Livelihood Dependency and Management on Semiarid Oak Forests

The Case of Southern Zagros, Iran

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Cover: The mountainous study area (up left), collected deadwood for fuel (up right), feeding goats from Persian oak twigs (bottom left) and Persian oak saplings grown from seeded acorns (bottom right).
(Photo: Alireza Salehi)

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Abstract

This thesis deals with the relationships between inhabitants' livelihoods and forest resources management at watershed level in the semiarid forests (woodlands) of Persian oak *(Quercus persica)* in southwest Iran. The ultimate objective of the studies is to lay a basis for planning woodland resource management, to suggest on strategies for improvements in implementation of management plans for sustainable use and conservation of these resources, and improvement of natural resources-based livelihoods of the communities. Paper I investigates the relationships between the traditional utilization, socioeconomic development during recent decades and land cover changes in the study area. Paper II aims to investigate dependency of inhabitant's livelihoods on the woodland resources by characterizing their forest-based activities. The impacts of these activities on the attributes of the woodland as well as the participation of inhabitants in these activities are studied in Paper III. In Paper IV, a diameter class model is developed in order to predict the effects of different management practices on growth and yield of stands of Persian oak.

Data on land cover change (Paper I) were collected through stereo interpretation with digital photogrammetric techniques applied to sets of scanned aerial photographs. Field data for all studies were gathered in 2003 from a woodland inventory. Socioeconomic data were gathered through interviews in 2006 (Paper I) and in 2008 (Papers II and III). Some data for model parameters in Paper IV were extracted from information of an adjacent forested area. In Paper II, canonical correlation analysis and pairwise correlation analysis were used to explore any significant relationships between the socioeconomic variables and the variables of the forest-based activities of the households. In Paper IV, linear programming was used to solve the planning problems.

Results show stability in crown cover density and in the number of large trees and an increment of the woodland area. This could be related to a change in the traditional pattern of the woodland utilization in the past decades. There is a high dependency of inhabitants' livelihoods on the woodland resources. The woodland-based incomes in Ganaveh are obtained by performing animal grazing, and collection of fuel wood, seeds, and ground fodder. The more income diversification and the better educational conditions for households, the less dependency on these resources. Lack of natural regeneration, relatively high incident of bad quality trees cause concerns for sustainability and conservation of the woodland as a result of the performed activities. Some efforts to reach social acceptance from the woodland users to protect the preserved areas from animal grazing and seed gathering for a period could be a good alternative for woodland rehabilitation. Fuel wood collection should not put the sustainability of the woodland in jeopardy. Although the accuracy of some parameters of the suggested diameter class model should be improved, the preliminary results show that the present prohibition of harvests seems contra productive. Rather, a regulated harvest of trees could enhance the livelihood of the Ganaveh households.

Keywords: Semiarid forests; Persian oak (*Quercus persica*); livelihood; conservation; Zagros; Iran

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Dedication

To my family, my wife Zahra, and my children, my son Amirsadra and my daughter Bahar and to all other children living in and near the Zagros forests.
Today these magnificent old forests suffer severely from deforestation, forest degradation, and biodiversity loss. If we want our children – and their children and grandchildren – to enjoy the numerous goods and services that these forest provide us, we need to pay for their conservation and sustainable use. Only then will we warrant sustainable livelihoods for our children to obtain the benefits of Earth's natural capital as expressed in unique ecosystems such as Zagros semiarid oak forests in the old world.

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I A. Salehi, E. Wilhelmsson and U. Söderberg (2008). Land Cover Changes in a Forested Watershed, Southern Zagros, Iran. *Land Degradation & Development* 19, 542-553.

II Alireza Salehi, Linley Chiwona Karltun, Ulf Söderberg, Ljusk Ola Eriksson (2008). Livelihood Dependency on Woodland Resources in Southern Zagros, Iran. Submitted manuscript.

III A. Salehi, U. Söderberg, L.O. Eriksson (2008). The Impacts of Forest-Based activities on Woodland Characteristics in Southern Zagros, Iran. Submitted manuscript.

IV Alireza Salehi, Ljusk Ola Eriksson (2008). A Model for Management of Mixed Coppice Stands of Semiarid Forests of Persian Oak. Submitted manuscript.

Abbreviations

ACD	Average of crown diameter
CCA	Canonical correlation analysis
CCD	Crown cover density
FRWO	Forest, Range, and Watershed Management Organization
HNRY	Headquarters of Natural Resources of Yasuj
LPG	Liquefied petroleum gas
NTFPs	Non-timber forest products
SLF	Sustainable livelihoods framework

1 Background

"To provide the timber to build the city of Gilgamesh, the forests of the Zagros range east of Babylonia were the first to be exploited and they provided oak (*Quercus*), cypress (*Cupressus*) pine (*Pinus*) and Juniper (*Juniperus*)."

(From one of the earliest stories ever written in 2700 BC. About Mesopotamian civilization quoted by Sands, 2005, P. 16)

The arid and semiarid regions, located in the tropical and subtropical zones of the world, account for approximately 30% of the world total area and are inhabited by approximately 20% of the total world population (Sivakumar et al., 2005). One-half of the world's countries have portions or all of their land in dryland environments including hyper-arid, arid, or semiarid zones (Ffolliott et al., 1995). The World Atlas of Desertification defines semiarid regions as those where the ratio of mean annual rainfall to mean annual potential evapotranspiration ranges between 0.2 and 0.5 (Sivakumar et al., 2005). Each semiarid region of the world is unique in a number of ways such as climate, soils, vegetation, animals, traditional management, and people's activities (Walker, 1979; Ffolliott et al., 1995). Vegetation types in these regions can range from forests to woodlands, savannas, shrublands, grasslands and, scrublands. In these regions, trees and shrubs play vital roles in maintaining an ecological balance and improving the livelihoods of people. The importance of natural forests, woodlands, and forest plantations and the goods and services from these lands to rural people is threefold according to Ffolliott et al., (1995): 1) Trees and shrubs provide goods essential to meet basic needs at the household and community level. 2) These resources furnish food and the environmental stability necessary for continued food production and security. 3) They can generate income and employment in a rural community. In semiarid forests, dependency on non-timber forest products (NTFPs) and environmental services of these resources has a high value (Siren 1986; Appasamy, 1993; Bellefontaine, 2000; Mahapatra and Tewari, 2005; Croitoru, 2007).

Because of population growth over the past few decades, the demand for goods and services from the natural resources of these regions has increased beyond the ability of the traditional management systems to meet them. Conflicts between various users of these resources are increasing as they are diminishing (Bellefontaine, 2000). Overharvesting of forests, overgrazing and land clearance for agriculture reduce numerous functions and services previously provided by semiarid forests. These are being threatened not only by deforestation, but also by the reduction of biodiversity that affects the subsisting tree cover formations (Siren 1986; Bellefontaine, 2000). There is an urgent need for responsible management of the natural resources of these regions of the world.

Forest degradation, inadequate knowledge of forestry practices and low levels of investments are three commonly faced problems for practicing forestry on a sustainable basis to people in dryland regions while much of the investment in forestry sectors in these regions of the world is governmental and public; A core of the problem for rural communities usually is that they derive insufficient benefits from their natural resources. In general, this situation is attributable to conventional forest management and administrative practices such as an orientation of the natural resources toward conservation, wood production, revenue collection, and regulation through punitive legislation. Consequently, a task of the forest manager is to engage people more fully, positively, and beneficially in management, utilization, and protection(Ffolliott *et al.*, 1995). Improved forest management requires attention to the livelihoods of people living in forests because of the links between their livelihoods and the forests (Sunderlin *et al.*, 2005).

In order to promote sustainable forest management, which is a long-term investment, it must be sustainable ecologically, economically and socially. To achieve all of these objectives none of the related values of the forest must be degraded and if possible, they should be improved; socially sustainable forest management requires equitable distribution of costs and benefits and the participation and collaboration of all parties (Sands, 2005). Appropriate policies, planning procedures, implementation methods, managerial strategies, and extension programmes are required to apply forestry on a sustainable basis in dryland regions (Ffolliott *et al.*, 1995).

Mediterranean vegetation eco-regions occur in the world's five Mediterranean climate zones (dry-summer subtropical)(Archibold, 1995) consisting of; the Mediterranean Basin, California, central Chile, southwest Australia and the western Cape in South Africa. All these eco-regions are characterized by dry summers and are home to tremendous diversity of habitats and species. Annual rainfall in these semiarid regions varies from approximately 300 mm to approximately 1000 mm depending upon the relative occurrences of summer and winter rains (Archibold, 1995; Hoekstra and Shachak, 1999). Oaks (*Quercus spp.*) are usually dominant woody species in woodlands of Mediterranean basin and California (Tachtadzjan, 1986). Two different formations of oak forests that consist of sclerophyllous evergreen forests of oaks and hilly deciduous forests of oaks are found in the Mediterranean Basin, in which the hilly oak forests become enriched with deciduous oaks towards the east (Merlo and Croitoru, 2005). The Zagros forests qualifies well as subtropical dry forests in a global context based on FAO definitions (Sands, 2005). In regional context these forests have a semi-Mediterranean type climate (Boudru, 1961 cited in Jazirehi and Ebrahimi, 2003) and are classified as semiarid forests (Jazirehi and Ebrahimi 2003; Sagheb-Talebi *et al.*, 2004).

The forests of Iran cover about 12.4 million ha and constitute 7.4% of the total area of the country. The Zagros forests, with an area of around 5 million hectares, account for almost 40% of the country's forests (Sagheb-Talebi *et al.*, 2004). The forests provide a home and livelihood for approximately 10% of Iran's population (DoE/GOIRI 2004). For over 1100 km from the north to south, along the Mountain Zagros – through southeast of Turkey, Iraq, and western Iran – stretches the belt of the primarily deciduous oak forests (Figure 2) occupying the elevation from 700 to 2300 m above sea level (Menitsky *et al.*, 2005). Annual precipitation in this region varies between 300 mm and approximately 1000 mm (Jazirehi and Ebrahimi 2003). The Zagros forests are considered as pastoral ecosystems, which are natural ecosystems that have been exposed for thousands of years to grazing by domesticated livestock in numbers large enough to influence their structure and function (Hoekstra and Shachak, 1999). Since centuries, there has been an extensive transhumance with seasonal grazing and a related pastoral lifestyle in this area (Abdi, 2003). In recent decades, a gradual transition from such a lifestyle to permanent settlement and year-round grazing has taken place, which has resulted in a heavy pressure on the vegetation cover in this region (Jazirehi and Ebrahimi 2003). More than 1.7 million ha of the Zagros forests have been deforested since 1962, and studies indicate that the increasing population, the low level of development, and the high dependency of local communities on the forests for their primary livelihoods appear to be the main reasons for this decline (Ghazanfari *et al.*, 2004). Zagros forests are currently considered as degraded forests. The lack of regeneration in these forests because of increased browsing pressure on regenerating trees is a major concern and there are no commercial-sized trees left in Zagros (Jazirehi and Ebrahimi 2003; Ghazanfari *et al.*, 2004; Pourhashemi *et al.*, 2004; Sagheb-Talebi *et al.*, 2004).

Forests and rangelands in Iran are under the governmental authority and supervision of the Forest, Range, and Watershed Management Organization (FRWO). The County Natural Resources Bureaus are the representative of the States Headquarter of Natural Resources, themselves under the administration of FRWO. The County Bureaus are responsible for the implementation of the forest projects, supervision, and management of the natural resources in the forested areas. Since 2000, the forest authority has developed new long-term programs for preservation, conservation, and sustainable use of the Zagros forests. The following principals are the main objectives of these programmes;

- Providing reliable information by long-term monitoring as a basis for planning for natural resources management.
- Modification of traditional forest management implemented by forest authority and forest users.
- Providing management models for sustainable use and conservation of these resources.
- Reducing the direct dependency of inhabitants' livelihoods on the natural resources and improvement of the natural resource-based livelihoods of communities.

These objectives address common issues for management of natural resources in dryland regions of the world, i.e. lack of data, incapability of traditional management systems, inadequacy of forestry knowledge and high dependency to natural resources (Ffolliott *et al.*, 1995; Sunderlin *et al.*, 2005; Abdallah and Monela, 2007; Croitoru, 2007). In line with these objectives this thesis provides some suggestions for management strategies for the sustainable use and conservation of the oak woodlands of Zagros and improvement of the woodland resource-based livelihoods of communities at watershed level in southern Zagros, Iran. Before unfolding the details of the objectives of this thesis it is, however, necessary to dwell somewhat on two topics that are central to this thesis: the natural assets and livelihoods framework in rural areas and the management of semiarid oak forests along with some characteristics of Zagros-oak forests.

1.1 Natural Assets and Livelihoods Framework

A livelihood comprises the assets, activities, and access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household (Ellis, 2000a). In this context, assets are defined broadly by many scholars and include natural (e.g., land, water, flora and fauna), social (e.g., community, family and social networks), financial (e.g., jobs, savings, credits), human (e.g., education, labor, skills, health and nutrition), and physical (e.g., roads, buildings and tools and machines) assets (Chambers, 1991; Carney, 1998; Bebbington, 1999; Ellis, 2000a; DFID, 2001; Dalal-Clayton et al., 2003).These assets determine the size and form of people's income (Dalal-Clayton et al., 2003). The access to, use of, and interaction among these assets serve as the foundation of a livelihood system and are influenced by a number of external factors as mediating processes(Ellis, 2000a). The external factors could be characterized as follows: the vulnerability–opportunity context, including changes in resource stocks, climate, disease incidence, population pressure, political systems, shifts in technology and markets; institutions, consisting of levels of government, NGOs, private sector, traditions, laws, and policies, incentives and services; and livelihood goals and implementation of livelihood strategies (Carney, 1998; Ellis, 2000a; Dalal-Clayton et al., 2003). Assets, together with external factors, constitute a sustainable livelihoods framework (SLF) (Dalal-Clayton et al., 2003). Natural assets are very important to those who derive all or part of their livelihood from natural resource-based activities (DFID, 2001). Consequently, forests are the most important natural assets of people living in and around the forest areas (Ali et al., 2007b). Natural resource-based activities such as fuel wood and seed gathering, animal husbandry and pastoralism, seeding, plantation and so forth are potential components of rural-livelihood strategies (Ellis, 2000a) that generate an income for household and address natural resources management issues.

Natural resource-based activities affect conditions and attributes of natural resource that produces environmental incomes. Environmental income is rent captured through alienation or consumption of natural assets within the first link in a chain, starting from the point at which the natural capital is extracted or appropriated (Sjaastad *et al.*, 2005) by the set of livelihood activities in which household members are engaged. In rural areas, mainly people farm or depend on natural resources (Dalal-Clayton *et al.*, 2003) and environmental income may contribute as an important part of their total income. Understanding the relationship between people's livelihoods and natural resource capacities in rural areas can help policy makers design and implement effective strategies for poverty reduction, livelihood improvement, conservation, and sustainable resource use (Vedeld *et al.*, 2004; Debnath and Dasgupta, 2006).

A deeper understanding of natural assets-based livelihood systems requires an understanding of the mechanisms by which incomes are generated from these resources. This is particularly true in view of the sustainability concept. A livelihood system is sustainable if it can cope with, recover from, and adapt to stresses and shocks, maintain and enhance its capabilities and assets, and enhance opportunities for the next generation (DFID, 2001). In order to understand the future trajectory of the livelihood system it is necessary to uncover the inner workings of the system. A number of questions need to be answered. Firstly, what are the sources of environmental income? Secondly, what is the status, or attributes, of the natural resources that give rise to these sources? Thirdly, what are the management systems that are applied to the natural resources that deliver the income? These issues – sources of income, natural resource attributes, and management systems – are interrelated in a fundamental way. For instance, a certain source of income, say fuel wood, will not be available unless the natural resource has the capacity to deliver fuel wood and there is a management system for regulating the use of that product. In the context of natural resources conditions and characteristics, silvicultural attributes could be refered to establishment, composition, growth, structure, health, and quality of forests to meet diverse needs and values of the many stakeholders (Nyland, 2002).

SLF can be used to describe the relationships between livelihood assets, natural resources-based activities, external factors, and the attributes of the natural resources (silvicultural attributes) (Figure 1). These relationships constitute a solid basis for discussions on future development strategies enhancing sustainability. Based on the suggested framework, under the influence of the external factors, any change in functions of natural resource-based livelihoods is reflected in attributes of the natural resources and vice versa. SLF can be used in both planning new development activities and assessing the contribution to the livelihood sustainability made by existing activities (DFID, 2001; Dalal-Clayton *et al.*, 2003; Ali *et al.*, 2007b). Since the World Commission on Environment and Development report in 1987, numerous studies around the world have used the SLF to suggest for improvements of forest resource conservation and forest-based livelihoods of communities in different areas of the world (e.g., Barrow and Hicham, 2000; Ellis, 2000b; Shackleton *et al.*, 2002; Kaushal and Kala, 2004; Conway *et al.*, 2005; Sunderlin *et al.*, 2005; Soini, 2005a; Soini, 2005b; Kusters *et al.*, 2006; Ali *et al.*, 2007a; Ali *et al.*, 2007b).

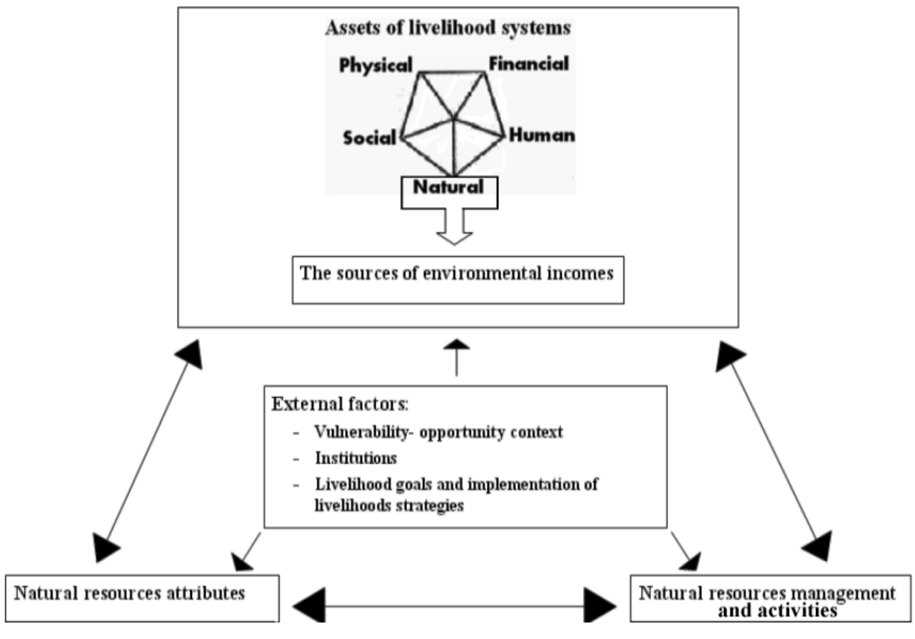

Figure 1. The proposed framework for study on relationships between the livelihood assets, natural resource-based activities, external factors, and the attributes of natural resources in a rural area as natural resources income generating system (adapted from Dalal–Clayton et al., 2003).

1.2 Management of Semiarid Oak Forest

Buongiorno and Gilless (2003) defined forest resource management as the art and science of making decisions with regard to the organization, use, and conservation of forests and related resources. Forest resource managers must make decisions affecting both the very long-term future of the forest and day–to–day activities. The geographic area of concern may be an entire country, a region, a watershed, a single stand of trees, or an industrial facility (Buongiorno and Gilless, 2003). Forestry in dryland regions is concerned with the management of trees and shrubs for conservation and sustainable use. It differs in many ways from the commercial forestry practiced in most tropical and other temperate ecosystems and it should be defined more broadly to improve the livelihoods and quality of life for local people living in these environments (Ffolliott *et al.*, 1995). Forest management in arid region includes traditional forestry practices (e.g., utilization of wood and non-wood forest products), forestry practices unique to dryland environments (e.g., sand dune stabilization, control of soil erosion), horticulture, livestock and wildlife management, management for water and recreation, or a combination thereof. In most cases, the value of forest products in the dryland regions is difficult to evaluate in monetary terms because many of the direct benefits from forest resources are not derived through a marketplace but are in most of cases instead forest products obtained directly from forest by family members and consumed by household (Ffolliott *et al.*, 1995).

The genus *Quercus* with 400–500 species is one of the most important forest-forming clades of woody angiosperms in the northern hemisphere in term of species diversity, ecological dominance, and economic value (Kappelle, 2006). Various oak species are sources of high-quality lumber, and it is the preferred firewood in lowlands and mountainous areas of many regions in the old world (Menitsky *et al.*, 2005) and new world (Kappelle, 2006). In most parts of the world, oaks have been eliminated from plains and low hills, and many present-day oak forests were heavily cut during the first half of the 20^{th} century, in order to supply charcoal – the main domestic fuel – to a growing population. Moreover, at present, oak wood is still the favorite domestic fuel in many rural villages, and cattle are raised in the understory of numerous oak forests; as a result, regeneration problems arise from a variety of causes, such as over grazing, frequent forest fires, and changes in microhabitat conditions (Kappelle, 2006).

Based on the differences in oak species and climatic conditions, the Zagros vegetation zone is divided into two distinct regions where the southern Zagros region has less humidity than the northern region (Jazirehi and Ebrahimi 2003; Sagheb-Talebi *et al.*, 2004). Pure stands of Persian oak (*Quercus persica* or *Q. branti* or *Q. branti var. persica*) contribute in approximately 62 % of the forest areas in Zagros region (Sagheb-Talebi *et al.*, 2004). This proportion is increased up to 69% in southern Zagros (Jazirehi and Ebrahimi 2003). Southern Zagros is the exclusive site for Persian oak (Sagheb-Talebi *et al.*, 2004). *Quercus persica* belongs to subgen of *Quercus*, section of *Cerris*, sub sec. *Aegilops* (Menitsky *et al.*, 2005). The stands of Persian oak are present almost everywhere and are represented by dry open forests with low (to 9–10 m) trees with hardy branches. The trees are distant from each other, between which there are patches of steppe vegetation with broad open or hemispherical crowns and grayish-green leaves, thus awarding the landscapes a park-like look (Menitsky *et al.*, 2005). More than 90% of oaks in the Zagros forests are in coppice form (Sagheb-Talebi *et al.*, 2004).Other main woody species of the Zagros forests are comprised as *Q. infectoria*, *Q.libani*, *Amygdalus scoparia*, *Pistacia mutica* (*P.*

khinjuk), *Acer cinerascens*, *Crategus spp*, *Cerasus spp*, *pyrus spp*. (Jazirehi and Ebrahimi 2003; Sagheb-Talebi *et al*., 2004; Menitsky *et al*., 2005).

Since the 1960s, concern has been evident regarding environmental degradation in arid regions (Latorre *et al*., 2001). In formulating a role for forestry in dryland environments, a consultation was organized largely by the Food and Agriculture Organization (FAO) in 1985. After that the Ninth world forestry congress in Mexico (1985) was recognizing the importance of "dryland forestry" as an emerging strategy in sustainable development (Ffolliott et al., 1995). Research on semiarid regions of forestry and forest resources management issues in general (see e.g. Walker, 1979; Le Houerou, 1993; Papachristou and Papanastasis, 1994; Ffolliott *et al*., 1995; Warren *et al*., 1996; Hoekstra and Shachak, 1999; Ross, 2004; Quinn *et al*., 2007) and in particular on management of semiarid oak forests (see e.g. Debussche *et al*., 2001; Caellas *et al*., 2004; Zavala and Zea, 2004; Henkin *et al*., 2005) have generated numerous publications. Nevertheless, only a few investigations have been conducted on related issues in Zagros (see e.g. (Hajabbasi *et al*., 1997; Ghazanfari *et al*., 2004; Pourhashemi *et al*., 2004; Pourreza *et al*., 2008; Salehi *et al*., 2008; Erfanifard *et al*., 2009) and there are only a few forest management growth models for semiarid regions to predict the effects of different forest practices on growth and yield conditions (Chojnacky, 1997; Adame *et al*., 2006; Adame *et al*., 2008). This could be due to the fact that there is inherently a low level of annual wood production in these regions and the wood utilization of this type of forests is not so economically important. Because of that, investments in management of natural forests and woodlands of these regions have been minimal and, as result, the need for investment analysis tools.

2 Aims of the thesis

This thesis deals with the relationships between inhabitants' livelihoods and forest resources management in semiarid oak forests (woodlands) based on studies in Ganaveh watershed in southwest Iran. These studies aim to strengthening the basis for woodland resources management, to suggest strategies for improvements in implementations of management plans for sustainable use and conservation of these resources, and improvements in natural resources-based livelihoods of the woodland users. In particular, the aims of this thesis are as the following:

- To investigate the historical background of land cover changes in relation to traditional utilization of the woodland resources and socioeconomic development in the area during recent decades
- To investigate the relationships between the socioeconomic characteristics of the woodland users and the conducted forest-based activities to derive the woodland products
- To investigate the impacts of the forest-based activities on the attributes of the woodland as part of the Ganaveh livelihood system
- To develop a management model to predict the effects of different forest management practices on growth and yield of the uneven-aged, mixed coppice stands of Persian oak (*Q. persica*).

3 Study area

The study was carried out in the Ganaveh watershed (30°27′N, 50°50′E), located 15 km north of the city of Dow Gonbadan (Gachsaran), the center of a bourgeoning oil and gas industry, in the province of Kohgiluyeh va Boyer Ahmad, Iran (Figure 2). The mountainous watershed with steep slopes covers an area of 6621 ha. The vegetation types, mainly oak trees and shrubs-bushes extend between 1200 and 2300 m (a. s. l.) and are differentiated and mixed in different parts of the area depending on ecological factors. The following figures are based on woodland inventory data gathered by of Headquarters of Natural Resources of Yasuj (HNRY) in 2003: oak (*Quercus persica*) 79%, wild almonds (*Amygdalus spp*.) 9%, wild pistachio (*Pistacia mutica*) 5% and other species (7%) are the most frequent woody species. Wild almonds consist of numbers of *Amygdalus* species of which some species are in shrub form (e.g., *A. lycioides* and *A. orientalis*) and grow widely on the ground. *A. scoparia* and *A. orientalis* are the most important species of wild almonds in the area. *Crataegus sp*. and *Acer cinerascens* are the most important of the other shrub species.

From measurements over a 15-year period (1986-2001), average annual precipitation is approximately 500 mm, and the mean annual temperature is 22.5 °C. The mean minimum temperature for January is 5.3 °C, the mean maximum temperature for July is 42.7 °C, and the mean number of days with a minimum temperature of 0 °C or lower is nine days. Soils vary from moderately deep, well-drained sandy loams to steep, gravel slopes with rock outcrops. These soils are classified mainly as lithic leptosols and calcaric regosols (data from HNRY). According to HNRY data, the woodland and shrub-bush land extend more than 5848 ha, and there are 133 ha of village and agricultural lands and another 640 ha of rocky area without any vegetation cover.

Ganaveh is a small village located in the center of the watershed. There are several indications of a modernization, such as availability of piped water, electricity, telephone, and asphalted roads, and a reasonable literacy level. Table 1 depicts some socioeconomic characteristics of the village in 2008. The village has experienced a population decline since last decades (Paper I) and for the period 2003-2007, the population growth rate was -15%. The negative population growth rate is probably caused by migration of households into urban areas. In 56% of the households, at least one member had migrated to urban areas (interview data 2008).

Table 1 *The socioeconomic profile of Ganaveh village in 2008.*

Attribute of the village	Quantity
No. of households	45
Males	53%
Females	47%
Total population	185
School	One elementary school
Primary school education – five years	81% of population
Illiterate	15% of population
Availability of piped water	All households
Electricity available	All households
Telephone available	Most households
Connecting road to the nearest city	15 km (asphalted)

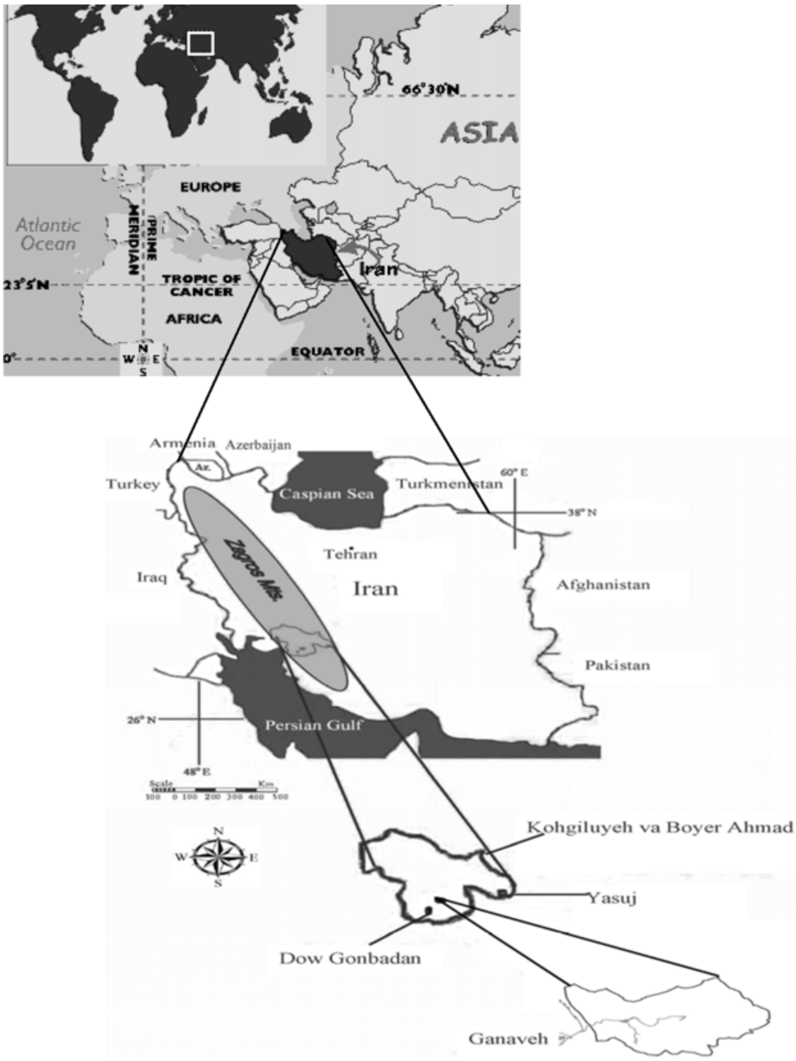

Figure 2. Location of Iran in the world, the Zagros region in Iran and the study area within the province of Kohgiluyeh va Boyer Ahmad.

4 Summary of Papers

4.1 Land Cover Changes in a Forested Watershed, Southern Zagros, Iran (Paper I)

To provide some reliable historical information as a basis for planning natural resource management, monitoring of land cover change to investigate the effects of traditional management on the woodland resources in recent decades is needed. Historical aerial photographs are the largest documented source of information available for research on vegetation and land use dynamics. Paper I aims to investigate the land cover changes in relation to traditional utilization and livestock grazing, socioeconomic development, and demographic changes during recent decades in the Ganaveh watershed. Data on land cover change were collected through stereo interpretation with digital photogrammetric techniques applied to sets of scanned aerial photographs from 1969 and 1993 with a systematic grid of sample plots provided by GIS techniques. Efforts were made to mitigate errors in the interpretation. Field data were gathered in 2003 from woodland inventory, biophysical, and demographic data and in 2006 from interviews. The results show that the crown cover density and the number of large trees were not observed to change over time, and an increment of the woodland area. These could be related to a change in the traditional use of the woodland resources.

4.2 Livelihood Dependency on Woodland Resources in Southern Zagros, Iran (Paper II)

Paper II explores the current relationships between people's livelihood and the woodland resources of the Ganaveh watershed as a basis for suggestion of strategies for sustainable use of these resources and improvement of the livelihoods of people in the community. Socioeconomic data (2008) with focus on forest uses and forest-based activities of the households were collected through interviews with heads of households and members of the village council. Canonical correlation analysis (CCA) and pairwise correlation analysis (Pearson correlation) were used to explore any significant relationships between the socioeconomic variables and the variables of the forest-based activities of households. Results show that the livelihoods of inhabitants of Ganaveh are highly dependent on the woodland resources. Goat husbandry is the most important activity for providing villagers' income. Fuel wood provided around the half of the total consumed energy by households. Collection of seeds is highly seasonal and households involve in this activity in masting years. Fodder from the woodland understory, mostly grasses and herbs, is collected by some households to feed their animals in winter. Among the key socioeconomic characteristics of the households, obtaining cash income from sources other than the woodland resources has a negative correlation with animal husbandry. Consumption of energy for cooking and heating has a positive correlation with collection of fuel wood while education level of family members has a negative correlation with the collection of fuel wood. The more income diversification and the better educational conditions for households are associated with less dependency on the woodland resources. Processing the woodland products before selling could increase the household cash income from the woodland resources. Investing in education and training of women particularly related to better use of the natural resources should be emphasized.

4.3 The Impacts of Forest-Based Activities on Woodland Characteristics in Southern Zagros, Iran (Paper III)

The improvement of forest resources could be an outcome of improvement in forest-based livelihoods strategies. The purpose of Paper III was to investigate the impacts of forest-based activities on the attributes of the woodland as part of the Ganaveh's livelihood system to suggest strategies for improving the implementation of forest resource management plans. Woodland inventory data and data from interviews were the same data used in Papers I and II. The results show that there is forest degradation in terms of a lack of forest regeneration and a relatively high incidence of bad quality trees, the frequency of which increases with tree diameter. These defects in the woodland attributes reflect the effects of the traditional management on vegetation cover, and are a cause of concern regarding the sustainability and conservation of the woodland. Overgrazing, seed gathering and drought in some years are probably the main reasons for poor natural regeneration in the area. Moreover, overgrazing and lopping of oaks in previous decades and the prohibition on cutting trees could be the main reason of the high incidence of the bad-quality of oak trees and the high rate of oaks in coppice form. So far, there is limited social acceptance and effective participation of inhabitants in forestry projects for conservation of these resources. Some efforts to gain social acceptance from the woodland users of the need to protect the preserved areas from animal grazing and seed gathering for a period could be a better alternative for woodland rehabilitation than seeding. The woodland could provide the needed quantities of fuel wood and the impacts of fuel wood collection on the sustainability of the woodland are not important. Thus, it seems that giving high priority to distribution of fossil fuels by the forest authority to conserve these resources is not necessary.

4.4 A Model for Management of Mixed Coppice Stands of Semiarid Forests of Persian Oak (Paper IV)

The purpose of Paper IV is to present a diameter class model to predict the effects of different forest management practices on growth and yield conditions of the mixed coppice stands of Persian oak (*Quercus persica*) in the semiarid forests in southern Zagros. The model was applied to the inventory data from 2003 in order to make some management recommendations for the Ganaveh woodland. Some data that was needed for the model were extracted from available information of an adjacent forested area. The model was analyzed under a set of different management strategies. Linear programming was used to solve the problems.

Controlling the animal grazing and maintaining the ban on tree cutting reflects the current efforts of the forest authority to preserve the woodland. The prohibition of harvests seems counterproductive as harvested volumes could be about 10-20 times larger than the current level of fuel wood collection. Without harvesting, the model suggests that controlling animal grazing will only have limited effect on the collected amounts of fuel wood, and then not until about 50 years from now. The effect of improved protection of natural regeneration becomes more pronounced if it is combined with harvesting of trees. The model runs also show that the policy regulations associated with harvesting are important. A steady state requirement is highly restrictive on the production level, whereas a non-declining harvest constraint regulates when harvest are allocated in time. Management regimes should be fairly straightforward to implement as they are specified as diameter limit rules.

Because of a number of critical assumptions of the model parameters, the predictions of the model are uncertain. There is clearly a need for better empirical support of the model parameters. Sensitivity analyses can be performed to indicate where better data is most needed. What would be most adequate would be field data including repeated measurements on permanent sample plots in order to estimate recruitment, stand growth, mortality and survival rates. Further refinements are needed for the modelling of livelihood implications. Engaging people in harvesting could add to the diversification of income sources already observed in the area (Paper II). NTFPs should be accounted for and management costs added.

Even though the model has several limitations and drawbacks in its current form it still appears to be a viable option for policy development as it generates results with bearing on such issues. With better understanding of the growth and yield conditions and the livelihood dependency of the inhabitants the presented modelling framework could be an effective tool in policy development in dialog with stakeholders.

5 Results and Discussion

5.1 Socioeconomic Development and Land Cover Changes

During the aerial photograph interpretation (Paper I), the total number of plots in the grid for the whole area was 252; of these, 138 were on slopes less than 45%. This means that about 55% of the area was assumed accessible. Thirty-one plots in the accessible area were in shadow in at least one of the photograph sets and were not interpreted. In total 107 sample plots were interpreted, which means 0.11% of the region was actually assessed. Fifty-two percent of the plots in the accessible area were on steep slopes (20.1 % - 45%), and 48% of them were on medium slopes (5.1% - 20%). The slope map shows only a few small patches with slopes 5% and less, and these are located in the centre of the area. The results in Paper I show that between 1969 and 1993, 'woodland' class increased by 38% whereas 'shrubland' class decreased by 19%. Only 17.5% of the 'shrubland' class turned into 'woodland' class and there was no difference shown for cultivated areas. However, farming activities increased between 1969 and 1993 but have decreased the last decade. Almost half of the area labeled as grazing in 1969 changed to the 'no trace' class in 1993. Moreover, the 'others' class (e.g., animal yards) decreased for 1993. During the early 1980s, the old village was abandoned, and a new settlement (Figure 3) was built out of non-forest construction materials, with better amenities such as electricity, potable water, and telephone lines and an asphalt road was constructed in 2003 (interview data - 2006).

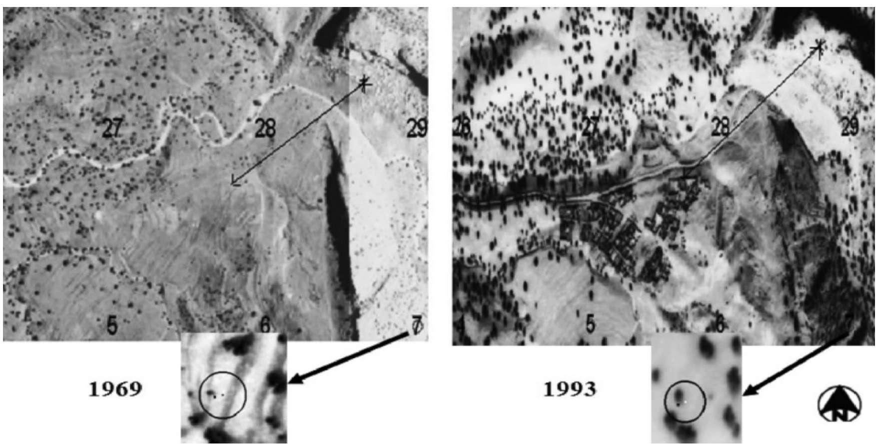

Figure 3. Systematic grid of circular plots with a radius of 15 m and a distance of 500 m on aerial photographs 1969 (1:20,000) and 1993 (1:40,000). Sample plot 7 is enlarged in two images. In the early 1980s, a new village was established in the center of the Ganaveh watershed.

Although the mean numbers of small trees and shrubs have decreased for both medium and steep slopes during this time, the result of the pairwise t-test was significant at the 95% level of only probability for steep slopes. The number of large trees was greater in 1993 for both medium and steep slopes, but the differences of the means were not significant at the 95% level of probability and there was also no significant change in the mean crown cover density (CCD) (%) for both slope classes. A comparison of changes in class of CCD in slope classes shows that CCD was apparently more stable in the steep slopes, while there was some clear cutting in some areas of the medium slopes. We can consequently say that steep slopes to some extent limit human accessibility to the woodland resource. Terrain conditions also seem to have imposed limitations on the development of agricultural land.

Forests and rangelands in Iran were nationalized through legislation passed in 1963. Based on the interviews, up until 20 years ago, camels were used for transport by the transhumance of nomads and the young branches of oak trees were lopped as fodder to feed the camels without regard to tree regrowth potential or the maintenance of woodland productivity. However, the area also supplied fuel wood and charcoal to nearby cities. Over the past two decades, as is also reported from other parts of the world (Hoekstra and Shachak, 1999), the nomadic people have been settled in other areas. Consequently, the intensive tree and branch cutting, sometimes performed by hired workers all around the area to supply fuel wood and the needed fodder for camels, has ceased. Nowadays, camels are no longer used and neither fuel wood nor charcoal is transported to nearby cities.

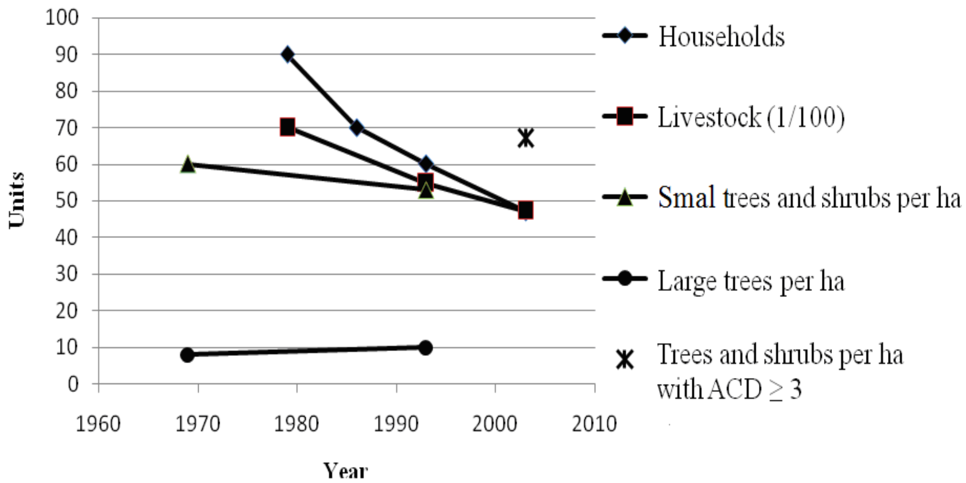

Figure 4. Development of human and livestock populations for the entire area and changes in the number of trees and shrubs per ha. (Tree and shrubs data from 2003 is based on field inventory; data of small trees and shrubs is from aerial photograph interpretation. Livestock represented by units of 100.)

Figure 4 shows the relationships indicated by the data between the change in the number of households and the livestock population, the mean number of small trees and shrubs, and the mean number of large trees per hectare between 1969 and 2003. Note that the mean number of trees and shrubs with an average of crown diameter (ACD) more than 3 m (measured in field inventory 2003) was very similar to that from the photo interpretation (1993). However, attention should be paid to the potential underestimation resulting from the photo scale for this variable. In general, the human and livestock population have decreased the recent decades and the lifestyle that was related to woodland utilization for construction materials and fuel thus has changed. In addition, the current negative population growth of the village implies that a rural depopulation is occurring. These socioeconomic adjustments seem to have contributed to woodland conservation. It also appears that the recent rural depopulation could affect the land cover, vegetation structure, and floristic composition of the woodland (Barbero et al., 1990; Preiss et al., 1997; Bradshaw and Mitchell, 1999; Debussche et al., 2001).

Socioeconomic development, decrease of the human and livestock population, and a change of livestock type during the last decades due to settlement of nomadic people have all influenced changes in the traditional pattern of woodland utilization. In response to the change in tradition brought about by the cessation of tree branch harvesting, the forest canopy has recovered and improved. The decline in both human and livestock populations, along with the change in exploitation of the vegetation, has possibly contributed to an increase in the woodland. Consideration should be given to the traditional pattern of the woodland utilization, a practice that has caused most oaks to grow in coppice forms.

Many studies have addressed land use-cover changes, and most of them have analyzed historical aerial photographs using computer-aided techniques (e.g., Houghton, 1994; Carmel and Kadmon, 1999; Kadmon and Harari-Kremer, 1999; Tekle and Hedlund, 2000; Fensham and Fairfax, 2003; Manier et al., 2005; Brook and Bowman, 2006; Rocchini et al., 2006). In Paper I we conducted our study on historical land cover change based on the analysis of data obtained through sample plots on aerial photographs. This approach enabled us to include the attributes of the cover and structure of the woodland in the statistical analysis. We could also analyze land cover change in an area of sparse vegetation where the delineation of forest boundaries is difficult (e.g., Schweik et al., 1997; Reid et al., 2000; Taylor et al., 2000; Al-Bakri et al., 2001; Atasoy et al., 2006).

5.2 Livelihood Dependency on the Woodland Resources

The woodland resources of Ganaveh were used communally by its inhabitants and the households in Ganaveh were the only natural resource users of the watershed (Papers I and II). Depending on the abundance of the resources, locals graze their animals and collect fuel wood, seeds and ground fodder in the watershed area without recognizing any territorial limits for their activities except for seeded areas, fenced areas and similar areas announced by the forest authority. The woodland-based incomes in Ganaveh are mainly obtained by performing these above mentioned activities. The following issues addressed high dependency of livelihoods of Ganaveh's inhabitants on woodland resources. 1) To obtain a portion of cash or kind income, which is fuel wood, approximately 72% of households use the woodland resources. 2) An average of 30% of household cash income comes from woodland resources while 25% of households have more than 50% of their cash income from the woodland. 3) According to interviews, there is a high dependency of 47% of interviewed households on the obtained cash income from the woodland resources and annually they count on that. Traditional animal husbandry (mainly goat husbandry) based on the pasture fodder was the most important activity for providing environmental income to the villagers. It constituted more than 80% of the assessed total income from the woodland resources. Therefore, the households who owned livestock were the most dependent on woodland resources. Second in importance was seed collection. It was also linked to animal husbandry, as the major use of acorns was for feeding animals in winters. It was less evenly practiced than animal husbandry:

three households accounted for more than half of the collected seeds and acorns of the village. The collection of seeds is highly seasonal, and households were involved in this activity in mast years to sell them in local markets or use them (acorns) as winter feed for their livestock. In 74% of the active households, women and children participated in deriving household income from woodland resources mainly in seed and acorn gathering. Fuelwood gathering and caring for animals were mostly the responsibility of the men. Fuel wood may have had a low assessed value but still provided approximately 54% of the total consumed energy. There is no official wood utilization. Annual grasses not only provide a great deal of fodder for the livestock grazing during the grazing seasons, but also they are collected as fodder for feeding animals in the winter. Masozera and Alavalapati (2004) assumed that households whose income from forests accounted for 40% or more of their total income were considered highly dependent on woodland resources. Our finding about the dependency of the livelihoods of Ganaveh's inhabitants on natural resources is in agreement with the reports of Ghazanfari *et al.* (2004) about the inhabitants of the rural areas in other parts of the Zagros region.

Terrain conditions and water shortage seem to have imposed limitations on the development of agricultural land. Nevertheless, in 2006, during the field inspection, we were informed that most of the dry farming land had been abandoned because of low fertility and population migration (Paper I).

Table 2 *Correlation between the first pair of the canonical variates (u_1 and v_1) and the standard scores of their original variables. Significant relationships are in* ***bold-Italic***.

Original variables	Correlation with u_1	Original variables	Correlation with v_1
Fodder collection	***0.4***	Family size	0.0
Fuel wood collection	***0.7***	Average age of members	0.1
Seed collection	0.0	***Average of school years of family members***	***- 0.4***
No. of grazing animal units	***0.4***	***Cash income from other sources %***	***- 0.6***
		N. of family assets	0.2
		Consumption of energy from LPG* (MJ)	- 0.1
		Consumption of energy from kerosene (MJ)	***0.3***
		Consumption of energy from fuel wood (MJ)	***0.5***
		Area of active agricultural lands (ha)	0.1

**Liquefied petroleum gas (LPG)*

The results of CCA (Table 2) reveal that the *average number of school years of the family members and cash income from other sources* have a negative relationship to *fodder collection*, *fuel wood collection* and *no. of grazing animal units*, whereas *consumption of energy from kerosene* and *fuel wood* have a positive relationship to the three aforementioned woodland-based activities. Therefore, the more income diversification, especially from the forestry sector, and the better the education of households, the less dependent the households are on woodland resources. It is believed that diverse livelihood systems are less vulnerable than undiversified ones (Ellis, 2000b). Although the results of CCA show that the consumption of kerosene adds to the dependency on woodland resources, the results of the pairwise correlation analysis do not show any significant correlations between kerosene consumption and any of the variables of the woodland-based activities. This suggests that fuel wood consumption is a more important correlate to forest-based activity than kerosene consumption.

Adhikari et al. (2004) reported that the collection of forest products from community forests is dependent on various socioeconomic variables, among which some variables, such as livestock holdings, education of family member, and household economic status, were consistent with our findings in this study. There appears to be no relationship between the woodland-based activities and family size. This agrees with the results of a study on rural villages in South Africa (Shackleton *et al.,* 2002) that also indicate that the use of resources does not necessarily increase linearly with an increase in family size. Analysis of data revealed that gender composition of households (no. of females) had not any correlation with any of mentioned forest-based activities at a statistically significant level. The limited dependency of the livelihood system on agriculture in this village is corroborated by an analysis of the areas actively under cultivation.

Referring to the results of CCA, improve the educational system of the village certainly will reduce the dependency of households to the woodland-based incomes. Comparison of average school years for males and females in active households showed that there is a statistically significant difference for males (6.0 years) and females (4.5) (p-value 0.04). This addresses the importance of attention on education and training of women. Processing of woodland products, such as processing the gathered seeds and acorns that is done mostly by women before selling, could be an opportunity to increase the household cash income from natural resources without increasing the stress on these resources. In this way, the role of women and children in the forest management and diversification of environmental income should be recognized. A number of relevant studies emphasize that women are important actors in natural resource use (Gupte, 2004; Fonjong, 2008; Shandra *et al.,* 2008). Thus it could be advantageous to have education and training also related to the use of the natural resources like further processing of seed and acorn. Stimulating the recreation aspect of the woodland and investing on green infrastructure in the area could be also a realistic long-term option to decrease direct dependency of livelihoods on the woodland-based incomes. In Paper II, while trying to identify the role of key socioeconomic factors on households forest activities, one should not forget the effects of external factors (external factors in SLF, Figure 1) such as market changes, mast years for seed gathering, climate changes, law, etc. For instance, some activities, such as animal husbandry and seed collection, are highly dependent on precipitation and climatic conditions. These all affect the livelihoods of households and we do not have sufficiently good data regarding them. Investigating the effects of such factors on forest products was beyond the scope of our study. The study refers to the particular conditions in that year and as aforementioned factors are important, it points to the need for further studies in this region. Another property of the data is that interviews were limited to head of households. This precluded a more thorough analysis of certain internal mechanisms of the households, such as the gendered division of work and responsibilities. Since all but two of the household heads of the active households were male, it is not unlikely that a bias in terms of natural resource activity on the part of women work afflicts the data.

5.3 Impacts of Forest-Based Activities on the Woodland Attributes

In Paper III, the results show that there is forest degradation in terms of a lack of natural regeneration. It is most severe for wild pistachio for which natural regeneration is totally lacking. Regeneration of oaks from seed is less frequent than regeneration from sprouts (46.2 per ha versus 129.2 per ha). More than 50% of the inventoried plots did not have any woody species regeneration.

The natural regeneration of trees is probably inhibited by overgrazing. Grazing as a driving force affects perennial species more than annual species (Hoekstra and Shachak, 1999). Evidence of overgrazing from an overpopulation of livestock has been implicated in recent years, i.e., 2003, and even in the last decades (Paper I). Moreover, the high percentage of observed traces of animal grazing as a disturbance factor in the surveyed sample plots (inventory data 2003) indicates that livestock grazing could be the principal factor of the poor regeneration in the study area. There appears to be heavier impacts of forest-based activities close to the village. Pourhashemi et al. (2004) reported a case study in northern Zagros, which found that the quality and density of trees improved with distance from the village in the study area as grazing intensity declined. There is no direct evidence indicating that seed, particularly acorn, collection alone would cause the lack of natural regeneration in the area. This is because oak, as the most frequent woody species, regenerates mostly in coppice form. Nevertheless, seed collection associated with animal grazing in the area adjacent to the village could aggravate the lack of natural regeneration. Practically the number of grazing animals is controlled by some factors such as affords, frequency of fodder, and so forth rather than the current stipulated law from the forest authority for holding of grazing livestock by households. Apart from overgrazing and seed gathering, drought in some years could be a factor contributing to the poor natural regeneration in the area (Paper I). The persistence of these forests could be due solely the excellent vegetative reproduction capacity of oaks through shoot regrowth after cutting (Pourhashemi *et al.*, 2004) or naturally damaging (Rackham, 2001). Therefore, being in coppice form is an inherent characteristic of oaks and forest activities from earlier decades (Paper I) which could also be a cause of the prevalence of coppice oaks. In this way, 54% of the oaks were in coppice form. Both diversity of tree size, sometimes referred to as structural diversity, and species diversity are useful in promoting general forest biodiversity (Buongiorno and Gilless, 2003) and the lack of natural regeneration for wild pistachio and the shortage of seed-regenerated trees (oaks) is a cause for concern in the sustainability and conservation of biodiversity of the woodland.

Another concern regarding woodland sustainability is the relatively high incidence of bad-quality trees (an average of 20%). Figure 5 depicts the percentage of bad-quality oaks in different diameter classes. There is a high percentage of bad-quality trees in diameter class 5 (cm) as well as a high percentage of bad-quality trees in the bigger diameter classes. One of the reasons for the relatively high rate of bad-quality oak trees could be related to the effects of overgrazing and the lopping of oaks in previous decades (Paper I). The prohibition on cutting of trees would mean that bad-quality trees are retained. The average dbh for both oaks and wild pistachio with $h \geq 2$ m is estimated to be 18 cm (inventory data 2003).

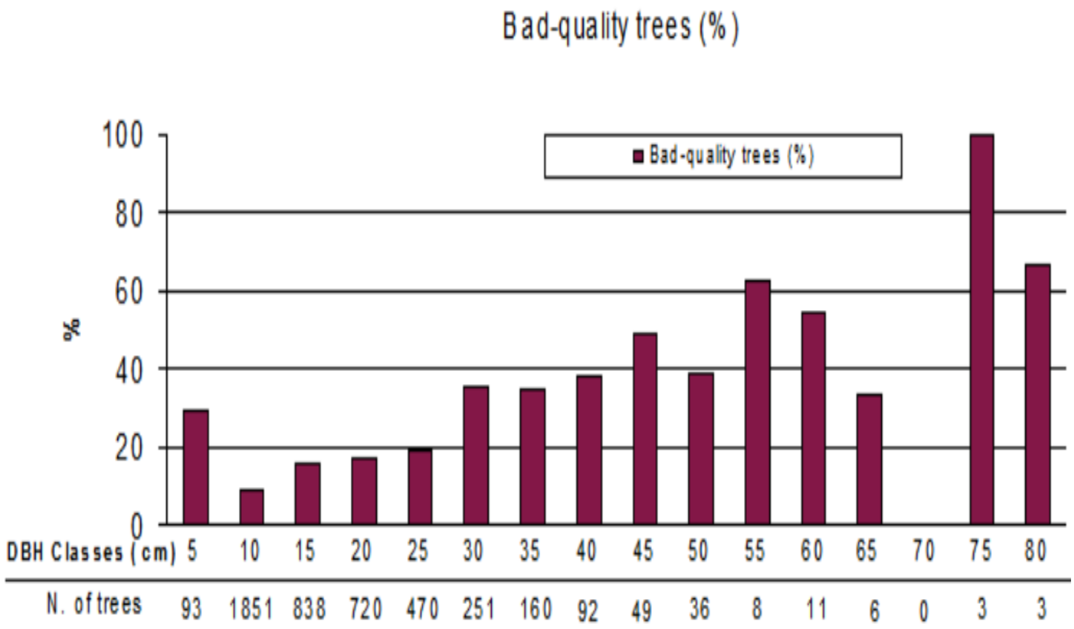

Figure 5. Distribution of bad-quality oak trees (%) in diameter classes in Ganaveh woodland.

One forest project involved the purchasing of seeds and the subsequent seeding of some areas in Ganaveh. However, there are no indications that the project meets conservation and sustainable objectives. There appeared to be a low social acceptance of the need to conserve the seeded areas, causing the failure of seedlings to survive (Paper III). In addition, the purchase of seeds caused more demand in the seed market, stimulating seed gathering activities. In the end, this could even have had a negative impact on woodland conditions, ultimately resulting in additional costs for the forest authority. A better alternative to seeding for woodland rehabilitation could be efforts by the forest authority to reach social acceptance from the woodland users to protect the areas from animal grazing. Because mostly grasses and herbs are collected as fodder, there should be no relevant impact of that activity on the sustainability of the woodland. At least, as long as fodder collection is conducted properly without cutting or damaging seedlings.

Woody species especially oak provides fuel wood and acorn for villagers. The average collection of approximately 0.02 m^3 fuel wood per ha per year in the watershed could be compared with the average annual growth rate for oak in the southern Zagros of 0.7 m^3 per ha per year (Jazirehi and Ebrahimi 2003). Judging from this the dependency does not seem to have the same detrimental effect on the natural resource base as reported in other cases from woodland areas (e.g., Abdallah and Monela, 2007) (Paper II). This shows that the woodland has sufficient potential to provide the needed quantities of fuel wood and fuel wood is an underutilized resource and it seems that giving high priority to the distribution of fossil fuels by forest authority, as it is a current project, to conserve woodland resources is not relevant. However, from the interviews (2008) it was not possible to determine how fuel wood collection was related to distance from the village. It may be that the exploitation rate of fuel wood increases, on average, the closer one gets to the village. Nevertheless, the impacts of fuel wood collection on the sustainability of the woodland should be limited. This is because, according to the interviews (2008), only deadwood is collected and there is no cutting or lopping of trees to provide fuel wood. The increase of CCD of the woodland during the period from 1969 to 1993 also attests to this fact (Paper I).

Table 3 depicts a summary of the assumed impacts of the forest-based activities as potential components of livelihood strategies on the sustainability of the woodland. A successful rural livelihood strategy is one in which the quantity, quality, and mix of assets are such that adverse events can be withstood without compromising future survival (Ellis, 2000a). Therefore, uncontrolled grazing and seed gathering could be critical issues for the sustainability of these resources.

Table 3. The assumed impacts of current forest activities on the sustainability of the Ganaveh woodland.

Activities	Likely impacts on sustainability of the woodland
- Livestock grazing (overgrazing)	- General shortage of regeneration
	- Increasing vulnerability on the growth of seedlings
	- Biodiversity degradation of woody species
* Seed and acorn gathering (overgathering)	* General shortage of natural regeneration
	* Biodiversity degradation of woody species
• Fodder collection	• Not so relevant
• Fuel wood collection	• Not important
• Seeding	○ Could improve the sustainability of the woodland but it is not important at the moment

So far, the participation of inhabitants in forest projects for conservation of woodland resources has not been effective. To ensure the sustainable use and conservation of the woodland, it is necessary to have a much closer connection between the forest authority and the woodland users. They should share the responsibility of forest management, which could be interpreted as participatory (joint, community) forest management (Kaushal and Kala, 2004; Visseren-Hamakers and Glasbergen, 2007). Improving the role of the village's council as a mediating factor could result in better participatory management of woodland resources in Ganaveh.

5.4 The Diameter Class Model

Numerous studies present management models based on diameter class models for management of uneven-aged forest stands (see e.g., Buongiorno and Michie, 1980; Solberg and Haight, 1991; Buongiorno *et al.*, 1995; Favrichon, 1998; Kolbe *et al.*, 1999; Hao *et al.*, 2005; Shao *et al.*, 2006). The diameter distribution, where the number of trees is specified by size classes, is one of the most common variables obtained from forest inventories in Iran. Therefore, diameter class models would seem appropriate for analyzing forest data to select optimal forest management strategies. In Paper IV, to make some management recommendations for the Ganaveh woodland, a diameter class model to predict the effects of different forest management practices on growth and yield conditions of the mixed coppice stands of Persian oak was developed.

The model was prepared for three regions that were constructed as overlapping circles with a radius of 2, 4 and 6 km, respectively. This resulted in forest areas of 650 ha, 1949 ha, and 3249 ha in regions 1, 2 and 3, respectively. The corresponding number of sample plots to regions in the 2003 inventory data was 50, 73 and 48, respectively. Besides the 2003 inventory data some data for deriving the model parameters were extracted from an adjacent forested area.

The management problem was formulated as a linear programming problem and analyzed under a set of different conditions. REFER reflects the current management, i.e. harvesting is not allowed. REFIM is identical to REFER except that animal grazing is controlled such that natural regeneration could occur in all regions as it does in the furthermost region. Version GPRNS is the base model that allows harvesting of trees. Harvested wood and collected fuel wood is valued equally, a possible interpretation being that everything is used as fuel. GRBNS analyses what would happen if foraging could be controlled as in version REFIM. GRSN1 and GRSN2 are sensitivity analyses of the sprout recruitment parameter, i.e. it is reduced with 10% and 20%, respectively. In all other respects GRBNS, GRSN1 and GRSN2 are identical to GPRNS. GPRND shows the effects of removing a steady state requirement that is imposed on GPRNS from year 100 and onwards. In addition to that GPROD also makes away with a non-declining harvest constraint that in the other versions is valid from year 1. Finally, version CONNS should illuminate the management implications of harvesting only for construction purposes, i.e. fuel wood is set a zero value, in other respects being identical to GPRNS. A maximum dimension of 25 cm is set for construction wood since the quality of larger trees tends to be too poor (Jazirehi and Ebrahimi 2003; Ghazanfari *et al.*, 2004).

Table 4. *The amounts of collected fuel wood and harvested wood per ha and year (m^3) over the first 100 years and the corresponding relative amount relative to version GPRNS.*

	Fuel wood (ha^{-1} y^{-1})	Harvest (ha^{-1} y^{-1})	Fuel wood (relative)	Harvest (relative)
REFER	0.023	0.000	1.50	0.00
REFIM	0.026	0.000	1.68	0.00
GPRNS	0.015	0.219	1.00	1.00
GRBNS	0.01	0.286	1.17	1.30
GRSN1	0.015	0.187	0.96	0.85
GRSN2	0.014	0.163	0.91	0.74
GPRND	0.013	0.420	0.87	1.91
GPROD	0.002	0.424	0.16	1.93
CONNS[1]	0.017	0.229	1.12	1.04

[1] *Fuel wood as if collected although not valued in the model; harvested volume only with dbh ≤ 25 cm.*

The production of harvested wood and fuel wood over the first 100 years, the period for which no steady state requirement is imposed, is presented in Table 4. For all versions with harvest except GPROD, the non-declining harvest constraint forces the solution to a constant harvest level over the entire planning horizon, making the comparison of harvests over time easy. Production of harvested wood increases by 30% when compared with GPRNS if foraging can be controlled. If sprout occurrence is reduced by 10% and 20%, the output is reduced by 15% and 26%, respectively.

Collected fuel wood is 10 - 20 times lower than the harvested volumes (Table 4). For GPRNS, it amounts to an average of 90 m^3 $year^{-1}$, compared to 1283 m^3 $year^{-1}$ of harvested wood. The pattern over time is more or less the same for all versions with harvest, i.e., the amount of fuel wood starts at about 120 m^3 $year^{-1}$ and gradually reduces to about 30 m^3 $year^{-1}$

after 100 years. This also reflects a reduction in standing volume from somewhere below 20 to about 8 m^3 ha^{-1}. Current procedures, version REFER, give substantially more fuel wood than when harvests are introduced. Another 18% is achieved when animal grazing is controlled. However, they all start at about the same level and it is only at year 50 that REFER gives about 50% more fuel wood than the other versions. This is also the time when REFIM starts to depart from REFER in terms of fuel wood.

Inspecting the regional pattern of harvests reveals that region 1 generally yields very small harvest volumes, at least for the first 50 years. It appears that because harvests are constrained region 1 is reserved mostly for fuel wood collection and, in later periods, to even out the harvest level.

The harvest pattern among diameter classes differs substantially between versions. It also varies over time for the same version. (We limit the analysis here to the first 100 years and to regions 2 and 3 due to the limited and irregular harvests in region 1). There is a tendency that the less regeneration you get the lower the diameter classes that are harvested. In version GPRNS, harvests are mostly in diameter class 3 (15 cm) during the first 50 years, then in class 4 (20 cm). With reduced sprout regeneration according to GRSN1 cuttings will be in classes 2 (10 cm) and 3 the 20 years and almost only in class 4 the last 50 years, whereas GPRSN2 leads to cuttings almost only in class 2 for the first 30 years and a switch to class 3 thereafter. With increased natural regeneration according to GRBNS, cuttings will dominate in class 4 for the first 50 years, then in class 5 (25 cm) and higher.

With less constrained versions you tend to get more pure diameter class harvesting policies, as expected. Removing the steady state condition, as in GPRND, results in harvests in class 7 (35 cm) and above. When production is geared for construction wood (CONNS), there is a pure class 5 harvesting policy for the first 70 years with harvests only from region 3, thereafter in class 4. Year 95 cuttings are in almost all classes in all regions to adapt to the steady state condition.

Figure 6 demonstrates that the steady state distribution imposed in year 100 could vary substantially between regions, although the only differences in management conditions, apart from the initial diameter distributions, are natural regeneration and fuel collection efficiency. Even though the management in REFER and GPRNS are different, at least in regions 2 and 3, the distributions are fairly similar for the smaller classes, indicating that natural regeneration has a decisive influence on the distribution. It can also be noted that the distributions after 100 years of all versions are associated with an inverse J-shape and that there is a marked difference between the initial and final distributions for the smaller classes.

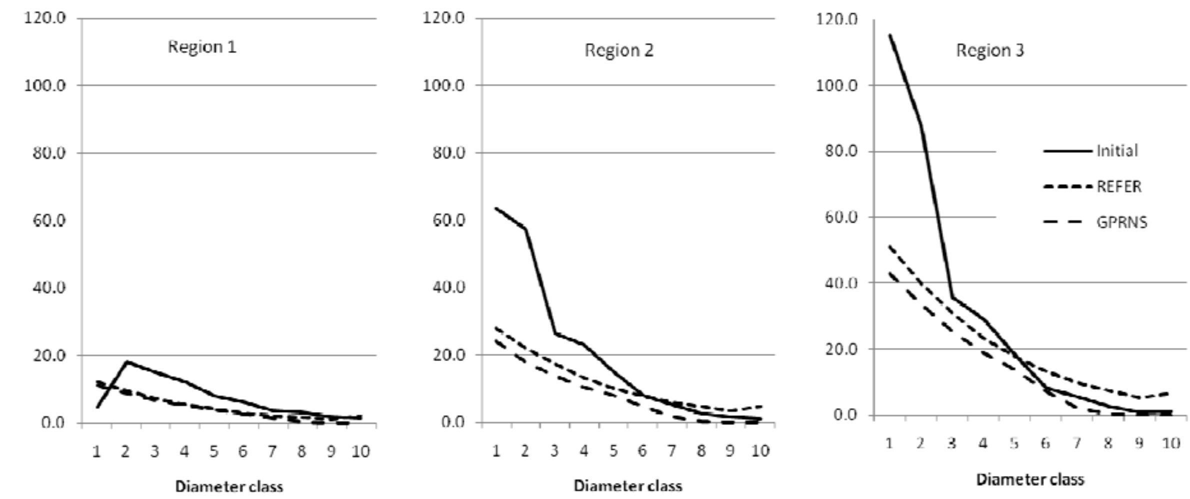

Figure 6. Diameter distribution (stems ha^{-1}) for different regions; the initial distribution, and the distributions before harvest in period 20 for alternatives REFER and GPRNS.

The model gives perspective to a number of management issues. Roughly about 10 times more volume could be recovered in case cutting of trees was allowed. Thus the present prohibition of harvests seems counterproductive. Engaging people in harvesting could add to the diversification of income sources already observed in the area (Paper II).

The REFIM version in some way reflects the current efforts of the forest authority, i.e. to control animal grazing while maintaining the ban on tree cutting. The model suggests that this will only have limited effect on the collected amounts of fuel wood, and then not until about 50 years from now. The effect of improved protection of natural regeneration is more pronounced if it is combined with harvesting trees. The harvest level is then increased by about 30% when compared with the case with today's level of natural regeneration.

However, these contentions should be considered with great caution as they hinge on a number of critical assumptions. Many of the parameters of the models have a rather tenuous basis. Recruitment modelling is unsatisfactory in most models, whatever the type (Porte and Bartelink, 2002). Some models avoid the problem by excluding in-growth altogether (see e.g. Solberg and Haight, 1991). In most models the correlation between the number of recruits on the one hand, and the stand basal area, the tree number, and diameter on the other hand is used but such regressions still result in poor statistical models and recruitment modelling remains unsatisfactory (Porte and Bartelink, 2002). For our model, the estimation problems were exacerbated by the fact that there is semiarid conditions with open vegetation cover, more than 50% of the plots lack regeneration, and most of sample plots were affected by animal browsing. Therefore, we could not find a significant correlation between the mentioned parameters and the number of natural regenerations. Nevertheless, we could find a poor relationship between recruits and distance of plots from the village. Yet, the fact that the steady state diameter distribution in year 100 has less trees in smaller classes than the current distribution may indicate an underestimation of regeneration.

For the assessment of mortality of sprouts some empirical evidence could be used. This was not the case with the mortality of natural seed regeneration. Instead it was derived from the model itself, assuming that the rest of the model was correct and a steady state would eventually develop. However, the relative flatness, especially in the relatively undisturbed region 3, of the inverse J-shaped diameter distributions of the model runs in year 100 compared with today's situation indicate that mortality may be underestimated.

Here, we use the simplest diameter class model possible, i.e. a model with constant transition probabilities. A number of models have been suggested that are density dependent that, thus, they have transition probabilities that are in some way dependent on the amount of trees in the class or in the stand (Solberg and Haight, 1991; Buongiorno *et al.*, 1995; Kolbe *et al.*, 1999). The density independence should not, however, be of major concern in this semiarid forest where trees rarely compete with each other. The transition probabilities may still be put to question because they yield an expected age of the larger diameter classes that is clearly below observed values (data from the Monj and Bard-Karkhaneh forest in Jazirehi and Ebrahimi (2003), thus indicating an overestimation of growth.

In summary, because of a number of critical assumptions of the model parameters, the present model has an uncertainty. There is clearly need for better empirical support of the model parameters. What would be most adequate would be field data including repeated measurements on permanent sample plots to estimate recruitment, stand growth, mortality and survival rates.

However, not only the growth and yield parameters of the model need to be scrutinized. It is also clear that how the objectives and constraints are introduced is of importance. One relates to the implementation of the management actions and the values associated with them. For instance, it has been assumed that all cut trees can be recovered, and, contrary to fuel wood, that there is no cost related to distance of transport.

Another question is raised by the observation that in many areas of the Zagros region utilization of NTFPs has higher value than utilization of timber (Sagheb-Talebi *et al.*, 2004). One of those NTFP's is acorn (Paper II), a source whose production is influenced by factors such as weather during anthesis, tree onotogeny, genetics of trees and site quality, weather during maturation, and predators. In short, acorn production is characterized by extreme variation among years and among individual trees (Healy *et al.*, 1999; Riccardi *et al.*, 2004). Acorn production requires a management strategy that considers tree diameter and the relationship between crown size and per unit crown area production(Healy *et al.*, 1999). The management strategies suggested by the model make the diameter distribution less steep, and encompass a smaller range of diameters, which in turn could be translated into diminished biodiversity (Krebs, 1989).

The constraints and objectives have a decisive influence on the results. This is particularly true of the steady state condition that equates the diameter distributions between years 100 and 150. Steady-state regimes can be viewed as ideal conditions that management could strive for (Buongiorno and Gilless, 2003). The results indicate that such requirements need to be handled with care. That the CONNS version can satisfy the constraint by harvesting and, in principle, leave the stems behind, is a sign of an unfortunate combination of requirements. Another issue concerns the objective function and the doubtful realism of discounting values. Inter-temporal transfer of values requires access to financial markets, which probably is not an option for most of the villagers of Ganaveh. In practice, at least in this case, it is probably of limited importance because the non-declining harvest, in combination with the steady state condition, sets a level that is not affected by the discount rate; maximizing the harvest level would yield the same solution.

Modelling of other woodland products (i.e., seeds and forage) is still difficult; one reason may be that the mechanisms of production and the physiological function of these forest products are still unknown (Ribeiro do Valle *et al.*, 2007).

6 Recommendations for Management Implementation

The studies give a basis for suggesting strategies for improvements in implementation of management plans for sustainable use and conservation of the woodland resources and improvement of natural resources-based livelihoods of the woodland users. The following statements are recommended:

- The forest appears not to be in a critical state since, over the last few decades, the forest area has increased and the crown cover density and the number of large trees have been stable.
- The lack of natural regeneration and the bad quality of trees is threatening the sustainability of the woodland. They probably result from current practices that involve animal grazing and no harvesting of older trees and need to be addressed.
- The present prohibition of harvests seems counterproductive. The growth and yield capacity of the oak forest could be better utilized if harvesting is allowed. It could also improve the quality of the trees.
- Acorn is one of the important forest products, both for forest regeneration and for livelihoods of woodland users while its production is characterized by extreme variation among years and among individual trees. It is recommended that before performing any harvesting operation, a population of good acorn producing trees should be reserved.
- The woodland could provide the needed quantities of fuel wood and the impacts of fuel wood collection on the sustainability of the woodland are not critical. Thus, distribution of fossil fuels by the forest authority to conserve forest (woodland) resources need not be of high priority.
- Livelihood dependency on the woodland is reduced by income diversification. Projects exploring options like further processing of seeds and increased recreational use would seem motivated. Engaging people in harvesting could also add to the diversification of income sources.
- Since livelihood dependency on the woodland is reduced with more educated household members and the average school years for females is lower than for males, improving the educational system especially for women could enhance sustainability in the woodland resources.
- Efforts to gain social acceptance from the woodland users to protect the preserved areas from animal grazing and seed gathering for a period could be a better alternative for woodland rehabilitation than seeding.
- Improving the role of the village's council as a mediating factor could result in better participatory management of woodland resources in Ganaveh.

- Periodically monitoring of land cover changes in permanent sample plots to have a thorough figure of the effects of implemented management plans on the woodland resources, and to provide more reliable parameters for development of management models.

7 Future research

In Paper II, we investigated the role of socioeconomic key factors of households on the forest-based activities. Little attention was paid to external factors that affect the livelihood system, such as market changes, masting years for seed gathering, climate conditions, law, etc. Further studies should extend the investigation of the effects of such factors. It is especially important to get data over time to assess the interplay of such factors in the livelihood system. Moreover, we conducted our study on strategies of natural resources-based livelihoods at household level by interviews of heads of households, further studies should extend interviews to other members of households e.g., women and children to illuminate the effects of sub-household conditions on strategies of natural resources-based livelihoods.

Processing of woodland products could be an opportunity to increase the household cash income from natural resources without increasing the stress on these resources, More studies should be conducted to investigate how to earn more environmental income from natural resources with improvement of processing methods.

Referring to Paper III, animal grazing and drought are presented as the main factors for poor natural regeneration in the area. If alternative fodder sources could be found, especially in droughts, they would provide an opportunity to protect woodland regeneration. Deciduous woody fodder species may play a significant role as sources of nutrients for livestock (Papachristou and Papanastasis, 1994). Conducting some studies to suggest alternatives as the fodder sources, i.e., making some treatments on oak leaves to be palatable for livestock, as it was carried out on other species (Krebs *et al.*, 2007) is suggested.

Research on the conditions of the soil seed bank in the area could be helpful to understand the impacts of the seed collection and animal grazing on the lack of the natural regeneration.

The diameter class model presented in Paper IV needs better empirical support of the model parameters. Future work should involve the design and establishment of permanent sample plots in order to estimate recruitment, stand growth, mortality and survival rates by performing repeated measurements.

To ensure the sustainable use and conservation of the woodland, it is necessary to have a much closer connection between the forest authority and the woodland users and share the responsibility of forest practices through participatory (joint; community) forest management. Future research could deal with strengths, weaknesses, opportunities, and threats of such a management strategy. It demands the cooperation of social and natural scientist and could be conducted in the form of case studies involving the concerned parties. This could lead to implementation methods that ensure conservation and sustainable use of the resources as well as improvement in the natural resource based livelihoods of the communities.

References

Abdallah, J.M. & Monela, G.G. (2007). Overview of Miombo woodlands in Tanzania. In: MITMIOMBO – management of indigenous tree species for ecosystem restoration and wood production in semi-arid Miombo woodlands in eastern Africa. *Working Papers of the Finnish Forest Research Institute* 50, 9–23. http://www.metla.fi/julkaisut/workingpapers/2007/mwp050.htm

Abdi, K. (2003). The early development of pastoralism in the central Zagros Mountains. *Journal of World Prehistory* 17(4), 395-448.

Adame, P., Canellas, I., Roig, S. & Del Rio, M. (2006). Modelling dominant height growth and site index curves for Rebollo oak *(Quercus Pyrenaica* Willd.). *Annals of Forest Science* 63(8), 929-940.

Adame, P., Hynynen, J., Canellas, I. & del Rio, M. (2008). Individual-tree diameter growth model for Rebollo oak (*Quercus Pyrenaica* Willd.) coppices. *Forest Ecology and Management* 255(3-4), 1011-1022.

Al-Bakri, J.T., Taylor, J.C. & Brewer, T.R. (2001). Monitoring land use change in the Badia transition zone in Jordan using aerial photography and satellite imagery. *Geographical Journal* 167, 248-262.

Ali, T., Ahmad, M., Shahbaz, B. & Suleri, A. (2007a). Impact of participatory forest management on financial assets of rural communities in northwest Pakistan. *Ecological Economics* 63(2-3), 588-593.

Ali, T., Ahmad, M., Shahbaz, B. & Suleri, A. (2007b). Impact of participatory forest management on vulnerability and livelihood assets of forest-dependent communities in northern Pakistan. *International Journal of Sustainable Development and World Ecology* 14(2), 211-223.

Appasamy, P.P. (1993). Role of non-timber forest products in a subsistence economy - the case of a joint forestry project in India. *Economic Botany* 47(3), 258-267.

Archibold, O.W. (1995). *Ecology of World Vegetation*. London: Chapman & Hall.

Atasoy, M., Karsli, F., Biyik, C. & Demir, O. (2006). Determining land use changes with digital photogrammetric techniques. *Environmental Engineering Science* 23(4), 712-721.

Barbero, M., Bonin, G., Loisel, R. & Quezel, P. (1990). Changes and Disturbances of Forest Ecosystems caused by human activities in the western part of the Mediterranean Basin. *Vegetatio* 87(2), 151-173.

Barrow, C.J. & Hicham, H. (2000). Two complimentary and integrated land uses of the western high Atlas Mountains, Morocco: The potential for sustainable rural livelihoods. *Applied Geography* 20(4), 369-394.

Bebbington, A. (1999). Capitals and capabilities: A framework for analyzing peasant viability, rural livelihoods and poverty. *World Development* 27(12), 2021-2044.

Bellefontaine, R. (2000). *Management of Natural Forests of Dry Tropical Zones*. Rome: Food and Agriculture Organization of the United Nations (FAO conservation guide, 32).

Boudru, M. (1961). *Geographie Forestieere*. Gembloux, Belgique: Institut Agronomique de I'Etata.

Bradshaw, R. & Mitchell, F.J.G. (1999). The palaeoecological approach to reconstructing former grazing-vegetation interactions. *Forest Ecology and Management* 120(1-3), 3-12.

Brook, B. & Bowman, D. (2006). Postcards from the past: Charting the landscape-scale conversion of tropical Australian savanna to closed Forest during the 20th century. *Landscape Ecology* 21(8), 1253-1266.

Buongiorno, J. & Gilless, J.K. (2003). *Decision Methods for Forest Resource Management.* Amsterdam: Academic Press.

Buongiorno, J. & Michie, B.R. (1980). A matrix model of uneven-aged forest management. *Forest Science* 26(4), 609-625.

Buongiorno, J., Peyron, J.L., Houllier, F. & Bruciamacchie, M. (1995). Growth and management of mixed–species, uneven–aged forests in the French Jura–implication for economic returns and tree diversity. *Forest Science* 41(3), 397-429.

Caellas, I., del Rio, M., Roig, S. & Montero, G. (2004). Growth response to thinning in *Quercus Pyrenaica* Willd. Coppice stands in Spanish central mountain. *Annals of Forest Science* 61(3), 243-250.

Carmel, Y. & Kadmon, R. (1999). Effects of grazing and topography on long-term vegetation changes in a Mediterranean ecosystem in Israel. *Plant Ecology* 145(2), 243-254.

Carney, D. (1998). *Sustainable Rural Livelihoods : What Contribution Can We Make?* London: Department for International Development.

Chambers, R. (1991). In search of professionalism, bureaucracy and sustainable livelihoods for the 21st-century. *Ids Bulletin-Institute of Development Studies* 22(4), 5-11.

Chojnacky, D.C. (1997). Modeling diameter growth for pinyon and juniper trees in dryland forests. *Forest Ecology and Management* 93(1-2), 21-31.

Conway, D., Allison, E., Felstead, R. & Goulden, M. (2005). Rainfall variability in east Africa: Implications for natural resources management and livelihoods. *Philosophical Transactions of the Royal Society of London Series a-Mathematical Physical and Engineering Sciences* 363(1826), 49-54.

Croitoru, L. (2007). Valuing the non-timber forest products in the Mediterranean region. *Ecological Economics* 63(4), 768-775.

Dalal-Clayton, D.B., Dent, D. & Dubois, O. (2003). *Rural Planning in Developing Countries : Supporting Natural Resource Management and Sustainable Livelihoods*. London: Earthscan.

Debnath, D. & Dasgupta, S. (2006). Livelihood generation and poverty reduction attempts in joint forest management activities in Madhya Pradesh. *International Forestry Review* 8(2), 241-250.

Debussche, M., Debussche, G. & Lepart, J. (2001). Changes in the vegetation of *Quercus Pubescens* woodland after cessation of coppicing and grazing. *Journal of Vegetation Science* 12(1), 81-92.

DFID, Department for International Development (2001). *Sustainable Livelihoods Guidance Sheets, Section 2* [online]. London the UK. http://www.livelihoods.org/info/guidance_sheets_pdfs/section2.pdf.

DoE/GOIRI , Department of Environment Government of the Islamic Republic of Iran (2004). *Conservation of Biodiversity in the Central Zagros Landscape Conservation Zone* [online]. Zagros Project Office. http://www.irandoe.org/zagros/Docs/Doc28.pdf

Ellis, F. (2000a). *Rural Livelihoods and Diversity in Developing Countries*. Oxford: Oxford University Press.

Ellis, F. (2000b). The determinants of rural livelihood diversification in developing countries. *Journal of Agricultural Economics* 51(2), 289-302.

Erfanifard, Y., Feghhi, J., Zobeiri, M. & Namiranian, M. (2009). Spatial pattern analysis in Persian Oak (*Quercus Brantii Var. Persica*) forests on b&w aerial photographs. *Environmental Monitoring and Assessment* 150(1), 251-259.

Favrichon, V. (1998). Modeling the dynamics and species composition of a tropical mixed-species uneven-aged natural forest: Effects of alternative cutting regimes. *Forest Science* 44(1), 113-124.

Fensham, R.J. & Fairfax, R.J. (2003). Assessing woody vegetation cover change in north-west Australian savanna using aerial photography. *International Journal Of Wildland Fire* 12(3-4), 359-367.

Ffolliott, P.F., Brooks, K.N., Gregersen, H.M. & Lundgren, A.L. (1995). *Dryland Forestry : Planning and Management*. New York: Wiley.

Fonjong, L.N. (2008). Gender Roles and Practices in Natural Resource Management in the North West Province of Cameroon. *Local Environment* 13, 461-475.

Ghazanfari, H., Namiranian, M., Sobhani, H. & Mohajer, R.M. (2004). Traditional forest management and its application to encourage participation for sustainable forest management in the northern mountains of Kurdistan province, Iran. *Scandinavian Journal Of Forest Research* 19, 65-71.

Gupte, M. (2004). Participation in a Gendered Environment: The Case of Community Forestry in India. *Human Ecology* 32, 365-382.

Hajabbasi, M.A., Jalalian, A. & Karimzadeh, H.R. (1997). Deforestation effects on soil physical and chemical properties, Lordegan, Iran. *Plant and Soil* 190(2), 301-308.

Hao, Q.Y., Meng, F.R., Zhou, Y.P. & Wang, J.X. (2005). A transition matrix growth model for uneven-aged mixed-species forests in the Changbai mountains, northeastern China. *New Forests* 29(3), 221-231.

Healy, W.M., Lewis, A.M. & Boose, E.F. (1999). Variation of red oak acorn production. *Forest Ecology and Management* 116(1-3), 1-11.

Henkin, Z., Gutman, M., Aharon, H., Perevolotsky, A., Ungar, E.D. & Seligman, N.G. (2005). Suitability of Mediterranean oak woodland for beef herd husbandry. *Agriculture Ecosystems & Environment* 109(3-4), 255-261.

Hoekstra, T.W. & Shachak, M. (1999). *Arid Lands Management : Toward Ecological Sustainability*. illustrated edition. Urbana University of Illinois Press.

Houghton, R.A. (1994). The worldwide extent of land-use change. *Bioscience* 44(5), 305-313.
Jazirehi, M.H. & Ebrahimi , M. (2003). *Silviculture in Zagros*. 1 edition. Tehran: University of Tehran Press (in Persian).
Kadmon, R. & Harari-Kremer, R. (1999). Studying long-term vegetation dynamics using digital processing of historical aerial photographs. *Remote Sensing Of Environment* 68(2), 164-176.
Kappelle, M.e. (2006). *Ecology and Conservation of Neotropical Montane Oak Forests*. Berlin: Springer, cop.
Kaushal, K.K. & Kala, J.C. (2004). Applying the sustainable livelihood approach to joint forest management projects in India. *International Forestry Review* 6(1), 13-18.
Kolbe, A.E., Buongiorno, J. & Vasievich, M. (1999). Geographic extension of an uneven-aged, multi-species matrix growth model for northern hardwood forests. *Ecological Modelling* 121(2-3), 235-253.
Krebs, C. (1989). *Ecological Methodology*. New York: HarperCollins.
Krebs, G.L., Howard, D.M. & Dods, K. (2007). Feeding *Acacia Saligna* to sheep and goats with or without the addition of urea or polyethylene glycol. *Asian-Australasian Journal of Animal Sciences* 20(10), 1551-1556.
Kusters, K., Achdiawan, R., Belcher, B. & Perez, M.R. (2006). Balancing development and conservation? An assessment of livelihood and environmental outcomes of non-timber forest product trade in Asia, Africa, and Latin America. *Ecology and Society* 11(2)
Latorre, J.G., García-Latorre, J. & Sanchez-Picón, A. (2001). Dealing with aridity: Socio-economic structures and environmental changes in an arid Mediterranean region. *Land Use Policy* 18(1), 53-64.
Le Houerou, H.N. (1993). Land degradation in Mediterranean Europe: Can agroforestry be a part of the solution? A prospective review. *Agroforestry Systems* 21(1), 43-61.
Mahapatra, A.K. & Tewari, D.D. (2005). Importance of non-timber forest products in the economic valuation of dry deciduous forests of India. *Forest Policy and Economics* 7(3), 455-467.
Manier, D.J., Hobbs, N.T., Theobald, D.M., Reich, R.M., Kalkhan, M.A. & Campbell, M.R. (2005). Canopy dynamics and human caused disturbance on a semi-arid landscape in the Rocky mountains, USA. *Landscape Ecology* 20(1), 1-17.
Masozera, M.K. & Alavalapati, J.R.R. (2004). Forest dependency and its implications for protected areas management: A case study from the Nyungwe forest reserve, Rwanda. *Scandinavian Journal of Forest Research* 19, 85-92.
Menitsky, Y.L. (2005). *Oaks of Asia*. Fedorov, A.A. (ed.). Enfield, NH: Science Publishers.
Merlo, M. & Croitoru, L. (2005). Valuing Mediterranean forests towards total economic value. In: ebrary, I. (Ed.) Wallingford: CABI Publishing.
Nyland, R.D. (2002). *Silviculture : Concepts and Applications*. New York: McGraw-Hill.
Papachristou, T.G. & Papanastasis, V.P. (1994). Forage value of Mediterranean deciduous woody fodder species and its implication to management of silvo-pastoral systems for goats. *Agroforestry Systems* 27(3), 269-282.
Porte, A. & Bartelink, H.H. (2002). Modelling mixed forest growth: A review of models for forest management. *Ecological Modelling* 150(1-2), 141-188.

Pourhashemi, M., Mohajer, M.R.M., Zobeiri, M., Amiri, G.Z. & Panah, P. (2004). Identification of forest vegetation units in support of government management objectives in Zagros forests, Iran. *Scandinavian Journal Of Forest Research* 19, 72-77.

Pourreza, M., Shaw, J.D. & Zangeneh, H. (2008). Sustainability of wild pistachio (*Pistacia Atlantica* Desf.) in Zagros forests, Iran. *Forest Ecology and Management* 255(11), 3667-3671.

Preiss, E., Martin, J.L. & Debussche, M. (1997). Rural depopulation and recent landscape changes in a Mediterranean region: Consequences to the breeding Avifauna. *Landscape Ecology* 12(1), 51-61.

Quinn, C.H., Huby, M., Kiwasila, H. & Lovett, J.C. (2007). Design principles and common pool resource management: An institutional approach to evaluating community management in semi-arid Tanzania. *Journal of Environmental Management* 84(1), 100-113.

Rackham, O. (2001). *Trees and Woodland in the British Landscape the Complete History of Britain's Trees, Woods & Hedgerows*. London: Phoenix press.

Reid, R.S., Kruska, R.L., Muthui, N., Taye, A., Wotton, S., Wilson, C.J. & Mulatu, W. (2000). Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: The case of southwestern Ethiopia. *Landscape Ecology* 15(4), 339-355.

Ribeiro do Valle, D., Staudhammer, C.L. & Cropper, W.P. (2007). Simulating non-timber forest product management in tropical mixed forests. *Journal of Forestry* 105, 301-306.

Riccardi, C.L., McCarthy, B.C. & Long, R.P. (2004). Oak Seed Production, Weevil (Coleoptera: Curculionidae) populations, and predation rates in mixed-oak forests of south east Ohio. In: *Proceedings of the 14th Central Hardwood Forest Conference,*10–21.

Rocchini, D., Perry, G.L.W., Salerno, M., Maccherini, S. & Chiarucci, A. (2006). Landscape change and the dynamics of open formations in a natural reserve. *Landscape And Urban Planning* 77(1-2), 167-177.

Ross, C. (2004). Native seed collection and use in arid land reclamation: A low-tech approach. *Environmental Monitoring and Assessment* 99(1-3), 267-274.

Sagheb-Talebi, K., Sajedi, T. & Yazdian, F. (2004). *Forests of Iran [in Persian with English Summary]*. Research Institute of Forests and Rangelands ,Iran.

Salehi, A., Wilhelmsson, E. & Söderberg, U. (2008). Land cover changes in a forested watershed, southern Zagros, Iran. *Land Degradation & Development* 19, 542-553.

Sands, R. (2005). *Forestry in a Global Context.* Wallingford: CABI Publishing.

Schweik, C.M., Adhikari, K. & Pandit, K.N. (1997). Land-cover change and forest institutions: A comparison of two sub-basins in the southern Siwalik hills of Nepal. *Mountain Research and Development* 17(2), 99-116.

Shackleton, S.E., Shackleton, C.M., Netshiluvhi, T.R., Geach, B.S., Ballance, A. & Fairbanks, D.H.K. (2002). Use patterns and value of savanna resources in three rural villages in South Africa. *Economic Botany* 56(2), 130-146.

Shandra, J.M., Shandra, C.L., London, B. (2008). Women, Non-Governmental Organizations, and Deforestation: A Cross-National Study. *Population and Environment* 30, 48-72.

Shao, G.F., Wang, F., Dai, L.M., Bai, J.W. & Li, Y.S. (2006). A density-dependent matrix model and its applications in optimizing harvest Schemes. *Science in China Series E-Technological Sciences* 49, 108-117.

Siren , G. (1986). Biomass production in semi-arid and arid zones *18th IUFRO World Congress* Ljubljana (Yugoslavian).

Sivakumar, M.V.K., Das, H.P. & Brunini, O. (2005). Impacts of present and future climate variability and change on agriculture and forestry in the arid and semi-arid tropics. *Climatic Change* 70(1-2), 31-72.

Sjaastad, E., Angelsen, A., Vedeld, P. & Bojo, J. (2005). What is environmental income? *Ecological Economics* 55(1), 37-46.

Soini, E. (2005a). Changing livelihoods on the slopes of Mt. Kilimanjaro, Tanzania: Challenges and opportunities in the Chagga Homegarden system. *Agroforestry Systems* 64(2), 157-167.

Soini, E. (2005b). Land use change patterns and livelihood dynamics on the slopes of Mt. Kilimanjaro, Tanzania. *Agricultural Systems* 85(3), 306-323.

Solberg, B. & Haight, R.G. (1991). Analysis of optimal economic management regimes for picea abies stands using a stage-structured optimal-control model. *Scandinavian Journal Of Forest Research* 6(4), 559-572.

Sunderlin, W.D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L. & Wunder, S. (2005). Livelihoods, forests, and conservation in developing countries: An overview. *World Development* 33(9), 1383-1402.

Tachtadzjan, A.L. (1986). *Floristic Regions of the World*. Berkeley: University of California Press.

Taylor, J.C., Brewer, T.R. & Bird, A.C. (2000). Monitoring landscape change in the national parks of England and Wales using aerial photo interpretation and GIS. *International Journal Of Remote Sensing* 21(13-14), 2737-2752.

Tekle, K. & Hedlund, L. (2000). Land cover changes between 1958 and 1986 in Kalu district, southern Wello, Ethiopia. *Mountain Research and Development* 20(1), 42-51.

Tempelman, M.D. (2000). Socio-Economic and Gender Analysis (Seaga) Training Tools in Support of Household Resources Management Sustainable development Department (SD), *Food and Agriculture Organization of the United Nations (FAO).* http://www.fao.org/sd/wpdirect/wpre0133c.htm

Vedeld, P., angelsen, A., Sjaastad, E. & Berg, G.K. (2004). *Counting on the Environment Forest Incomes and the Rural Poor*. Washington: World Bank.

Visseren-Hamakers, I.J. & Glasbergen, P. (2007). Partnerships in forest governance. *Global Environmental Change* 17(3-4), 408-419.

Walker, B.H. (1979). *Management of Semi-Arid Ecosystems* Amsterdam.

Warren, A., Sud, Y.C. & Rozanov, B. (1996). The future of deserts. *Journal of Arid Environments* 32(1), 75-89.

Wilde, V.L., Mattila, A.V. (1999). Gender Analysis and Forestry. In: Brindley, B. (Ed.) Case Studies. *Food and Agriculture Organization; Forests, trees and People Programme.*

Zavala, M.A. & Zea, E. (2004). Mechanisms maintaining biodiversity in Mediterranean Pine-Oak forests: Insights from a spatial simulation model. *Plant Ecology* 171(1-2), 197-207.

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