agronomy (1989) seems to meet our objectives: "A sustainable agriculture is one that, over the long term, enhances environmental quality and the resource base 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".

2.2.2 Land use planning

Land use planning is defined as: a systematic assessment of land and water potentials, alternatives for land use and economic and social conditions in order to select and adopt the best land use options (FAO, 1993). This should include the institutional feasibility, as well as the ecological, social and economic sustainability, Land use planning aims at improved sustainable use of land and management of resources, which is an urgent necessity. According to Pieri (1997) and Van Lier et al. (1994), population growth and its consequences are placing ever increasing pressure on the land and have created competition for and conflict over access to and use of this limited life-supporting resource. Moreover, there is increasing demand for land from sectors other than agriculture for infrastructural facilities, industry, housing, and increasingly recreation and tourism.

With respect to agricultural use, current conflicts are more acute in developing countries, because of their higher population growth rate and their generally less favourable economic conditions that prevent them from acquiring food from the world market. Moreover, in many developing countries land tenure rights are not well regulated, and therefore uncertain. Therefore, questions on how and to whom these limited resources should be allocated and how they should be managed to maintain their quality, urgently need answers to avoid or resolve these conflicts.

This is the more pressing, since agriculture is the main economic activity of most developing countries, and only sustainable agriculture is likely to generate the long-term benefits required to achieve development and poverty alleviation. Even in countries such as Iran, that are rich because of their oil resources, agriculture plays a very substantial role in self-reliance of the nation, when encountering economic crises, such as the low oil price in 1998. Thus, development of support systems for land use planning, to be applied as tools in decision-making on allocation or reallocation of available resources, as a basis for change towards a sustainable situation, is quite relevant for such countries.

The question "for whom" is very important in land use planning (Zander & Kächele, 1999; Van Lier et al., 1994; Huizing & Bronsveld, 1994). It implies that people are not a trivial part of the plan, but actually at its heart. Hence, it should always be in the mind of planners that the plan should be executed by people and that what land users do not like, is very hard to implement, especially in remote areas. The objective of land use planning therefore, should not be limited to suggestions of alternatives or confirmation of the current situation. It should rather be the development of guidelines for the users that assist them in making the right decisions at tactical and/or operational level on current or alternative land uses (Zander & Kächele, 1999). Land use planners therefore, should assist decision makers in taking steps, directed towards sustainable use of the natural resources.

Land use planning in this study follows the approach illustrated by Van Keulen et al. (2000), that starts from analyzing the current situation to identify the problems, then possible land uses for a better future are sketched and evaluated biophysically, economically and socially, with respect to the different objectives of various stakeholders, to arrive at a compromise solution. To comply with this approach, in future land use plans for rangelands the following objectives have been considered:

- Enhance the level of production (alternative land uses) and identify the most efficient way of use (alternative management).
- Reduce the level of risk by replacing annual plant species by perennials.
- Protect the quality of the natural resources and their biodiversity and prevent land degradation.
- Meet the needs and requirements of various stakeholders.

2.2.3 Decision-making: concept and process

When a series of land use plans has been identified within the methodology of this PSS, representing the window of opportunities under the prevailing constraints, decisions should be made aiming at selection of the most beneficial one according to the perceptions of engaged stakeholders. Hence, this requires a description of the process of decision-making and the type of problems resolved with the assistance of the PSS.

Concept

A decision is a specific commitment to action, usually in conjunction with a commitment of resources. A decision process is a set of actions and dynamic factors that begins with identification of a stimulus for action and ends with a specific commitment to action (Mintzberg et al., 1976). Decision-making starts with identification of a problem. A problem is defined as a situation where an individual or group perceives a difference between a present state, and a desired state, where alternative options are available, and it is not clear which option performs best (cf. Ackoff, 1981). To solve the problem, the individual or group should identify and analyze alternative courses of action with a significant effect on this perceived difference and be able to set priorities among these alternatives, so that one may be selected. The decision-makers in this process are individuals or groups having a problem in common and directly or indirectly providing value judgments on the decision process, necessary to define and choose between alternative courses of action (Chankong & Haimes, 1983).

Decision making stages

Simon's model (1960) of decision making process have been adopted. This model, which is following procedural rationality and satisfying behavior of decision makers, includes three main phases as follows:

The intelligence or problem formulation phase. This involves scanning of the environment for situations (problems or opportunities) demanding a decision. Here, data are collected, processed, and examined for clues that may lead to identification of problems or opportunities.

The design phase. This involves designing, developing and analyzing possible courses of action, which includes the processes of understanding the problem, generating solutions and test solutions for feasibility.

The choice phase. This involves selection of specific course of action from the alternatives available.

The decision making process is an iterative process and may need several cycles of implementation of these three phases before the best management alternative (decision) is finally selected (Yanuariadi, 1999).

2.2.4 Problem identification

Problems may be classified in three types: "well-structured", "ill-structured" and "unstructured" (Sharifi, 1999). A problem is defined as well-structured, when all phases of the decision making process can be formalized (Sol, 1982). In this case, it is possible to derive the best solution by preparing a decision rule or decision procedure, such as a set of steps, a formula or a procedure to collect and analyse data. A problem is unstructured when none of the phases of the decision making process can be formalised. For solving such problems no fixed procedures exist, either because the frequency of the decisions involved is too low to warrant preparation a decision procedure, or because the decision procedure is not understood well enough, or is too unpredictable to allow development of a stable fixed procedure (Sharifi, 1999). Ill-structured problems take an intermediate position. For an ill-structured problem, only some of the phases of the decision making process can be formalised. According to Simon (1960), the type of a problem determines which phase of decision-making should be most strongly emphasised. Ill-structured problems need more emphasis on the intelligence and design phases of the decision making process, whereas well-structured problems require more emphasis on the choice phase.

2.2.5 *Decision Support Systems (DSS) and Planning Support Systems (PSS)*

Decision support systems (DSSs) are a class of sub-systems of management information systems. DSSs support analysts, planners and managers in the decision making process (Sharifi, 1998). They can reflect different concepts of decision making and different decision situations. The term Decision Support System has been defined as:

- A system or methodology that assists in poorly or ill-structured decisions, by facilitating interactive and participatory decision processes (Klosterman, 1997).
- A system that makes some contribution to decision making (Sprague & Watson, 1986).
- An interactive computer-based system that helps decision-makers to utilize data and models to solve semi- or unstructured problems (Gorry & Morton, 1971).
- A contemporary jargon for an integrated approach to the age-old problem of helping people make better decisions (Stuth & Lyons, 1993).
- Computerized tools to analyze large amounts of data and complex relations for making rational decisions (Makowski, 1994).

While the methodology developed in this study is computer-aided and it tries to be interactive and participatory, the definitions of Klosterman (1997) and Gorry and Morton (1971) most closely cover the approach followed in this study. On this basis, we define DSS as a class of computer system that helps decision makers/planners in their decision making processes where: human judgment is an important element in decision making process and where human information processing capacity is limiting the decision making process.

DSS concept

Decision Support Systems that have been designed for planning in industry and commerce (Bennett, 1983; Thieraf, 1982) aimed at using the computer for evaluation of alternatives and thus arrive at a better-informed decision. An important point in relation to DSSs is that the decision maker is responsible for the decision and the DSS is a tool to provide a larger window of opportunities. Hence, the user is the central part of the system and the DSS can be considered analogous to a hand-held calculator in that it supplements, rather than supplants, the decision making process (Stuth & Lyons, 1993). DSSs are making use of models that use various types of data as inputs, and give alternative solutions as outputs. The primary objective of DSSs is to assist specific decision-makers, individually or as groups. This allows custom design of the system, in which the decision maker can develop the decision support system interactively, which provides the opportunity to adapt the analytical models used in the decision making process. DSSs are interactive, as they allow the decision-maker to systematically generate and evaluate a number of alternative solutions (Klosterman, 1997). They are integrative in the sense that they incorporate substantive knowledge of the decision-maker, along with quantitative data and formalized existing knowledge of processes, to create solutions and evaluate all alternatives with respect to a range of pertinent criteria. They are also participatory in permitting decision-makers to examine the consequences of application of different information and modeling approaches and to select alternative decision criteria, objectives and constraints.

General structure

Generally, a DSS starts from a database for storage and management of data, in such a format that they can be used whenever needed. Secondly, a DSS requires a processing part (model base), comprising the required functionality. Finally, the DSS requires an interface component. All three components should have the flexibility to accommodate different types of software and techniques. For data management, many options are available, from simple tables to sophisticated user-friendly databases such as Excel. Many tools are also available for the model base of the system, such as simulation models, physical models, linear and non-linear models. The level of sophistication is determined by the complexity of the problem at hand and the availability of information. Turban (1995) has further elaborated these components and designed a DSS architecture as shown in Figure 2.1.

Characteristics

Among the many characteristics attributed to DSSs (Girard & Hubert, 1999; Fischer & Makowski, 1996; Stuth & Lyons, 1993), the most important are:

- They must support decision making on poorly structured problems.
- They must be interactive and the user must be able to run them as many times as needed to reach a satisfactory solution. The more flexible, the better the system.
- They should be knowledge-based to support efficient solution-generation for complex problems.
- They should allow inclusion of human judgment as a major input in the DMP.

- They should support a variety of decision-making styles, and be easily adaptable to provide new capabilities, as the need of the user dictates. Therefore, the DSS as a sub-system of the management information system should be capable of generating sufficient alternatives, allow evaluation of alternatives and selection of the most acceptable one.

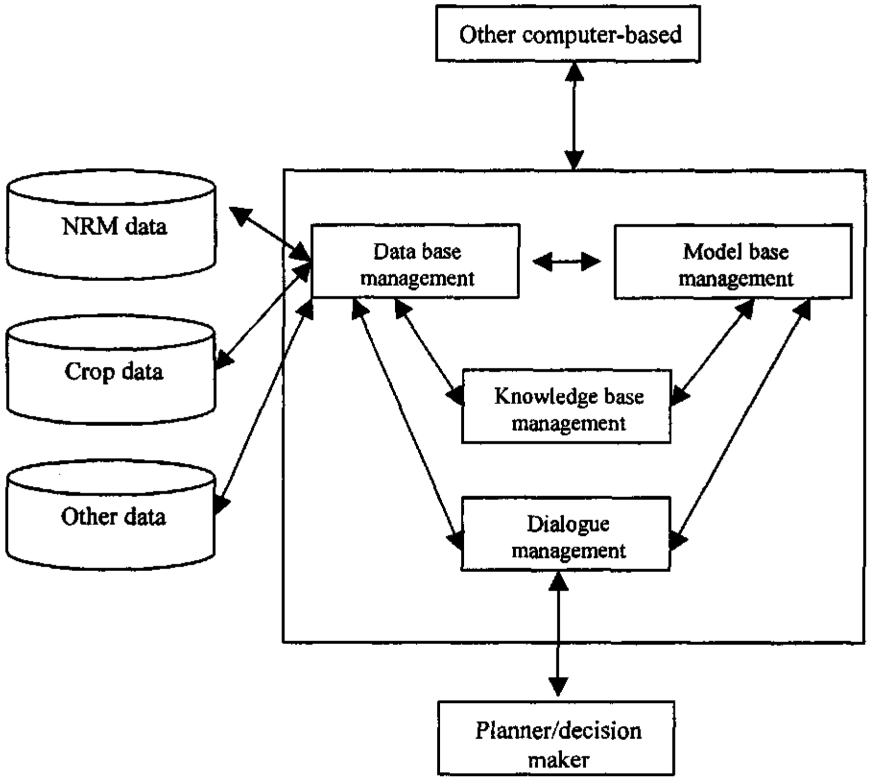


Figure 2.1 Overall architect of a planning support system (adopted from Turban, 1995).

What is a Planning Support System (PSS)?

Planning support systems are very similar to DSSs. They also provide interactive, integrative and participatory procedures for dealing with poorly structured problems, here the subject of decision is a plan. However, as a planning system, it also pays attention to planning problems and strategic issues, and explicitly facilitates group interaction and discussion (Klosterman, 1997). PSSs should provide intelligence, have the ability to deal with novel situations and new problems, be able to apply knowledge acquired from experience, and use the power of reasoning effectively as a guide to behavior (Klosterman, 1997). A PSS must also utilize a full range of different technologies, each appropriate for resolving a particular type of problem (Han and Kim, 1989). Overall, it should support resource analysis, scenario development and analysis, trade-off analysis and choice of an acceptable plan. The basic skeleton of the PSS developed in this study is shown in Figure 2.2. The socio-economic information constitutes an important part and is used in all processes to take into account the multiple objectives of all the stakeholders.

2.3 Planning Support System for Range land allocation

2.3.1 Structure

Development of a Planning Support System for allocation of rangelands aims at creating an ongoing process of social design, interactive dialogue, and debate in which planners, policy makers and the local population play a role in deciding how the collective concern of society should be managed (Healey, 1992). A conceptual planning support system should be consistent with a planning concept e.g., exploratory land use planning. It should comprise a phase of analysis of the current situation, and a core-processing phase to identify ways to realise societal goals through examination of the possibilities and constraints.

Thus, PSS for rangeland allocation, as a specific type of decision support systems includes the following main components:

A database management system: Which includes data bases designed to accommodate and organize the basic spatial and thematic data, provide facilities for selection and manipulation of data as well as interrelating data from various sources.

A model base management system: Which includes quantitative and qualitative models that support resource analysis, assessment of potential and capacities of resources at different levels of management. This is the most important components of the system, which forms the foundation of model-based planning support (Sharifi, 2000). It includes three classes of models (Figure 2.2), which make use of the existing data, information and knowledge for identification of problem, formulation and selection of proper solution. These models are:

- A resource analysis model
- A planning model which integrates potential and capacity of the resources (biophysical), socio-economic information, goals and

objectives of the different stakeholders to allow generation of alternative feasible scenarios for solving the problem
- An evaluation model: which allows appraisal and evaluation of different scenario and identification of the one which is most acceptable by all involved parties.

A knowledge base: which provides information on data and existing processing capacity and models which can be used to identify problem, to generate solutions, to evaluate and appraise them, and finally to communicate the results to the decision makers.

A user friendly interface: which allows smooth and easy communication with the system, visualization and communication of the results of analysis to the decision makers in a manageable and understandable form.

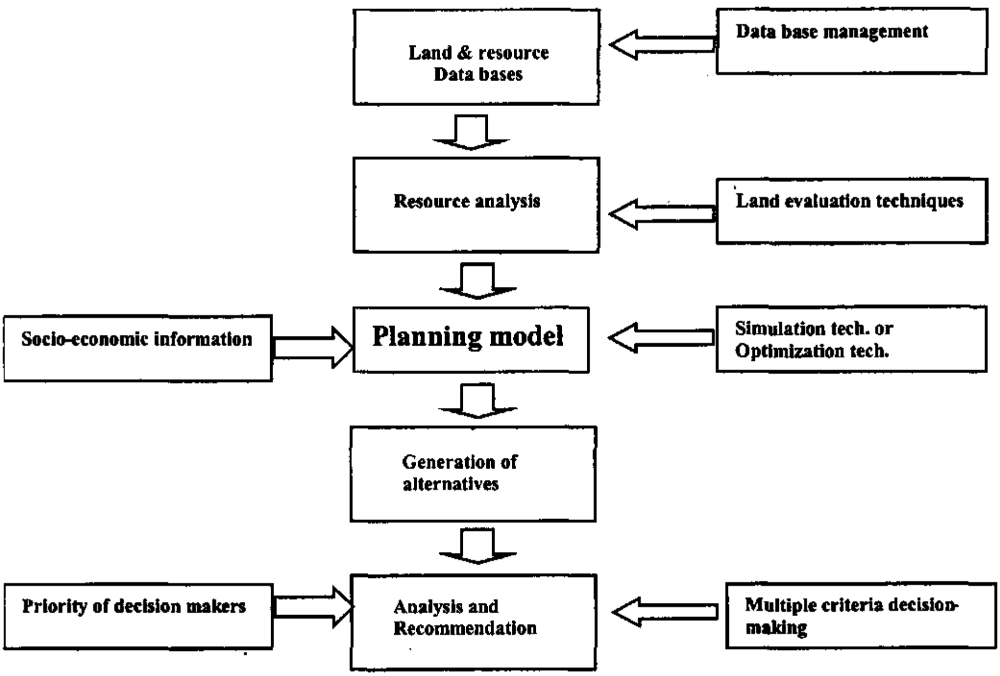


Figure 2.2 Skeleton of a model-based planning support system (source: Sharifi, 2000).

2.3.2 Relevance of a PSS in allocation of rangelands in Iran

Recalling the three elements of the decision making process, i.e. intelligence, or problem formation, design for identification of possible courses of actions and choice to select the appropriate action, reveals that decision making requires skills and tools. Wrong decisions may make the situation worse. Of the many difficulties encountered in the process of land allocation in Iran, the greatest are lack of skill of the decision makers and experts to make the right decisions, the heterogeneity of the land with respect to environmental and economic characteristics, divergent and conflicting objectives of stakeholders, and lack of unequivocal national policies. The functions of a PSS in easing these difficulties are discussed in the following paragraphs.

Heterogeneity of the land

Communal natural rangelands are vast and generally heterogeneous. Heterogeneity refers to variability in productivity of the species, as a result of variation in soil characteristics and plant properties, and as a consequence variation in quality of the land. Furthermore, the quality of the land dictates the 'best use', i.e. the most suitable agricultural alternative in view of established objectives, to arrive at a more productive agricultural system. In the planning support system, the impact of the quality of the land on inputs and outputs of alternative land uses is included, which offers the opportunity to both government agencies and households, to negotiate on the most suitable tract of land for a specific household. The population intently follows the process of deeding the land, and nobody is prepared to accept less than what he thinks he deserves. If no compromise can be reached on the allocation of the land, chaos may be the result. PSS with its GIS component allows rapid, reliable and reproducible spatial analysis. Results, displayed on maps facilitate the process of description and should be more easily understandable for the households.

Divergent objectives of stakeholders

There are different expectations from implementation of the land deed program by various stakeholders. For farmers (pastoralists) land ownership and the benefit they can derive from the land are the main issues. The smaller the number of landowners that are created through the program, the more acceptable it is in the eyes of these stakeholders. The governor and his staff consider the rangelands as a source of employment, hence the larger the number of pastoralists involved in the land deed program, the more satisfied they are. From the environmentalists' (Directorate of Watershed Management, Environmental Protection Organization, etc.) point of view, rangelands are sources of biodiversity (gene pools) and soil protection agents. Exploitation of rangelands should be minimal in their opinion, and all destructive activities should be forbidden. On the opposite side of the spectrum are stakeholders that expect from the rangelands fulfillment of other regional and even national desires. Rangelands can be used for mining, for infrastructural facilities, such as roads and for housing. These parties would like to take full advantage of all possibilities of rangelands, without consideration for their specific characteristics. A PSS capable of taking into account all different objectives of the various stakeholders, can assist decision-makers in taking well-founded decisions with respect to land allocation, based on explicit consideration of the different aspirations, and transparent reasoning that can be subject to debate.

Level of skill in decision making

The chances of making the right decisions decline as the planning area is more remote and less accessible, due to lack of accurate data, knowledge and supporting devices to appraise the possible impact of decision. It has often been observed, that wrong decisions by experts or policy makers, e.g. wrong allocation of the land for housing or mining, have resulted in irreversible damages, many times larger than could possibly have been caused by, for example, overgrazing. Furthermore, in dealing with difficult problems, such as land allocation, experts try to ignore the problems, instead of solving them. Improved political decision making and better resource management can only result from more accurate, objective, consistent, and timely information about the issues involved (Sarokin and Schulkin, 1991). A framework for integration of the available information and knowledge for the purpose of examining the consequences of different opinions on the future of the land, therefore, becomes indispensable as an aid in the decision-making process, such that better decisions are made.

Unstable policies and political pressures

A problem for the low productive lands is that policy makers change their decisions and policies with respect to these lands, without any consideration for the consequences. On the other hand, because of the sheer size of the area, there are always incentives to use the land in many different ways to solve political problems. In the process of land allocation, in a PSS, the political points of view can be made explicit and the consequences of different policy views can be explored, which will make the debate more transparent and could make arguments more convincing. Thus, the PSS may contribute to a more stable future.

2.3.3 *Design of a Planning Support System for land allocation (PSSLA) in Iran*

A planning support system for land allocation in Iran is designed to assist in the process of determining the size and location of economically viable grazing enterprises. PSSLA generates alternative land use scenarios at district level, based on different land use policies. From this set, the plan is selected that is in agreement with the prevailing land use policies. At local level, however, the system should also assist in determining the size and location of an economically viable livestock enterprise, as well as the size of the land holding for an individual livestock unit and a livestock-owner. Group ranching is a possible system for the study area, considering the presence of many small stockholders in the current situation. However, the system also allows creation of other types of grazing systems, such as a set of completely individual holdings. The pattern of land rehabilitation, to transform land qualities from their current state to the required state, is also selected in the PSSLA in a dynamic way within the required time horizon. PSSLA is based on a mathematical model in terms of solution technique, however it is conceptually an explorative model, in that it attempts to generate 'the best' land use for the future and indicates how the required decision making should proceed, assuming a smoothly running organisation. In terms of the principles of explorative land use studies, some concession has been made, in that only the land use alternatives are considered covered by the routine land rehabilitation program of the government to generate results close to reality. As a consequence, completely innovative solutions, abstracting fully from the current situation, may thus be overlooked.

Structure of the system

The planning support system developed in this study comprises a set of interacting modules that are, compiled in different environments. Results of one module are used in the next module in a hierarchical pathway. Development of the methodology follows the pathway suggested for model based planning (Sharifi 2000). The overall structure of the PSS (Figure 2.3) follows the methodology of Sharifi (1992) and includes three main modules: land evaluation, district and local planning. The land evaluation module is based on the methodology of the FAO guidelines for land evaluation for rainfed agriculture and extensive grazing (FAO, 1983; 1991) and is compiled in a GIS environment. Planning at district and local levels uses the methodology of multi-objective decision-making, following the procedure used by Veeneklaas et al. (1991) and for multi-attribute decision making, that used by Mohamed (1999). The model is using LP developed in the GAMS[1] environment. For the multi-attribute decision-making process, DEFINITE[2] software is utilized.

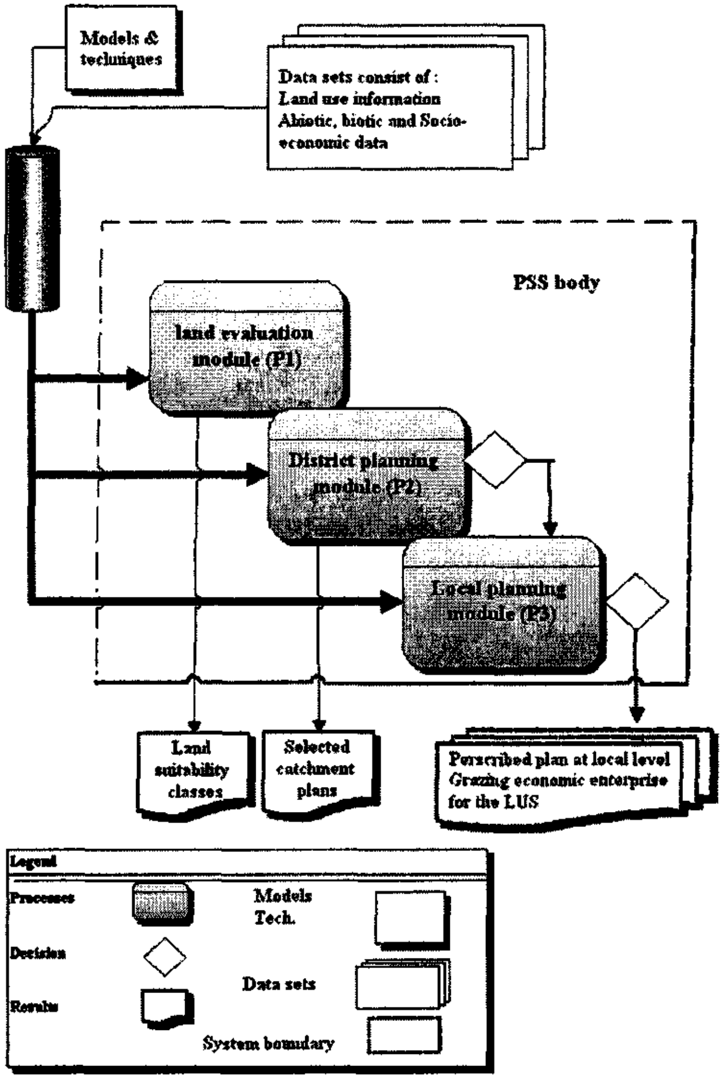


Figure 2.3 Structure of the planning support system.

---

[1] GAMS is an environment for linear programming from GAMS corporations. This software can be obtained through www.GAMS.com.

[2] DEFINITE is a MODSS supporting decision system with a FINITE set of alternatives in relation to a finite number of criteria. The software is fully described by Janssen (1992).

Land evaluation module

Land evaluation is used to identify alternative land uses or changes in management that better meet national or local needs, and to describe the consequences of each feasible change (FAO, 1991). The basic objective of land evaluation module is to examine whether the land quality is compatible with current or intended land use. Current land use plays a major role in land evaluation (Tri, 1993; Funnpheng et al., 1994), through possible associated historical damages or improvements, and must therefore, be carefully considered. For extensive grazing systems, emphasis in the assessments is mainly on possible changes in grazing management. The reasons for this emphasis are the low productivity of the land, the fragility of the ecosystem and the need for protection of plant biodiversity. However, when past grazing management has resulted in extinction of desirable plant species, there may be no other choice but accepting more risky interventions, such as re-seeding.

Land evaluation can be carried out at different spatial scales, of which district and local level are relevant for the purpose of land allocation in extensive grazing regions. The methodology of land evaluation used in this study, graphically illustrated in Figure 2.4, has been used in many studies, cf. Funnpheng et al. (1994), Huizing & Bronsveld (1994) and Rossiter & Van Wambeke (1989). Six principles of FAO (1991) have been adhered to in developing this land evaluation module:

- A multidisciplinary approach has been followed, by considering all available data relevant (biophysical and socio-economic). These data have been collected in a study by the Directorate of Watershed Management (published in several volumes in 1992 which will be cited as they are used). In addition, complete information on inputs and outputs of different land use types are given in Chapter 3.
- Matching the requirements of land use types with the quality of the land was implemented through preparation of a land requirement table for both rainfed agriculture and extensive grazing, and a soil map.
- Comparison of alternatives is not included in the land evaluation, since all alternatives are included in the district planning module and subsequently evaluated on the basis of their input requirements and outputs in the course of the district planning process. In this way, a land unit may be shared by various land use alternatives.
- Results of the evaluation are expressed in terms relevant to the conditions of the study area.
- Land suitability is assessed in terms of sustainability, both from an economic and from a biophysical point of view, e.g. in terms of rainfed

forage production, which is a more soil protective and profitable agricultural activity than rainfed cereal production.
- The intensity of land evaluation, in terms of application of available data and/or collection of new information, was adapted to the intensity of information required for a well-managed program for rainfed agriculture and range rehabilitation.

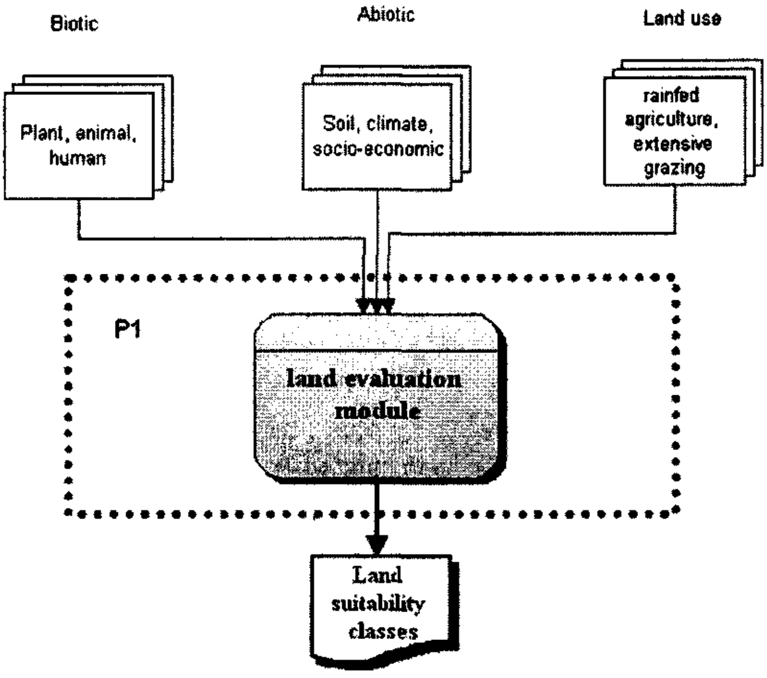


Figure 2.4 Structure of the land evaluation module for rainfed cropping and grazing land.

2.3.4 District planning module

Determination of the best land use plan(s) on the basis of stakeholders consensus is the task of this module. The overall structure of the method used at district level is shown in Figure 2.5. It is useful to consider in some more detail the concept of conflicts of interest among different groups in society, or more specifically, different groups involved in or having an interest in the use of land, each looking for the 'best' or optimal land use, considering its own objectives. Since each group of stakeholders has its specific goals with respect to land use, it seems most appropriate to consider the "best" as a multi-objective issue. Multiple goal problems require special techniques to tackle. In the last decade, in a number of studies dealing with land use analysis and/or land use planning, (interactive)[3] multiple goal linear programming ((I)MGLP) has been applied to deal with these types of problems (Lu, 2000; Savadogo, 1999; Huizing & Bronsveld, 1994; Van Keulen & Veeneklaas, 1995; Ayyad & Van Keulen, 1987). The district-planning module in this study also applies the IMGLP technique. In this process, the LP model is set up to be solved for a single objective, and is solved in successive runs, each run with a different objective function; the result of each run serves as a scenario (land use alternative). Hence, the decision-maker is supplied with several scenarios or alternative land use plans. It is then necessary to select the 'most desirable' scenario. This selection is based on the results of a multi-criteria analysis sub-module in the district-planning module. This selected scenario is subsequently used as input in the local planning module.

As shown in Figure 2.5, alternative land use types are suggested for the study area. Quantitative information on all relevant inputs and outputs of these alternatives is required, which can be estimated on the basis of information from identical land use systems, e.g. empirical and/or comparative studies (Stoorvogel, 1995; Veeneklaas et al., 1991) or through simulation studies. Crop growth simulations were not considered suitable in this study, because of the complexity of the vegetation of the rangelands, in terms of species composition, for which no calibrated simulation models are available and data scarcity. As the district planning module requires information on both, primary (plant) and secondary (livestock) production, animal feed requirements are calculated in the grazing sub-module of the district module.
Although in the current study mechanistic crop growth models have not been applied, they could constitute a useful part of the methodology. They will increase its flexibility and broaden the range of applicability of this planning support system.

[3] Conceptually, the interactive capabilities of the MGLP-methodology have been emphasized (de Wit et al., 1988), but in actual practice the method has not been applied interactively.

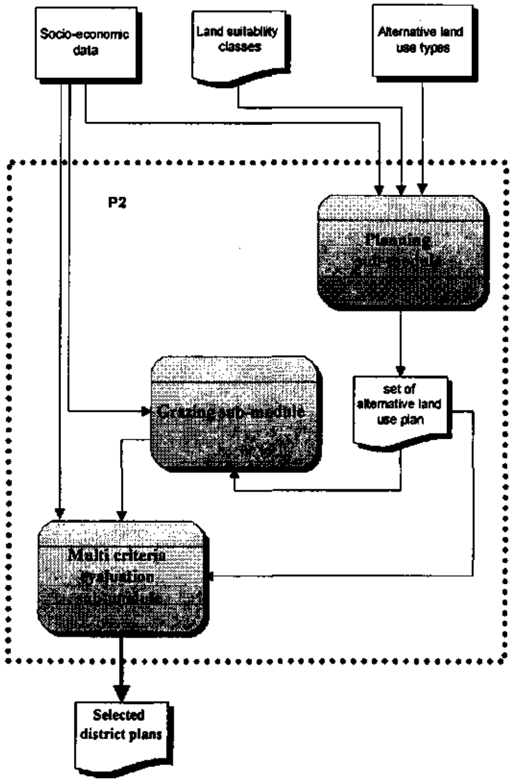


Figure 2.5 Overall structure of the district planning module.

2.3.5 Local planning module

The module at local level (Figure 2.6) is used within the policy selected at district level. The local area covers the grazing usufruct of the village and the module uses detailed information on households, their opportunities and constraints. Consequences of selection of any specific tract of land is transparent by this module to farmers and planners. This local planning module comprises three sub-modules: land allocation, identification of economically viable grazing enterprises and land improvement. The land allocation sub-module uses a linear programming model with a set up similar to that for scenario generation at district level and GIS for spatial analysis. This sub-module is used in identification of the area of a specific tract of land required for an individual livestock unit, and subsequently the area for each household in the village on the basis of its livestock and given land use type. In the planning module, different policy views can be introduced, leading to different criteria and hence alternative land allocations. The land improvement sub-module describes implementation of the selected land use plan, both temporally and spatially.

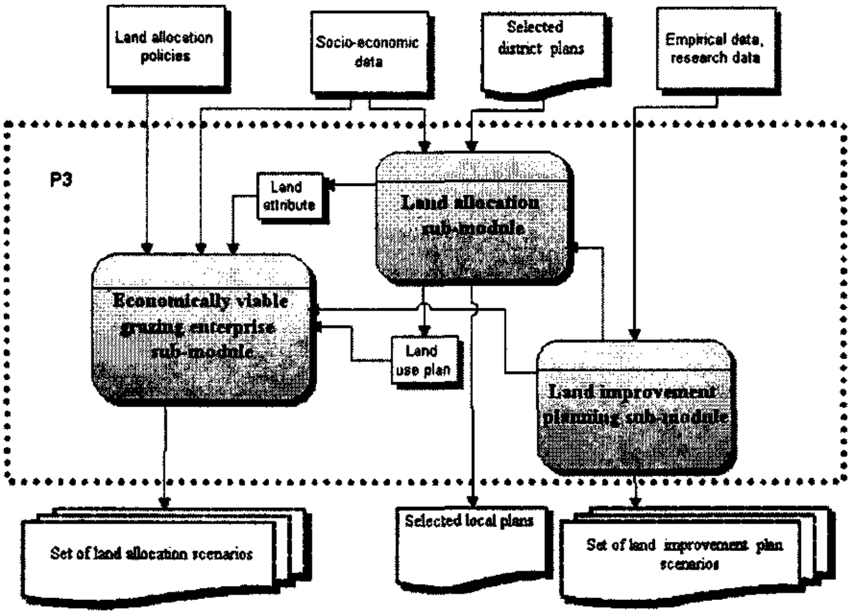


Figure 2.6 Schematic presentation of the local-planning module.

Experts may use this computer-aided PSS as a tool to facilitate the process of planning for land allocation. It supports three phases of decision making processes remarked by Simon (1960), i.e. in the first phase it uses GIS and other data bases for collection, storage and retrieval of data, in the second phase possible courses of actions (alternative land uses) are designed and analysed and in the final phase it supports selection of the most suitable action.

2.4 Study area

The study area was selected on the basis of data availability. In addition, the Esfahan Directorate of Watershed Management suggested that a study area should be located in the area selected for a land deed program.

2.4.1 General

Zayanderod is one of the most important rivers of Iran. It is vital for the city of Esfahan for the supply of drinking water and to the Esfahan alluvial plain for irrigation. The watershed of the river extends over two provinces, Esfahan and Charmahal. This watershed has been divided into

28 basins or sub-districts, each called a parcel. The research area is one of these parcels, designated B2, and has been selected to be deeded. It is located between 50° 7' 16" and 50° 40' 34" E and between 32° 45' 12" and 32° 56' 48" N, west of Esfahan, on the western side of Chadegan city and north of the Zayanderod dam (Figure 2.8).

2.4.2 *Physical characteristics*

Thirty percent of the area has a slope between 30 and 60 percent and approximately half is located between 2200 and 2400 meters a.s.l., i.e. the study area is a high elevation steep site. Its most important physical characteristics are given in Table 2.1.

Table 2.1: Physical characteristics of the study area.

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

2.4.3 *Climate*

Climatic data for the study area were obtained from 18 meteorological stations, of which three synoptic stations and one rain gauge are located very close to the study area, the others are located within the Zayanderod basin, but outside the study area. Meteorological data, such as temperature and rainfall for the years 1979 to 1989 were used in the study. According to Köppen's method (Azad, 1992), the area is classified as continental moderate or cold with cool summers and very cold winters. As Chadegan meteorological station records show, average annual precipitation is 332 mm, average annual maximum and minimum temperatures are 21 ^{0}C and –1.6 ^{0}C, respectively. The area has a Mediterranean-type rainfall regime, characterized by rainy winters and dry summers (Azad, 1992). The rainy season starts in October and extends till May. Fifty percent of the precipitation falls in the form of snow, the reminder as rain in autumn and spring.

2.4.4 Runoff

According to Azad (1992), the runoff coefficient is high, so that from the total surface area of about 227 km^2 and 332 mm annual precipitation, annual outflow is about 15.2 million m^3. The maximum recorded rate of flow of the study area is 33 m^3/s.

2.4.5 Rangelands

Rangeland has been defined as "a tract of land that is used for grazing by livestock or wildlife, where natural vegetation is the main forage resource" (FAO, 1991). According to that definition, almost 50% of the total area, or 11000 hectares, consists of rangelands, i.e. grazing lands (31.3%), and fallow lands (17.8%). Current land uses in 1992 are given in Table 2.2.

Table 2.2: Land use in parcel B2 (Source: Mazroei, 1992).

Land use	*Area (ha)*	*Proportion (%)*
Irrigated arable land	6431	28.3
Rainfed arable land	4805	21.3
Fallow land	4056	17.8
Rangeland	7090	31.3
Built-up areas	200	0.8
Gardens	118	0.5

Range condition

Range condition has been classified on the basis of scoring for two components, soil and vegetation. Criteria used in the scoring are: vegetation composition, degree of soil degradation, productivity of the vegetation (kg/ha), plant regeneration rate and presence of litter. The maximum partial score for vegetation composition is 25, soil degradation status 30, productivity 20, regeneration 15 and presence of litter 10. The range condition is classified 'excellent' when the sum of the partial scores is between 100 and 88, 'good' between 88 and 70, 'fair' between 50 and 69, 'poor' between 30 and 49 and 'very poor' between 29 and 0. Partial scores have been assigned by experts in the field through visual observation. Following this methodology, most of the rangelands in the area have been classified as poor, some parts as fair, and excellent or good ranges are absent (Mazroei, 1992). More than 21.3% of the rangelands has been converted to rainfed cereals, with very low production: these lands are also classified in poor condition.

Trend

The trend or direction in rangeland vegetation composition is defined as progressive when the plant community is moving towards its climax, constant when there is no change and regressive when, through any pressure, such as heavy grazing, succession comes to a standstill, and the gap between the climax composition and the actual situation is widening. The presence of undesirable species and invaders, such as *Euphorbia* spp. and *Sophorea alopecoroides*, and the absence of palatable species indicated that the trend in rangeland vegetation composition is regressive in this region. Evidence of heavy grazing is visible on the pasture plants, indicating that continuous overgrazing is one of the reasons for the current trend.

Vegetation

A vegetation map of the area has been prepared on the basis of vegetation physiognomy. The portion of the plant that is normally grazed by animals was cut and dried for determination of forage availability. To arrive at an estimate of the carrying capacity, available forage dry matter (kg/ha) was divided by 1.7 kg*30, a rough estimate of the monthly feed requirements of a medium-sized sheep. This characteristic is defined as Animal Unit Month (AUM).

Some important vegetation characteristics are summarized in Table 2.3.

Table 2.3: Summary information on the rangelands in the study area (Source: Mazroei, 1992).

Vegetation type code[1]	Range trend	Range condition	Carrying capacity (AUM)
Assp. Cega	Negative	Poor	1. 4
Bare land	-	-	-
Coba. Erbi	Negative	Poor	1. 7
Coba. Scor	Negative	Poor	1. 8
Erbi. Assp. Eude	Negative	Poor	2. 0
Erbi. Scor. Soal	Constant	Fair	2. 1
Eude. Nomu. Scor	Negative	Poor	1. 2
Eude. Phpe	Negative	Poor	1. 2
Eude. Soal	Negative	Poor	1. 1
Piac. Scor	Negative	Poor	1. 2
Piac. Scor	Negative	Poor	1. 2
Rock 1	n.a*	n.a	0. 0
Rock 2	n.a	n.a	0. 0
Rock 3	n.a	n.a	0. 0
Sela. Assp	Negative	Poor	1. 6

[1]As br=*Astragalus brachycalyx*
Cega= *Centaurea gaubae*
Erbi=*Eryngium billardieri*
Nomu=*Noaea mucronata*
Phpe=*Phlomis persica*
Soal=*Sophora alopecuroides*
Assp= *Astragalus spp.*
Coba=*Cousinia bachtiarica*
Eude=*Euphorbia descipiens*
Piac=*Picnomon acarna*
Scor=*Scariola orientalis*
Sela=*Serratula latifolia*

* n.a: not applicable

2.4.6 *Arable farming*

Both, irrigated and rainfed arable farming are practiced in the study area. Irrigated farming is limited, because of restricted availability of water resources. Rainfed arable farming is a very common practice, because, according to religious and cultural beliefs, it is considered (cereals in particular) a token of land ownership. Current practices are accelerating erosion, because of selection of the wrong sites, e.g. steep slopes, and inappropriate cultivation methods, e.g. plowing parallel to the slope aspect. Fertile topsoil is washed away rapidly, and land productivity decreases as a consequence. The principal crops are winter wheat and winter barley. Crops are harvested for grain in favourable rainfall years and grazed in unfavourable years.

The principal irrigated crops are wheat, barley, potato and forages, such as alfalfa. Sources of water are rivers, wells and small streams. According to the Esfahan Water Organization, 121 wells, 35 streams, and 66 Ghanats[4] are available.

The Provincial Agricultural Organization reports a total area occupied by gardens of 103.6 hectares, and other crops 6680 hectares, values slightly different from those of Mazroei (1992).

2.4.7 *Socio-economic conditions*

The population of the area (1992), as reported by the Department of Education is 14,788 of which 5,935 are over 7 years old. From the school age children 14% does not attend school. According to Eftekhari (1992), during 1989-1992 more than 100 families have left their villages for the cities, mainly because of insufficient income. Esfahan, Gom and Tehran are attractive cities for these migrants. Two other types of migration occur, especially practiced by young men, leading to a relative surplus of women in the study area. The first type is the search for employment in the cities, the other is associated with education. After being educated in the city, youngsters rarely return to the countryside. This migration runs contrary to government policies. However, for the study area with its limited land resources, it is not a negative development. The demographic composition shows that males are concentrated between ages 1 and 4 and females between 1 and 9. This shows that the community is very young, and indicates the urgent need for creation of employment opportunities, as

[4] Ghanat is an ancient system of water supply in Iran, in which several wells are connected to each other by an underground canal.

an alternative to migration. There are 649 carpet looms in the area, 12 welding workshops and four garages. Carpets are mainly produced by women and children, providing substantial economic benefit to the households. Moreover, children work as herdsmen and women as farmers. The distribution of the sources of revenue is given in Table 2.4.

Table 2.4: Sources of revenue in the study area (Source: Watershed Department of the Esfahan Branch of Jihad, 1992).

Activity	*Share(%)*
Agriculture and animal husbandry	74
Services	16.1
Government	5.1
Handicrafts and carpet making	4.8

2.4.8 Animal husbandry

Sedentary animal husbandry is the only extensive animal husbandry system in the study area. Herds most commonly are composed of 75% goats and 25% sheep. Cattle and calves are kept indoors and on the farms within the villages, while sheep and goats graze the rangelands (Eftekhari, 1992). Sheep and goats are of local breeds, such as Lori-bakhtiari. It is fat tailed and coarse wool breed. Average ewe weight is 50 kg, weaned lamb 20 and goat 30 (Table 2.5).

Table 2.5: Characteristics of Lori-bakhtiari breed (Sadat mansour & Siamansour, 1985).

Characteristic	Ram	Ewe
Height (cm)	70 - 75	58 – 72
Length (cm)	100 – 114	108 – 112
Matured body weight (kg)	67 - 71	50 – 67
Initial body weight (kg)	3.7	3.2
Weight of fat tail (kg)	8 - 10	7 – 8
Percent of twines (%)	-	25
Milk (lit)	-	85 - 100
Wool (kg)	2.5 - 3	2

The grazing period lasts eight months a year (May to December), which is unacceptably long. The reproductive cycle of sheep starts in October, when mating takes place. To increase pregnancy rate and twin production, supplementary feed is provided before mating (August-September). During pregnancy sheep graze on-farm and are supplemented with concentrates (October- December). January is the period of peak lambing. Grazing starts as following the onset of body weight recovery in March-April (Figure 2.7).

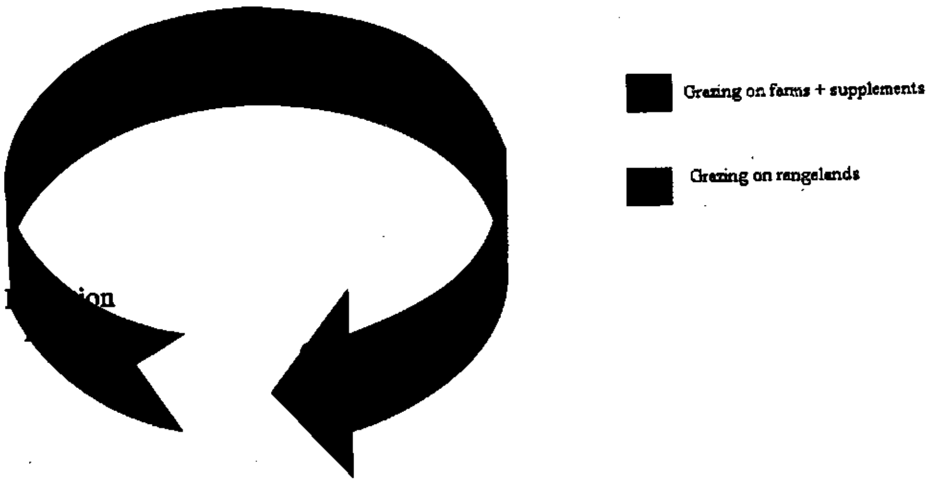


Figure 2.7 Schematic representation of the annual sheep grazing and supplementation cycle in the study area.

Some intensive livestock farms operate in the study area (Table 2.6). Government support is available for expansion of intensive animal husbandry, mostly in the form of very low interest loans and/or subsidized building materials, such as iron profiles, cement, etc.

Table 2.6: Intensive animal husbandry in the study area (Source: Eftekhari, 1992).

Animal species	*Capacity*
Poultry	40000 heads y^{-1} in two rounds
Dairy	42 heads
Sheep	2830 heads

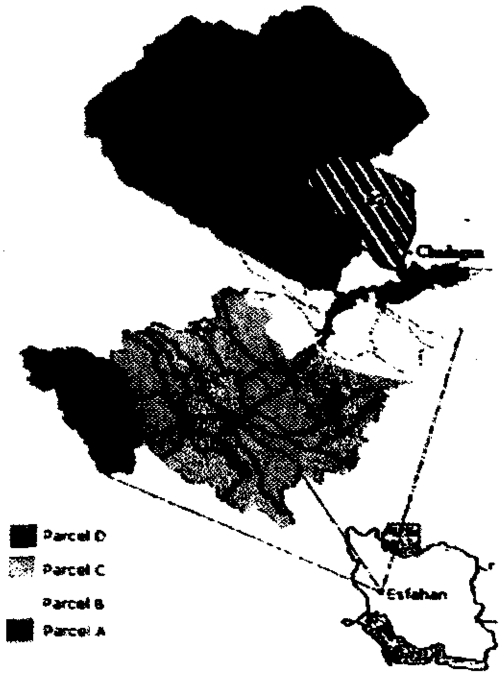


Figure 2.8 Location of the study area (B2), within the Zayanderod basin.

3 Land evaluation: procedure and operationalization

3.1 Introduction

Land, which is defined as "an area of the surface of the earth, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area" (FAO, UNDP & UNEP, 1994; FAO, 1976) is becoming a scarce resource. Impact of use by an increasing number of people is an important reason for the scarcity (Heady & Child, 1994). According to FAO and UNDP (1994), almost all land suitable for cropping is already under cultivation. Thus, farm expansion is realised mostly through conversion of natural resources, such as rangelands to other land uses.

Large areas of land, marginally or not at all suitable for crop production, have been plowed in nearly all dryland regions of the world. Much of this land has subsequently been abandoned, without any effort to protect it or restore it to productive farm land (Brengle, 1982). In Iran, conversion of rangelands to dryland cereal production, with its aftermath land degradation and subsequent land abandonment, unfortunately, has become routine procedure.

The basis for sustainable use of land is systematic assessment of land and water potentials, formulation of alternative land uses and identification of the economic and social conditions, in order to select and adopt the best land use (FAO, 1993). This process is known as land use planning, with land evaluation at its core. Land evaluation assesses the suitability of land for specified land uses (van Diepen et al., 1991).

For land evaluation, various methods exist, ranging from pure intuition and ad hoc decisions to sophisticated formal quantitative methods (van Diepen et al., 1991). Among these, the FAO methodology (FAO, 1993; 1985) has been widely applied (Alfaro et al., 1994; Huizing & Bronsveld, 1994). The area and quality of the rangelands in Iran are subject to rapid change through changes in vegetation composition as a result of inappropriate grazing practices, impact of other land uses, such as mining and industrial activities, clearing of land for rainfed farming and expansion of residential areas. In such a dynamic situation, availability of a proper land evaluation method would be welcomed by decision-makers (Zheng & Sponeman, 1989). As an answer to this need, GIS (Geographic Information Systems) techniques, that have been widely used since the 1980s (Petch et al., 1995), and allow easy processing of spatial data and maps, have been incorporated in land evaluation procedures.

This chapter deals with the description and implementation of the land evaluation procedure, the first module of the Planning Support System described in Chapter 2. Land evaluation is performed for rainfed agriculture and extensive grazing on the basis of the FAO guidelines for rainfed agriculture (FAO, 1983) and extensive grazing (FAO, 1991). Section 3.2 provides information on the concept, method, and procedures, including the terminology used in land evaluation, section 3.3 describes implementation of the methodology in the study area.

3.2 Methodology

3.2.1 Evolution

An extensive review of the historical development of land evaluation methods is given by van Diepen et al. (1991). Historically, land evaluation is rooted in soil science. The first efforts at evaluation (classification) of the land through preparation of a map originated in the geography branch of soil science. From 1950 to 1980 extensive efforts in soil mapping were undertaken in many countries with a remarkable role of soil scientists in both preparation and interpretation (evaluation) of the maps.

Land capability classification (LCC), introduced by the United States Department of Agriculture (USDA) is an important step in the evolution of land evaluation. The LCC system was originally developed to assist farmers in farm layout, crop rotation selection and design of conservation practices. LCC classifies a specific tract of farmland on the basis of its use capability. Soil map units therefore are grouped on the basis of their responsiveness to management and similarities in hazard, limitation, or risk. Americans played additional roles in the development of land evaluation by creation of two more classification methods: USBR (U.S. Bureau of Reclamation), which is a land suitability classification and Stories Index Rating, an agricultural rating of soil for purposes of land tax assessment and land use zoning. Since 1950, many interpretative evaluation systems have evolved on the basis of American methods and local knowledge.

By 1970, many countries had developed their own system of land evaluation, which seriously hampered exchange of information. FAO then took the lead in attempts at standardisation of the procedure. In 1972 the background document was prepared, and one year later, the first draft of a framework was written. This document was distributed to many scientists

and experts for comments and recommendations and resulted in a general framework for land evaluation, published in 1976 (cf. FAO, 1976). Subsequently, FAO developed a specific manual for rainfed crops: Guidelines for land evaluation for rainfed agriculture (FAO, 1983). Two years later, on the basis of the expectation that more than fifty million hectares of land could be developed for irrigated agriculture within the next 25 years, Guidelines for land evaluation for irrigated agriculture was published (FAO, 1985). In 1991, FAO issued special Guidelines for land evaluation for extensive grazing, motivated by the need felt for attention to a quarter of the world's land surface, classified as rangelands, which form the major resource for raising livestock. Development of the methodology is still in progress and new ideas are added to the procedure continuously. In the past decade, the FAO land evaluation procedures have been tested and applied in many places, both by FAO and others[1]. As examples, Land Evaluation for Environmental Planning in Yemen (Started: August 1993, End date: August 1998) and Land Use Planning in Botswana (Started: 1991, End date: December 1996) have been carried out by FAO; and by others, for example in Costa Rica and Thailand by Alfaro et al. (1994), and Huizing and Bronsveld (1994), respectively. Currently, land evaluation has been incorporated in the process of land use planning, as supported by
FAO (Figure 3.1).

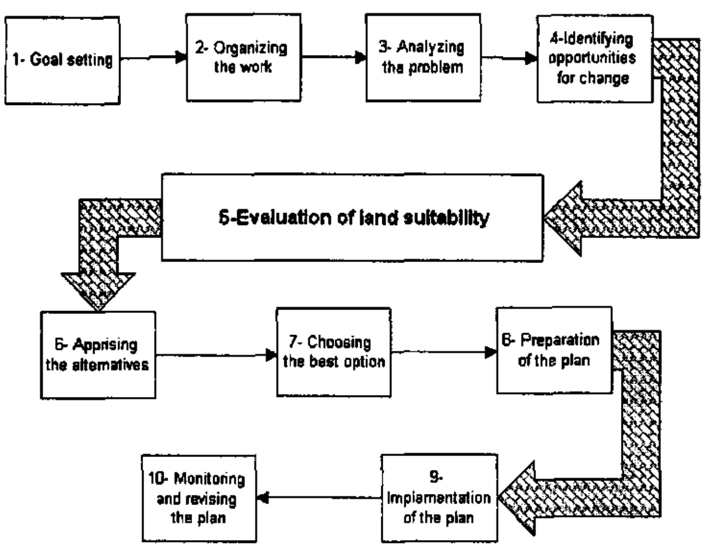


Figure 3.1 The process of land use planning with land evaluation at its core (Source: FAO, 1993).

[1] Information on FAO projects is available at www.FAO.org.

The essence of land evaluation is to compare and match the requirements of each potential land use with the relevant characteristics of each kind of land. The result is a measure of the suitability of each kind of land for each kind of land use. These suitability assessments are then examined in the light of economic, social and environmental considerations on the basis of finding an alternative plan for the use of the land in future.

3.2.2 Objectives

The principal objective of land evaluation, as described by FAO (1983), is to select the proper land use for each defined land unit. This objective may be realised by answering questions on the suitability of current land uses and/or management, identifying advantages and disadvantages of the current situation and establishing whether alternative land uses could lead to significantly improved productivity or improved protection of land qualities.

The agricultural sector in the semiarid zone cannot compete with other sectors because of its low productivity, the consequence of low and erratic rainfall. Yet, de Wit and Seligman (1992) believe that this is too narrow a view of endowment, because an acceptable livelihood does not only depend on the availability of natural resources, but also on the socio-economic context. Given the capital, the necessary land area, and a favourable input-output ratio, agriculture in the semiarid zone may support a standard of living compatible with the standards of that region. This view appears justified in Iran as witnessed by successful land improvement programs, in which land has been allocated to the people and enough capital and proper management packages were provided. Successful examples have provided enough incentives to government experts to spend substantial amounts of money and time on expansion of the program. Climatic variability and unreliability and heterogeneity of the land on the other hand have led to failures. Hence, land use and management should be selected with great care, which is the most important task of land evaluation. Therefore, an appropriate land suitability classification is of major importance prior to the implementation of land reclamation projects. Classifying government projects in two major classes, related to arable farming and animal husbandry, respectively, the suitability of the land should be tested for cultivation of rainfed crops and for extensive grazing.

3.2.3 Procedure

Prior to execution of the land evaluation, some methodological decisions have to be taken. This refers particularly to selection of the scale and intensity of the study, land uses and land use types.

3.2.3.1 Scale and intensity

Four spatial scales for land evaluation have been proposed by FAO (1991), i.e. continental, national, district and local. For land allocation, the district and local levels are recognised as relevant. At district level, vegetation, climate, culture, land tenure system, and social and economic behaviour of residents are relatively similar. The district was also the unit for most watershed management studies in Iran and ample information at this level is therefore available. In this study the scale of district is assigned to the B2 sub-catchment and local to the grazing land of a village (the village grazing usufruct).

As defined by FAO (1976), three levels of intensity may be distinguished: reconnaissance, semi-detailed and detailed. The relevant level is normally reflected in the scale of the resulting maps. Reconnaissance deals with broad inventories of resources and development possibilities at regional and national scales. Economic analyses are included only in very general terms, and land evaluation is qualitative. Semi-detailed, or intermediate levels deal with more specific aims, such as feasibility studies for development projects. Such studies may include farm surveys; economic analyses play a much more important role, and land evaluation is usually quantitative. This level provides information for decisions on the selection of projects, or whether a particular development or change is desirable. The detailed level deals with surveys for actual regional planning and design, or farm planning and advice. This type of studies is often carried out following the decision for implementation of a plan. It is claimed by FAO (1991) that for reasons of scale and costs, studies at a more detailed level than reconnaissance are not advisable for extensive grazing. For the purpose of rangeland allocation, a semi-detailed study seems adequate, because there are many problems that can not be solved in rainfed agriculture, e.g. as an alternative land use, and extensive grazing, even if detailed information is available.

3.2.3.2 Quantitative and qualitative

Two different perceptions can be distinguished with respect to quantitative land evaluation. On the one hand, that expressed by Nix (1968), that equates quantitative land evaluation with prediction of attainable yield for any crop under a defined system of management at any location. This perception has been followed by many scientists

(Goudriaan & van Laar, 1994; van Keulen & Wolf, 1986; Penning de Vries & van Laar, 1982) by combining appropriate crop growth models, which were developed completely out of the mainstream of land evaluation, with long term weather data, soil data and plant physiological data. The alternative is the perception expressed by Vink (1960), that defines quantitative land evaluation as one that includes farm economic analysis.

Land evaluation, in the first definitions of FAO (1976), was considered quantitative when economic criteria were included. Subsequently, this point of view was revised and now quantitative refers to the way of expressing the evaluation results, independent of the procedure followed.

In the FAO concept, a qualitative classification is defined as "one in which relative suitability is expressed in qualitative terms only, without precise calculation of costs and returns". A qualitative classification, as described in the framework for land evaluation (FAO, 1976), is based mainly on the physical production potential of the land, with economic considerations only present in the background. These classifications are commonly applied in reconnaissance studies, aimed at a general appraisal of large areas.

Based on these definitions, our land suitability classification falls in the category of qualitative land evaluations. This may seem at odds with the predefined achievements of the study, but it was selected, because of constraints, e.g. lack of data and the special features of the plant community.

*3.2.3.3 **Land unit***

A land unit is defined as "an area of land, usually mapped, with specified and more or less uniform characteristics, employed as a basis for land evaluation". To arrive at more or less uniform land units for rainfed agriculture, FAO (1983) suggested the following criteria for classification:

- Major climate, growing period, and agronomic zone.
- Soil series, soil association and other soil mapping units.
- Land systems and land facets.

For extensive grazing, however, a land unit classification system, based on landform, soil and vegetation, has been given preference (FAO, 1991).

In both cases, characteristics of the areas mapped in the same unit, should fall within specific (rather narrow) boundaries. When information is available, homogenous land units can be generated by selection of relevant thematic maps and overlay operations. Relevance of the maps is judged by their information content with respect to land suitability classification.

3.2.3.4 Land characteristics

For the purpose of land evaluation, land comprises all the features of the natural environment that have an influence on its potential for land use in the area under study. Hence, land is not simply the soil, rock and landform, but includes climate, natural vegetation, animals, pests and diseases (FAO, 1991).

Having unequivocally identified the land units, and demarcated them on the map, the properties of the units are summarised in their land qualities that can be translated into land characteristics and matched against land requirements. Characteristics of the land should have a significant effect on its classification, otherwise they should be neglected to restrict data collection. Land characteristics in this study were classified in three categories: common, complex and distinctive. Common characteristics are important for satisfying the land requirements, but are the same all over the study area, e.g. the study area falls in a single class of suitability with respect to rainfall. Complex characteristics are combinations of properties that can be represented by one ecological characteristic. For example, botanical composition of the vegetation is the integrated expression of many soil chemical and/or physical factors. Replacement of soil chemical analyses with ecological studies may save time and money. Distinctive land characteristics play essential roles in classification and should be quantified as accurately as possible, e.g. slope steepness.

3.2.3.5 Land use and land use types

Since land suitability can only be assessed for a specified type of land use, description of the relevant land uses is a distinct focus in land evaluation (FAO, 1991). Once land uses have been fully described, their requirements can be determined. Relevant in this context is discrimination between current and alternative land uses and determination of major land uses and land utilisation types.

Current or alternative

Land evaluation may apply to current or potential suitability of land for specified land uses, which is described by FAO (1976) as: "A classification of current suitability refers to the suitability for a defined use of land in its present condition, without major improvements. A current suitability classification may refer to the present use of the land, either with existing or improved management practices, or to a different use. A classification of potential suitability refers to the suitability of the land unit for a specified use at some future date and after implementation of the major proposed improvements".

As discussed in Chapter 2, when the current situation is not satisfactory and/or destructive, introduction of alternative land uses is inevitable for the sake of sustainability. Land evaluation in that case refers to assessment of land suitability for alternative land uses.

Need for change towards sustainable use

The first motive for conducting a land evaluation is the need for change. This need usually arises from unsatisfactory results of the current system of land use and the human aspiration for the best, which in terms of land use is the sustainable one both from economic and soil conservation points of view. The most relevant stakeholders, the local farmers, should evidently identify what is the best. It is surprising that people do not respond to the need for change, despite the fact that they are fully aware that the quality of their land is deteriorating. Why is sustainable use of land not a consideration? This is a question that can be answered on the basis of the hierarchy of needs described by Winsemius (1995) and Pieri (1997). In this hierarchy, sustainability is at the top, and is aimed at only when all other needs, situated lower in the hierarchy, are satisfied. For instance, a household starts considering safety and security, after its physiological requirements have been satisfied (Figure 3.2). Thus, in regions of low productivity, sustainability may not come to the fore, when the elementary (nutritional) requirements of the population are not completely met. Recommendations on the basis of land evaluation should try to stimulate the stakeholders towards changes in the direction of sustainability. For instance, implementation of a new agricultural land use type, leading to production of more forage is a step towards economic progress, poverty alleviation and, as a consequence towards sustainability.

Considering the point of view of de Wit and Seligman (1992) and the opinion of local experts, based on successful examples of land rehabilitation, potential productivity of the land appears higher than currently realised. Consequently, there is scope for change to an improved land use system, even though that is not considered yet by the local population.

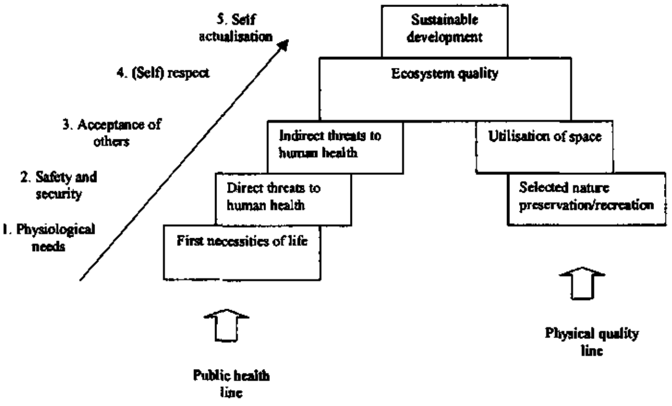


Figure 3.2 The environmental hierarchy of needs (Source: Beek et al., 1997).

Land use types

Land use may refer to broad categories, such as rainfed agriculture or irrigated agriculture, which is defined as a major land use and is "a subdivision of rural land use". A subdivision of a major land use, such as rainfed annual crops, a sub-division of rainfed agriculture, is still considered a major land use. Major land uses are normally applied in reconnaissance studies. When land uses are defined in much more detail, they are called land utilisation types. "Land utilisation 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. In detailed or quantitative land evaluation studies, the kinds of land use considered will usually consist of land utilisation types. They are described with as much detail and precision as the purpose of the study requires" (FAO, 1985).

Taking into account the objectives of land allocation in Iran, the proposed land rehabilitation program of the government and the environmental conditions of the study area, two major land uses are considered: rainfed agriculture and extensive grazing. For each, several range rehabilitation projects have been proposed by the government of Iran. Identification of land utilisation types, therefore, is based on selection of activities suitable for the ecological conditions.

3.2.3.6 Land use requirements

Land use requirements are defined as "required elements of a specific activity for successful operation" (FAO, 1991). For each land utilization type it is necessary therefore, to establish the optimum conditions for its operation, the range of conditions that are below optimum but feasible, and conditions that are outside that range.

These land use requirements are specified on the basis of a series of factors (diagnostic factors), and classified through factor ratings, which form the basis for the suitability classification of a particular land unit for specific land use types. Land use requirements for rainfed agriculture have been classified in three categories (FAO, 1983):

- Crop requirements, i.e. the physiological requirements of the crop or crops.
- Management requirements, that are related to the selected technology or management system.
- Conservation requirements, related to prevention of soil degradation.

For extensive grazing two categories of requirements are suggested (FAO, 1991): those related to the level of primary or plant production and those related to the level of secondary or livestock production. Grazing capacity is one of the key factors (attributes) in this context. Subsequently, it has been suggested that "land use requirements for extensive grazing must be grouped according to these two production levels, and where applicable, under both the requirements for growth, management and conservation should be given" (FAO, 1991).

Mirnezam (1972) discusses the effect of soil depth on production of rainfed cereals in Iran. Soil depth is an important characteristic for soil water holding capacity and, as such may be critical to the production of rainfed cereals (Brengle, 1982). Positive effects of soil depth and negative effects of steep slopes on soil moisture availability are evident (Pantastico & Venable, 1993; Schafer, 1988). Furley et al. (1996) emphasises the significant effects of soil depth, slope and soil texture on distribution of plant communities. In the words of Holechek et al. (1989) "Slope angle is of considerable importance in range management, because it affects both vegetation productivity and use by range animals", and they emphasise that "soil depth has considerable influence on range productivity, since it determines how much moisture soil can hold". Soil water holding capacity therefore was selected as a key attribute.

Natural vegetation composition, is a reflection of the potential productivity of the land and cumulative effects of land use history. It is also an important element for identification of alternative land uses, both in terms of possible alternative agricultural activities, or of changes in grazing management. As production of the rangelands is species-dependent, current yield has been identified as another key attribute. There are some examples of yield-based classifications of rangelands. In Pakistan, for instance, <50 kg, 51 to 250 kg and >250 kg have been suggested for classification of rangelands in poor, medium and high quality, respectively (Rodrigues, 1994).

According to Kardavani (1992), Iranian rangelands could be classified in five suitability classes. Recommendations for that classification are >400 kg/ha/y as class 1, 400 - 200 as class 2, 200 - 100 as class 3, 100 - 50 as class 4 and less than 50 as class 5. This classification was incorporated in our methodology. Current yield was introduced in the land requirement table to take the carrying capacity of the land into consideration.

3.3 Implementation

The land evaluation procedure consists of three phases: preparation of data, identification of relevant land uses and application of a GIS-based model for evaluation. To direct and focus data collection, problem identification and selection of land uses are required. Development of the land evaluation model comprises a phase of digitising and combining maps to generate the land units and a phase of classification of the land unit map on the basis of the land requirement table.

3.3.1 Problem identification

While the study area is presently unable to meet the needs of its current population, population growth continues. As a result, land degradation continues, through overexploitation and mismanagement. Even though Iran's new land reform may be considered a barrier against overexploitation, through land privatisation, ways must also be found for the conversion of land use systems with low productivity to more productive and sustainable land use systems. In this subsection we take a look at problems of existing land uses to arrive at identification of alternative land use systems for development of a productive and sustainable situation.

3.3.1.1 Rainfed cereal production

Zagross region is characterised as semiarid (Javanshir, 1976; Meigs, 1953), and in terms of annual rainfall should be suitable for rainfed cereal production (Heyne, 1987; Nuttonson, 1953). Grain production of rainfed wheat and barley in the study area is facing serious constraints and yields are much lower than potential, e.g. 2 tons ha^{-1} in Charmahal province

(Moradmand & Mehnatkesh, 1997) and in India (Kurmvanshi et al., 1996). Average annual yield of wheat in the study area is 400 kg ha^{-1} (Esfahan Organization of Agriculture, Annual Reports), which is considerably below the 1000 kg ha^{-1} attainable in favourable years. Yield stability, that forms an element of economic sustainability, is also low (Table 3.1). Yield fluctuations of irrigated and rainfed cereals, expressed as coefficient of variation (c.v.), are 7 and 61%, respectively. This low and erratic production of grain illustrates that "much of the semiarid land is not suited to crop production, but can be used as grazing land" (Brengle, 1982).

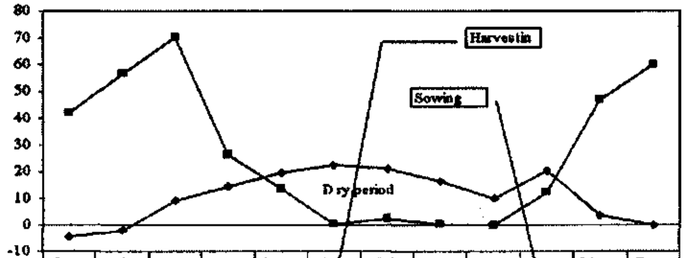
Table 3.1: Irrigated and rainfed average grain yields (kg/ha) of wheat and barley in Chadegan (Source: Esfahan Organization of Agriculture, Annual Reports).

Year	Wheat		Barley	
	Irrigated	Rainfed	Irrigated	Rainfed
1983	3000	300	3100	360
1984	2800	320	2900	350
1989	2900	180	3000	180
1990	2700	200	2800	200
1992	3300	600	3100	700
1994	3100	800	3000	700

Two major climatic problems exist for grain production: erratic rainfall and short growing period.

Distribution of rainfall

Two major characteristics of semiarid regions that are vital to agricultural production are amount and distribution of precipitation (Gregory, 1991; Cooper et al., 1987; Brengle, 1982; Gregory et al., 1978). The effect of annual rainfall on rainfed production has been studied extensively (Musick et al., 1994; Bouzza, 1990; Houérou & Host, 1977; Duncan & Woodmansee, 1975). The distribution of rainfall within the growing season, however, appears equally important (van Keulen, 1975; Lomas, 1972), and an unfavourable distribution may negatively affect yield, even if total water supply might seem adequate (Frére et al., 1987; Skima, 1970). A substantial part of the variation (61% to 93%) in yield of wheat in the Mediterranean region could be explained by rainfall distribution (Hadjichristodoulou, 1987). Analysis of 10 year rainfall data from Chadegan Climatological Station, shows that 48 mm, representing 12% of total annual precipitation (Figure 3.3) falls during the growing season (late March to late May). Thus, unfavourable distribution of precipitation is one of the main causes of the low productivity.



	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature (°C)	-4.46	-2.17	9.4	14.3	19.7	22.4	21.4	16.3	10	20.5	3.68	0
Rainfall (mm)	42.2	56.77	70.26	26.24	13.5	0.45	2.5	0.35	0.2	12.54	46.7	60.17

Figure 3.3 Seasonal variations in temperature and precipitation for the last 10 years in the study area.

Short growing period

A specific minimum heat sum is required for a crop (species or variety) to reach maturity (Goudriaan & van Laar, 1994; Nuttonson, 1953). That heat sum is calculated as:

$$\sum GDD = \int_{sowing}^{harvesting} (((T_{max} + T_{min}) / 2) - T_{base})dt$$

where,

ΣGDD = Total growing degree days (d°C)
T_{max} = maximum daily air temperature (°C)
T_{min} = minimum daily air temperature (°C)
T_{base} = base temperature (°C)

Reported base temperatures for wheat range between 0 °C (Hodges, 1991; van Keulen & Seligman, 1987; van Keulen & Wolf, 1986) and 6 °C (Alizadeh, 1989). Experimental data on heat sums of wheat are not available from the study area, hence data from a research station between Esfahan and Chadegan, located at 32° 38' N and 51° 22' E were used (Nekoei, 1992). Setting the base temperature to 0, these data suggest a total heat requirement exceeding 2000 d^{0}C for maturation of wheat *var. Sardari,* the variety used in the study area, both rainfed and irrigated. Calculations for the study area on the basis of average moisture availability, show that plants can accumulate 1662 d^{0}C, which is insufficient to reach maturity for this wheat variety. Local farmers have not changed the variety to tackle the problem. On the basis of their experiences they believe that *Sardari* is the best variety and they rather graze the wheat when the grain is not harvestable.

Financial

In addition to climatic problems, gross margin analysis of dryland wheat farming shows that the profit equals about US$ 6/ha. Therefore, from a financial point of view, it is not attractive to grow wheat for grain. During our last interviews in the study area, in 1999, many farmers no longer appeared interested in growing rainfed wheat, because they said it is not even worth harvesting.

Nevertheless, rainfed cereals is continued and occupies 39% of the study area. Various reasons exist for this land use, such as lack of alternative employment, ownership regulations and occurrence of favourable years, resulting in satisfactory yields. Moreover, 4% of the households do not own irrigated land for production of wheat, thus rainfed wheat serves as their food resource. Therefore rainfed agriculture, cereal and other crops, remains as a land use in our exploratory land use plan for:

- Avoiding social conflicts, e.g. not loosening the current sense of ownership.
- Creation of a ground for gradual land use changes toward more sustainable situation, step by step change from annuals to perennials; and
- Reseeding as an inevitable range rehabilitation activity in the study area.

3.3.1.2 Rangelands

Rangelands are negatively affected by both, unsuitable land uses, e.g. cropping on steep slopes, and inappropriate land management practices, e.g. overexploitation.

Unsuitable land uses

Expansion of dryland farming, encroaching on rangelands is an example of unsuitable land use, which is evident almost everywhere in the study area. In total, this includes now thousands of hectares of land, that, however are more suitable for grazing (Brengle, 1982).

Inappropriate management

Inappropriate range management is characterized by excessive livestock densities, and inadequate vegetation management (FAO, UNDP & UNEP, 1994). Uncontrolled exploitation of the vegetation of rangelands causes a transition from a 'higher-class' plant community, such as grass steppe to a 'lower one', such as shrub-steppe (Beskow et al., 1995). Overstocking and extended grazing periods are current characteristics of inappropriate management practices in the study area. As a result, the vegetation of the rangelands is so degraded, that the production of palatable plant species is approaching zero. A survey in the area has shown that only a handful of palatable species has remained, while inside 16 year-exclosures they are abundant. This means that the rangeland could be returned to useful grassland, if it would be managed properly. However, stocks of native seeds are low and re-seeding should be included in future management practices.

3.3.2 Data collection

Current land uses were appraised at the beginning of the study. It was accepted that there is no room for adaptation of irrigated agriculture, neither expansion (digging new wells is not allowed), nor reduction (is not acceptable). Moreover, irrigated agriculture is market-oriented and it is unlikely that crop production can be changed according to the purposes of the present study, e.g. production of more forage. More importantly, these lands are privately owned and are, therefore, not included in the land allocation program. Thus, irrigated arable cropping was not considered a relevant land use for this land evaluation. Rainfed cereals and rangelands were selected as relevant major land uses.

In 1992, the study area was investigated by the Esfahan Directorate of Watershed Management. Results of that study, e.g. soils, climate, water resources and socio-economic characteristics are used in this land evaluation. However, the information was re-examined, and updated or expanded when necessary.

The most extensively used information is that of a soil survey carried out and analysed by Eskandary (1992). On the basis of field and laboratory data, he distinguished four land types, e.g. mountains, hills, plateau and upper terraces and gravel-colluvial fans. These land types were divided in 12 land components or units taking the manual of multi purpose lab classification" (publication No. 212 of Iranian Soil Institute) into account. In this land segmentation method, land cover, slope, altitude, current land use and soil limiting factors are very important (Figure 3.4).

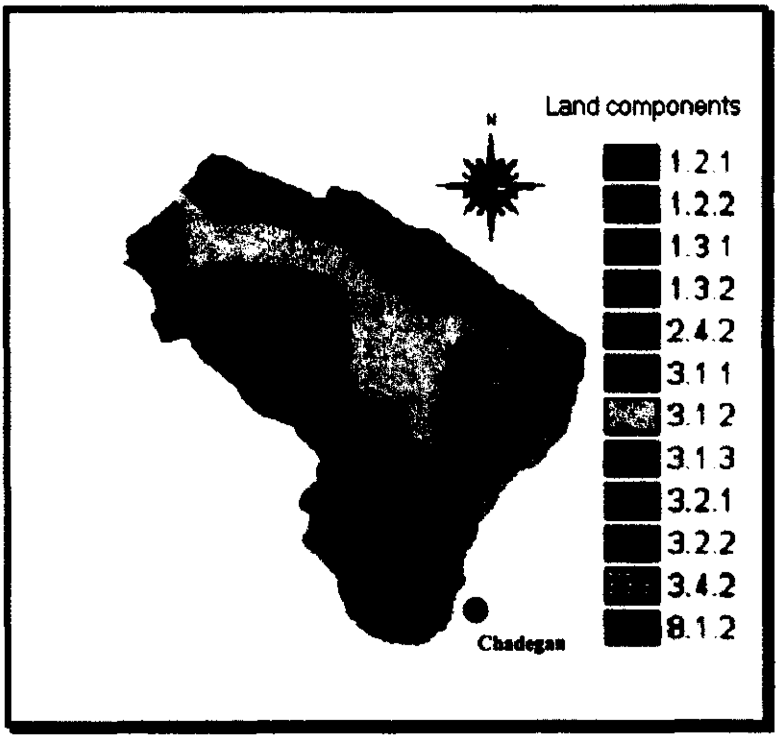


Figure 3.4 Land components of the survey area. Soil sampling points are marked.

3.3.3 Land units

From the list of land units those that are relevant to this study, not in the irrigated parts, are described. In description of the land units there are common characteristics, biased from land types, and detailed that are used for segmentation of land types to land units.

Common characteristic of land form 1.2:
High mountains, comprising sharp or round elongated peaks. Formed on lime or metamorphic stones.

Unit 1.2.1
Rock outcrops: > 70% of the area
Slope angle: 40 to 70%
Altitude: 2700 to 3642 meters above sea level
Limitations: stone outcrops, steep slops, lack of vegetation cover, short growing period and cold winter.

Unit 1.2.2

Rock outcrops:	> 30% of the area
Slope angle:	35 to 40%
Altitude:	2700 to 3642 meters above sea level

Limitations: stone outcrops, steep slops, lack of vegetation cover, short growing period and cold winter.

Common characteristic of land type 2.4:

Hills consisting of metamorphic stones and slates, associated with marl and limestone.

Unit 2.4.2

Rock outcrops:	>10% of the area
Soil texture:	dominated by clay
Slope angle:	12 to 25%
Altitude:	2265 to 2600
Limitations:	steep slopes, shallow soil, lack of vegetation cover, erosion, stoniness

Common characteristic of land types 3.1, 3.2, and 3.4:

Old and eroded plateaus, formed from alluvial material associated with slate and metamorphic stones. Soil depth ranges from shallow to very deep. Soil textures are silty clay, clay, clay loam and silt.

Units 3.1.2

Slope angle	2 to5%
Altitude:	2200 to 2560
Limitations:	Erosion, heavy clay soil

Unit 3.2.2

Slope angle	2 to5%
Altitude:	2200 to 2400
Limitations:	Erosion, shallow soil, stoniness,

Unit 3.4.2

Slope angle	2 to 8%
Altitude:	2100 to 2300
Limitations:	Erosion, limestone hard pan

Common characteristic of land types 8.1:
Colluvial fans covered by angular gravel formed from metamorphic stones and slates. Soil textures are silty clay in the top soil and clay in deeper layers.

Unit 8.1.2

Slope angle	8 to 12%
Altitude:	2400 to 2600
Limitations:	steep slopes, shallow soil, and hard pan

In addition to the soil unit map, maps of soil depth and land use, prepared during the same survey, were digitised. Six classes of soil depth were distinguished, i.e. 0-10 cm, 10-25, 25-50, 50-80, 80-120, and >120 (Eskandary, 1992). On the land use map, four types of land use were indicated: irrigated arable cropping, rangelands, rainfed arable cropping, and home gardens (Eskandary, 1992). Furthermore, bare land and rocks are shown.

Vegetation information, available as a map (Figure 3.5) and in the form of a report (Mazroei, 1992) was also used. Ten vegetation types were delineated on the map on the basis of vegetation physiognomy. For the different vegetation types, grazing capacity, range condition and trend has been determined. Nine of the vegetation types are in poor condition and characterised by negative trends and one is in fair condition and exhibits a constant trend. Two vegetation types produce more than 100 kg/ha, the others around 50.

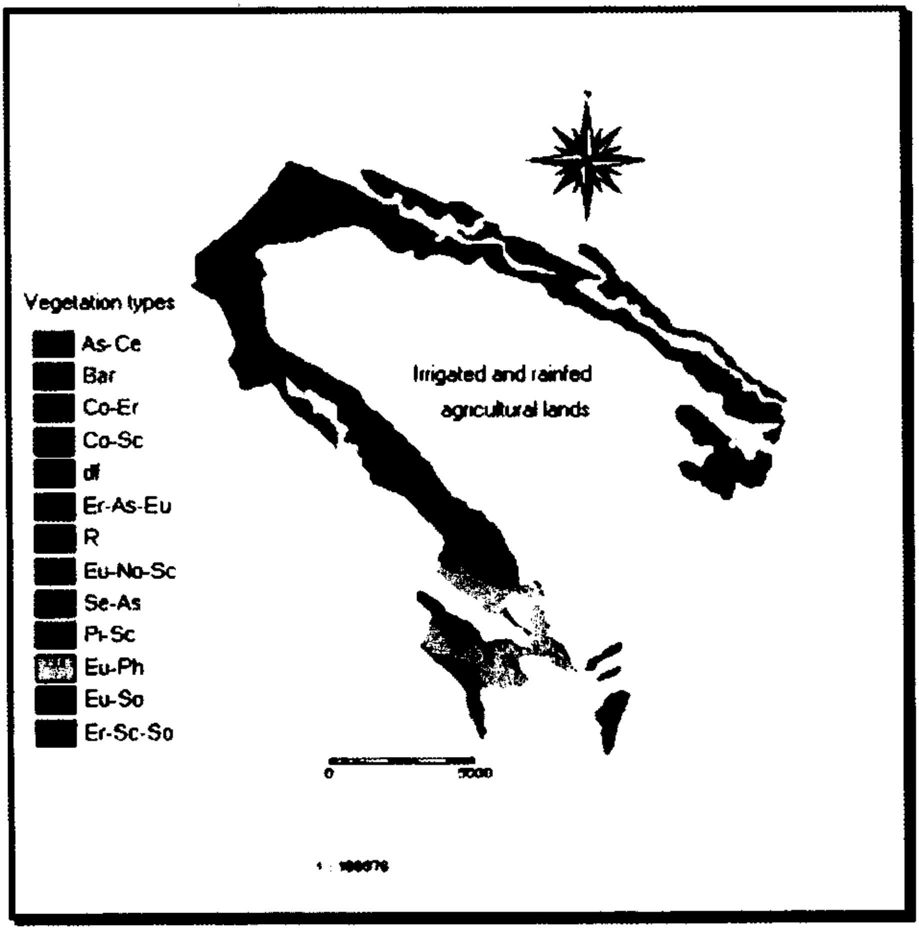


Figure 3.5 Range vegetation types. Almost all vegetation types are of low feeding value[2].

3.3.4 Land use types

Appraisal of the proposed land rehabilitation projects of the government shows that they refer to two major land uses: rainfed agriculture and extensive grazing. For a biophysical land evaluation therefore, selection of

---

[2] As = *Astragalus spp.*, Ce = *Centaurea spp.*, Bar = Bare lands, Co = *Cousinia bachtiarica,* Er = *Eryngium billardieri*, Sc = *Scariola orientalis*, Se = *Serratula latifolia,* df = Rainfed, Eu = *Euphorbia decipiens*, No = *Noaea mucronata*, Ph = *Phlomis persica*, So = *Sophora alopecuroides*, Ir = Irrigated agriculture, Pi = *Picnomon spp.*, R = Rock

these two major land uses is sufficient, because land use types will be discriminated on the basis of their management differences, which are treated in further steps of the PSS.

3.3.5 Identification of land units

Five maps were used for creation of the "land mapping units" (LMU) map: soil depth, soil texture, slope, land use, and vegetation cover. The slope map was created through interpolation of contour lines in an ILWIS[3] environment. Maps were classified first and then crossed to create a cross table. On the basis of different formulas, using map calculation facilities of ILWIS and on the basis of land requirement information (Table 3.2), two maps of land suitability classes were prepared, indicating 3 classes of suitability for rainfed agriculture and 3 for extensive grazing (Figure 3.6).

3.3.6 Identification of land use requirements

Moisture availability was identified as the most important characteristic in determining the performance of the proposed land uses. Annual precipitation, soil water holding capacity and rooting conditions therefore, were identified as criteria for definition of land use requirements for both rainfed arable farming and rangeland. Soil texture, soil depth and slope were used as diagnostic factors or key attributes (Table 3.1). On the basis of aboveground biomass of the rangeland vegetation, which is one of the factors indicating the level of required inputs for rehabilitation, two vegetation classes were defined: above (S2) and below (S3) 100 kg/ha. S1 (> 400) does not exist in the study area.

---

[3] ILWIS is a GIS package created by ITC, Enschede the Netherlands.

Table 3.2: Land requirement diagnostic factors and factor ratings for rainfed arable farming and forage production on rangelands for extensive grazing.

Land requirement	Diagnostic factor	LUTs							
		Rainfed arable farming				Rangelands			
		S1	S2	S3	N	S1	S2	S3	N
Moisture availability	Rainfall (mm)	>450	450-300	300-150	<150	>450	450-300	300-150	<150
Capacity to retain water and susceptibility to erosion	Slope (%)	0-5	5-15	15-25	>25	0-15	15-25	25-60	>60
	Soil texture	SCL	CL	SiC	C, SGr	SCL, CL	C, SiC	SiC, C	SGr
Rooting condition	Soil depth (cm)	>50	50-25	25 -10	<10	>50	50-25	25-10	<10
Vegetation condition	Weight of dry matter	-	-	-	-	>400	400-100	100-30	<30

S1= suitable S2= moderately suitable S3= marginally suitable N= not suitable

3.3.7 Land evaluation results

Four suitability classes have been identified for rainfed arable farming: 1874.5 hectares of S1, 3240.5 hectares of S2, 1223.5 hectares of S3 and 26 hectares of S4 (or N) as described in Table 3.3.

Table 3.3: Land mapping units, their characteristics, areas and suitability classes for rainfed arable farming.

LMU	Area (hectare)	Slope(%)	Soil unit	Soil depth (cm)	Suitability class
1	12.25	5-15	3.1.2	25-50	2
2	26	>25	3.4.2	50-80	4
3	26.75	15-25	3.1.2	50-80	2
4	33.25	0-5	2.4.2	10-25	3
5	78.75	15-25	2.4.2	10-25	3
6	86	5-15	3.1.3	80-120	2
7	88.25	0-5	3.2.2	25-50	2
8	91.25	15-25	3.4.2	50-80	3
9	240.75	15-25	8.1.2	25-50	3
10	304	5-15	2.4.2	10-25	3
11	365.5	0-5	3.4.2	50-80	1
12	406	0-5	3.1.3	80-120	1
13	475.5	5-15	8.1.2	25-50	3
14	512.75	5-15	3.2.1	25-50	2
15	532.5	5-15	3.4.2	50-80	2
16	1103	0-5	3.1.2	50-80	1
17	1755.75	5-15	3.1.2	50-80	2
18	1911	0-5	3.2.1	25-50	2

Examination of the LMUs for rangelands shows that 355 hectares of rangelands are suitable (S1), 3286 hectares are moderately suitable (S2), and 2810 hectares marginally suitable (S3), for range rehabilitation, e.g. reseeding. Of the land, 578 hectares are not suitable, and should be left for conservation purposes. Details of the characteristics of the LMUs and their suitability classes are given in Table 3.4.

Table 3.4: Land mapping units, their characteristics and suitability classes for rangeland for extensive grazing.

LMU	Area (hectare)	Soil unit	Soil depth (cm)	Slope (%)	Vegetation biomass (kg/ha)	Suitability class
1	35	1.2.1	0-10	>60	<100	4
2	65	1.2.1	0-10	0-15	<100	4
3	210	1.2.1	0-10	25-60	<100	4
4	174	1.2.2	25-50	0-15	<100	3
5	19	1.2.2	25-50	15-25	<100	3
6	59	1.2.2	50-80	>60	<100	4
7	11	1.2.2	50-80	15-25	<100	3
8	94	1.2.2	50-80	15-25	>100	3
9	890	1.2.2	50-80	25-60	<100	3
10	120	1.2.2	50-80	25-60	>100	3
11	16	1.3.1	0-10	15-25	<100	4
12	193	1.3.2	50-120	>60	<100	4
13	58	1.3.2	50-120	0-15	<100	3
14	129	1.3.2	50-120	0-15	>100	3
15	138	1.3.2	50-120	15-25	<100	3
16	94	1.3.2	50-120	15-25	>100	3
17	525	1.3.2	50-120	25-60	<100	3
18	60	1.3.2	50-120	25-60	>100	3
19	498	2.4.2	10-25	0-15	<100	3
20	32	2.4.2	50-80	0-15	<100	2
21	42	3.1.1	>120	0-15	<100	2
22	65	3.1.1	>120	0-15	<100	2
23	2	3.1.1	>120	15-25	<100	2
24	18	3.1.1	>120	15-25	>100	2
25	22	3.1.2	50-80	0-15	<100	2
26	204	3.1.2	50-80	0-15	>100	1
27	151	3.1.3	80-120	0-15	>100	1
28	843	3.2.1	25-50	0-15	<100	2
29	559	3.2.2	25-50	0-15	>100	2
30	745	3.4.2	50-80	0-15	<100	2
31	229	8.1.2	25-50	0-15	>100	2
32	332	8.1.2	25-50	0-15	<100	2
33	160	8.1.2	25-50	15-25	<100	2
34	184	8.1.2	25-50	15-25	>100	2
35	53	8.1.2	25-50	25-60	>100	2

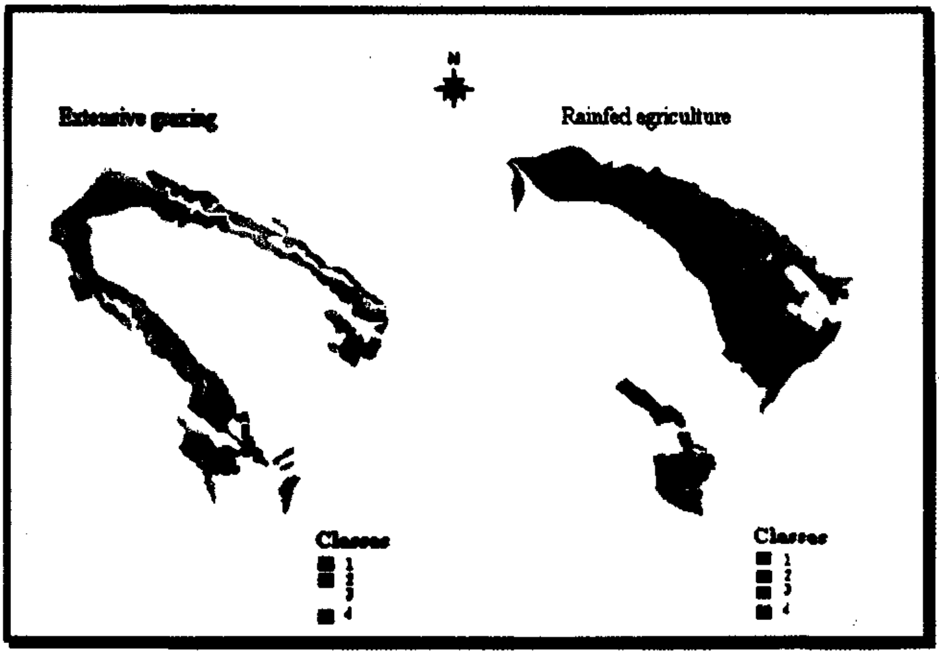


Figure 3.6 Suitability classes for extensive grazing and rainfed agriculture.

These units are used in the land use system of the PSS. For each unit a series of agricultural production techniques is specified in terms of inputs and outputs. These activities are used in further steps of the study. The land units emerging from this land evaluation also characterize the land on the basis of its production value.

3.3.8 Discussion

On the basis of the land evaluation exercise and taking into account the answers to our questions by various stakeholders, we have concluded that:

- A small part of lands (26 ha) occupied by rainfed cereals is located on steep slope having considerable soil depth (Table 3.3). This contradiction, to author's experiences, comes from mismatch of the boundaries of a map created by computer, slope map, and the soil depth map made on the basis of fieldwork. Counting on slope map as the more precise one, this small part of land is suggested to reconvert to rangelands avoiding annual plowings and it consequent erosion.
- Cultivation of cereals is deeply rooted in the culture of the local farmers and despite its ecological and economic drawbacks, it is not easy or even logical to ask for its immediate cessation. Lands classified as S1 and S2 (Table 3.1) could be used to fulfil desires of the farmers. Conversion of these lands to a mixed agricultural system,

such as a mixture of rainfed legumes and rainfed cereals appears feasible because of their considerable soil depth providing suitable rooting condition. Such an agricultural system represents a transitory situation, aiming at gradual conversion of rainfed cereals to rainfed forage. It would also be more sustainable in terms of plant nutrients, as the legumes can fix atmospheric nitrogen, part of which contributes to maintenance of grain production.

- Marginally suitable rainfed lands (S3) should return to rangeland for their shallow soil and/or steep slope (Table 3.3). This conversion from an annual crop to native perennial plants should reduce loss of soil through erosion and lead to more sustainable production.
- Small parts of the study area (355 ha), currently occupied by rangelands are located on deep soil and slight slope (Table 3.4). several agricultural practices could be applied for rehabilitation of these lands from cultivation of forage crops to conduction of grazing systems.
- Considerable area of the rangelands (3286 ha) are fallen in class 2 for extensive grazing. Presence of native species, however in small amount, calls for more cautious agricultural practices such as inter-seeding and/or proper grazing systems.
- Lands classified as S3 in Table 3.4 are covered by unpalatable species such as Astragaluses and some grasses. These areas are located on mountainous with considerable rock outcrops. Grazing systems accompanied with hand seeding, where possible, are suggested land rehabilitation practices.
- Shallow soil, severe steep slope and rock outcrops are reasons for classification of lands as S4 for extensive grazing (Table 3.4). These lands are suggested to be reserved for wildlife.

4 Development and operationalization of the district planning module

4.1 Introduction

Forages produced on rangelands are almost free for pastoralists. Recently, the government of Iran has introduced a nominal charge of 200 Rls[1] per animal per year, i.e. a negligible amount. Hence, this situation provides a very strong incentive for the population to maximise the use of forage from rangelands. It also illustrates the failure of introduction of alternative range management schemes that recommend investing in range improvement. As a consequence of overgrazing without investing in land improvement schemes, land degradation has reached alarming levels, so that many people have been forced to seek for solutions, as expressed during interviews. The current situation, therefore, appears an opportunity for experts to step in, and suggest range management methods and techniques that require more patience and money.

The total animal population in the study area is around 30000 goats and sheep. As a first rough estimate, it is assumed that daily feed requirements amount to 2 kg of dry matter for medium-sized animals, i.e. annual feed requirements for the total flock amount to approximately 21600 tons. Moreover, a total of about 2400 head of cattle are present in the study area, requiring 7000 tons of hay. Hence, total feed requirements are about 29000 tons annually.

Irrigated fodder production in the study area is around 15300 tons, originating from cultivation of *Onobrychis sativa, Medicago sativa, Trifolium spp.* and *Vicia spp.* (Table 4.1).

Table 4.1: Irrigated forages in the survey area (source: Eftekhari, 1992).

Source	Area	Yield (t/ha)	Total production (t)
Onobrychis sativa	1143	11	12573
Trifolium repens	300.5	5	1495
Medicago sativa	118	6.5	762
Others	111.5	2.7	307
Sum	1 673	-	15269

[1] US$ = 6500 Rls in 1992.

When the stubble of 2005 hectares of irrigated wheat and 607 hectares of irrigated barley, yielding about 33 kg/ha or 86 tons in total, is added, total forage production in the study area amounts to around 15400 tons annually.

To provide adequate feed for all livestock in the region, about 13100 tons (Table 4.2) must be produced from rainfed forages and improved rangelands. Studies of Vahabi (1983) and unpublished measurements of the Esfahan Research Centre for Animal Sciences and Natural Resources, during ten years outside and inside grazing excluded areas, suggest that under natural conditions, a production level of 600 kg/ha of dry matter is attainable in grazing exclosures. As that production level is insufficient to cover the identified forage deficit, alternative land use techniques should be examined that would lead to alleviation of the constraint. To reach a balance, either the number of livestock should be reduced, or forage should be imported from outside the area.

Table 4.2: Supply and demand balance of the forage in the study area.

Source of forage	Quantity (t)	Forage demand	Quantity (t)	Deficit (t)
Irrigated forage	15400	Calves	6915	
Rangelands	500*	Sheep & goats	22000	
Total	15900		29000	13100

* Current production of rangelands after Mazroei (1992).

In Chapter 3, a land suitability assessment was performed for rainfed agriculture and extensive grazing. Since these are the two major land uses, for each a number of alternative agricultural activities may be identified, representing improvements to the current situation. Whether such alternatives will actually be implemented, not only depends on their technical feasibility, but also on the socio-economic and political context of the decision making process, which requires taking into account, additional social and environmental criteria. Hence, alternative technologies must be socially acceptable, economically viable and environmentally sustainable. Then the next task is to assist the decision-makers in selection of the best alternative, which is the core objective of multi-criteria decision making methods (Jankowski, 1995). Within the Planning Support System developed in this study, a district-planning module (DPM) has been developed to support this decision making process. This module is based on a multi-objective decision making method (MODM), to identify suitable alternatives that contribute to realisation of the objectives of stakeholders involved in the decision making process, and a multi-attribute decision making model (MADM), to rank the set of feasible choice alternatives and identify the most preferred one. In Sections 4.2 to 4.6 various components of the module are described, while in Section 4.7 its application is illustrated.

4.2 Structure of the district planning module

As illustrated in Figure 2.5, the district-planning module, which is used for determination of the land use policy at district level, comprises three sub-modules, the planning sub-module (P2.1), the grazing sub-module (P2.2) and the multi-criteria evaluation sub-module (P2.3). In the planning sub-module, information on the proposed alternative LUTs, the policy views based on socio-economic information, and the quality of the land units from the land evaluation module, are combined. It makes use of a multi-objective decision model, to produce a set of acceptable alternative land use patterns. The grazing sub-module uses vegetation data of each land use pattern and livestock information, to calculate grazing capacities at district level. By considering the decision makers' priorities, e.g. those of the Office of Natural Resources (ONR) and of the farmers, and using outputs of the planning and grazing sub-modules, the multi-criteria evaluation sub-module ranks the alternative land use patterns, in support of identification of the most suitable district land use policy.

4.3 Planning sub-module (P2.1): description of the method

In this section, inputs and outputs of the planning sub-module, together with techniques and terms used in its construction are elaborated. The planning sub-module is based on techniques used in multi-objective decision making processes. Subsequently, arguments are presented for selection of a specific land use system and its components. Then, the procedure for estimation of yield potentials for alternative land uses is detailed. Finally, generation of different scenarios as output of the model is explained (Figure 4.1).

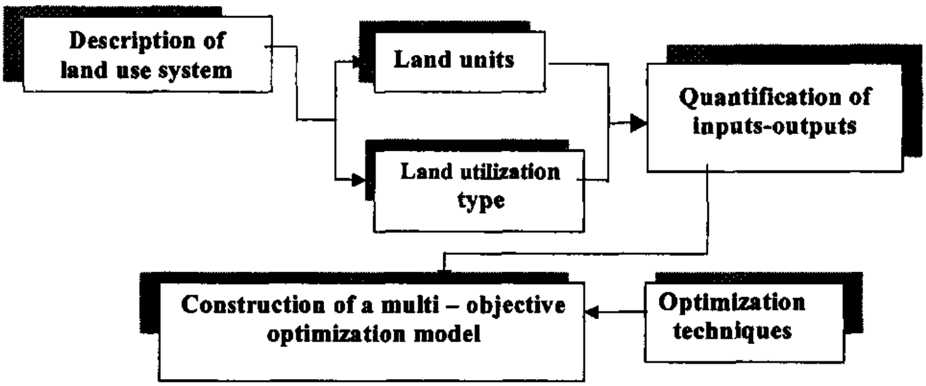


Figure 4.1 Steps in the planning sub-module.

4.3.1 Land use system

A commonly accepted definition of land use planning is: an attempt to find the best use of land considering one or several goals. As 'best' may be different for different objectives, as defined by different stakeholders, a compromise may have to be identified, that represents an acceptable land use plan, identified on the basis of an optimisation model (Schipper, 1996; van Keulen & Veeneklaas, 1995; Romero & Rehman, 1989).

An optimisation model, such as a linear programming model, optimises an objective function by selecting a set of land use activities and technologies, given a set of constraints. It is akin to the nature of these models that all activities provided for optimisation should be described fully quantitatively (Stoorvogel, 1995; Huizing & Bronsveld, 1994; El-Shishiny & Attia, 1985). As optimisation models are system-based, they require quantitative definition and description of the systems.

In the realm of land use analysis and planning, the system often is referred to as a land use system (LUS). A land use system, as any other system, should embrace a boundary, defined inputs and outputs and processes to convert the inputs into outputs (Fresco et al., 1994).
The concept of land use system and the variety of existing definitions have been extensively discussed by Mohamed (1999). The concept of LUS used in the present study is very close to the FAO definition (1991;

1983; 1976), i.e. a combination of land unit and land use type. Land use system in this study is a combination of a land suitability class (LMU) and an agricultural land use alternative (LUT).

4.3.1.1 Land units

A land unit is an area of land delineated on a map and embracing specified land characteristic and/or qualities (Fresco et al., 1994; FAO, 1976). These land characteristics are described in biophysical terms and, as suggested by Zonneveld (1997), should be homogenous at an acceptable level. As described in Chapter 3, overlaying of maps for the creation of homogenous land units may result in small and unmanageable units that are not applicable in land use planning for vast and low productive lands, such as rangelands. Therefore, land suitability classification should generate polygons of acceptable size. Uniformity of the characteristics of the polygons should be further achieved by defining classes with relatively narrow upper and lower boundaries. These polygons are used as land units in the land use system.

4.3.1.2 Land utilisation types

The most important characteristic of the land use system is the land use type, because of its dynamic character and the possibility for change. Beek (1997) also emphasises this importance in his definition of land utilisation type as a specific way of using the land, actual or alternative. Land use type has a decisive effect on inputs required and outputs of the land. It also represents the major characteristic of the functionality of the land use system.

Preference for current or alternative land use depends on identifying an appropriate concept for sustainable use and on satisfying the increasing expectation of man from land. This means that the performance of an alternative land use must have been firmly established, before selecting it. The performance of an alternative land use can be investigated through experimental research, i.e. examination of the production of different land uses under the same circumstances, wherever an example can be found (subjective procedure), or through application of theoretical knowledge as formalised in simulation models (objective method).

In the land use planning cycle illustrated by van Keulen et al. (2000), that is applied in this study, the suitability of an alternative land use is examined from two angles: biophysical and socio-economic. They argue that a land use type in an exploratory land use study should be characterised by technical feasibility, social acceptability and economic viability.

Alternative land uses are introduced in the current study to contribute to the solution of the current problems of land degradation and forage shortages and to arrive at a situation of sustainable land use. Creation of a sustainable situation in the study area requires replacement of current land use types with improved alternatives. Realisation of such replacement depends on the bio-physical suitability, economic viability, sustainability of and political support for the alternatives.

Bio-physical suitability

Bio-physical suitability of land, expressed as "technical coefficients" for alternative LUTs, could be assessed with crop growth simulation models, or acquired from qualified experts or experienced local farmers, or derived from results of experiments or from actual practices of the same land use on identical sites (Stoorvogel, 1995). Iran's Technical Office of Range (1985) has estimated that almost 12 million hectares of Iran's surface area are occupied by rainfed cereals (fallow lands included). That office also claims that only 4 million hectares of these lands are biophysically suitable for that use. Therefore, in 1985 a national plan for conversion of 2 million hectares of inappropriate rainfed cereals to legumes, or legume-cereal rotational systems, was prepared by that office and ratified by the national Higher Agricultural Council. Implementation of the plan was started in 1986 and is still continuing in 22 provinces, including Esfahan. Data from an identical land use system (LUS, Shirmohammadi, 1991) were used in the current study for estimation of its actual production level. Furthermore, a national research program is executed on productivity assessment of different varieties of *Medicago sativa* (conducted by Iran's Research Institute for Forest and Rangelands). Data collected from sites where the conversion was realised were also compared to data collected from research sites (Bagherzadeh, 1995; Ghasriani, 1992; Akbarzadeh, 1990), for selection of the most reliable results.

Economic viability

This refers to the lower level in the hierarchy of needs of local farmers as described in Chapter 3. Households are (more) likely to adopt a new technique when it is financially attractive. It has been reported that *Medicago sativa var. Gharayonge* and *Cody* have been successfully established and yielded 1 to 2.1 t/ha/y of dry matter, under conditions similar to those in the study area (Bagherzadeh, 1995). Zaeifi et al. (1994)

have reported that a mixture of 50% legumes and 50% grass appeared the most productive treatment in their trial, yielding 700 kg dry matter per hectare annually. Measurements in the framework of the current study have indicated that production levels of 1000 kg/ha for *Medicago sativa* and *Onobrychis sativa* are attainable.

Sustainability
An alternative production technique should also be environmentally sustainable, i.e. it should not present environmental hazards or loss of quality of the natural resources. Replacing annuals by permanent vegetation is a core objective in many studies aiming at protection of the soil in pursuit of sustainability. In the methodology developed in this study, coefficients, characterising the extent of permanent plant cover of all activities are calculated, and used as a criterion for sustainability. Since use of chemical fertiliser will not be continued, e.g. only at the beginning of the project 50 kg of subsidised ammonium phosphate is given to the farmers, soil fertility, to some extent, and endurance of native species should be maintained through the fraction of plant production, left on the ground as litter. Hence, a coefficient known as Proper Use Factor, expressed as a fraction of aboveground biomass (Stoddart et al., 1975), is also calculated and used as another indicator of sustainability.

Political support
This refers to government support, which is expected for the introduction of an alternative technique. Under unfavourable production conditions, such as those of rangelands in arid regions, with a relatively poor population, households are rarely willing to invest in more sustainable techniques, that become remunerative only in the long run, and require capital investment. It would therefore be advisable to propose alternatives that are inline with the policy of the government, to be eligible for subsidies and bank loans. The Government of Iran invests in the conversion of low production rainfed cereals to rainfed forages. This usually is practiced in areas with rainfall exceeding 250 mm, restricted by environmental limitations such as slope steepness and/or infertility of the soil as a consequence of annual plowing for cereals. The contribution per hectare of land comprises 50 kg of chemical fertiliser and 50 kg of seeds. In addition, the equivalent of U$[2] 62/ha as a low interest loan is provided by the Agricultural Bank. Re-conversion of cereal lands to rangelands is also supported. Up to U$ 9000 in a very low interest loan is provided for

[2] All values given in US$ are equivalent values. At the time of calculation a US$ was equal to 6500 Iranian Rials.

all participants together in a grazing usufruct, if they participate in government-supported land reclamation programs. The selection procedure for alternatives in this study is set up in such a way that the maximum contribution from the government is attained. To take into account the regulations pertaining to political support of the government, a coefficient matrix for subsidies has been calculated and incorporated in the optimisation model.

On the basis of the established criteria and the results of the land evaluation sub-module, six alternative land use types (LUTs) appeared suitable. The suitability of each of the alternatives was assessed on the basis of the degree of success of the projects reported to the Esfahan Office of Natural Resources, the study of Shirmohammadi (1991) on converted sites, and various reports from experimental sites (for example Bagherzadeh, 1995; Akbarzadeh, 1990). The alternative techniques are as yet not widely practiced in the study area by farmers. However, components of those techniques have been introduced successfully by government agencies in limited areas. Alternatives have been selected intentionally from the list of land rehabilitation techniques of the government of Iran. The benefits of this selection are twofold: first, data from sites, where rehabilitation projects have been implemented already, become available, which are used for quantification of inputs and outputs of this land use type, secondly, selection of these land uses makes the farmers eligible for government support, which provides a very important incentive to take part in the program. The alternative land use types are:

LUT1- Cultivation of alfalfa. In this system, land is allocated to a monoculture of *Medicago sativa var. Gharayonge*. The system is forage-oriented, and is a soil conservation method, because Medicago provides cover for at least 6 years.

LUT2- Allocation of 50% of the land to alfalfa and 50% to a rotation of wheat and fallow. In this system, wheat is cultivated every other year. This system is forage-and food-oriented, and has soil conservation characteristics.

LUT3- Allocation of 30% of the land to alfalfa and 70% to a wheat-fallow rotation. This is also a food- and forage-oriented system, however with less soil conserving characteristics.

LUT4- Cultivation of native grasses, in conjunction with a legume such as alfalfa or native *Astragalus* spp. This system is suitable for more harsh environments. It is a forage- and soil conservation-oriented system.

LUT5- Cultivation of a native grass, such as *Bromus tomentellus*. This system is suggested for steep slopes. It is a forage-oriented system, that promotes soil conservation, through its permanent plant cover.

LUT6- Inter-seeding; this method is used to preserve palatable species. Implementation of this LUT is cheaper and it is soil conserving. Hand seeding is applied and there is no risk for disappearance of species present.

In addition, two current land use types are included, rainfed cereals and intensive grazing, as LUT7 and LUT8, respectively.

Looking at these land use types, may lead to the question why all proposed agricultural land uses are based on reseeding, while rangelands may re-vegetate naturally. Indeed, improved management alone can lead to restoration of some degraded ranges. However, adequate seed production and seedling establishment of the desirable species are very important. Determining whether a range can be restored by natural means or will require artificial re-vegetation is a matter of judgement. The decision should be based on the types of plants remaining and their residual biomass, the expected rate of recovery, the cost of alternative approaches, and finally climate. More importantly, it depends on the production potential of reseeded sites and the consequences of reseeding for the carrying capacity. The natural rate of recovery depends on many factors, such as the types of plants remaining and their residual biomass, the size of the seed stock and soil conditions. Land that has become bare as a result of continuous farming (Figure 4.2) may take from 25 to over 75 years to completely re-vegetate naturally (Vallentine, 1989). It should be emphasized that range seeding is not a substitute for appropriate range management; in fact it requires more intensive grazing management, as will be described in the next chapter. Range re-seeding is generally suggested in regions with annual rainfall exceeding 275 mm (Vallentine, 1989), which is the situation in the study area. In addition, the selected sites are suitable, according to the criteria described by Gates (1967):

- Low quality farmland or old fields, being returned to permanent grazing land.
- Go-back land currently producing forage low in quality or quantity.

- Open rangelands with few desirable forage plants remaining, but with high potential.
- Grasslands infested with brush and having little grass left.

Figure 4.2 Range that did not improve properly even after 12 years protection from grazing. Reseeding of these devastated areas is necessary.

4.3.2 Quantification of inputs-outputs

An agricultural activity or land utilisation type (LUT) is an agricultural production technique specified by its inputs and outputs in quantitative terms (Veeneklaas et al., 1991). Inputs and outputs are usually defined as a set of coefficients, that can be incorporated in a linear programming model in a so-called I/O matrix. Columns of these matrices represent agricultural activities and rows land units, or vice versa.

4.3.2.1 Inputs

Quantification of capital inputs is based on performance of the suggested land use types, currently practiced elsewhere. These inputs comprise seeds, chemical fertiliser for the first year of the land rehabilitation program, and expenses for planting.

Labour has not been taken into account, neither as input nor as constraint, because in the region activities are based on family labour, there is no need for hiring outside labour, and usually family labour is not paid.

Expenses for planting are set to the costs of hiring the necessary tractor. The time horizon of six years used in the study, is based on the longevity of *Medicago sativa* in the region. In the model, all required capitals are combined in the matrix as a single value (Table 4.3).

Table 4.3: Required capital of the land use systems (US$/ha). Values are calculated for a period of six years.

	LMU1	LMU2	LMU3	LMU4	LMU5	LMU6
LUT1	111	111	111	-	-	-
LUT2	154	154	154	154	154	-
LUT3	145	145	-	-	-	-
LUT4	51	51	51	51	51	-
LUT5	46	46	46	46	46	46
LUT6	-	-	-	-	27	27
LUT7	106	106	106	-	-	-
LUT8	0	0	0	0	0	0

Subsidies are supplied in the form of seeds and fertiliser. Some low interest bank loans are available, however not to everybody and because of this uncertainty, they have not been incorporated, though they may form very effective policy instruments. The amount of subsidy available per hectare of each land use was calculated and incorporated in the model (Table 4.4).

Table 4.4: Subsidies for the land use systems (US$/ha).

	LMU1	LMU2	LMU3	LMU4	LMU5	LMU6
LUT1	77	77	77	-	-	-
LUT2	38.5	38.5	38.5	38.5	-	-
LUT3	26	26	-	-	-	-
LUT4	20	20	20	20	20	-
LUT5	15	15	15	15	15	15
LUT6	-	-	-	-	27	27
LUT7	-	-	-	-	-	-
LUT8	-	-	-	-	-	-

4.3.2.2 Outputs

An important issue in land use planning is estimating the performance of the suggested land uses. Yield of an alternative land use is the most suitable characteristic for comparison to the current situation and consequently its selection or rejection. This yield can be calculated or estimated at three levels: potential, station and actual.

Calculation of potential yield as described by Fresco et al. (1994) is mainly based on the genetic characteristics of the crop considered and the temperature and radiation conditions at the site where the crop is planned; all other factors influencing yield are considered to be at their optimum level. In the last two decades many models have been developed for simulation of this potential yield (Goudriaan & van Laar, 1994; van Diepen et al., 1989; de Wit & van Keulen, 1987; van Keulen & Seligman, 1987; van Keulen and Wolf, 1986). Most of these models calculate yields of annual crops during one growing season, in daily time steps. It is very unlikely that in the actual situation farmers ever can attain potential production, due to many constraints: technical, social and economic.

Station maximum yields, referring to the best yields attained on-station, under experimental conditions, are generally lower than calculated potential yields because of local soil constraints and/or sub-optimal crop, soil and water management practices, and higher than under farm conditions. The gap between yield on station and on-farm conditions is not only related to technical and climatic factors, but also to the size of the plots. An agricultural activity on a small parcel, such as on-station, receives much more attention, money and time per unit area than on a larger area, the farm of a household.

In the current study, yields are not only determined by the biophysical capacity of the land, but also by the socio-economic context, constraining development, and by the availability of the production factors labour and capital for possible alternative land use practices, i.e. actual farmer yields (Figure 4.3).

Actual yield is most reliably determined in the field under the prevailing conditions. Thus, the yield levels used in this study are set equal to the yields of the same land use systems under similar conditions.

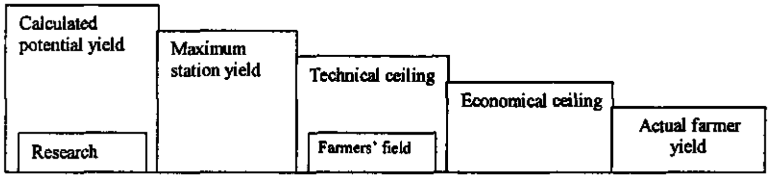


Figure 4.3 An example of yield gap analysis (Source: Fresco et al., 1994). There are technical and economic limitations at farm level.

The area of land given to a household is ultimately based on its quality, which determines its production level. This production level is proportional to the relative suitability of the land for the land use under consideration. The production level of the most suitable site for a specified land use can be set equal to that at an identical well-managed site somewhere else, but the problem of calculating the yields for other suitability classes remains.

On the basis of yield level, FAO (1976; 1983) has classified land in four classes at 25% yield intervals. These levels have been used by Fresco et al. (1994) to classify normative yields in the same suitability classes. Starting from the production level of the most suitable land, and applying the classification system of FAO, we have calculated the production level of each subsequent lower suitability class by reducing the yield by 25%.

Sustainable forage production is the main goal of the system and the main output of the system is expressed in total forage production from *Medicago sativa* and native grasses plus straw from wheat. To avoid overestimation, and consequently overgrazing in dry years, actual yield (derived from identical sites) for more water-demanding species, such as *Medicago sativa*, was reduced by 30%, derived from maximum and minimum yield reports of Bagherzadeh (1995), Ghasriani (1992) and Akbarzadeh (1990).

It is assumed that land utilisation types 1 to 3 (LUT1 to 3), producing only forage, such as alfalfa or mixtures, such as alfalfa and wheat, are cut, while the others are grazed. Thus, for soil conservation purposes and to prevent degradation of the vegetation, a Proper Use Factor was applied. In the terminology of range management, this factor is defined as the percentage of the vegetation that is exploited under proper management (Stoddart et al., 1975). The proper use factor for alfalfa was set to 95% of the actual yield, for other land use systems, in the absence of experimental data, they were defined on the basis of land quality and empirical assessments of plant characteristics (Table 4.5).

Table 4.5: Proper use factor for LUS.

	LMU1	LMU2	LMU3	LMU4	LMU5	LMU6
LUT1	95%	95%	95%			
LUT2	95%	95%	95%			
LUT3	95%	95%				
LUT4	70%	70%	70%	60%	50%	
LUT5	60%	60%	50%	50%	40%	
LUT6					40%	30%
LUT7*						
LUT8*						

* LUTs 7 & 8 are current land uses without any control for use.

Mathematically, total forage production of an area is calculated as:

$$f_{ij} = \hat{f}_{ij} * k_i * PUF_i$$

$$F = \sum_i \sum_j f_{ij} * s_{ij}$$

where,

F = Total forage produced in a given scenario (kg)

$i \& j$ = LUT and LMU, respectively

f_{ij} = Forage produced on $LUT_i LMU_j$ (kg/ha)

$\hat{f}_{ij}$ = Actual yield LUT_i from an identical site (kg/ha)

k_i = Reduction factor related to the suitability of the land

PUF_i = Reduction factor related to proper use factor of $LUT_i LMU_j$ (%)

s_i = Area of the land $LUT_i LMU_j$ (ha)

For wheat, actual yield was set to 400 kg/ha, i.e. average grain production in the study area in the current situation. It is assumed that the land suitability effect also applies to the production of wheat. Forage and wheat production of the land use systems over a time horizon of six years, as used in the model, are shown in Table 4.6.

Table 4.6: Outputs (kg of wheat and forage/ha) of the land use systems, for a period of six years from planting date.

	LMU1		LMU2		LMU3		LMU4		LMU5		LMU6	
	F	W	F	W	F	W	F	W	F	W	F	W
LUT1	4000	-	3000	-	2250	-	-	-	-	-	-	-
LUT2	2480	600	1860	450	1395	338	1046	-	-	-	-	-
LUT3	1966	840	1474	630	-	-	-	-	-	-	-	-
LUT4	2150	-	2150	-	2150	-	1613	-	1209	-	-	-
LUT5	1800	-	1800	-	1800	-	1800	-	1350	-	1012	
LUT6	-	-	-	-	-	-	-	-	900	-	900	-
LUT7	642	1200	482	900	361	675	-	-	-	-	-	-
LUT8	-	-	-	-	-	-	540	-	405	-	304	-

Note: F and W refer to forage and wheat, respectively.

Expected revenues of anticipated activities are summarized in Table 4.7.

Table 4.7: Revenues (US $/ha) of the land use systems, as a result of anticipated agricultural activities.

	LMU1	LMU2	LMU3	LMU4	LMU5	LMU6
LUT1	297	223	167	0	0	0
LUT2	257	193	145	108	0	0
LUT3	262	197	0	0	0	0
LUT4	250	250	250	188	141	0
LUT5	207	207	207	207	155	116
LUT6	0	0	0	0	110	110
LUT7	120	90	68	0	0	0
LUT8	0	0	0	33	25	19

The degree of cover by the vegetation in critical times (April and May), is an important issue in the eyes of environmentalists for its soil conservation role. Land cover of the land use system in the model is therefore considered an output of the system (Table 4.8).

Table 4.8: Estimated land cover (%) at critical periods (late April to late May) for relevant LMU/LUT combinations. The remainder is bare land, stones and litter.

	LMU1	LMU2	LMU3	LMU4	LMU5	LMU6
LUT1	80	60	45	-	-	-
LUT2	40	30	22	17	-	-
LUT3	26	19	-	-	-	-
LUT4	40	40	30	30	22	-
LUT5	35	35	35	30	30	10
LUT6	-	-	-	-	30	20
LUT7	20	20	15	-	-	-
LUT8	-	-	-	10	10	10

4.3.3 Construction of a multi-objective optimisation model

Following quantification of inputs and outputs of the land use systems, we introduce the environment and technique for examining the functionality of the system. The problem of land allocation rarely results in a unique solution, because of the (at least partially) conflicting objectives of various stakeholders. Hence, for analysis of the problem, a model is required, capable of tackling such type of problems, and allowing generating alternative solutions.

A multi-objective decision making model is used, when a decision maker is faced with several conflicting objectives, and a number of continuous decision variables bounded by mathematical constraints (Romero and Rehman, 1989). The planning sub-model comprises an interactive multiple goal linear programming (IMGLP) model to simulate the situation.

In this sub-section, the way in which the land allocation problem at district level is solved through application of a linear programming model is explained.

4.3.3.1 Why different objectives?

The objectives in agricultural land use planning have extended beyond providing income by producing food and fibre (Zander and Kächele, 1999). The multiple objectives mostly originate from the growing concern about sustainability of the land resources, and require arriving at an acceptable compromise, including effective contributions of all parties involved. This has been expressed by Grant and Thompson (1997) as " the most reliable way to modify human behaviour for effective natural resources management is to bring key decision makers through a process of discovery". Identification of the different objectives and their incorporation in the planning exercise, is a contribution to that process, in addition to providing appropriate information on land use options. Generation of different scenarios, as a consequence of the inclusion of the different objectives, enables the land use planner to integrate the results in such a way, that opportunities and limitations, relationships, and interdependencies become explicit. Especially important in this type of planning is accepting the existence of conflicting goals, and showing their trade-offs in contributing to sustainable agricultural development (van Kooten, 1993; Romero and Rehman, 1989). Examples of conflicting objectives in the study area are production of wheat, a desire of the farmers, but opposed by environmentalists or a reduction in subsidies, advocated by financial specialists, which is at odds with realisation of rehabilitation of the land, planned by the government.

4.3.3.2 The role of linear programming in land use planning

Land use planning is directed to finding the best use of land, in view of accepted objectives and environmental and social opportunities and constraints (Schipper et al., 1995). Linear programming is a tool, in which an objective function is optimised by selecting from alternative activities (opportunities), subject to a number of constraints. Linear programming therefore is a suitable tool for selection of the best land use and can play a major role in land use planning.

Linear programming allows integration of knowledge from various disciplines and provides facilities to analyse the impact of various factors in land use planning, as illustrated at farm level by Sharifi (1992). Among the advantages, quoted by Sharifi (1992) for application of linear programming in land use planning are:

- Incorporation of different production techniques for producing various crops by treating each alternative technology as a separate activity.
- Incorporation of quality differences in resources, by treating each quality class of a resource with its own set of technical coefficients and right hand side.
- Support of policy analysis by translation of policy issues into specific analytical questions that can be addressed by the model, to simulate the response to possible policy changes.
- Support of multi-objective decision problems by using composite, compromise or interactive multiple goal programming techniques.

Linear programming models have been widely used in solving land use problems (Campbell, 1988; Campbell & Heady, 1979; Heady & Timmons, 1975). Summarising, a LP model is a mathematical model and provides a wide variety of insights for different levels of decision making, which otherwise would not be easily discerned (Campbell et al., 1992).

4.3.3.3 Interactive Multiple Goal Linear Programming (IMGLP) as a technique in the Multi-Objective Decision-Making (MODM) process

In the realm of multi-objective decision-making (MODM) for land use planning, the decision-maker can focus on the IMGLP technique. This technique allows progressively more detailed specification of the decision-maker's preferences through an interactive process on the basis of the model.

In the first round of this process, the maximum and minimum values of each goal are established, after which interaction with the decision-maker starts. Not all the goals can attain their most favourable value at the same time. Therefore, the decision-maker is asked to set certain limiting values for various goals (as constraint or bound) and to indicate which goal should be optimised. Then the model is solved and the decision-maker will judge the result. If the decision-maker is not satisfied, tighter limits may be set for some or all of the goals and the model is run again. The process can be repeated several times, until the decision-maker is satisfied (Schipper, 1996).

4.3.4 Objectives of the model

The model will try to meet the identified conditions for sustainable use of the land. Maximisation of gross margin and forage production in conjunction with minimisation of capital inputs and subsidies are economic objectives of the model to guarantee acceptability of the results by different stakeholders. Production of a minimum amount of wheat is introduced as a goal to generate socially more acceptable solutions. Environmental considerations are included through maximisation of the vegetation cover. Stakeholders, their goals and criteria are shown in Table 4.9.

Table 4.9: Various goals, purposes and criteria according to different stakeholders.

Interested stakeholder	Goals	Purpose	Outputs (criteria)
Farmers Pastoralists LONR	More income (A better lifestyle)	More forage More stock	*More* Income
LONR Environmentalists NGOs EDWM ONA	Biophysical sustainability	Multiple use of the land Higher quality/quantity of the plants	*Higher* vegetation cover *More* Metabolizable energy and crude protein
The governor Courts LONR Farmers Pastoralists ONA	Social security	Employment Political stability Common satisfaction Self-sufficiency of the district	*More* Forage Wheat Grazing capacity
LONR Farmers Pastoralists ONA Environmentalists	Sustainable ecosystem	Holistic management approach Soil conservation Water harvesting Biological erosion control	*Less* Subsidy *Smaller* Area of current land uses *Higher* Grazing capacity *More* Forage Wheat

LONR = Local Office of Natural Resources
NGO = Non Governmental Organization
EDWM = Esfahan Directorate of Watershed Management
ONA = Organization of Nomads' Affairs

4.3.5 Scenarios

A scenario is defined here as a set of assumptions about the operating environment of a particular system at a given time (Turban, 1995). Scenario is a well-known term in the realm of land use planning studies and contains three elements: a description of the current situation, a number of alternative futures and a set of pathways from the present to the future (Hinloopen & Nijkamp, 1984; Schoonenboom, 1995; Veeneklaas & van den Berg, 1995). A land use scenario is defined as a set of hypothesised changes in the socio-economic and/or biophysical environment (Stoorvogel, 1995). Scenarios may be analysed through an optimisation model, which is often a linear programming model. Different scenarios, based on different hypotheses, may be generated in a relatively short period of time, which is useful in the process of land use policy analysis.

Three scenarios have been generated on the basis of ideals of different stakeholders:

Maximum benefit: more productive lands can contribute to the revenues of the households more effectively. Non-judicious use of the land is reduced or may be abolished completely, when it produces more income. This scenario aims at maximization of the income of the households and its solutions are assumed to be welcomed by farmers, pastoralists and LONR.

Minimum subsidy: minimization of subsidy use is selected as objective in this scenario, as sustainable use of the ecosystem in a holistic management approach should not rely on subsidies. This approach is supported by LONR, ONA and the agricultural bank. Reduced subsidies, however, are not appreciated by farmers.

Maximum land cover: Protection of the soil is the objective of this scenario. This objective plays a role in the considerations of LONR, environmentalists, NGOs, EDWSM and ONA .For these stakeholders the social impacts of the results are of secondary importance, as they consider conservation of the land an important task of the present generation.

4.3.6 Structure of the model

The model consists of five main components:

1- Indices: in the GAMS[3] notation, used in this study, indices are called sets and are assigned to land mapping units and land use types, with 8 and 6 members, respectively:

sets
*lut land use type /lut1*lut8/*
*lmu land mapping unit /lmu1*lmu6/*

2- Given data: data are introduced in table and vector formats. In the model, vector data are defined as parameters. The area of land mapping units is the only parameter in the model, while all inputs plus expected monetary revenues of the systems are introduced as tables.

[3] Information on this software is available on Internet at http://www.gams.com.

The example below shows this one parameter, lndx (abbreviation for land area), with its domain, LMU.

Parameter lnd x(lmu)
/Lmu1 1499
Lmu2 2592
Lmu3 978
Lmu4 335
Lmu5 3285
Lmu6 2810/;

The six tables in the model, identified by "in", "ca", "fp" & "wp", "sub" and "co" represent expected income (Table 4.7), capital required (Table 4.3), forage and wheat production (Table 4.6), subsidy levels (Table 4.4) and vegetation cover (Table 4.8) of the land use systems, respectively. Domains of all tables are LMU and LUT.

3- Decision variables "x" (endogenous variables): variables should be declared by a variable statement. Each variable is given a name and a domain, if appropriate, and optionally a text. The objective function that should be maximised or minimised is a variable without domain. In a multi-objective decision making process, the objective function is changed each run, to represent one policy view.

variables
f objective function
x(lut,lmu); (x hectares of land from specific lmu allocated to specific lut)

Positive variable x;

4- Equations: These represent constraints (inequalities) to restrict the feasible area on the basis of available resources for fulfilment of the desires of the stakeholders, and equations for calculation of outputs. Equations are declared in separate statements.

5- Command line: this line specifies whether the objective function of the model is subject to maximisation or minimisation.

The definition of constraints in the planning sub-model was rather an elusive exercise. The objective value of one scenario could constrain the objective of the next scenario. As indicated, three scenarios were considered, representing the four policy objectives of stakeholders. The value of the constraints in the given scenarios, are calculated in an interactive and iterative procedure, using information on the original values and their corresponding values in the zero rounds. Therefore, different values for one constraint in different scenarios is related to interactivity of the procedure and the trade off between specified constraint and other factors i.e. area of unimproved lands. The objective and constraints in each scenarios is given in the following:

Objective and constraints of* Maximum benefit*: (Sc1)

Max z

z =e= sum((lut,lmu),(x(lut,lmu))*((in(lut,lmu)+(sub(lut,lmu)))-(ca(lut, lmu))));

In words: maximise the gross margin (z) over all LUTs and LMUs.
In mathematical notation:

$$\text{Maximize } z{=}e{=}\sum_i \sum_j x_{ij}\left(\left(in_{ij} + sub_{ij}\right) - ca_{ij}\right)$$

$$i = 1,\ldots,n \;\; and \;\; j = 1,\ldots,m$$

where,[4]

x = area of the land
i = index of lut (n)
j = index of lmu (m)

Land constraint:
land(lmu)..sum(lut, x(lut,lmu)) =l= lnd x(lmu);
In words: summation of the area over all LUTs on one LMU must not exceed the area of that LMU.

In mathematical notation: $\forall j \quad land\ x_j \geq \sum_i x_{ij} \quad i = 1,\ldots,n$

Investment constraint:
invest..sum((lut,lmu),x(lut,lmu)(ca(lut,lmu)-sub(lut,lmu))=l=568895;*
In words: summation of the investments over all LUTs and all LMUs should not exceed the current value by more than 10% equal to US $ 568895 for the study area. In this equation, investment is the money that

[4] x, i and j are consistently used the same for all mathematical notations.

the land users themselves should spend on the land and equals the total money required for rehabilitation minus the subsidies.
In mathematical notation:

$$\sum_i \sum_j x_{ij}\left(ca_{ij} - sub_{ij}\right) \leq 568895 \quad i = 1,...,n \text{ and } j = 1,...,m$$

Subsidy constraint:
*subss..sum((lut,lmu),x(lut,lmu)*sub(lut,lmu))=l=158496;*
In words: summation of the subsidies over all LUTs and LMUs should not exceed the maximum value allowed equal to US$ 158496.
In mathematical notation:

$$\sum_i \sum_j x_{ij} \times sub_{ij} \leq 158496 \quad i = 1,...,n \text{ and } j = 1,...,m$$

Wheat constraint:
*we..sum((lut,lmu),x(lut,lmu)*wp(lut,lmu))=g=486000;*
In words: summation of wheat production over all LUTs and all LMUs should exceed the wheat requirement of 4% of all district households equal to 486000 kg for the study area.
In mathematical notation:

$$\sum_i \sum_j x_{ij} \times wp_{ij} \geq 486000 \quad i = 1,...,n \text{ and } j = 1,...,m$$

Objective and constraints of* Minimum subsidy *(Sc2)

Min subsidy
*subsidy=e=sum((lut,lmu), sub(lut,lmu)*x(lut,lmu));*
In words: minimise subsidies over all LUTs and all LMUs
In mathematical notation:

$$\text{Minimize } subsidy = \sum_i \sum_j x_{ij} \times sub_{ij}$$

Forage constraint:
*forage..sum((lut,lmu),x(lut,lmu)*fp(lut,lmu))=g=15080825;*
In words: total forage produced over all LUTs and all LMUs should exceed the minimum required, which is equal to 15080825 kg for the study area.
In mathematical notation:

$$\sum_i \sum_j x_{ij} \times fp_{ij} \geq 15080825 \quad i = 1,...,n \text{ and } j = 1,...,m$$

Wheat constraint:
*wheat..sum((lut,lmu),x(lut,lmu)*wp(lut,lmu))=g=25992;*

In words: summation of wheat produced over all LUTs and all LMUs should exceed the minimum possible value. This value is calculated in an interactive and iterative procedure considering the trade of between production of wheat and other activities and the area of land that remains unimproved.

In mathematical notation:

$$\sum_i \sum_j x_{ij} \times wp_{ij} \geq 25992 \quad i = 1,\dots,n \text{ and } j = 1,\dots,m$$

Land constraint:

land(lmu)..sum(lut, x(lut,lmu)) =l= lndx(lmu);

In words: summation of the area over all LUTs on one LMU should not exceed the area of that LMU.

In mathematical notation: $\forall j \quad land\ x_j \geq \sum_i x_{ij} \quad i = 1,\dots,n$

Objective and constraints of* Maximum land cover *(Sc3)

Max coverage

*coverage =e= sum ((lut,lmu),x(lut,lmu)*co (lut,lmu));*

In words: maximise vegetation cover of the land over all LUTs and all LMUs.

In mathematical notation:

Maximize $coverage = \sum_i \sum_j x_{ij} \times co_{ij}$

Land constraint:

lndc(lmu)..sum(lut, x(lut,lmu)) =l= lndx(lmu);

In words: summation of the area over all LUTs on one LMU should not exceed the area of that LMU.

In mathematical notation: $\forall j \quad land\ x_j \geq \sum_i x_{ij} \quad i = 1,\dots,n$

Subsidy constraint:

*subss..sum((lut,lmu),x(lut,lmu)*sub(lut,lmu))=l=277200;*

In words: summation of subsidies over all LUTs and all LMUs should not exceed the maximum available subsidies for the region that is US$ 277200 for Chadegan region.

In mathematical notation:

$$\sum_i \sum_j x_{ij} \times sub_{ij} \leq 277200 \quad i = 1,\dots,n \quad and \quad j = 1,\dots,m$$

4.4 Grazing sub-module (P.2.2)

Management of grazing systems is generally more complex than that of either a crop or livestock production system, because the manager must balance the nutritional requirements of different classes of stock with a food supply that varies seasonally and may show large variations between years (Finlayson et al., 1995). In land use planning for rangeland, identification of the sustainable grazing capacity is very important. That is also the case in our PSS model, because of its effect on the size of the economically viable livestock enterprise. Estimates of the grazing capacity take into account both, the quantity of the forages and their quality and the requirements of the animal.

4.4.1 Animal requirements

Body size

The quality of forage, in terms of intake by animals, can be expressed in the nutrient value index (NVI, Crampton et al., 1960), which is the daily intake of digestible forage per unit metabolic body weight, relative to standard forage. Metabolic body weight is defined as live body weight to the power 0.75 ($W^{0.75}$). This is based on the fact that animal heat production is proportional to its surface area, which in turn is proportional to $W^{0.75}$. Metabolic body weight is used in calculations of daily intake and required metabolizable energy.

Energy

Effective utilisation of nutrients by the animal is conditional on an adequate supply of energy, which is of paramount importance in determining the production of the animal (NRC, 1981). Energy deficiency, if continued, leads to overall weakness of the animal, and consequently to reduced fertility, milk production, etc. (Singh and Sengar, 1970; Sachdeva et al., 1973). Rangelands are composed of a mixture of plant species, and its nutritional quality can vary, depending, among other factors, on its botanical composition. In the model, the energy supplied by a range is calculated as the summed energy content of all species present in a clipped sample.

Energy content of feed stuffs can be expressed in different characteristics, e.g. GE (gross energy), DE (digestible energy), ME (metabolizable energy) and NE (net energy), and can be determined with various methods, e.g. microbial and enzymatic method, chemical analysis, physical and structural characteristisation and near infrared reflectance spectroscopy. ME is used most frequently, and also in this study.

Protein

Proteins are principal constituents of the animal body and are continuously needed in the feed for cell repair and synthesis processes (NRC, 1981). Below a level of 6% crude protein in the diet, intake is reduced. Continued protein deficiency leads to growth reduction and reduced disease resistance. A qualitative assessment of the forage of a range, therefore, should include also its protein content. In this study, however, we focus on metabolizable energy content of the plant species for the following reasons:

- Average protein content of the available forage in the study area will increase through introduction of legumes in the land use system.
- Metabolizable energy is used world-wide as a quality characteristic by animal nutritionists (ARC, 1965; van Es et al., 1978; AIAS, 1981; Gartner & Hallam, 1984).

4.4.2 Supply and demand

With respect to feed supply, schematically, three situations can be distinguished on rangelands: (i) energy requirements are equal to supply, (ii) energy supply exceeds demand, (iii) energy demand exceeds supply. In association with these three conditions, it is assumed that:

- If available forage is of high quality, rumen fill is not attained, since feed requirements are met before that fill is reached (van Soest, 1985).
- Because of the negative relationship between digestibility and intake (van Soest, 1985), daily intake is equal to fill when energy supply and demand are almost equal.
- Under energy-deficient conditions on the range, animals should be supplemented with high-energy feed.

In the grazing sub-model, these three conditions for each land use type are identified by comparing energy supply and energy demand.

The model calculates energy supply in a subroutine through an iterative and interactive procedure (Figure 4.1). Demand is calculated in the main model, when information is available on weight and type of the livestock (Figure 4.4).

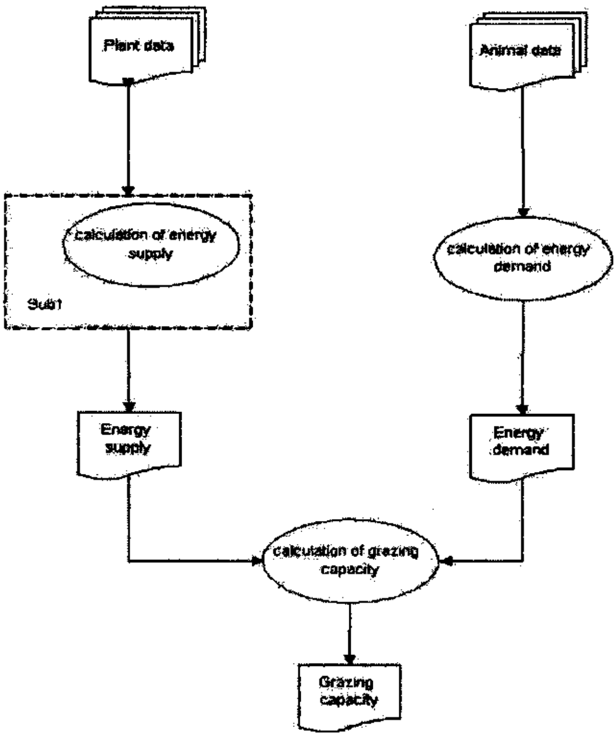


Figure 4.4 Structure of the grazing sub-model.

Energy supply

Metabolizable energy and crude protein contents of the most dominant rangeland species in Esfahan province were measured at different phenological stages by Ghorchi (1995) and Sadeghian (1996), using in situ procedures, synthetic bags and fistula (Table 4.10). The information relevant to the grazing period is selected and used. Energy supply of rangeland equals the sum of the energy contents of the constituent plants. A sample of vegetation, in a quadrat, is clipped, and after determining species composition, its metabolizable energy calculated as below. Taking into account the size of the quadrat metabolizable energy per unit area with the same vegetation composition is calculated.

$$RME = (ME_1 * P_1) + (ME_2 * P_2) + ... + (ME_n * p_n)$$

where,

RME = Total metabolizable energy (MJ/kg).

$ME_{1..n}$ = Metabolizable energy of plant species 1 to n (MJ/kg).

$P_{1..n}$ = Percentage of species 1 to n in the vegetation composition.

Table 4.10: Energy and protein contents of ten dominant range species of Esfahan province (adopted from Sadeghian, 1996).

Species	Energy (MJ kg^{-1})	Protein(gr kg^{-1})
Bromus tomentellus	7.54	97
Agropyron trichophorum	8.8	92
Stipa barbata	7.12	49
Astragalus cyclophyllus	9.22	135
Onobrychis melanotricha	8.8	119
Eryngium billardieri	8.88	132
Ferula ovina	6.7	134
Cachrys ferulacea	9.64	117
Medicago sativa	9.9	162
Vicia variabilis	7.96	220

A sub-routine has been developed to interactively process information on the type and proportion of forage species available on each land use type (Figure 4.5). The procedure continues until the sum of the percentages reaches 100. Total energy content is then returned to the main program for further calculations, as well as to the screen for information (an example of the model is presented in Appendix 1).

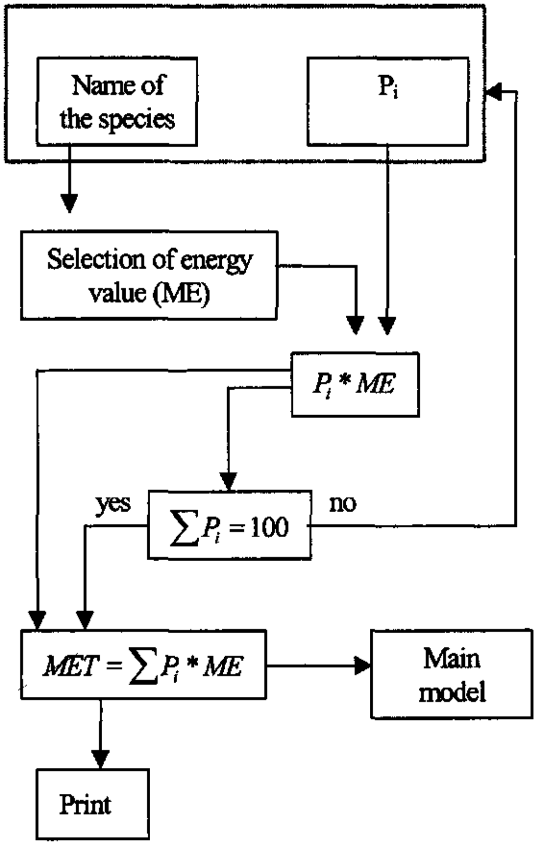


Figure 4.5 Algorithm of the energy supply sub-routine. P_i is the percentage (by weight) of species$_i$ in the sample collected from the range.

Energy demand

Estimation of daily intake of the livestock serves two purposes. First, it allows calculation of the grazing capacity in a routine procedure. Second it defines daily ME availability to the livestock from the rangelands. Rumen capacity is defined as the quantity of material that can be ingested, before rumen distension causes cessation of intake, and is assumed to be a function of animal live weight (Grovum and Williams, 1977). Daily animal intake is often expressed as a function of metabolic weight. Empirical results show that daily consumption of sheep and goats is between 3 (Crampton et al., 1960) and 5% (Haenlein, 1978) of their live weight. For the study area and the local animal breed, livestock experts have suggested the following equation, closely resembling that of Haenlein (1978):

$$DI = 0.13\,W^{0.75}$$

where,

DI = Daily dry matter intake of the animal (kg).

W = Live weight of the animal (kg).

Various equations have been proposed for calculation of metabolizable energy requirements of sheep and goats (cf. Finlayson et al., 1995; Gartner & Hallam, 1984). MAFF (1975) calculates metabolizable energy required for maintenance (MEM, MJ/d), as:

$$MEM = 1.8 + 0.1W$$

Complex models have been developed, that take into account all aspects of grazing behaviour (cf. Herrero, 1997). These models are difficult to apply because they are data-demanding. An intermediate model is that of Finlayson et al. (1995), that calculates metabolizable energy required for a 'normal' sheep and/or goat, including the growth of tissues and wool, and has been applied in this study:

$$MEI_{normal} = \left[\gamma 3 - \frac{\gamma 4 EBW}{EBW_{max}} \right] * EBW^{0.73}$$

where,

MEI_{normal}= Metabolizable energy required for a 'normal' level of maintenance, tissue and wool growth (MJ/d)

$\gamma 3$ = 1.833 MJ $kg^{-0.73}d^{-1}$ (Source: St-Pierre and Bywater, 1987)

$\gamma 4$ = 1.095 MJ $kg^{-0.73}d^{-1}$ (Source: St-Pierre and Bywater, 1987)

EBW = Empty body weight (kg)

EBW_{max} = Empty body weight of an average animal at maturity (kg)

4.4.3 Grazing capacity

Grazing capacity is defined as the maximum stocking rate a rangeland can support without deterioration (Ibrahim, 1975) or the maximum stocking rate of an animal type with a specific production objective, that a certain land unit can support without deterioration during a defined grazing season (FAO, 1991). Grazing capacity in these definitions is not explicitly linked to the quality of the forage, which is, however, a very important characteristic. In our model, calculation of grazing capacity starts from daily intake of the animal, which is determined by the interactions between required metabolic energy, physical capacity of the rumen and availability of the various pasture components. In a formal definition, this implies that grazing capacity is the maximum stocking rate a range can support on the basis of its supply of metabolizable energy. On the basis of this definition, the quality of land, the associated quality of the forage and the status of livestock are combined, albeit implicitly. Sustainability enters the definition through the proper use factor in the calculation of the available forage supply of the land use system.

As discussed, grazing capacity, is calculated by comparing energy supply and demand. Three calculation procedures for grazing capacity are given, in dependence on the nutritional situation (i) demand and supply equal, (ii) demand exceeds supply, and (iii) supply exceeds demand.

(i): Energy supply in the daily intake from forage approximately equals demand. Daily consumption is assumed equal to rumen capacity, and grazing capacity is calculated as:

$$GC = \frac{FA}{DC * 30}$$

where,
GC= Grazing Capacity (A.U.M.(=Animal Unit Months/ha))
FA = Forage available on range (kg/ha)
DC = Daily consumption of the livestock (kg/AU)

(ii): Daily energy supply is less than demand. Hence, livestock must be supplemented with a high-energy source, such as barley. However, as rumen capacity is limited, daily intake from rangelands and the supplement combined should meet the energy requirements, while rumen capacity should not be exceeded. The ration is then calculated as:

$$\begin{cases} aX + bY = MEI \\ X + Y = DC \end{cases}$$

where,
a = Energy content of range forages (MJ/kg).
b = Energy content of supplement (MJ/kg).
MEI = Energy requirement of the livestock (MJ/d).
X = Daily intake from rangeland (kg).
Y = Daily intake from supplement (kg).
DC = Total daily intake (kg).

Grazing capacity per month is subsequently calculated as:

$$GC = \frac{FA}{x * 30}$$

(iii): Daily energy supply exceeds daily demand. The animal will eat to satiation. Daily intake from the range (DCR) is calculated as:

$$DCR = \frac{MEI}{a}$$

where,

a = Energy content of range forages (MJ/kg).

Grazing capacity, per month, then equals:

$$GC = \frac{FA}{DCR * 30}$$

In the module, demand and supply are calculated and compared, and the grazing capacity of the range for the three foregoing situations will be calculated (Appendix 1).

4.5 Multi-criteria evaluation sub-model

Selection of the best land use pattern, on the basis of results from the planning module, is the next step in the land allocation procedure. In the PSS, preferences of decision makers are taken into account through the multi-criteria evaluation sub-module to support selection of the land use pattern closest to their desires.

4.5.1 Concept

The concept of multi-attribute (criteria) decision making (MADM) can be defined as the process of classifying and arranging a set of options in such a way that choice is facilitated and accelerated. MADM includes several attributes , also referred to as criteria, in the decision making process. An attribute is a characteristic of an option/object, that can be evaluated objectively or subjectively by one or several persons, according to a measurement scale (Colston & Bruyn, 1989). On the basis of the values of these attributes and the priorities that the decision maker assigns to each one, also referred to as weights, the available options are evaluated and one of the following types of results is generated:

- Identification of the best alternative (accepted).
- Identification of the worst alternative (rejected).
- Complete ordination of alternatives.

Multi-attribute decision-making makes use of at least one two-dimensional matrix. One dimension of the matrix represents the various alternatives and the other the criteria by which the alternatives must be evaluated and ranked. The estimated or calculated impact of each alternative on each criterion is called criterion score and these scores are values of the matrix cells.

4.5.2 Methods

The multi-attribute decision making procedure (Figure 4.6) starts with construction of the two-dimensional matrix, the so-called evaluation matrix (Voogd, 1983) or effect table (Janssen, 1992). Elements of this matrix reflect the characteristics of a given set of choice possibilities that are determined on the basis of a given set of criteria. For example, in this study, the outcome of each scenario is a land use plan, or one choice possibility, that may be evaluated on the basis of many criteria, such as forage production, net benefits, wheat production, etc. The characteristic of a choice possibility with respect to a specific criterion, such as kg of forage, appears in the table as criterion score. Priority or relative importance of each criterion will be derived at a later stage.

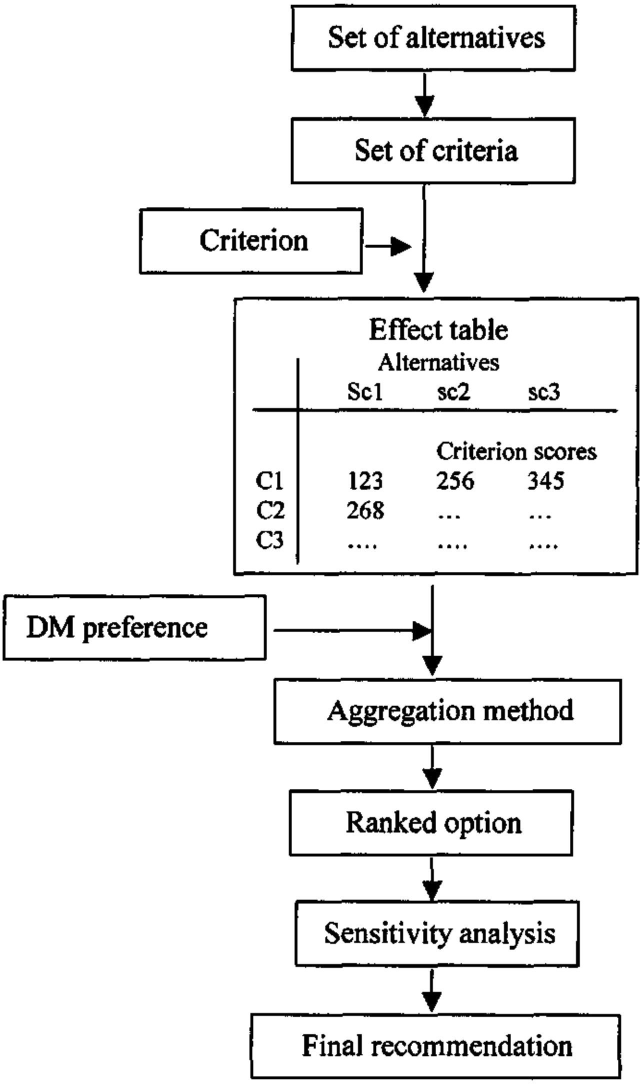


Figure 4.6 General structure of the Multi Criteria Evaluation (MCE) model (from Sharifi, 1998).

The next step is selection of the evaluation method. Many methods are available, mostly based on aggregation of the partial utility of each score/attribute and its associated preferences, yielding a unique preference structure for the whole set. Three types of evaluation methods are frequently applied (Sharifi, 1998):

- Aggregation of criteria (attributes) to form unique meta-criteria. This is also referred to as the compensatory approach. These methods are based on the hypothesis that poor performance of one alternative option in one aspect (criterion/attribute) can be compensated by high performance in another aspect. Examples of this approach are weighted summation and multi-utility methods (Janssen, 1992). These methods are quantitative, hence suitable to express the level of attractiveness of the alternatives. They require quantitative criterion scores, and priorities and provide a complete ranking, and information on relative differences between alternatives (Janssen, 1992).
- Outranking, which is based on pair-wise comparison of all alternative options. This is also referred to as the partially compensatory approach, based on the assumption that in the real world some forms of compensation are acceptable, others not. An example of this approach is the ELECTRE method, commonly used in France (Roy, 1978; Janssen, 1992).
- Non-compensatory approach, which assumes no compensation between the criteria. An example of this approach is the Dominance method (Sharifi, 1998). In this method, elimination is based on thresholds set for each criterion scores.

In this study, the weighted summation method was used, applying facilities of DEFINITE software, to rank the alternatives. The weighted summation method is slightly detailed for information purposes.

Very often, criteria scores belong to different categories of measuring units, for example, kilogram and hectare. To make them compatible, they have to be transformed into one common measurement unit through standardisation. Three types of standardisation methods have been described by Voogd (1983):

1) $\textit{Standardized score}_i = \dfrac{\textit{Score}_i}{\sum \textit{score}_i}$

2) $\textit{Standardized score}_i = \dfrac{\textit{Score}_i}{\textit{Maximum Score}_i}$

3) $\textit{Standardized score}_i = \dfrac{\textit{Score}_i - \textit{Minimum score}_i}{\textit{Maximum score}_i - \textit{Minimum score}_i}$

Standardisation is conversion of the value of the effect from "fact" to value judgement. All three transformation methods illustrated transform the value of score i to a value within the range 0 to 1. These methods are purely mechanistic, while some value conversion methods rely on value judgement of decision makers. In those methods, commonly a scale from 0 to 100 is used to cover the range from the accepted minimum to maximum values of the criteria, as based on the expectations of the decision-maker(s).

A simple form of these transformation methods is called direct interview technique, in which the decision-maker is invited to supply numerical values for certain criterion scores, with the best and worst scores assigned the values 100 and 0, respectively. When some intermediate values are available, a relation between effect value and value judgement can be calculated and the complete curve can be plotted by means of interpolation. Consequently, all values of effects can then be tabulated in the so-called value or effect table (Binat, 1992).

4.5.3 Evaluation of the scenarios

Evaluation of the scenarios involves selection of the criteria, determination of the impact of each scenario on each of the criteria, i.e. the criterion scores and deciding on the degree of importance of the criteria. Selection of the criteria may be based on attainability, veto approaches or desirability (Voogd, 1983; Sharifi, 1998). In this study the criteria have been selected on the basis of desirability, which involves judgement of the degree of realisation of the objectives of decision makers. The most important aspiration of the farmers in the area is production of more forage, the fundamental component in improvement of extensive grazing systems. This is accompanied by concerns on soil conservation, the aspiration of LONR's experts. On the basis of these aspirations, six criteria have been selected and scored for all scenarios:

- Forage production and carrying capacity: These two criteria are so closely intertwined that they should be considered as a single criterion; because of the effect of the quality of the forage, carrying capacity has been scored and used in the effect table. For calculation of the grazing capacity of the range, the composition of the herds was set equal to the current situation in the study area, e.g. 25% sheep and 75% goats.
- Land cover: This characteristic is of great concern to both environmentalists and natural resource experts, as it directly affects soil erosion, one of the major processes causing land degradation. Land cover represents the degree to which the soil is protected by plant cover. It is of special importance at critical periods, i.e. when

high-intensity rainstorms may induce soil loss. For natural vegetation, the covered area was derived from measurements on grazing-excluded sites in the study area. For Medicago, the value of Jing Hua (1996) was adopted, e.g. 80%.

- Gross margin: Profitability is of high priority for the farmers. Gross margins for all land uses were calculated for a period of six years, under the assumption of an annual inflation rate of 20%.
- Subsidies: For all suggested land use types, except production of wheat, the government supplies subsidies. These subsidies are used as a policy instrument to stimulate implementation of the desired projects, aiming at rehabilitation of rangelands. The amounts of subsidies are fixed and they are routinely scored.
- Production of wheat: Wheat is traditionally and culturally part of the heritage of the local population of the study area. It is also important from the food security point of view and sufficient wheat production would facilitate implementation of the scenarios. Wheat production was scored as its average in recent years.

4.5.4 Priorities

Priority setting is the responsibility of decision-makers. Answers of stakeholders to questions asked in the current research revealed three major directions of concerns: economic, social (=cultural) and environmental. Consensus exists among stakeholders on the highest priority for economic criteria, e.g. forage production and gross margin. The next priority, from the local farmers' point of view, is assigned to cultural issues, as exemplified by the production of wheat. This is not in agreement with the opinion of environmentalists. The lowest priority is assigned to environmental factors, represented by vegetation cover.

The methodology used for assigning priorities is called Analytical Hierarchy Process. The aim of this method is to derive quantitative weights from qualitative statements on the relative importance of criteria, obtained from pair-wise comparison of all criteria (Janssen, 1992). A nine-point scale is applied to express differences in importance:

1- equally important = 1;
2- moderately more important = 3;
3- much more important = 5;
4- very much more important = 7;
5- extremely more important = 9.

In this context, first a criteria tree structure was developed and at each level of hierarchy the pair wise comparisons within the elements of each sub-set/criteria was carried out.

4.5.5 Sensitivity analysis

Multi-criteria evaluation comprises several components. Uncertainty, associated with the results may originate from ambiguity in one or all its components, such as criteria, criterion scores or criteria priorities. To examine the effects of such uncertainties on the final result, a sensitivity analysis can be performed. Such a procedure of course, is irrelevant, when criterion scores and priorities can be estimated with complete certainty, and when all methods of evaluation yield more or less the same ranking of the alternatives. Since that is not normally the case (Voogd, 1983), sources of uncertainties should be identified. In this study, a MonteCarlo method as defined by Janssen (1992) and implemented in DEFINITE software was used to assess the sensitivity of the ranking to the scores (score uncertainty) and to the weights (weight uncertainty). Since only one method is used, there is no need for analysing method uncertainty.

4.6 Operationalisation of the methodology

4.6.1 Land use systems

Land use systems are composed of eight land utilisation types and six land units. On Figure 4.7 suitability of LUTs on different LMUs are shown on the map. The legend however gives information on applicability of the LUTs on different LMUs. For example LUT1 can be applied on LMU1 to LMU3. Empty boxes refer to LUTs not applicable on the specified LMU.

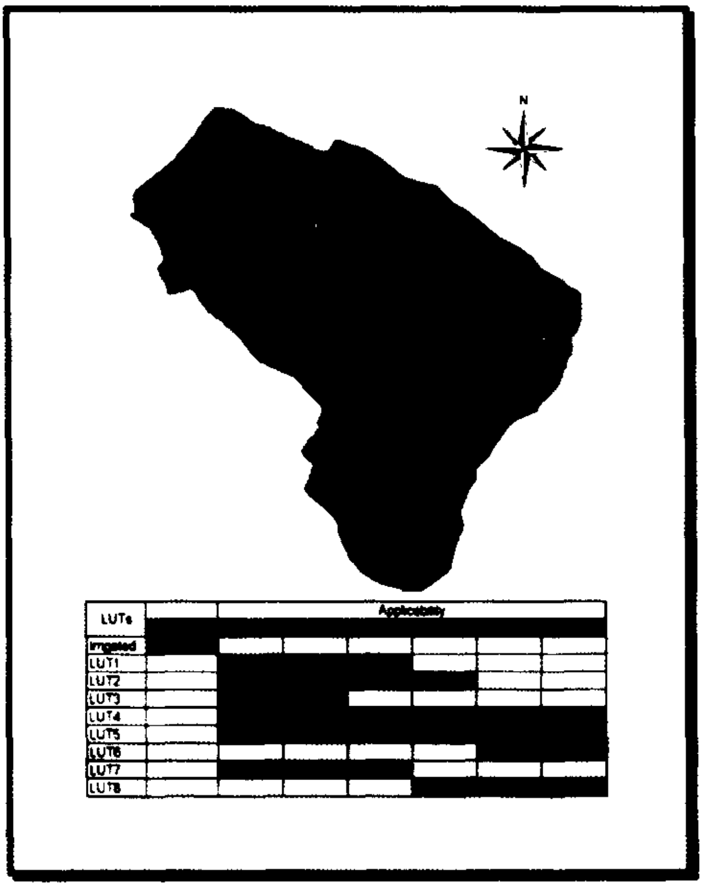


Figure 4.7 Land use system is illustrated as a map and a legend. Suitability of each LUT on each LMU is shown by filled boxes. Links between the LMUs in the legend and their location on the map are shown by different colours.

4.6.2 *Generation of land use policy scenarios*

A scenario is generated on the basis of realisation of the objective(s) of stakeholders. Unlike the irrigated sector of the region, usually farmers do not have unambiguous ideas about sustainable use of the rangelands, partly because of their place in the hierarchy of needs (Chapter 2) and partly because of the lack of a sense of ownership. On the other hand, local government representatives pursue various reasonable, albeit sometimes conflicting, objectives in their land deed program. Mohamed (1999) suggests that in land use planning, different objectives should represent conflicting choices, but should not totally contradict each other. In this sense, conflicting but not contradicting objectives of experts were expressed through three policy views: "economic", with major emphasis on gross margin, "cultural", represented by emphasis on production of wheat and "environmental", represented by vegetation cover in critical periods and the area of land remaining untouched. The associated objective functions were set as: maximisation of income (maximum benefit scenario), maximisation of vegetation cover (environmental scenario), and minimisation of subsidies (political scenario).

For generation of the scenarios, first a base model was constructed, applying the IMGLP technique. Coefficient matrices, constraints and objective functions were set as single goals and a simple linear programming model was constructed and run for the so-called zero round. In this round, in each of the runs, the constraints are set to their minimum values. To attain the extreme value for each of the objectives, the model was run in the zero round for all policy views and the results recorded as *extreme solutions*. Then the values of the constraints were varied within the feasible area to reach an acceptable solution, which is identified as the *compromise solution*. The land use pattern generated in each scenario is used to calculate the grazing capacity of the scenario. Other attributes are calculated within the LP model. All attributes together are characterised as a *land use scenario*.

4.6.3 *Application of the grazing sub-module*

Average weight of the local breeding-ewe is set to 50kg and of the goat to 30. Daily intake of ewe and goat are calculated as 2.5 and 1.5 kg dry matter respectively (Appendix 1). Energy demands for ewe and goat are also calculated as 19 and 12MJ/d respectively. For calculation of energy supply and associated grazing capacity, the sub-module was run for the land use system of all scenarios (Table 4.14 row carrying capacity).

4.6.4 Scenario analysis

The LP model was run for three scenarios: maximum benefit (SC1), minimum subsidies (SC2) and maximum land cover (SC3). In all scenarios, incorporation of current land uses (LUTs 7 and 8) was avoided as much as possible through examination of different objective values and constraints. For comparison, the same criteria were used and scored for the current situation, serving as the base scenario.

Base scenario (current situation)
Currently, annual forage production on rangeland (including the portion of straw fed to animals) is 469 tons and wheat production 799 tons. No subsidies are granted and it represents 1261 hectares (equal to 10% of the total area) of land cover. Total annual income is US$ 5955. Assuming a grazing period of three months, grazing capacity equals 833 animal units.

SC1: Maximum benefit

As farmers are entrepreneurs, their highest ambition is to realise the maximum possible benefit. The government also aims at increasing the benefits from the land. In the model, benefit is affected by costs and subsidies. The current level of government subsidies available for Chadegan region is equal to US$ 46200/y, which is insufficient for land reclamation, even if all regional subsidies would be allocated to the study area (for nearly 12000 hectares). As that is an unrealistic assumption, we have assumed (rather arbitrary, for illustration purposes) a maximum of 70% allocated to the study area. In view of the economic situation of the farmers, it was also assumed that the total investment by local farmers for rehabilitation should not exceed 10% of the current total investment for production of wheat. These assumptions were incorporated in the model for the generation of a compromise solution. Following an interactive (interaction with natural resources experts) and iterative procedure, a compromised solution was achieved with values for income, subsidies and grazing capacity 13, 22 and 18%, respectively, below their extreme values. Compared to the current situation, however, improvements are significant (Table 4.11)

Table 4.11: Results (annual values) of a compromise solution in the 'Maximum benefit' scenario.

Criterion	Current situation	Extreme value	Compromise value	Difference from extreme (%)	Difference from current (%)
Forage (kg)	469 441	3 539 708	2 972 688	-16	84
Wheat (kg)	798 625	0	77 600	100	-90
Subsidies (US$)	0	52 832	30 799	42	Infinite
Land cover (ha)	1 261	4 177	3 183	-24	60
Income (US$)	5 921	325 244	284 045	-13	98
Investment (US$)	89 552	98 474	93 573	5	-4
Carrying capacity (AUP)*	833	5 478	4 488	-18	81

* Carrying capacity is calculated on the basis of available forage for consumption of an animal unit (AU) for a grazing period of three months (P).

The distribution of land use types on land mapping units (Figure 4.8) illustrates that a contribution of current land uses has to be accepted, due to restricted availability of subsidies.

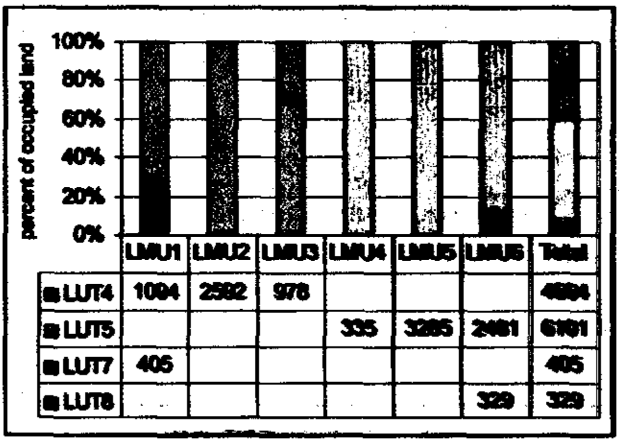


Figure 4.8 The overall pattern of land use in SC1.

SC2: Minimum subsidies scenario

This scenario is in line with the objectives of government agencies: They aim at reducing the subsidies, without endangering the range rehabilitation program. Hence, subsidies are minimised, subject to the condition of production of at least half the amount of forage and wheat produced in other scenarios. The results for this scenario are given in Table 4.12.

Table 4.12: Results (annual values) of the 'Minimum subsidies' scenario. Since the extreme value of the subsidies approaches the current situation, it is not included in this table.

Criterion	Current situation	Minimum subsidy scenario	Difference from current situation (%)
Forage (kg)	469 441	2 271 158	79
Wheat (kg)	798 625	4 332	99
Subsidies (US$)	0	21 437	100
Land cover (ha)	1 261	2 621	52
Income (US$)	5 922	232 702	97
Investment (US$)	89 552	57 431	36
Carrying capacity (AUP)	833	3 475	76

In this scenario, 22 hectares of current rainfed cereals and 4584 hectares of current grazing systems are retained (Figure 4.9).

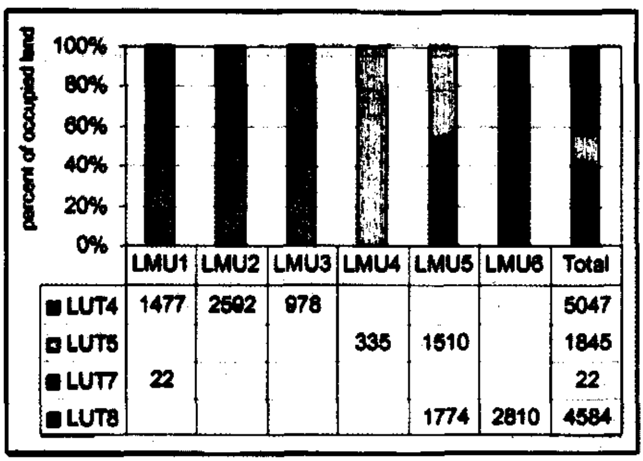


Figure 4.9 The overall pattern of land use in SC2.

SC3: Maximum land cover

This scenario emphasises the objectives of environmentalists, expressed here as maximisation of land cover as a contribution to soil conservation through reduction of the impact of rain on the soil. Maximising land cover results in required subsidies that exceed availability. Land cover was therefore maximised again with subsidies limited to the maximum available for the region (Table 4.13).

Table 4.13: Results (annual values) of a compromise solution for the 'Maximum land cover (Environmental)' scenario.

Criterion	Current situation	Extreme value	Compromise value	Difference with extreme value (%)	Difference with current value (%)
Forage (kg)	469 441	3 912 768	3 288 753	-16	86
Wheat (kg)	798 625	0	0	-100	-100
Subsidies(US$)	0	87 026	46 200	-47	Infinite
Land cover (ha)	1 261	4 843	3 968	-18	68
Income (US$)	5 922	297 206	294 536	-1	98
Investment (US$)	89 552	134 454	91 843	-32	2
Carrying capacity (AUP)	833	6 448	5 086	-21	84

In this situation, still 1293 hectares rangeland remain unimproved (LUT 8, Figure 4.10).

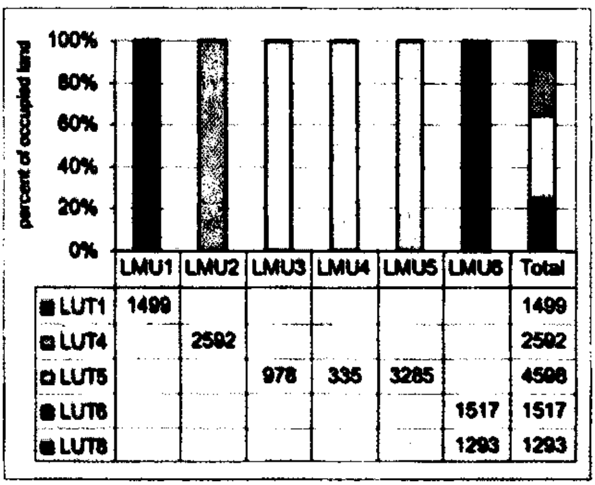


Figure 4.10 The overall pattern of land use in SC3.

4.6.5 *Multicriteria evaluation of different scenarios*

The relevant criteria were selected and classified in three groups: economic, social and environmental. For each group, relevant factors were determined and scored to generate the effect table (Table 4.14).

Table 4.14: The effect table.

	Unit	Base	Sc1	Sc2	Sc3
Economic					
Investment	US$	89552	93573	57431	91843
Income	US$	5955	284045	232702	294536
Carrying capacity	AUP	833	4488	3475	5086
Subsidy	US$	0	30799	21473	46200
Culture					
Wheat	Kg	798625	77600	4332	0
Environment					
Land cover	Hectare	1261	3183	2621	3968
Current land use	Hectare	6430	329	4584	1293

Notes:
Current land uses should be avoided due to their environmental damages and are taken into account as cost.
$SC_{1..3}$ = Scenarios
AUP = Animal unit per grazing period

Subsequently, using the reactions of the decision makers, the farmers and experts, priorities were assigned to the criteria by pair-wise comparison of their level of attractiveness. The method used for standardisation was the goal method in which the decision makers pronounce their opinion on both, the maximum and minimum values expected. Income for example, can be financially lowered to zero (Table 4.15) because environmentalists believe that the value of the land is not rather financial but it is tie to self guarding of the environment. Dominant perceptions on priorities from decision maker's point of view are:

Economy > cultural > environmental
Carrying capacity > income > investment > subsidy
Current land use > land cover

Table 4.15: Weights for the criteria.

	Standardization method	Minimum range	Maximum range	Weight level 1	Weight level 2	Weight
Economic				0.6		
Investment	Goal	250000	561440		0.142	0.085
Income	Goal	0	1767216		0.251	0.15
Carrying capacity	Goal	3000	5086		0.547	0.328
Subsidy	Goal	0	277200		0.061	0.036
Culture				0.2		
Wheat	Goal	0	4791		1	0.2
Environment				0.2		
Land cover	Goal	1200	3968		0.25	0.05
Current land use	Goal	0	6430		0.25	0.15

Scenarios were evaluated using the weighted summation method. The result shows (Figure 4.11) that scenario 3 (environmental) is the most attractive.

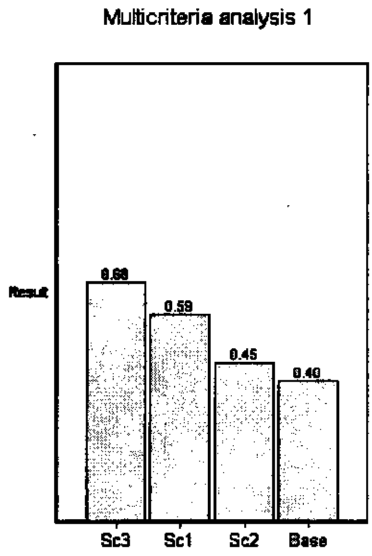


Figure 4.11 Result of the multi criteria analysis.

The results of ranking scenarios are shown in Figure 4.11. As it is shown in Table 4.14 current situation represented by base scenario is not economically attractive in terms of the level of investment and income and its final output, the carrying capacity, while Sc3 presents outstanding results for income and carrying capacity. Base scenario, which is culturally attractive, cannot compete others for its economically low output and environmentally large areas of unimproved lands and creation of minimum land cover. Sc3 culturally shows weak, for its none wheat production. Sc3 defeats Sc1 for its higher grazing capacity and land cover. This scenario is a strong alternative to Sc3 and can be selected if farmers are insisting on cultivation of the wheat.

4.6.6 Sensitivity analysis

A range in uncertainty for each effect can be derived from the maximum deviation of the scores from the values included in the effect table or from the weights used. For example, if the score for an effect is 200, an uncertainty of 10 percent indicates that the confidence interval for the score is between 180 and 220. This results in a probability table. Each entry in this table represents the probability that an alternative assumes a certain rank number, given the expressed uncertainty percentages on the effect scores.

Sensitivity of the ranking of scenarios to the value of the criterion scores and weights was tested. It was assumed that the scores and weights for all criteria may deviate by 20% from the values used (Table 4.16).

Table 4.16: Probability table assuming 20% deviation for weights and effects.

Alternatives/Positions	1	2	3	4	Total
Sc3	0.580	0.050	0.260	0.110	3.100
Sc2	0.010	0.460	0.530	0.010	2.490
Sc1	0.020	0.480	0.200	0.300	2.220
Base	0.380	0.010	0.020	0.590	2.180

This probability table shows that the ranking, given an uncertainty of 20%, is sufficiently reliable. The probability that Sc3 is the best alternative (rank 1) equals 58%. The probability that Base is the worst is 59%.

4.7 *Problem of subsidy allocation*

An important problem encountered in this study is that of allocation of subsidies. Results of the district planning module show that the current system of subsidy allocation defies its purpose, because the total subsidy requirements over all land mapping units and all land use types exceeds the available subsidies. This is related to the large variation in subsidy absorption of the various land use systems. Most of the available subsidies are channelled to the more productive activities, such as LUT1 (Table 4.17). This means that the government is focusing on expansion of these LUTs. However, as available subsidies decline, the capacity of the government to stimulate implementation of alternative land use types decreases. In that situation, they might:

- Withdraw support from productive LUTs, that are subsidy-demanding and allocate the money to other LUTs to expand the land rehabilitation scheme as much as possible. This is socially and environmentally desirable, but is counter-productive with respect to the emphasis of the government on the introduction of more productive LUTs.
- Maintain emphasis and spend the subsidies on relatively small areas of these more productive LUTs, and neglect the remainder of the area. This would in general be the easiest way of using the available subsidies. However, that would prevent government agencies from working in a comprehensive way.

It is therefore suggested that an alternative system of allocation of the subsidies with smaller differences among the Land Use Types might lead to a more acceptable solution.

Table 4.17: Subsidy allocation (US$/ha).

	LMU1	LMU2	LMU3	LMU4	LMU5	LMU6
LUT1	77	77	77	N*	N	N
LUT2	38.5	38.5	38.5	38.5	N	N
LUT3	26	26	N	N	N	N
LUT4	20	20	20	20	20	N
LUT5	15	15	15	15	15	15
LUT6	N	N	N	N	27	27
LUT7	0	0	0	N	N	N
LUT8	N	N	N	0	0	0

* N indicates no subsidy right.

4.8 Discussion

District planning allows the planner to formulate a unique and consistent policy for the district that is or may be to the benefit of the majority of the households. Output of the district planning model, e.g. a certain set of land use plans holding their goals to be met during the specified time horizon, is an answer to a blind spot in Iran's range rehabilitation programs. This is achieved through the exploratory nature of the methodology used in the district planning module. One of the important features of these types of models is the inclusion of an evaluation of the current situation, which provides an opportunity for redesigning the land use plan and/or correct implementation of actions that might have the wrong consequences.

Use of these types of models also has many disadvantages, such as the high information demand and even the method itself. In natural resource management, especially under natural conditions, planning envisages risks due to unpredictable climatic events such as drought and floods, as well as pest and disease incidences.

Quantification of the states, rates and financial value of all elements of the natural environment is not always easy, or even possible. An example in case is the value of a ton of eroded soil, because the loss of (future) revenue, associated with a given level of soil erosion is virtually impossible to estimate. The effects of these processes, if they could be properly quantified, on making decisions, e.g. ranking of the alternatives, is striking

Effects of moral considerations of the stakeholders are difficult to incorporate directly. For example, even if wheat production, as representative for a cultural objective, could be financially compensated by cultivation of the forage, that does not resolve the problem of land ownership, which is the main reason for cereal dryland farming. The mathematical procedure applied in the PSS may result in identification of a solution that may not be applicable for political and/or economical reasons. It is suggested therefore that planners present a range of feasible solutions, instead of a single one. The decision maker can then, on the basis of the ranking of his priorities decide on the most 'acceptable' plan.

5 The local planning module: Description and implementation

5.1 Introduction

A major problem in Iran's current land allocation method is transferring land tenure from the government to the farmers, in such a way that communal use is still possible. In the current procedure, the households that have shared a grazing licence are entitled to receiving a joint land deed certificate. In other words, the same land is allocated to the same group of households, with the difference, however, that the grazing licence is replaced by a land certificate. Both, the area of land for a specific household and its exact location are unknown. Another major problem in the current land deed program is that it does not include the right of land trade (selling or buying of the deeded land). Hence, this strongly limits the possibilities associated with land ownership. The consequence of these ambiguities and problems is lack of willingness to spend money on or accept responsibility for the payback of the loan on 'a piece of land' as anticipated in the land deed guidelines.

This chapter describes development of a local land allocation model, the so-called local planning module, dealing with one grazing usufruct and aiming at solving the indicated problems. It respects the rights of the people, e.g. offers the chance of selection of the land they may like, and addresses the property of the individuals, while treating the land in units as disaggregated as possible. Outputs of the module are presented at three levels: the area required per livestock unit, the area required for one individual household and the area suitable for a group of households sharing land for grazing, called a ranching group.

5.2 Individualisation and group ranching

Privatisation as the main objective of rangeland allocation can be realised through individualisation or shareholding. As discussed in preceding chapters, we were aiming at creation of individual holdings, but for various reasons that appeared not always possible. Individual ranching may not be feasible, when:

- Stockholders do own small numbers of livestock, as in sedentary animal husbandry.
- Land values vary too much within the area due to differences in qualities or accessibilities, and households might be exceeding the carrying capacity of the land.
- Stockholders for any reason are interested in being present on different land mapping units.

According to demographic information supplied by the Technical Office of Range Management (TORM, 2001), the total population of Iranian livestock owners comprises 916,000 households of which 200,000 (21%) practice transhumance and usually own economically viable herds. On the other hand, herd size of 73% of the Iranian stockholders is below 20 head. The carrying capacity of the rangelands has been estimated at 180,000 households, one fifth of the current number of holdings (TORM, 2001). Reducing the number of households involved in livestock keeping is, in many cases, not possible for various reasons. As an alternative, group ranching as a solution to avoid local conflicts and political challenges, is an accepted option in the rangeland allocation procedure in Iran.

The concept of group ranching as used here, is to some extent similar to the grazing management system developed in the 1960s and early 1970s in Kenya (Wilson & Maki, 1989), that has been practiced, tested and criticised for many years (Southgate & Hulme, 1996; Lusenaka, 1996; Makilya et al., 1996; Galaty & Salzman, 1992; Oxby, 1981). Varying degrees of success of group ranching have been reported. Oxby (1981) claims that the results of evaluations of the system depend on the ultimate goals of the planners. He believes that the sense of ownership is promoted by group ranching, economically however, the success is questionable. In this study, an attempt has been made to use the Kenyan experiences, modify the systems to meet specific sustainability criteria and include them as alternatives in the methodology. For instance, land trade, which has been criticised in Kenya (Galaty & Salzman, 1992), because land was sold to exogenous parties, is permitted, but restricted to within or between ranching groups. This allows some members of the group to expand their property to create an economically viable private unit. Others may sell their small land holdings, and find alternative, more remunerative employment.

5.3 Local planning module

5.3.1 Introduction

The local planning module tries to realize the objectives that have been set in the course of executing the district planning module. It is composed of three sub-modules: land allocation, land improvement and grazing enterprise identification, and uses five sources of information:

- Socio-economic information from a socio-economic database;
- Land units from the land evaluation module (Chapter 3);
- District policy from the district planning module (Chapter 4);
- Empirical or experimental data on land rehabilitation from the literature and/or from expert knowledge;
- Land allocation visions (policies) from the policy makers.

Partitioning of the land into grazing usufruct units and implementation of the district policy in the local planning module are tasks of the land allocation sub-module. Identification of the required size of holdings for individual and for group ranches is performed in the grazing enterprise identification sub-module. The required land improvement programme, describing the pathway from the present to the future in terms of required measures to reach prescribed goals, is identified in the land improvement sub-module. In addition, the impact of selecting a specific tract of land on the budget of the household for a specified time, is estimated in this sub-module (Figure 2.6).

5.3.2 Land allocation sub-module

In the district planning module, land use systems were described in a two-dimensional matrix, comprising land units as one dimension and land use types as the other. In the land allocation sub-module, another dimension is added to the land use system matrix, i.e. the usufruct boundary (in the present study the usufruct consists of the land belonging to a village for grazing). Hence, land units are sub-divided in smaller areas, each belonging to a specific village, e.g. LUT1LMU1 is partitioned into LUT1.LMU1.USU1, LUT1.LMU1.USU2, ... LUT1.LMU1.USU5. In terms of modelling, one "set" of usufruct is added to the model, having five members.

The land allocation sub-module starts by partitioning the study area into usufruct areas, which have been delineated on a 1: 50,000 topographic map by the Esfahan Office of Natural Resources (Figure 5.1). A single objective linear programming model with the same structure and the same input-output coefficients as that selected for the district scenario is constructed. The concept of this model is the same as the one that has been evaluated best in the district planning phase. The sub-module yields a complete catalogue of land uses for all usufructs. In addition, the quantities of inputs required and of outputs produced on each tract of land in each usufruct are determined.

The same criteria and criterion scores as described for the district-planning module are calculated to express the value of the land (based on its production) on one hand and the required inputs on the other. The criteria taken into account are grazing capacity, forage production, income from each land unit and the required investments and subsidies. The results of this sub-module show the farmers the potential gains or losses from a tract of land, as an aid in decision making.

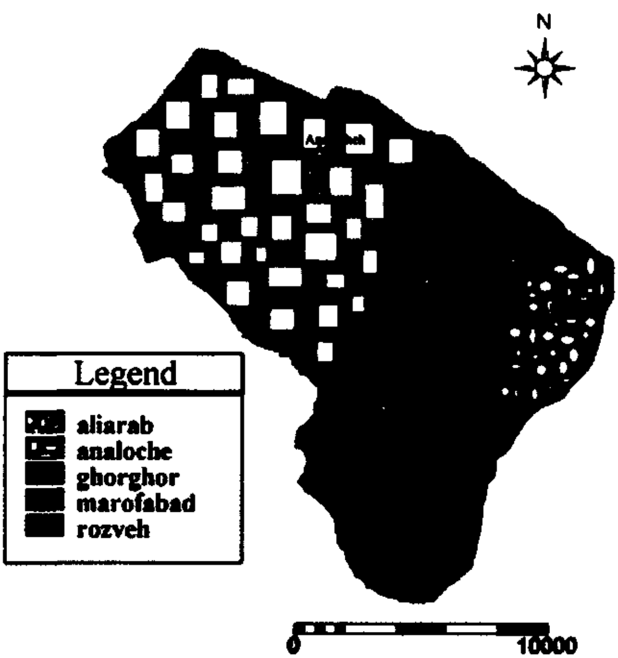


Figure 5.1 Grazing usufruct of each village.

5.3.3 Land improvement sub-module

Information generated in this sub-module is used for two purposes: (i) in the grazing enterprise identification sub-module to determine the production of the land; (ii) to show the economic consequences of selection of a piece of the land for any point in time, which is used to sketch the future as perceived by the households.

Application of this sub-module introduces a dynamic aspect in the PSS, required for appropriate treatment of land improvement. The suggested land use alternatives all comprise perennial species that require a period of establishment to reach stable performance (Edwards, 1989; Kenneth, 1973). This was necessary because these land use systems are designed for Iranian rainfed situations, where the vegetation should attain enough stability to survive the fluctuating nutrient and moisture availability associated with unpredictable and erratic rainfall.

Implementation of land improvement programs often depends on availability of money and/or equipment. Limited availability of these means may require that the land improvement program, in addition to being spread in time, has to be split in space: for example, a land unit could be divided into five blocks and cultivation started block by block with intervals of a year. This sub-module takes into account the time course of inputs and outputs of any land unit on a specific land mapping unit within a usufruct boundary.

Having information about the area, location and time horizon of the plan for a tract of land available, e.g. through specification of both LMU and LUT, the impact of selection of that land for any specified time can be simulated. In other words, when the land has been selected, its inputs and outputs can be calculated and shown to the household (Figure 5.2).

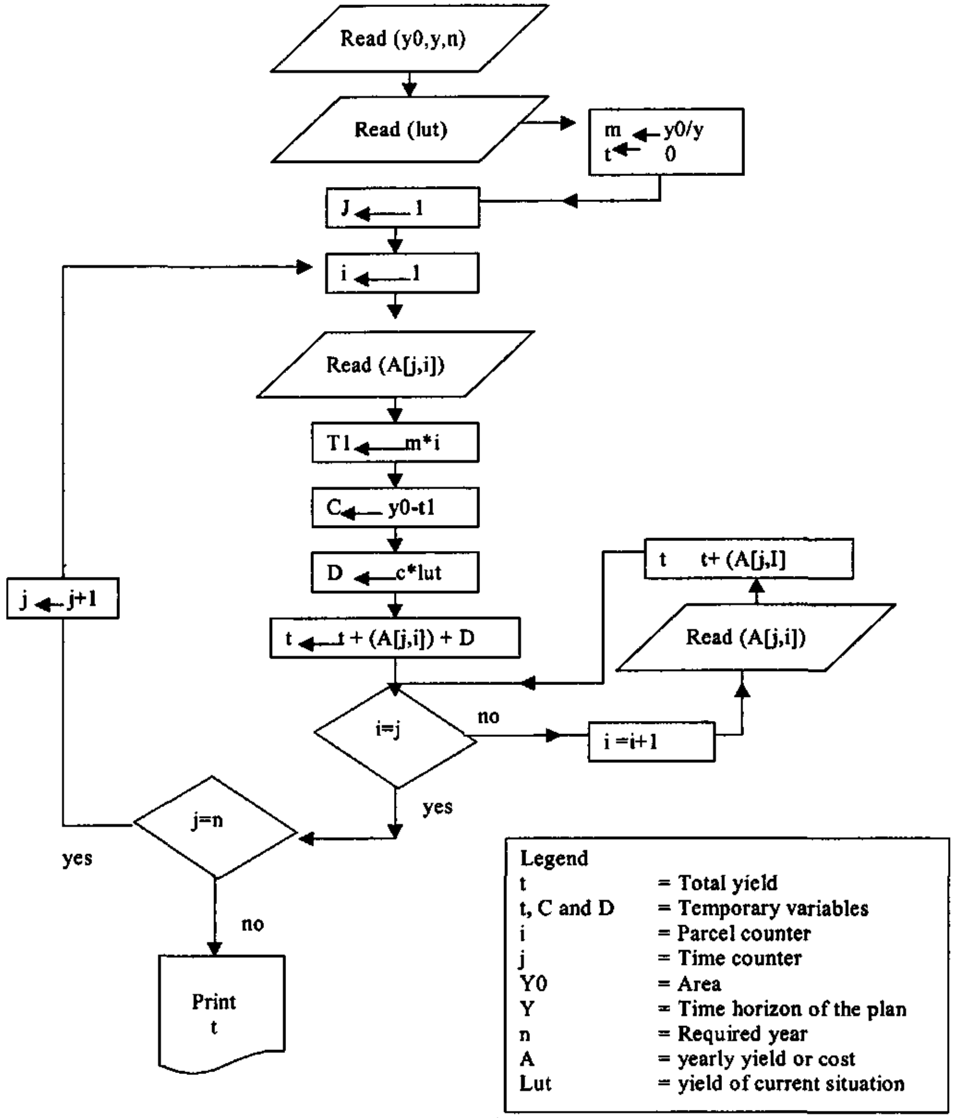


Figure 5.2 Algorithm of a model for calculation of the impact of selection of a tract of the land for a specified time. This model can be applied to any combination of LMU (Figure 5.1) and LUTs.

In this model the total land area is partitioned in blocks, each with a specific area, on the basis of the time horizon of the plan. It is assumed that the blocks are cultivated sequentially with one-year intervals. Inputs and outputs of each LUT are specified per hectare and introduced as input in the model. For each year, inputs and outputs of cultivated and non-cultivated blocks are summed by the model and saved in a temporary variable. This loop will continue until the time horizon of the plan has elapsed. Thus, for any specified time period, cumulative inputs and outputs are available.

Land improvement programmes

As the land improvement sub-module calculates inputs and outputs following implementation of land improvement programmes (alternative land uses), they are described here in detail. Recall that describing procedures are modified version of those practiced by Forest and Range Organization of Iran.

LUT1

This LUT comprises cultivation of a productive and ecologically suitable legume, such as *Medicago sativa*. The crop is sown in late winter or spring (March – April). The first harvest, cutting or grazing, at a much lower yield than the maximum, takes place the following autumn (October – November). In subsequent years, harvesting or grazing starts between May and July. LMU1, LMU2 and LMU3 are suitable for this LUT, as indicated in Chapter 4. The distribution of the LUT over LMUs is determined by the land allocation sub-module. Depending on the area of any specific LMU and available capital, the total area can be reclaimed in one year or it can be divided into blocks, reclaimed successively over a given time period. A typical timetable for introduction of the LUT in a unit divided in blocks is given in Table 5.1, assuming a time horizon of five years.

Table 5.1: Implementation schedule* of LUT1 in a unit partitioned in 5 blocks, over a time course of 5 years. The procedure is restarted in year 6.

Year	Block #				
	1	2	3	4	5
1	Seeding				
2	Rest	Seeding			
3	Grazed	Rest	Seeding		
4	Grazed	Grazed	Rest	Seeding	
5	Grazed	Grazed	Grazed	Rest	Seeding
6	Seeding	Grazed	Grazed	Grazed	Rest
7	Rest	Seeding	Grazed	Grazed	Grazed

* Blank cells represent the current situation. Grazing may be replaced by cutting.

LUT2

For LUT2 the land is divided into two blocks: a perennial legume is cultivated on one block, while on the other cereals are grown every other year. When productivity of the planted legume declines, blocks are exchanged. The implementation schedule for this land use type is given in Table 5.2. This LUT is proposed for LMU1 to LMU4.

Table 5.2: Management scheme for the legume–cereal rotational farming system of LUT2.

Year	Block #	
	1	2
1	Seeding legume	Cereal
2	Rest	Fallow
3	Forage	Cereal
4	Forage	Fallow
5	Forage	Cereal
6	Forage	Seeding legume
7	Cereal	Rest
8	Fallow	Forage

The implementation pattern of the plan for a block is given in Table 5.3. It is assumed that each LMU has to be split into three blocks due to lack of means and each block into two parcels.

Table 5.3: Management scheme of the legume–cereal rotation in a split farming system of LUT2.

Year	Block #					
	1		2		3	
	Parcel 1	Parcel 2	Parcel 1	Parcel 2	Parcel 1	Parcel 2
1	Seeding legume	Cereal				
2	Rest	Fallow	Seeding legume	Cereal		
3	Forage	Cereal	Rest	Fallow	Seeding legume	Cereal
4	Forage	Fallow	Forage	Cereal	Rest	Fallow
5	Forage	Cereal	Forage	Fallow	Forage	Cereal
6	Forage	Fallow	Forage	Cereal	Forage	Fallow
7	Cereal	Forage	Forage	Fallow	Forage	Cereal
8	Fallow	Forage	Cereal	Forage	Forage	Fallow

LUT3

This land use type basically comprises the same components as LUT2. The difference is that in LUT3 the land is divided into three blocks: one is cultivated with legumes and the other two with the cereal-fallow rotation.

This system allows 'continuous' wheat cultivation, which is preferable, where rainfed cereals are a key commodity, and makes sense from a food security point of view. The pattern of the rotation is given in Table 5.4.

Table 5.4: Management scheme of the legume–cereal rotational farming system of LUT3.

Year	Block number		
	1	2	3
1	Seeding legume	Cereal	Fallow
2	Rest	Fallow	Cereal
3	Forage	Cereal	Fallow
4	Forage	Fallow	Cereal
5	Forage	Cereal	Fallow
6	Cereal	Fallow	Seeding legume
7	Fallow	Cereal	Rest
8	Cereal	Fallow	Forage

Similarly to LUT2, a block can be split into several parcels, if needed.
LUT4 and LUT5

These LUTs are based on cultivation of native species. LUT4 is a legume-grass mixture, and LUT5 a monoculture of native grasses. Most LMUs are suitable for these LUTs. In the land improvement sub-module a gradual introduction of these LUTs is assumed, over a five-year period. Land improvement starts on fallow or less productive land, to minimise immediate impact on the household's regular benefits. Land therefore, is divided into 5 parcels: each year, rangeland plants are introduced in one parcel as schematically presented in Table 5.5.

Table 5.5: Schematic representation of the conversion of land into a rest rotational grazing system. Complete conversion of the system takes 6 years.

Year	Block				
	1	2	3	4	5
1	Seeding				
2	Rest	Seeding			
3	D-Grazed*	Rest	Seeding		
4	Grazed	D-Grazed	Rest	Seeding	
5	Grazed	Grazed	D-Grazed	Rest	Seeding
6	Grazed	Grazed	Grazed	D-Grazed	Rest
7	Rest	Grazed	Grazed	Grazed	D-Grazed
8	Grazed	Rest	Grazed	Grazed	Grazed

*** D-grazed is deferred grazing in which grazing takes place when plant species are completely mature.**

LUT6

For the steep slope sites, that currently are covered by *Astragalus spp*. as an excellent protective cover or by remnants of palatable species, current plant cover should at least be maintained. Thus, inter-seeding, as used by the local Offices of Natural Resources, in which new species are introduced in the existing vegetation, is a useful technique for these sites. Selections of species are used, not only for production purposes, but also for soil conservation. *Bromus tomentellus*, *Psathyrostachys fragilis* and *Agropyron trichophorum* are suitable species. Annual production of this system can not be expected to exceed 300 kg/ha. The vegetation needs a three-year establishment period to develop bunches and rhizomes. The pattern of implementation of this LUT is schematically presented in Table 5.6.

Table 5.6: Schematic representation of the implementation pattern for LUT6 (see text for explanation).

Year	Block number	
	1	2
1	Seeding	
2	Rest	
3	Deferred grazing	Seeding
4	Normal grazing	Rest
5	Deferred grazing	Deferred grazing
6	Normal grazing	Normal grazing
7	Deferred grazing	Deferred grazing
8	Normal grazing	Normal grazing

5.3.4 Economically viable grazing enterprise identification sub-module (EGEM)

The EGEM sub-module is designed for identification of the required size of the grazing enterprise, which is dependent on many characteristics, such as the population of each village (its growth rate, culture and background of land tenure), its herd size as a basis for selection of individual or group ranching, the quality of the land and the availability of other sources of revenue (tasks of P1 resulting in synthesized data bank) . Land allocation has both socio-economic and technical aspects; hence the sub-module has to deal with these two issues. Considering sustainability as the final objective, the technical part of the sub-module is designed to prevent overgrazing, and the social part takes care of the problem of overpopulation, both of which are considered threats to sustainable use of the land. Sequentially, the sub-module performs three tasks to reach its goals, e.g. P1 to P3 in Figure 5.3.

Most important is the way we tackle the problem of elimination of surplus siockholders, which is the core issue of the sub-module. This is treated in the second task of the sub-module (P2 in Figure 5.3) through generation and operationalization of some policy views. Implementation of these policy views leads to generation of three land allocation patterns with their advantages and disadvantages. These solutions refer to three types of land-ownership: individual ranching, sub-individual ranching and group ranching.

Selection among the suggested solutions depends on the specific situation of each village, the aspirations of the households and the perception of local government representatives and is a matter of consultation and mutual commitments, e.g., preparation of promised subsidy and means from the governmental side and application of the prescribed agricultural practices from the household side.

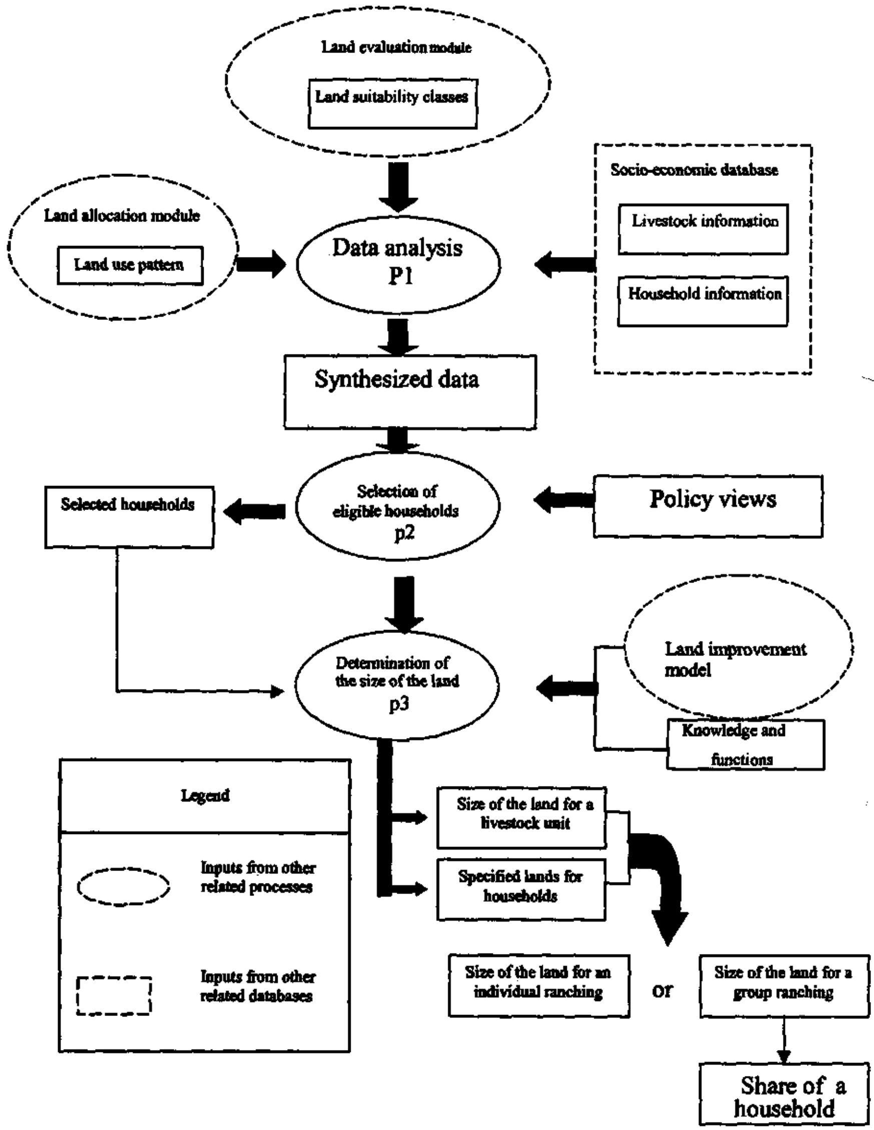


Figure 5.3 Configuration of the EGEM sub-module. P1 to P3 are three tasks of the sub-module.

Socio-economic issues

The land allocation modelling exercise becomes complex because of the necessity of finding a solution to social problems in parallel with political initiatives. Three major social problems that should be addressed are:

- Who is eligible to receiving land rights?
- How to organise the selection procedure for land by households?
- How can conflicts over a tract of land be resolved?

Eligibility

Eligibility addresses the problem of overpopulation, either in terms of the number of households or their livestock and the way one wants to avoid excess livestock and/or households. Solutions to this problem strongly depend on local conditions; hence it is difficult to formulate a generally applicable procedure. Therefore, a framework should be established that can easily be adapted to different conditions.

As shown in Figure 5.3, selection of eligible households is based on socio-economic information and policy views. Analysis of the socio-economic information may result in elimination of some households that do not really 'deserve' to receive land. An example is a household not actually involved in pastoralism anymore, but buying lambs, raising them on the free forage of the rangelands, and selling them at the end of the grazing season. In such a situation, the grazing usufruct is usually claimed as an inherited asset that is not officially recognised by the government.

In addition, eligibility of the households is based on the policy of the government and an in-depth analysis of the social interests of the local population that are not the same everywhere. To formulate the framework, we resort once more to generation of scenarios, taking into account possible governmental policies on eligibility. Generation of eligibility-determination scenarios is very case-specific and is based on the insights of the stakeholders and experts in particular.

Eligibility policy

Three scenarios were formulated and operationalized in EGEM on the basis of three eligibility policy views. These policy views represent different opinions of the government representatives about the eligibility of the households on the basis of alternative socio-economic principles.

Equality policy (scenario)

Equality, as used here, implies equal rights of all households in the land deed program, without any consideration for their capacity for investing in land or their current dependence on the land. In other words, it is assumed that all households that had right of use in the past, are eligible for receiving land.

Since the current livestock density is usually higher than the ultimate grazing capacity[1] of the usufruct area, accommodation of all households requires determination of a livestock adjustment factor. This factor, expressed as a percentage (RF), is applied to all households, for example, a reduction in the size of the herds by 5%. The sub-module uses the following equation to derive the adjustment factor:

$$RF = (1 - (\frac{ANL}{AV})) * 100$$

where,

ANL = Permitted number of livestock (head, equal to the grazing capacity of the usufruct)

AV = Current livestock density (head)

Dependence policy (scenario)

In this scenario, households owning more livestock are favoured. The argument is that they are more dependent on the rangelands and therefore are more likely to invest in the land. This implies that households owning small numbers of livestock should keep them on the farms (zero grazing) or even sell them. This policy would most likely lead to individual ranching.

Households, in this scenario, are classified on the basis of their degree of dependence on the rangelands. Then land allocation starts from the most suitable land mapping unit and the households with the highest degree of dependence. Land allocation is continued until this LMU is exhausted, after which the process starts for the next LMU.

Since the degree of dependence on the rangelands is an essential part of this scenario, it is relevant at this stage to discuss the identification of dependence classes.

[1] Ultimate grazing capacity is grazing capacity of the land after implementation of the land improvement programmes.

What is a fully dependent household?

Determination of the minimum land area required for individual households is based on the minimum income required for a 'normal' life, because of the land scarcity. Interviews with council members of the five villages have shown that for a middle class[2] family, comprising five members, annual requirements for a normal life style are $923.

Net benefits from a lamb amount to $15 and 80% of the lambs are usually sold. To earn enough money for a normal life, therefore, the land holding for a fully dependent household should allow grazing of at least 77 ewes.

Classes of dependence

The cost of collecting information on individuals is usually high relative to the cost of determining whether an individual falls within a class with a range in characteristics. Hence, some form of classification is usually preferred to individual investigation.

An essential part of any classification is the decision on the number of classes that should be distinguished. Gregory (1978) suggests that the range in values in any class should be small and the number of classes should be at most ten. We think that the number of classes is optional and should be determined on the basis of the specific conditions for each land deed programme.

Various mathematical techniques are available for classification that can be applied in dependence of the degree of detail in available household data. Cluster analysis is a well-known classification method for which the number of classes has to be set beforehand. A simple method to define the number of the classes could be preparation of a histogram and analysis of the frequency distribution of the household population.

For the purpose of land allocation, it is suggested that the herd size of the majority of the households should be used as determinant of one class. This class may be identified by calculating the number of livestock per household. Another class should be established for households owning enough livestock to run an individual property. These conditions are derived from the anticipated role of individually managed rangelands in the creation of more sustainable and productive livestock production systems (Dadafarid, 1994) and the function of the presence of the majority of the households in one class for the acceptability of the plan.

As an example, four classes for 'degree of dependence' have been established, as illustrated in Figure 5.4, to show that despite the

[2] The term middle class as used here refers to a family that is not very rich nor very poor.

prevalence of a low degree of dependence among households in most villages on rangelands, individual ranching is an important option for villages such as Analoche (Figure 5.1).

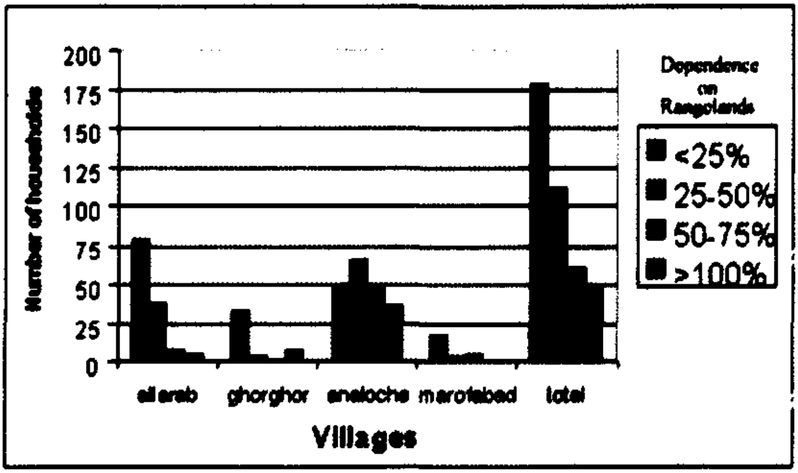


Figure 5.4 Dependence of households on rangelands. Dependence is determined on the basis of the number of livestock of the household, with a household owning a herd of 77 head or more being fully dependent.

Conservative policy (scenario)

This scenario is based on the assumption that small livestock holders can relatively easily be influenced. Their benefit from the rangelands is small and they might be easily convinced to stay out of the range. They could produce forage for their livestock on the farm and keep the animals away from the rangelands, when ordered. The same procedure as in the dependence scenario is followed, with the exception that land allocation starts with the establishment of co-operatives consisting of groups of households. Land allocation starts from the biophysically most suitable land units and proceeds from one LMU to another.

Technical issues

Calculation of the size of the land holding

From a technical point of view, a solution for the problem of allocation of the land is straightforward. Grazing capacity (GC), as an important land attribute, has been calculated in the land allocation sub-module[3] in animal units per grazing period or A.U.P. The area of land, required per livestock unit, is the inverse, or:

$$LAOA = \frac{1}{GC}$$

where,

LAOA = Area of land required per animal unit (ha).
GC = Grazing capacity of the land (Animal units per hectare per grazing period).

By taking this into account, the model distributes the land on the basis of its quality. In other words, when the quality of the land is higher, its grazing capacity is higher, and as a consequence LAOA is smaller. Selection of higher quality land, therefore leads to smaller areas of land.

Two more points are important in determining the size of the holding: first the way to determine the number of livestock a household owns and secondly (when classes of households are considered) the averaging of the area for a class of households.

The current number of livestock can be interpreted as the degree of dependence of the households on grazing land and may serve as a basis for calculation of the land area that should be allocated to a household. However, this number varies over time and would certainly be exaggerated by households, if its importance in determining land allocation is realized. It is suggested therefore, to utilize the average number over the last five years in the calculations, as derived from the vaccination census.

Determination of the share

The number of shares a specific household can hold in the cooperative or group ranch is related to its permitted number of livestock and eventually the area of land it owns. In this study each hectare of land allocated to one household is equal to one share. The share is tradable and its value depends on the quality of the land at the time of trading.

[3] Grazing capacity can be calculated within the land allocation module or by using an individual grazing model as described in Chapter 4.

Conflicts over a tract of land

Due to its attractiveness, a certain tract of land may be desired by many households . In the study area, as in many rural regions of Iran, there are traditional ways to solve such problems. Some of these procedures are, in order of their frequency of use:

- A meeting is convened and the advice of elders is heeded, if all parties are satisfied.
- A special type of dice (with 0 and 1) or a coin is used.
- A meeting with the local representative of the government is convened to solve the problem.
- Rarely, the case is taken to court.

5.4 Operationalization of the sub-module

5.4.1 Basic characteristics

Population

Land allocation is directly related to the number of households in an area. Hence, in the land allocation procedure, the first consideration is the current population or an estimated population density for the future.

A projection for the future is often based on extrapolation of recent developments through a calculated trend. However, though extrapolation often works well in the industrial realm, it is wrought with uncertainties when applied to human behaviour. A point in case is population growth, where extrapolation frequently has resulted in unsatisfactory predictions. Reliability of population projections decreases when they are more specific in space and time, because population growth is dependent on human welfare (Todaro, 1992), of which the dynamics are difficult to predict.

Human welfare reflects the integrated effects of culture, policies of the government and the economic situation (Todaro, 1992). One of the expressions of the rural culture of Iran is "the more children the better", as a consequence of the need for family labour. This attitude may be encouraged by government policies or discouraged by (unfavourable) economic conditions. Accurate extrapolation of population growth in the rural society of Iran therefore is impossible, due to lack of a steady trend. As illustrated in Figure 5.5, after Iran's revolution in 1978, population growth increased, as a result of encouraging policies of the government and it decreased after 1986, under the influence of economic pressure in the aftermath of the Iran-Iraq war. This descending trend is continuing according to the Iranian government. In addition, in the study area emigration is common practice currently, as described in Chapter 1.

In this study no extrapolated data are applied, because of the variability in both the number of livestock and of households. For illustration of the application of the methodology, information collected in 1994 by the Esfahan Office of Natural Resources has been used for calculation of the size of land holdings. When applied for actual land allocation, reliable, up-to-date data are required.

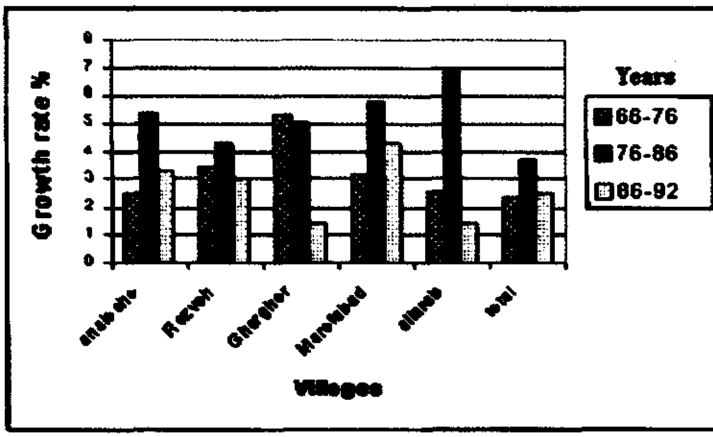


Figure 5.5 Dynamics of population growth rate in different villages in the study area.

Livestock

Analysis of the size of the herds in four villages shows that herds of between 10 and 20 head per household dominate, which indicates a majority of small stockholders (Figure 5.6). Participation of this class of stockholders calls for solutions that emphasise co-operation. This can be realised in the form of group ranching. This system is introduced through a co-operative organisation for each element of the land use system (LMU and LUT).

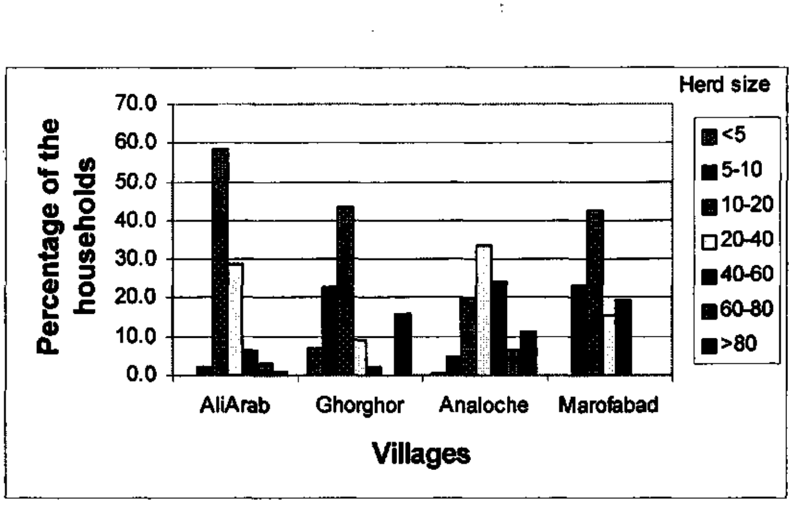


Figure 5.6 Herd size per household in four villages in the study area.

Grazing usufructs

The study area is partitioned in five large units or properties (Figure 5.1). Grazing licences have been issued for four units so far, granting grazing rights to the village located in each unit. The village council, composed of the elders, is the representative of the village community, and is responsible for enforcement of the regulations incorporated in the grazing licences. The local planning module was run for all units. As an example, the results of the local planning module for one village are described here.

5.4.2 The case of AliArab village

This unit is 1445 hectares, representing 13% of the study area, and comprising 86, 460, 247, 360 and 292 ha of LMU1, LMU2, LMU3, LMU5 and LMU6, respectively.

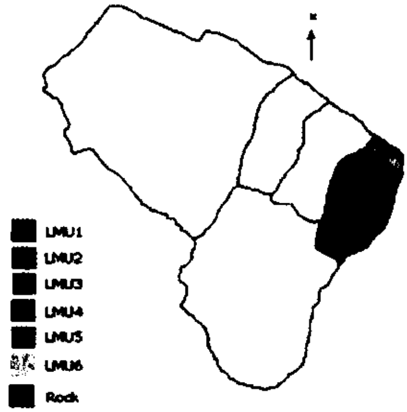


Figure 5.7 Property of Ali Arab with its land mapping units.

There are 142 households in the area, of which 125 are farmers. Sources of revenue of the farmers are agriculture including animal husbandry (Table 5.7) and products from carpet looms. The village comprises seven carpet looms and one textile loom. Gross margin of a carpet is $54 and two carpets annually can be produced.

Table 5.7: Agricultural activities in Ali Arab village (Source: Chadegan agricultural services).

Commodity	Area (ha)		Gross margin ($)		Total ($)
	Irrigated	Rainfed	Irrigated	Rainfed	
Cereals	789	2300	61068	20700	81768
Beans	56	-	3248		3248
Forages	135	-	11745		11745
Potato	130	-	20800		20800
Total	1110	2300	96861	20700	117561

Application of the land allocation sub-module

The land allocation sub-module was applied to the unit to design a land use pattern. Outputs of the sub-module are summarised in Table 5.8. The largest area of this unit (607 hectares) is occupied by LUT5, i.e. cultivation of a native and grazing resistant grass such as *Bromus tomentellus*. LUT1 is suggested for 546 hectares and 292 hectares is allocated to inter-seeding, LUT6.

Table 5.8: Land use plan calculated by the land allocation sub-module (LUS column) for AliArab village and criterion scores (values for the scores refer to a period of six years; grazing capacity refers to a grazing period of 3 months).

LUS	Area (ha)	Forage (kg)	Wheat (kg)	Subsidies ($)	Vegetation cover (ha)	Income ($)	Investments ($)	Grazing capacity (A.U.P.[1])
LUT1 on LMU1	86	344000	0	6622	69	22618	9546	412
LUT1 on LMU2	460	1380000	0	35420	276	86940	51060	1648
LUT5 on LMU3	247	444600	0	3705	86	43472	11362	405
LUT5 on LMU5	360	486000	0	5400	108	44640	16560	443
LUT6 on LMU6	292	262800	0	7884	58	32120	7884	220
Total	1445	2917400	0	59031	597	229790	96412	3128

[1] A.U.P. is Animal Units per grazing Period.

Compared to the ultimate forage production of each LUT, the results of the land improvement sub-module (Figure 5.8) show a very low forage production, with an associated low animal population in the early stages of implementation of the plan.

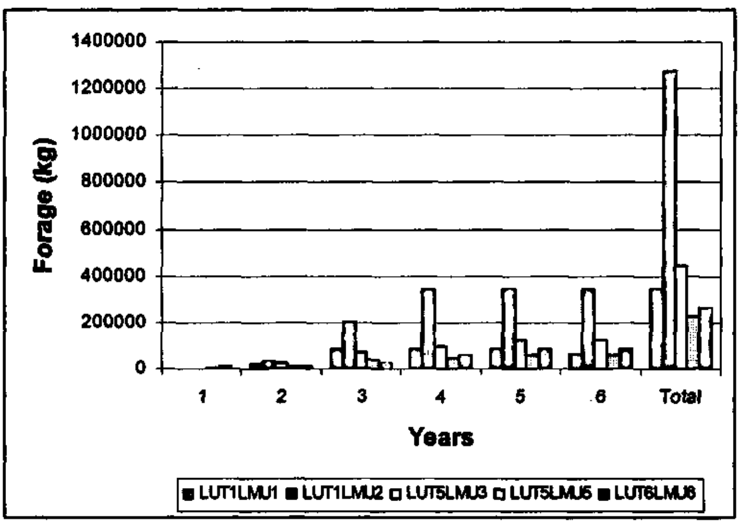


Figure 5.8 Development of forage production of improved land uses in Ali Arab. Total production refers to the total forage production of the block under cultivation.

An important practical question is how to deal with such a decrease in grazing capacity. In the study it appeared that the number of livestock in the area strongly fluctuates. Animal husbandry is ranked as the second most important agricultural activity in the region (Eftekhari, 1992). When households are in urgent need of cash, reducing herd size through sales is the first solution. The director of the local Natural Resources Office indicated, that at the time of the Hadj (the pilgrimage to Mekka) many households sell all of their animals, because they need the money and because of lack of honest people to entrust the herd. Moreover, climatic factors may force households to reduce the size of their herds in unfavourable years.

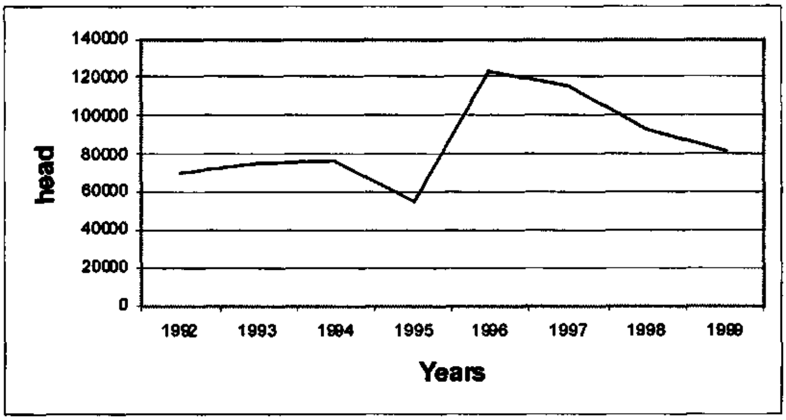


Figure 5.9 Variation in livestock population in Chadegan region.

No information was available on variations in livestock numbers of individual households in the study area. The information in Figure 5.9 has been derived from the vaccination census of the whole region.

Such fluctuating numbers of livestock of the households should not make planners overly optimistic in expecting that the farmers would yield to any pressure in accepting the plan. Possible solutions to pass through this critical phase could be importing forage from outside the region or reducing the size of the herds. Both solutions need strong support from the government.

Land per livestock unit

Land requirements for an individual animal (LRIA) for different land use types are shown in Table 5.9.

Table 5.9: Area of land required for an individual animal. Calculated as 1/grazing capacity per grazing period.

Land use system	Grazing capacity per grazing period (AUP)	Land for one head (ha)
LUT1LMU1	4.7	0.2
LUT1LMU2	3.6	0.27
LUT5LMU3	1.6	0.62
LUT5LMU5	1.2	0.83
LUT6LMU6	0.8	1.25

Land allocation in the equality scenario

Currently, the animal population in AliArab village consists of 3541 sheep and goats (Eftekhari, 1992). According to information from the Esfahan Office of Natural Resources, only 1066 heads are grazing legally on the rangelands. Our calculations (Table 5.8) show that after implementation of the proposed land improvement programme, total grazing capacity equals 3128 A.U.P. The implication is that the livestock population of the usufruct should be reduced by 12% to match the ultimate grazing capacity.

In this scenario, land is allocated to all households of the usufruct (those included in the grazing licence). The procedure starts with calculation of the adjusted number of livestock for all households, followed by classification of the households into appropriate classes. Average area of land (AAL) which should be allocated to a household within a specific class and LUS is calculated on the basis of the weighted averaging method, using the number of livestock of each household (LEH) as weight, e.g. (ΣLEH * LRIA * frequency of household)/total number of households in the class (Table 5.10).

Table 5.10: Household classes and the average area of land (AAL (ha)) a household in a specific class and LUS can own.

Herd size (head)	Dependency		Frequency of households	AAL on LUT1 LMU1	AAL on LUT1 LMU2	AAL on LUT5 LMU3	AAL on LUT5 LMU5	AAL on LUT6 LMU6
	(%)	Class						
0 – 15	0-20	1	16	3	4	9	12	18
15 – 20	20-30	2	63	4	5	12	17	25
20 – 30	30-50	3	29	6	8	18	24	37
30 – 40	50-75	4	9	8	10	24	32	48
>40	100	5	8	11	15	34	46	70

The last step in the procedure involves selection of the land with its specific LUT by the households, and establishment of the ranchers group (i.e. co-operative). For example, if all households of dependency class 1 require land from LUT1LMU1, then an equally shared ranching group having 16 members can be established. The total land allocated to this group would be 48 hectares, while if they wish to have land from LUT6LMU6 their total land would be 288 hectares. For the sake of trade ability, the value of the share has been suggested to be adapted to the grazing capacity of the land (the number of permitted livestock), endorsed by experts of the local Office of Natural Resources. In this way households are encouraged to improve the quality of their land.

Land allocation in the dependence scenario

For the dependence and conservative scenarios, it is assumed that the 12% surplus livestock should be removed by reducing or restricting the number of households with land use rights. In the dependence scenario, the aim is to allocate the land to those households that are most dependent on the land. To operationalise that aim, we start from the best LMU, in terms of land quality, and the most dependent households. First, all land is allocated in the most favourable LMU, followed by the subsequent LMU, and so forth. As an example, let us again assume five classes of households, as shown in Table 5.11 to facilitate the explanations.

Table 5.11: Household classes and the average area of land (AAL (ha)) a household in a specific class and LUS can own. Since there is no reduction factor, AALs are 12% higher than in the equality scenario (Table 5.10).

Herd size (head)	Dependency		Frequency of households	AAL on LUT1 LMU1	AAL on LUT1 LMU2	AAL on LUT5 LMU3	AAL on LUT5 LMU5	AAL on LUT6 LMU6
	(%)	Class						
0 – 15	0-20	1	16	3	5	10	13	20
15 – 20	20-30	2	63	4	6	13	19	28
20 – 30	30-50	3	29	7	9	20	27	41
30 – 40	50-75	4	9	9	11	27	36	52
> 40	100	5	8	12	17	38	52	78

Land allocation starts for eight households that have the capacity, in terms of endowments (herd size exceeding 40 heads) for individual ranching. Each of these households can be allotted 12 hectares of land, if they stick to LUT1LMU1. Land allocation commences from LUT1LMU1 as the best land available. The total land area for the 8 members of class 5 equals 96 hectares, 10 hectares more than are available. For that, 14 hectares of LUT1LMU2 is added to the property of this class of households. The rest of the land from LUT1LMU2, which is 446 hectares, is allotted to other classes of households. Nine households have the capacity (herd size between 30 and 40 heads) for sub-individual ranching (two or three households on one ranch). Four ranches on the same land, three of 22 hectares each and one of 33 hectares (refers to class 4 in Table 5.11), would be allocated to these four households. Subsequently, cooperatives or groups are established, for example, the first equally shared group consists of households of class 3 (Table 5.11), which now has 29 members. The total land area, located on LUT1LMU2, allocated to this group is 261 hectares (29 members * 9 hectares for each). This leaves 86 hectares of LUT1LMU2. A group composed of 14 members from class 2 (Table 5.11), are nominated for the remainder of the land on LUT1LMU2. A group having 19 members of class 2 is located on LUT5LMU3 (19*13=247 hectares). Two groups are allocated to LUT5LMU5 and LUT6LMU6, composed of 18 and 10 members of households class 2, respectively. As a consequence, 2 households of class 2 and all members of class 1 (Table 5.11) remain landless and should look for alternative sources of income.

Small stockholders are not selected in this scenario for qualitatively good lands. The same procedure is used for land allocation on other LUTs and LMUs. The results are summarised in Table 5.12 as an example.

Table 5.12: An example of land allocation in the dependence scenario.

Land use system	System of ranching	Number of Ranches	Number of households per ranch	Area of each ranch (ha)	Total area (ha)	Suggested number of shares of each household
LUT1LMU1	I	8	1	12	96	96
LUT1LMU2	SI	9	2 or 3	22 or 33	99	99
"	G	1	29	261	261	261
"	"	"	14	84	84	84
LUT5LMU3	"	"	19	247	247	247
LUT5LMU5	"	"	19	360	360	360
LUT6LMU6	"	"	10	280	280	280

As a result of application of the dependence scenario, 108 households out of 125 are accommodated. Governmental support should be provided to 17 landless households, which are also small stockholders.

Land allocation in the conservative scenario

Land allocation in this scenario follows the same procedure as the dependence scenario, except that we start from establishment of the cooperatives, with the aim of allocating the land in favour of small stockholders. As a result of application of this scenario, 119 households receive land rights in the land deed program and 6 households are left out. Since in this case the landless households own large herds, government support for establishment of an industrial animal husbandry operation is required.

5.5 Assessment of eligibility scenarios

It is very difficult to judge à priori what scenario is 'better' before having it presented to the population and assess its reaction. As a rough analysis, however, it could be said that the first scenario is preferable when employment is the main social and political debate, because of the broadest contribution of the households in this scenario. In terms of sustainable use of the land, the second scenario is preferable, especially if smaller stockholders would sell their rights to larger stockholders who take better care of the land. The third scenario is welcomed when people are strongly attached to the land, commitment for full co-operation of small stockholders exists and a governmental concession for establishment of industrial animal husbandry is available.

5.6 Conclusions

The local planning module cannot give a concrete solution, because of the complexity of the procedure and the unknown ultimate decision of the households. This is because the problem of land deeding is ill-structured and cannot be totally formalized. For example, it is predictable that not always all households want to remain within a group. Flexibility of the model, however, gives the opportunity of answering novel questions at its disposal. This support system is a powerful tool for iterative screening of available options and selection of virtually the most successful one.

Group ranching seems inevitable for the current herd size of the farmers. To arrive at a pragmatic procedure, the study has come up with the following:

- Group ranch members should be provided with the right of "inter or between-group land trade". This is encouraged by specification of shares, with values derived from the quality of the land. The emphasis on internal land trade has two intellectual reasons. First, it provides an opportunity for land expansion of a member that would lead to a larger property and eventually better land care as described in Chapter 1 (also see Lusenaka (1996) for the same conclusions for Kenya). Second, the land would not be transferred to other sectors, such as industry or housing, rather than agriculture as has happened in Kenya (Galaty & Salzman, 1992).
- Land should not be over-segmented under any circumstances.
- Cooperation of the local population is the key factor in the successful application of the module. Therefore, traditional land ownership, wherever that plays a role, must be incorporated in construction or reconstruction of the ranches as much as possible.

6 Discussion and conclusions

6.1 Scope of the study

Summary
In policy preparation and implementation associated with the current land deed programme in Iran large amounts of data have been collected, that have been stored in different forms, in various offices, without central administration, and could therefore be called 'dead' data. Probably one of the main reasons for accumulation of unused data is lack of a systematic procedure through which these data could be utilized effectively by experts in support of the complex land deed programme. The goal of the study described in this thesis was to develop and evaluate a planning support system for the land deed programme, based on a rational procedure for problem solving. The system is based on the model-based planning-support procedure, as described by Sharifi (2000) and aims at assisting the planner to cope with the complexity of the planning environment, the qualities of the resources and the objectives of the decision makers. As Sharifi (op. cit.) claims, "it is not enough to say that planning involves making decisions about the use of resources, because the best use of any particular set of resources will depend very much on what one is trying to achieve". To deal with the diversity in and complexity of the land allocation process, including consideration of aspirations and objectives of different stakeholders, planners require access to appropriate techniques, dealing with multiple objective decision making, and multiple criteria analysis. Development and application of such techniques in a formal methodology directed to the land allocation process, is one of the achievements of this study. The methodology is not only intended to 'mechanically' generate solutions, but also to stimulate the creativity of the planners/experts in developing innovative production techniques and policy visions, adapted to the specific situation, evaluate these through the various phases of the method and arrive at an acceptable (compromise) solution without violating the main principles.

As planning is a dynamic process, incorporation of the time dimension is an important element in the study. The main modules of the system, the district and local planning modules, were constructed in a GAMS (1998) LP modelling software. To deal with the time dimension in the base models, without going into complex techniques, such as dynamic programming, a special model was developed . The uncertainty associated with planning for the future, is reduced through application of the principles of exploratory land use planning (van Keulen et al., 2000), and the use of basic data from identical (or comparable) sites.

6.2 Conclusions

6.2.1 *The planning support system*

Development and operationalisation of this planning support system has illustrated that it:

- Provides a systematic framework for using available information in solving agro-technical and socio-economic problems associated with the land allocation programme.
- Sketches a pathway towards sustainable use of the rangelands through increasing the production of the land, which is a step forward in the hierarchy of needs.
- Represents an interactive system of problem solving, applicable under various circumstances.

Application of the PSS has shown that district planning allows the planner to assess the impacts of various policies relevant to the district and select the most appropriate and agreeable, e.g., the one that is producing more benefit for the majority of the households. Output of the district planning model, e.g. a set of goals that should be attained in the course of the time horizon considered in the study, is an answer to a blind spot in Iran's range rehabilitation programs, that is achieved through the exploratory nature of the methodology used in the district planning module. One of the advantages of such a support system is that it allows regular evaluation of the situation, which provides the opportunity for updating of results and/or modifications in the implementation of actions that have not led to the desired developments.

The mathematical procedure included in the PSS does not simply generate one solution, which may not be applicable for political and/or economic reasons. It is suggested therefore that planners use the system to generate a range of acceptable solutions, instead of a single one or be sure that the solution is capable of resolving as much problems as possible.

Use of these types of models is faced with many imperfections, such as the high information demand. The method itself does not take into account, that in natural resource management, working under natural conditions, future planning remains uncertain, because of risks associated with unpredictable climatic events such as droughts, floods, and invasions of pests and diseases. Moreover, quantification of the value of all elements of the natural environment is not always easy or even possible. This holds for example for the value of a tonne of eroded soil. The effect of such elements in the decision making process, e.g. ranking of the alternatives, remains therefore arbitrary to some extent. However, different values can be assumed, and the effect on the final result examined.

The local planning module is not designed to generate a concrete solution, which is almost impossible, due to complexity of the procedure, associated with the fact that the problem of land deeding is ill-structured and cannot be totally formalized, and the unknown ultimate decision of the households. Rather, it is intended to support the process. Cooperation of the local population is a key element in the application of the module. Therefore, traditional land ownership, where that is an issue, must be incorporated in construction or reconstruction of the ranches as much as it is possible.

Including the effects of moral considerations of stakeholders presents serious problems, for example even if wheat production, as representative for cultural aspirations, financially could be compensated by cultivation of forage, it cannot resolve the problem of land ownership[1] which is the main reason for dryland cereal farming.

6.2.2 Application of the Planning Support System to the Iran situation

On the basis of the land evaluation exercise and taking into account the answers to our questions to various stakeholders, we have concluded that:

- Small parts of land showing unrealistic land uses in the analysis, e.g. rainfed cereals on steep slopes having shallow soil depths, are the result of mismatches of boundaries on various maps. These small parts of land should be 'converted' conservatively. For example, allocation of small polygons of rainfed areas to rangelands avoids annual plowings and it consequent erosion.
- Cultivation of cereals is deeply rooted in the culture of the local farmers and despite its ecological and economic drawbacks, it is not easy or logical for that matter, to ask for its immediate cessation. Conversion of rainfed cereals to a mixed agricultural system, such as a mixture of rainfed legumes and cereals creates a transitional situation, aiming at gradual conversion of rainfed cereals to rainfed forage. It would also be more sustainable in terms of plant nutrients, as the legumes can fix atmospheric

[1] Cultivation of rainfed wheat by farmers is a sign of land ownership, while government interventions hold the opposite effect.

nitrogen, part of which contributes to maintenance of soil fertility and grain production.

- Marginally suitable rainfed lands should return to rangeland because of their shallow soil and/or steep slope. This conversion from an annual crop to native perennial plants should reduce loss of soil through erosion and lead to more sustainable production systems.
- The presence of native species, in whatever small numbers, calls for more cautious agricultural practices, such as inter-seeding and/or proper grazing systems.
- Shallow soils, very steep slopes and rock outcrops are classified as lands non-suitable for extensive grazing. These lands are suggested to be reserved for wildlife.

6.3 Discussion

The system serves as a basis for discussion in that it does not allocate specific tracts of land to each individual household, but leaves that to negotiations with the land users. The PSS serves to support the decision-making process, and provides guidelines for a sustainable management programme.

In the course of the study it was concluded that in many cases, there is no other choice but formation of group ranches. The similarity of the current land deed process to land reform programmes in Africa (especially Kenya) some decades ago, allows comparison of both situations. In Kenya, some three decades ago, the starting point was the concept that a group ranch is an enterprise in which a group of households jointly hold a freehold title to land. They aim collectively at maintaining agreed stocking levels, and at herding collectively, but maintain individual stock ownership. At present, the group ranches are being sub-divided into separate plots managed by individual households. The study of Lusenaka (1996) shows that this process has proceeded to such an extent, that individualisation has caused segmentation of the land into small plots.
To avoid, as far as possible, the weak points of group ranching in Africa, this study suggests that:

- Social and economic interests of the population should form the core of any land deed programme;
- Land evaluation should be performed on a quantitative basis, so that outputs and inputs of any part of the land can be identified explicitly;

- All households should be free to join the group ranch of their choice;
- Households should have the right to sell their land, when better opportunities present themselves, but land trade should not lead to alienation of the land from the group and/or the agricultural sector.
- Trading should be facilitated. Thus land should have value derived from its quality. As a step forward, the quality of the land and the expense of land improvement are addressed in the land evaluation, district and local planning modules of the PSS, respectively.

One of the goals of the current study was to make optimal use of available information and show the added value of this information, when used in a coherent planning system. Therefore, the land suitability classification was based on relevant available information. It could be argued that comprehensive evaluation of land for extensive grazing would require additional information, such as distance to available sources of water and/or to the village. These characteristics are not only important for grazing management, but also may have significant effects on the value of the land. As this information was not available at the time of this study, it could not be used, but it may be included in further development of the PSS.

The district planning component of the system allows the planner to formulate a unique policy for the district, using all opportunities available and considering exchange of the resources.

The local component of the system pays attention to the households and their dependence on the rangelands. This facilitates the process of eligibility assessment, makes the criteria transparent and therefore supports selection of individuals and/or groups of households for land allocation. Its grazing capacity sub-module comprises a computerized model, written in a simple language (Qbasic) that can easily be modified. Application of this sub-module is hampered by lack of data, but this limitation will be removed as ongoing studies on energy content of rangeland plants continue.

This PSS could make a substantial contribution to the process of land allocation and might be used as a tool by experts and other interested parties in that process.

Application of the PSS in the actual practice of policy formulation and policy implementation faces problems. It requires educated experts and equipment for the creation of digital information and tools for generation and implementation of various types of software. These are not adequately available. Current socio-economic information in Iran does not cover all aspects of data required for construction of the model. For example, there is no explicit information on revenues generated from rangelands by various households. Moreover, this type of model should be used with caution: results should represent as much as possible reality, and not confirm or strengthen pre-conceived ideas of policy makers. Creation of beautiful maps, and plausible data may satisfy the planners and their chiefs, but only if these are based on solid information from reality, analysed with scientific integrity, could they possible contribute to stimulation of developments in the desired direction.

Decision makers can only be convinced through testing of the results in real practice ('the proof of the pudding is in the eating'). It is suggested, therefore, that in a new case, planners create a sample plane, test it and after satisfactory performance, execute it at a larger scale.

6.4 Suggestions for further studies

Growth simulation models have not been used in this study, because of the special characteristics of the rangelands and lack of data. In general, it has been argued that the quality of growth simulation models is as yet insufficient to reproduce production situations under natural conditions in less-developed countries. As the planning support system should be based on realistic estimates of the production capacity of the rangelands in the not too distant future, experimental data from grazing exclosures have been applied. To improve the quality of growth simulation models for the specific rangeland situation under semi-arid conditions, collection of climate and production data in grazing exclosures is suggested. Such information might support construction of simple simulation models with acceptable predictive capabilities.

Rainfed agriculture faces uncertainties, associated with low and erratic rainfall, and therefore in planning, risk should be considered. In some years, as in 1998/99 and 1999/00, rainfall was so low that rainfed crops completely failed. Incorporation of such uncertainties in scheduling future activities needs attention in future studies.

Accurate modelling of the grazing capacity requires information on the energy expenditure in the grazing situation, for which no accurate data are available. On the other hand, (digestible) energy contents of rangeland plants for the study area are neither known adequately. Studies on energy supply of rangeland plants have recently started in Iran and it is suggested to continue these. Energy demands under different topographic conditions in Iran are also required. A major problem in predicting animal intake under grazing conditions in heterogeneous vegetation is the effect of selectivity of the animals. More research in this field is urgently needed.

Ackoff, R.L. 1981. The art and science of mess management. TIMS Interfaces, vol. 11, no. 1, pp. 20-26.

AIAS (Australian Institute of Agricultural Science), 1981. A manual of Australian agriculture (L. Reid (ed.)) 4th edition. Heinemann, Melbourne, Australia. 431 pp.

Akbarzadeh, M. 1990. Comparison of yearly production of some perennial medics in Oromieh province. Publication No. 63, Research Institute of Forests and Rangelands, Tehran, Iran. 33 pp. (La: Farsi).

Alfaro, R., Bouma, J., Fresco, L.O., Jansen, D.M., Kroonenberg, S.B., Van Leeuwen, A.C.J., Schipper, R.A., Sevenhuysen, R.J., Stoorvogel, J.J. and Watson, V. 1994. Sustainable land use planning in Costa Rica: A methodological study on farm and regional level. In: L.O. Fresco, L. Stroosnijder, J. Bouma and H. van Keulen (eds). The future of the land. Mobilising and integrating knowledge for land use options. John Wiley and Sons, Chichester, UK. pp. 183-202.

Alimolaei, S. 1984. A rangeland's profile of Bakhtiarian province. Faculty of Natural Resources, University of Tehran. Karaj, Iran. 93 pp. (La: Farsi).

Alizadeh, A. 1989. Principles of applied hydrology. Astaneghods, Mashhad, Iran. 518 pp. (La: Farsi).

American Society of Agronomy (ASA), 1989. Decision reached on sustainable agriculture. Agronomy News, January. 15 pp.

ARC (Agricultural Research Council), 1965. Requirements for energy. In: The nutrient requirements of farm livestock. No. 2. Ruminants. ARC, London, section 6, 193-257.

Ayyad, M. A. and Van Keulen, H. (eds.) 1987. The Mariut project. Final report submitted to the Directorate General International Cooperation (DGIS), Part 3. Centre for Agrobiological Research (CABO), Wageningen, the Netherlands.

Azad, M. 1992. Report on B2 parcel of Zayanderod. Vol. I. Hydrology and climate. Watershed Directorate of Esfahan Jihad of Sazandegi. Esfahan, Iran. 179 pp. (La: Farsi).

Azadeh, F. and Ahmadian, S. 1993. Agricultural history of Iran. Jashnvareh honari-adabi rosta. Tehran, Iran. 176 pp. (La: Farsi).

Azadivar, F. 1991. Animal husbandry or range management. Forest and Rangeland J., Tehran, Iran.11: 37-39. (La: Farsi).

Babakhanlo, B. 1985. Instruction of range management plans. Forest and Range Organization of Iran. Technical Report No. 53. Tehran, Iran. 37 pp. (La: Farsi).

Bagheri, M. R. 1994. The most suitable system of rangeland utilization in Kabkan province. Faculty of Natural Resources, University of Tehran, Karaj, Iran. pp. 125-179 (La: Farsi).

Bagherzadeh, K. 1995. Effect of weeding on productivity of 12 rainfed medic species. Esfahan Center for the Research of Animal Science and Natural Resources, Esfahan, Iran. 26 pp. (La: Farsi).

Basiri, M. 1987. Integrated development plan of Charmahal. Vol. V. Vegetation. Ministry of Planning and Budget. Tehran, Iran. 35 pp. (La: Farsi).

Basiri, M. 1984. Iran's range problems in brief. Faculty of Agriculture, Esfahan University of Technology. Esfahan, Iran. 21pp. (La: Farsi).

Bavari, A. R. 1980. An introduction to Iranian traditional agriculture. Bongahe Tarjomeh va Nashre Ketab, Tehran, Iran, 125 pp. (La: Farsi).

Beek, K. J., de Bie, C. A. and Driessen, P. M. 1997. Land evaluation (FAO method) for sustainable land use planning and management: Status and perspectives. International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands. 24 pp.

Bennett, J. L. 1983. Building Decision Support Systems. Addison – Wesley Publishing Co., MA. USA.

Beskow, A., Elissalde, N. O. and Rostango, C. M. 1995. Ecosystem change associated with grazing intensity of the Puna Nifas rangelands of Patagonia, Argentina. Journal of Range Management 48: 517-522.

Bouzza, A. 1990. Water conservation in wheat rotation under several management and tillage systems in semiarid areas. Ph.D thesis, University of Nebraska, USA. 132 pp.

Breman, H. and De Wit, C.T. 1983. Rangeland productivity and exploitation in the Sahel. Science 221: 1341-1343.

Brengle, K. G. 1982. Principles and practice of dryland farming. Colorado Associate Press, Boulder, Colorado, USA. 177 pp.

Campbell, J., Radke, J., Gless, T.J. and Wirtshafter, R. M. 1992. An application of linear programming and geographic information system: cropland allocation in Antigua. Environment and Planning 24: 535-549.

Campbell, J., 1988. Using natural resource information in land use planning and developing agricultural diversification strategies. Report presented at Eastern Caribbean State Natural Resource Management Project Conference, November 1988, Castries, St

Lucia; copy available from Organization of American States, P.O. Box 1231, Port of Spain, Trinidad.

Campbell, J. and Heady, E.O. 1979. Potential economic impacts of alternative environmental problems. Report 87, Centre for Agriculture and Rural Development, Iowa state University, Ames, IA, USA.

Chankong, V. and Haimes, Y.Y. 1983. Multiobjective Decision Making: Theory and Methodology, North Holland, Amsterdam.

Cissé, M.I. and Breman, H. 1980. Influence de l'exploitation sur un pâturage á Andropogon gayanus Kunth var. tridentatus. Revue d'Elevage et de Médicine véterinaire des Pays tropicaux 33: 407-416.

Colston, G. and Bruyn, C. 1989. Models and methods in multiple objectives decision making. Mathematical/Computer Modelling 12: 1201-1211.

Cooper, P.J.M., Gregory, P.J., Tully, D. and Harris, H.C. 1987. Improving water use efficiency of annual crops in the rainfed farming system of West Asia and North Africa. Experimental. Agriculture 23: 113-158.

Crampton, E. W., Donefer, E. and Lloyd, L.E. 1960. A nutritive value index for forage. Journal of Animal Science 19: 538-544.

Dadafarid, A. 1994. Effect of range management training courses on utilisation performance of households of Khoy province. Faculty of Natural Resources, University of Tehran, Karaj, Iran. pp. 123-129 (La: Farsi).

Dashlyboron, P. N. 1986. General concept of Iranian rangelands. Forest and Range Organization of Iran, Tehran, Iran. 20 pp. (La: Farsi).

de Ridder, N., Stroosnijder, L., Cisse, A. M. and Van Keulen, H. 1982. PPS Course Book, Volume I. Wageningen Agricultural University, Department of Soil Science and Plant Nutrition, Wageningen, The Netherlands. 231 pp.

de Wit, C.T. and Seligman, N.G. 1992. Introduction. In: Alberda, Th., H. Van Keulen, N.G. Seligman and C.T. De Wit (eds.) Food from Dry Lands. An integrated approach to planning of agricultural development. Systems Approaches for Sustainable Agricultural Development, Vol. 1, Kluwer Academic Publishers, Dordrecht, The Netherlands. pp. 1-6.

de Wit, C. T. and van Keulen H., 1987. Modelling production of field crop and its requirements. Geoderma 40: 253-265.

Dobbs, T. L. and Becker, D. C. 1991. Sustainable agriculture policy analysis: South Dakota on-farm case studies. Journal of Farming System Research and Extension 2: 109-124.

Duncan, D.A. and Woodmansee, R.G. 1975. Forecasting forage yield from precipitation in California's annual rangeland. Journal of Range Management 28: 327-329.

Edwards, L.M. 1989. Dry matter growth performance of red clover and Italian ryegrass as cover crops spring-seeded into fall-seeded winter rye in relation to soil physical characteristics. Journal of Soil and Water Conservation 44: 243-247.

Eftekhari, A. 1992. Report on B2 parcel of Zayanderod. Vol. III. Socio-economics, agriculture and animal husbandry. Watershed Directorate of Esfahan Jihad of Sazandegi, Esfahan, Iran. pp.116-136. (La:Farsi).

El-Shishiny, H. E. and Attia, B. B. 1985. Multi-objective modelling for the planning and management of new lands in Egypt. A case study. IFAC System Analysis Applied to Water and Related Land Resources, Lisbon, Portugal. pp. 205-208.

Eskandary, Z. 1992. Report on B2 parcel of Zayanderod. Vol. V. Soil. Watershed Directorate of Esfahan Jihad of Sazandegi, Esfahan, Iran. 85 pp. (La: Farsi).

FAO, 1993. Guidelines for Land Use Planning. FAO Development Series 1. FAO, Rome, Italy. 96 pp.

FAO, 1991. Guidelines: Land evaluation for extensive grazing. FAO Soils Bulletin No. 58. FAO, Rome, Italy. 170 pp.

FAO, 1985. Guidelines: land evaluation for irrigated agriculture. FAO Soils Bulletin No. 55. FAO, Rome, Italy. 243 pp.

FAO, 1983. Guidelines: land evaluation for rainfed agriculture. FAO Soils Bulletin No. 52. FAO, Rome, Italy. 249 pp.

FAO, 1976. A framework for land evaluation. FAO Soils Bulletin No. 32. FAO, Rome, Italy.

FAO, UNDP and UNEP. 1994. Land degradation in south Asia: its severity, causes and effects upon the people. World Soil Resources Report, No. 78. FAO, Rome, Italy. 100 pp.

Fazilati, A. and Eraghi, H. H. 1984. Rangelands: Consequences of land misuse and proper procedure for rehabilitation. Forest and Range Organization of Iran, Tehran, Iran. 32 pp. (La: Farsi).

Finlayson, J.D., Cacho, O. J. and Bywater, A. C. 1995. A simulation model of grazing sheep: 1. Animal growth and intake. Agricultural Systems 48: 1-25.

Fischer, G. and Makowski, M. 1996. Multiple criteria land use analysis. International Institute for Applied Systems Analysis (IIASA), Laxenberg, Austria. 15 pp.

Francis, C. A. and Youngberg, G. 1990. Sustainable agriculture: An overview in sustainable agriculture in temperate zone. In: C. A.

Francis, C. B. Flora and L.D. King (eds.) Johan Wiley and Sons, New York. pp. 1-23.

Frére, M., Maracchi, G., Miglietta, F. and Conese, C. 1987. Agroclimatological classification of the Mediterranean and Southwest Asian areas. In: Drought tolerance in winter cereals, Proceedings of an International Workshop 27-31 October 1985, Capri, Italy.

Fresco, L. O., Huizing, H., van Keulen, H., Luning, H. A. and Schipper, R.A. 1994. Land evaluation and farming system analysis for land use planning. FAO working document.

Fresco, L. O. and Kroonenberg, S. B. 1992. Time and spatial scales in ecological sustainability. Land Use Policy 9: 155-169.

Funnpheng, P., Chitchumnog, T., Mekpaiboonwattana, S., Pramojanee, P., Patinavin, P., Saifuk, K., Bronsveld, K. and Huizing, H. 1994. Implementation of an information system as a tool for land use planning in Thailand. ITC Journal 4:374-384.

Furley, P.A., Anderson, M.G. and Brooks, S. M. 1996. The influence of slope on the nature and distribution of soils and plant communities in the Central Brazilian cerrado. Advances in Hill Slope Processes. 1: 327-346.

Galaty, J. and Salzman, C.P. 1992. The Maasai group-ranch: Politics and development in an African pastoral society. When-Nomads-Settle. Praeger, New York, USA. pp. 157-172.

Gartner, J.A. and Hallam, D. 1984. A quantitative framework for livestock development planning: Part 3-Feed demand and supply. Agricultural Systems 14:123-142.

Gates, D. H. 1967. Range seeding: success or failure. Fact sheet 120, Oregon Agricultural Extension Service. 2p. In: Vallentine, 1989.

Ghasriani, F. 1992. Comparison of yearly production of some perennial medics in Kordestan province. Publication No. 85, Research Institute of Forest and Rangeland, Tehran, Iran. 24 pp. (La: Farsi).

Ghorchi, T. 1995. Determination of chemical composition and digestibility of range plants in Esfahan province. Faculty of Agriculture, Technical University of Esfahan, Esfahan, Iran. 90 pp. (La: Farsi).

Girard, N. and Hubert, B. 1999. Modelling expert knowledge with knowledge-based systems to decision aids: the example of a knowledge based model on grazing management. Agricultural Systems 59: 123-144.

Gorry, G. A. and Morton, S. M. S. 1971. A framework for management information systems. Sloan Management Review 13: 56-70.

Goudriaan, J. and Van Laar, H. H. 1994. Modelling potential growth processes. Kluwer Academic Publishers. 238 pp.

Grant, W. E. and Thompson, P. B. 1997. Integrated ecological models: simulation of socio-cultural constraints on ecological dynamics. Ecological Modelling 100: 45-49.

Gregory, P.J. 1991. Concepts of water use efficiency. In: H.C. Harris, P.J.M. Cooper and M. Pala (eds.) Soil and crop management for improved water use efficiency in rainfed areas, ICARDA, Aleppo, Syria. pp. 9-20.

Gregory, P.J., McGowan, M. and Biscoe, P.V. 1978. Water relations of winter wheat. 2. Soil water relations. Journal of agricultural Science (Camb) 91: 103-116.

Gregory, S. 1978. Statistical methods and the geographer. Fourth edition. Longman Science and Technical, USA. 240 pp.

Grovum, W. L. and Williams, V. J. 1977. Rate of passage of digesta in sheep. 6. The effect of level of food intake in mathematical prediction of the kinetics of digesta in the reticulorumen and intestines. British Journal of Nutrition 38: 425-436.

Hadjichristodoulou, A. 1987. Stability of performance of cereals in low rainfall areas as related to adaptive traits. In: Drought tolerance in winter cereals, Proceeding of an International Workshop 27-31 October 1985, Capri, Italy.

Haenlein, G. F. W. 1978. Dairy goat management. Journal of Dairy Science 61:10-11.

Han, S. and Kim, T.J. 1989. Can expert system help with planning? Journal of American Planning Association, 55(3), 296-308.

Hansen, J. W. 1996. Is agricultural sustainability a useful concept? Agricultural Systems 51: 117-143.

Hansen, J. W. and Jones J. W. 1996. A systems framework for characterising farm sustainability. Agricultural Systems 51: 185-201.

Hardin, G. 1968. The tragedy of the commons. Science 162: 1234-1248.

Hauptli , H., Katz, D., Thomas, B. R. and Goodman, R. M. 1990. Biotechnology and crop breeding for sustainable agriculture. In: C. A. Edwards, R. Lal, P. Madden, R.H. Miller and G. House (eds.) Sustainable agricultural systems. Soil and Water Conservation Society, Ankeny, Iowa. pp. 141-156.

Heady, H. and Child, R. D. 1994. Rangeland Ecology and Management. West View Press. 519 pp.

Heady, E.O. and Timmons, J. F. 1975. US land need for meeting food and fibre demands. Journal of Soil and Water Conservation 30: 15-22.

Healey, P. 1992. Planning through debate: the communicative turn in planning theory. Town Planning Review 63:143-162.
Herrero, M. 1997. Modelling dairy grazing systems: an integrated approach. Ph.D. thesis, University of Edinburg, UK. 282 pp.
Heyne, F. G. 1987. Wheat and wheat improvement. American Society of Agronomy. Madison, Wi., USA.
Hinloopen, E. and Nijkamp, P. 1984. Information system and uncertainty in planning. In: Nijkamp, P. and Rietveld, P. (eds.) Information systems for integrated regional planning. Contributions to economic analysis 149. North Holland Publishing, Amsterdam, the Neterlands. pp. 101-119.
Hodges, T. 1991. Predicting crop phenology. CRC press. Boston, USA.
Holechek, J. L., Piper, R. D. and Herberl C. H. 1989. Range management, principles and practices. Prentice Hall. Englewood Cliffs, New Jersey, USA.
Houérou, H. N. Le and Host, C. H. 1977. Range production and annual rainfall relations in Mediterranean Basin and Africa Sahelo-Sudanian Zone. J.Range Management. 30:181-189.
Huizing, H. and Bronsveld, K. 1994. Interactive multiple-goal analysis for land use planning. ITC Journal 4: 366-373.
Ibrahim, K. 1975. Glossary of terms used in pasture and range survey, research, ecology and management. FAO-AGPC-MISC/34. FAO, Rome. 162 pp.
Jankowski, P. 1995. Integrating geographical information systems and multi-criteria decision methods. International Journal of Geographical Information Systems 3: 251-273.
Janssen, R. 1992. Multi objective decision support for environmental management. Environment and management. Vol. 2. Kluwer Academic Publisher, Dordrecht, the Netherlands.
Javanshir, K. 1976. Atlas of woody plants of Iran. The National Society for the Conservation of Natural Resources and Human Environment, Tehran, Iran. 163 pp. (La: Farsi).

JingHua, S., MingZhu, S., Sun-JH, Song-Mz. 1996. Establishment of model for sown pasture in the desert pain area of the Tarimu Basin. Grassland of China No. 6, 11-13. (La: Chinese. Abstract in English available in CAB CDROMs).

Kardavani, P. 1992. Rangelands, problems and solutions. Tehran University Publications No. 2119, Tehran, Iran. 504 pp. (La: Farsi).

Kardavani, P. 1995. Rangelands, problems and solutions. Second edition. Tehran University Publications No. 2119, Tehran, Iran. 514 pp. (La: Farsi).

Karimi, M. 1987. Climate of central Iran. Faculty of Agriculture, Esfahan University of Technology, Esfahan, Iran. 87 pp. (La: Farsi).

Kershaw, A. K. 1973. Quantitative and dynamic plant ecology. Second edition, London: Edward Arnold. 308 pp.

Klosterman, R. E. 1997. Planning support system: a new perspective on computer-aided planning. Journal of Planning Education and Research 17: 45-54.

Kurmvanshi, S. M., Tripathi, M. L., Jain, K. K. and Sharman, R. S. 1996. Relative performance of rainfed wheat (Triticum aestivum) under different dates of sowing in Vindhyan plateau of Madhya Pradesh. Indian Journal of Agronomy 41: 645-647.

Lockeretz, W. 1988. Open question in sustainable agriculture. American Journal of Alternative Agriculture 3: 174-181.

Lomas, J. 1972. Forecasting wheat yield from rainfall data in Iran. WMO Bulletin, January pp. 9-14.

Lu Changhe, 2000. Breaking the spiral of unsustainability. An exploratory land use study for Ansai, the Loess Plateau of China. Ph.D. Thesis, Wageningen University. 257 pp.

Lusenaka, F.W. 1996. Group ranch subdivision and household socio - economic performance in Kajiado district. Nairobi ; Leiden : Ministry of Planning and National Development ; Africa Studies Centre. 38 pp.

MacRae, R. J., Hill, S. B., Mehuys, G. R. and Henning, J. 1990. Farm-scale agronomic and economic conversion from conventional to sustainable agriculture. Advances in Agronomy 43: 155-98.

MAFF (Ministry of Agriculture, Fisheries and Food) 1975. Energy allowances and feeding systems for ruminants. Technical Bulletin 33. HMSO, London.

Makilya, J., Lembuya, P. and Ntiati, P. 1996. Kenya: linking enterprise to conservation. How the Kenya Wildlife Service is aiming to put in place incentives for community conservation. Rural-Extension-Bulletin No. 10: 56-60.

Makowski, M. 1994. Methodology and modular tool for multi criteria analysis of LP models. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. 12 pp.

Mazroei, F. 1992. Report on B2 parcel of Zayanderod. Vol. II. Vegetation cover. Watershed Directorate of Esfahan Jihad of Sazandegi, Esfahan, Iran. 60 pp. (La: Farsi).

Meigs, P. 1953. World distribution of arid and semiarid homoclimates. Arid Zone Research 1: 203-210.

Mintzberg, H., Raisinghani, D., and Theoret, A., 1976. The structure of "Unstructured" Decision Processes" Administrative Science Quarterly, 21: 246-275

Mirnezam, H. 1972. Moisture conservation in dryland farming. Publication No. 344, Soil Science and Soil Fertility Organization of Iran. Ministry of Agriculture, Tehran, Iran. 10 pp. (La: Farsi).

Mobayen, S. and Tregubov, V. 1970. Explanatory Guide to the Map of the Natural Vegetation of Iran, College of Forestry, Bulletin No. 14, Karaj, Iran. 35 pp.

Moeinodiny, H. 1993. Iran's range managements in brief. Forests and Rangelands Journal, Tehran, Iran. 17: 38-43.

Mohamed, A. M. 1999. An integrated agro-economic and agro-ecological framework for land use planning and policy analysis. ITC Publication No. 74, ITC, Enschede, The Netherlands. 188 pp.

Moradmand, R. and Mehnatkesh, A. 1997. Nitrogen and phosphorus demands of *Triticum aestivum* var. Sardari grown in Lordegan. Charmahal agricultural research center. Ministry of Agriculture, Shahrekord, Iran. 804 pp.

Mosavi Nejat, A. R. 1996. Management's effect on range condition, range trend and grazing capacity of Semnan province rangelands. Faculty of Natural Resources, University of Tehran, Karaj, Iran. 195 pp. (La: Farsi).

M.P.B. 1998. Iran's statistical yearbook (March 1996 – March 1997). Ministry of Planning and Budgeting, Tehran, Iran. 804 pp.

Musick, J. T., Jones, Stewart, B. A. and Dusek, D. A. 1994. Water-yield relationship for irrigated and dryland wheat in the US southern plains. Agronomy Journal 86: 6, 980-986.

Nekoei, A. 1992. Wheat growth determinants in Esfahan. Faculty of Science, University of Esfahan, Iran. 125 pp. (La: Farsi)

Nix, H.A. 1968. The assessment of biological productivity. PP.77-87. In: G.A. Stewart (ed.), land evaluation, papers of CSIRO symposium (Canberra). MacMillan of Australia. Melbourne.

Noy-Meir, I. 1976. Rotational grazing in a continuously growing pasture: a simple model. Agricultural Systems 1: 87-112.

Noy-Meir, I. 1978a. Grazing and production in seasonal pastures: Analysis of a simple model. Journal of applied Ecology 15: 809-835.

Noy-Meir, I. 1978b. Stability in simple grazing models: effects of implicit functions. Journal of theoretical.Biology 71: 347-380.

NRC, 1981. Nutrient requirement of goat # 15. National Academy Press, Washington D.C., USA. First print. 95 pp.

Nuttonson, M.Y. 1953. Phenology and thermal development as a means for a physiological classification of wheat varieties and for predicting maturity dates of wheat. Report American Institute of Crop Ecology, Washington, USA. 108 pp.

O'Connell, P.F. 1992. Sustainable agriculture, a valid alternative. Outlook on Agriculture 21: 5-12.

Olembo, R. J. 1994. Can land use planning contribute to sustainability? In: L.O. Fresco, L. Stroonsnijder, J. Bouma and H. van Keulen (eds). The future of the land. Mobilising and integrating knowledge for land use options. Johan Wiley and Sons, Chichester, UK. pp. 369-376.

Oxby, C. 1981. Group ranches in Africa. ODI-Review 2: 45-56.

Pantastico, C. M. and Venable, D.L. 1993. Competition in two species of desert annuals along a topographic gradient. Ecology 74: 2192-2203.

Pazireh, M. A. 1994. Possession forms and their relation to range deterioration. Faculty of Natural Resources, University of Tehran, Karaj, Iran. 225 pp. (La: Farsi).

Penning de Vries, F.W.T. and Van Laar, H.H. (Eds.) 1982. Simulation of plant growth and crop production. Simulation Monographs, Centre for Agricultural Publishing and Documentation (Pudoc), Wageningen, the Netherlands. 308 pp.

Petch, J. R., Pauknerova, E. and Heywood, D. L. 1995. GIS nature conservation: The Zdarske vrchy project, Czech Republic. ITC Journal 2: 133-142.

Pieri, C. 1997. Planning sustainable land management: the hierarchy of user needs. ITC Journal 3/4: 223-228.

Platteau, J. P. 1996. The evolutionary theory of land right as applied to Sub-Saharan Africa: A critical assessment. Development and Change 27:29-86.

Reed, J. D. and Bert, J. 1995. The role of livestock in sustainable agriculture and natural resource management. In: J.M. Powell, S. Fernándes-Rivera, T.O. Williams and C. Rénard Livestock and sustainable nutrient cycling in mixed farming system of sub-Saharan Africa. Vol. II: Technical Papers, ILCA, Addis Ababa. pp. 461-470.

Rodrigues, A. 1994. Rangeland production system in Balochestan, Pakistan. Journal of Range Management 16: 21-24.

Romero, C. and Rehman, T. 1989. Multiple criteria analysis for agricultural decisions. Elsevier, Amsterdam.

Rossiter, D. G. and van Wambeke, 1989. LES: Automated Land Evaluation System. Department of Agronomy, Cornell University. Ithaca, New York.

Roy, B. 1978. ELECTRA II, un alghorithme de classement fonde sur une representation floue des preferences en multiples. Cah, CERO 20, 3-240. Presence de criteres. In: A. Sharifi 1998.

Sachdeva, K. K., Sengar, O. P. S., Singh, S. N. and Lindahl, I. L. 1973. Studies on goats. I. Effect of plane of nutrition on the reproductive performance of does. J. Agric. Sci., Cambridge 80:375.

Sadat mansour, M., Siamansour, S. 1985. Fundamental of sheep raring. University of Tehran. pp. 325.

Sadeghian, M. 1996. Variability of energy and protein and dry matter degradation at different phenological stages of 13 range plants of Esfahan province. Open University of Khorasgan, Esfahan, Iran. 92 pp. (La: Farsi).

Salmasi, D. 1995. Problems of small size range management plans. Faculty of Natural Resources, University of Tehran, Karaj, Iran. 130 pp. (La: Farsi).

Sanders, J. O. and Cartwright, T.C. 1979. A general cattle production systems model. Part 2- Procedures used for simulation animal performance. Agricultural Systems. 4:289-309.

Sarokin, D. and Schulkin, J. 1991. Environmentalism and right-to-know: expanding the practices of democracy. Ecological Economics 4:175-189.

Savadogo, M., 1999. Crop residue management in relation to sustainable land use. A case study in Burkina Faso. Ph. D. Thesis, Wageningen University. 159 pp.

Schafer, G.N. 1988. A site growth model for Pinus elliottii in the south Cape. South African Forestry Journal 146:12-17.

Schipper, R. A. 1996. Farming in a fragile future. Economics of land use with application in the Atlantic Zone of Costa Rica. Ph.D. thesis, Wageningen Agricultural University, Wageningen, the Netherlands.

Schipper, R. A., Jansen, D. M. and Stoorvogel, J. J. 1995. Sub-regional linear programming model in land use analysis: a case study of the Neguev settlement, Costa Rica. Netherlands Journal of Agricultural Science 43: 83-109.

Schoonenboom, I. J. 1995. Overview and state of the art of scenario studies for the rural environment. In: J. F.Th. Schoute, P.A. Finke, F.R. Veeneklaas and H.P. Wolfert (eds). Scenario studies for the rural environment. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Seraj, N. 1970. Range management: plans and their problems. Proceedings of the Second Conference of Range Experts. Forest and Range Organization of Iran, Tehran, Iran. pp. 124-127 (La: Farsi).

Sharifi, M. A. 2000. Planning Support Systems to Enhance Sustainable Land Utilization Resource. Social Sciences Division, International Institute for Aerospace Survey and Earth Sciences. Presented at the Seminar on Impact of Land Utilization Systems on Agricultural Productivity Asian Productivity Organization & The Iranian Ministry of Agriculture 4-10 November, Tehran, Islamic Republic of Iran

Sharifi, M. A. 1999. Remote sensing and decision support systems. In: A. Stein, F. van der Meer F. and B. Gorte (eds.) Spatial Statistics for Remote Sensing. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Sharifi, M. A. 1992. Development of an appropriate resource information system to support agricultural management at farm enterprise level. Ph.D. thesis. Wageningen Agricultural University, Wageningen, The Netherlands. 217 pp.

Sharifi, M. A. 1998. Decision support systems. Lecture notes for Esm-2 course. Social Sciences Division, ITC, Enschede, the Netherlands.

Sheidaei, G. and Nemati, N. 1970. Some information about Iran's rangelands. Forest and Range Organization of Iran, Tehran, Iran. 43 pp. (La: Farsi).

Sheidaei, G. and Nemati, N. 1978. Modern range management and forage production in Iran. Forest and Range Organization of Iran, Tehran, Iran. 290 pp. (La: Farsi).

Shirmohammadi, E. 1991. Assessment of the range rehabilitation plans. Faculty of Natural Resources, University of Tehran, Karaj, Iran. 142 pp. (La: Farsi).

Simon, H. A. 1960. The new science of management decisions. Harper and Brother, New York.

Singh, S. N. and Sengar, O. P. S. 1970. Investigation on milk and meat potential of Indian goats, 1965-70. Final Technical Report Project A7-AH18. Raja Balwant Singh College, Bichpuri (Agra) India. In: NRC 1981. Nutrient Requirements of Goat: Angora, Dairy, and Meat Goat in Temperate and Tropical Countries. National Academy Press. 91 pp.

Skima, D. E. 1970. Summer fallow for dryland winter wheat in the semi-arid Great Plains. Agronomy Journal 62: 15-17.

Sol, H.G. 1982. Simulation in information system development, Ph.D. thesis. University of Groningen, Groningen, the Netherlands.

Southgate, C. and Hulme, D. 1996. Land, water and local governance in a Kenyan wetland in dryland: the Kimana Group Ranch and its environs. Rural Resources, Rural Livelihoods working Paper Series No. 4. 62 pp.

Sprague, R. H. and Watson, H. J. 1986. Decision Support System: Putting theory into practice. Englewood Cliffs, N.J.: Prentice-Hall.

Stoddart, L.A., Smith, A. D. and Box, T. W. 1975. Range management. Third edition, Mac Graw-Hill Book Company, USA. 531 pp.

Stoorvogel, J. J. 1995. Integration of computer-based models and tools to evaluation alternative land-use scenarios as part of an agricultural system analysis. Agricultural Systems 49: 353-367.

St-pierre, N. R., and Bywater, A.C. 1987. Development of a dynamic model of sheep growth and composition. Ministry of Agriculture and Fisheries Research Paper 2/87, Ruakura, Hamilton, 30 pp.

Stuth, J.W. and Lyons, B.G.D. 1993. Decision support systems for the management of grazing lands. UNESCO, Man and Biosphere series, vol. II. 301 pp.

Taghian, A. Z. 1988. Esfahan's rangelands. M.sc. thesis, University of Esfahan, Group of Geography. Esfahan, Iran. pp. 155-158. (La: Farsi).

Technical Office of Range, 1985. A plan for re-conversion of 2 million hectares of unsuitable dryland areas. Forest and Range Organization, Tehran, Iran. 22 pp.

Thieraf, R. J. 1982. Decision Support System for Effective Planning and Control. Prentice System for Brush and Weed. Technology Selection. Texas Agriculture Extension Services and TX. USA. Ranching System Group, Texas A&M University.

Todaro, M. P. 1992. Economic development in the third world. Fourth edition. Longman, Burnt Mill, UK. 697 pp.

TORM, 2001. Introduction to Iran's rangelands. Presented in Launching meeting for the Asian thematic program network on rangeland management and fixation of shifting sand dunes. Held at Yazd, Islamic Republic of Iran, May 2001. Forest and Range Organization of Iran, Tehran, Iran. PP. 20.

Tri, L. Q. 1993. Present land use as a basis for land evaluation in Mekong Delta. ITC Journal 4: 377-385.

Turban, E. 1995. Decision support and expert system: management support system. Macmillan Publishing Company, New York.

Vahabi, M. R. 1989. Vegetation cover and composition, forage production and infiltration rate of grazed and ungrazed conditions in Fereidan province. M.sc. thesis, faculty of Natural Resources, University of Tehran, Iran. 389 pp. (La: Farsi).

Vallentine, J. F. 1989. Range development and improvements. Third edition. Academic Press Inc., USA. 524 pp.

van Diepen, C. A., van Keulen, H., Wolf, J. and Berkhout, J. A. A. 1991. Land evaluation: from intuition to quantification. Advances in Soil Science 15: 139-204.

van Diepen, C. A., Wolf, J., Van Keulen, H. and Rappoldt, C. 1989. WOFOST, a simulation model of crop production. Soil Use and Management. 5: 16-24.

van Es, A. J. H., Vermorel, M. and Bickel, H. 1978. Feed evaluation for ruminants: New energy system in the Netherlands, France and Switzerland. General introduction. Livestock Production Science 5: 327-330.

van Ittersum, M. K., Rabbinge, R. and Van Latesteijn, H. C. 1998. Exploratory land use planning and their role in strategic policy making. Agricultural Systems 58: 309-330.

van Keulen, H., van Ittersum, M. K. and De Ridder, N. 2000. New approaches to land use planning. In: R. Rötter, H. van Keulen, A.G. Laborte, C.T. Hoanh and H. H. van Laar (eds.) Systems research for optimising future land use in South and Southeast Asia. SysNet Research Paper Series No. 2, IRRI, Los Baños, Philippines. pp. 3-20.

van Keulen, H., Kuyvenhoven, A. and Ruben, R. 1998. Land use and food security in developing countries: DLV's approach to policy support. Agricultural Systems 58: 285-307.

van Keulen, H. and Veeneklaas, F. R. 1995. Options for agricultural development: a case study for Mali's fifth region. In: F.W.T. Penning de Vries, P. Teng and K. Metselaar (eds.) Systems Approaches for Agricultural Development. Kluwer Academic Publishers, Dordrecht, the Netherlands. pp. 367-380.

van Keulen, H., Berkhout, J.A.A., van Diepen, C. A., van Heemst, H.D.J., Jansen, B.H., Rappoldt, C. and J. Wolf, 1987. Quantitative land evaluation for agro-ecological characterization. In: A.H. Bunting (ed), Agricultural Environments. CAB International, Wallingford, Oxon, UK, pp. 185-197.

van Keulen, H. and Seligman, N.G. 1987. Simulation of water use, nitrogen nutrition and growth of a spring wheat crop. Simulation Monographs, Centre for Agricultural Publishing and Documentation (Pudoc), Wageningen, the Netherlands. 310 pp.

van Keulen, H. and Wolf, J. 1986. Modelling of agricultural production: weather, soils and crops. Simulation Monographs, Centre for Agricultural Publishing and Documentation (Pudoc), Wageningen, the Netherlands. 479 pp.

van Keulen, H. 1975. Simulation of water use and herbage growth in arid regions. Wageningen, Center for Agricultural Publication and Documentation (Pudoc), Wageningen, The Netherlands. 176 pp.

van Kooten, G. C. 1993. Land resource economics and sustainable development. UBC Press, Vancouver, Canada.

van Lier, H. N., Jaarsma, C. F. and de Buck A. J. 1994. Sustainable land use planning. Proceedings of International Workshop, 2-4 September 1992, Wageningen, The Netherlands. pp. 1-11.

van Soest, P.J. 1982. Nutritional ecology of the ruminant. O & B Brooks, Inc., Corvallis.

Veeneklaas, F. R. and Van den Berg, L. M. 1995. Scenario building: art, craft or just a fashionable whim? In: J.T.P. Schoute, P.A. Finke, F.R. Veeneklaas and H.P. Wolfert (eds.) Scenario studies for the rural environment. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Veeneklaas, F. R., Cissé, S., Gosseye, P.A., Van Duivenbooden, N. and Van Keulen, H. 1991. Competing for limited resources: the case of the fifth region of Mali. 4. Development scenarios. CABO-DLO, Wageningen, the Netherlands. 143 pp.

Ven G.W.J. van de, 1996. A mathematical approach to comparing environmental and economic goals in dairy farming in the Netherlands. Ph.D. Thesis, Wageningen Agricultural University. 239 pp.

Vink, A.P.A. 1960. Quantitative aspects of land classification. Transactions 7th International Congress of Soil Science (Madison, Wisconsin, USA). 4:371-378.

Voogd, H. 1983. Multi criteria evaluation for urban and regional planning. Pion Ltd, London.

Wilson, R.T. and Maki, M.O. 1989. Goat and sheep population changes on a Masai group ranch in South-Western Kenya, 1978-1986. Agricultural Systems 29: 325-337.

Winsemius, P. 1995. Sustainable development – sustaining the peace, sustaining the planet. Presentation during the Clingendael series of the Netherlands-Canada/1995 Distinguished Lecture, The Hague, the Netherlands.

World Commission on Environment and Development (WCED), 1987. Our common future. Oxford University Press, Oxford, UK. 400 pp.

Yanuariadi, T. 1999. Sustainable land allocation, GIS-based decision support for industrial forest plantation development in Indonesia. ITC Publication No. 71. ITC, Enschede, the Netherlands.

Zaeifi, M., Valizadeh, M., Marefat, G. and Davarpanah, H. 1994. Study of stability of an agricultural system using a compound cultivation technique. Proceedings of the first National Range and Range Management Seminar in Iran. August 1993, Esfahan, Iran.

Zander, P. and Kächele, H. 1999. Modelling objectives of land use for sustainable development. Agricultural Systems 59:311-325.

Zheng, D. X. and Sponeman, J. 1989. Terrain classification from landsat data as an approach to land evaluation: The case of the Ordos Plateau, Inner Mongolia. Chinese Journal of Arid Land Research 2: (4), 345-356.

Zonneveld, I. S. 1997. Land ecology. An introduction to landscape ecology as a base for land evaluation, land management and conservation. SPB Academic Publishing, Amsterdam.

Appendix 1

Grazing capacity of the rangelands is calculated through this program, which is written in Qbasic.

```
DECLARE SUB capacity (wu!, SY1!, E!, L, t)
DECLARE SUB forage (SY1, t)
10
COLOR 14, 1
CLS
REM calculation of daily intake and energy demand on the basis of
REM body weight
LOCATE 5, 5
PRINT " What is the weight of one Ewe around?"
PRINT "    1- 40 kg"
PRINT "    2- 50 Kg"
PRINT "    3- 60 Kg"
PRINT "    4- none"
INPUT "            Enter a number:", Ewe
IF Ewe > 4 OR Ewe < 1 THEN GOTO 10
   SELECT CASE Ewe

CASE 1: ne1 = INT((1.833 - (1.095 * 40 / 45)) * 40 ^ .75): mish = 40 * 5! / 100
CASE 2: ne1 = INT((1.833 - (1.095 * 50 / 55)) * 50 ^ .75): mish = 50 * 5! / 100
CASE 3: ne1 = INT((1.833 - (1.095 * 60 / 65)) * 60 ^ .75): mish = 60 * 5! / 100
CASE 4: ne1 = 0:  mish = 0

   END SELECT
30
CLS
LOCATE 5, 5
PRINT " What is the weight of one goat around"
PRINT "    1- 10 Kg"
PRINT "    2- 20 Kg"
PRINT "    3- 30 Kg"
PRINT "    4- 40 Kg"
PRINT "    5- none"
INPUT "            Enter a number:", goat
IF goat > 5 OR goat < 1 THEN GOTO 30
20
LOCATE 15, 5
INPUT "Are the goat lactating (y/n):", g$
 IF g$ = "y" OR g$ = "n" THEN
    IF g$ = "y" THEN

        SELECT CASE goat
CASE 1:     ne2 = INT(((1.833 - (1.095 * 10 / 15)) * 10 ^ .75) + (1.23 * 4.19)): boz = 10 * 5!
/ 100
CASE 2:     ne2 = INT(((1.833 - (1.095 * 20 / 25)) * 20 ^ .75) + (1.23 * 4.19)): boz = 20 * 5!
/ 100
```

```
CASE 3:    ne2 = INT(((1.833 - (1.095 * 30 / 35)) * 10 ^ .75) + (1.23 * 4.19)): boz = 30 * 5!
/ 100
CASE 4:    ne2 = INT(((1.833 - (1.095 * 40 / 45)) * 40 ^ .75) + (1.23 * 4.19)): boz = 40 * 5!
/ 100
CASE 5:    ne2 = 0:       boz = 0
     END SELECT
   END IF

      IF g$ = "n" THEN

        SELECT CASE goat
          CASE 1:     ne2 = INT((1.833 - (1.095 * 10 / 15)) * 10 ^ .75): boz = 10 * 4.5 / 100
          CASE 2:     ne2 = INT((1.833 - (1.095 * 20 / 25)) * 20 ^ .75): boz = 20 * 4.5 / 100
          CASE 3:     ne2 = INT((1.833 - (1.095 * 30 / 35)) * 30 ^ .75): boz = 30 * 4.5 / 100
          CASE 4:     ne2 = INT((1.833 - (1.095 * 40 / 45)) * 10 ^ .75): boz = 40 * 4.5 / 100
          CASE 5:     ne2 = 0: boz = 0
     END SELECT
     END IF

 ELSE
   CLS
   LOCATE 5, 5
   COLOR 12 + 16
   PRINT "Please type (y/n)"
   COLOR 14, 1
   GOTO 20
 END IF
CLS
LOCATE 5, 5
PRINT " What is the weight of one Lamb around"
PRINT "    1- 20 Kg"
PRINT "    2- 30 Kg"
PRINT "    3- 40 Kg"
PRINT "    4- none "
INPUT "           Enter a number:", lamb

IF lamb > 4 OR lamb < 1 THEN GOTO 60

 SELECT CASE lamb

        CASE 1:     bareh = 20 * 5! / 100: ne3 = 2.9
        CASE 2:     bareh = 30 * 5! / 100: ne3 = 3.6
        CASE 3:     bareh = 40 * 5! / 100: ne3 = 4.2
        CASE 4:     cd3 = 0:   ne3 = 0:        bareh = 0

 END SELECT

60
```

```
CLS

LOCATE 5, 5
PRINT " What is the topography of the range?"
PRINT "    1- Montainous"
PRINT "    2- hill sides"
PRINT "    3- plain"
PRINT "    4- This is not the case"

INPUT "           Enter a number:", rac

IF rac > 3 OR rac < 1 THEN GOTO 60

 SELECT CASE rac

  CASE 1:    nef1 = (ne1 * 50 / 100) + (ne1)
         nef2 = (ne2 * 20 / 100) + (ne2)
         nef3 = (ne3 * 30 / 100) + (ne3)

  CASE 2:    nef1 = (ne1 * 25 / 100) + (ne1):
         nef2 = (ne2 * 10 / 100) + (ne2):
         nef3 = (ne3 * 20 / 100) + (ne3):

  CASE 3:    nef1 = (ne1 * 5 / 100) + (ne1):
         nef2 = (ne2 * 5 / 100) + (ne2):
         nef3 = (ne3 * 5 / 100) + (ne3):

  CASE 4:    nef1 = (ne1):
         nef2 = (ne2):
         nef3 = (ne3):

 END SELECT
CLS
PRINT ""
PRINT "³ Animal type ³  Required   ³ Daily consumption (Kg) ³"
PRINT "³             ³ energy(MJ/d)  ³                      ³"
PRINT
```

```
PRINT "³  Ewe     ³ "; nef1; "           "; mish
LOCATE 5, 62
PRINT "³"
PRINT
```

```
PRINT "³  Goat    ³ "; nef2; "           "; boz
LOCATE 7, 62
PRINT "³"
PRINT
```

```
PRINT "³   Lamb      ³ "; nef3; "                    "; bareh
LOCATE 9, 62
PRINT "³"
PRINT
```

```
LOCATE 20, 4
INPUT "press any key to continue", t
CALL forage(SY1, t)
LOCATE 20, 3
INPUT "press any key to continue", rrrr
wu = 1
CALL capacity(wu, SY1, nef1, mish, t)
wu = 2
CALL capacity(wu, SY1, nef2, boz, t)
wu = 3
CALL capacity(wu, SY1, nef3, bareh, t)
LOCATE 5, 5
PRINT "The results are stored in: Ewe.bas ,Goat.bas,Lamb.bas files"

SUB capacity (wu, SY1, E, L, t)
CLS

IF wu = 1 THEN OPEN "Ewe.bas" FOR OUTPUT AS #1
IF wu = 2 THEN OPEN "Goat.bas" FOR OUTPUT AS #1
IF wu = 3 THEN OPEN "Lamb.bas" FOR OUTPUT AS #1

a = SY1         'energy/kg of range
B = 3.11        'energy/kg of barly
c = 2.28        'energy/kg of cotton

IF wu = 1 THEN PRINT #1, "EWE"
IF wu = 2 THEN PRINT #1, "GOAT"
IF wu = 3 THEN PRINT #1, "LAMB"

PRINT #1, "Energy demand ="; E; "MJ/d", "Daily consumption is ="; L; "kg"
PRINT #1,
PRINT #1, "Energy of range forage/kg ="; a; "MJ"
PRINT #1,
REM PRINT #1, "energy of barly/kg ="; B * 4.19; "MJ"
REM PRINT #1,
REM PRINT #1, "energy of cotton/kg ="; c * 4.19; "MJ"
REM recalling that L is the daily intake of the animal and sy1 the energy of a kg of the
forage of the range
m = L * SY1
REM it calculats how much energy is gained by animal through his daily intake
```

```
PRINT #1,
PRINT #1, "Range energy supply in animal daily intake ="; m; "MJ/d"
IF m = E THEN
PRINT #1,
PRINT #1, "Energy demand and supply are equal"
PRINT #1,
PRINT #1, "range yeild is equal to "; t; "kg"
PRINT #1,
PRINT #1, "Range capacity/AUM is equal to ", (t / (L * 30))
END IF
IF m > E THEN
PRINT #1,
PRINT #1, "Energy demand is less than energy supply"
PRINT #1,
PRINT #1, "range yeild is equal to "; t; "kg"
PRINT #1,
PRINT #1, "Range capacity/AUM is equal to ", (t / ((E / a) * 30))
y = NE
END IF
IF m < E THEN
PRINT
PRINT #1, "Energy demand is greater than energy supply"
PRINT #1,
PRINT #1, "range yeild is equal to "; t; "kg"
y = (E - (L * (B * 4.19))) / (SY1 - (B * 4.19))
PRINT #1, "Range capacity/AUM is equal to "; y
PRINT #1,
PRINT #1, "you need some supliments to compensate the deficit range energy supply"
END IF
CLOSE 1

END SUB

SUB forage (SY1, t)
CLS
number = 1
lost = 100
SY1 = 0
sycd1 = 0
100
CLS
LOCATE 3, 3
PRINT "What is the  vegetation cover type. Please make a choice"
   PRINT "   1- Bromus tomentellus"
   PRINT "   2- Agropyron trichoforum"
   PRINT "   3- Stipa barbata"
   PRINT "   4- Astragalus cyclophyllus"
   PRINT "   5- Onobrychis melanotricha"
```

```
  PRINT "   6- Eurotia ceratoides"
  PRINT "   7- Sedlitzia rosmarinus"
  PRINT "   8- Eryngium billiardi"
  PRINT "   9- Freula ovina"
  PRINT "   10- Cachris ferulacea"
  PRINT "   11- Atriplex veruciferum"
  PRINT "   12- Artemisia siberi"
  PRINT "   13- Vicia variabilis"
  PRINT "   14- Others"
  INPUT "          Enter a number:", type1
  IF type1 > 14 OR type1 < 1 THEN GOTO 100

   CLS
REM this is the way number is treated

      IF number < 4 THEN
        IF number = 2 OR number = 3 THEN
          LOCATE 3, 9
          COLOR 12 + 16, 1
          PRINT , lost; "percent is left"
          COLOR 14, 1
        END IF
120
      LOCATE 5, 5
      INPUT "What is the percentage of the selected species in a 1 kg sample: ", contri
        IF contri <= 0 OR contri > 100 OR contri > lost THEN
          CLS
          LOCATE 5, 5
          PRINT "Your number is not acceptable. Try again."
          GOTO 120
        END IF
      END IF

    IF number = 4 THEN contri = lost - contri
 CLS
 SELECT CASE type1
            CASE 1:    y1 = 1.8 * 4.19
            CASE 2:    y1 = 2.1 * 4.19
            CASE 3:    y1 = 1.7 * 4.19
            CASE 4:    y1 = 2.2 * 4.19
            CASE 5:    y1 = 2.1 * 4.19
            CASE 6:    y1 = 2 * 4.19
            CASE 7:    y1 = 2.6 * 4.19
            CASE 8:    y1 = 2.1 * 4.19
            CASE 9:    y1 = 1.6 * 4.19
            CASE 10:   y1 = 2.3 * 4.19
            CASE 11:   y1 = 1.8 * 4.19
            CASE 12:   y1 = 1.8 * 4.19
```

```
            CASE 13:    y1 = 1.9 * 4.19
            CASE 14:    y1 = 1.6 * 4.19
    END SELECT
        CLS
        ty1 = y1 * contri / 100
        SY1 = SY1 + ty1
        lost = lost - contri
        number = number + 1

            IF lost > 0 AND number < 5 THEN GOTO 100

LOCATE 5, 5
PRINT "Available energy="; SY1; "MJ/Kg"
CLS
LOCATE 5, 5
INPUT "how much is consumable forage yield of the range kg/ha"; t

END SUB
```

Samenvatting

Het planningsondersteunend systeem, dat ontwikkeld is in de huidige studie is gebaseerd op een methodologie die uit de volgende componenten bestaat:

- Databases met gegevens over de land resources
- Modellenstructuur bestaande uit drie modules
  - Landevaluatie module
  - Planningsmodule op districtsniveau
  - Planningsmodule op lokaal niveau

Databases met gegevens over de land resources

Drie databases zijn ontwikkeld waarin de beschikbare informatie is samengevat en beschikbaar gemaakt voor gebruik in het planningsondersteunende systeem, met daarin: (i) landkwaliteiten, (ii) landgebruik en (iii) sociaal-economische gegevens. In 1992 is in het gebied een studie uitgevoerd door het Esfahan Directoraat voor Beheer van het Stroomgebied. Van de informatie die tijdens die studie is verzameld is uitgebreid gebruik gemaakt voor het ontwikkelen van de database met landkwaliteiten. Gegevens zijn beschikbaar met betrekking tot de bodem, de vegetatie, het klimaat en de hydrologie.

Verschillende landgebruikstechnieken zijn geselecteerd en gegevens met betrekking tot die productietechnieken zijn verzameld van verschillende plaatsen in de Zagross regio, met speciale aandacht voor de provincie Esfahan. Een database met gegevens over landgebruik is ontwikkeld, waarin opgenomen zowel huidige als alternatieve landgebruikssystemen, met als voornaamste elementen landbouwkundige productietechnieken met al hun inputs and outputs.

Sociaal en economisch gedrag van de boeren met betrekking tot natuurlijke weiden is bestudeerd om gegevens te verzamelen voor constructie van de sociaal-economische database. De mate van afhankelijkheid van de boerenhuishoudens van de natuurlijke weiden en hun voornaamste bronnen van inkomen zijn de belangrijkste elementen van die database.

Modellenstructuur

De belangrijkste componenten van het ontwikkelde planningsondersteunende systeem (PSS) zijn een geografisch informatiesysteem, een lineair programmeringsmodel en een multi-criteria evaluatiemodel. Daarnaast zijn twee additionele modellen ontwikkeld, één om de draagkracht van de natuurlijke weiden te berekenen en het andere voor het berekenen van de input-output coëfficiënten van landgebruikssystemen voor gegeven tijdsperioden, i.e. in de loop van de uitvoering van landverbeteringsprogramma's.

Landevaluatie module

Landevaluatie in deze studie is uitgevoerd volgens de FAO-methodologie voor regenafhankelijke landbouw (1983) en voor extensieve beweiding (1991). Deze procedure omvat vier elementen: (i) verzamelen van gegevens en het maken van kaarten, (ii) samenstellen van een tabel met benodigde landhoedanigheden, (iii) maken van overlays van de kaarten en (iv) op elkaar afstemmen van de benodigde landhoedanigheden en de landkwaliteiten. Het op het ITC ontwikkelde Integrated Land and Water Information System (ILWIS) is gebruikt als GIS-omgeving. Het resutaat van deze procedure was identificatie van zes landgeschiktheidsklassen voor extensieve beweiding en regenafhankelijke akkerbouw. Tijdens de landgeschiktheidsclassificatie zijn individuele percelen geïdentificeerd die homogeen werden verondersteld in termen van landhoedanigheden, hetgeen verdere ontwikkeling van het planningsondersteunende systeem vergemakkelijkte.

Planningsmodule op districtsniveau

Het doel van deze module is ontwikkeling van het 'beste' landgebruiksplan op districtsniveau. De formele computermodule geeft antwoord op de volgende vagen: welke verschillende landgebruikstypen kunnen worden onderscheiden, wat zijn de outputs en de benodigde inputs voor ieder van die alternatieven, welk landgebruikspatroon voldoet het 'best' aan de doelstellingen van de verschillende belanghebbenden? De planningsmodule op districtsniveau bestaat uit drie sub-modules: planning op districtsniveau, beweiding en multi-criteria evaluatie. Deze sub-modules zijn gekoppeld op een hiërarchische manier, waarbij informatie tussen de drie kan worden uitgewisseld. Sociaal-economische informatie speelt een belangrijke rol in deze module. Door toepassing van een interactief meervoudig doelprogrammeringsmodel (IMGLP), dat dient als een technisch hulpmiddel bij het oplossen van een probleem met meervoudige doelstellingen, worden sociaal-economische informatie en beleidsopties gecombineerd in een interactieve en iteratieve procedure om vier verschillende scenario's te genereren.

De draagkracht van het land, uitgedrukt in termen van het aantal dieren dat kan grazen zonder (permanente) schade aan de vegetatie te veroorzaken, voor het landgebruikspatroon behorend bij ieder van de scenario's wordt berekend in de beweidings sub-module. In die sub-module wordt het ruwvoer, geproduceerd in elk van de landgebruiksscenario's, gekarakteriseerd in termen van energiewaarde. Vergelijking van de geproduceerde energiewaarde met de benodigde energie voor het vee, levert de draagkracht. Deze karakteristiek, in combinatie met de scores voor andere criteria, die worden berekend in de planningsmodule op districtsniveau, wordt gebruikt voor evaluatie van het 'aantrekkelijkheidsniveau' van de verschillende scenario's. In de laatste stap van de planningsmodule op districtsniveau worden de verschillende scenario's beoordeeld en geëvalueerd via een multi-criteria evaluatie. Het meest 'aantrekkelijke' scenario vormt de uitvoer van die module.

Dit geselecteerde landgebruiksplan dient als invoer voor de planningsmodule op lokaal niveau, en beïnvloedt dus direct de noodzakelijke bedrijfsgrootte. De geschiktheid van het geselecteerde landgebruiksplan wordt beoordeeld op basis van de bijdrage die het levert aan het realiseren van de doelstellingen van de verschillende belanghebbenden, alsmede op grond van de overeenkomsten die het vertoont met beleid op districts- en eventueel nationaal niveau.

Planningsmodule op lokaal niveau

Deze module wordt operationeel binnen het kader van het geselecteerde plan op districtsniveau, en is bedoeld om de oppervlakte vast te stellen die nodig is per vee-eenheid, zowel als de bedrijfsgrootte voor een individueel huishouden. De module bestaat uit drie sub-modules: landverdeling, landverbetering en identificering van het weidebedrijf.

Gebruikmakend van eenzelfde procedure als voor de selectie van het scenario op districtsniveau, wordt in de sub-module voor landverdeling een interactief meervoudig doelprogramma gebruikt. Het model wordt toegepast om verschillende landgebruikspatronen op lokaal niveau te genereren. De waarde van het land is gekoppeld aan z'n productievermogen. Daarbij wordt speciaal gelet op de draagkracht, direct afgeleid van het ruwvoerproductievermogen, als de meest relevante karakteristiek voor waardebepaling van het land.

De sub-module voor landverbetering bestaat uit een database en een intern model, en heeft tot doel om mogelijke landverbeteringsprogramma's te evalueren, door voor ieder (deel-)perceel verbeterd land alle inputs en outputs te berekenen. De maatregelen voor landverbetering die in deze module worden beschouwd zijn typisch toegesneden op het studiegebied en kunnen (in andere studies) worden aangepast aan de specifieke situatie in een studiegebied. De uitkomsten van deze module vormen de invoer voor de sub-module voor identificatie van een economisch levensvatbaar weidebedrijf.

De essentie van de sub-module voor identificatie van het economisch levensvatbare weidebedrijf is het vaststellen van de benodigde oppervlakte land voor een individueel huishouden of voor een groep huishoudens die gemeenschappelijk een stuk land exploiteert. In de module wordt eerst aandacht besteed aan het probleem van over-exploitatie. Drie beleidsopties zijn geformuleerd met betrekking tot het recht van huishoudens om in aanmerking te komen voor landeigendomsrechten, waarbij oplossingen worden voorgesteld voor de problemen van overbevolking en over-exploitatie.

Wanneer veedichtheid en draagkracht van het land in evenwicht zijn, begint de procedure voor toewijzing van landeigendomsrechten in overeenstemming met het beleid van de overheid aan de ene kant en in overeenstemming met de doelstellingen en wensen van de lokale bevolking aan de andere kant. Land wordt op perceelsbasis toegewezen aan individuele huishoudens of aan groepen van huishoudens. De resultaten van deze selectieprocedure worden besproken met de huishoudens en hen wordt gevraagd zich te verbinden tot actieve deelname aan het geformuleerde landverbeteringsprogramma.

De oppervlakte land die aan een huishouden of een groep huishoudens wordt toegewezen hangt af van de waarde van het land in termen van de productie van ruwvoer. Hoe hoger de productiviteit van het land, hoe kleiner de oppervlakte benodigd voor een economisch levensvatbaar weidebedrijf. Die oppervlakte wordt berekend op basis van de geschatte huidige omvang van de veestapel, een karakteristiek met een grote onzekerheidsmarge. Er is een procedure voorgesteld om de grootte van de veestapel voor ieder huishouden vast te stellen.

Curriculum vitae

NAME: FARAHPOUR Mehdi

DATE OF BIRTH: 24 September 1954

Education:

B.Sc. Forest and Range Engineering, University of Mazandaran - Sari, Iran 1978

M.Sc. Range Management University of Tehran- Karaj, Iran 1992

DISSERTATION TITLE:

A planning Support System for Iran's Rangeland *Allocation*. Case of Chadegan sub-region.

COURSES TAUGHT:

Range Ecology, Esfahan University of Technology

Range Management and Improvement, Esfahan Jihad Training Center for Higher Education.

Range Analysis and Inventory, Esfahan Jihad Training Center for Higher Education.

GIS and Range Management, Esfahan University of Technology, Esfahan Jihad Training Center for Higher Education and Forest and Range Research Institute of Iran.

Mapping Land Cover and Vegetation Habitat, Joint courses of Ministry of Jihad-e-Keshavarzi, and Khajenasir University, Tehran, Iran and International Institute of Geoinformation Science and Earth Observation, ITC, Enschede, The Netherlands.

PUBLICATIONS:

Farahpour, M. 1991. Mosir (*Allium ascalonicum*) a by-product of rangelands. J. of Pashohesh va sazandegi 10:66-71.

Farahpour, M. 1992. A study of rangelands in Shiraz. Engineering Integrating co. Tehran, Iran. 246pp.

Farahpour, M. 1992. The effect of water absorbent on seed germination and establishment of some Iranian range species. M.Sc. Thesis. Faculty of Natural Resources, University of Tehran, Karaj, Iran.

Farahpour, M. 1995. Study of Daskan sub-basin. Volume 10, Synthesis of information. Engineering Services Co., Esfahan bureau, Esfahan, Iran. 430pp.

Farahpour, M. 1995. Silvicultural study of Bazoft catchment. Volume 10, Synthesis of information using GIS. Engineeing Services Co., Esfahan bureau, Esfahan, Iran. 130pp.

Farahpour, M. 1995. Silvicultural study of Armand catchment. Volume 10, Synthesis of information using GIS. Engineering Services Co., Esfahan bureau, Esfahan, Iran. 145pp.

MASTERS THESES ADVISED:

Mohajeri, A. R. 2000. Role of range management on range capacity and condition. Imam Khomaini Higher Training Center, Tehran, Iran

Mirsaeidi, A. 2000. Soil seed bank. A case of Kohpaye region of Esfahan province. Imam Khomaini Higher Training Center. Tehran Iran

Chitsaz, R. 1999. Possibility of mapping salinity of Segzi region in Esfahan using RS and GIS. Faculty of Natural Resources, Esfahan University of Technology, Esfahan, Iran.
Iravani, M. 1999. Determination of habitat of three rangeland plants species using RS and GIS. Case of Vahregan catchment. Faculty of Natural Resources, Esfahan University of Technology, Esfahan, Iran.
Ansari, W. 1999. Autecology of Atriplex verrucifera M.B. Faculty of Natural Resources, Esfahan University of Technology, Esfahan, Iran.
Ebrahimi, S. 1998. Modeling range capacity through application of GIS. Faculty of Natural Resources, University of Tarbiat Modares, Noor, Iran.
Moshtaghian, M. B. 1997. Seed germination test and salinity resistance assessment of Salsola Rigida Pallas and Nitraria shoberi L. Faculty of Natural Resources, Tehran University, Karaj, Iran.
Moslemi, M.R. 1997. A study of soil and water relationship using ordination methodology. A case of Kolahghazi national park. Faculty of Natural Resources, University of Tarbiat Modares, Noor, Iran.
Sadeghian, M. 1996. Analysis of some Iranian rangeland plants. Khorasgan Free University, Esfahan, Iran.

POSITIONS HELD:

1987 - 1991 Head of Range Department of Charmahal's Jihad Organization in Charmahal e Bakhtiari province of Iran.
1991 - 1994 Director of Esfahan Research Center for Animal Science and Natural Resources, Esfahan, Iran.
1995 - 1997 Research Deputy-Director of Esfahan Research Center for Animal Science and Natural Resources, Esfahan, Iran.
1997 - 2000 Head of Division of Watershed Management of Esfahan Research Center for Animal Science and Natural Resources, Esfahan, Iran.
2000 - Current Head of Department of Range Research of Forest and Range Institute of Iran, Tehran, Iran.

RESEARCH INTERESTS:

Range ecology
Vegetation monitoring and survey
Productivity measurement
Socio-economic assessment of natural resources
Modeling range ecosystems from socio-economic point of view
Land degradation assessment
Seed technology
Seed ecology of range species