CGIAR Challenge Program on
WATER & FOOD

INTEGRATED WATERSHED MANAGEMENT IN THE UPPER CATCHMENTS OF KARKHEH RIVER BASIN OF IRAN

Editors: M. Ghafouri, H. Siadat and T. Oweis

CPWF project: Strengthening Livelihood Resilience in Upper Catchments of Dry Areas by INRM (PN 24)

12

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Contents

Abbreviations

AEZ	Agro-ecological zones
AEZWIN	AEZ for Windows
AHP	Analytic hierarchy process
AREEO	Agricultural Research, Education, and Extension Organization
CGIAR	Consultative Group on International Agricultural Research
CI	Consistency index
CMA	Catchment management authorities
CP	Challenge program
CPWF	Challenge Program on Water and Food
CWANA	Central and West Asia and North Africa
DARI	Dryland Agricultural Research Institute
ESS	Eco-system services
FRWO	Forests, Ranges, and Watershed Management Organization
GLASOD	Global Assessment of Soil Degradation
ICARDA	International Center for Agricultural Research in the Dry Areas
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
INBO	International Network of Basin Organizations
INRM	Integrated Natural Resources Management
IWM	Integrated watershed management
KRB	Karkheh River Basin
LUT	Land use types
MCE	Multi-criteria evaluation
MEA	Millennium Ecosystem Assessment
NGO	Non-governmental organization
PRA	Participatory rural appraisal
PTD	Participatory technology development
SDSS	Spatial decision support system
SIG	Sistemas de información geográfica
SMART	Significant, meaningful, appropriate, results-oriented, time-framed
SMSS	Soil Management Support Services
SWOT	Strengths, weaknesses, opportunities and threats
TMU	Terrain mapping units
UNDP	United Nations Development Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
USDA	United States Department of Agriculture
WANA	West Asia and North Africa

Executive summary

Integrated watershed management should be pursued to improve people's livelihoods and the ecosystem. It can be achieved when all stakeholders agree on a joint vision and action plan. Scientists should support the process with information about the limits of exploitation of ecosystems, efficient and sustainable methods to use natural resources, and mechanisms for cooperation and they should provide indicators of progress.

Priority issues for integrated watershed management in the upper Karkheh River Basin (KRB) were identified in a workshop with 70 stakeholders from Honam and Merek watersheds. The decisions reached were that:

- Stakeholder coordination before and after implementation of projects is essential
- Participation of women needs to be encouraged
- A holistic system of resource management is required; teamwork is an essential feature
- Community participation during implementation of projects is essential
- Criteria and indicators for integrated watershed management are required
- A land-use plan is required; the farming of steep slopes must be reduced
- Land users need further training and skill development
- Forests and rangelands require protection; the carrying capacity of rangelands must be respected
- Ecosystem degradation must be prevented; religious motives may be used to better protect natural resources
- Water harvesting is essential to improve livelihood resilience
- Non-farming jobs need to be created to reduce stress on the natural resources and prevent erosion; the government should stimulate privatization
- Planning and implementation of integrated watershed management need a Catchment Management Authority.

Planning rural development in an environment-friendly manner needs knowledge of the location and size of lands with different suitabilities. It is proposed to develop and make operational a spatial decision support system for the Honam and Merek watersheds. The system will comprise an analytic hierarchy process, a modern multi-criteria evaluation method, and a geographic information system.

Agricultural development is a component of integrated watershed management. Significant obstacles are the small sizes of the farms and the fragmentation of the land holdings. Land consolidation has been limited because of the farmers' traditions, religious inheritance laws, and the inadequate control capacity of local authorities. A participatory approach to land consolidation is needed to gain acceptance by the farmers and to remove obstacles.

Management of rangelands and forests should be based on their carrying capacities so that land degradation is prevented, biological diversity is preserved and vital natural resources are saved. Current practices are quite different; trees are cut to feed leaves to livestock and to obtain wood to make charcoal, leading to fragmented forests and open areas. As a consequence, a significant number of forage tree and shrub species are already very rare.

Erosion and deposition both cause major problems and need to be reduced. The Karkheh Dam reservoir is already in a critical condition as a result of the influx of sediments from degraded upstream areas (but not from the selected pilot watersheds of Honam and Merek). The main causes of erosion are road construction that leaves soil exposed, up-and-down plowing of narrow strips of farm land, and overgrazing of rangelands. The extraction of construction material from the river bed has disturbed the geomorphology of the river and destroyed its ecological system. Plans, accompanied by adequate regulations, need to be developed and implemented for the conservation of upstream waterways and the main river. The active involvement of the main stakeholders, including local communities, is needed to ensure success. Public awareness plays an important role in implementation.

Supplemental irrigation is crucial for agricultural development in the upper KRB. But, there is little surface water storage in the rainfed areas, the volume of groundwater is limited, and much of the arable land is sloping. Fortunately, options may exist to expand supplementary irrigation. These include:

- Pumping water from the Honam spring and conveying it along gently sloped open channels
- Constructing underground dams in ephemeral rivers to store sub-surface water
- A small dam is being constructed in an ephemeral river upstream of the Sarab Firouzabad qanats in the Merek area and some of the stored water can be used for supplemental irrigation
- Artificial recharge stations can increase underground storage at suitable locations in the Merek Plain.

Stimulation of agricultural development needs a more integrated approach to innovations and technologies. It is essential that farm productivity and income increase through new and resource efficient crop management techniques and tools, as well as post-harvest processes. Methods and materials should be adapted to local conditions through active participation by local communities, with particular attention to environmental friendliness, sustainability, and resilience to climate change. Regular participatory evaluation of the process of development of integrated watershed management enables the stakeholders, especially local communities, to propose adjustments and to adapt concepts and plans to local needs and conditions

Women have a significant role in raising livestock and the marketing of its products. But the provision of development services to women has been limited. The following interventions appear necessary for women:

- Capacity building in modern livestock and crop husbandry, including mechanization
- Increasing participation in community organizations (rural councils, cooperatives, etc.) by encouraging women and rural managers
- Providing access to bank credit and government support services.

Chapter 1.

Integrated Watershed Management in Upper Karkheh river Basin

F. Turkelboom, A. Bruggeman, S.A. Mirghasemi, P. M. Milani, A. Ghaffari and E. De Pauw

Chapter 1. Integrated Watershed Management in Upper Karkheh river Basin

F. Turkelboom, A. Bruggeman, S.A. Mirghasemi, P. M. Milani, A. Ghaffari and E. De Pauw

1.1 Introduction

The Livelihood Resilience project was one of the Phase 1 research projects of the Challenge Program on Water and Food (CPWF), an initiative of the Consultative Group on International Agricultural Research (CGIAR). The project was implemented in the KRB in Iran, during the period June 2004 to June 2009.

The overall goals of the project were to strengthen the livelihood resilience of the rural poor and to improve environmental integrity in the upper catchments of the dry areas (Turkelboom *et al*., 2004). Given the complex combination of biophysical and economic constraints, it was not an easy task to strengthen farmers' livelihoods. In addition to the usual technical skills, this required participatory skills, livelihood analysis, and strong inter-disciplinary and inter-institutional cooperation. Most of these 'soft skills' are underdeveloped in the developing countries of the dry areas. Therefore, two main objectives were envisioned for this project:

- To improve the adaptive capacity of the stakeholders involved to strengthen their livelihoods in these marginal dry environments in a sustainable way
- To develop an appropriate methodology that will combine livelihood-enhancing strategies with watershed management in such a way that could be used beyond the study sites in a wide spectrum of dry environments.

The project's research process was guided by the CGIAR's 'Integrated Natural Resources Management' (INRM) framework, and made operational by a number of strategies and a well-balanced effort between diagnostic, problem solving, and process tools. The research work combined a large-scale analysis of the KRB by GIS and rapid assessments, with a detailed study in two different sub-catchments. These two benchmark research watersheds were the Merek watershed (242 km^2) in Kermanshah Province and the Honam watershed (142 km^2) in Lorestan Province (Figure 1.1).

The project required the active involvement of the researchers and staff of five research institutes under the umbrella of the Agricultural Research, Education, and Extension, Organization (AREEO) and the Forest, Range, and Watershed Management Organization (FRWO), both based in Tehran, Iran. At the provincial level, the main players were the Agricultural Research Centers in the Provinces, which house researchers of these organizations, the Jihad-e-Agriculture Organization, and the Agricultural Extension Offices. There were different disciplinary teams:

- Agro-ecological characterization and land use
- Water and drought
- Soils and nutrient management
- Natural vegetation
- Erosion
- Livelihoods
- Gender
- Participatory technology development
- Integrated watershed management.

Most teams had various sub-teams and included provincial researchers, who managed or assisted with the activities in the watersheds. The project was coordinated by ICARDA and benefited from the additional scientific support provided by the Catholic University of Leuven.

One of the specific objectives of the Livelihood Resilience project was to amalgamate the findings and experiences of the studies and activities in the two benchmark watersheds into watershed management principles for the upper catchments of dry mountainous environments. The results of this work are summarized in this report.

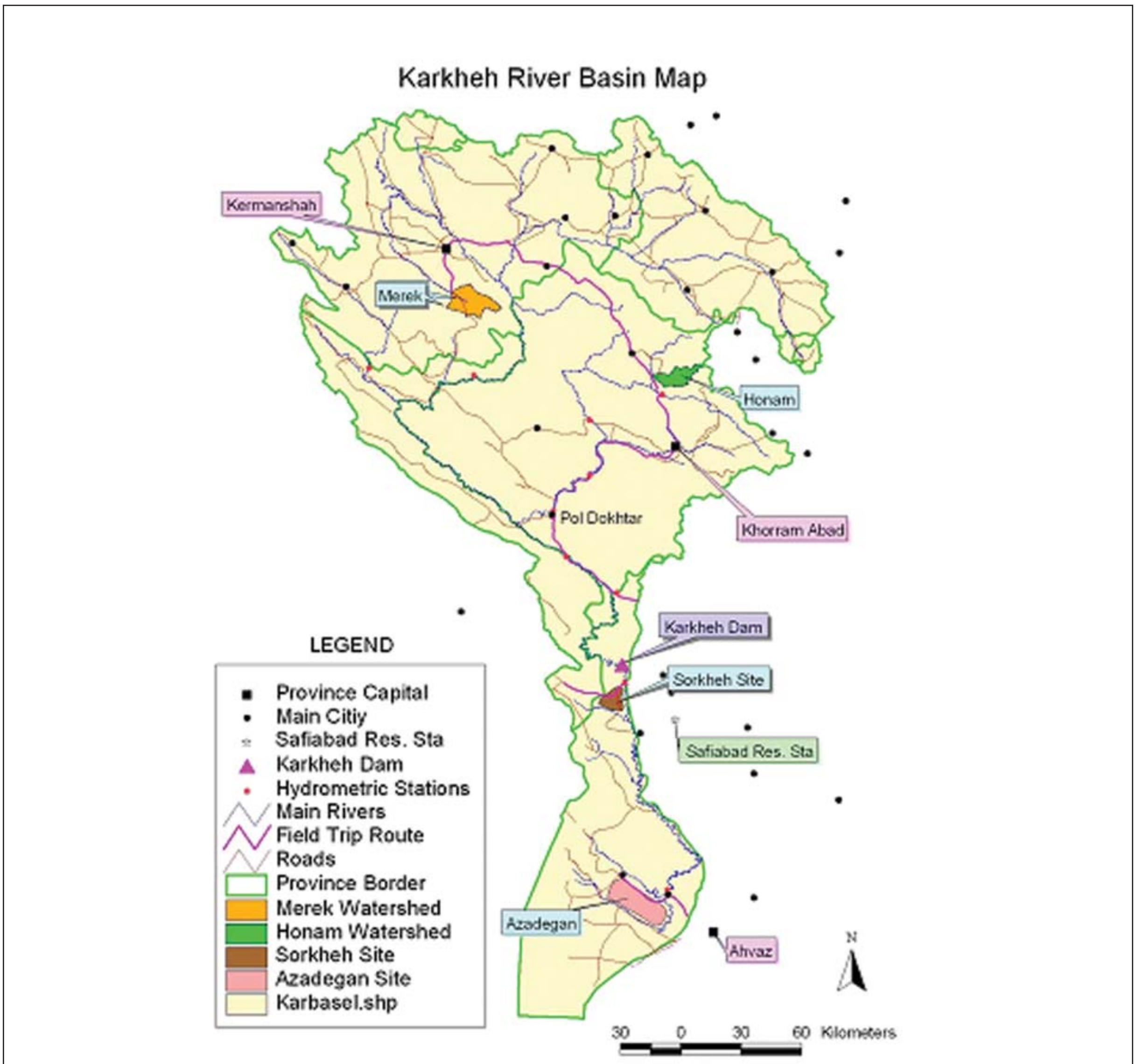

Figure 1.1 Location of the Evan, other plains, and the nearest cities with respect to Karkheh River and Dam

1.2 Principles of integrated watershed management

1.2.1 Introduction

A list of 36 principles for the integrated management of watersheds is provided. Most of these principles are directly supported by the priority issues established by the stakeholder workshop (refer to Chapter 1) and by the papers that elaborate particular aspects. The list can be seen as a practical summary of this report.

1.2.2 Principles

Planning

- Planning should not be confined to one sector. It should be integrated, comprehensive, and intra- and inter-sector. Use comprehensive planning and allow upstream-downstream interactions
- Select a proper 'study unit' as the basis for planning – a watershed, an area defined by political boundaries, or the geographic borders of the plains
- Use PRA and participatory planning
- Emphasize conservation of soil and water resources as the basic resources for development
- Mitigate the negative effects of accelerated erosion (on- and off-site effects)
- Rehabilitate the vegetation cover in areas of high soil erosion
- Take into account the water balance of the watershed and prohibit careless water withdrawals from groundwater resources
- Plan for increased productivity of the various resources (water, soil, land, crops, and humans)
- Pay due attention to the conservation of biodiversity, wild life, and the ecosystem
- Consider the economic aspects of plans and projects
- Study the existing conditions of watersheds using a participatory approach (resources, potentials, problems, solutions) and carry out a participatory diagnosis
- Carry out comprehensive studies and avoid parallel actions
- Plan for job-creating projects that secure people's livelihoods
- Develop markets for the direct selling of agricultural products and provision of inputs, omitting the middle-men
- In planning for rural development, pay close attention to education, health, training, and institutional aspects.

Planning requirements and conditions

- Prepare criteria and standards, particularly for the on-going developmental projects
- Use indigenous knowledge and farmers' innovations
- Invite women to participate in planning and decision making and respect their opinions
- Promote the attitude of team work among people and government agencies
- Encourage cropping patterns that fit land suitability
- Use of watershed resources should be consistent with scientific principles and should not have grave or destructive environmental consequences
- Prevention is better than cure.

Implementation

- Avoid religious, traditional, legal, and technical conflicts and their impacts on the integrated management
- Observe existing laws and guidelines or, if necessary, revise them
- Update laws and regulations, institutions, and organizations
- Observe traditional and conventional systems and users' rights in natural resource projects (on rangelands, forest management, and reforestation

in national parks and watershed management projects)
- Improve existing systems of use or replace them with modern and more appropriate systems
- Determine suitable cropping patterns in each area. Several suitable cropping patterns should be demonstrated to farmers from which they can select
- Identify and cooperate with the existing institutions that support IWM
- Use multi-disciplinary and mixed projects
- Use applied and participatory methods, particularly with extension agencies
- Ensure capacity building at different levels and in various disciplines in coordination with the universities
- Apply spatial planning and sustainable development principles

Make monitoring and evaluation participatory with stakeholders

- Development should come from within and be self-motivated
- Stimulate positive thinking and avoid negative thoughts.

1.3 Combining rural development goals with ecological limitations in dry mountains

1.3.1 Challenges for watershed development in semi-arid mountains

Integrated watershed management (IWM) has mainly been tested in temperate and tropical areas, with little adaptation to dry areas. Given the unique features of dry mountains, it is reasonable to expect that watershed management in dry areas has some specific characteristics.

Many semi-arid mountain areas in the world have experienced rapid population growth during the past decades and, consequently, the pressures on land have become intense (e.g. overgrazing, upslope extension of cultivation, over-cutting of shrubs, over-exploitation of water resources). As a result, the fragile ecosystems (fragile vegetation, thin soils, and limited surface and groundwater resources) are exposed to intensive degradation processes. The hydrological system in the dry mountains is also distinct; it experiences erratic and often intensive precipitation, while the hydrological networks are intermittent with interruptions at the foot slopes (usually colluvial fans). In most countries, policies and institutional settings are often discipline-oriented and not conducive to the holistic management of natural resources while simultaneously improving local livelihoods.

In the semi-arid mountains of Iran, watershed degradation has accelerated during the last decades because of rapid population growth, mechanization of plowing, nationalization of rangelands and water resources, and the decline of traditional management systems. The major features of degradation in the watersheds of the Zagros Mountains are:

Vegetation degradation:

- Overgrazing of the rangelands which are holding livestock at almost three times their carrying capacity
- Deforestation by cutting for firewood
- Conversion of the rangelands of the foot slopes to arable land.

Land degradation:

- Gullies are formed by concentrated runoff from overgrazed rangelands, from steep land tilled in an up-down direction, and from poorly-drained roads and rural infrastructure
- Marl areas are hotspots for gully erosion because of their susceptibility to erosion

- Soil fertility loss due to nutrient mining and soil erosion
- Spring floods in narrow valleys.

Water degradation:
- Over-use of surface and ground water
- Water pollution by agro-chemicals (fertilizers and pesticides), industrial effluent, domestic sewage, and inappropriately stored manure piles.

Although watershed management in Iran started in the 1950s and is a national priority, its implementation is suffering from conflicting national priorities (e.g. food self-sufficiency versus natural resources conservation), uncoordinated government actions in the sectors, focus on structural works, top-down approaches, and lack of community participation (Sharifi, 2002). On the positive side, some important successes have been achieved. Human and institutional capacity for watershed management has expanded dramatically in Iran, and many lessons have been learned (Sharifi, 2002). But there are only a few examples of participatory and IWM projects in Iran, such as those in the Rimaleh catchment, Lorestan Province and the Hableh Rud catchment, Tehran Province.

The purpose of the Livelihood Resilience project was to develop a holistic and participatory watershed management approach in cooperation with multiple stakeholders. The project took place in two benchmark watersheds – Honam watershed in Lorestan Province and Merek watershed in Kermanshah Province. These were representative of the upper KRB in the Zagros Mountains of Iran.

The principles listed below are based on international experiences and the experiences of the Livelihood Resilience project. Some of them are universal, while others are tailored to the Iranian conditions of dry mountain ecosystems.

1.3.2 How to plan and conduct IWM projects

Trust: Trust building among different stakeholders is the basis for any successful project. This requires 'meaningful participation' and consultation throughout the project, starting from design, through implantation to evaluation. In this process, different partners decide together on an equal basis, work together each using its comparative advantages, and share the costs of the desired interventions.

Team building for the project: Inter-disciplinary project teams contain people with different reference frameworks, objectives, incentives, and characters. Trust among members and a good team spirit are essential. Team spirit can be stimulated through joint problem analysis, joint field trips, gathering in an out-of-office environment with no mobile telephone connections, and useful capacity building events. Although it is essential to constantly stimulate critical reflection, leadership should also stimulate positive thinking and avoid excessive negative thoughts.
Learning from past lessons: There is no need to re-invent the wheel, as there is a vast experience of IWM approaches around the world (Box 1.1) and a small, but increasing, number of success stories in Iran. New projects should learn from their 'lessons learned' and so avoid their mistakes.

Inter-sector planning and stakeholder participation: No single institution can manage IWM planning alone. Therefore, planning should not be confined to one sector only. Consequently, all existing institutions that can influence the success of IWM projects should be

Box 1.1: Evolution of watershed management approaches

Watersheds are commonly used as operational units for natural resources management in mountainous areas for several reasons. Watersheds are distinct units where bio-physical processes (water flow, erosion, nutrient flows, vegetation regeneration, etc.) and socio-economic processes (traditional practices, life style, irrigation, grazing, nutrient management, etc.) interact in a specific geographic area. This makes the 'watershed' an appropriate unit for managing natural resources.

Watershed management projects have been implemented all over the world during the last 50 years and they have undergone a significant evolution (FAO 2006). The first generation of watershed management approaches was technology-driven. The objective was to find technical fixes for 'watershed problems'. The problems were usually forest degradation, erosion, or downstream sedimentation and flooding. Technical fixes were applied to resolve the problems. The projects were usually led by foresters, water specialists, and irrigation engineers. These projects were popular during the 1960s up to the 1980s. The disadvantage of this approach was that local farmers did not have a sense of ownership of the interventions. Once the land management measures needed maintenance, villagers waited for the government agencies to fix 'their' structures. As a consequence, many such interventions did not survive for long after the ends of the projects.

The second generation of watershed management approaches can be called the 'participatory watershed approaches'. These projects used a real bottom-up approach. Local communities were the main sources of information and action. The local livelihood problems were used as an entry-point to reflect on alternative ways to use the natural resources. Solutions were found by combining local knowledge and outsider expertise and implementation was done as much as possible by the local communities. Such projects were initiated by NGOs during the 1980s. Donors and government agencies started to use this approach from the 1990s onwards. However, it was observed in some watersheds that excessive water harvesting in the upper reaches led to downstream shortages. In extreme cases, the catchment became 'closed', as no water flowed out of the catchment any more.

The third generation of watershed management approaches is called 'the collaborative watershed approaches'. It was realized that significant elements of natural resources management (sustainable grazing, equitable water use, payment for environmental services, and treatment of sewage water) can only be achieved when agencies with legal responsibilities are involved in the process. Such projects have involved multi-stakeholder processes and have combined 'bottom-up' and 'top-down' approaches. This approach started around 2000 and is now being tested at many sites around the world.

contacted and invited to participate in the planning and execution of the project. Stakeholders include the farming communities, catchment management authorities (CMAs), government agencies, NGOs, local Islamic Councils, and local members of parliament (Ghafouri, 2008). A stakeholder analysis will identify their mandates with respect to watershed management, their capacities and interests, their visions about the desired future of the watershed, and their relationships with other organizations.

Knowledge sources: All stakeholders should recognize that all participants have knowledge and expertise that is relevant to the project. The types of knowledge are of course different, and one type of knowledge should not be treated as superior to another. Knowledge can come from a range of sources – policy makers, local decision makers, researchers, extension agents, staff of the executive sector, NGO staff, community leaders, and, last but by no means least, farmers. This indigenous knowledge is often undervalued and underutilized. Farmers' innovations can be a potential starting point for development.

Attention to household diversity and gender: It is important to consider diversity in the target communities. The weakest community members often need special support in negotiations (e.g. for sharing water rights), and special attention should be given to make the voice of women heard in decision making. It is also important to be flexible with respect to locally important livelihood systems (e.g. an approach for nomadic communities is quite different from that for settled communities).

Define goals: The goals of any IWM intervention should become clear in the early stages of a project. The initial diagnosis can help to sharpen and define the goals. Goals should be defined in close consultation with all the major stakeholders. A basic principle in setting goals for IWM in dry mountains is to balance rural development goals with the ecological limitations of dry mountains. Therefore, the success of the IWM projects should be measured both in social and environmental terms.

Facilitation: To achieve satisfactory and sustainable results, professional facilitation skills are required to guide stakeholder and community processes during the diagnostic phase, and particularly during the problem-solving phase. As such skills are often rare, they can be brought in from abroad. But, at the end, out-scaling of IWM projects will only be possible when locally trained facilitators become available.

Participatory monitoring and evaluation: Traditional monitoring and evaluation is usually about satisfying bureaucratic and/or donor requirements. However, when this is done in a participatory and reflective way, such exercises can accelerate the progress of the parties involved along their learning curve and improve performance. The 'Impact Pathways' approach is a useful method for planning the future directions of the project from the onset (more information on this approach is available at: http://boru.pbwiki.com/). The innovative aspect of this approach is that it starts with the desired outcomes and then reasons back to the required steps. In addition, the required institutions, their role in the different stages of the project, and the different milestones are discussed with all the partners from the outset. To aid the monitoring process, it is essential to define SMART indicators.

Out-phasing of IWM projects: The IWM projects usually mobilize a lot of human and financial resources and good-will for a few years. However, the higher the inputs, the higher the risk for collapse at the end of the project. This potential risk should be contained and planned for from the beginning of the project. Collapse can only be avoided when ownership of the interventions lies squarely with the local communities and local institutions, and when maintenance costs are within the reach of these local actors.

1.3.3 Start-up and diagnostic phase

Selecting target areas: Selection of target areas should take place at two levels.

- In the early stages of IWM testing and improvement, target areas should represent a (problematic) socio-economic or ecological situation. Useful tools for regional analysis are agro-ecological zoning, similarity analysis, rainfall and drought analysis, and hydrological and sediment analysis. In mountain areas, 'watershed' areas are convenient and logical study areas, as their borders usually coincide with the borders of hydrological processes, economic activities, and administrative borders. However, it is important to realize that watershed borders are not meaningful for nomadic herders, as their cattle usually use the rangelands of several catchments.

- An important selection criterion is the interest of local communities in participating in IWM. Here it is important to get an assessment of real interests, and not interests biased by inflated expectations arising from (imaginary) project funds.

Participatory appraisal: Joint visits to the target area and participatory rural appraisal (PRA) exercises are very useful for clarifying the interactions between livelihoods and natural resources (e.g. coping strategies for dry spells and land degradation) and to frame the problems of and opportunities for the target area. This common consensus building about the situation and what needs to be done is very important, as it will provide the basis for defining the goals and the institutional roles.

Role of research in the diagnostic phase: Not all issues, such as the biophysical potentials and limitations of the catchments areas (e.g. sustainable water consumption rates, required ecological base flow, and rangeland carrying capacity) can be answered during a PRA. If an understanding of these features is considered crucial for a successful IWM, then expert organizations need to be involved.

1.3.4 Strategy to combine rural development goals with the ecological limitations of dry mountains

Ecosystem services of mountainous watersheds: 'Ecosystem services' (ESS) are defined as 'the benefits that nature and ecosystems provide to the society' (MEA, 2005). Dry mountain watersheds provide a whole set of ESS to local communities and Iranian society as a whole (Figure 1.2), although many of them are not at all well-documented or recognized. Besides agricultural production, which provides the main source of food and livelihoods for the local communities, there is also the important role of the upper catchments on the water cycle (i.e. accumulation of snow, groundwater recharge, and provision of water for local and downstream users, natural control of erosion and floods, natural capacity for water purification). Other ESS are the food, forage, and medicines derived from the rangelands, preservation of biodiversity, enchanting natural landscapes, fresh air and, potentially, ecotourism. The assessment and quantification of these services requires a good understanding of agro-ecological zones (AEZs), water resources, land and range capabilities, livelihood requirements of local communities, and stakeholder analysis.

Maximizing ecosystem services: Maximizing one service at the cost of another will usually result in an undesirable situation for society. To avoid this, each intervention or project should be evaluated in terms of its effects on the other services. The challenge is to achieve multi-functional mountain catchments, where all or most of the ESS are respected. This can be done

Provisioning ESS	Regulating ESS	Cultural ESS
• Crop production • Forage for livestock • Meat and wool • Fish • Medicinal and edible plants • Genetic plant and animal resources • Honey • Water for local home consumption and irrigation • Water for downstream users and hydro-power • Fresh air	• Snow accumulation • Water recharge of aquifers • Natural capacity for water purification • Erosion control by natural vegetation • Natural flood control • Carbon sequestration • Pollination of crops • Biological control of agricultural diseases	• Enchanting landscapes and biodiversity • Environmental awareness and education ('outdoor classroom') • Eco- and agro-tourism • Research opportunities

Constituents of well-being
• Viable livelihood options • Local employment • Healthy living environment • 'Sense of place' • Relaxation and inspiration

Figure 1.2 Actual and potential ESS provided by dry mountain watersheds in Iran

more efficiently by actively searching for 'win-win situations'. Win-win situations will combine the sustainable delivery of several services, such as economic, environmental, social, and cultural benefits for local communities and environmental, educational, and recreational benefits for the larger public. In practice, the challenge is usually to balance the needs of the local population (income generation, food, fuel, water, fodder, and nutrients) with maintenance of the service provision of the natural resource base. To achieve such a balance, four types of interventions are required:

- Improved institutional arrangements for watershed governance
- Integrated spatial planning
- Development and testing of technical interventions for private land
- Community-based management of natural resources.

Source principle: While restoration activities will be necessary for degraded areas, on-going degradation and pollution should be addressed, as much as possible, at the source of the problem, rather than at the symptom level. For example, as much as possible, pollution should be addressed at the sources of pollution; erosion and flooding should be addressed first by looking at the causes of runoff and sediment generation; and for rangelands, it is important to know what the factors are that drive rangeland degradation.

1.3.5 Respecting and managing the ecological limitations of dry mountains

Respecting ecosystem thresholds: There are several possible pathways for watersheds in dry mountains, but the adopted strategy should never jeopardize the sustainability of the natural resource base of a watershed. The ultimate bottom line for development should be to respect the ecological thresholds, beyond which ecosystem integrity breaks down and the sustainable provision of ESS cannot be guaranteed anymore. A few examples of ecological thresholds are provided below. To be on the safe side, to cope with the whims of the climate, there should be a safety margin between the actual user levels and the ecological threshold levels.

Local people as stewards of the catchments: Securing support from local communities is essential for successful IWM. Therefore, IWM views communities with their traditions as stewards of the watersheds. Management must be undertaken with and through local people, and seek to bring benefits to local communities and contribute to their well-being through the provision of ESS. Another entry-point is to use religious motives for natural resources protection.

Land-use planning: To ensure the sustainable delivery of ESS, an effective land-use plan, which is based on a thorough assessment of the natural resource base and economic realities, is required. Such a plan should encourage agricultural activities, lifestyles, customary laws, and traditional building practices that are in harmony with the environment, while discouraging or prohibiting land uses and activities that are inappropriate in scale and/or character. Spatial planning approaches are required to support sustainable land use. In any case, considering the climatic variability, land-use plans cannot be based on detailed land capability maps. Under the circumstances of dry mountains, it is more appropriate to define broad land-use classes, such as irrigated land, dryland, rangelands, and forests. These categories take into consideration biophysical limitations, without limiting the flexibility of the farmers to cope with variable climate and market prices.

Land suitability in the dry mountains of Iran is influenced by climate, topography, soil type, and aspect, as well as crop requirements. Two important examples are:

- **Slope angle:** hotspots of degradation are foot slopes above 12%. With the advent of the tractor and loose legal regulations, a lot of foot slopes steeper than 12% have been taken under cultivation. Up-and-down plowing not only results in accelerated rill and gully erosion, but also causes severe tillage erosion. Therefore, the necessary measures should be taken to avoid annual cultivation of this land. Alternatives are no-tillage practices, perennial crops (which do not require plowing), or reversion to rangelands.
- **Erodible parent material:** Marl ($CaCO_3$) is a soft rock, and especially sensitive to rill and gully erosion. After clearing the natural vegetation, this type of landscape usually develops into ‘badlands’ and becomes a major source of sediment. This can result in a filling up of the hydro-power dams with sediments. Therefore, it is important to reduce arable agriculture in this type of land, and stimulate sustainable rangeland management.

Water – the most critical natural resource in the dry mountains: To assess sustainable water extraction levels, it is important to take into account the water balance of the watershed, the flows required to fulfill the required ESS of the catchment (such as downstream flow, ecologically required flow, natural capacity for water purification, green versus blue water), and the return flow from irrigation practices. Groundwater resources need special attention, as extraction rates and groundwater reserves are not easy to monitor. Promising technologies that increase water productivity in upper catchments are groundwater recharge, groundwater dams, small dams, pumping up water combined with gravitational distribution, supplementary irrigation, and water harvesting.

The dry mountains of Iran are characterized by high spatial and temporal variability of water availability. Thus rigid water-use regulations are not so useful. Rather, dynamic water-use regulations and drought early-warning systems are recommended.

Rangelands and forests – the neglected source of biomass and biodiversity: Rangelands are located in the areas that are not used for arable agriculture. Accessibility and the steepness of their gradients are important to grazers. The concept of a fixed 'carrying capacity' to manage grazing in dry areas is falling into disuse. Instead 'opportunistic grazing' or 'dynamic carrying capacity' is considered more appropriate to cope with these fluctuating rangeland resources. In practice, this can be managed by 'resting/rotational grazing' practices (e.g. 5 years/3 years) and 'flexible starting date' in conjunction with the rangeland condition. This can only work if communities agree among themselves with such arrangements, and when they have opportunity to propose the arrangements themselves.

Some rangelands are important erosion hotspots and sediment sources. These are usually located on steep and concave foot slopes. In order to avoid further degradation, they need to be planted with unpalatable plants, so they are self-secured against overgrazing. However, such interventions should be targeted on very specific areas and should not cover more than a few percent of the total rangeland.

To tackle deforestation of rangelands, alternative energy sources need to be identified.

Rural infrastructure: Rural roads are essential for marketing and general welfare, but their effects on gully erosion and land degradation should be minimized.

1.3.6 Improve income and food security and secure livelihood resilience

Consider local aspirations: Try to find out what really matters to local people. It might be that it is not simply 'increase yields'. In mountainous areas, where livelihood depends strongly on the climate, other aspirations might include diversification options, resilient and climate-proof production systems, local job opportunities, and less drudgery.

Comparative advantage versus risk prevention: Two major strategies are generally followed when choosing new enterprises or technologies for livelihood resilience. One strategy is to make use of the local comparative advantage of the area. Such a strategy results in profit maximizing activities, but they are usually quite risky, especially if these activities can be affected by the climate or market prices. A diversification strategy reduces risks by preparing for fluctuating precipitation or market prices. Such a strategy usually results in less profit, but is more resilient. A healthy balance between these strategies is recommended (both at the individual household and at the community level).

Develop adapted technologies and increase local expertise: Farmers constantly require new sustainable technical options that support livelihood resilience and strengthen the natural resource base. A proven methodology for developing new and useful technologies in Iran is 'participatory technology development' (PTD). It has been a useful approach which links the expertise of local people, with the expertise of researchers and the staff of the extension and executive sectors. A good way to incorporate indigenous knowledge is to search for local innovations and innovators. However, in order to produce useful results, there needs to be a real commitment on the part of all PTD members. Criteria for useful technologies are listed in Chapter 3. With this approach, development will come from within local communities and participating farmers will have ownership of the 'new' technologies. Potential options for the dry mountains are nutrient management for barley and wheat (e.g., azotobacter), improved agronomic management options and crop varieties (e.g. early planting of chickpea and new chickpea varieties), high-value crops (e.g. saffron, mushrooms, and shallots), rangeland rotations, water harvesting, and supplementary irrigation.

Special attention to women's needs: To make sure that women also benefit from an IWM project, it is not sufficient to have a separate (and usually small) 'women's program'. The women must be provided with opportunities to participate in planning and decision making. As a result of this early involvement, special activities or PTD groups can be set up to address the specific concerns or ambitions of women, and improve their skills. There is great potential for special micro-credit programs, livestock activities, and marketing.

1.3.7 Legal framework and governance for IWM

Co-management / collaborative watershed governance: Kerr *et al.* (2002) compared the performance of different watershed management approaches. Top-down technocratic approaches showed the poorest performance. Participatory approaches were much more effective. But, with a combined participatory and technocratic approach, the solutions were found to be superior. The need for such an approach became clear when it was realized that significant parts of natural resources management (sustainable grazing, equitable water use, payment for environmental services, treatment of sewage water) can only be achieved when agencies with legal responsibilities are involved in the process. Such projects involved multi-stakeholder processes and combined 'bottom-up' and 'top-down' approaches.

Multi-stakeholder governance: Effective IWM depends on the presence of transparent decision making structures, which seek the active involvement of communities and concerned stakeholders in shaping the watersheds. Multi-stakeholder discussions and interactions, which can lead to the development of a commonly-agreed desired state (or 'vision'), will enable identification of the diverse ESS that are expected from the watersheds concerned. Multi-stakeholder governance will increase communication, trust, linkages, ownership, and joint commitment to the shared vision and the desired outcomes. Multi-stakeholder governance also requires enforceable rules (based on legally-backed standards, regular inspections, and spot checks) and when conflicts over resource management arise, the responsible governance agency needs to mediate and/or intervene to resolve the conflicts. This will require strong CMAs. Multi-stakeholder forums can be organized at the catchment or basin levels.

Legal frameworks: As an extensive framework is already available in Iran, IWM can operate within the existing laws and guidelines. However, if these are not helpful, steps should be taken to update or revise them (e.g. rights of communities to control and manage 'their' common pool of resources).
The CMA can develop regulations and bylaws that are applicable for a specific catchment. When the natural resource rights of traditional and conventional systems and users result in sustainable land use they should be integrated in local regulations as much as possible.

New roles for government: In collaborative watershed governance, the role of government agencies needs to shift from 'delivering and implementing solutions' to 'providing an enabling environment'. Examples of ways to do this include:

- Overcome disciplinary planning and fragmented mandates
- Minimize bureaucracy
- Provide better and reliable government services, such as better education opportunities, better health services, and develop markets for buying inputs and selling agricultural products
- Provide political endorsement of multi-stakeholder forums and their decisions
- Devolve authority so that decisions are made at the lowest possible level
- Develop enabling legislation
- Provide sustainable funding for watershed management institutions and their programs
- Replace 'input subsidies' by 'smart subsidies' and economic instruments that enable sustainable farming practices
- Ensure land tenure or land-use security (private or communal)
- Strengthen capacity building and increase awareness of sustainable management of watersheds
- Encourage public-private partnerships.

New roles for research: Technical expertise and analytical skills make research agencies useful and attractive partners for a multi-stakeholder watershed management forum. However, in order to fulfill expectations, the

Box 1.2: Essential features of multi-stakeholder forums for watershed management (Figure 1.3):

- A multi-stakeholder forum facilitates linkages and enhances communication between stakeholders. It can assist in bridging the gap between research, policy, and executive agencies.
- It requires effective facilitation, coordination, and negotiation at different levels.
- A multi-stakeholder forum should be a legitimate and accepted forum for dialogue, conflict resolution, and planning.
- The decision making process should be clear.
- A clear and shared vision, goals, objectives, and actions should be developed at an early stage.
- Planning should be proactive and include a solid and participatory monitoring and evaluation system.
- A reflective approach (e.g. share 'lessons learned') accelerates the learning of all involved.
- There should be sufficient time and resources to find acceptable social arrangements.

traditional approach of research agencies needs to evolve and a more demand and problem-oriented action research approach needs to be adopted. This requires stronger inter-disciplinary interaction, participatory methods, and the use of nested scales. New research topics that will be required include:

- Development of a common language and approaches
- Consistent data-sets
- Risk mapping and risk assessment
- Practical decision support tools
- Best management practices
- Benefits of IWM
- Indicators to monitor progress
- Understanding the relationship between livelihood (and poverty) and natural resources
- The role of women in natural resources management
- Power relations between stakeholders
- Legal, economic, social and communication tools.

Capacity of local institutions: Participatory watershed management needs credible local institutions. Potential local community organizations in Iran are the 'Islamic Councils', or established, traditional, community-based organizations. However, many of these local institutions are ill-equipped to deal with the challenges of designing, negotiating, monitoring, and sanctioning

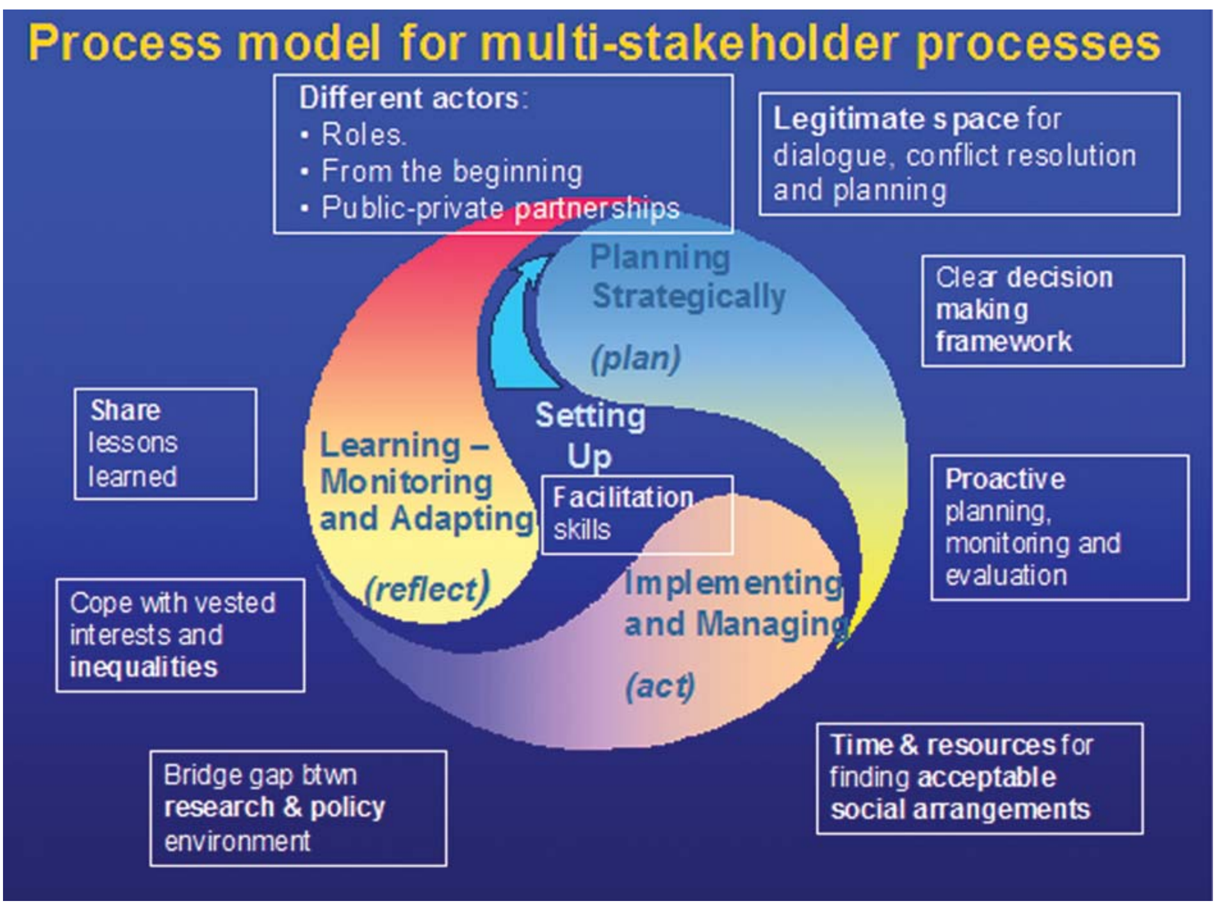

Figure 1.3. Features of successful multi-stakeholder forums at the catchment or basin level (Box 1.2)

for natural resources management. Therefore, local institutions need to be strengthened to enhance their decision making capacities and their capacities to instigate community-initiated change. External assistance and supervision is often required, especially at the start.

Community-based management for common pool resources: Common pool resources (such as rangeland, groundwater, and surface water) usually suffer from the 'tragedy-of-the-commons syndrome', especially if these resources are nominally the property of the state. Degradation of common pool resources is widespread in the mountainous watersheds of Iran (e.g. rangelands, biodiversity, surface water, and groundwater) and they are often the most important resource for the poorest of the local communities.

For the most part, successful interventions are based on collective action and control by local communities; there is a certainty that their efforts to take care of the natural resources will benefit themselves in the long run. However, to be successful, the benefits of the interventions to local communities should be substantial, and the transaction costs for designing and implementing solutions must be manageable and cost-effective (e.g. mechanisms for upstream-downstream cost and benefit sharing, social fencing). For poor and marginalized communities, positive discrimination can be made regarding the cost of the quota vis-à-vis that of more prosperous communities.

1.4 Soil survey: the basis for productive natural resource management

1.4.1 Introduction

A soil survey is an inventory of the soil resources and comprises a soil map, descriptions of the soils and soil map units, and predictions of soil behavior for different uses and management. Soil properties are identified for each tract of land in the survey area. Observations of color, texture, structure, and other characteristics of the different layers (horizons) are noted. The soil profile of each hole is compared with other soil profiles in the area. Using this procedure, the soils are classified, named, and delineated on a map as groups of soils in a landscape.

Some samples of soils from sites that represent typical types of soil in the survey area are collected for laboratory analyses. In this way, the chemical and physical properties determined in the laboratory are linked with day-to-day field observations by the person mapping the soil. Determination of soil characteristics and their limitations is one of the most important duties of soil researchers. Soil maps help the user estimate the soil properties of a parcel of land without actual sampling and testing (Seelig, 1993).

Soil is the result of complex natural processes that are affected by climate, time, geological materials, topography, and living organisms. Identification and classification of soils during the mapping process requires accurate information about the environment that affects soil formation. The soil survey report is, therefore, an inventory of local natural resources. The ability of the land to produce crops is limited and limits to production are set by climate, soil, and landform condition, and the use and management applied to the land. Accordingly, knowledge of the land resources endowment and its potential is an essential prerequisite to the planning of optimum land use and subsequent sound, long-term agricultural and natural resource development programs. Soil is one of the most important components of the land. Soils identification and determination of their geographical distribution and characteristics provides the necessary basic information for land-use planning.

Information on the degree of soil salinity and the occurrence of water tables is helpful in identifying areas more suited to wildlife than to the cultivation of crops. Soil survey reports can also be used to determine the suitability of soils for irrigated and rainfed crops in the area. A soil survey is an inventory of the soils that affect basic human needs – food, water, and shelter. Soil survey reports provide information that can be used for agricultural production, environmental protection, highway and building construction, recreation and wildlife management, and land-use planning and zoning for healthy city and rural environments.

Soil interpretation refers to the behavior and response of soils to human activities. Soils with similar responses to a particular use or treatment are often grouped together. Common interpretations are land-use capability classifications, range site classifications, woodland suitability groups, engineering classifications, wind and water erodibility groups, and the estimated yields of commonly grown crops.

Soil survey reports of areas proposed for irrigation may contain a discussion of soil management and suitability ratings under irrigation, any limitations, and management problems. Estimated yields under irrigation may also be presented. The irrigation potential of each map unit is provided in all soil surveys, even though irrigation may not be an immediate concern.

1.4.2 Soil surveys in the Merek and Honam watersheds

Semi-detailed soil surveys were conducted in the Merek and Honam watersheds as part of the research activities to:

- Assess the agricultural potentials of the soils
- Investigate soil properties that restrict crop production
- Determine and interpret management–dependent soil properties.

The results of these surveys could then form the basis for assessing the sustainability status of the soil resources and suitable uses for the soil and water.

The soils were classified at the subgroup level according to the USDA soil classification system (Soil Survey Staff, 1999). Guidelines given by Van Wambeke and Forbes (1986) were adopted for naming the soil map units. The soil units were identified based on geomorphologically interpreted aerial photographs and field observations. Photo-interpretation, soil mapping, and soil map legend construction were performed using a geopedological approach (Zink, 1989). This approach is based on a hierarchical system that favors the use of topographic and physiographic criteria for distinguishing different levels of geomorphic units, which can be readily deduced from aerial photographs, thus allowing the extrapolation of field data from selected sample areas to larger ones. One of the benefits of geomorphologically defined survey units is that they are relatively easy to identify from aerial photographs. They repeat themselves across the landscape and thus provide a basis for recognizing areas with similar resource characteristics. They are permanent and closely related to a wide range of environmental phenomena, including soil conditions (Briggs and Shishira, 1985). This approach assumes that a landscape has a hierarchical structure, such that small uniform areas (referred to as landforms in the present study) are nested in larger, spatially contiguous, but composite, areas.

1.5 Agro-ecological zoning of Karkheh River Basin

1.5.1 What is agro-ecological zoning?

Agro-ecological zoning is the activity of dividing an area of land into small units with similar characteristics with respect to land suitability, potential crop production, and environmental impact. Land suitability can be determined as described in the Chapter 2. An AEZ is a land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use. The constraints may arise from population density or limited markets for produce. The AEZs are typically presented on maps. The AEZ concept involves the representation of land in layers of spatial information and a combination of the layers of spatial information using a GIS. The combination/overlay of layers produces agro-ecological cells.

An AEZ map can help answer such questions as,‘Which parts of a watershed are the best for producing wheat?,‘Where should a new salinity-tolerant sorghum variety be introduced?’, and ,‘Is the local production potential adequate to support the future population?’ Figure 1.4 demonstrates graphically the steps that are undertaken to produce an AEZ map. A computer program (AEZWIN) is available to assist with the multiple criteria analysis for land resources appraisal (FAO, 2003).

1.5.2 How to use agro-ecological zoning

While land suitability is a characteristic that is particularly applicable at the farm level, AEZs characterize the farming environment at the landscape level. It takes the form of maps (as in Figure 1.4) and is a tool for agricultural planning and evaluation. Because it integrates information about soil and climate, the AEZ concept is fully compatible with IWM.

The climate of the KRB is mostly semi-arid or arid, but it has a tremendous diversity of soil and water resources, topography, and land-use systems. This diversity occurs within a context of a scarcity of both water and land resources, of poverty, and of a growing population. This makes good land-use planning essential and agro-ecological zoning is a valuable tool for agricultural planning. By integrating the key components of the agricultural environments, it offers a bird-eye view of the internal diversity, agricultural potential, and constraints that decision makers find easier to understand than a stack of single-theme maps.

The dryland areas of Iran are characterized by considerable weather variability, as well as abiotic stresses, in particular drought and cold. There are also very diverse landscapes and soil patterns. The combination of these interacting factors leads to different

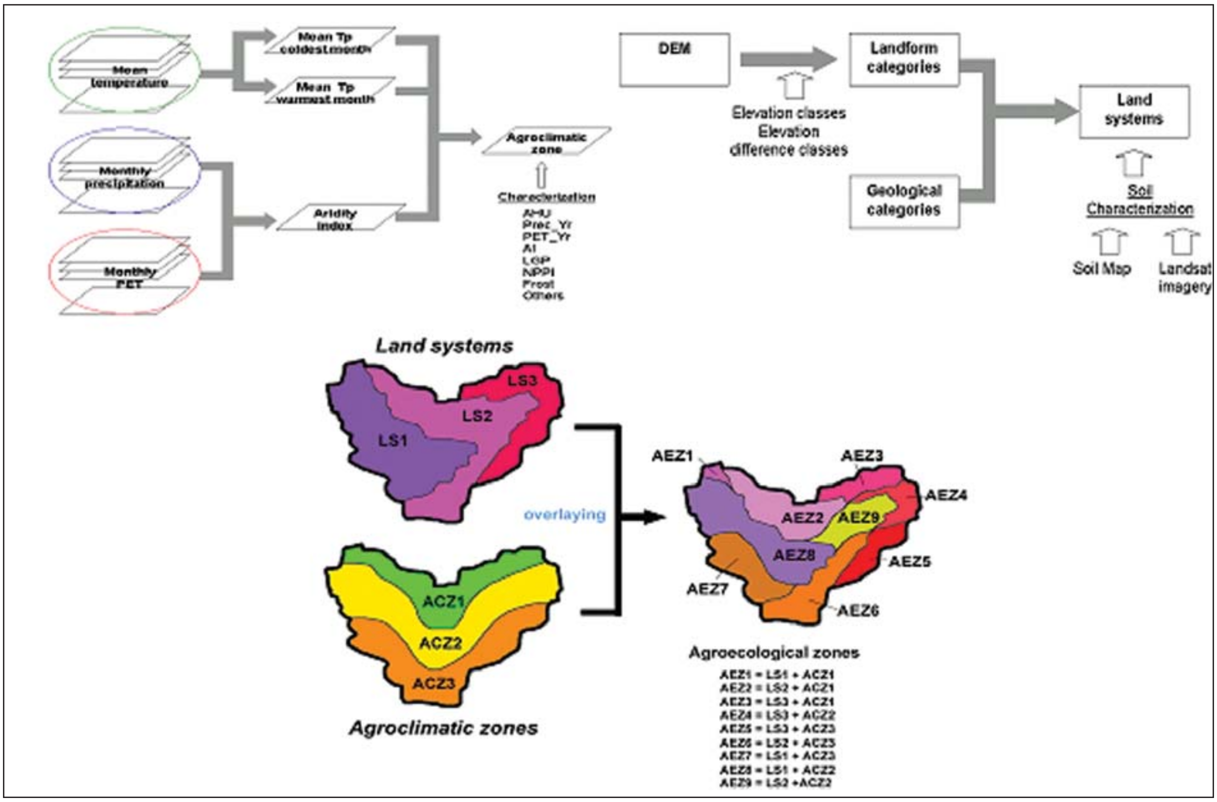

Figure 1.4. The procedure to establish agro-ecological zones

agro-ecological conditions, which can be suitable for some crops, but marginal or unsuitable for others. The intensification of crop production in these areas needs to take into consideration agro-ecological diversity by adapting cropping and land-use patterns appropriate to the opportunities and constraints of each agro-ecological niche.

1.5.3 Examples from KRB

The FAO (2008) reports on applications of the AEZ concept at the national level. The agro-ecological zoning methodology and software packages have been used in studies which address a wide range of land management issues. These include improved land-use planning (China, Kenya, Mozambique, Grenada, and Tanzania), formulation of population policies (Malaysia, Philippines, and China), national agricultural development (Kenya and Bangladesh), agricultural research planning and management (Bangladesh and Indonesia), natural resources management (Brazil), technology targeting (Bangladesh), and disaster preparedness (Bangladesh).

1.5.4 The way forward

The AEZ map for the KRB (Figure 1.5) was made by the overlaying of single raster themes related to climate, terrain, soils, and land use. Three layers were considered adequate in order to generate the AEZ map. These were the agro-climatic zones, the land use/land cover, and soils (+ landforms).

The themes used for overlaying are simplifications of more complex thematic classifications. Simplification was necessary in order to avoid (i) replication of the single-theme maps and (ii) unnecessary complexity for the purpose of the AEZ map.

The methodology of agro-ecological zoning is well described and available (De Pauw *et al.*, 2008). Adaptations to specific local conditions or requirements may be needed and can be made by national scientists.

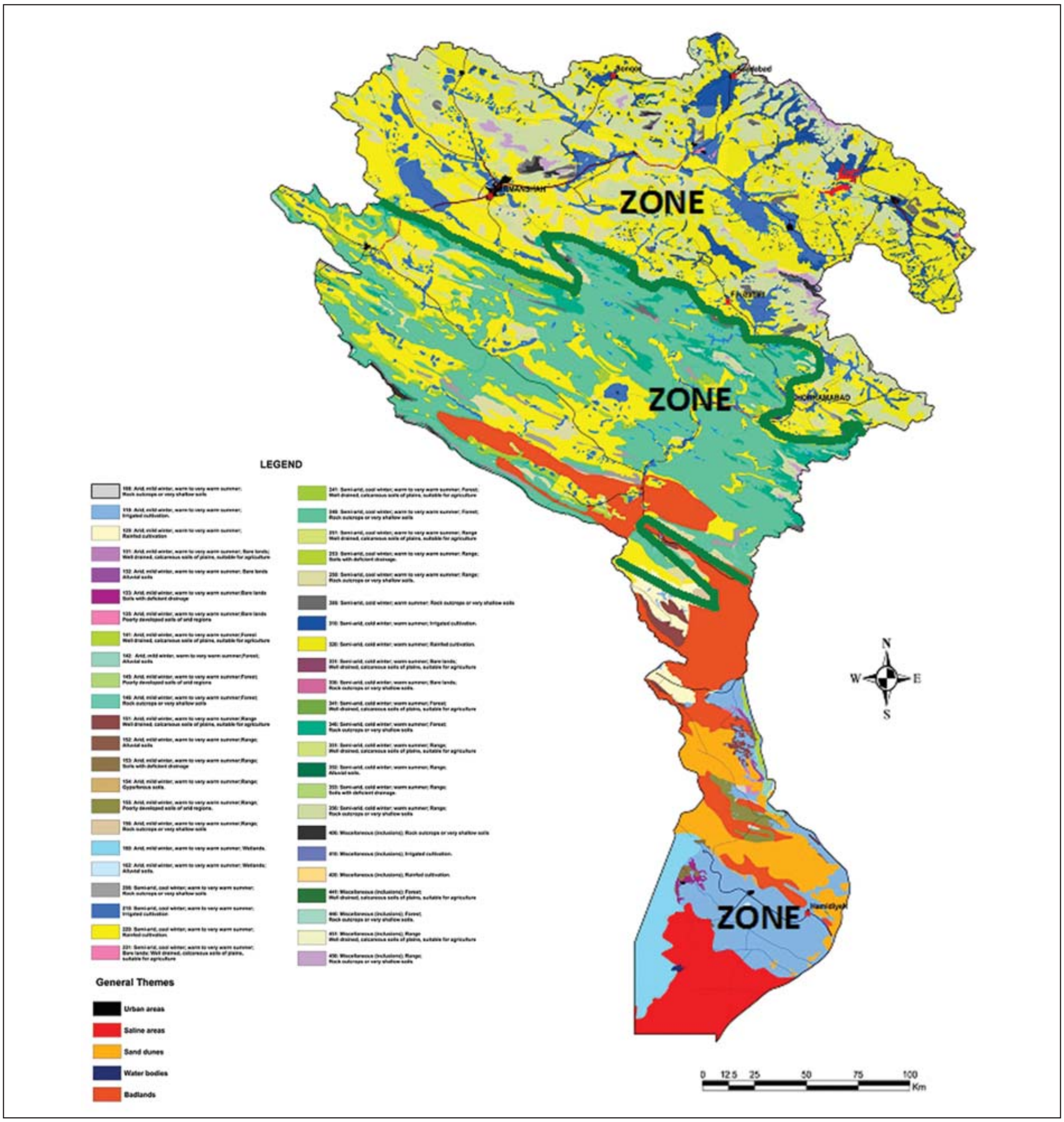

Figure 1.5. Agro-ecological zones of the KRB (De Pauw *et al.*, 2008).

1.6 Stakeholder consultation

1.6.1 Introduction

The ecosystems of the semi-arid mountain areas are fragile and prone to degradation, in particular when land-use pressure increases and policies and institutional settings are not conducive to the sustainable management of natural resources. In the semi-arid mountains of Iran, watershed degradation has recently accelerated because of rapid population growth, mechanization of land preparation, nationalization of rangelands and water resources, and decline of the traditional management systems. Although watershed management in Iran started in the 1950s and is a national priority, its implementation suffers from contradicting national priorities (e.g., food self sufficiency versus natural resources conservation), uncoordinated interventions by sector governments, a focus on infrastructure, top-down approaches, and a lack of community participation. Nevertheless, successes have been achieved and the national capacity for watershed management has expanded.

Watershed management projects have been implemented over the past decades in many countries, including Iran, where the successes and failures have been documented and lessons have been learned. Based on all the insights and results, a more holistic and participatory approach to watershed management has been developed. This Section focuses on the first provincial stakeholder workshop held on the subject and the directions that it gave the project for further actions.

1.6.2 Identification of stakeholders and institutional analysis

There are many watershed activities in Iran that make use of natural resources, including arable farming, rangeland grazing, forestry, road building, expansion of cities, and mining. The persons and organizations that manage these activities are stakeholders in watershed management. The increasing number and intensity of uses of the natural resources cause conflicts among stakeholders. Given the lack of communication and discussion among the stakeholder groups, there is no explicit prioritization of activities or planning of interventions beyond the very broad outlines of the national and local government plans. As a result conflicts intensify the benefits to the people of the natural resources decrease to less than what is possible, and degradation proceeds.

Intensive consultations between communities and other stakeholders, institutional analysis, and experts, as well as technical knowledge and monitoring facilities are needed to provide a thorough analysis of the issues.

In natural resource management, actions to address the threats to assets in the catchments require strong partnerships. The biophysical landscape connects people and ecosystems, groups of community organizations, government agencies, and governance arrangements. For a sustainable situation, it is vital to recognize the interactions among stakeholders and determine adequate institutional arrangements for the different organizations. For successful planning and implementation of IWM in any region we need:

- Integration between natural resources management programs
- Planning for sustainability at the local level
- Adoption of sustainable practices
- Innovation in the use and management of water
- Engaged stakeholders and institutions

- Stronger community-government partnerships.

To optimize the use of the watershed resources and to realize sustainable development, it is necessary to consider the multiple objectives, interests, and concerns of the stakeholders.

1.6.3 Watershed management principles

Integrated watershed management strategies and principles were developed in the current project to improve livelihood resilience in the upper catchments of the KRB. The contributions to the principles are presented in Chapter 4 of this report.

In the Livelihood Resilience project we considered and compiled the physical attributes of two representative upland catchments, Honam, in Lorestan Province, and Merek, in Kermanshah Province. The project consulted with the stakeholders of these catchments and sought their participation and input in the strategic planning of watershed management, in establishing and prioritizing the key issues for development, and in identifying 'best management practices' (Figure 1.6). We took into consideration the strengths, weaknesses, opportunities, and threats that existed in the two areas.

1.6.4 Stakeholders analysis

A two-day workshop was organized and implemented in Kermanshah (Figure 1.7). Its purpose was to discuss with all stakeholders from the region how they envisaged the future in the two catchments under optimal conditions, the key constraints and opportunities, and what should be done to achieve that vision. A wide range of stakeholders (Table 1.1) was identified by the project leaders and all were invited to send a representative to the workshop.

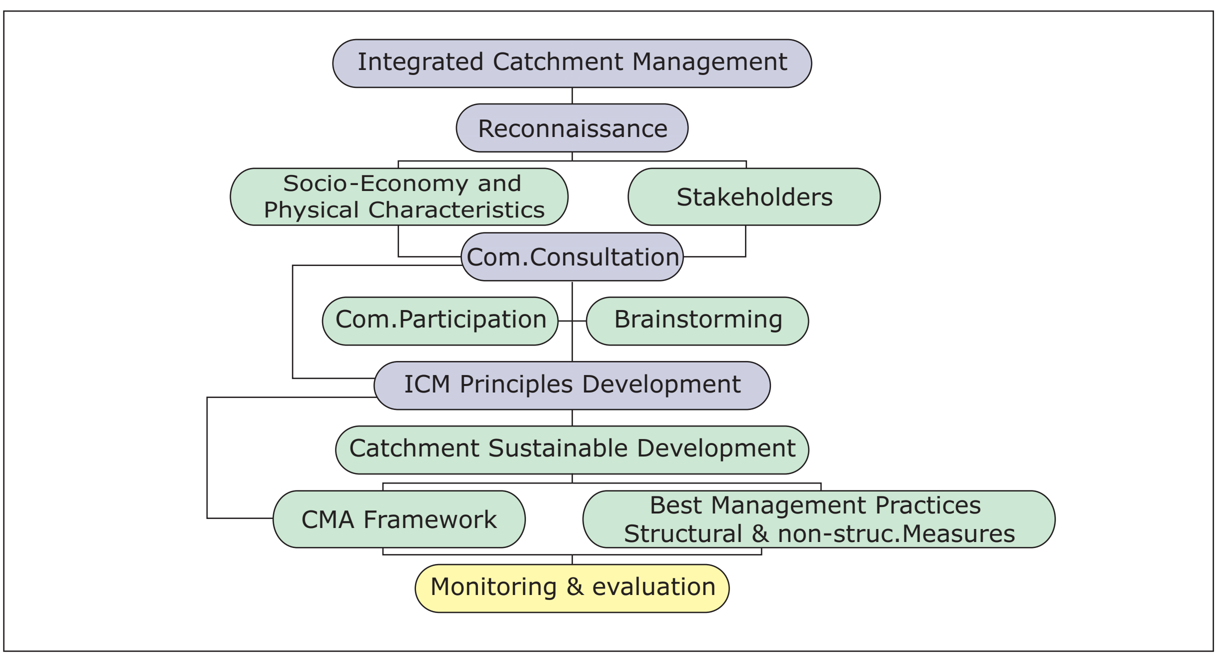

Figure 1.6. Flow chart of the planning for IWM

Figure 1.7. The poster distributed to announce the workshop

Table 1.1. Stakeholders of the upper catchments of the KRB

1. Basin people (selected farmers, herders, and others)
2. Natural Resources Office
3. Watershed Management Office
4. Soil and Water Office (Agricultural Organization)
5. Water Board of the Ministry of Energy
6. Center for Fishery
7. Domesticated Animals Center
8. Pest and Disease Combat Center
9. Environmental Office
10. NGOs
11. Village's Cooperation Office
12. Veterinary Center
13. Rural Road Office
14. Water and Sewage Office
15. County Government
16. Village Government Office
17. Governor
18. General Governor
19. Healthcare Center
20. Imam Khomeini Charity Foundation
21. Welfare Office
22. Town Council
23. Education Office
24. Members of Parliament
25. Karkheh Watershed Management Office

1.6.5 Materials and methods

Seventy stakeholders from the major provinces of Kermanshah, Lorestan, Hamadan, and Ilam responded to the invitation. A facilitator and some helpers were present to guide and steer the discussions, to trigger ideas, and help participants with filling forms.

In the first part of the meeting, we presented a number of maps of the pilot catchments in the KRB – Honam and Merek – to provide background information about the upper catchments and their roles in water and sediment production. Scientists of the CGIAR-CP projects, Livelihood Resilience and Water Productivity, presented brief reports about their research activities. These presentations included water resources, soil erosion, soil studies, soil fertility, vegetation cover, dryland farming, supplementary irrigation, socio-economic studies, and the current management structure in the catchments.
In the second part of the meeting, the SWOT (strengths, weaknesses, opportunities and threats) analysis was introduced. Participants were asked to list all SWOT issues that they recognized in relation to the management of the watersheds. In particular, we wanted to learn from the stakeholders how they saw the management principles and strategic planning.

At the end of the first day, participants were divided into four groups. One-quarter of the completed forms were given to each group to identify the five most important issues under each category. The outcomes were written on large posters. Then, all participants were given three votes (of different weights) and asked to allocate these to the issues that they considered to be most important. Table 1.2 shows the results of the first round of voting. Of the 27 issues recognized in the SWOT analysis, 15 scored points at this stage.

Then, the participants were asked as a group to identify the key issues from any of the four categories that relate to the principles and strategies for watershed management. The results are shown in Table 1.3 It should be noted that items in this Table are considered as 'issues' regardless of their categorization as a strength, weakness, opportunity or threat.

Interestingly, almost half of the issues identified in an earlier stage were not given any votes for priority. After removing the issues that did not receive any votes and sorting the ones that did, the list of issues (Table 1.4) could be recognized as the priorities of the stakeholders of the upper KRB watersheds.

Table 1.5 expresses the same results as Table 1.4, but is worded in such a way that action can be undertaken. It is a key result of the project.

1.6.6 Results and discussion

The guiding principles mentioned in Table 1.5 should be considered by experts from different disciplines and by government organizations to ensure collaboration. Research should be conducted to measure the level of success of IWM programs by comparing progress with targets and indicators. Collaborative approaches should improve the values of the indicators in the environmental, social, and economic dimensions. Planning of IWM and implementing it needs an organization which might be called a CMA. This is a vital institution that is missing in Iranian catchments. All current organizations and government bodies have generally only one main concern in their lines of duties and these are usually in conflict with each other. There is an urgent need for an organization tasked to solve these conflicts and manage the watershed as its main responsibility.

The IWM programs will not be successful without community support and participation. One aspect in particular needs emphasis – the participation of women. The fact that women have a vital role should be underlined for community involvement in watershed management,

The CMA should propose some laws and enforce them, e.g. on balancing livestock and rangeland capacity and on farming on steep slopes. Regulations and enforcement by themselves are not enough to keep the environment balanced, and they should be accompanied by structural and non-structural interventions, e.g. water harvesting to improve livelihood resilience, job creation, and more efficient overall water use.

One aspect of macro policy – privatization of government land – was picked up by the workshop participants who recognized the importance of public involvement in natural resources management. More than 80% of the natural resources, pastures, paddocks, and forests, is owned by the government. However, the communities will exploit these resources and cause destruction unless ownership and full responsibility for maintenance and rehabilitation is given to them.

In the two pilot catchments, Honam and Merek, the priority issues (Table 1.5) will be used to select the best management practices and design a framework for a CMA (see Figure 1.6).

Table 1.2. Results of the first round of voting on issues for the SWOT analysis

Strengths	**Score**
Climate diversity in the KRB	5.33
Willingness of the communities to participate	4.33
Availability of soil and water resources	1.83
Watershed residents' indigenous knowledge	1.50
Availability of adequate engineers and experts	0
Rich ecosystem	0
Resources exploitation diversity	0
Weaknesses	
Lack of criteria and indicators for IWM	7.00
Lack of holistic system in resources management and teamwork	5.33
IWM weakness before and after implementation of projects	4.33
Livelihood difficulties and lack of water harvesting for water use efficiency improvement	2.33
Not enough attention to the relative advantages of the natural ecosystems of the region	1.66
Inadequate mechanization and use of existing water resources	1.33
Weakness in attracting women's participation	1.33
Lack of protection for forests and rangelands and improvement and balancing livestock in the rangelands	2.00
Insufficient training and skills of the land users	2.00
Lack of suitable indicators and standards for evaluation of activities	1.00
Lack of coordination between research and executive sectors	0.66
Lack of a land-use planning study	0
Opportunities	
Using the private and cooperative sectors' potentials and abilities	2.66
Using religious motives for natural resources protection	1.33
Using the genetic capacity of livestock and vegetation by balancing between them	1.33
Development of secondary activities such as fisheries and processing industries such as canned/preserved food	0.50
Government policy for privatization	0.33
Suitable opportunities for attracting technical people in various fields	0
Threats	
Unemployment and stress on natural resources and soil erosion	4.50
Farming development over steep slopes	2.33
Ecosystem degradation and disruption of the environmental balance	2.66
Climate change	1.16
Groundwater drawdown	1.00
Frequency of disastrous floods and its acceleration	0
Degradation of indigenous genetic reserves	0

Table 1.3. Results of the second round of voting for the SWOT analysis

Issue	Score
Lack of criteria and indicators for IWM	8
Lack of a holistic system in resources management and teamwork	4
Climate diversity in the KRB	0
Unemployment and stress on natural resources and soil erosion	1
IWM weakness before and after implementation of projects	10
Willingness of the community to participate	2
Using the private and cooperative sectors' potentials and abilities	0
Farming development over steep slopes	0
Livelihood difficulties and lack of water harvesting for water use efficiency improvement	1
Lack of protection for forests and rangelands and improvement and balancing livestock in the rangelands	2
Insufficient training and skills of the land users	1
Ecosystem degradation and disruption of the environmental balance	1
Availability of soil and water resources	0
Lack of a land-use planning study	4
Watershed residents' indigenous knowledge	0
Weakness in attracting women's participation	1
Using genetic capacity of livestock and vegetations by balancing between them	0
Using religious motives for natural resources protection	1
Inadequate mechanization and use of existing water resources	0
Lack of suitable indicators and standards for the evaluation of activities	0
Groundwater drawdown	0
Climate change	0
Ecosystem degradation	1
Lack of coordination between research and executive sectors	1
Development of secondary activities such as fisheries and processing industries such as canned/preserved food	0
Government policy on privatization	1

Table 1.4. Priority for improving IWM issues

Priority	Issue
1	IWM weakness before and after implementation of projects
2	Lack of criteria and indicators for IWM
3	Lack of a holistic system in resources management and teamwork
4	Lack of a land-use planning study
5	Willingness of the community to participate
6	Lack of protection for forests and rangelands and improvement and balancing livestock in rangelands
7	Ecosystem degradation plus disruption of the environmental balance
8	Unemployment and stress on natural resources and soil erosion
9	Livelihood difficulties and lack of water harvesting for water use efficiency improvement
10	Insufficient training and skills of the land users
11	Weakness in attracting women's participation
12	Using religious motives for natural resources protection
13	The government decision on privatization
14	Farming development over steep slopes

Table 1.5. Principles and priorities to achieve effective IWM in Honam and Merek watersheds

Priority	Principle
1	Stakeholder coordination before and after implementation of projects is essential
2	Criteria and indicators for integrated watershed management are required
3	A holistic system of resource management is required. Teamwork is an essential feature
4	A land-use planning study is needed
5	Community participation during implementation of projects is essential
6	Forests and rangelands require protection. Presence of livestock and rangeland carrying capacity must be in balance
7	Prevent ecosystem degradation and disruption of the environmental balance
8	Job creation to reduce stress on the natural resources and to control soil erosion
9	Promotion of water harvesting to increase water use efficiency and improve livelihood resilience
10	Train land users and develop their skills
11	Encourage women's participation
12	Use religious motives for natural resources protection
13	Use government support for privatization
14	Control farming development and encroachment over steep slopes

Chapter 2.

Land Degradation and Management in Karkheh River Basin

Y. Norouzi Banis, D. Lotfollahzadeh, M. Ghaitour, T. Farhadinezhad, Z. Masri, D. Nikkami, A. Ghaffari, E. De Pauw and H. Siadat

Chapter 2. Land Degradation and Management in Karkheh River Basin

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2.1 Soil erosion

2.1.1 Introduction

Long-term records of suspended sediment measurements in the main hydrometric stations in the KRB indicate that the basin is in a critical condition with respect to the sediment load from the upstream areas into its river system. The large amount of sedimentation in the recently constructed Karkheh Dam reservoir confirms this observation. In the two selected pilot watersheds, Honam and Merek, the situation is not as critical because of some specific climatic and topographic conditions. These sites do not load the river network with considerable amounts of sediment. However, there are different forms of soil erosion, caused by different factors, which might affect, in significant ways, local community livelihoods in the pilot watersheds.

2.1.2 Main causes of soil erosion

Six important and common causes of soil erosion were distinguished during surveys in the Honam and Merek watersheds and other areas of the upper KRB.

- Road construction projects without proper management and without drainage systems for concentrated runoff leave large amounts of disturbed soils exposed to severe erosion. Development of deep gullies on either side of the road, specifically downstream of the culverts, is a clear sign of this phenomenon. This increases project costs both at the construction site and downstream.
- Over-extraction of construction materials from the river bed, especially in the Honam River, has severely disturbed the geomorphology of the river. This has destroyed the ecology of the river system at the sites and this may not be easily restored.
- Tillage of the soil on sloping land is often only feasible in the direction of the slope. This is because the arable fields are laid out in narrow strips. Tillage leaves the soil exposed to rainwater runoff. The arable land gets divided into smaller and smaller pieces as a result of inheritance laws and the division line is usually in the slope direction. Moreover, a large proportion of the soil nutrients is in the top layer that gets carried away by the flowing water. As a result, hill slope farming cannot be sustainable or economical in the long run.
- Plowing on slopes causes tillage erosion; the top soil is pushed down a little every time a plow passes. Specific signs of tillage erosion can be observed from the clear drop in elevations between the plowed land and neighboring unplowed land. Soil flux measurements and chemical and physical tests of top soil samples above and below the surveyed fields give further insights into the process of land degradation.
- Gully and rill erosion occur when runoff water becomes concentrated and flows on the surface for tens of meters and more. This occurs on sloping arable fields and large impenetrable surfaces such as roads. This process has divided some arable fields into unproductive pieces the rehabilitation of which is not easy.
- Overgrazing of rangelands in both catchments has removed a large

fraction of the vegetation cover and left the surfaces unprotected against rain drops and runoff erosion. These problems can be aggravated by the reduced permeability resulting from livestock compaction of the surface. In such conditions water erosion occurs even under moderate slopes.

2.1.3 Potential Solutions

Proper regulations and implementation plans are needed to conserve the upstream lands and water at both sites and especially in Honam. The success of these plans depends on the active involvement of all the main stakeholders including the local communities. Public awareness plays an important role in the proper implementation of most development plans.

Organizations responsible for projects to develop rural infrastructure, such as roads, pipelines, and mines, should plan for a minimum disturbance and exposure of top soils. For example, in road construction, the first stage of the project – cut and fill – should start only when immediate implementation of the next stages – compaction of the top soil layers and installation of runoff drainage systems – have been ensured.

Suitable regulations and plans are required for conservation of the existing forests and restoration of degraded ones. These should make provision for an adequate and timely supply of fossil fuel to fulfill community needs.

Approval and enforcement of relevant legislations are needed in order to prevent further illegal land-use changes and to encourage reforestation and maintenance of the existing rangelands and forests.

Maintaining a balance between the rangeland capacity and the number of livestock grazing on it and the seasonal timings will provide the basis for sustainable rangeland exploitation. This almost ensures sufficient vegetation cover to reduce the concentration of runoff which causes water erosion.

For soil conservation in the rangeland areas of the pilot sites, we suggest enclosure schemes, rangeland seeding, and growing suitable fruit trees, such as grapes and walnuts, on trajectories along compatible structures.

Farmer participation in conserving the rangelands and forests may be effective only if modifications are made in the legislation regarding the ownership of natural resources. Such modifications must be made at the national level. Better management of dry farming practices on steep slopes and erodible soils will reduce water erosion. Encouraging farmers to adopt contour tillage and introducing threshold slope angles for minimum tillage can be effective soil conservation measures. Farmers need to be trained in the best use of appropriate agricultural machinery and contour plowing. Suitable crop rotation systems have to be introduced to the farming communities to ensure high yields and sustainable soil fertility. The technologies adopted by successful farmer innovators in different fields of farming practice which have potential for dissemination need to be identified. Contour plowing is possible on consolidated land with a slope of less than 10%. To avoid tillage erosion, it is suggested to stop up-and-down tillage in dry farming areas on slopes greater than 10%.

Adoption of these recommendations needs the active participation of the local communities in all decision making stages, as well as a powerful IWM system across the country.

2.2 Land and soil degradation

2.2.1 Introduction

The principles of land suitability and AEZ assume that the soil and land are stable resources and do not significantly change over time or as a consequence of exploitation. Such assumptions are incorrect where degradation occurs.

Land and soil degradation assessments have recently attracted the attention of the public and planners because the significant adverse effects of degradation on agronomic productivity and food security, the environment, and the quality of life have been reported (Bridges *et al.,* 2001). As a result, the estimate of the number of people and animals the land can support without being significantly stressed has been decreased. There are negative productivity consequences resulting from land degradation because of the loss of water and nutrient storage capacity. The type and intensity of land degradation can be affected by several factors. These include poor land management, inadequate technology, overpopulation, and poverty. Each of these may be the consequence of factors related to social and political structures.

Degradation of water is associated with degradation of the land. It can be seen in unfavorable changes in the volume of water that the land supplies to streams and groundwater, the predictability of the flow, the frequency of floods, river droughts, and the quality of the water.

2.2.2 Problem definition

The dynamic nature of land and soil degradation, the associated processes, and their dependence on climatic, pedological, land cover, land use, and management factors give rise to spatial and temporal variability. Mapping this variability will produce information that is essential for IWM. In land and soil degradation mapping, field studies are perhaps the most precise part, but they are time consuming and expensive. Finding a precise and cost-effective method for mapping is an important issue in land and soil degradation studies. Remote sensing with airplanes or satellites is slowly becoming an important tool for monitoring land degradation.

2.2.3 Case study from KRB

The study was initiated by the Iranian Ministry of Jihad-e-Agriculture in Honam, one of the sub-basins of the KRB, Iran. In this research, the Global Assessment of Soil Degradation model, known as GLASOD (Oldeman, 1988; Oldeman *et al.,* 1991) was used for all working units and the geopedology (Zinck, 1988) and terrain mapping units (TMU) methods (Meijerink, 1988) were used for mapping soil degradation. In essence, the GLASOD database contains information on soil degradation within map units as reported through a questionnaire by numerous soil experts around the world. It includes the type, degree, extent, cause, and rate of soil degradation (GLASOD, 2008). The accuracy and precision of the maps will be evaluated by comparing them with field observations. Tables 2.1 and 2.2 contain the map units and the number of soil samples that have been taken in the Honam sub-basin for the geopedology and TMU methods.

2.2.4 Potential Solutions

It is essential to know the spatial distribution of the areas susceptible to degradation and to be able to assess hazard severity in order to protect the land from further degradation and undertake effective mitigation measures. A land and soil degradation map is one of the fundamental, scientific, and applied maps in the executive, research, and education sectors. Like a soil map, watershed atlas, gully erosion map, and landslide hazard map, a land degradation map will be used as one layer in the research and study plans.

Techniques and models to quantify land degradation range from the simple to the sophisticated. In the research reported here we used the GLASOD methodology (Figure 2.1).

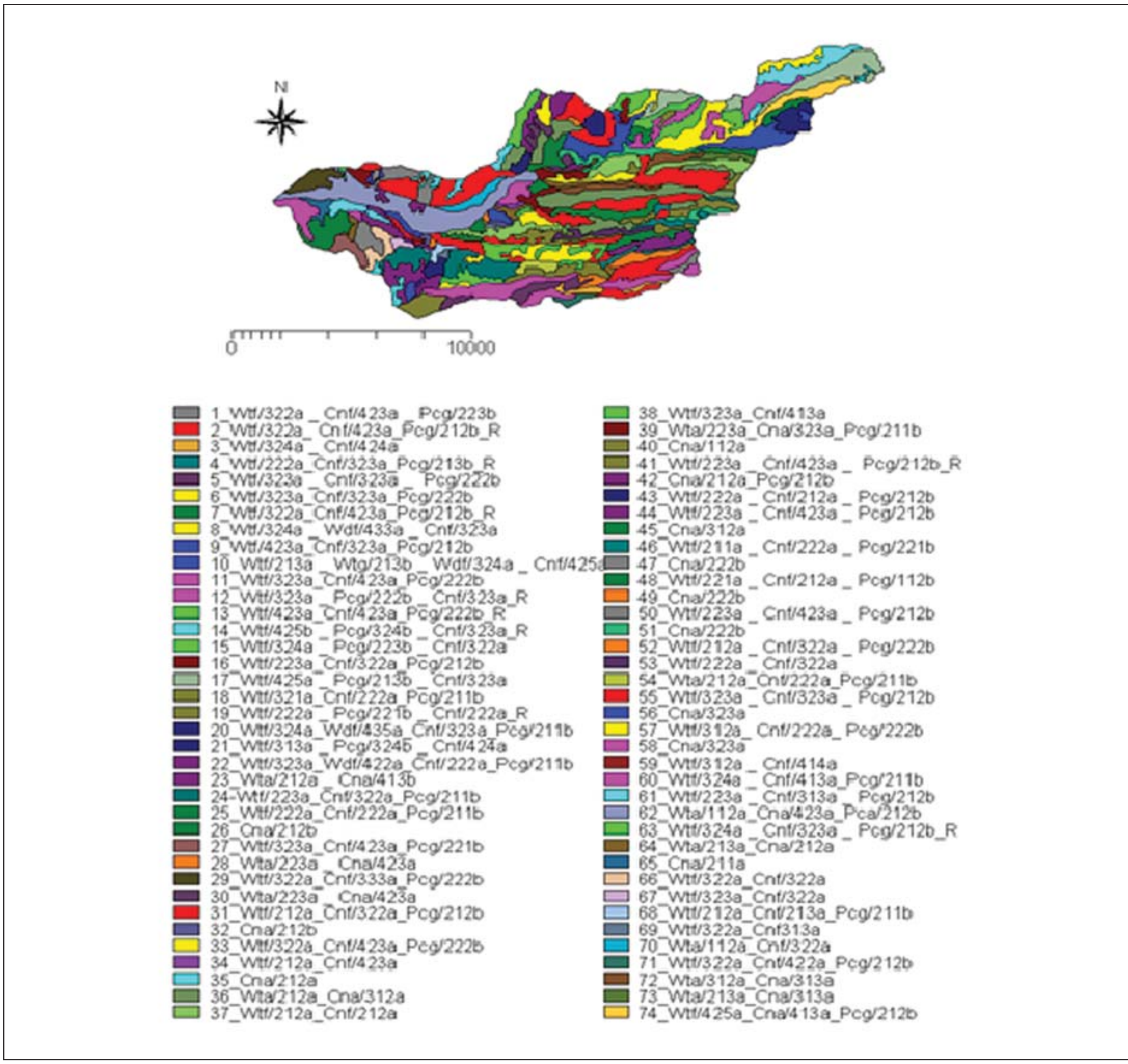

Figure 2.1. Soil degradation map of Honam prepared by using the GLASOD model

Table 2.1. Map units and number of soil samples for the geopedology method

Map unit	Unit name	Replicates	Area (ha)	No. of samples
1	Mo11	10	2,133.5	9
2	Mo21	1	281.62	2
3	Hi21	1	82.29	2
4	Hi31	3	68.94	4
5	Pi11	8	1,824.7	8
6	Pi21	8	99.27	8
7	Pi31	2	87.08	4
8	Va21	1	26.82	1
9	Mo12	4	2,423.4	4
10	Pi12	1	104.4	3
11	Pi22	1	56.6	3
12	Mo13	2	314.2	4
13	Mo14	1	1,279.4	4
14	Pi13	1	122.1	3
15	Mo22	1	362.1	4
16	Mo23	3	815.8	6
17	Pi14	2	81.2	2
18	Pi23	2	52.0	2
19	Va11	1	27.4	1
20	Mo15	6	542.5	4
21	Mo24	3	79.9	4
22	Hi22	2	67.8	4
23	Hi32	1	7.1	1
24	Pi15	6	302.1	6
25	Pi24	1	97.7	3
26	Hi12	1	47.7	2
27	Mo16	2	103.4	4
28	Hi23	4	65.9	4
29	Hi33	7	81.4	6
30	Pi16	8	306.0	8
31	Pi25	7	564.8	8
32	Pi32	4	887.4	8
33	Va12	1	229.0	2
34	Va22	1	17.2	1
35	Hi13	1	34.7	2
36	Pi17	3	336.7	6
37	Pi26	1	22.5	2
Total	-	112	14,036.6	149

Table 2.2. Map units and number of soil samples for the TMU method

Map unit	Unit name	Replication	Area (ha)	No. of samples
1	MS11	1	268.5	3
2	MS12	1	338.5	3
3	MS13	1	669.5	5
4	MS14	1	27.5	1
5	MS21	1	1,84.25	3
6	MS22	1	222.75	3
7	S11	1	948.75	7
8	S12	1	569.75	5
9	S13	1	404.25	5
10	S14	1	529.75	5
11	S21	2	53.5	1
12	S22	1	29.25	1
13	S23	1	247.5	3
14	FD11	1	908.25	7
15	FD12	1	39.5	1
16	FD13	1	73.25	2
17	FD14	1	104.75	2
18	FD15	1	346.5	4
19	FD16	1	114.25	2
20	FD17	1	207.75	3
21	FD18	1	203.5	3
22	FD19	1	147.75	2
23	FD21	1	409.75	5
24	SD11	1	52.75	1
25	SD21	3	122.5	3
26	SD22	1	289.5	3
27	SD23	2	167.75	4
28	SD24	1	1,435.5	10
29	SD25	2	419.75	5
30	SD26	2	529.75	6
31	SD27	1	98.75	2
32	SD28	1	1,005.25	7
33	SD29	1	569.25	5
34	SD31	1	206.5	4
35	SD32	1	79.25	1
36	SD33	1	55.5	1
37	SD34	1	405.5	6

Table 2.2. (Continued)

Map unit	Unit name	Replication	Area (ha)	No. of samples
38	SD35	1	129.25	2
39	SD36	1	69.25	1
40	SD37	2	32.5	1
41	SD38	4	165.5	2
42	SD41	1	119.5	2
43	SD42	1	49.5	1
44	SD43	1	625.25	5
45	SD44	1	283.75	2
46	SD51	1	75.25	1
Total	-	56	14,036.25	151

2.3 Land suitability

2.3.1 Introduction

What is 'land suitability'? The attribute 'suitability' of land is used to determine the opportunities and limitations of a specific piece of land for specific types and species of crops. Land varies greatly in terms of topography, climate, geology, soil, and vegetation cover. As a result, its suitability for agriculture ranges from very high – capable of supporting a large biomass with water and nutrients (tropical plantations) – to zero – deserts. A clear understanding of the opportunities and limitations presented by these relatively permanent factors of the environment is an essential part of the rational discussion of changes in land use (McRae and Burnham, 1981).

Land suitability is the fitness of a certain type of land for a defined use. The land may be considered in its present condition or after improvements. Land suitability is assessed for sustained production in a rational cropping system (FAO, 1976; McRae and Burnham, 1981). Land suitability can be quantified by various methods to explain or predict the potential of the land for specified purposes (Dent and Young, 1981; FAO, 1985; Van Diepen *et al.*, 1991; Sys *et al.*, 1991) on the basis of its attributes (Rossiter, 1996).

2.3.2 How to use land suitability

By using land suitability as a criterion in land-use planning, unpleasant surprises, like poorly performing crops or ecological disasters, are minimized. Land suitability helps to answer such questions as, 'Is this area suitable for wheat production?' The procedure to determine land suitability can be characterized as the translation of the plentiful information accumulated about land into a form usable by decision makers. Proper use of the attribute 'suitability' of land is therefore an element in rational land-use planning. In contrast, inappropriate land use corresponds with the inefficient exploitation of natural resources, especially soil and water, which leads to destruction of the natural resources and causes poverty and other social problems, and potentially the destruction of civilization (Rossiter, 1994).

Climate, soil, and topography are the three important categories of the natural environment about which information is required for judging land suitability. These characteristics do not change in the short term.

2.3.3 Case study from KRB

As an example, we look at land use in the KRB. Over many years of farming, local farmers have established which of the crop species and management processes they have access to have the best chance of success; where success is a combination of yield, yield stability across years, quality of the product, and other features. If nothing will change, then it will not help to tell the farmer about the suitability of his land. However, when changes of crops and crop management are anticipated on the farm or watershed scale (as promoted by Farahani *et al.,* 2008), then knowledge of the suitability of each piece of land is useful. It may indicate that intensification, with proper inputs, is likely to be rewarding. Land that is presently under-used can be designated for resettlement by farmers who are cultivating steep slopes or encroaching upon forest lands. It is necessary to establish (i) the best condition for its operation, (ii) the range of conditions which are less than optimal, but still acceptable, and (iii) the conditions that are unsatisfactory.

Ghaffari *et al*. (2008) considered how climate change may affect land suitability in the KRB. They concluded that the area of land that can currently be classified as highly, moderately, or marginally suitable for wheat is likely to increase as a consequence of a rise in temperature unless this is accompanied by a drop in annual precipitation, in which case the areas in each category will decrease.

2.3.4 Solutions: how to proceed

Determination of land suitability is best done with the FAO Framework for Land Evaluation (FAO, 1976) using five steps, as follows.

Step 1. Identification of homogeneous land units
Evaluate individual grid cells. These 'homogeneous' land units are defined by their climatic, topographic, and soil characteristics from a crop requirements point of view.

Step 2. Definition of land-use types
The evaluation determines the feasible land-use types (LUT) by single crops. In the pilot watersheds in the upper KRB, these crops are barley, wheat, lentil, chickpea, potato, sugar beet, and safflower. The evaluation does not consider interactions between crops as they can occur through common practices such as fallowing, rotations, etc. If certain crops are normally grown under irrigated conditions, the evaluation extends only to the areas where irrigation water is effectively available.

Step 3. Establishing the edaphic requirements of the defined land-use types
Information is collected from the literature about the ecological requirements of the crops selected for the LUTs. The main sources are Sys *et al.* (1993), ECOCROP (1998a, 1988b), Edwards *et al.* (1983), Ghaffari (2000), and international and national research institutes' reports and internet sites. The crop requirements are expressed as a set of threshold values that indicate the boundaries between the land suitability classes. The S1 level (very suitable) has no or slight limitations, the S2 level (moderately suitable) has moderate limitations, and the S3 level (marginally suitable to unsuitable) has severe limitations; very severe limitations result in a non-suitable (N) class. The values for these class-defining thresholds are based on expert knowledge.

Step 4. Identifying land limitations and rating their severity
Once crop requirements are agreed upon, it is possible to match them with the actual values of the rated characteristics

for each grid cell. The easiest way to do this matching is by converting the values of the rated characteristics into limitation ratings, using the threshold values of Step 3 and 'best-bets' in cases of doubt.

Step 5. Land suitability classification
This step involves combining the limitation rating layers of climate with those of topography and soils. The integration is done according to method of the most limiting factor. The final rating is determined by the factor that is most limiting. This means that, for example, a severe limitation in the moisture regime cannot be compensated for by, for example, an excellent soil.

The land suitability classification can be summarized by the equation:

$$Suiti = Max (Suit_{Temp}, Suit_{Cold}, Suit_{Prec}, Suit_{Soil},i, Suit_{Topo})$$

where, Suiti is the combined $suit_{ability}$ of the piece of land under consideration, the value of which is determined from climatic, soil and topographic factors, Max is a function that selects the highest limitation rating, $Suit_{Temp}$ is $suit_{ability}$ according to the thermal regime, $Suit_{cold}$ is the suitability according to the cold period, $Suit_{Prec}$ is the suitability according to the moisture regime, $Suit_{Soil}$,i is the fraction of each grid cell with soil $suit_{ability}$ class Si, $Suit_{Topo}$ is the $suit_{ability}$ according to the local topography. Figure 2.2 illustrates the procedure of this equation in a graphical manner.

2.3.5 Local adaptations

To improve the precision of the land suitability assessment, we found it useful to modify the methodology as follows:

- For some crops (e.g. wheat, barley, maize) the temperature requirements are expressed more precisely in terms of growing degree days (cumulative temperature above a crop-specific threshold) than as the average temperature for the year, the growing season, or specific months
- Aspect (exposure to slopes with different directions) is a factor which affects the temperature of sloping land. South-facing slopes are warmer and drier than north-facing slopes. The difference can be as much as 2 to 3°C
- We consulted the land-use map of the region to improve upon the accuracy of the soil map.

2.3.6 Results

The methodology adopted combines the climate and land quality attributes which most influence crop suitability. These include long-term average annual rainfall, accumulated temperature, soil, and topography data. Good management is assumed – including the use of appropriate crop varieties, fertilizers, and sowing date – and social and economic factors are excluded. Overall suitability is recognized by the simple limitation approach in preference to a weighted GIS model which scores attributes. The results showed that under current climate condition 8.7% of the area is highly suitable for winter wheat, 7.6% moderately suitable, and 28% marginally suitable. The remaining 55.7% is unsuitable. Under climate change scenarios, the suitability of land for winter wheat showed considerable variation. With increased temperature and precipitation, the 'highly and moderately suitable' areas increased, but with decreased precipitation the 'highly suitable' areas decreased as much as 91%. The methodology could readily be adapted and developed for other soil and climatic conditions.

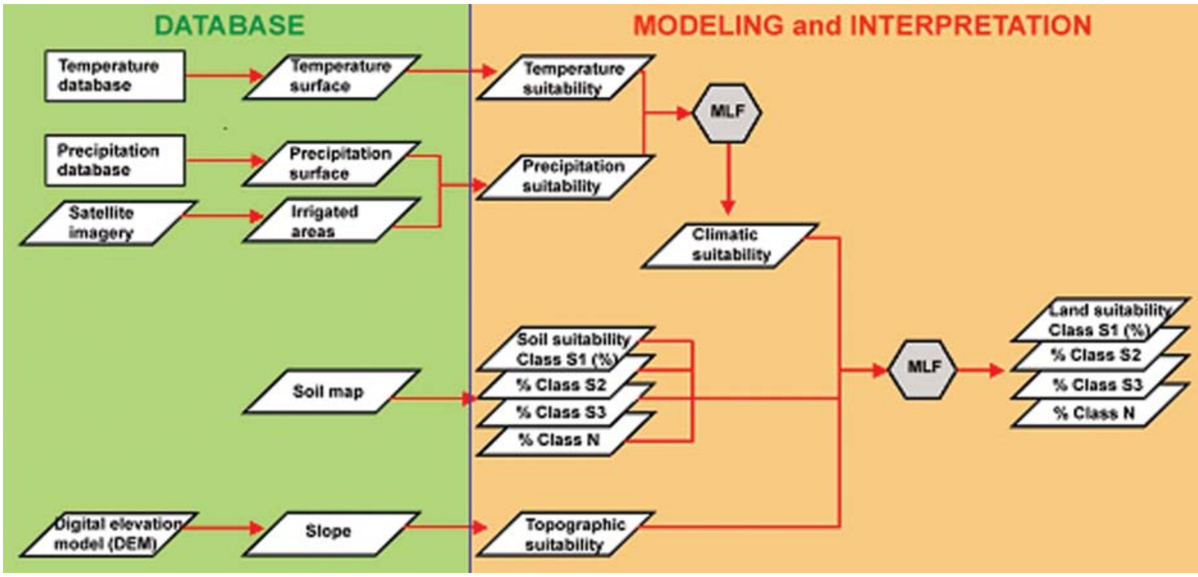

Figure 2.2 Flowchart of the land suitability classification procedure

2.4 Land consolidation

2.4.1 Introduction

One of the most challenging issues in agricultural development in Iran is farm size and the fragmentation of the land holdings of many farmers. Small farm holdings constitute a significant share of the total cropped area of the country, while they pose a big hurdle to proper agricultural extension services and IWM. Table 2.3 presents the size distribution of farms in the country according to the 2003 general census on agriculture (http//www.sci.org.ir).

2.4.2 Why is fragmentation a problem?

About 35% of Iranian farms are smaller than 1 ha. Many of these land holdings consist of several pieces of land, and these small units are managed by different farmers who do not follow the same practices. Under such conditions, the up-scaling of activities and mechanization to achieve some economies of scale are not possible. The small size of such holdings is a sign of the poverty of the owners and this is usually associated with low levels of education and literacy. As such, the extension of agricultural advisory services becomes a huge task that goes beyond the abilities of the government organizations.

Small land holdings and land fragmentation are serious barriers to development work, such as road construction, leveling and shaping of agricultural fields, construction of irrigation networks, mechanization of agricultural activities such as harvesting, and implementation of large-scale conservation agriculture. Yet, such development activities are necessary for successful rural development.

On these small farms many of the poor households do find at least some work and income. Consolidation of farmland holdings to allow modern agriculture to develop will probably create a significant out-migration of members of the households. Job creation outside agriculture should, therefore, accompany any land consolidation program.

Table 2.3. Size distribution of agricultural land holdings in Iran

Size of holding (ha)	Number of holdings	Cropped area (ha)
< 1	1,205,033	407,070
1 < 2	522,956	655,129
2 < 5	797 006	2,377,091
5 < 10	491,156	3,230,892
10 < 20	295,179	3,788,275
20 < 50	135,649	3,736,337
50 < 100	24,576	1,547,657
100 < 200	6,723	836,590
200 < 500	2,021	544,556
500 < 1,000	312	196,293
> 1,000	118	3,458

2.4.3 Case study from KRB

Interviews with farmers and our field observations have shown that the KRB is no exception in this regard, a similar situation prevailing there. Fragmentation of lands is particularly severe in dryland zones in the upper KRB, where rural residents try to convert sporadic pieces of rangelands into rainfed fields for cultivation of cereals in small parcels. This process continues further and further in the absence of strict controls by local authorities. Inheritance laws further aggravate the situation by allowing division of the land among the heirs after the original owner dies.

2.4.4 Solutions to tackle the problem

For the last three to four decades, the authorities have been seeking ways and means to encourage small farm holders to consolidate their agricultural lands. The government has made efforts and allocated budgets for this activity in almost all development plans for the country. Some regulations have also been made for this purpose. There are numerous success stories in land consolidation in Iran, particularly where mono-cultures, such as rice, are grown. The government provides grants and privileged loans to the farmers who cooperate with this program. Development activities, such as land grading and construction of irrigation and drainage networks, are provided with large government subsidies. The Production Cooperatives formed by such groups of farmers are among the more successful agricultural institutions.

Unfortunately, progress has been limited because of the contradictions and differences between this program and the farmers' traditions, religious inheritance rulings, and the inadequate capacity of the responsible authorities. The figures in Table 2.3 were collected in 2003 and are evidence of the fact that the problem still prevails.

Some principles of IWM involve large-scale decisions and programs that are difficult to implement in areas with many small farms spread over different locations and each managed differently. Land consolidation is one of the keys to the successful application of these principles. To remove the obstacles, a participatory approach to land consolidation needs to be adopted. To gain acceptance by the majority of the farmers, much social work is needed to promote the idea of land consolidation and supporters for this program need to be identified. The PTD approach, as adopted in the Livelihood Resilience project, is a very promising approach and could be adopted for land consolidation purposes in this region.

Chapter 3.

Watershed Management Elements

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Chapter 3. Watershed Management Elements

A. Shahmoradi, M. Heydarizadeh, S.B. Moosavi, M. Effati, E. Sharifi, A.M. Kheirkhah, M. Ghafouri and A. Sareshtehdari

3.1 Management of rangelands and forests based on their carrying capacities

3.1.1 Introduction

The main objectives of IWM should be improvement of the natural resources base and enhancement of the livelihoods of the populations that depends on it. This means that the management of rangelands and forests has to be based on their carrying capacities. Carrying capacity refers to the optimum level of vegetation use (use of forage and medicinal plants, and other kinds of exploitation) over a long period without ecosystem deterioration. According to recent statistics and information, rangelands and forests in Iran cover about 98 million ha. They form also the major portion of most watersheds. Since vegetation cover is the integrator and a key indicator of functional processes in rangelands and forests, management of related watersheds cannot attain its goals without proper management of these resources.

3.1.2 Problem definition

In most watersheds in the country, human activities have resulted in vegetation degradation, and affected the size, abundance (density and frequency) and diversity of plant species and vegetation. The main factors of degradation in the vegetation of the rangelands include those resulting from overgrazing, non-season grazing, over-harvesting of the plants which are used for medicines or other special concerns, conversion of the rangelands into rainfed croplands, and inappropriate land management. The cutting of forest trees by the local people either for leaves to feed livestock or for wood to make charcoal has resulted in fragmentation and open areas of various sizes in the forest ecosystems of the watersheds. As a result, the present intensity of exploitation of the rangelands and forests exceed the carrying capacity of these resources.

Changes in the traditional herding practices of the rural and pastoral people, such as overstocking and off-season grazing, have prompted the biological degradation of the rangeland and forest ecosystems. Consequently, biological productivity and conservation of biodiversity in the ecosystems have decreased through the degradation of the rangelands and forests, and even of the irrigated lands. A considerable number of desirable forage species or medicinal species of the rangelands have disappeared. Many forest species are now very scarce. Biological degradation, as the major indication of land degradation, has triggered many environmental, social, and economic problems for local people. The disturbances have resulted in, among other things, migration from rural to urban areas and a breakdown of traditional social values and practices.

3.1.3 Case study from KRB

Evaluation of the rangelands and forests of the two sub-catchments of Honam and Merek in the KRB showed severe biological as well as physical degradation. As a result of long-term overgrazing, off-season grazing of rangelands, and the cutting of forest species for their leaves to feed the herds and for their wood to make charcoal, most of the desirable forage species are near extinction. These species include:

- Forage species such as *Prangos ferulacea, Ferula ovina, Dorema Aucheri, Dactylis glomerata Bromus tomentellus, Trigonella elliptica, Kochia prostrata, Sanguisorba minor*
- Medicinal species such as *Thymus kotschyanus, Hypericum perforatum, allium hirtifolium*
- Other valuable species such as *Fritillaria imperialis and Allium ampeloprasum*

Most of the forest species are about to be totally wiped out from their forest habitats. These include *Crataegus aronia, Crataegus microphylla, Crataegus monogyna, Pistacia khinjuk, Crataegus psedoheterophylla, Cerasus brachypetala, Cerasus mahaleb, Cotoneaster luristanica, Amygdalus carduchorum, Amygdalus elaeagnifolia, Amygdalus haussknechtii, Amygdalus kotschyi, Pyrus syriaca, Olea europaea, and Ulmus carpinifolia*. At the same time, the rangeland ecosystems have been invaded by undesirable plant species. Considerable parts of the study sites have been converted to rainfed farms which have low production and low benefits, as compared to the original highly productive rangelands. Some of these rainfed fields are located on steep slopes and severe soil erosion can be seen in most of them, as a result of the rangeland conversion.

3.1.4 Potential solutions

To solve the problem of vegetation degradation in the rangelands and forests and conserve these vital resources – and to enhance the livelihoods of the populations that depend on them – it is necessary to consider and implement the following activities at the watershed level:

- Identify all the plant species in the rangelands and forests
- Evaluate the conditions of the rangelands and forests and the trends in these conditions, including the status of biodiversity
- Determine the duration of the grazing season based on ecological characteristics and the phenology of plant species
- Assess the actual and potential capacities and productivities (of forage, medicinal plants, recreational value, and other ecosystem services)
- Assess rangeland suitability (considering topography, access to drinking water for livestock, and livestock species – sheep, goats, and cattle)
- Determine and document the actual and potential carrying or grazing capacities of the rangelands
- Watershed managers should prepare proper management schemes for rangelands and forests based on their documented carrying capacities. Community grazing licenses should be based on normal years. The schemes can include rehabilitation and programs to adjust the stocking rate, range seeding, rotation or rest/rotation grazing systems, and other range improvement methods.

In short, management of the rangelands and forests based on their carrying capacities is a major principle for IWM. It provides the final solution to avoid land degradation and preserve biological diversity. This solution would restore and save the vital natural resources that form the major portion of most watersheds in the country.

3.2 Water supply for supplemental irrigation: Small reservoirs, stream diversion, and groundwater

3.2.1 Why supplementary irrigation is needed?

Supplementary irrigation is defined as the addition of small amounts of water to essentially rainfed crops when the rainfall fails to provide sufficient moisture for normal plant growth. Its purpose is to improve and stabilize yields (Oweis and Hachum, 2006). The shortage of soil moisture in the rainfed areas presents itself usually during the most sensitive stages of crop growth. In the Mediterranean-type climate, this shortage occurs usually in the spring and summer. The regions that have a Mediterranean-type climate are West Asia and North Africa (WANA). Iran is located in West Asia and supplementary irrigation is a very effective and water-efficient method to overcome drought. Further information about drought and its impacts can be found in a guide on how to avoid drought by Knudson *et al.* (1998), which is summarized in Box 3.1.

One of the main problems in Honam and Merek is the low crop yields achieved under rainfed farming. They are one-third or less the yields obtained under irrigated farming. The yield in rainfed farming can be doubled or tripled with supplementary irrigation. Water sources for supplementary irrigation are surface runoff and, increasingly, shallow groundwater aquifers. However, development of supplementary irrigation has two constraints:

- Limitations to the amounts of storable and extractable water
- Slope – most of the rainfed fields are on steep slopes.

Box 3.1. How to reduce drought risk

The drought risk reduction guide (Knudson *et al.,* 1998) provides a step-by-step process for users to identify actions that can be taken to reduce potential drought-related outcomes before a drought occurs.

Step 1 begins with making sure that the right people are brought together and supplied with adequate data to make informed and equitable decisions during the process.

Steps 2 and 3 narrow the focus of the study. They identify the high priority drought-related impacts that are relevant to the user's location or activity.

Step 4 demonstrates that in order to reduce the potential for the identified impacts to occur in the future, it is necessary to understand the underlying environmental, economic, and social causes of the impacts.

Steps 5 and 6 utilize all of the previous information to identify feasible, cost-effective, and equitable actions that can be taken to address the identified causes.

In this manner, true drought vulnerabilities can be addressed that will subsequently reduce drought-related impacts and risks. To promote this process, it is essential to construct a guide to assist individuals and organizations through a process of identifying specific actions that can be taken to reduce short- and long-term drought risks.
http://www.drought.unl.edu/plan/handb

3.2.2 Potential options for water supply

Rainfed land is generally located upslope from irrigated land. In such cases, the water has to be made available at higher elevations. This can be done by constructing diversion structures in the upper reaches of rivers, conveying the water through open channels or pipes, or by using a pumping system.

Given the shortage of surface water at the end of spring and in the summer, it is necessary to store water in small dams or to recharge aquifers. The possibility of constructing underground dams and using of lateral waters in ephemeral rivers has to be studied.

Although our case studies for supplementary irrigation were undertaken in the Honam and Merek sub-catchments, they can be considered to be typical for all the catchments of the upper KRB. Following are some basic definitions for artificial recharge, underground storage and small dams.

Groundwater recharge

Groundwater recharge is the process by which aquifers are replenished with water from the surface. A number of factors influence the rate of recharge, including the soil type, plant cover, slope, rainfall intensity, and the presence and depth of confining layers and aquifers. Most of the groundwater recharge in WANA occurs in the winter months when precipitation is highest (http://waterquality.ifas.ufl.edu/). Groundwater recharge is crucial for sustainable groundwater management and the volume-rate abstracted from an aquifer should be less than or equal to the volume-rate that is recharged. Recharge can help move excess salts that accumulate in the root zone to deeper soil layers and into the ground water system. Another environmental issue is the disposal of waste through the water flux, such as dairy farms, industrial, and urban runoff. (Source: http://en.wikipedia.org/wiki/Groundwater_recharge).

Groundwater dams

Groundwater dams or sub-surface dams are structures that intercept or obstruct the natural flow of groundwater and cause water to be stored underground. They have been used in several parts of the world, notably India, Africa, and Brazil. They are used in areas where the flows of groundwater vary considerably during the course of the year, from very high flows following rain to negligible flows during the dry season. The principle of the groundwater dam is that instead of storing the water in surface reservoirs, water is stored underground. The main advantage of groundwater dams is that evaporation losses are much less for water stored underground. Furthermore, the risk of contamination of the stored water from the surface is reduced because parasites cannot breed in underground water. The problem of submergence of the land, normally associated with surface dams, does not occur with sub-surface dams.

Small dams

There is no universal specification for a ‘small’ dam. Some state agencies consider dams less than 5 m high as small. The National Inventory of Dams, maintained by federal agencies, uses a combination of height and impoundment size as a cutoff for inclusion. Dams, reservoirs, flood levees, embankments, and river training works constitute structural measures for better flood management. Non-structural measures are also important for flood management, including monitoring of precipitation, river and reservoir stages and flow measurements, forecasting, early warning, and disaster warning. In the lean season, the river flow is generally reduced as a result of withdrawals from dams through canals or pipelines. However, it can be augmented by supplies from withdrawals from reservoirs further upstream. The benefits of small dams are that lower chances of floods and lower peak flows reduce agricultural and non-agricultural losses.

3.2.3 The way forward

Honam sub-catchment

During winter and early spring there is sufficient water in the upstream and downstream parts of the Honam sub-catchment, but the local geo-physical conditions do not allow water storage. Construction of small dams is not favored because there is the possibility of a high loss of water through leakage. The next solution is water conveyance from uplands streams through open channels or pipes along gentle slopes. The problem in this case is that the water would be available for just one supplementary irrigation, there would be no water in the river for a second or third irrigation later in the season. Therefore, a reasonable option is to abstract water from the Honam spring using a pumping system and convey it through gently sloping open channels. Water from Honam spring is currently taken from the higher left bank of the river and conveyed through a pipeline that crosses the river bed. The construction of underground dams in ephemeral rivers in order to use sub-surface water resources should be also considered.

Merek sub-catchment

A small dam project is under construction in an ephemeral river in the upstream parts of the Sarab Firouzabad's qanats. The amount of stored water will be sufficient to allow it to be used for supplementary irrigation. On the Merek plain and downstream of Sarab Firouzabad it is more difficult to construct small dams because of the gentle slope of the riverbed. However, the area has suitable groundwater resources. Therefore, the installation of stations to artificially recharge ground water should allow the supplementary irrigation of rainfed lands. In Merek, as in Honam, the studies should consider the possibility of constructing underground dams in ephemeral rivers and the use of sub-surface water resources.

3.3 Criteria for developing agricultural technologies

3.3.1 Introduction

The core strategy of an integrated approach to watershed management is to facilitate a process by which multiple and often conflicting values, perspectives, livelihoods, interests, needs, and priorities can be combined in a way that can be sustained under local conditions with local resources through local management. In the context of agricultural innovations, aspects of the local socio-economic and environmental conditions as well as local practices need to be taken into consideration in drawing up criteria for developing and promoting agricultural technologies.

3.3.2 Defining the problem

Some of the features of the conventional approach to introducing agricultural innovations and technologies to farmers' communities contradict the characteristics of an integrated approach. For example:

- Usually technologies introduced to farmers' communities target a particular crop and seek to increase its production or quality with little thought about complementary activities that can enhance the added value
- The effectiveness of changes brought about by the technology inputs is

usually assessed by conventional criteria – productivity, yield, and quality
- A complex technology that requires drastic changes in farming systems usually relies on outside expertise and is unlikely to be adopted by farmers
- Changes instigated by new technologies and innovations usually entail a sudden upheaval of vital components of existing farming systems, making it difficult for the farmers to adapt
- Excessive use of resources can produce misleading results that are difficult to sustain
- Many innovations and new technologies are not sensitive to the local environment and lead to detrimental effects
- Even useful technologies that show good results at first are often not sustainable because the tools and inputs required are not easily available after the project ends
- Many ideas and technologies have shown promising results under the controlled conditions of a research station, but failed under the changing and unpredictable local climate conditions.

3.3.3 Possible solutions

A more integrated approach to the promotion of agricultural innovations and technologies adopts a holistic look at the relations between the local conditions and livelihoods. This leads to characteristics that can be described as follows:

- Any increase in production or yield is qualified by i) productivity, which implies equitable and sustainable use of resources and ii) income, which means that the changes would have to be assessed by their effects on household economies
- Changes in crops or practices build on the knowledge and skills of the local farming communities. New technologies need to be simple enough for the farmers to understand, implement, and modify as they see fit
- Technologies that improve post-harvesting and processing issues and add value to the products
- The changes can be sustained by local resources and fit in with the local environment. Such changes are often incremental and gradual. This allows active participation by the local communities which can adapt to the changes on their own conditions
- An integrated approach takes a realistic look at the resources that are limiting the activities of the local communities. This guides us to technologies that are resource efficient and not too taxing on resources
- There needs to be a balance between resource use and environmental friendliness in agricultural technologies. In that way we can expect a long-term, sustainable outcome that is effective and in harmony with the local environment
- The availability of tools and inputs is considered, especially for resource-poor farming communities
- New technologies should be climate resilient.

3.3.4 Agricultural innovation process

The approaches for introducing agricultural innovations and technologies must accommodate a more participatory process of multi-stakeholder negotiations and collaboration. This includes seeking and experimenting with ideas that can bring about gradual, equitable, and sustainable change, while connecting with the wider concerns and trends.

It is advisable to adopt an approach, like PTD. The PTD tries to change the research and development approach and methodology from a conventional linear mode – whereby researchers and experts work on innovations and then transfer their conclusions to the farming communities through extension services and implementing agencies – to a more interactive, multi-stakeholder partnership to develop ideas through constant interactions and decision making based on consensus. These ideas can be from local innovators or outside experts.

Frequent reflection from different perspectives on the process of agricultural innovation is necessary. Regular participatory evaluation of the consequences of activities and roles can enable stakeholders, especially local communities, to demand and make modifications in order to better adapt the ideas to local needs and conditions.

3.4 Capacity building for women

3.4.1 Introduction

One of the principles of IWM is to give due attention to the socio-economic aspects and to the interaction of people with the natural resources in the watershed. In other words: a watershed will run into problems when there is no equilibrium between its natural ecosystem and human activities. Therefore, it is very important to give due consideration to the 'human dimension' in planning development programs for a watershed. Within this dimension, the gender issue and its interactions with the natural environment deserve particular emphasis. This contribution focuses on the empowerment of women and on overcoming the low level of their involvement in decision making and management.

3.4.2 Defining the problem

In spite of the fact that women constitute half of our human resource in rural areas and despite the important role that they play in agricultural and livestock activities, the development plans of the country have always put the emphasis on men. This approach has led to the unfortunate situation whereby the potentials and capabilities of rural women have not been properly identified and recognized. Consequently, the capacities of this large portion of the society have not been fully used in rural development. By the same token, adequate capacity building has also been lacking in this regard.

The abovementioned problem can easily be observed in the selected sites of the project. While women play a major role in agricultural and livestock activities, our study shows that provision of developmental services (such as extension-education support services and formation of local community institutions) have been limited. Yet, these are needed for capacity building and enhancement of the skill levels of women. In this short note we attempt to present an overall look at the situation in the country and in the study sites. After that, we give some suggestions about capacity building for improving livelihood in the KRB.

3.4.3 Statistics

The share of women in the agricultural work force in Iran is reported to be about 40%. Agricultural statistics show that rural women form 60% of the work force in rice production, 90% in vegetable production, 50% in cotton and oil seed crops, and 30% in orchard husbandry. The contribution of women to livestock production activities is also high with 65% in overall livestock production and 90% in raising silk worms. For rural handicrafts 75% of the production is done by women.

Studies carried out in Honam and Merek show that the share of women in field activities (planting, crop husbandry, harvesting, and marketing) is 28%, in livestock 68%, and 100% in handicrafts. More data are presented in Table 3.1. The numbers reflect the important roles of women in household income and economy. The high level of activities is actually amazing since rural women have not benefitted from capacity building. Our findings indicate that women in Honam and Merek did not receive any agricultural and livestock production training and have not had extension services. Additionally, they have limited access to governmental financial support – including credit – to optimize and expand economic activities. Also, their role in decision making in the community institutions i.e. rural councils, cooperatives, no-interest credit funds, etc, is very limited. Compared with men, women have a very weak voice in the decisions concerning family and village affairs.

3.4.4 The way forward

The following activities are suggested for improving the status and conditions of rural women:

- To improve the knowledge, skill, and productivity of rural women, appropriate training about modern scientific practices should be provided. It will be very beneficial to distribute extension brochures and organizing training classes
- Special institutions should be established for and supported by rural women. This can increase their participation in community organizations, such as rural councils and cooperatives, and enhance their management abilities. Such skills will encourage women to take more active roles in rural development
- Draw the attention of local rural planners and managers to the capabilities of the women and promote a positive attitude. Women make up half the population of the villages and it is necessary to involve them in development plans
- Due consideration should be given to the needs of rural women when new technologies or facilities are introduced
- Facilitate rural women's access to bank credit and government support services

Table 3.1. Participation in activities and decision making in Honam and Merek

Type of activities and decisions	Women's participation %	Men's participation %	Others
Marketing agricultural products	2.5	97.5	-
Marketing livestock products	23	77	-
Decisions about the village	9.2	80.8	-
Membership of local institutions	11.6	88.4	-
Livestock ownership	23.4	76.6	-
Land ownership	3.4	96.6	-
Decisions about land	10	76.9	13.1
Decisions about livestock	27.7	61.7	10.6
Control over income from livestock	36.1	52.5	11.4
Control over income from agriculture	10	74.2	15.8

- Mechanize the current traditional technologies for processing livestock products. This will empower women and reduce their workloads.

3.5 Integrated watershed management organizations

3.5.1 Introduction

Integrated watershed management is defined as a process of planning, organizing, leading, controlling, and supervising the implementation of activities to manage watershed resources in order to maximize the products and services for residents of the watersheds and minimize damage to natural resources. Achieving maximum benefits for stakeholders while keeping damage to a minimum requires appropriate design of an organization that will manage these tasks. It must be supported by specific laws and regulations of the central government to be able to manage the complex process. And it must increase community participation.

A 'village Islamic Council' (vIC) is part of the Iranian government structure in each village. Its role and mandate have been set by the laws of the Iranian central government and its members are elected by the people of the catchments. There is a hierarchy of Islamic Councils in the country as shown in Figure 3.1. At the lowest level n the hierarchy are the vICs. The Province High Islamic Council is at the top and three (for villages) or two (for towns) levels of Islamic Councils are in between.

3.5.2 A Possible role for the village Islamic Council in watershed management

Because vICs connect local people to the central government, they may be potential institutions to manage watersheds effectively and in an integrated manner. They could be strong as the structure combines in one organization the implementation of plans at the village level and strategic thinking plus supportive legislation at the national level. This is depicted in Figure 3.2.

However, the mandate for IWM will be new to the Islamic Councils and not all of them may be capable or motivated to pursue this with the attention needed. Other options such as Community Based Organizations, which are specifically set up and selected for certain tasks, may be an alternative option. It may be expected that Islamic Council members will need extensive training in the principles of watershed management and strong tools to support their decisions making. Council members will also need to learn 'negotiation' because conflict resolution is an essential skill in watershed management where compromises always need to be found between stakeholders. Furthermore, ways must be found to avoid excessive administrative delays in the multi-layered institution of the Islamic Councils (see Figure 3.2).

The purpose of the activities of the vICs for watershed management can include:

- Improved livelihood and livelihood resilience of local people
- Improved economic development
- Improved status of the natural resources
- Improved social conditions (education, migration, employment) especially for the poorest
- Higher level and higher frequency of achieving agreements and mutual commitments
- Visible examples of collective action towards the sustainable use of resources
- More effective policy changes
- Decreased number of conflicts

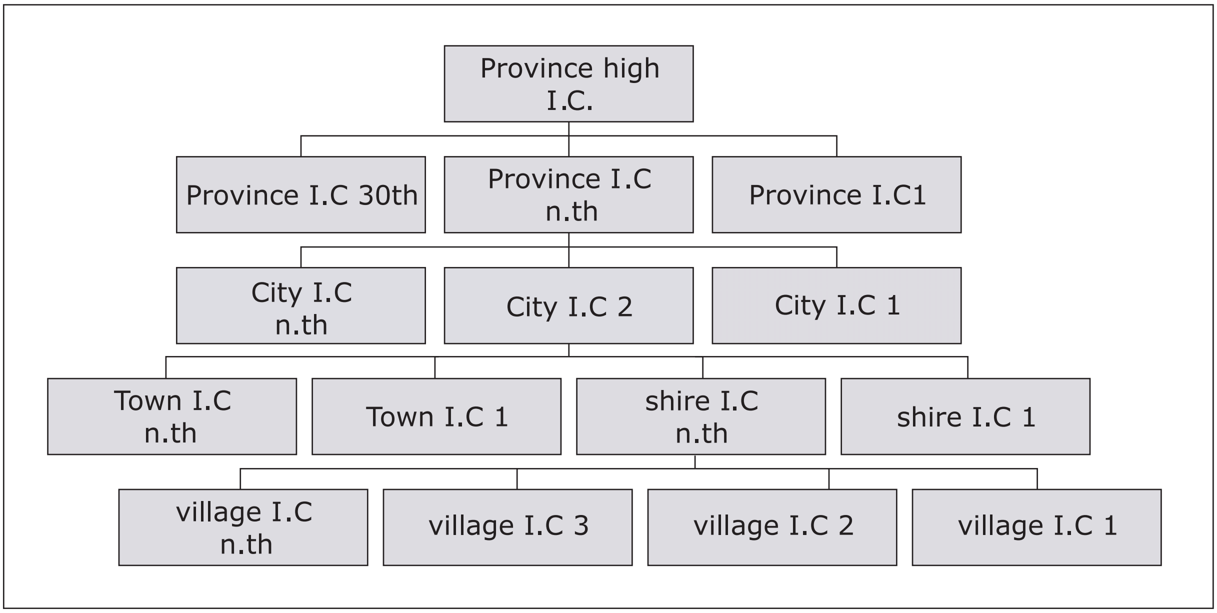

Figure 3.1. Hierarchy of the country's Islamic Councils

- Decreased number of activities that are illegal or damaging to the environment including those by private companies.

The potential tasks of a vIC with respect to watershed management can be summarized into five categories:

- Provide leadership in planning and organization processes. Set standards for the indicators of development and monitor performance through these indicators
- Supervise implementation of plans for (i) the conservation and improvement of the rural environment, (ii) the use of natural resources, (iii) soil erosion control on farms, orchards, rangelands, and forests, and (v) the maintenance of canals. Correct non-compliance with regulations
- Mobilize people to participate in community activities and visit the library and cultural center. Encourage groups that are now under-represented, especially women and youth, to make use of government activities, such as social, economic, cultural, educational, and health services
- Strengthen local institutions for IWM and for demand-driven, capacity building. Facilitate multi-stakeholder links and negotiations
- Coordinate with higher level managers and communicate with the Shire (District) Islamic Councils.

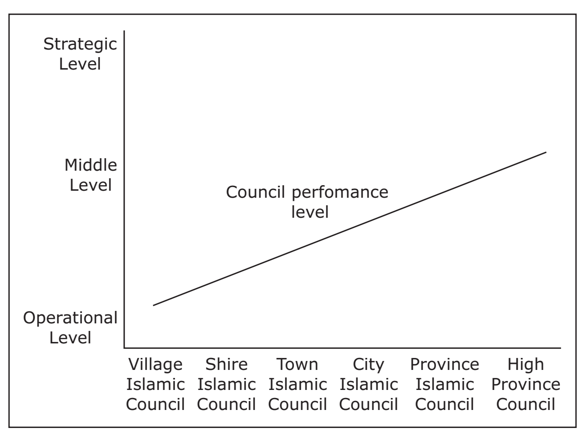

Figure 3.2. The level of the main activities of the different Islamic Councils and their possible role in watershed management.

3.6 A spatial decision support system for upper catchments

3.6.1 Introduction

The objective of estimating land suitability and agro-ecological zoning is to identify the inherent capacity of a land unit to support the most appropriate use of the soil based on specific local characteristics (soil, precipitation, temperature, and other factors) and on the preferences of decision maker. Making these evaluations for large surfaces used to be complicated because of the enormous amount of spatial data and attributes to be analyzed (Collins *et al.,* 2001). However, developments in decision theory, spatial analysis, and computers facilitate the use of algorithms that process data and spatial and non-spatial information from other sources, such as those about the environment. Also, it is now possible to incorporate and analyze the experiences and insights of people in the evaluation process, which is important because the experiences or judgments of decision makers are sometimes more important than the available biophysical information (Saaty, 1980).

The objective of this section is to propose the joint application of the analytic hierarchy process and GIS in the form of a spatial decision support system (SDSS). The purpose of the SDSS is to localize and spatially quantify the location of suitable lands for different crops and cropping systems in the upper catchments of dry mountains by means of a multi-criteria spatial analysis.

3.6.2 Analytic hierarchy process (AHP)

Multi-criteria evaluation (MCE) was introduced to GIS in the 1990s through a series of papers describing various MCE methods. These were implemented in GIS software and applied to various types of decisions. Malczewski (1999) provided an account of the methods used, including Boolean operators and simple additive weighting. A slightly more complex MCE method is the analytic hierarchy process (Saaty, 1980), which was transferred to a GIS environment by Banai (1993) and Eastman (1997). The common procedure of GIS-based MCE is to determine decision alternatives and decision criteria, establish the performance of alternatives in those criteria, and aggregate the performance values to a single evaluation score for each alternative in order to create a preference ranking.

Multi-criteria decision making in general, and the analytic hierarchy process (AHP) in particular, is a group of concepts, models, and methods to aid decision makers in describing, ordering, hierarchizing, evaluating, selecting, or rejecting alternatives based on an evaluation according to various criteria (Montserrat and Barredo, 1996). Given that not all criteria have the same importance and that each one of them contributes in a different way to the decision, the criteria should be well defined, grouped, and organized in various hierarchies (Saaty, 1980).

The AHP was designed to emulate the twofold manner in which people face situations of complex decisions; (i) an innate ability of humans to make clearly defined judgments on small problems and (ii) in the decision making process, people's experiences and knowledge are at least as valuable as the data used (Saaty, 1980). The AHP breaks a complex and non-structured situation into its components and orders them into a hierarchy. Paired comparison (pair to pair) techniques are used within each hierarchy so that decision makers can make simple judgments at each level of the hierarchy. In AHP, to make the method operational, the decision maker has to make a comparison for every pair of criteria which is, first qualitative and then quantitative and rank these comparisons on a scale from one to nine. This scale is presented in Table 3.2 The method then creates a matrix containing the pairwise comparison judgments for the criteria, from which a priority vector of the relative weights for these elements is derived. Moreover, because more information than is necessary is retrieved from the decision maker, the method can deliver an inconsistency measure. Then global priorities are calculated for each decision alternative through the aggregation of the results within each hierarchy. The mathematical bases and details for the application of the process are described in Saaty (1980).

3.6.3 Stages of the AHP

The AHP method is characterized by the phases of:

- Decomposition of a decision problem into a hierarchy of goals and objectives and their ordering

- Judgment of the relative importance weights of the attributes
- Synthesis to overall evaluation scores.

The decomposition principle is applied to structure a complex problem into a hierarchy of clusters (see Figure 3.2), sub-clusters, sub-sub-clusters, and so on. For the weighting process, Saaty (1980) proposed a pairwise comparison approach to further reduce the number of elements involved in a preference judgment.
This approach is applied to construct pairwise comparisons of all combinations of elements in a cluster with respect to the parent of the cluster. These pairwise comparisons are used to drive the 'local' priorities of the elements in a cluster with respect to their parent. In the pairwise comparison matrix, two elements are compared using a scale that ranges from 'overwhelmingly more important' (9:1) to 'equally important' (1:1) and their inverse values (down to 1:9).

The principle of hierarchical composition or synthesis to overall evaluation scores is the last step. The comparisons are synthesized to get the priorities of the alternatives with respect to each criterion and the weights of each criterion with respect to the goal. Each local priority is then multiplied by the weight of its respective criterion. The results are summed to get the overall priority of each alternative.

Structuring of the hierarchy

The simplest form (see Figure 3.3) used to structure a decision problem is a hierarchy consisting of different levels. The goal of the decision for which a

Table 3.2. Linguistic measures of preference (Saaty, 1980)

Linguistic expression of the relative importance of one member of a comparison pair relative to another	Number assigned to the linguistic expression (intensity of importance)
Equal preferences of indifference	1
Weak preference	3
Strong preference	5
Demonstrated preference	7
Absolute preference	9
Intermediate values	2, 4, 6, 8

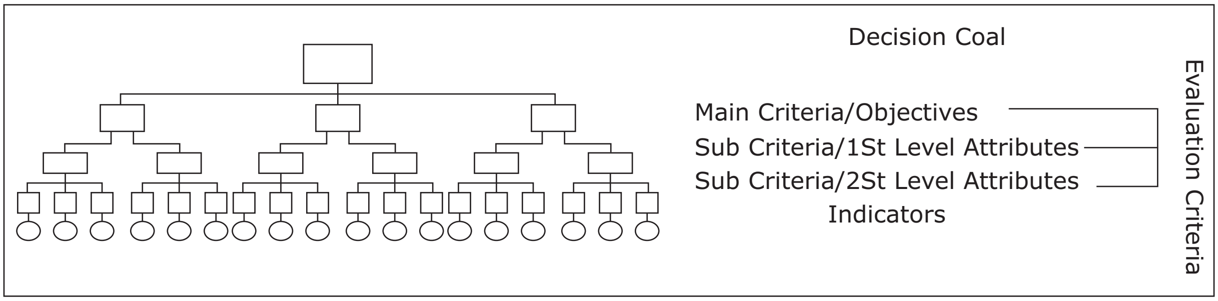

Figure 3.3 Systematic decomposition of the decision problem into main/objectives, attributes/sub-attributes, and indicators using the AHP (adapted from Saaty 1980).

solution is needed forms the top of the hierarchy. This is followed by the problem decomposed into smaller parts that state the pertinent concerns. A proper decision can be made based on these smaller parts, which are called the evaluation criteria. The evaluation criteria consist of two major types, objectives and attributes, which are also represented by different hierarchical levels. The desired condition of the system, which an individual or a group of individuals would like to achieve, is expressed by the objective or main criteria, while attributes or sub-criteria are used to characterize the respective sub-objectives.

The structuring of a hierarchy depends on the vision held about the system, the amount of information available, and on the type of interventions considered. The structure makes it possible to have a global vision of the complex relationships in the system. It helps the decision maker to determine whether the aspects obtained in each level are comparable or not.

Evaluation

The schematic overview of the evaluation process is shown in Figure 3.4 The process starts with the maps of the sub-criteria that were identified as important by the experts. These maps will be standardized and given a relative weight. The sub-criteria will be added within each one of the criteria and then added and weighted to obtain a map of continuous values of suitability. In the final phase the areas with low or null possibility of exchange for legal reasons will be eliminated from the final suitability map. Finally, the map will be classified into categories of suitability to facilitate its use.

Weighting of the criteria and sub-criteria

Sub-criteria are measured in different dimensional units and it is necessary to standardize (transform) them to a common unit (values of 0 to 1) before the analysis. The weights for the criteria and sub-criteria will be assigned by the experts. There is a risk that the weight assigned by the experts to each criterion or sub-criterion will be inadequate as a result of erroneous or incongruent paired comparisons. To eliminate such a risk, the methodology includes the calculation of a consistency index (CI) that measures the solidity of the comparisons (Saaty, 1988; Malczewski, 1999). A value of CI below 0.10 is considered adequate. Consequently, once the results are obtained, the weightings that showed an inadequate consistency (CI >0 .10) will be eliminated, and the average of the consistent weightings considered. The maps of standardized sub-criteria will be multiplied by the weights derived, resulting in the maps of weighted sub-criteria. These maps will be added to obtain a map of land suitability when it is considered as a single criterion (Figure 3.4). The procedure will be repeated in a similar way with the other sub-criteria and added to obtain the final suitability map.

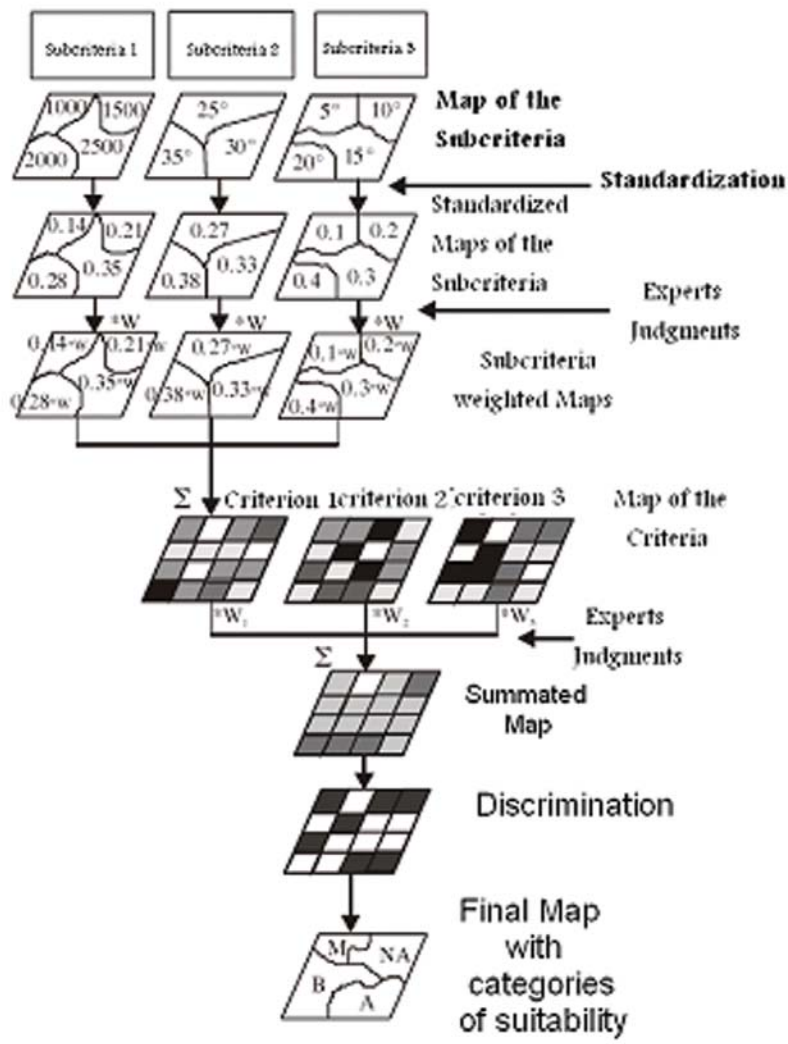

Figure 3.4. Aggregation sequence of classes and weights for the hierarchies defined in the application of the spatial AHP to define areas of different suitability in the upper catchments. (Adapted from Bustillos-Herrera *et al.*, 2007).

Chapter 4.

Developing a land-use plan for the Merek and Honam pilot catchments of the Karkheh River Basin

M. Ghafouri, M. Roghani and M.R. Tabatabaei

Chapter 4. Developing a land-use plan for the Merek and Honam pilot catchments of the Karkheh River Basin

M. Ghafouri, M. Roghani and M.R. Tabatabaei

4.1 Preamble

The development of watershed management programs based on the nexus of society, economy, and environment is required to ensure the sustainability of catchment assets. Soil, water, and vegetation conservation is achieved through IWM in order to support the residents of the catchments. In the general framework of the CPWF Livelihood Resilience project, PN24, in KRB, Iran, the development of watershed management principles was considered essential for the conservation of catchment systems. The project considered and compiled the physical attributes of the two representative sub-catchments of Honam and Merek, located in the upstream parts of the KRB. It also consulted with the stakeholders of the catchments and sought their participation in the general strategic planning, development of watershed management principles, and prioritization of structural and non-structural measures for the catchments' remedial works. The development of these catchments in line with livelihood resilience would be helpful in developing best management practices for the sustainable development of such catchments.

In the KRB, some catchments have suffered from mis-management problems, such as the clearing of native forest for agriculture and fuel, salinization of land and water, erosion, and soil degradation. Among many current issues in the KRB, is the increasing rate of wheat cultivation which is in line with the country's desire for self-sufficiency in this product. Wheat, as a strategic product, has a guaranteed purchase price, announced by the government, to encourage farmers to increase wheat production. As irrigated lands are limited and already registered to freehold owners, other farmers have started converting rangelands, mainly on inappropriate slopes, to rainfed wheat growing fields. Similar to irrigated lands, the extent of dryland farming is limited as well; therefore, farmers have pushed to claim marginal lands mainly on steep slopes which are susceptible to erosion, productivity decline, and runoff generation. The problem has been exacerbated by mis-management of these marginal lands, such as plowing along the slope and ignoring rotation in some instances. Stakeholders' interests and participation were attracted to the project. The present report focuses on the current land use, potentials, and constraints of the Honam and Merek catchments, as representative catchments of the upper KRB and has come up with a near optimum land use for improving sustainability of the catchments resources.

4.2 Study areas

Two pilot catchments, Merek and Honam, were selected for this study. The Merek catchment, with an area of 24,207 ha, is located between 34°38' and 34°09' N and between 47°04' and 47°22' E, It is located 35 km southeast of Kermanshah City in Kermanshah Province. Based on the nearest synoptic meteorological station in the study area – Kermanshah station – the catchment climate is semi-arid and cold. The average maximum daily air temperature is 37.7°C in July while the average minimum is -3.8°C in January. The average annual rainfall during the period 1966 to 2001 was about 357 mm.

Honam catchment is located in the southern part of Alashtar City in Lorestan Province. The catchment area is 14,200 ha and is located between 33°45´ and 33°51´ N and between 48°12´ and 48°28´ E. Figure 1.1 shows the KRB and the positions of the pilot catchments.

In both catchments, rainfall during autumn is about 30% of the annual precipitation, during winter about 45%, and during spring about 25%. In summer there is negligible rainfall. The coinciding of the vegetation dormant season with the peak rainfall period means that the precipitation can be stored and the aquifers recharged for subsequent use for agricultural purposes.

4.3 Problem definition

The rapid growth of the population and the need for new sources for food production has resulted in conflicts in the natural resources areas between various economic activities, such as agricultural production, raising livestock, and rural/urban residential development. Along with this, mis-management of soil and water resources and plant exploitation embedded in land-use change has intensified soil erosion and river and estuary flooding.

Research on soil and water conservation and the prevention of runoff waste and consequent flooding have produced impact assessments on human interference in nature. Knowledge of and solutions for the optimum exploitation of current resources, form a set of watershed management measures and drive the potential operation of the catchments. The constraints to the proper use of resources determine the rural development programs. Pragmatic, scientific strategies are based on the macro planning strategies of the country and the research requirements of these are ranked according to the above criteria.

In this research, the constraints, difficulties, and current potentials of each section are reviewed. Using watershed management science, proper alternatives for improving the catchment and enhancing the socio-economic conditions of the catchment's residents to improve livelihood resilience are suggested.

4.4 Methodology of integration

The integration of the basic studies in each of the Merek and Honam catchments produced land-use planning maps that show suitable land that can be allocated for specific purposes in each catchment. For instance, the areas suitable for dryland farming, irrigation, or rangeland development are delineated on the maps. The approach starts with recognition of the catchments' strengths, weaknesses, constraints, and potentials. Basic studies, such as physiographic, land use, pedology, vegetation, and socio-economic surveys and investigations are used in this process to produce recommendations for improving catchment sustainability conditions and livelihood resilience. This is the focus of this research. Looking at the current situation, we are able to determine the pros and cons of the LUT. For example, dryland farming on steep slopes causes excessive runoff and tillage erosion, or rangeland conversion to dryland farming accelerates erosion. Using the base maps of the catchments and overlaying them with other information layers we should be able to come up with a proper land-use plan. In this plan the land parcels of the catchments are used based on their potentials and erosion is minimized while production is maximized. If the recommended land use is adopted along with some recommendations on agricultural activities, erosion control, and educational/extension programs, the sustainability of the catchments assets for resilient livelihoods will be guaranteed. The importance of having a CMA in place for each pilot catchment is emphasized in the present report. The purpose of establishing CMAs is to make sure that the planned land use is operative and any land-use change is based on the plan.

4.4.1 Agricultural planning

To achieve a better understanding of the agricultural lands in the pilot catchments and to facilitate presentation of the executive plans, the existing maps of the catchments were integrated. Generally speaking, based on the suitability of the slope for agricultural activities, the existing lands are classified into the following three classes:

- Lands suitable for agriculture having slopes of less than 5%
- Lands unsuitable for agriculture having slopes of more than 12%
- Lands with a potential for agriculture having slopes of less than 12% and with no limitation for farming.

Lands unsuitable for agriculture should be used in conjunction with some auxiliary systems and made economically viable for agricultural activities while, at the same time remaining environmentally sustainable. So conversion of rangelands to agricultural lands should be accompanied by training classes for both users and authorities. Rainwater harvesting systems can be used on lands having slopes of more than 5% for growing almonds and walnuts. Also, forage production should be encouraged for livestock; this would reduce grazing pressure on the rangelands in both catchments.

4.4.2 Rangeland remediation program

In both pilot catchments, some general rule guides for rangeland remediation can be given.

- Implement grazing management on good condition rangelands with slopes above 30%
- Undertake dense seeding or plant seedlings on rangelands with average to poor conditions and having slopes of less than 20%
- Implement seeding or plant seedlings on rangelands with average to very poor conditions and having slopes of between 20 and 30%
- Undertake seed distribution on rangeland with average to very poor conditions and having slopes of between30 and 40%
- Implement a mass planting of seedlings for rangelands of average to very poor condition and having slopes of between 40 and 60%
- Totally exclude agricultural activities on rangelands with slopes above 60%.

As both pilot catchments have an annual rainfall of around 400 mm, there are no limitations to rangeland improvement.

4.4.3 Soil erosion control planning

Soil conservation and erosion control is a major part of any integrated watershed management plan. Presenting conjunctive plans for the optimum use of catchment resources results in the control and reduction of the erosion rates in the catchments. To reach such a goal, erosion types within the two catchments were considered based on the existing data and methods from the erosion studies. Parts of the catchments have a surface erosion type that decreases crop production and, consequently, the revenue of farmers. Soil erosion studies showed that the highest erosion in the Merek catchment occurs over land units PI111 and PI331 in the form of tillage and water erosion, therefore, some mechanical/structural measures need to be considered for these areas. Structural measures include gabions, masonry, etc. to control sediments. These structures are built across some parts of the steep stream network. The sediment collected by these structures provides a good ground for planting trees or, in some cases, for forage crops. It should be noted that both biological and structural methods should be used in the two catchments.

4.4.4 Flood prone areas, flood generation and spatial effects

Flood prone, flood generation, and recharge areas are recognized by considering vegetation maps, slopes, and soil permeability indexes. Generally speaking, for flood control planning, some of the following information is needed:

- Flood prone areas, such as agricultural lands and residential areas with very gentle slopes
- Flood generation areas, having slopes greater than 20% and soils with low to very low permeability
- Spatial distribution of flood generation areas over the catchments; this is important for deciding on the locations for flood control structures.

4.4.5 Executive recommendations

This section, Executive recommendations, looks at the total planning for agriculture, rangeland, erosion control, flood control, and development programs in the catchments. Generally speaking in agriculture, it is suggested that most lands with slopes below 5% are suitable for irrigation. At the same time, water resource deficiencies need to be overcome as follows:

- Check dams constructed across water ways and floodways for recharge of groundwater
- Small dams constructed to collect surface runoff
- Rainwater catchment systems constructed for rainwater harvesting
- Change crop production patterns to fit the climate and soil/water resources
- Use new irrigation systems and reduce irrigation water losses in farms and orchards
- Promote community participation in projects for livelihood improvement.

In rangeland sections, biological measures, such as seed distribution, mass seeding and planting of seedlings, planting seedlings, and proper management of rangelands, such as grazing control, livestock commuting control, enclosure, and the water supply for livestock, are to be considered.

Improvement in the vegetation cover of the catchment and adoption of proper agricultural activities results in erosion control, which has positive outcomes on both the agricultural and livestock production of the catchment. Also, construction of suitable structural works can help to contain sediments within the catchment.

Conjunctive and integrated use of the above mentioned biological and mechanical works, together with proper managerial measures, can create clear and optimistic horizons for the rural people. Correct implementation of the plans presented by authorities and decision makers has an important effect on the environment, livelihoods, and economy of the catchment.

4.5 Investigation of the potential, strengths, weaknesses, and constraints of the Merek catchment

Strengths, weaknesses and constraints of both the Merek and Honam catchments have been specified based on the physiographic information available in the GIS reports of the catchments and land use. The classification of land for either dryland farming or orchards, according to its slope, is based on both local experience and engineering judgments.

4.5.1 Merek catchment strengths

- Feasibility of using community participation in reaching the development goals in the region
- Existence of extensive lands with suitable slopes for irrigation i.e. lands with slopes less than 3 to 5% comprise 45% of the total catchment area
- Existence of suitable hillsides for dryland farming of orchards with slopes of between 5 and 12% comprise 25% of the catchment area
- Annual rainfall of 350 mm with a total precipitation of 84.72 million m^3, which plays a significant role in water resources related projects (242.07 km^2*0.35m = 84.72 million m^3)
- Existence of suitable rangelands
- Reasonable yields of the current limited number of orchards in the region shows the potential of the catchment for developing new orchards
- Presence of a rather long wet season in the region
- Existence of suitable quarries and borrow pits
- Communal properties and livestock production in the area
- Existence of suitable sites for multi-purpose runoff storage for agriculture, raising livestock, groundwater recharge, ecotourism and recreation, fisheries, environmental improvement, and wild life
- Land-use diversity, such as forests, rangelands, irrigation, dryland farming, and the potential for dryland orchard development.

4.5.2 Catchment constraints

- Some of the land users distrust the executive sectors' plans
- Signs of ineffective community participation in the previous projects
- Large average number of frost days in a year.

4.5.3 Catchment weaknesses

- Groundwater level drawdown, as shown in water resources studies of the Merek catchment
- Uncontrolled irrigation lands with no attention to their potential
- Occasional flooding causing property damage
- Erosion of rangelands and agricultural farms
- Unsuitable rangeland plant types
- Unsuitable management and the negative trends of the rangelands
- Improper plowing and acceleration of erosion and decline of fertility
- Improper land use
- Low income of rural families
- Lack of modern irrigation techniques, such sprinkler and drip irrigation systems and wastage of water
- Water loss during conveyance in the traditional, unlined channels
- Users unaware of new technologies for better operation
- Lack of integrated management in the optimum operation of catchment resources.

4.5.4 Catchment potentials

Analysis of the observed rainfall and runoff data shows a very low annual runoff coefficient of 4.3% for Merek; this is a consequence of the flatter slopes of the plains area of the catchment. While the plains area is suitable for irrigation, the highlands of the catchment, with their steeper slopes, have higher runoff generation potential. Runoff generated during the rainfall seasons of autumn, winter, and spring, can be used for groundwater recharge. Figure 4.1 shows the time distribution of flow at the Merek gauging station where the winter and summer months have the highest flow. Briefly, the catchment potentials are as follows:

- Feasibility of controlling 61.04 million m^3 (57.4 million m^3 + 3.64 million m^3 = 61.04 million m^3) of runoff in the form of surface storage, ground water recharge, flood irrigation, etc. as shown in water resources studies of the Merek and Honam catchments
- Possibility of rainwater harvesting and control of part of the average annual precipitation (132 million m^3) over the catchment
- Possibility of ground water recharge for agricultural water needs and recovery of water level drawdown
- Expansion of agricultural lands under both irrigation and dryland farming
- Potential for small dam construction for aquifer recharge, recreation and ecotourism, and fisheries
- Establishment of quick producer enterprises, such as mushroom production, honey bees, closed shelter livestock breeding, and fisheries for the livelihood resilience of catchment residents and for reducing stress on the rangeland and other resources, thus facilitating their recovery
- Using rainwater harvesting systems on sloping lands to develop rainfed orchards for species such as walnuts, almonds, and other fruit trees
- Develop conversion industries parallel with production in agriculture
- Develop the land in the valleys and establish orchards
- Rainfed forage production for semi-industrial livestock breeding to reduce the pressure on rangelands and facilitate their recovery
- Establish factories for livestock feed production using the remnants of

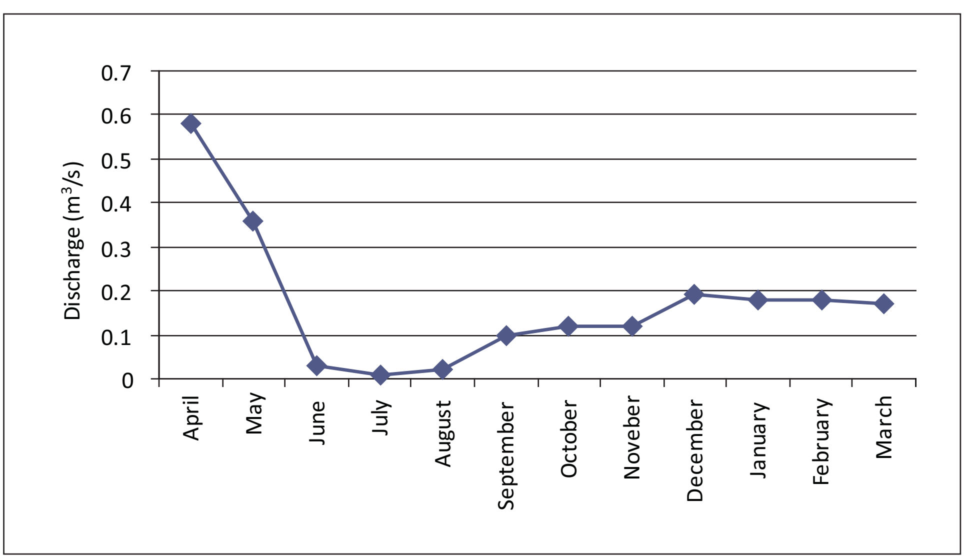

Figure 4.1. Flow chart of the planning for IWM

husks and plants, such as the by-products from sugar beet factories, to reduce the dependency on rangelands

- Develop oak forests along with other management programs
- Possibility of implementing remediation and recovery projects including seeding and planting seedlings
- Possibility of increasing the revenues of catchment residents using the above plans.

4.5.5 Groundwater investigation in the Merek catchment

Among the catchment weaknesses identified in section 4.5.3 is groundwater drawdown, which is occurring at an alarming rate and should be managed by balancing it with the excess catchment runoff and recharge.

The depth of the water table at the south eastern edges of the catchment plain, at Mahidasht, is from 5 m to more than 10 m. This depth decreases to from 1 m to 5 m in the north western part of the plain, towards the Merek River. In the central regions, the water table depth is low and gradually increases towards the western and eastern edges and also towards the mountains. The maximum water table depth is in April and the minimum is during November to December. Investigations during the water years of 1997/98 to 2005/06 showed that the annual drawdown of the water table in the catchment was considerable and was gradually increasing. Table 4.1 shows the average water table depth during the above nine year period.

According to the data in Table 4.1, the average water table depth in the Merek catchment dropped from 7 m in 1997 to 14.2 m in 2006: a total of 7.2 m drawdown in nine years. Besides the considerable drawdown, the annual water table fluctuation increased as well – from 2 m in 1997 to 5 m in 2006.

The groundwater unit hydrograph in Figure 4.2 indicates that the drawdown can be replenished during the wet months, thus flood spreading and recharge measures can help the system regain its balance.

Integration of the existing potentials of the catchment, such as alluvial fans, rainfall in the dormant season, considerable area of land suitable for

Table 4.1. Average water table depth of the Merek catchment during the period 1997 to 2006

Water year	Water table elevation (m)	Average water table depth (m)	Average water table fluctuation (m)
1997/98	1397.3	7	2
1998/99	1397.2	7.1	1
1999/2000	1397.1	8.2	3
2000/01	1397.1	8.2	3
2001/02	1393.2	12.1	5
2002/03	1391.2	14.2	3
2003/04	1391.3	14.1	5.1
2004/05	1390.8	14.6	4.7
2005/06	1391.2	14.2	5

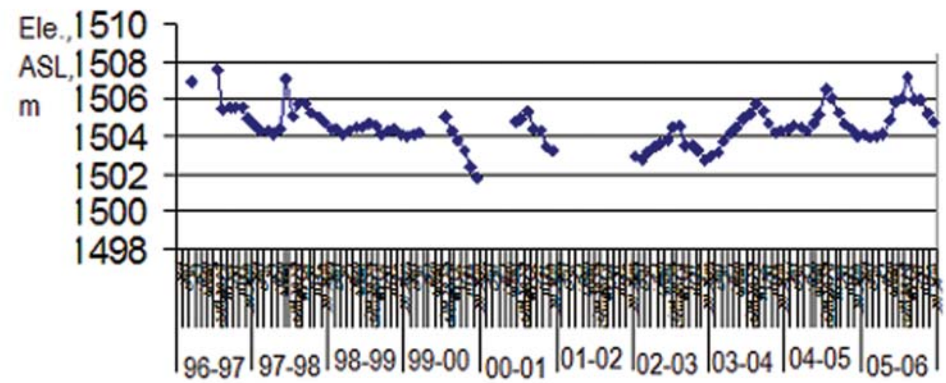

Figure 4.2. Ground water elevation (m), Merek catchment

irrigation, and people's desire for better situations and their willingness to cooperate in the region's development can guarantee the success of the watershed management works.

4.5.6 Suitable recharge areas of the Merek catchment

The alluvial fan sediments (Qf) in the Merek catchment have an area of 826.2 ha. This constitutes 3.41% of the catchment area, which is far less than the area of the agricultural lands. Although the area of the alluvial fans is limited, it does provide an opportunity for the recharge of ground water. In addition to new alluvial fans (Qal) with an area of 390.6 ha, the total area suitable for recharge comprises 5.2% of the catchment area.

Table 4.2 and Figure 4.3 show the extent of each of the geologic formations of the catchment.

4.5.7 Merek shallow groundwater system

There are four qanats in this catchment and the total volume of water carried during the period October 2006 to September 2007 was 2.2 million m^3. Some villages take their drinking water (about 0.25 million m^3 per year) from these qanats, while other villages use well water (about 0.033 million m^3 per year). The qanat monthly yield curves are shown in Figure 4.4.

4.5.8 General recommendations

The following recommendations are made to improve catchment stability and the livelihood conditions of the residents.

Animal husbandry and rangelands

- Remediate and recover the rangelands including seed distribution, planting seedlings and planting multiple varieties of seedlings
- Operate enclosures in areas with high erosion, rock lands, and steep slopes of between 40 and 60%
- Implement rangeland management, such as grazing systems and control of livestock entrance and exit times
- Implement rangeland projects on communal lands
- Convert traditional livestock raising and husbandry to semi-industrial and modern types to reduce stress on the rangelands and provide for the possible exploitation of the industrial and herbal plants of the catchment

Table 4.2. Area and percentage of geologic formations of the Merek catchment- (Soil Studies Report).

Geologic formations	**Area**	
	ha	**Percent**
Sarvak	1,350.7	5.58
Ilam	2,796.2	11.55
Gorpi	2,647.9	10.94
Amiran	126.8	0.52
Kashkan	2,970.3	12.27
Shahbazan	767.3	3.17
Old alluvial terraces	4,497.2	18.58
New alluvial terraces	72.5	0.3
Alluvial fans	826.2	3.41
Agricultural lands	7757.1	32.05
New alluvial sediments	390.6	1.61
Total	24,208.8	100

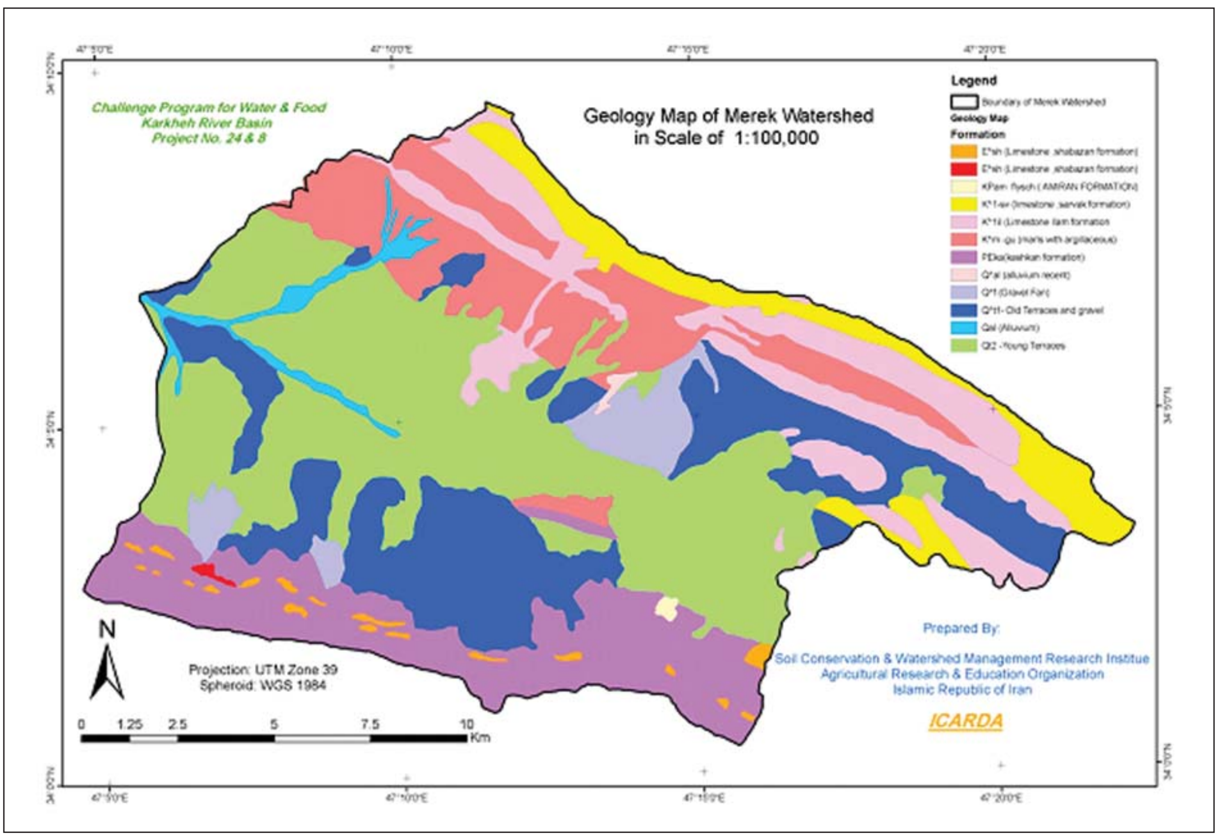

Figure 4.3. Merek geological map and the locations of suitable recharge areas.

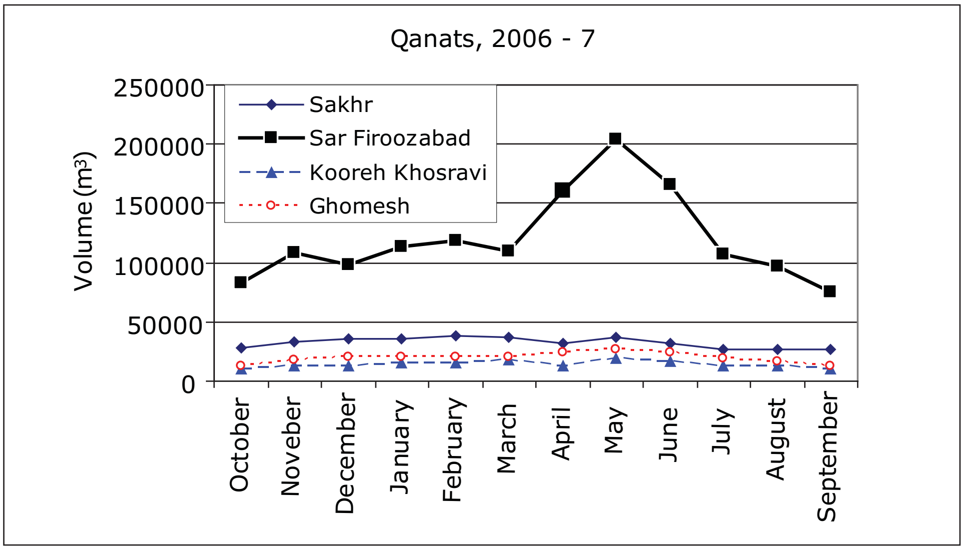

Figure 4.4. Monthly discharge curves of the Merek qanats 2006/07

- Promote rainwater catchment systems in order to provide trough and water reservoirs for livestock
- Prevent the allocation of rangeland for agricultural activities
- Construct sanitary places for livestock.

Agriculture

- Change the agricultural systems especially the irrigation methods
- Develop rainfed orchards on steep lands along with facilities for supplementary irrigation during periods of drought or water shortage
- Extend crop rotation and suitable cropping patterns

- Convert low producing dryland farms to orchards and forage production
- Prevent irrigation of lands with slopes greater than 12% and also of areas with shallow soils
- Adopt modern management methods in dryland farming
- Expand irrigation on suitable areas
- Line traditional channels to reduce conveyance losses of water
- Form NGOs for community participation in projects like the establishment of orchards on steep slopes.

Reduction of flood hazards

- Conserve and enclose on a rotational basis more than 60% of the lands, especially lands with natural erosion, such as colluvial lands
- Improve vegetation cover by seeding, planting seedlings, mass seeding, and planting bushes on hill slopes along with developing forests in suitable areas
- Introduce better farm management practices, especially plowing operations for steep slopes
- Construct suitable mechanical structures for runoff control and collection
- Base soil conservation and land-use planning on land suitability and erosion control
- Plant seedlings and develop orchards along floodways and stream networks
- Prioritize watershed management measures in the sub-catchment based on their spatial effects during flooding.

Water resources

- Construct troughs and water reservoirs for livestock in various parts of the watershed area
- Use the water collected behind the control structures
- Develop rainwater catchment/ harvesting systems for agriculture, industry, and recreation
- Implement aquifer management and recovery.

Recreational regions

- Build a small dam in the northern parts of the sub-catchment, especially the northwestern part, and plan the multi-purpose use of water for recreation, fisheries, aquifer recharge, flood control, and soil and water conservation, while still supplying the water requirement of downstream lands
- Undertake roadside beautification using rainwater harvesting systems and supporting systems to collect the runoff from roads
- Protect parts of the catchment highlands as parks and wildlife support areas.

Some of the sites suggested for different purposes are shown in Figures 4.5 to 4.7.

Recommendations for economic, industrial, and educational issues

- Establish a suitable operational system for land use with the objective of rangeland recovery and balance livestock numbers against rangeland capacity while allocating adequate resources for livestock producers and nomads and encouraging them to participate in natural resources remediation projects
- Train livestock producers on the

Figure 4.5. Suggested dam site in the northwestern part of the Merek catchment-looking downstream (See Figure 4.3 for the locations in the catchment)

Figure 4.6. Suggested dam site in the northwestern part of the Merek catchment-looking upstream

Figure 4.7. River bed conditions at the dam site with the objective of runoff infiltration, Merek catchment

sustainable operation of rangeland

- Train farmers on proper irrigation and farming practices
- Provide the facilities required for livestock producers, such as water troughs, animal immunizations and vaccinations, fuel supply, fertilizers, and forage supply
- Encourage community participation in the implementation of watershed management projects and explain the benefits of these projects to the community
- Introduce land users to the banks and support them in their applications for financial facilities.

4.5.9 Current land use in Merek

Socio-economic studies show that the major activities in the Merek catchment are farming and animal husbandry. The major LUT in the catchments include irrigated and rainfed agriculture and rangelands. Therefore, watershed planning should be directed towards improving the economic conditions of the people in the region and the watershed management measures should consider these facts. Figure 4.8 shows the land use of the catchment as extracted from the Landsat ETM + Image 2002. This map shows some clear differences from the current land use on the ground when field inspection is performed. For example, the actual extent of the irrigation operation is bigger than that shown on the map.

As shown in Figure 4.8, large parts of the middle sections of the catchment are potentially suitable for irrigation. However, irrigation is limited because of deficiencies in the water resources.

The constraints to dryland farming are mainly soil, topography, and, more specifically, the amount of rainfall and its seasonal distribution. In this regard,

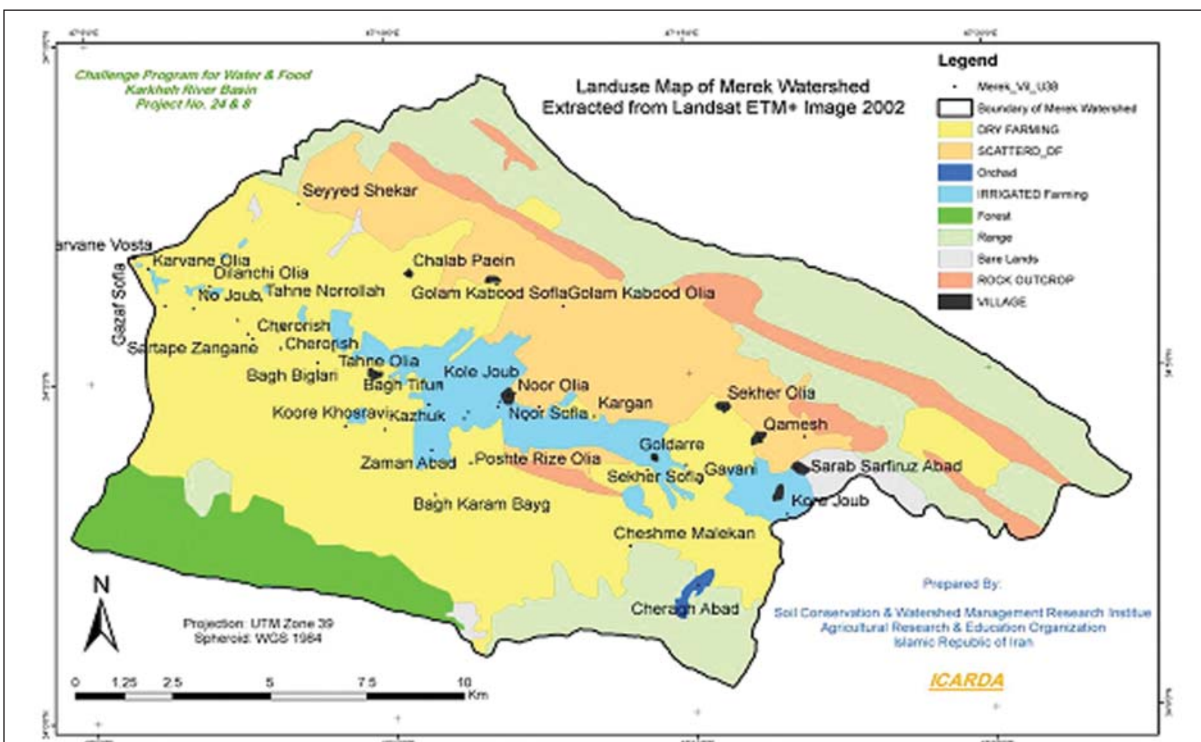

Figure 4.8. Current land-use map of the Merek catchment

the future is bleak for the region with some rainfed farming taking place on steep lands with slopes of up to 20%. Integration of the information to produce a sustainable plan has been focusing on these current facts. Figures 4.9 to 4.17 show the outputs of the decision model in the GIS environment. The development of executive programs should give due consideration to the alternatives presented here, which have a large role in the sustainable exploitation of the catchment resources.

4.5.10 Integration of data for total catchment land-use planning in Merek

To develop an optimum land-use plan for the catchments, the rules and criteria that need to be followed should consider the constraints and the potentials. Different data layers can be used in this process. However, data limitations need to be noticed. By using topography, soil, vegetation, erosion potential, and current land use in a GIS system and making queries and overlaying operations, suitable areas for dryland farming, irrigation, orchards, and rangelands/forest development in the Merek catchments were found (Figure 4.9). In the operation, some other resources, such as surface and ground water, and descriptive data, such as a socio-economic surveys were taken into consideration as well. Following are the GIS criteria for finding near optimum land use for the catchment. Note that the maps that were produced using the criteria explained below were integrated to obtain the final suggested land-use plan for the Merek catchment (Figure 4.17). This plan depicts the areas suitable for irrigation, dryland farming, rangeland, and forest development, etc. It should be noted that suitability for irrigation, for instance, does not necessarily mean that water is available for irrigation farming. Thus, any plan for irrigation should consider the availability of water and the downstream water rights as well. The GIS criteria for different land uses were as follows:

- The GIS criterion for locations suitable for irrigation farming include (Figure 4.10) a suitable slope of less than 5%, land units suitable for irrigation and the type of crop, and land suitability descriptive data. (Criterion 1). The land identified by this criterion is suitable for both irrigation and dryland farming, but the proportions of each depend on the water availability

Criterion 1:

Slope less than 5%, suitable features of the pedology map (PI121, PI132, PI331, and PI231), and land suitability descriptive data

- Defining GIS criterion for locations suitable for upland dry farming (Figure 4.11). This criterion is based on the attributes of Criterion 1 plus water and tillage erosion maps. Some other land units are considered as well

Criterion 2:

Slope greater than or equal to 5% and less than 10%, and pedology map features (PI121, PI132, PI331, and PI231)

- Defining GIS criterion for locations suitable for the mixed cropping of orchards and forage dry farming (Figure 4.12)

Criterion 3:

Slope between 3% and 12% and soil units from pedology map features (PI111, PI131, HI231, HI121, HI111, and HI221) Slope between 10% and 12%, pedology map features (PI121, PI132, PI331, and

PI231), water and tillage erosion (PI131 and PI111), and using land suitability descriptive data Vegetation Types Map Field survey

- Defining GIS criterion for locations suitable for orchard dry farming (Figure 4.13)

Criterion 4:

Upper part of the catchment
Slope between 12% and 30%, pedology map features (PI111, PI131, PI331, HI231, HI121, HI111, and HI221)

Lower part of the catchment
Slope between 12% and 30%, pedology map features (PI121, PI132, and PI231)

- Defining GIS criterion for locations suitable for range seeding and afforestation (Figures 4.14 and 4.15)

Criterion 5:

A: Range
Slope greater than 30% and soil units of HI121, HI361, PI121, HI111, PI131, PI132, PI231, PI111, HI231, HI221 and PI331

B: Range-forest or Forest
Slope between and soil units of MO353, MO342, MO212, MO211, MO321, MO332, MO322, MO312 and MO311

4.5.11 Application of the methodology to Honam catchment

Honam catchment, as part of Sarab Seyed Ali watershed, lies between 33°30' 15'' and 33°37'11'' N and between 49° 08'00'' and 49°17'35'' E and has an area of 140.16 km^2. The highest elevation of the catchment is at 3560 m above sea level (asl) and lies in the east of the catchment. The lowest point is at 1480 m asl and lies in the west of the catchment near the outlet. The mean elevation of the catchment is 2051 m and its average annual rainfall is 554 mm. Considering the area of the catchment and the amount of rainfall, the average annual volume of precipitation is 77.65 million m^3.

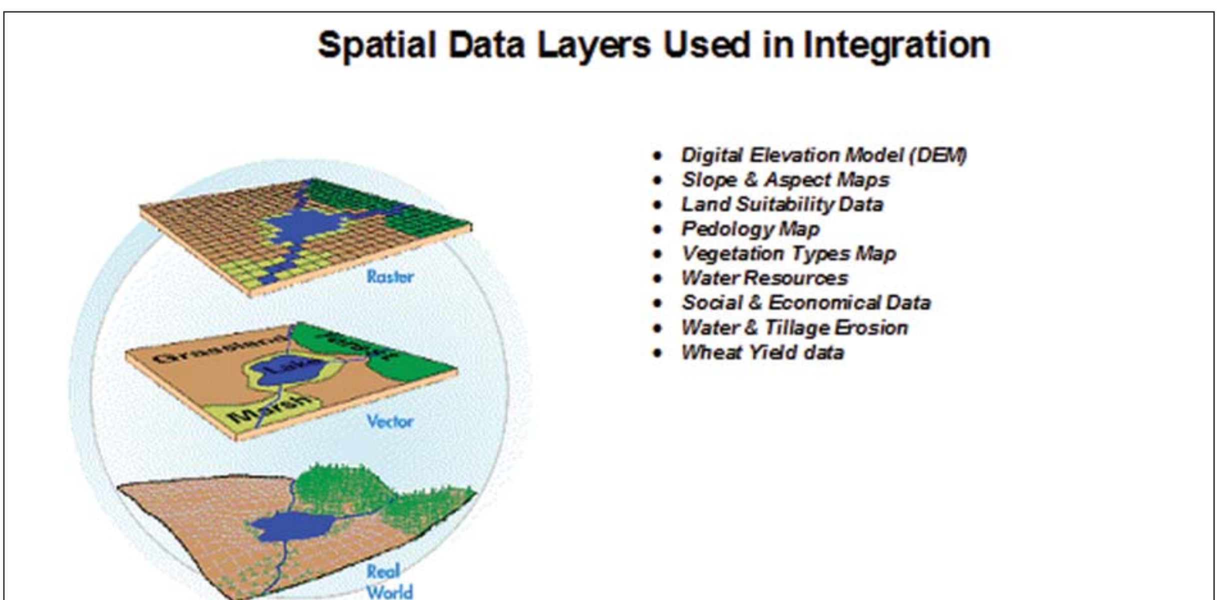

Figure 4.9. Integration of data layers in GIS

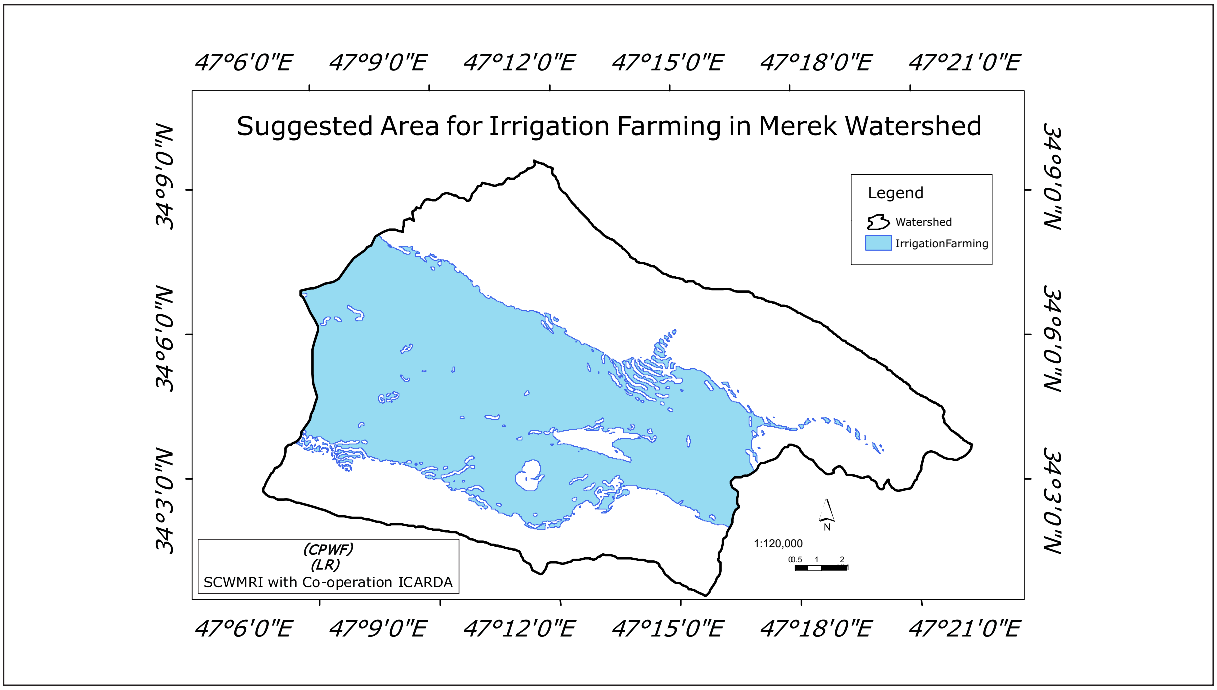

Figure 4.10. Location of lands suitable for irrigation in Merek (based on Criterion 1)

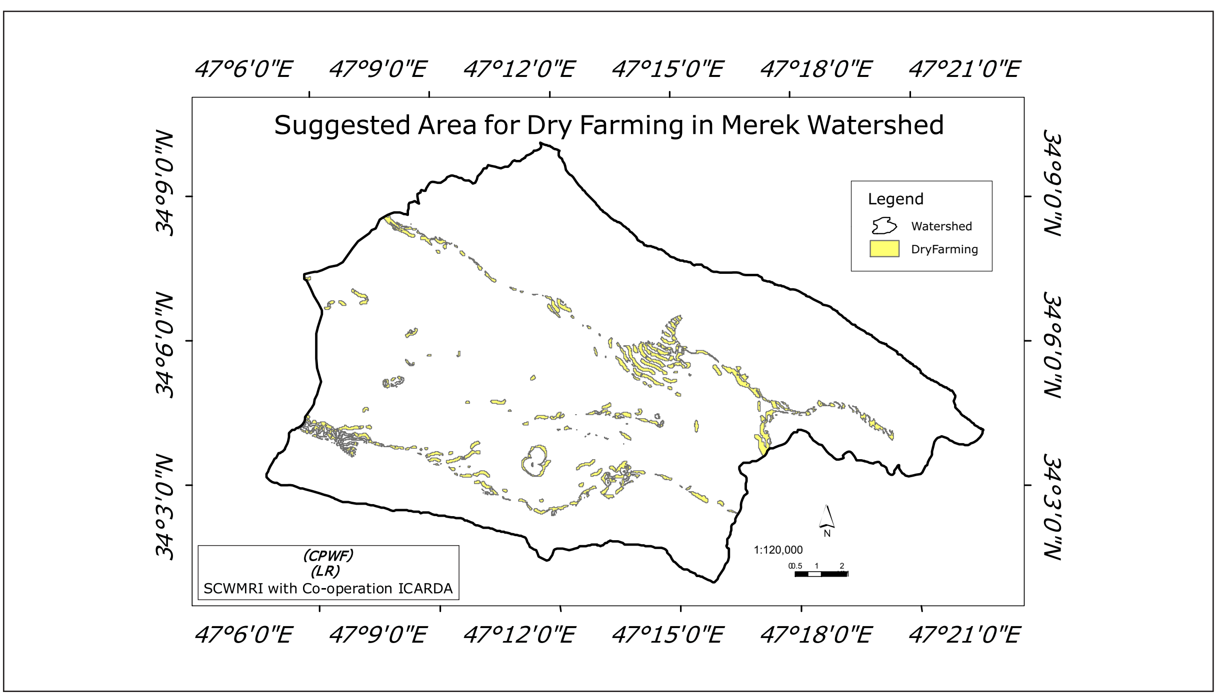

Figure 4.11. Location of lands suitable for rainfed farming in Merek (based on Criterion 2)

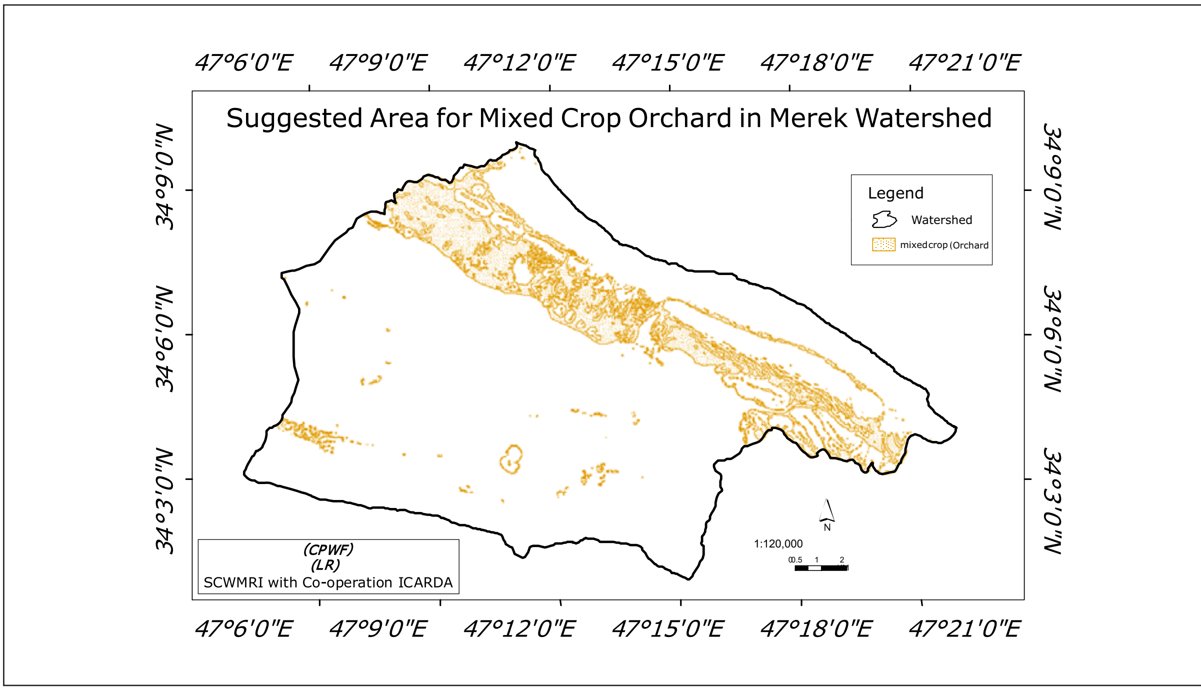

Figure 4.12. Location of suitable lands for mixed cropping of rainfed orchards and pasture in Merek (based on Criterion 3)

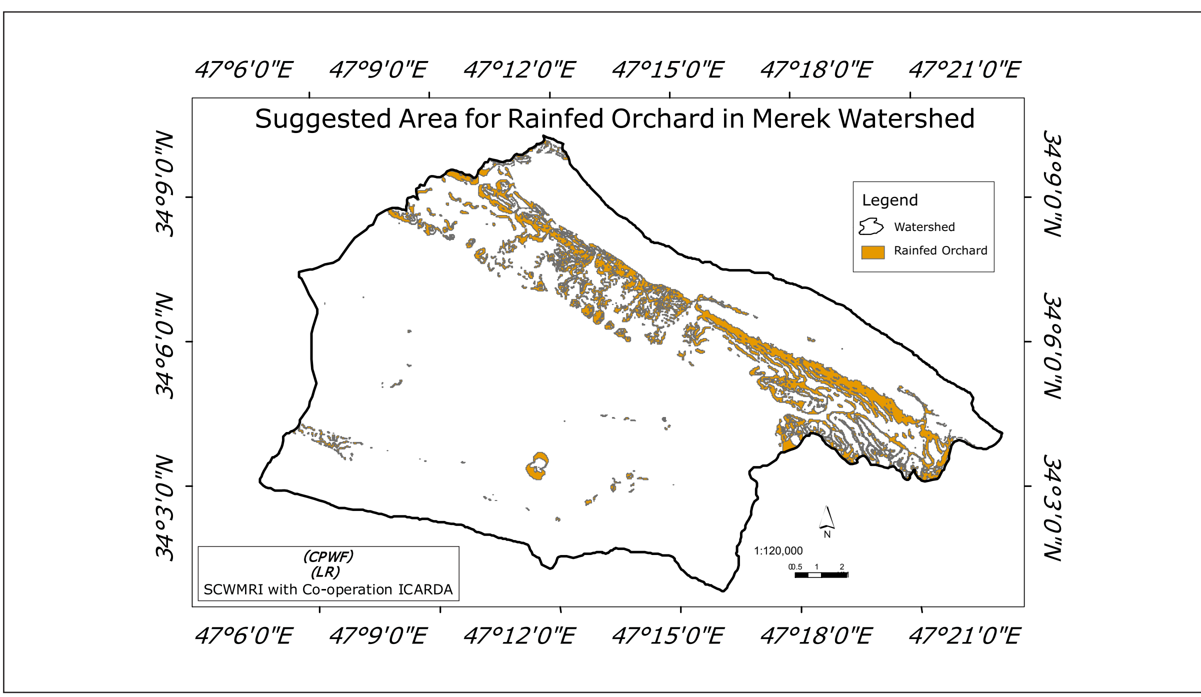

Figure 4.13. Location of suitable lands for rainfed orchards in Merek (based on Criterion 4)

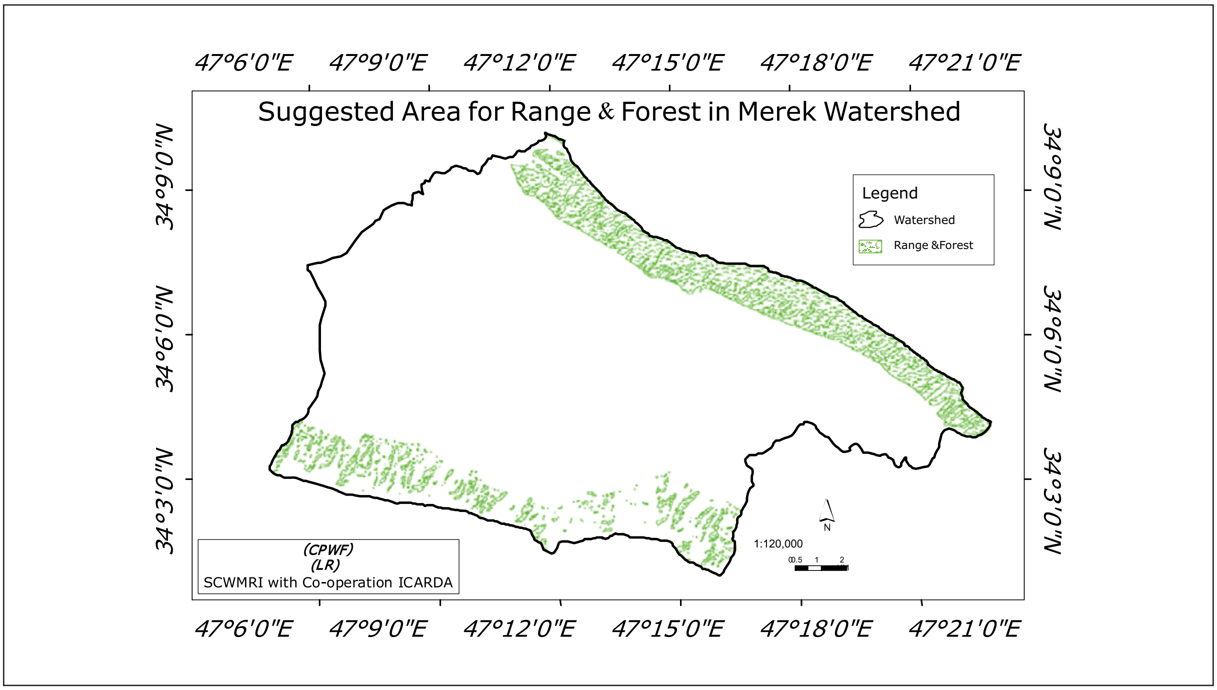

Figure 4.14. Location of suitable lands for developing forest and rangelands in Merek (based on Criterion 5)

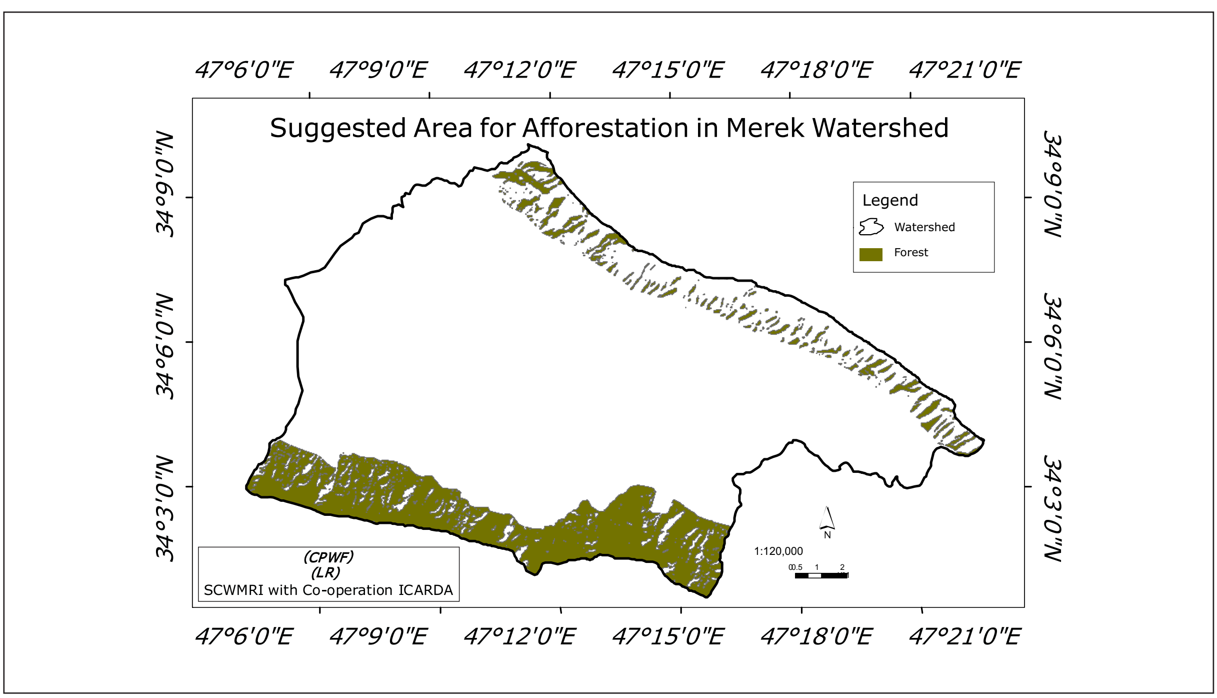

Figure 4.15. Location of suitable lands for developing forest in Merek (based on Criterion 5)

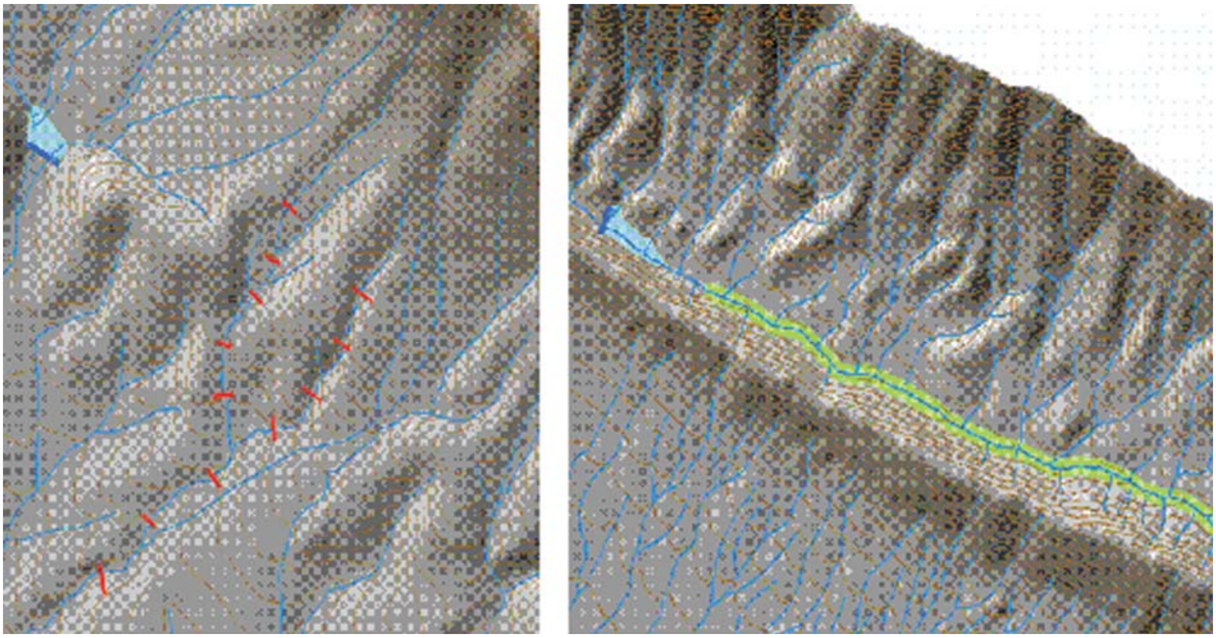

Figure 4.16. Samples of typical suggested dam sites for runoff collection for groundwater recharge (left) and tree planting along the valley (right)

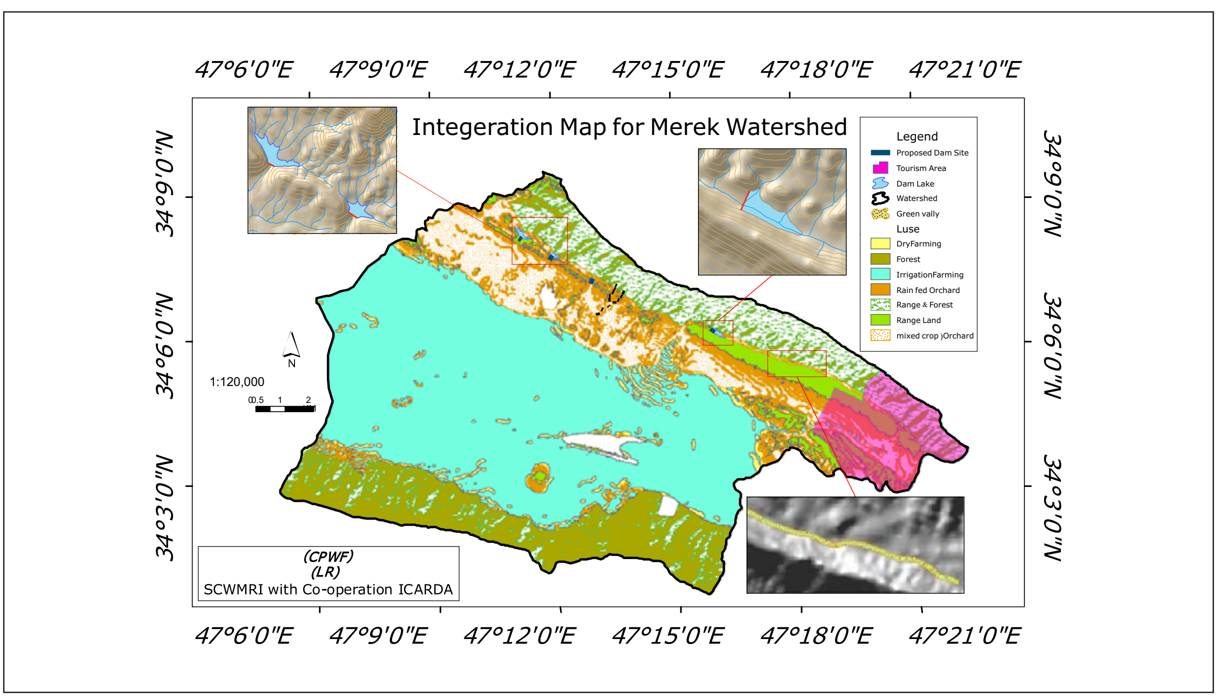

Figure 4.17. The integrated plan for suggested land use for the Merek catchment

Simple calculation indicates that the runoff coefficient in the Honam catchment is 0.44 which is 10 times that of the coefficient in the Merek catchment. The high runoff coefficient implies the importance of surface water in the region. The annual surface runoff volume in Merek is 5.435 million m^3 while that in Honam is 57.432 million m^3 which dictates a greater use of runoff control structures, such as check dams and small reservoirs. Figure 4.18 illustrates the general landscape of the Honam catchment.

The methodology explained for Merek was applied also to the Honam catchment, Lorestan Province. Current land use in the catchment is shown in Figure 4.21, and the results of the integration exercise are shown in Figure 4.28 for comparison.

4.5.12 Catchment strengths

In this section, only the specific strengths of Honam catchment are listed and those similar with Merek catchment are not included to avoid redundancy.

- Existence of extensive steep lands covered with soil with slopes of between 15 and 40%
- Annual rainfall of 554 mm with a total precipitation of 77.65 million m^3 which plays a significant role in water resources related projects
- Existence of extensive suitable rangelands
- Limited presence of orchards over the flat lands and steep lands, which shows the capability of catchment in developing dryland farming orchards
- Annual runoff volume of 57.432 million m^3
- Existence of different water resources, such as springs and qanats.

Figure 4.18. A general view of Honam catchment

4.5.13 Catchment constraints

- Considerable number of frost days
- Small area of flat lands for agricultural development

4.5.14 Catchment weaknesses

- Lack of integrated management for optimum exploitation of the catchment resources
- Shortage of lands with gentle slopes for irrigation development
- Dryland farming over steep lands
- Flooding in the catchment with occasional property damage
- Negative trend of rangelands
- Use of improper irrigation methods over rather steep and hilly lands.

4.5.15 Catchment potential

Comparison of the outlet discharges of the Honam and Merek catchments explains the significant differences between the physical and hydrological characteristics of these two pilot catchments. When planning for catchment management, these differences should be considered. Given these differences, using one typical plan for both catchments is incorrect. Instead, a specific plan needs to be designed by experienced experts for each catchment.

Water resource studies of the Honam catchment show that this catchment has far better conditions than that of the Merek catchment. There are many springs with rather high yields, such as Peresk spring, which can compensate for water shortages in both the middle and the lower parts of the catchment. Figure 4.19 shows the average monthly discharge of the Honam outlet. The most significant part of the discharge is in April and May, while the minimum discharge occurs in October and November.

Investigation of the deep wells in the catchment shows that the water table of the upper parts, i.e. the Peresk area, is around 35 m deep and it decreases by 0.5 m as one moves downstream toward Farajolahi village. Although the extent of arable land is small in this catchment because of the rough topography, the use of groundwater may be considered for irrigating some drylands in the lower parts. The residents suffer many limitations because of the rough topography and geologic conditions in this catchment. Rocky steep lands and limited arable lands are among the main limitations. Figures 4.20 and 4.21 show the geology and current land use of the Honam catchment. Other potentials for Honam catchment are summarized as follows:

- Feasibility of controlling 10 million m^3 of surface runoff
- Possibility of water storage, ground water recharge, flood irrigation, etc. (Water Resources of Merek and Honam Report)
- Possibility of rainwater harvesting and control of a portion of the average annual rainfall over the catchment
- Potential for developing and improving the dryland faming of forage crops for semi-industrial livestock production, thereby reducing pressure on the rangelands

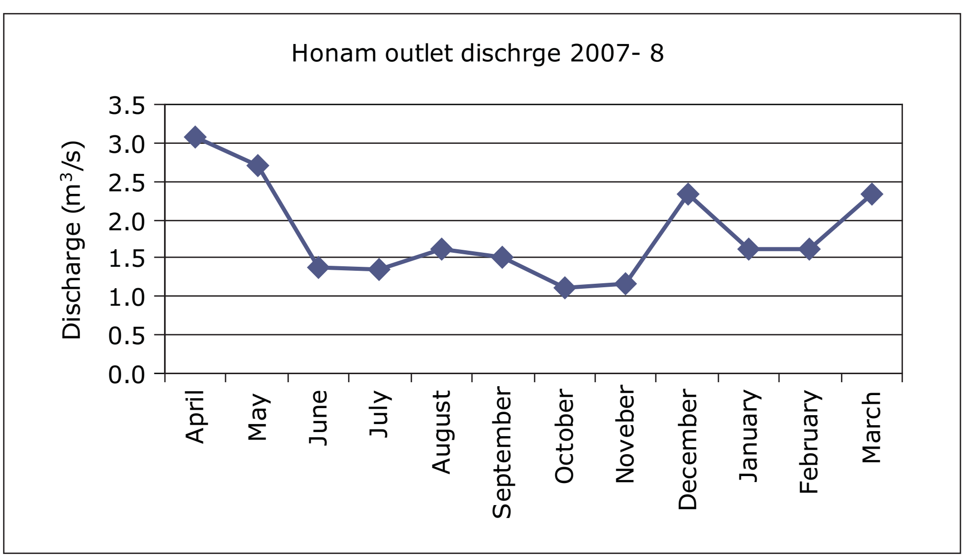

Figure 4.19. Honam outlet discharge 2007/08

- Possibility of developing industrial
- factories for livestock feed production using the by-products of harvests from the farms and waste from the sugar beet factories
- Possibility of developing oak forests and plantation of new suitable and economically valuable trees.

4.5.16 General recommendations

The recommendations made here are similar to those for the Merek catchment; however, the criteria for land-use planning are somewhat different and are determined, in the main, by the slope of the land as shown in Table 4.3.

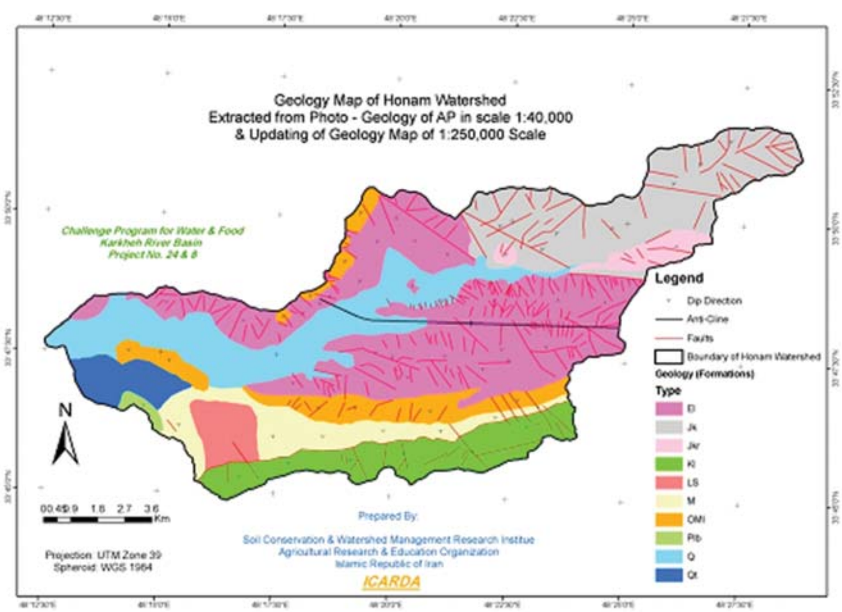

Figure 4.20. Geological map of the Honam catchment

Table 4.3. Suggested land use for Honam catchment

Figure	Slope (%)	Aspect	Suggested land use
4.22	0 - 5		Irrigation farming
4.23	5 - 12		Irrigation expansion
4.24	0 - 12		Dryland farming
4.25	12 - 30		Rainfed orchards
4.26	> 30	NW, N, NE and W	Forest plantation
4.27	> 30	SW, S, SE and E	Rangeland

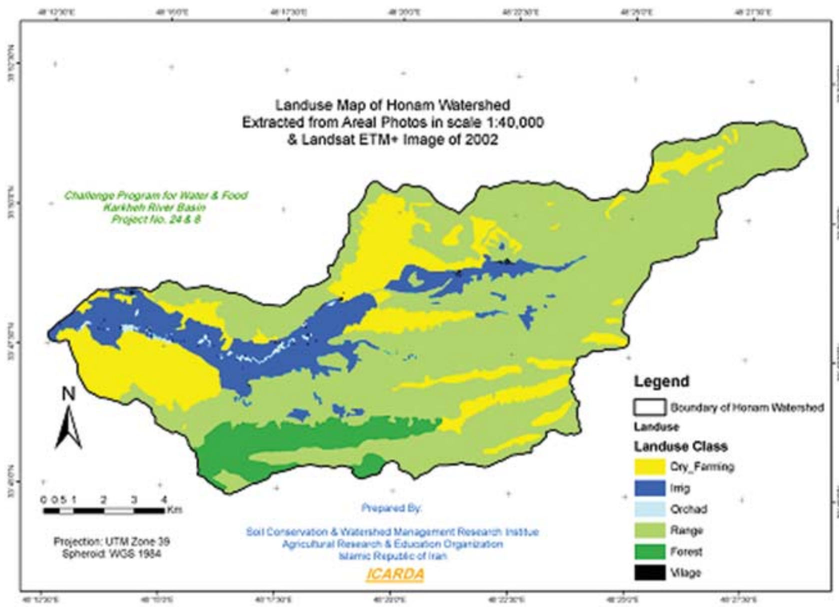

Figure 4.21. Current land use of the Honam catchment

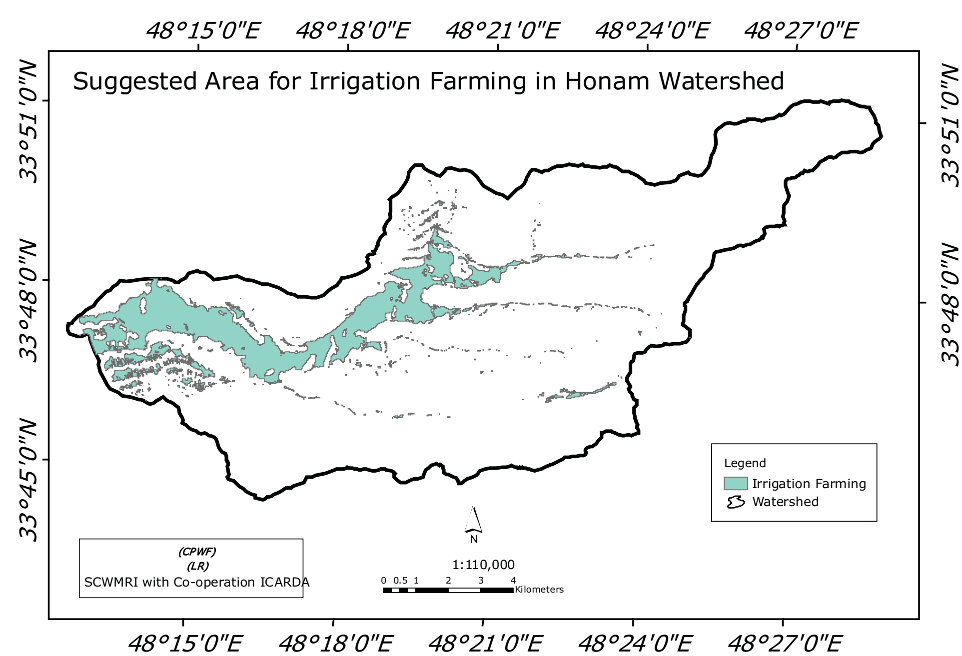

Figure 4.22. Suggested area for irrigation farming under the present conditions in Honam catchment

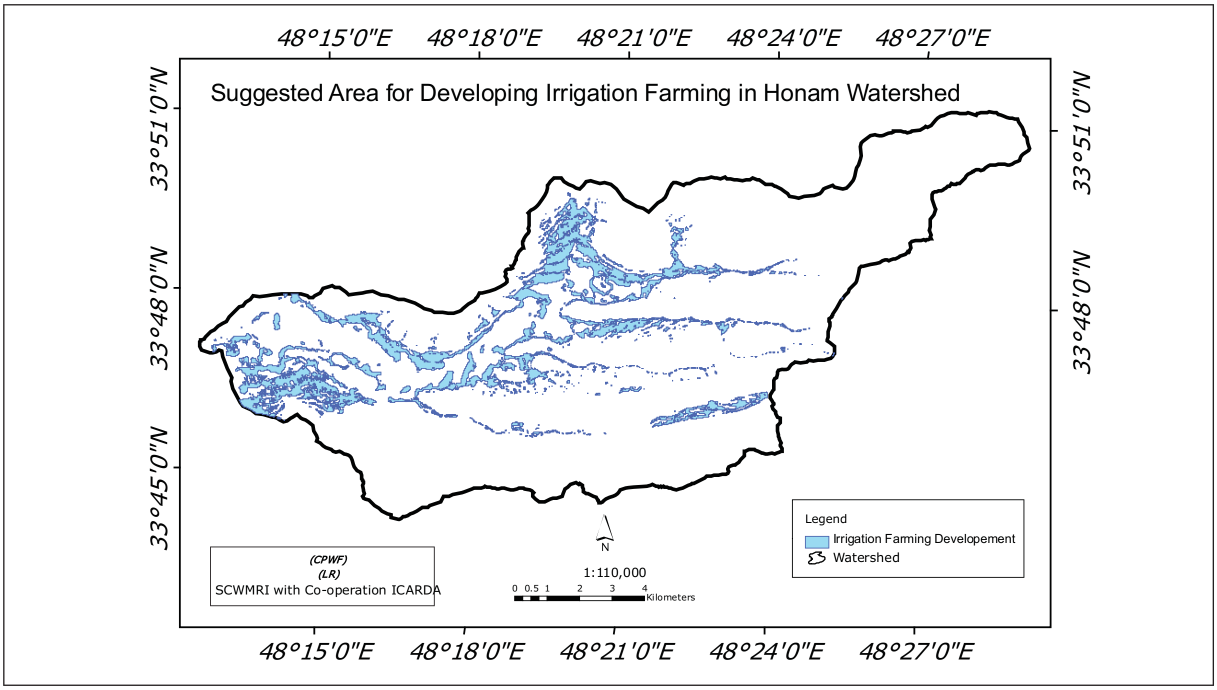

Figure 4.23. Suitable areas for future irrigation farming development in Honam catchment

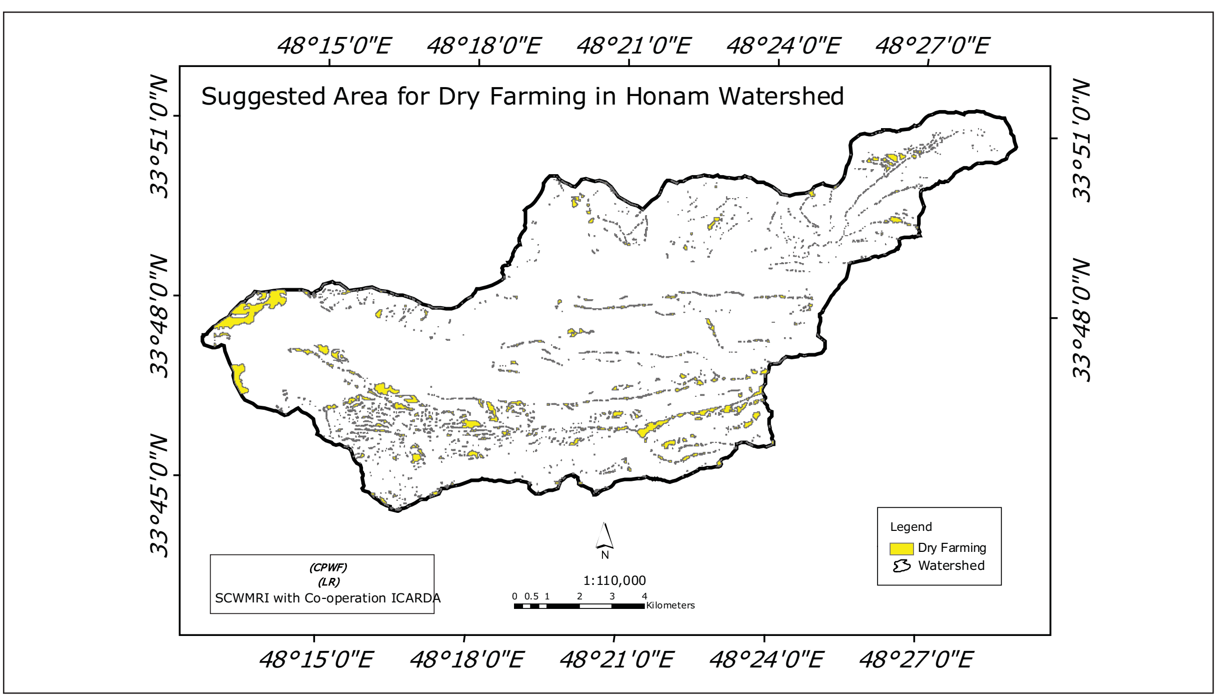

Figure 4.24. Suggested areas for dryland farming in Honam catchment

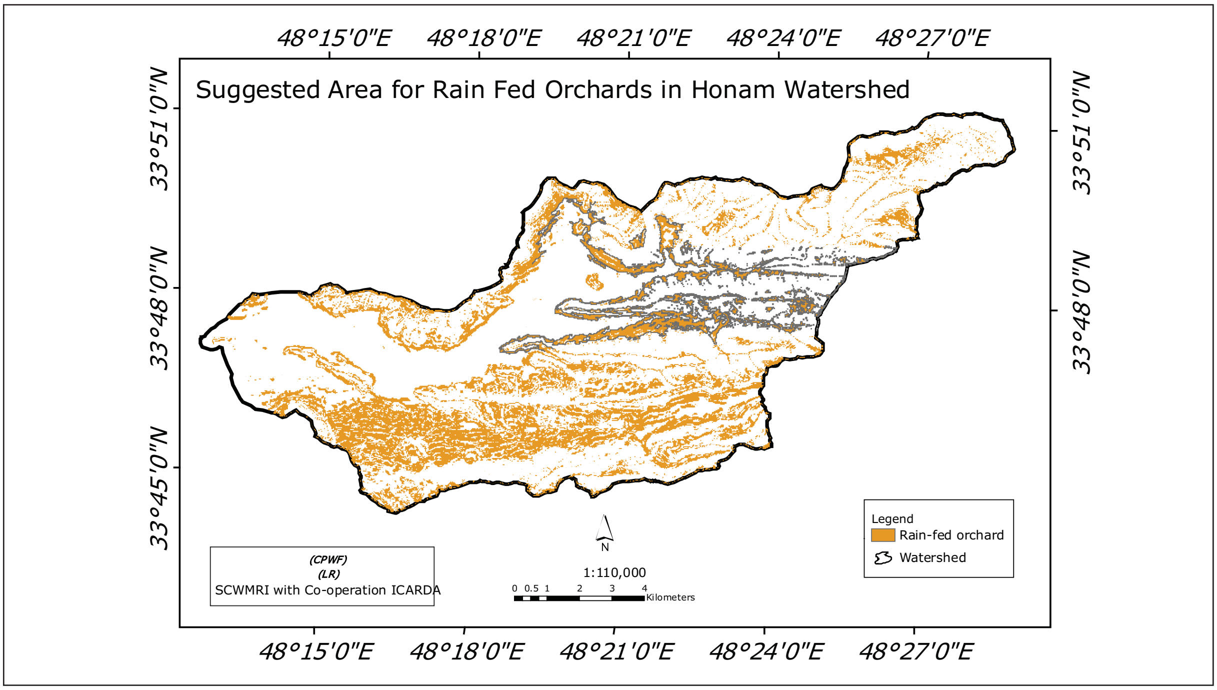

Figure 4.25. Suggested areas for the development of rainfed orchards in Honam catchment

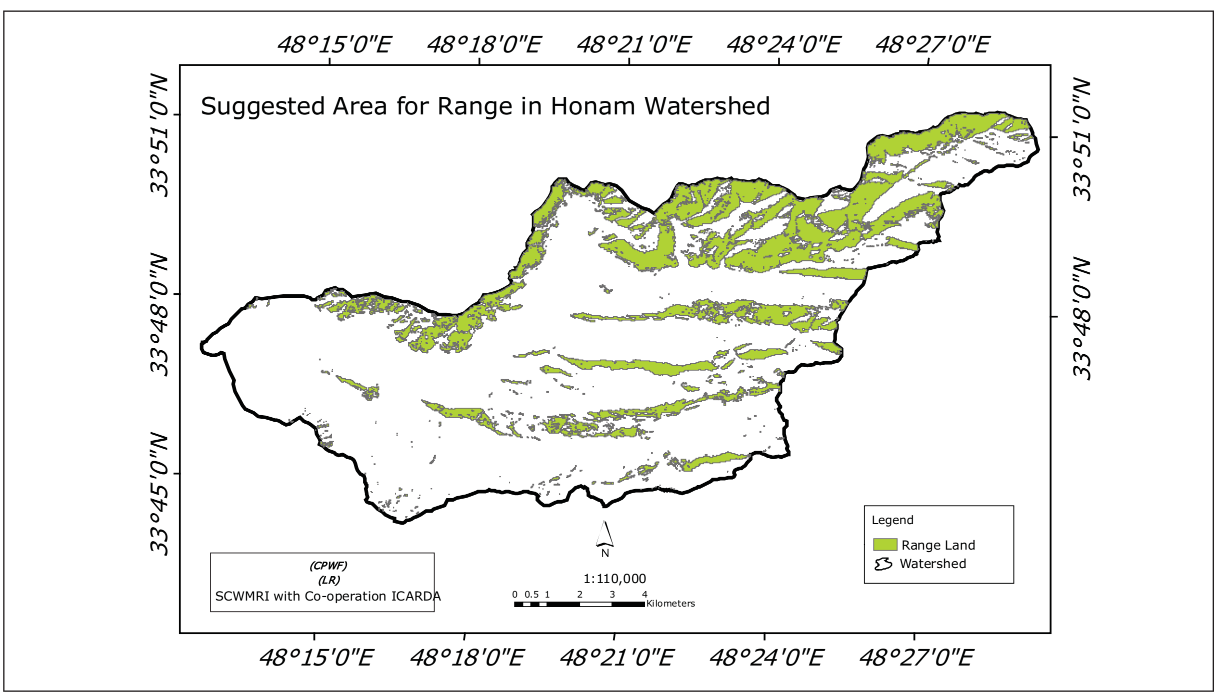

Figure 4.26. Suggested areas for rangeland development in Honam catchment

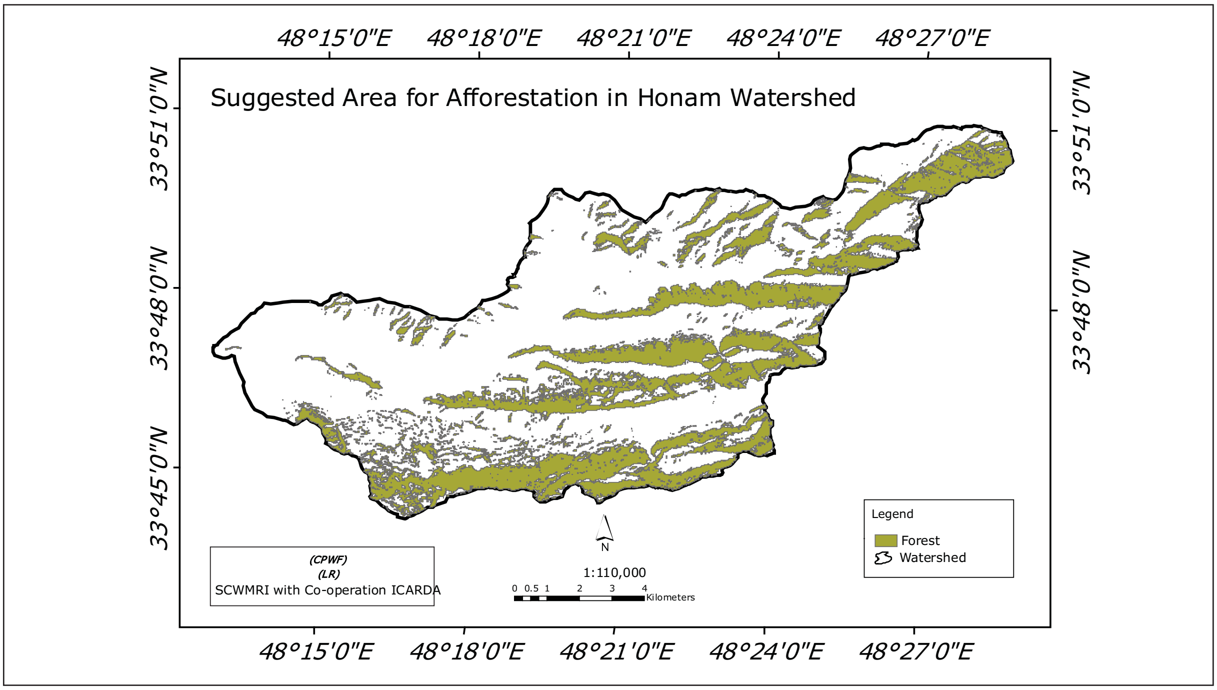

Figure 4.27. Suggested areas for forest development in Honam catchment

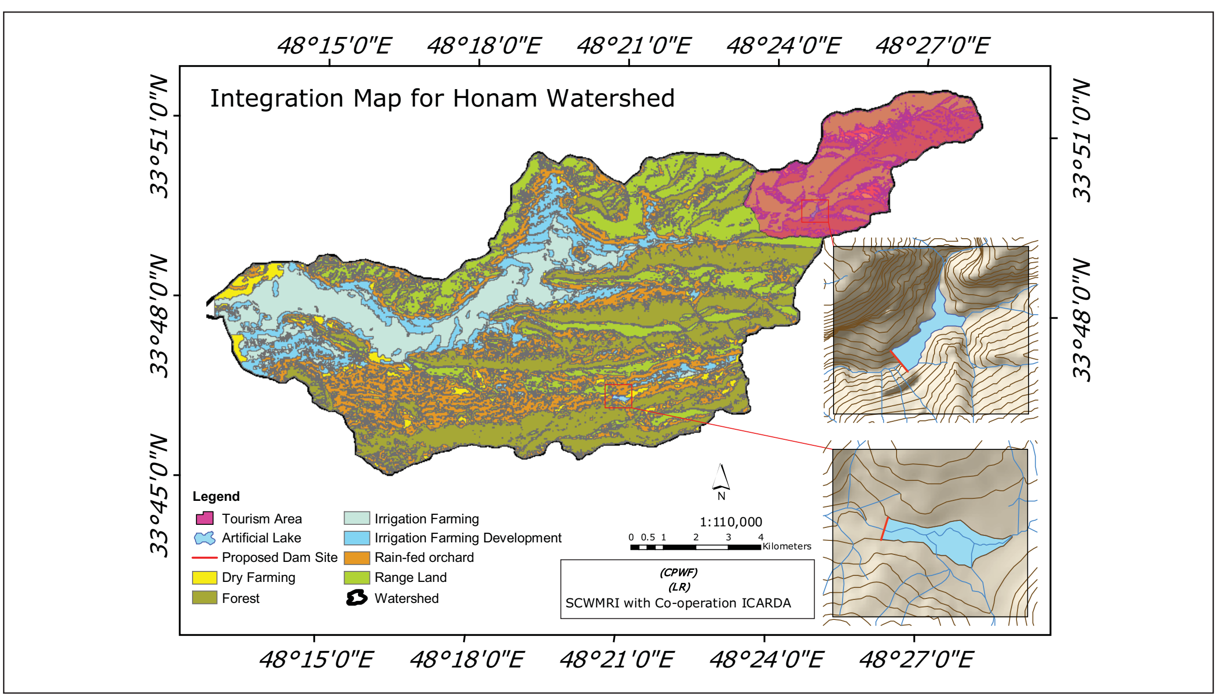

Figure 4.28. Suggested land-use plan for Honam catchment

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