ASSESSMENT OF LAND DEGRADATION WITHIN WADI ZIQLAB CATCHMENT

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DEDICATION

I Gratefully and Proudly Dedicate this dissertation To My Father and Mother Soul who always wanted the best for me, God bless them.

To my brothers, sisters and their families for their help and support.

To my wife.

To my sons Ayman and Ehab

To my sweet hearts Daughter Nagham

And to whom I love

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LIST OF ABBREVIATIONS OR SYMBOLS

WORD OR SENTENCE	ABBREVIATION
- And others	et al.
- Centimeter	cm
- Degree of freedom	df
- Degree centigrade	°C
- Food Agriculture Organization	FAO
- Hectare	ha
- Jordan Metrological Department	JMD
- Land and Survey Department-Jordan	LSDJ
- Least significant differences	LSD
- Ministry of Agriculture	MoA
- Millimeter	mm
- National Soil Map and Land Use Project	NSMLUP
- Organic matter	OM
- Percent	%
- Royal Jordanian Geographic Center	RJGC
- Standard deviation	SD
- land utilization types	LUTs
- is a remote sensing application with raster graphics editor capabilities	ERDAS
- is suite consisting of geographic information system	ARCGIS
- Geographic information system	GIS
- United Nations Convention to Combat Desertification	UNCCD
- World Meteorological Organization	WMO
- International Union for Conservation of Nature	IUCN
- Global Environment Facility	GEF
- Global Assessment of Soil Degradation	GLASOD
- The International Soil Reference and Information Centre	ISRIC
- Remote Sensing	RS
- Million Cubic Meter	MCM
- United States Agency for International Development	USAID
- Meter	m
- Coordination of Information on the Environment	CORINE
- Universal Transverse Mercator	UTM
- World Geodetic System 1984	WGS84

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ABSTRACT

This study was conducted in Wadi Ziqlab catchment to evaluate the extent of land degradation as a result of land use/cover changes during the period 1953-2008. Three sets of remotely sensed data were used in the evaluation; aerial photography of 1953, 1978, and Quick Bird imagery of 2008. Land use/cover changes were monitored using remote sensing and geographic information system (GIS) with field verifications. Biophysical data, ownership property, land suitability and size of ownership were also evaluated.

Land suitability evaluation was performed according to FAO framework for land evaluation, based on the simple limitation methods. The evaluation was carried for current land utilization types (LUTs) practiced in the study area. The catchment includes the following land use/cover classes: field crops, orchards, forest and rangeland.

Overall 4414 ha (42%) was changed from one land use to another since 1953, while the land use of 6081 ha (58%) of the area was never subjected to any changes. The main land use/cover changes were expansion of orchard cultivation into areas of field crops, forest and rangeland. Urban area spread into agricultural lands around villages. These changes are attributed to the increase in total population of the area and

improvement of infrastructure. During this period, only area of orchards and urban areas increased about 22.4% and 6.2%, respectively.

The impact of land use changes on land degradation was evaluated using soil organic matter content, soil texture, and thickness of A-horizon. Data on theses indicators were collected from each land use from 40 sites. Samples were taken for 2-4 land uses at each site. Total numbers of soil samples were 218.

Organic matter content varied according to the type of land use. Soil continuously used as forest had the highest organic matter (4.5%). When forest and rangeland were converted to orchards, organic matter content was reduced and the thickness of A-horizon significantly increased

The average thickness of A-horizon was about, 14.6cm, 12.7cm, 9.5cm, and 10.3cm for field crops, orchards forest, and rangeland respectively. There were significant difference between field crops and forest, field crops and range, and forest and orchards. Plowing of orchards and field crops resulted in mixing the soil surface, thus resulted in increasing the thickness of the A-horizon of cultivated land than forest or range land. Although field crops had thicker A-horizon, as compared with orchards, it was not significantly different.

Clay content for soil of different land cover were about 57.5%, 60.4%, 50%, and 48.4%, for field crop, orchard, forest, and rangeland, respectively. There were significant differences between clay content field crop and forests, field crops and range, and between orchards and range land. The highest clay content was for cultivated land as compared with forest and range land.

The implementation of soil conservation measures covered about 66% of the area cultivated with field crops, and 88% of the area cultivated with orchards in 2008. Organic matter increased significantly with availability of stone wall and depended on the time of construction. The thickness of A-horizon significantly increased with availability of stone wall, but decreased when stone walls were constructed for more than 55 years, due to poor maintenance.

Data indicated that the size of ownership had decreased with time. In 1952, plot size varied from 0.7 to 1.5 ha/person, while in 2004, it was reduced to 0.08-0.3 ha/person.

Land fragmentation was primarily confined to private land. The largest area in Wadi Ziqlab falls within the category of less than 0.1 ha, followed by 0.4-1 ha category and category of 1-2 ha. Most of these plots were located near or around villages. Small areas are not used according to their suitability. Therefore, land fragmentations have a direct impact on the land use of the private area.

Urban expansion was uniform around old villages during the early days. Lately, random urban expansion took place on agricultural land.

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1. INTRODUCTION

Jordan is dominated by Mediterranean arid and semi arid climate, and has limited land and water resources. Large portions of its rural population rely on agriculture for meeting their basic food needs. Rainfed agriculture is considered as one of the main contributor to agriculture production system in Jordan.

Increasing population and land use interaction have lead to various types of land degradation. In many parts of Jordan, highly intensive land use activities have often resulted in land degradation.

Degradation of land caused by natural or man-induced processes, involves the reduction of the resource potential productivity by one or a combination of many processes acting upon the land. Such reduction in resource productivity leads to abandoning or "deserting" of the land.

Land degradation within the Wadi Ziqlab catchment is caused by soil erosion, extended urbanization on agricultural land, and removal of natural vegetation. The soils of Wadi Ziqlab area are particularly susceptible to erosion due to the widespread occurrence of thin soil surface overlying dense impermeable subsoil, which resulted in the removal of the soil protective vegetation covers. Other related factors include topographic features and climatic condition. Gully erosion and mass movement are less widespread in Wadi Ziqlab catchment but it is considered as a problem.

Deforestation is widespread in Wadi Ziqlab catchment and is considered as the main cause of land degradation (Fisher et. al., 1966). During the last two decades, less than 60 thousands forest trees were removed and replaced with fruit trees, houses, or buildings (MoA, 2009).

Fragmentation is also considered as a major problem, which prevents land development. Multiple ownership of single plot is also dominant and hinders proper farming. Thus, land left unused and exposed to degradation.

The degradation of soil conditions is a very serious process since it is not easily reversed. A systematic analysis of available land resources and their utilization, based on sound land suitability evaluation and proper use planning is needed to optimize their utilization. The utilization of land resources should be based on the potential suitability of land in order to avoid soil degradation and, at the same time, to sustain their productivity. The extent of land degradation in this area nictitate undertaking proper evaluation of soil utilization prior to any proposal for changing land use.

The general objective of this study is to evaluate the extent of land degradation within Wadi Ziqlab catchment as a result of changes in land use.

The specific objectives are to:

- Assess temporal land covers change and land suitability in Wadi Ziqlab catchment for different land utilizations.
- Examine and identify factors that govern land cover changes and the distribution of different land utilizations.
- Determine the causes and extent of land degradation in Wadi Ziqlab catchment.

2. LITERATURE REVIEW

2.1 Land degradation

Land degradation is defined as a lowering of the productive capacity of land (Oldeman, et al., 1991), or soils for present and future use (FAO, 1980). It has significantly contributed to lowering yield of crops and livestock (FAO, 1994).

Desertification is defined as land degradation in arid, semi-arid and dry sub-humid regions, resulting from various factors, including climatic variations and human activities (UNCCD, 1994). It is a comprehensive expression of economic and social processes as well as those natural or induced ones, which destroy the equilibrium of soil, vegetation, air and water in the areas subject to edaphic and/or climatic aridity (FAO, 1999).

Land degradation affects the biological and economic productivity of an area due to processes like soil erosion, salinization, crusting, loss of soil fertility or depletion of seed banks with impacts on the vegetation cover especially its biodiversity and/or its density (Le Houerou, 1996).

Land degradation involves the reduction of the renewable resource potential by one or a combination of processes acting upon the land. The resource potential relates to agricultural suitability (rainfed or irrigated arable cropping, animal husbandry, forestry, and fishery), primary productivity level, and natural biotic functions (FAO, 1993b).

The effect of process, causing a land degrading differs, depending on the inherent characteristics of the land, specifically soil type, slope, vegetation and climate. Thus, an activity that, in one place, is not degrading may in another place, cause land degradation because of different soil characteristics, topography, climatic conditions or other circumstances. Moreover, equally erosive rainstorms occurring above different soil types may results in different rates of soil loss. It follows that the identification of the causes of land degradation must recognise the interactions between different elements of the landscape which affect degradation and the site-specificity of degradation (Stocking and Niamh, 2000).

Land degradation processes do occur without human interference (Stocking and Niamh, 2000). Degradation processes are dynamic, thus they respond to a change in the quality and productivity of soils (FAO, 1993b). These processes include physical, biological, and chemical deterioration due to erosion, laterization, salt accumulation, excessive leaching, and nutrient imbalance (Lal, 1988). Accelerated land degradation is most commonly caused as a result of human intervention in the environment. The effects of this intervention are determined by the natural landscape (Stocking and Niamh, 2000).

2.2 Causes of land degradation

Land degradation can be caused by natural or by human induced-processes (FAO, 1993b; FAO, 1999; UNCCD, 1994). It is a phenomenon that is caused by different biophysical and socio-economic factors. Socio-economic factors have increased largely during the last few decades (Wakindiki and Ben-Hur, 2002). Biophysical factors include rainfall variation (i.e. amount, intensity, distribution, and rainfall frequency of occurrence), geomorphologic aspects of the area, soil properties, and surface features characteristics i.e. slope characteristics such as length, degree, and aspect (de Sherbinin, 2002). Socio-economic factors include poverty, land fragmentation, low standard of living and earning, low level of education, and health condition (Wall and Smit, 2005).

2.2.1 Natural land degradation (biophysical factors)

Natural land degradation is generally slow because a steady state may develop between soil formation and soil degradation. Natural degradation represents 'inherent land quality' (Fitzpatrick, 2002**),** as affected by its intrinsic properties, climate, terrain and landscape position, and climax vegetation and biodiversity especially land biodiversity. Causes of land degradation are the agents that determine the kind, and the rate of degradation process (Working Group on Land Degradation and Desertification of the International Union of Soil Sciences, 1999).

2.2.1.1 Soil

Soil in its natural state is in a dynamic equilibrium, with its environment. It strongly interacts with the biosphere and is teeming with micro- and macro-life. The natural changes occurring on a geologic time scale are controlled by soil-forming factors and lead to soil formation (Lal et al., 2004).

Although soil degradation is only one aspect of land degradation, variables of its progress can be used as indicators of land degradation (Stocking and Niamh, 2000). Soil degradation is defined as diminution of soil potential or actual utility, and reduction in its ability to perform ecosystem functions. Soil degradation is activated by three processes physical, chemical and biological. The inherent characteristics of soil (texture, clay minerals, structure, horizonation, etc.) affect the type of soil degradation (Lal et al., 2004).

Physical degradation refers to adverse changes in soil physical properties, including porosity, permeability, bulk density, structural stability, and infiltration capacity, accelerated erosion by water and wind (FAO, 1979; Lal et al. 2004).

Soil erosion by water is, for most landscapes, is the most common way in which soil degradation occurs. A considerable linkage exists between erosion and other types of degradation **(**Stocking and Niamh, 2000).

Soil fertility differs with land use, agro-ecological zones (Maitima et al., 2004). Papiernik, et al, (2007), indicated that intensive tillage and cropping has significantly depleted the surface soil organic matter in landscape. These provide a detailed documentation of the effects of soil translocation by tillage on the physical and chemical properties of soil profiles in hilly landscapes, and are important for continued efforts to incorporate tillage erosion into soil erosion and crop productivity models (Papiernik, et al, 2007).

2.2.1.2 Climate

Land surface is an important product of climate system. The interaction between land surface and the atmosphere involves multiple processes and feedbacks, all of which may vary simultaneously (WMO, 2005).

Each region has a particular pattern of spatial heterogeneity, biological history, and temporal heterogeneity imposed by climate and its interaction with biological processes. The effect of environmental conditions and disturbance regimes on the patterns that occur on different patches within a landscape may create a constant change in the value of species composition and diversity (Regassa, 2005).

Climate-related factors such as increased drought could lead to an increase in the vulnerability of some land to desertification and to escalation of the desertification process (Working Group on Land Degradation and Desertification of the International Union of Soil Sciences, 1999).

Climate exerts a strong influence over dryland vegetation type, biomass and diversity. Precipitation and temperature determine the potential distribution of terrestrial vegetation and constitute the principal factors in the genesis and evolution of soil. Precipitation also influences vegetation production, which in turn, controls the spatial and temporal occurrence of grazing and favours nomadic lifestyle. Vegetation cover becomes progressively thinner and less continuous with decreasing annual rainfall. Dryland plants and animals display a variety of physiological, anatomical and behavioral adaptations to moisture and temperature stresses brought about by large diurnal and seasonal variations in temperature, rainfall and soil moisture (WMO, 2005).

It is frequently stressed that the changes of vegetation type can modify the characteristics of the regional atmospheric circulation and the large-scale external moisture fluxes. Changes in surface energy budgets resulting from land surface change can have a profound influence on the Earth's climate (WMO, 2005).

2.2.1.3 Topography

Topography is invariably cited as one of the "soil forming factors (King, 1983). It is an important factor affecting the nature and distribution of soils (Gregorich and Anderson, 1985).

Differences in soil formation along hillslope result in significant differences in soil properties (Brubaker et al., 1993). Soil properties follow systematic patterns of distribution on the landscape. Properties such as organic matter content, bulk density, and texture all vary with landscape position. (Malo et al., 1974).

The influence of landscape position on soil properties has also been related to soil erosion (Brubaker et al., 1993). In general, severity of erosion increase with slope steepness, thus, potentially producing more runoff and less infiltration on the steeper upper slope positions (Stone, et al., 1985)

2.2.1.4 Hydrology and water resources

The hydrologic cycle is a complex system of interactions, and on a catchment scale involves atmospheric moisture (precipitation, evaporation, interception, and transpiration), surface water (overland flow, surface runoff, subsurface and groundwater outflow, runoff to streams and ocean), and subsurface water (infiltration, groundwater recharge, subsurface flow and groundwater flow). All these interactions direct the changes in the morphology and habitat of land and are intimately connected with climate, geology, topography and general catchment features (Molnar et al. 2002).

2.2.2 Human-induced land degradation (socio-economical factors)

Human-induced land degradation in semi-arid areas is regularly cited as one of the principal causes of desertification (UNCCD, 1994). Widespread degradation is a direct consequence of human needs, improper utilization, short-sightedness, poor planning, and cutting corners for quick economic returns resulting from immediate needs (Lal, 1988; Dregne, 1978; and Stewart and Robinson, 1997), uncertainty or lack of an alternative (FAO, 1993a), and adoption of unsuitable agricultural practices (Lal, 1988; Lal, 1984; Evans, 1990; Fu, 1989).

Planning is done to select and accommodate land use options that are the most beneficial to land users without degrading the resource base or the environment, include the process by which physical, social, and economic conditions are accommodated (USAID, 2007a). Numerous tools are employed to help in these exercises; some of them include land suitability assessments, land classification, and biodiversity inventories and assessments. All of them benefit from regular and frequent public engagement.

Rossiter, (1996) indicate land suitability referring for productive of land utilization type can be considered as a direct indication of land suitability, and may change over time

2.2.2.1 Land use/land cover change

Global land use has significantly changed during the past decades. Historically, the driving force for most of land use changes is population growth (Ramankutty et al., 2002). At the global and regional scales, population growth is often used as a proxy for land use change (Kok, 2004), but at lower scales, a set of complex drivers are important too (Lambin et al., 2001).

Human activities involve changes in the environment, sometimes expressed as modification at landscape levels, agriculture, forestry, dams, and industry, almost any activity developed on a significant scale, modifies the natural environment (Ruiz-Luna, and Berlanga-Robles, 2003), resulting in unknown ecological effects (De Kimpe and Warkentin, 1998; Shaxson, 1998; and Sanchez-Maranon, et al. 2002).

Land-use/land-cover changes are local and site specific, occurring incrementally in ways that often escape our attention. Yet, collectively, they add up to one of the most important facets of global environmental change: deforestation, desertification, biodiversity loss, land cover and the water cycle, land cover and the carbon cycle, and urbanization (de Sherbinin, 2002).

Land degradation processes are usually active in areas where the vegetation cover has been seriously damaged (Hill, 1993; and Kok et al., 1995). Land degradation arises from the fragility of dryland ecosystems, which under excessive pressure of human use or changes in land use causes loss in productivity and the ability to recover (Reining, 1978; and Grainger, et al., 2000).

In the Middle East, human interference has upset the natural balance and led to widespread removal of the soil cover (Beaumont and Atkinson, 1969). Soil erosion is caused by deforestation, overgrazing, and cultivation of unsuitable agriculture land (Beaumont and Atkinson, 1969; Lal, 1984; and Lal, 1988; Solaimani, 2009). It can become a serious environmental and economic problem (Del Mar et al., 1998).

2.2.2.2 Deforestation

Deforestation occurs in both woodlands (in semi-arid, and sub-humid areas) and dense forests (in humid tropical areas). It is considered as major cause of forest cover loss, leading to further land degradation (Farshad, 1997; and GEF, 2003). Deforestation includes forest loss for fuelwood or charcoal consumption and conversion to anthropogenic grasslands, or converting the forest for other land use such as orchard or field crops.

Deforestation can accelerate land degradation (Farshad, 1997) and increase erosion from forest and agriculture land (Benneh, et al. 1996). The long standing deforestation has increased the rate of erosion since millennia in Turkey. (Kapur et al, 2006).

Deforestation enhances water erosion and degradation of the physical and chemical properties of soil. Such degradation was quantified in a study in southern Spain. The reduction in the amount of organic matter, cation exchange capacity, and available water content were significant in this degraded soil due to deforestation, and if were ignored without remediation (Nash, et al., 2006)

Deforestation, loss of soil fertility, droughts, erosion processes and salinisation of irrigated areas were considered the main causes triggering desertification (Rubio and Luis, 2006). Although rates of deforestation seem to be highest in uplands and in dry deciduous forest, tropical rain forests provide particularly sensitive environments with generally highly weathered soils that are low in available nutrient reserves for plant and easily degraded by intensive land use (Benneh, et al., 1996).

Deforestation and cultivation increased soil bulk density and penetration resistance but decreased mean weight diameter of aggregates (Lal, 1998), infiltration declined with Deforestation and cultivation duration (Lal, 1998),

Ronggui and Tiessen (2002), in Northern China found the grassland soils are being seriously degraded under cultivation and grazing. When pasture was heavily degraded, organic carbon, total Nitrogen and cation-exchange capacity declined. There are two major processes of soil degradation in china, soil erosion and organic matter mineralization (Ronggui and Tiessen, 2002), Deforestation is mainly due to expansion of the cultivated lands and to forest fires. Large areas of woodlands in the dry sub-humid and the upper semi-arid zones have been cleared illegally for fruit tree plantations in sloping areas, without taking any conservation measures to prevent water erosion (UNCCD, 2008). Riezebos and Loerts, (1998), found that the transition from forest to agricultural use leads to a significant decrease of organic matter in the topsoil. Land use change can may induce substantial modification of quality and quantity of soil organic matter (Shrestha, et al., 2008).

Converting tropical dry forest into cropland and pasture, with land degradation expressed as soil erosion being the main environmental consequence, (Cotler, and Ortega, 2006)

2.2.2.3 Overgrazing

Overgrazing is perhaps the most significant anthropogenic activity that degrades rangelands and causes desertification in terms of plant density, plant chemical content, community structure, and soil erosion (Manzano and Navar, 2000; and FAO, 1999).

Globally, about 75 million hectare of land are strongly degraded by overgrazing, by largely destroyed the original biotic functions (Sinha, 1998). In arid and semi-arid environments, land degradation is particularly related to areas surrounding point sources of water, either natural or artificial, such as wells or boreholes (Lange, 1969). Domestic animals (sheep, goats, and cattle) prefer to graze in the vicinity of a watering point. When food is depleted in this area, they move away from the source of water but return regularly to drink (Friedel, 1997; and Pickup et al., 1993).

Overgrazing affects land in two major ways. It leads to the loss of the vegetative cover of rangeland or pasture in areas where livestock density is beyond the carrying capacity. High livestock density also results in soil compaction because of trampling (GEF, 2003). Also cause erosion due to constant trampling (Nuru, 1996)

Overgrazing of vegetations by livestock includes other effects of livestock, such as trampling. Overgrazing leads to a decrease of the soil cover, which increases the water and wind erosion hazard. Trampling may cause compaction of the soil. A widespread effect of overgrazing is the encroachment of unfavorable (unpalatable or noxious) shrub species. Although this phenomenon certainly influences grazing potential, it is not distinguished as soil degradation, as the soil itself is not affected (Oldeman et.al., 1991).

2.2.2.4 Improper land use

The main causes of degradation on croplands are improper land use, weak capacity for sustainable water and land use planning and implementation, and inappropriate agricultural policies and incentives. These factors lead to inefficient and wasteful use of land and water resources; inappropriate crop intensification, especially under mono-cropping systems, expansion of agriculture to marginal lands, and the use of farm machinery and agronomic practices that are not suitable for local soil and water conditions (GEF, 2003).

Environmental degradation caused by unsuitable land use is a worldwide problem that has revived the issue of sustainability (Pierce and Larson, 1993; Zinck and Farshad, 1995; and Hurni, 1997).

Improper land use types and conversions, such as rangeland to cultivated land, rangeland to forestland and forestland to cultivated land, are attributed to the acceleration of the desertification development while the opposite can control the desertification development (Chengyuan and Shaohong, 2006). Both cultivated land and forestland have more effects on the desertification development than rangeland (Chengyuan and Shaohong, 2006)

When the fallow period for land under intensive cropping is shortened, it weakens the natural ability of soil to recover its fertility, leading ultimately to land degradation, lower crop productivity, and reduced incomes (GEF, 2003).

Agriculture production, in Jordan today, strongly depends on rainfall, since greater part of the cultivated area lies on plateaus, where only rain-fed agriculture is possible (Al-Saad et al., 2004). Land degradation in Jordan is not related to increased precipitation, but to periods of prolonged drought interrupted by more frequent extreme events (Cordova, 2000; Maher, 2005). Less rainfall can reduce plant density and cause soil erosion (Taimeh, 1999).

Taimeh (1989) indicated that a recession of the vegetative cover was caused by the accelerating rate of desertification coupled with misuse of the land and overgrazing in east of Jordan. While, Khresat et al., (1998b) has related land degradation in north-western Jordan to improper farming practices, overgrazing and the conversion of rangelands to croplands in marginal area, where rainfall is not enough to support cropping in the long-term.

Soil conservation measures especially the physical ones are quite costly to implement, therefore, most of the time they are ventures undertaken by the government (Ray, 2007). In Jordan most of the physical soil conservation structures, such as Zarqa river basin project, and Yarmouk river basin project, were established by the government. These measures reduced the effect of run-off, controlled erosion, surface runoff and discouraged the growth of gullies (Ray, 2007; and Dano and Florita, 1992), and reduce the silt deposition at downstream (Pendke, 2009). This eventually made cultivating areas under these conservation schemes possible. (Ray, 2007; and Pendke, 2009). Soil conservation structure can improve land suitability, or shift some area from one class of land suitability to other class.

Improved soil management practices, and associated technologies such as soil conservation measure and rehabilitation can help reduce land degradation caused by soil erosion, and can improve land productivity (FAO, 1999; FAO, 1987; UNCCD, 2008), and to control desertification (UNCCD, 2008). Soil conservation measures such as terraces, rock barriers and hedgerows were reducing surface runoff and soil loss. Terraces, rock barriers and hedgerows reduced soil loss by 80%, 78% and 68%, respectively, in area with steep slopes ranging from 30% to 60% (Dano and Florita, 1992; Maitima et al., 2004). Terraces and rock barriers reduce surface runoff by 66.5% and 61.1% respectively. Hedgerows, on the other hand, were found to reduce surface runoff by 33.2% during the first year, and by 49.4% during the second year (Dano and Florita, 1992). Farmers especially in cropland. Farmers need to create favorable conditions to prevent soil erosion (Maitima et al., 2004).

2.2.2.5 Land tenure and land fragmentation

Majority of land in Jordan is claimed as pastoral areas. The classifications of land tenure include: (1) privates owned land (mulk); (2) communal land held by farmers and periodically redistributed (musha'a); (3) religious land (waqf); and (4) Governments land, which can be granted in use rights to the public (miri) (USAID, 2007b).

Privately-owned lands can be owned individually or by groups, as the land may not have been partitioned through inheritance for several generations. This complicates registration and land market transactions. Land control disputes are an ongoing problem in the area northeast of Amman, Jordan (Rae, 2002)

Land fragmentation due to inheritance is heavily practiced as the result of the Islamic traditional law of inheritance, where the fathers land is divided between siblings once the father died (Sharakas et al., 2006). Fragmentation has a significant impact on technical productivity and efficiency (Jha et al., 2005). Also fragmentation can lead to reductions in total genetic variation, dispersal barriers and, the potential loss of key biotic interactions for plants (de Sherbinin, 2002).

Fragmentation can also make species more vulnerable to disease and storms, and alter relationships between predator and prey, (de Sherbinin, 2002).

2.2.2.6 Socio-economic factors

Objectives for land use change differ between the developed and developing countries. In developed countries, land use change is based on economic reasons such as large scale farming or urban development and an increasing need to conserve biodiversity and environmental quality for current and future generations (Bouma et al., 1998), whereas in the developing countries, rapid population growth, poverty and the economic situation are the main driving forces (Lambin et al., 2003; Meertens et al., 1996; and Ramankutty and Foley, 1999).

The relation between human population growth and land use/land cover change is much debated (Ningal, et al., 2008). The impact of human settlements on the available land suitable for agriculture, have been rising rapidly during recent years (Daily and Ehrlich, 1990).

Most of the projected population increase (88%) is in Africa and Asia, where land development has been increasing faster than anywhere else in the world and where food shortages are common. Even in United States, land with highly productive soils, roughly 3% of the total U.S. area, has a higher level of urbanization (5%) than that of any other soil productivity category (Nizeyimana et al., 2001).

The Mediterranean region has been affected by anthropic disturbance for thousands of years, and is, nowadays, one of the most significantly altered hotspots in the world (Falcucci et al., 2007).

2.2.2.7 Climate change

Climate change will almost certainly change a region's soils with respect to their carrying capacity, their resilience, sensitivity and susceptibility to stress, and the potential reversibility of damage to them. It is important that the impact of climate change on soils is considered in parallel with impacts caused by unsustainable land management. The two often interact leading to a greater cumulative effect on soils than would be predicted from a summation of their effects (Working Group on Land Degradation and Desertification of the International Union of Soil Sciences, 1999).

Changes in land cover and vegetation status contribute to climate change, alter biodiversity and modify hydrological cycle.

Climate change and global warming effects, contributes to increase of mean temperature, and frequent occurrence of natural disasters including droughts and floods, accelerating the land degradation (Brauch, 2006).

Land degradation in the Highland and the steppe regions of Jordan is expected to accelerate in the future because of projected rainfall reduction (Taimeh, 1999). Changes in the agro-ecological system, namely soils' properties, indicated that a higher level of aridity should be expected within the sub-humid to semi-arid ecosystems. Risk inflicted by the type of climate or climatic changes indicated that present climate is responsible for several active degradation processes ((Taimeh, 1997; Taimeh, 1999).

Climatic change is responsible for the development of unfavorable soil properties that accelerate the degradation of many plant species. Coupled with the effect of continuing drought incident, removal of plant cover could greatly enhanced (Taimeh, 1991).

2.3 Processes of land degradation

Land degradation means reduction or loss of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation (Coxhead and Shively, 2005).

2.3.1 Deterioration of soil physical properties

Degradation of soil physical properties include porosity, permeability, bulk density and structural stability (FAO, 1999). The greatest change in soil physical properties occurs during land clearing process. These changes tend to be negative. Using heavy machinery to clear land leads to soil compaction, which reduces root penetrability, aeration, infiltration rate, water permeability, and crop yield. The mechanical land clearing damage soil physical properties more than slash and burn whereas, agro-forestry systems improve soil physical properties (Vander Weert, 1974; Seubert et al., 1977; and Alegre et al., 1986).

Deterioration of physical properties can occur as a result of many interrelated processes, including sealing, crusting, reduction in permeability, compaction, lack of aeration, degradation of structure and limitations of rooting (FAO, 1995).

Soils generally possess favorable physical properties when first brought under cultivation from a virgin condition. As cultivation continues soil, the soil becomes less porous and friable. Organic matter content is reduced with a resulting tendency for breakdown of soil aggregates. As dispersion of aggregates progresses, the soil particles become more closely packed together, bulk density increases, and the volume of pore space is reduced. Aggregate dispersion commonly proceeds more rapidly at the soil surface than at levels below the surface. Area under cultivation is exposed to the beating action of raindrops in addition to exposure to other forces of structural decline.

Difficulties with crust formation following rainstorms tend to develop as dispersion of aggregates in the surface layer continues. This condition often introduces problems of securing satisfactory seed germination and usually reduces the rate of water absorption, thus increasing runoff losses (Neal, 1952).

Generally, as a result of using heavy machines, soil contents of carbon and nitrogen are most susceptible to change at the surface (Desjardins et al., 1994). Soil organic matter is an important factor for improving the stability of soils, since it improves the soil resistance against wind and water erosion (Lal and Stewart, 1990), the soil water holding capacity, and the nutrient availability for plants (Tisdale and Oades, 1982; Rasmussen and Collins, 1991; and Gregorich et al,. 1994), and for maintaining the productivity and the stability of the woodland ecosystem (Buschiazzo, et al., 2004).

Forest soils maintained high levels of organic matter comparable to soil from the continuously cultivated fields, which exhibited lower organic matter contents than those in soil kept under prolonged fallow (Fuller and Anderson, 1993; Funakawa et al., 1997; Sanchez et al., 1983; and Brown and Lugo, 1990). Litter fall is a major contributor to soil organic mater in the forest ecosystem (Chen and Chiu, 2000).

Organic matter contents of the soil are depleted after successive cropping following clearing (Sanchez, 1983; Skidmore et al., 1975; Sarma et al., 1995; and FAO, 1971). Shifting cultivation causes an appreciable change in organic matter content resulted in nutrient imbalances, (reduction in water holding capacity, iron, aluminum, nitrogen, calcium, magnesium, potassium, phosphorus, and cation exchange capacity) (Jha et al., 1976). Soil fertility is strongly linked to soil organic matter through its influence on soil physical properties and plant nutrient supply (Paustian et al., 1992).

Soil organic matter and stable soil structure are important soil properties affected by cultivation (Martel and Mackenzie, 1980). Erosion is significantly related with the lack of stability of soil structural (Beaumont and Atkinson, 1969). Organic binding substances tend to be responsible for the stabilization of surface soil aggregates. Whereas, repeated cropping with annuals that supply little organic matter to the soil, require extensive cultivation, and provide minimal vegetative cover usually result in rapid deterioration of soil aggregate status (Harris et al., 1966; Skidmore et al., 1975; Elliott, 1986; and Neal, 1952).

Conversion of forest land to cultivated land seems to reduce clay and increase sand contents (Brown and Lugo, 1990). Lavkulich and Rowles (1971), indicate that clay content increased in cultivated Ap and B horizons and this attributed change to the grinding effect of cultivation on the surface horizons.

Beside soil formation process and soil erosion, differences in soil texture, organic matter content can be attributed to differences in cultivation practices, especially on different topographic position; the upper and lower linear and footslope positions (Brubaker et al., 1993). Maximal erosional activity at the shoulder position was reflected in coarser textured material while fine-textured material accumulated at lower landscape positions (Malo et al., 1974).

In a study to evaluate the effects of cultivation and topography on soil properties, Gregorich and Anderson (1985) reported a reduction in the Ap horizon thickness, organic carbon content with cultivation from upper to lower slopes. Meanwhile, maximum thickness occurred at the lowest point of uncultivated areas.

2.3.2 Water erosion

Soil erosion occurs in a natural, undisturbed environment, but under such conditions soil formation generally compensates for erosion, thereby maintaining a state of equilibrium (Beaumont and Atkinson, 1969).

Erosion is significantly related with the lack of stability of soil structure (Beaumont and Atkinson, 1969). Organic binding substances tend to be responsible for the stabilization of surface soil aggregates. Whereas, repeated cropping with annuals that supply little organic matter to the soil, require extensive cultivation, and provide minimal vegetative cover usually result in rapid deterioration of soil aggregate status (Harris et al., 1966; Skidmore et al., 1975; Elliott, 1986; and Neal, 1952).

Water erosion is a serious problem, on farmland and over a large part of the world, particularly on gently to steeply sloping land of both humid and semiarid areas (Moresco, 1974).

Erosion is likely to occur when land is cultivated, especially where a wide range of crops is grown, where fields are bare of crop and at risk of erosion by water or wind at most times of the year (Evans, 1990). Human interference has upset the natural balance and led to widespread removal of the soil cover in the Middle East (Beaumont and Atkinson, 1969).

Accelerated by man's actions (Evans, 1990; and Hill, 1993), soil erosion is caused by deforestation, overgrazing, and cultivation of agriculturally unsuitable land (Beaumont and Atkinson, 1969; Lal, 1984; and Lal, 1988). It can become a serious environmental and economic problem (Del Mar et al., 1998).

Erosion by wind and water is considered the major cause of land degradation in the Jordan area (Khresat et al., 1998a).

2.4 Land degradation in Wadi Ziqlab catchment

Wadi Ziqlab catchment is part of the Northwest Jordanian mountains. Wadi Ziqlab hillslope benches, and the colluvial slopes along the Wadi bottom are used for pasture, olive and pomegranate groves, cultivation of grains and vegetables, and human habitation (Banning et al., 1994; and Banning, 1996).

Land degradation in Wadi Ziqlab catchment is caused by many factors, soil erosion, overgrazing, deforestation, improper farming practices, and expansion of urban areas (Fisher et. al., 1966).

Soil erosion occurs under different conditions in the catchment whether due to natural or human interference. Human interference can easily upset the natural balance and lead to rapid removal of soil through improper land use or improper agricultural practices. Erosion by water is more active than wind erosion in Wadi Ziqlab catchment. Removal of surface soil by erosion results in the appearance of impermeable subsoil material at soil surface, where runoff tends to be more concentrated into channels (Fisher et. al., 1966). Shatnawi (2002), found there are about 45000 m^3 of soil transported to Sharhabeel dam as sediments every year.

Absence of vegetation cover by over grazing, and uncontrolled deforestation in Wadi Ziqlab catchment, result in soil pores to be clogged with fine material. The infiltration capacity of the soil is reduced, and rate of runoff are greatly increased (Fisher et. al. 1966). Overgrazing of the rangeland in the Steppe Zone of Jordan by sheep and goats has lead to a steady degradation in the land quality and increased soil erosion (Abu-Sharar, 2006).

Improper farming practices, overgrazing, conversion of rangelands to croplands in marginal areas, and uncontrolled expansion of urban and rural settlement at the cost of cultivable land are among the major causes of land degradation in North-Western Jordan (Fisher et al., 1966; and Khresat et al., 1998a).

Rainfall in Jordan region varies from year to year in quantity, distribution, intensity and duration. These factors along with deterioration soil properties accounts for soil erosion variability (Al-Kharabsheh, 2004).

The historic desertification in the Decapolis was connected with severe degradation of soils, and caused by agricultural mismanagement and deforestation (Lucke and Michael, 2007).

Man induced destruction of natural forests by deforestation and expansion of farmland (land cultivation) and grazing into these forests over the past centuries have been recorded as main causes of desertification in Highland region (Abu-Sharar, 2006).

2.5 Assessment of land degradation

Land degradation assessment is a complex issue that involves many disciplines of natural and social sciences. Land degradation assessment investigates the levels of land degradation associated with the changes in land use and biodiversity. Assessment of land degradation could be done in many ways: 1) assessing the changes in soil fertility; 2) assessing the levels of soil erosion; 3) assessing changes in ecosystem complexity, and 4) assessing changes in ecosystem of land use productivity (Maitima et al., 2004).

The earliest assessment of land degradation is biophysical and focuses at the farm level, resulting in the formulation of the Universal Soil Loss Equation (USLE) (Wischmeier, 1976). Early attempts to assess land degradation at larger scales, such as at river basin and bioregional scales, and with a combination of remote sensing and ground-based techniques, have encountered difficulties mainly due to the lack of financial resources and the limits of those technologies. In 1979, FAO prepared a methodology for soil degradation assessment with detailed criteria for each type of biophysical degradation. Subsequently FAO in collaboration with UNEP conducted a Global Assessment of Progress on Desertification in 1984 and 1992 which indicated a global estimate of land degradation or desertification areas ranging from 2,001 M ha to 3475 M ha, i.e. 13% to 23% of the earth's surface.

The first Global Assessment of Soil Degradation (GLASOD) in the early 1990s provided a systematic qualitative assessment of the extent and severity of land degradation, and its results formed the basis for the World Atlas of Desertification. ISRIC's, recently introduced SOTER data as well as information linking migration and population pressure to land degradation which was used to upgrade this to the Second Edition of The World Atlas of desertification 1997. This expert assessment method used a mapping base, a set of semi-quantitative definitions on soil degradation, case studies, and a team of national and international experts. In spite of its utility, because of its lack of baseline-measured data and its subjective (expert) approach, its results are not quantitatively replicable, nor do they provide reliable indicators of degradation phenomenon. Most of the indicators used for this assessment were biophysical and did not include the institutional and policy driving forces of land degradation. Furthermore, existing methods for assessing land degradation have not met the requirements of users at sub-national, national, regional and international levels (GEF, 2001)

Earlier works on assessing land degradation are mainly carried out on assessing deterioration of the quality of soil. For instance the GLASOD and ASSOD projects have all been used in assessing soil qualities. As the concept of land degradation and desertification evolves, many have realized that the assessment of degradation should combine socio-economic as well as institutional indicators into the assessments. The advancement of science and technology has also brought new opportunities for such an assessment. Remote sensing and GIS technologies have now been widely applied to assess, monitor, and predict the type, extent as well as severity of land degradation.

2.6 Land suitability evaluation

Increasing demand on food as a result of population growth has created more pressure on land resources (Bauer, 1973). Land suitability is a component of sustainability evaluation of a land use (de la Rosa, 2000). The concept of using the land for the suitable utilization lies within the land use planning process (Bauer, 1973), which aims at optimizing the use of land while sustaining its potential by avoiding resources degradation ((FAO, 1976).

Land suitability analysis is a prerequisite for sustainable agricultural production. It involves evaluation of the criteria ranging from soil, terrain to socio-economic, market, and infrastructure (Prakash, 2003).

Land evaluation is formally defined as “the assessment of land performance when used for specified purposes” It involves the execution and interpretation of basic surveys and studies of land forms, soils, vegetation, climate, and other aspects of land in order to identify and make a comparisons of promising kinds of land use in terms application to the objectives of evaluation (FAO, 1976).

The function of land evaluation is to understand the relationships between land conditions and land use, in addition to presenting planners with comparisons and promising alternative options (Beek, 1981).

Land evaluation aims to determine the suitability of land for alternative, actual or potential land uses that are relevant to area under consideration. The suitability assessment is based on the productivity, suitability and sustainability of land use systems (Beek et al., 1987).

One of the main purposes of land evaluation is to avoid misuse and degradation of land resources. It can be considered as an integral part of environmental control (FAO, 1975).

There is no intrinsically 'good' or 'bad' land, only land that is more or less suited for possible use depending on their physical attributes, such as soil characteristics, climate, terrain, and water resources. These are the subject of natural resources inventories such as soil and land system surveys (Rossiter, 1990). Land evaluation predicts land performance, both in terms of expected benefits and constraints to productive land use, as well as the expected environmental degradation due to these use (Rossiter, 1996).

Methodologies of land evaluation (FAO, 1976; FAO, 1983; FAO, 1985; FAO, 1991) are used for supporting government planning programs (FAO, 1993a). It produces information on the suitability of different tracts of land for specific land uses and to provide qualitative and/or quantitative information on the expected productivity of land use, as their sustainability, labour requirement, capital needs, and gross margin. These information are essential for selecting appropriate land uses, on bases of various criteria for different tracts of land (Bronsveld et al., 1994).

Suitability is a function of crop requirements and soil/land characteristics. Matching the land characteristics with the crop requirements results in determining suitability. The suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use (FAO, 1990).

It has been recognized that the quality of land suitability assessment and hence the reliability of land use decisions depend largely on the quality of soil information used to derive them (FAO, 1976; Ghaffari et al., 2000; Bouma, 2001; Mermut and Eswaran, 2001; Bogaert and D'Or, 2002). Agricultural crop suitability involves integration of information from various streams of science. There are many criteria upon which land suitability depends. The suitability analysis evaluates many alternative land use types under the light of various criteria from various disciplines. The criteria are both qualitative and quantitative (Malczewski, 1999).

Soil maps are the traditional source of information for land suitability analyses (Daigle et al., 2005). The coverage of soil maps, especially those with enough details, is usually limited and the cost of extending this coverage is high (McKenzie et al., 2000).

Based on the scale of measurement of the suitability there are two types of classifications in FAO framework, qualitative and quantitative. In the qualitative classification the classes are evaluated based on physical production potential of the land, commonly employed in reconnaissance studies. It is used to evaluate environmental, social and economical criteria. Qualitative methods usually express the suitability in more than two classes, whereas the screening process determines two classes only, i.e. unsuited land and potentially suited land. The potentially suited land has no severe limitations and will be subsequently analyzed in more detail by quantitative methods (van Lanen, et al., 1992)

The quantitative classification is uses defined numerical terms; where comparison between the objectives is possible. In this classification considerable amount of economic criteria are used. Quantified land evaluation made an evolution in land suitability evaluation by introducing quantification of the indicators of land suitability over an entire area. However, the indicators must be quantifiable. In such land suitability analysis, geographical information systems and geo-statistical techniques are widely used (Beek, et al., 1987).

2.7 The use of Geographic Information System (GIS) and Remote Sensing (RS) in land evaluation

A Geographic Information Systems (GIS) has been defined as a computer assisted system for the acquisition, storage, analysis and display of geographic data according to user-defined specifications (Laurini and Thompson, 1992). The most powerful capability of GIS is their ability to analyze spatial data based on descriptive attributes. The use of GIS software can help to eliminate data integration problems caused by the different geographic units to which different data sets are related (Burrough, 1986).

GIS and RS technology makes it possible to evaluate various scenarios before they are carried out. It has proven to be helpful for designing more effective resource management strategies. It is widely accepted that satellite remote sensing offers considerable advantages for land degradation assessments. With a comprehensive spatial coverage, it is intrinsically synoptic, and provides objective, repetitive data which contribute to resource assessments and monitoring concepts of environmental conditions in drylands (Hill et al., 1995; Lacaze et al., 1996).

GIS functionality can play a major role in spatial decision-making. Considerable effort is involved in information collection for the suitability analysis for crop production. This information should present both opportunities and constraints for the decision maker (Ghaffari et al., 2000).

GIS have the ability to perform numerous tasks utilizing both spatial and attribute data stored in it. It has the ability to integrate variety of geographic technologies like GPS, Remote Sensing etc. The ultimate aim of GIS is to provide support for spatial decisions making process (Foote and Lynch, 1996). In multi-criteria evaluation many data layers are to be handled in order to arrive proper suitability, which can be achieved conveniently using GIS.

GIS and Remote Sensing (RS) techniques for the spatial delineation of different land cover- land uses in large watershed areas, has taken place in the last twenty years. The progress has been accelerated by the introduction of new improvements in GIS and RS technologies. The progress is also enhanced by the needs, worldwide, of a user friendly tool for the assessment of land degradation by soil erosion, high input output efficiency of such techniques, time saving and low to moderate technological requirements, the current increases of the available and necessary input data (i.e. land use and land cover data, elevation stream flow, and other geo-morphological data), as well as the ease of attaining necessary data especially in the developing countries with limited finance for such purpose (Mellerowicz et al., 1994; Molnar and Julien, 1998).

GIS allows overlaying of maps with different thematic data (e.g. soil, land use, watershed, district and village maps) and thereby facilitates map integration and analysis. GIS distance modeling makes it possible to assess the interaction of (potential) land uses, and the physical infrastructure and market. The accuracy of the map usually depends upon resolution (Ziadat, 2007; Riezebos, 1989; Ziadat et al., 2003). It is indicated that the accuracy of site-specific suitability using a high detail soil map (1:10,000) was only 60-70%, which is questionable in terms of providing reliable information for land use planning. GIS play an important role as a platform for the preparation, management and representation of spatial information. GIS have proved to be a valuable tool for any study at landscape level (Nekhay et. al., 2009). The analysis of the study area on a territorial basis involves the use of GIS, for the management and analysis of geographical information, and the geographical information as an abstraction or representation of the real world.

Satellite remote sensing allows a retrospective, synoptic viewing of large regions, thus providing the potential for a geographically and temporally detailed assessment of land-use and land-cover changes in estuarine watersheds (Yang and Zhi, 2005). Remot sensing (RS) provides information about the various spatial criteria/factors under consideration, can provide us the information like land use/cover, drainage density, topography etc. RS in combination with GIS will is a powerful tool to integrate and interpret data. The integrated GIS and RS technology apart from saving time and yielding good data quality have the ability to locate potential new cropland sites (Leingsakul et al., 1993).

The value of GIS to agriculture continually increases as advances in technology accelerate the need and opportunities for the acquisition, management, and analysis of spatial data on the farm and throughout the agriculture value chain **(**Pierce and David, 2007).

2.8 Previous study at Wadi Ziqlab catchment

In an attempt to survey and describe the various kinds of mass wasting featuring in Wadi Ziqlab Drainage basin. Nuafleh (1995) conducted a geomorphological survey of mass wasting features, and produced a landslide susceptible map, divided according to slopes slightly, moderately and highly susceptible to land sliding.

The study recommendations focused on the importance restraining the environmental hazards of land sliding by building stone walls, preventing cultivated agricultural practices, and afforestation of hilly steep areas.

In an evaluation of the woodland and range in Wadi Zeqlab. Radaideh, (2006) found that the natural vegetation cover in the area are affected by climatic factors especially rainfall and relative humidity, soil and geomorphology variation. Meanwhile, the cultivated areas (olives, and field crops) are concentrated near urban areas, and along the stream flow.

Also, he found that the natural vegetation cover decreased between 1953 to 2000, due to deforestation, overgrazing, and expansion of agriculture and urban areas. In a survey of water resources in Wadi Ziqlab catchment. Zoubi (1995), found that an average 54.3 MCM falls on the catchment each year. This volume is divided into 83.25% evapo-transpiration, and 16.75% of deep percolation. There are four springs in the catchment. The discharge of these springs ranges between 0.13 m3/hr in the dry season, and 5.13 m3/hr in the wet season. Most of the inhabitants in Wadi Ziqlab area depend on the rainfalls in their agriculture.

Ziqlab dam is located on Wadi Ziqlab, in northwest side of Jordan. The dam drains in a catchment area of 106 km. The yearly value for mean rainfall, mean annual runoff are 512.1 mm, 13.04 MCM and 9.6% respectively.

An up to date rating curve relating the actual storage capacity of the dam to the surface area had been constructed. The maximum water storing capacity of the dam has been decreased to 2078 MCM due to a sediment accumulation. This implies that the total amount of 1.62 MCM of the sediments accumulated since the operation of the dam 35 years ago (Shatnawi, 2002).

Fisher et al. (1966), The Wadi Ziqlab watershed region has distinctly limited agricultural potential, the limitations largely resulting from serious and progressive ecological deterioration. Since this deterioration is a result not only of ancient and long-continued disturbance of a naturally delicate balance but is also being accelerated by present pressure on land resources. The watershed has a combination of physical factors which make problem of soil erosion particularly serious. Great altitudinal range gives the catchment a very rapid rate of normal erosion - a rate which is exacerbated by present land use practices. He developed a land capability map, and recommended that:

- Cultivation on land in class VIII with slope over 22 degrees; which have extreme erosion hazard, ought to be stopped. Meanwhile, on such steep slopes grazing is almost as dangerous as cultivation
- Field crops can only continue to be raised on land of class VI and class VII if suitable conservation measures are introduced.

Wadi Ziqlab is a deeply incised valley draining towards the Jordan, parallel to the Wadi el-Arab but much steeper. Chalk and limestone are exposed at the slopes, which show the region's geological structure well. Average annual precipitation at this site reaches 300 mm. Colluvia in Wadi Ziqlab show that massive erosion and sedimentation took place in prehistory, and that current soils are much less developed than the paleosols.

Although the lower terraces give evidence of recent soil movements, no red colluvia could be observed there. In this context, the evidence from Wadi Ziqlab merely suggests that the Mediterranean Red Soils were eroded before 11,000 BC.

Ongoing deposition is evident as all Neolithic sites in Wadi Ziqlab were covered by grayish yellow soil of strongly varying thickness, and incision continued, too, indicated by the absence of these sites on the lowest wadi terraces.

A look into the Jordan valley and Wadi Ziqlab indicates that mainly soft, easily erodible chalk from the steep slopes was deposited there, since CaCO3-contents are very high throughout these profiles.

Mohawesh (2002), the analyses indicated that the conversion of forest to cultivated farms had effect on physical and chemical properties of soil. Among those mostly affected distribution of texture, bulk density of surface soil and subsoil, infiltration rates of cultivated lands, organic matter decreased on cultivated land, which have effects on decreases of nitrogen, phosphorus, and base cations. Electrical conductivity, cation exchange capacity also decreased, while the soil pH increased in surface and subsurface soil of cultivated land as compare to the forest soil. He conclude, that the degradation of physical and chemical properties, will effect on soil quality and fertility, where lead finally to crop productions.

Wadi Ziqlab catchment suffers from earth flows and earth slumps During February 1992, 290 earth flows and earth slumps were generated (Field and Banning, 1998). Similar features, preserved on the wadi slopes, were formed by the same process but during an earlier time. These processes can cause land degradation, because all the soil on up slopes could be washed down to the wadi and the land become bare. Large earth slumps in Wadi Ziqlab are often associated with flat benches and concentric head scarps and washed away.

3. MATERIALS and METHODS

3.1 Materials

3.1.1 Study area

Wadi Ziqlab catchment is located within an area that extends from the Highlands of Northern Jordan, to Eastern mountains bordering Jordan Valley. The study area is located between 32°23"- 32°34" North to 35°33"- 35°50" East. The catchment has a 24 km long, 8 km wide, and covers about 105 km² (Figure 1).

3.1.1.1 Topography

Wadi Ziqlab occupies one of the steep east bank of Jordan Valley. It extends from the western part of the plateau around Irbid into the Valley floor. The elevation within the catchment is highly variable. It falls from 1075 m above sea level, at the upper South-East portion of the catchment, to about 200 m below sea level, at the confluence of the Wadi Ziqlab with the main stream of the Jordan Valley in the West (Figure 2), (Fisher, et. al. 1966).

The general direction of drainage area is to the West-Northwest. The drainage pattern of the area consists of two parallel tributaries in the upper reaches, which units at the lower part of the catchment to form the main stream of Wadi Ziqlab. During the summer months, April to October, only the lower portion of the main stream below sea level 200 m has water flow (Figure 3).

Wadi Ziqlab catchment consists of 43 sub-catchments. The area of the sub-catchment varies from 5.3 to 782 ha. There are 25 wadi branches with total length of 215 km, connecting to the main stream. Figure 3 shows the distribution of streams path and sub-catchment area.

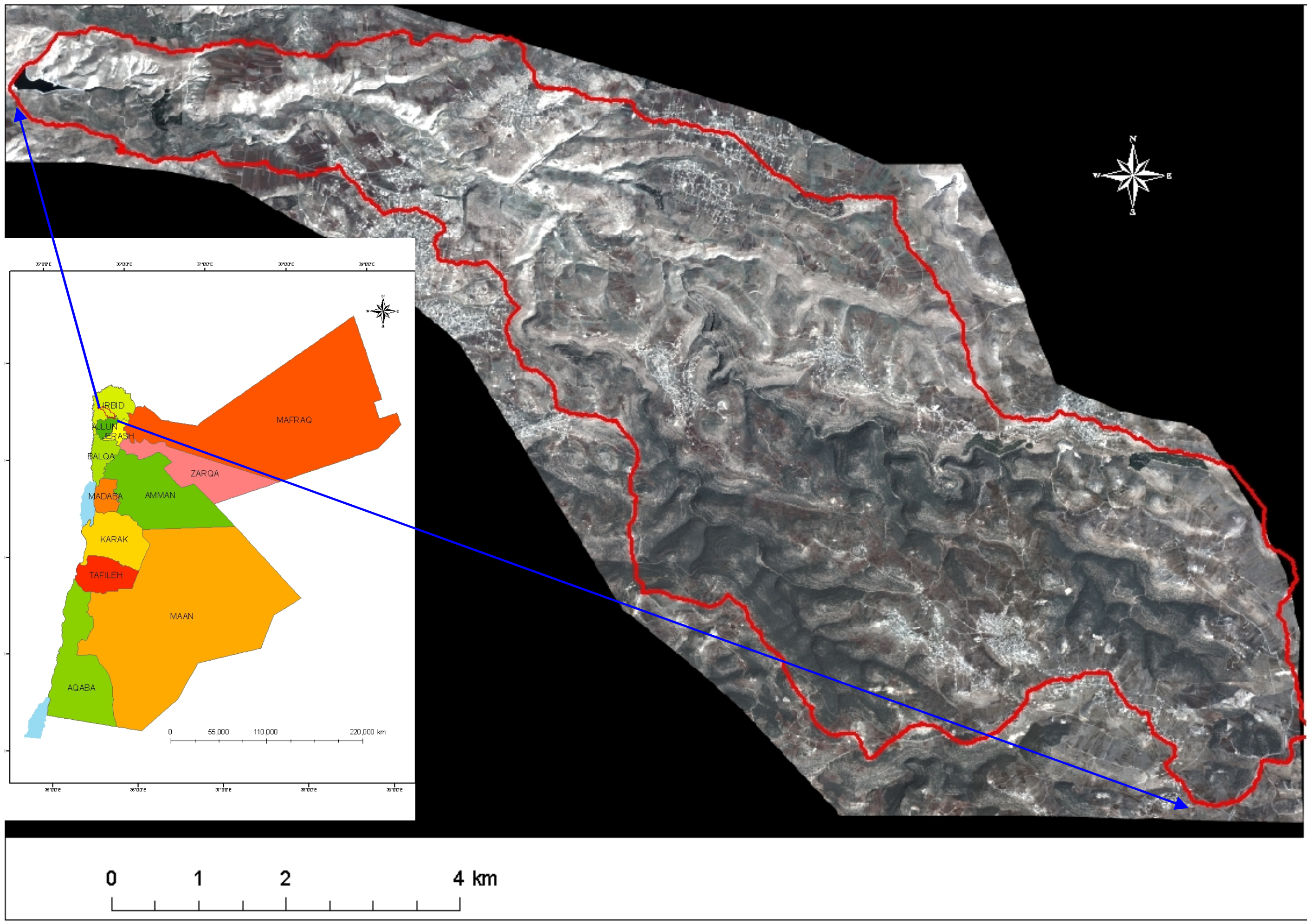

Figure 1: Location of study area, showing the boundary of Wadi Ziqlab catchment.

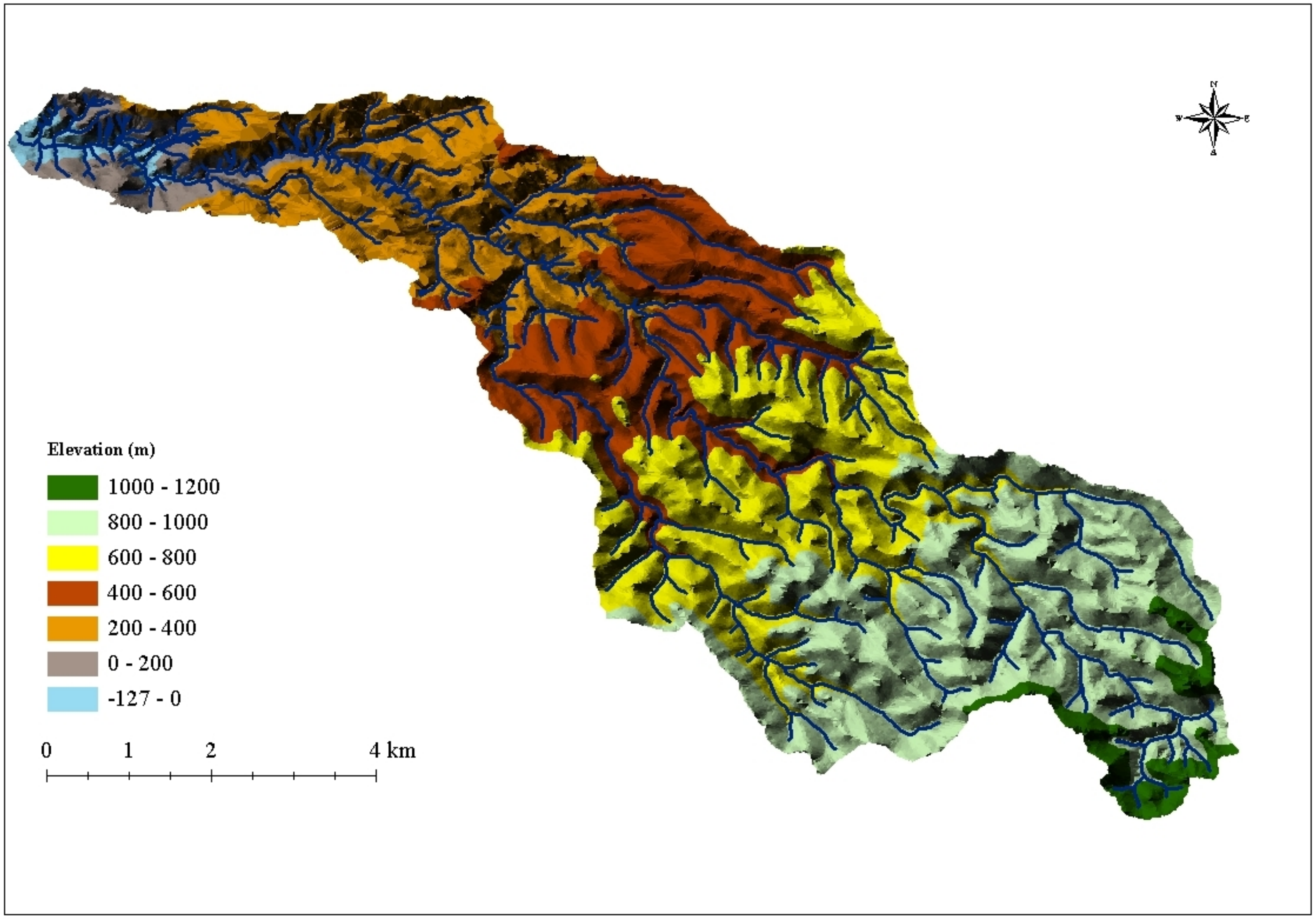

Figure 2: Elevation within Wadi Ziqlab catchment.

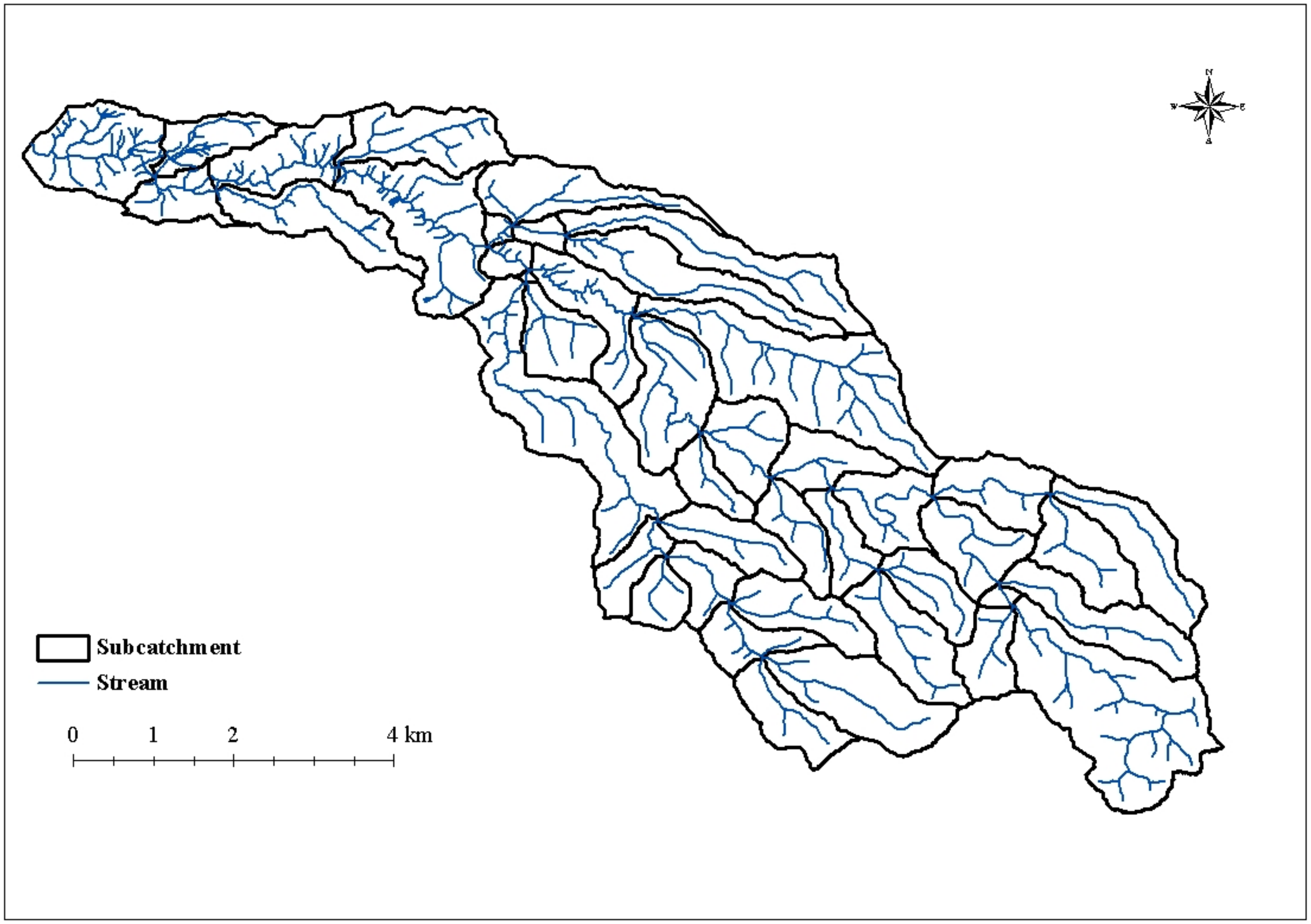

Figure 3: Distribution of sub-catchment and streams flow of Wadi Ziqlab catchment.

3.1.1.2 Geology

The study area consists mainly of ten formations, which belong to Ajlun, Balqa, Waqqas Conglomerate, and Jordan Valley Groups.

Wadi As Sir limestone formation (Ajlun group): Wadi Al-Sir formation is the oldest exposed rock unit. The formation crops out along the deep valleys. Only the upper 40m are cropping out and constitute an upper carbonate member and lower dolomite member. The well bedded thin to massive limestone, dolomitic limestone, dolomite limestone, dolomite and chert concretions were deposited in marine environment under lagoonal to tidal (Bender, 1974; Moh'd, 2000), and cover about 46% of Wadi Ziqlab area (Nuafleh, 1995). Sheib formation (Ajlun group): Sheib formation, consists mainly of marl limestone, yellow and gray marl, (Bender, 1974), and cover about 11% of Wadi Ziqlab area (Nuafleh, 1995). Wadi Umm Ghudran formation (Balqa group): Wadi Umm Ghudran formation contains vertebrate bearing sandstones that reach a thickness of 12 m to less than 50 cm thick in some places. Based on the presence of Globotruncana Concavata, it belong to Santonian in age (Bender, 1974). Amman Silicified Limestone formation (Balqa group): Amman Silicified Limestone formation (60m) is of Campanian Maestrichtian age, consists of the chert beds and concretions with occasional hrecciated textures, limestone concretions, laminated and fossiliferous chalk which is rich in vertebrate remains. Fossils include ammonites, bivalves, gastropods and baculites. The depositional environment is shallow marine (Bender, 1974; Moh'd, 2000). Al-Hisa phosphorite formation (Balqa group): Al-Hisa phosphorite formation (10-15m) is of Maestrichitian age, consists mainly of phosphate, phosphatic chert coquina, marl and limestone, and cover about 17% of Wadi Ziqlab (Moh'd, 2000 and Nuafleh, 1995). Muwaqqar Chalk Marl formation (Balqa group): Muwaqqar Chalk Marl formation range in thickness from 120-320m and consists of massive marl-chalky cliffs in its lower part, a sequence of alternating soft chalk and chalky limestone in the upper part, and hard limestone concretions within clayey marl towards its top. Fossils include pecten-like bivalves, fish teeth and vertebrate remains and occasional tube-like horizontal to inclined burrows (Bender, 1974; Moh'd, 2000). Umm Rijam Chert Limestone formation (Balqa group): Umm Rijam Chert-Limestone formation covers most of the sheet area and is about 220m thick. It consists of alternative of chalky limestone, marl limestone, and kerogenous limestone. It can be subdivided into three units: a lower marly chalk, a middle bedded chalky limestone, and an upper chert unit (Moh'd, 2000). Shallala Chalk formation (Balqa group): Shallala Chalk formation was deposited within a warm shallow open marine environment. Glauconite in the upper part, indicates brief shallow phase. It consists of the chalk and/or chert limestone (Bender, 1974; Moh'd, 2000). Tayyiba Limestone formation (Jordan Valley group): Tayyiba Limestone formations crops out in mountains overlooking the Jordan Valley. Two member can be distinguished at lower glauconitic and an upper cliffy limestone (Bender, 1974; Moh'd, 2000). Irkheim formation (Waqqas Conglomerate group): Irkheim formation is exposed in highlands overlying the rift, and consists mainly of three categories of chert limestone separated by marl (Bender, 1974; Moh'd, 2000).

The geological pattern of rock outcrop within the Wadi Ziqlab catchment is relatively simple, being dominantly composed of marine sediments of Cretaceous age (Fisher, et. al. 1966, Ionides, et al. 1939). Most of these strata consist of limestone or limy material, with high contents of calcium carbonate, (Bender, 1974; Beaumont and Atkinson, 1969; Fisher, et. al., 1966).

3.1.1.3 Climate

Jordan lies on the eastern margins of the Mediterranean climatic zone of the Eastern Mediterranean. This climate is characterized by warm, long dry summers, cool, wet winters and insufficient amount of precipitation (Freiwana and Kadioglub, 2008; Taimeh, 1999).

More than 80 percent of the country receives less than 200 mm annual precipitation (Taimeh, 1999). Jordan can be divided into four main ecosystems. Two major ecosystems can be found in the study area: Sub-tropical semi-arid in area close to the floor Jordan Valley and Mediterranean sub-humid within eastern upland.

Sub-tropical semi-arid: Semi-arid areas dominate in Jordan Valley north of Deir Alla. High summer and cool winter temperature characterize this ecosystem. Annual rainfall varies from 250-400 mm (Taimeh, 1999). Temperature is high during summer and winter, mean annual air temperature varies from 22.4 Cº at Baqura to 23.9 Cº at Deir All (Appendix A. Table 1).

Mediterranean sub-humid: This climate dominates the Highlands east of the Jordan Valley. The winter has a cool temperature, while the summer has mild temperature. Relative humidity is maximum during winter and very low during summer. Rainfall varies from 350 mm at the eastern part, to 550 mm towards the northwestern portion. The rainy season extends from November until March (Taimeh, 1999). Temperature is high during summer and cold during winter, mean annual air temperature varies from 14.3 Cº, at Ras Muneef to 17.9 Cº, at Irbid (Appendix A. Table 1).

3.1.1.3.1 Rainfall

Rainfall at Wadi Ziqlab catchment varied according to elevation. The rainfall data was collected for six stations, and covered 34 years (1978-2008). Baqura, Deir Alla, and

Deir Abo-Saeed, represent (low land) the Western part of catchment. Meanwhile Irbid, Ras Muneef, and Irhaba represent (Highland) the Eastern part of catchment.

Rainfall records indicated variations in rainfall distribution within the catchment as well as variation in the annual rainfall. The Eastern parts receive an annual average of 528 mm/year, whereas the Western parts receive only 375 mm/year. Appendix B. Table 1 2 shows the maximum, minimum and mean annual rainfall for different stations. Figure 4 shows the rainfall isohyets, using Thiessen polygon (Zoubi, 1995).

3.1.1.3.2 Air temperature

Air temperature at Wadi Ziqlab catchment varied according to elevation. Mean annual maximum air temperature was 29.9 Cº and 29.2 Cº at Baqura and Deir Alla stations, respectively for the Western part of the catchment (Appendix A. Table 1), while the mean annual maximum temperature was 23.1 Cº, and 18.5 Cº, at Irbid and Ras Muneef stations, respectively, for the Eastern part of the catchment.

The mean annual minimum air temperature was 17.9 Cº and 15.7 Cº at Baqura and Deir Alla, respectively for Western part of the catchment. While the mean annual minimum air temperature was 12.7 Cº, and 10.1 Cº, at Irbid, and Ras Muneef stations, respectively, for Eastern part of the catchment, Figures 5, 6, and 7 show mean annual maximum, mean annual minimum and mean annual air temperature for the four stations.

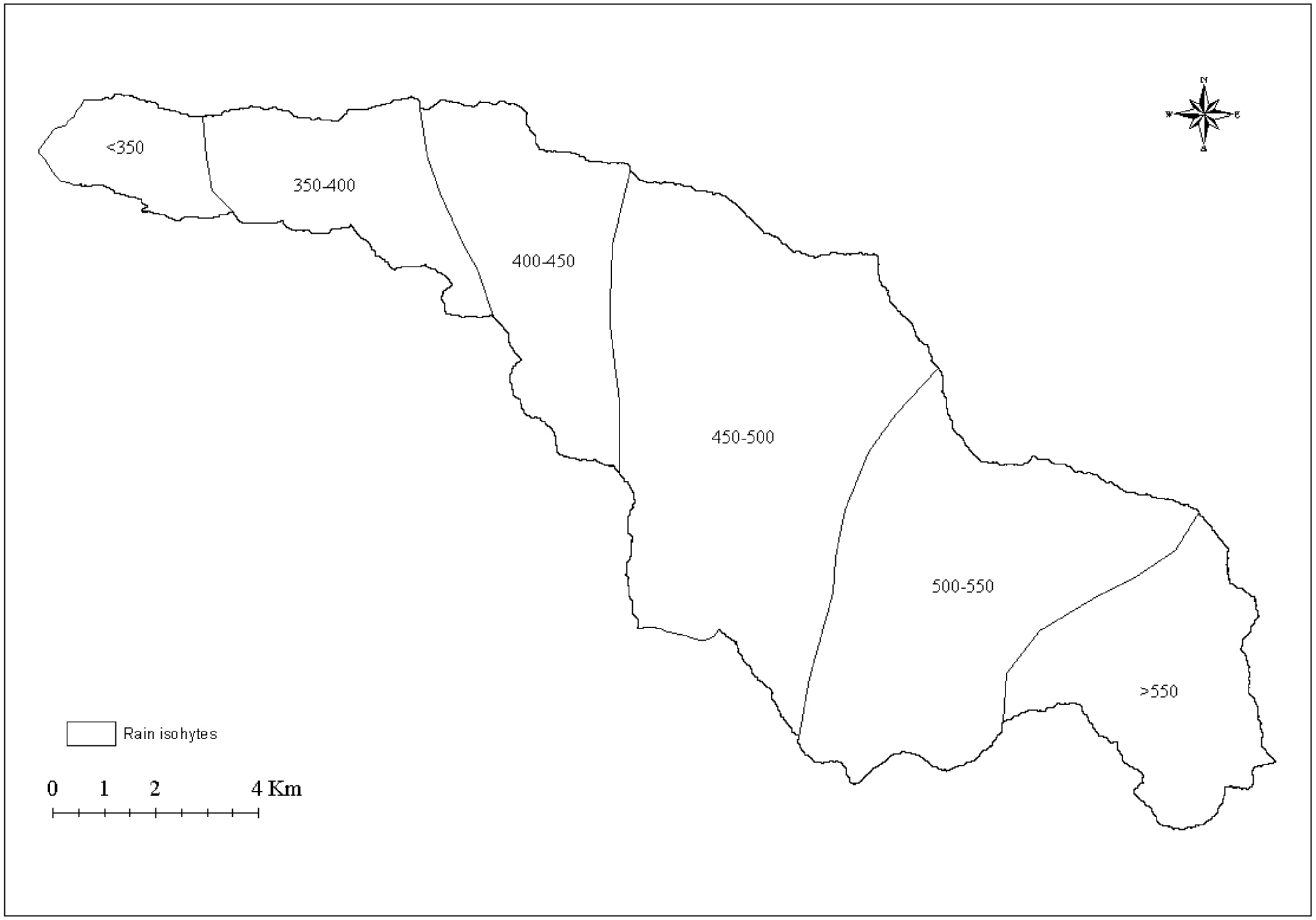

Figure 4: Rain isohyets of Wadi Ziqlab catchment.
Source: Zoubi, 1995. Using Thiessen Polygon.

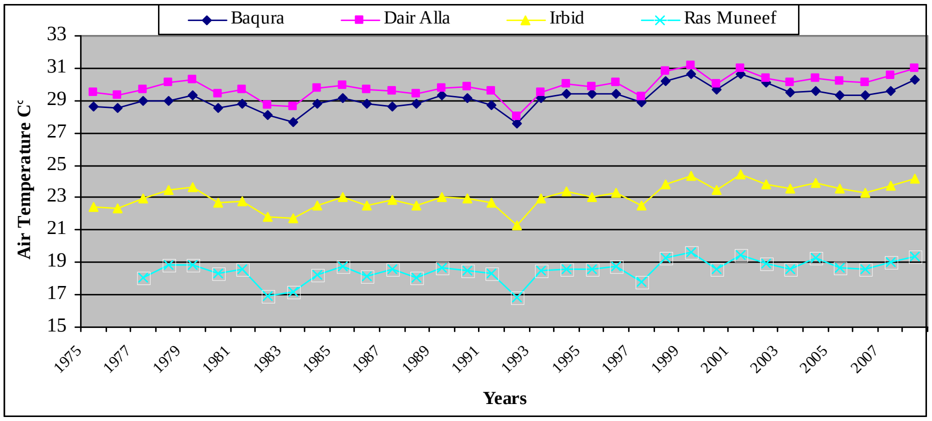

Figure 5. Variation of mean annual maximum air temperatures for selected stations at Wadi Ziqlab catchment.

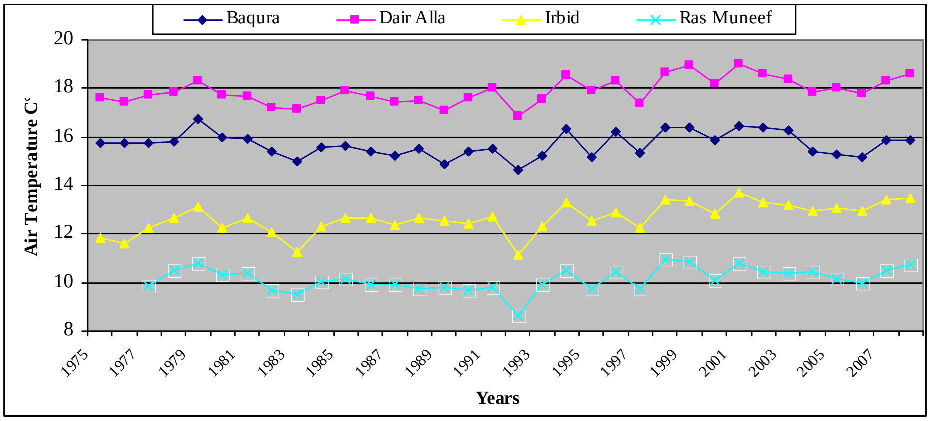

Figure 6. Variation of mean annual minimum air temperatures for selected stations at Wadi Ziqlab catchment.

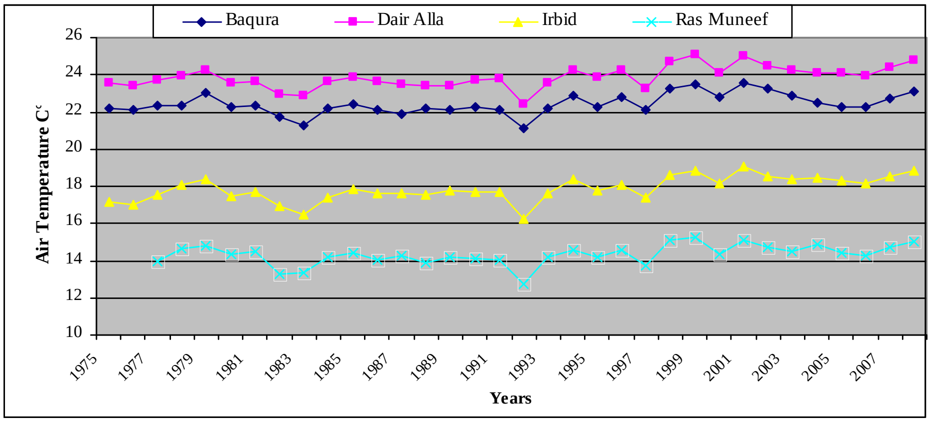

Figure 7. Variation of mean annual air temperatures for selected stations at Wadi Ziqlab catchment.

3.1.1.4 Land cover

Currently, orchard trees cover about 26%. The predominant fruit trees are olive (*Olea europacal*), apple (*Melus domestica*), grapes (Vitis vinefera), fig and stone fruits. Field and summer vegetable crops include: wheat (*Teriticum aestivum, T. turgidum*), barley (*Hordium vulgare*), onion (*Allium cepa*), tomato (*Solanum lyccoerscum*), okra (*Abelmoschus esculentus*), and others, cover about 12%. Forest, rangeland, and urban area cover about 29%, 24%, and 7%, respectively.

The land cover during 1950's was as follow: 25% of the area was used for rainfed field crops, primarily crops such as: wheat, barely, lentils, and vegetables such as okra, onion and tomato. About 4% of the area was covered with orchard, mainly olive trees. The rest of the area was covered as follow: about 33%, 37%, and 1% covered with forest, rangeland, and urban area, respectively. Roads were limited. Distance of cultivable land from urban area, and shortage of machinery governed the land utilization and allocation of land utilization.

Wadi Ziqlab is very rich with different wild and cultivated plant species. Radaideh (2006) reported the presence of 664 varieties of trees, 264 shrubs, 453 varieties of under trees grasses, and 2733 varieties of grasses (includes grassland, pasture, and hay-fields).

3.1.1.5 Land ownership and distribution

The land ownership follows family lines boundaries. Land is shared among children after the death of their fathers. This had continued over several generations. The distribution of ownership is as follow: Government land, occupies about 2600 ha, or 25% of the total area. Private land and (road networks), occupies about 7900 ha, or 75%. Distribution of Wadi Ziqlab catchment according to the plot size, using the following categories: ≤0.1, 0.11-0.20, 0.21-0.40, 0.41-1.0, 1.1-2.0, 2.1-3.0, 3.1-5.0, and

>5.1 ha, were as follows: 320 or (3%), 322 or (3.1%), 506 or (4.8%), 1727 or (16.5%), 1965 or (18.7%), 1020 or (9.7%), 1106 or (10.5%), and 3530 ha or (33.6%), respectively.

3.1.2 Resources

3.1.2.1 Soil

Wadi Ziqlab catchment has contains many soils with different properties. Haploxerepts, Haploxererts, and Xerorthents are the major Great Soil Groups (MoA. 1994). Typic Haploxerepts group are moderately deep, fine, loam/or very gravelly soils derived from limestone, and are slightly to highly calcareous. Lithic Haploxerepts group are shallow fine/loamy soils on limestone, and are slightly to highly calcareous. Lithic Xerorthents group are very shallow fine/loamy/very gravelly soils originated from limestone, and highly calcareous. Vertic Haploxerepts group are deep, red, with shallow cracks, originated from limestone, and slightly to highly calcareous. Chromic Haploxererts group are deep soils, red/brown with deep wide cracks, originated from limestone, and moderately to highly calcareous (MoA. 1994). Appendix C table 1 and Table 1 summarize dominant soils and their properties. Figure 8 gives the distribution of major soil sub-groups.

3.1.2.2 Water resource

Rainfall and ground water are the main water resources in Wadi Ziqlab catchment (Tutundjian, 2001; Zoubi, 1995). Surface water, includes the flow from springs and seasonal flood. Average base flow within the catchment during the period of 1976 to 1993 is about 6.58 MCM. The average spring flow is estimated at about 0.05 MCM/year (Zoubi, 1995). There are four main springs in Wadi Ziqlab with permanent flow. Other springs flow temporarily in the winter and become dry in summer (Zoubi, 1995).

Table 1. Summary of different soil mapping units properties of Wadi Ziqlab catchment.

Map Unit	Soils	Geology	Texture	Colour	Description
1	ChromicHaploxererts	Limestone	Clayey	Red	5YR 4/4 to 4/6, clay to silty clay, deep crack
17	LithicHaploxerolls*	Limestone	Clayey	Dark	5yr 3/3 to 7.5yr 3/3, silty clay loam to silty clay, with dark organic rich topsoil over lithic contact to limestone or chert within 50cm of the surface
10,17,23	LithicHaploxerepts	Limestone	Clayey	Red	2.5YR3/4 to 5yr 4/6, silty clay to clay, with a lithic contact to limestone or chart within 50 cm of the surface
10,17,25	LithicXerorthents	Limestone	Loamy	Brown	7.5YR 4/4 to 10YR 4/4, silty clay loam to clay loam, over lithic contact to hard limestone or chert within 24cm
1	TypicHaploxererts	Limestone	Clayey	Red	5YR3/4 to 4/4, clay to silty clay, crack
7	TypicHaploxerepts	Limestone	Clayey	Brown	7.5YR 4/4 to 10YR 5/6, silty clay to clay, with a moderate to strong HCl reaction, formed on upland colluvium
25	TypicHaploxerepts	Limestone	Loamy	Brown	7.5YR 4/4 to 10YR 5/6, silty clay loam to clay loam, with a moderate to strong HCl reaction, formed on upland colluvium
7,17	TypicHaploxerepts	Limestone	Clayey	Red	5YR 4/4 to 6YR 4/6, silty clay to clay, with a moderate to strong HCl reaction, formed on upland colluvium
23	TypicHaploxerepts	Limestone	Clayey	Red	2.5YR 4/4 to 6YR 4/6, silty clay to clay, nil or slight reaction to HCl, formed on upland colluviums
7,10	VerticHaploxerepts	Limestone	Clayey	Red	5YR3/4 to 4/4, silty clay to clay, substantial cracking
1	VerticHaploxerepts	Limestone	Clayey	Red	5YR 3/4 to 4/4, silty clay to clay, no calcic horizon present or is below 90cm, substantial shallow summer crack

Source: National Soil Map and Land Use Project, scale 1:50,000 MoA, 1994.
Loamy: very fine sand, amount of clay less than 35%; rock fragments are less than 35% by volume
Clayey: clay contents over 60%.
*Modified from MoA, 1994.

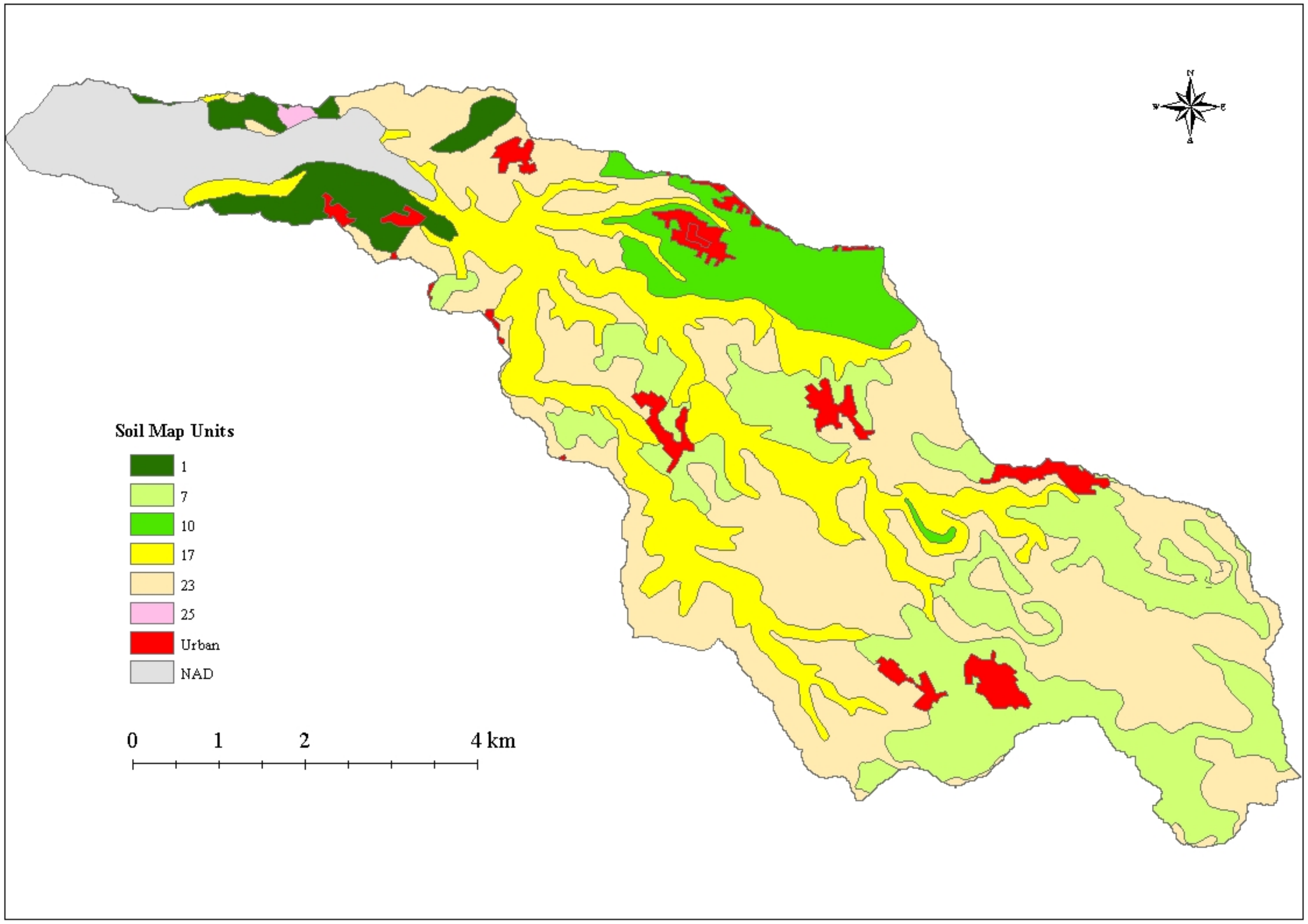

Figure 8: Soil mapping units of Wadi Ziqlab catchment. NAD: no available data
Source: National Soil Map and Land Use Project, MoA, 1994.

There are four wells in Wadi Ziqlab catchment. Two deep wells used since 1983 (Eun Alhamam one and two). The capacity of both wells is about 176 m^3/hour (Zoubi, 1995). The third well is used since 2006 with capacity of about 40 m^3/hour, and the fourth one has a capacity of about 80 m^3/hour and is in use since 2009 only.

Sharhabeel Dam is the only dam found in the catchment. It is a rockfill gravity dam, constructed in 1966 with a total capacity of 4.4 MCM. The quality of the water collected in the dam is good and can be used for domestic purposes with slight treatment by filtration and disinfecting, or for agricultural purposes (Tutundjian 2001 and Shatnawi, 2002), or recharging ground water (AL-Sheriadeh, et al., 1999; Margane 1999).

3.1.2.3 Population

There are 14 villages located in Wadi Ziqlab catchment, with a population of about 59303 in 2004 (DOS, 2004).

The population density in Wadi Ziqlab catchment varied from 87 to 154 person/km^2 in 1952, and increased to 389 to 943 person/km^2 in 2008 (Table 2). Most of the local populations depend on agriculture, civil service, and the army.

3.1.2.4 Deforestation and overgrazing

Deforestation is one of the main reasons of land degradation in Jordan, for last 25 years, there are less than 60 thousands forests trees are injured or completely damaged, an average of 2385 trees a year. Table 3 shows, most of the deforestation happened on the Government land. The most dangerous of the deforestation by remove the trees completely, there are about 23 thousands forests trees are completely removed, and about 36 thousands forest trees are injured by over grazing or cutting. Plate 77 show different types of deforestation.

Table 2. Distribution and development of population of villages within Wadi Ziqlab during the period from 1952-2004.

Village name	Registered village area (ha)	Population			Density person/km^2		
		1952	1979	2004	1952	1979	2004
Deir Abo Saeed	1208	1587	4780	14145	131	396	1171
Enbeh	1372	1198	2655	6662	87	194	486
Jenien Essafa	721	801	1688	3752	111	234	521
Kofor Kiefia	213	147	384	618	69	181	291
Mazar Shamaliyyeh	1597	2442	6642	12422	153	416	778
Merehba	227	238	699	*	105	308	*
Irhaba	954	1120	3250	7655	117	341	802
Rkhayyem	623	0	27	129	0	4	21
Samad	1214	599	1128	1086	49	93	89
Sammo	518	796	2529	6213	154	488	1199
Samt	158	204	785	*	129	497	*
Sowwan	475	0	8	12	0	2	3
Tebneh	421	900	2161	5805	214	513	1379
Zmal	466	700	1602	3028	150	344	650
Zoobya	437	430	1381	2860	98	316	655
Total	**10600**	**11162**	**29719**	**64387**	**105**	**280**	**607**

Source: Department of Statistics, reports: 1952, 1978, and 2004.
* These village are currently part of Deir Abo Saeed.

Table 3 show, there are 60% injured and 40% of forest trees are completely destroyed. The injured tree, can survive and developed with the time, but the destroyed tree the main problem here, because it removed and no replacement.

Deforestation on private forest cover was 9%, usually this happened because the farmer decided to replace it with orchard tree. About 91% of deforestation happened on government area, and no replacement for these trees.

Table 3. Injured and destroyed forest trees in government and private forest for the period between 1985 to 2009.

Year	Cases	Government forest		Private forest		Total		Total
		Injured	Destroyed	Injured	Destroyed	Injured	Destroyed	
198	125	1226	206	29	26	1255	232	1487
198	102	943	270	32	35	975	305	1280
198	99	420	1380	7	219	427	1599	2026
198	134	569	983	55	34	624	1017	1641
198	148	1001	2016	509	161	1510	2177	3687
199	173	626	479	405	120	1031	599	1630
199	152	522	429	40	15	562	444	1006
199	249	436	438	55	28	491	466	957
199	254	5888	4139	100	66	5988	4205	1019
199	177	4882	2359	120	55	5002	2414	7416
199	305	3016	834	10	530	3026	1364	4390
199	171	6168	2252	1	649	6169	2901	9070
199	287	2338	1281	57	334	2395	1615	4010
199	109	948	500	12	97	960	597	1557
199	131	952	438	12	143	964	581	1545
200	120	420	744	10	385	430	1129	1559
200	138	643	678	50	39	693	717	1410
200	112	960	344	60	21	1020	365	1385
200	43	496	449	13	21	509	470	979
200	18	166	52	35	10	201	62	263
200	14	290	7	0	7	290	14	304
200	16	150	19	24	12	174	31	205
200	43	220	72	30	41	250	113	363
200	55	309	72	100	82	409	154	563
200	15	646	37	12	14	658	51	709
	3190	34235	20478	1778	3144	36013	23622	5963

Source: Mazar Shamaliyyeh and Al Korah agricultural directorates: document, MoA, 2009.

Animal husbandry has effect on land cover, there are some families depending on animal and animal production as a main source of income. Table 4 shows the number of animal distribution according to the villages. Hostilely all sheep, goats and some time cows depend upon grazing. Appendix F, Plate 23 shows grazing area of different types of animals and effect on land degradation.

Table 4. Distribution of animal by villages within Wadi Ziqlab catchment 2009.

Village	Sheep	Goat	Cow
Deir AboSaeed	964	1217	89
Enbeh	1765	1801	342
Jenien Essafa	2654	1520	581
Mazar Shamaliyyeh	4082	3922	239
Merehba	482	475	10
Irhaba	917	378	128
Sammo and Kofor Kiefia	2955	511	90
Samt	224	275	36
Tebneh	156	2091	54
Zmal	419	304	43
Zoobya	432	395	1
Total	15050	12889	1613

Source: Mazar Shamaliyyeh and Al Korah agricultural directorates, document, MoA. (2009).

3.1.3 Methods of soil conservation at Wadi Ziqlab catchment

Different methods of soil and water conservation were employed at Wadi Ziqlab catchment long time ago. Until recently, same methods are used, while other new methods such as terraces were used when new machinery became available. The main methods of soil conservation are:

- **Stone tree basin:** Stone tree basin used as soil conservation for each single tree separately, (Appendix F plate 12 shows the recent and old stone tree basin). Stone tree basin used as soil conservation for each single tree separately, (Appendix F plate 13 shows the recent and old stone tree basin, and shows the effect of stone tree basin on soil conservation, and how can protect the tree and soil around the root zone).
- **Stone wall**: Stone wall structure is widely used at Wadi Ziqlab catchment, in past and present for the following reasons:
  - Availability of abundant stone at the surface of soil, especially at eastern part of the catchment.
  - Cleaning of the land from surface stone.

- Stone walls can be easily built.

  Appendix F, plate 14, show different condition of stone wall. Appendix F, plate 15, shows show one olive farm with stone wall and other without stone wall. This means that the stone wall mostly depend upon availability of stone on the field.

- **Terraces:** Terraces as a new soil conservation structure was used recently in Wadi Ziqlab catchment. Appendix F, plate 16 shows different type of soil terraces. Terraces are nearly-level strips built along contours. Their main purpose is to intercept runoff and control erosion. Terraces control erosion in many ways. They divide fields into small separate drainage areas and reduce the length of the slope. Runoff and its damage are reduced. Water is conserved on the field or moved off in a controlled manner.
- **Contour line (Gradoni):** Contour line usually used on steeply land and deep soil, for range crops and afforestation. Appendix F, plate 17 shows some area constructed with contour line and planted with forest trees. Contour cultivation on 2% slopes reduced soil loss by 28% and runoff by 61%, compared to traditional (Chamberlain 1990).
- **Wadies controls**: As it is mentioned before, the total length of wadies within Wadi Ziqlab catchment is 215 km. Different ways were used for controlling the wadi bank. Wadies were protected by construction the dike across the wadi, or by constructing a stones along both sides of the wadi. Appendix F plate 18, show the old and new dike constructed across the wadi. Appendix F, plate 19a, shows the stone wall constructed along the wadi to control width and banks of wadi. Plate 19b show unobstructed wadi, and how much of soil erosion can take place.

3.2 Methods

3.2.1 Database preparation

GIS software was used as a platform for data analyses and management of products. The following maps and data were used in this study:

- Topographic maps at scale of 1:25000, produced by Royal Jordanian Geographic Center (RJGC), for year 1997. Topographic map was used to produce the contour lines and Digital Elevation Model (DEM) map.
- Different land cover maps were produced, use aerial photos at scale 1:10,000 obtained from (RJGC) for year 1953 and 1978. Satellite image Quick Bird, resolution (60 cm) prepared by (RJGC) 2008
- Ownership and land size distribution was produced, use cadastral maps at scale1:10000 obtained from (Land and Survey Department-Jordan, 2004).
- Soil map at scale 1:50000, prepared by National Soil Map and Land Use Project, Ministry of Agriculture, 1994.
- The polygon boundaries are digitized by on-screen digitizing, for topographic maps, aerial photo for years 1953 and 1978, and satellite image for year 2008.
- Digitizing errors was calculated by producing a land cover map with buffer values of 2 m for each polygon in 2008 land cover map. Subtracted the original area from area with buffer. Divide the result by the buffered area and multiplied by 100.

3.2.2 Land cover analyses

Land cover analyses aimed to study, land cover change since 1953. Satellite image (2008) and aerial photos (1953 and 1978) were analyzed to investigate land covers and land cover changes during the period from 1953-2008.

Land cover mapping was carried out through classification, and interpretations of aerial photos taken in 1953, and 1978, and satellite images of 2008.

3.2.2.1 Aerial photos and satellite image processing and classification

Aerial photos were scanned, georeferenced to the coordinate system (WGS84, projection: UTM zone 36) using a topographic map which was produced in 1978 at a scale of 1:25000 by RJGC. An image-to-image registration technique in the ERDAS imagine 9.3 software, was used to georeference and mosaic all the 24 aerial photos for 1953, and 1978.

The satellite images and other maps used in this study were projected to a common coordinate system and resampled to the same spatial resolution.

Visual interpretation of aerial photos and satellite images was enhanced through the use of lines, points and polygons to draw the land covers maps of 1953, 1978 and 2008 with ArcGIS 9.1 software. Figure 9, summarizes the process of land cover analyses.

Field visits were necessary for validating results of land cover interpretation and for description of the characteristics of each land cover class and land use. Selective sampling technique was used for this purpose. This technique was chosen because prior to field visit, classification of aerial photos and satellite images was carried out where different classes of land cover were established.

3.2.2.2 Description of land cover classes

The land cover was classified according to CORINE system (Coordination of Information on the Environment) (Bossard, et. al 2000). The system divides land into five classes at level one. The classes are: artificial surfaces, agricultural areas, forest and semi natural surfaces, and water bodies. These classes are subdivided into 15 subclasses at level two and to 44 sub-subclasses at level three (Bossard, et. al 2000).

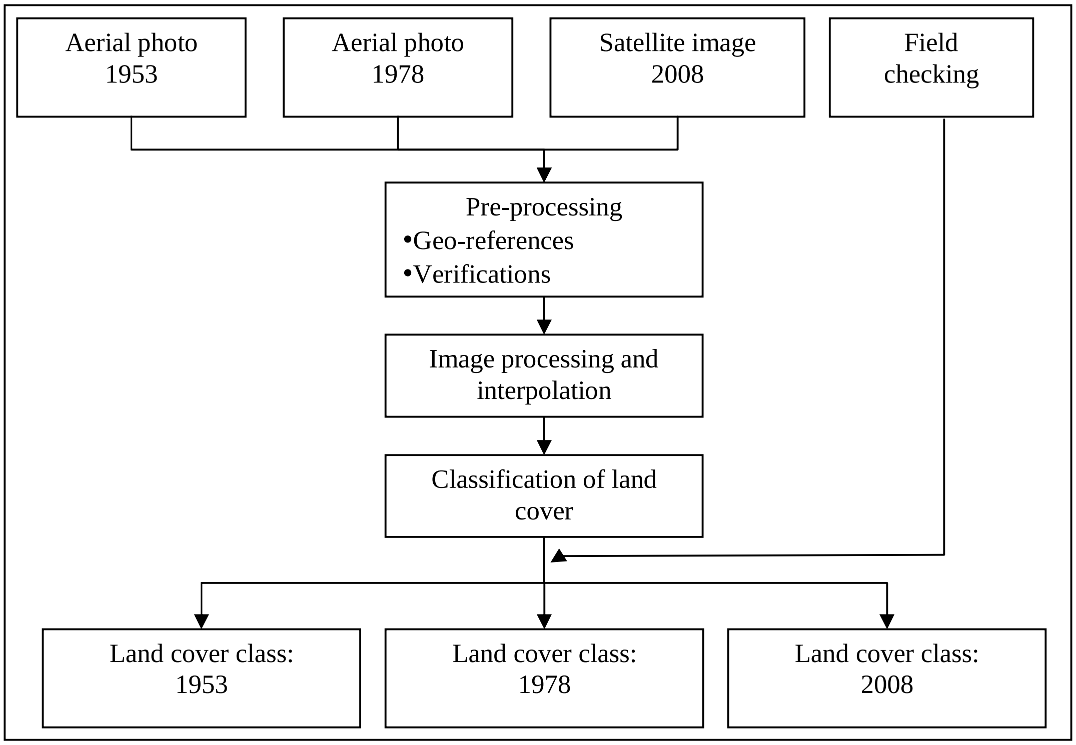

Figure 9. Flow chart showing steps used for land cover mapping.

A land cover classification was carried according to CORINE programme as a base (keys). The CORINE system was implemented using 1953 and 1978 aerial photos and 2008 satellite image. CORINE was modified to fit condition prevailing in the study area. Table 5 shows the categories according to CORINE classification.

3.2.2.3 Land use/cover change adapted to CORINE classification

A map showing land cover changes was developed by overlapping and intersecting the land covers in 1953, 1978 and 2008. The procedure is based on the comparison of the land cover at 1953 with land cover at 1978, and by comparing land cover at 1978 with land cover of 2008. Figure 10 shows a summary of land covers change.

Table 5. Land covers classification adopted to CORINE system.

CORINE land cover classes level 1	**CORINE land classes cover level 2**	**CORINE land classes cover level 3**
1. Artificial surface	1.1. Urban fabric	1.1.1 Continuous urban: Old village, building cover more than 50%
		1.1.2 Discontinuous urban: Extended village, building cover more than 25%
		1.1.3 House at farm: Scattered houses on a farms, far from villages
	1.2. Industrial, commercial	1.2.1 Quarrys: Area excavated for stones or sands used for constructions
		1.2.2 Animal farm: Poultry, cows, or sheep farms
2. Agricultural area	2.1 Permanent crop	2.1.1 Field crop: Winter or summer field crops
		2.1.2 Irrigated agriculture: Irrigated orchards
	2.2 Tree	2.2.2 Orchard: More than two variety of trees
		2.2.3 Olive: Olive trees
3. Forests and semi-natural area	3.1 Forest	3.1.1 Low forest (a).
		3.1.2 Moderate forest (b)
		3.1.3 Dense forest (c)
	3.2 Shrub and range	3.2.1 Shrubs and range: Include the area with annual grasses, Permanent and perennial shrubs
4. Water body	4.1 Artificial water body	4.1.1 Areas covered by manmade small dams, known as Sharhabeel dam.

a- Forest trees cover less than 25%.
b- Forest trees cover 26-50%.
c- Forest trees cover 51-75%.

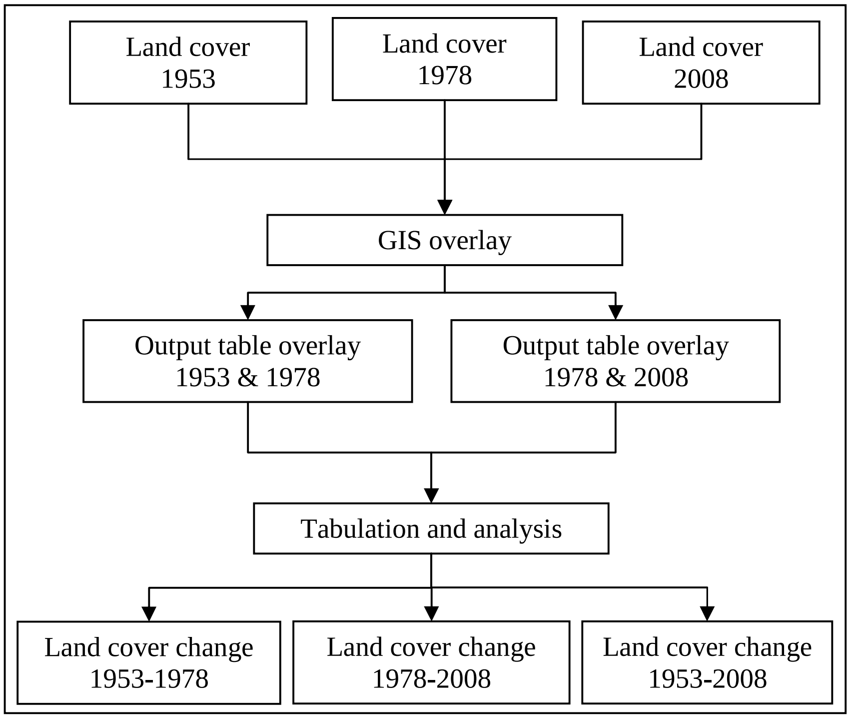

Figure 10. Flow chart showing steps used to assess land covers change.

3.2.2.4 Land covers versus land suitability and plot size

Land cover maps and land suitability map were prepared by overlapping and intersecting the land covers in 1953, 1978, 2008, and land suitability. The procedure is based on the comparison of the land cover maps in 1953, 1978 and 2008 with land suitability map, to compare land suitability with actual land use, i.e. where the actual land use is fitted or is similar to land suitability. Figure 11 shows summary of assessment of land suitability versus land cover and plots size. The objective of these comparisons was to evaluate whether the land is used according to it is suitability, and to evaluate the effect of fragmentation, or plot size on land cover and land cover change.

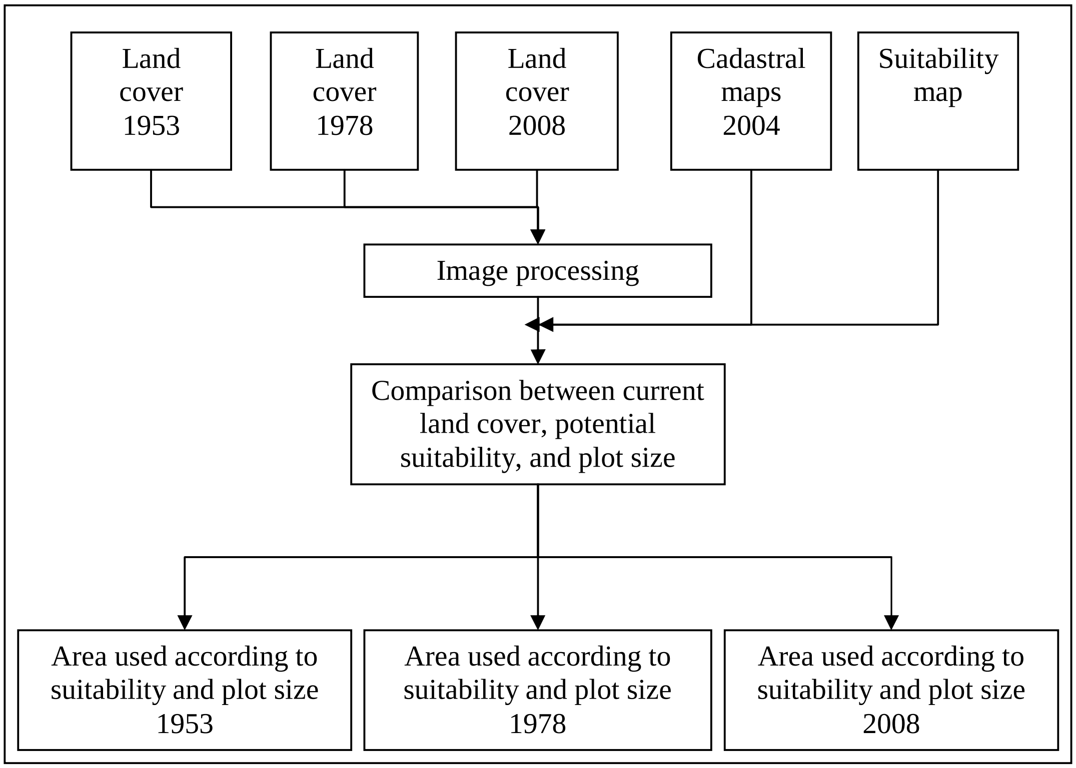

Figure 11: Flow chart showing steps used to assess land suitability with land cover and plots size mapping procedure.

3.2.3 Land ownership and parcel size

Cadastral maps that cover the study area were obtained in digital format from the Land and Survey Department (LSD). Then they were transformed, and reclassified according to ownerships and parcel size with GIS.

Land ownership was classified for each plot according to the type of ownership, (Government or private land). The cadastral maps were classified according to parcel size with the following categories: ≤0.10 ha, 0.11-0.20 ha, 0.21-0.40 ha, 0.41-1.0 ha, 1.1-2.0 ha, 2.1-3.0 ha, 3.1-5.0 ha, and >5 ha. The cadastral map (for selected villages) was overlapped with different land covers to evaluate effect of plot size on land cover change. Figures 12, and 13 show the cadastral maps for Mazar Shamaliyyeh and Al Korah District. Figure 14 shows only a Sammo cadastral map as a single village for more detailed to shows the shape of each parcels.

3.2.4 Land suitability

The FAO Framework (FAO, 1976) was used to evaluate the land suitability for: rainfed arable (field crops), rainfed perennials (fruit trees), drip irrigation (supplementary irrigation for fruit trees), forest area and rangeland (FAO, 1983). Criteria used in the evaluation were developed by the Ministry of Agriculture and Hunting Technical Services LTD (1994). Required land qualities and their associated land characteristics were aggregated into five main groups; Climate, soil depth, erosion, topography and rockiness.

3.2.5.1 Land suitability procedure

Land suitability procedure applied in this study was adopted by Ministry of Agriculture - Jordan (MoA, 1994).

The basic categories employed by the MoA (1994) include:

- **Climate:** Precipitation and air temperature.
- **Soil:** Soil properties such as soil depth and soil texture.
- **Erosion:** Assessment of gully erosion.
- **Topography:** Slope percentage, and length.
- **Rockiness:** Surface stoniness content and rock out crop.

3.2.5.2 Suitability ratings:

Suitability ratings are sets of values which indicate how the selected land use requirements are satisfied by particular conditions of the corresponding land quality (FAO, 1983). Ratings are made in terms of four classes (Table 6).

Table 6. Suitability classes, based on the productivity level (FAO, 1983)

Suitability degree	Code	Symbol	Description
Highly suitable	1	S1	Land has no limitations to the sustained application of the defined use.
Moderately suitable	2	S2	Land having limitations, which will reduce production levels but is still physically and economically suitable for the defined use
Marginally suitable	3	S3	Land having limitations, which will reduce production levels such that it is economically marginal for the defined use.
Not suitable	4	NS	Not suitable for the agricultural production

Source: National Soil Map and Land Use Project ,MoA, 1994.

3.2.4.3 Land utilization types (LUT's)

Land utilization in the study area was surveys. The following LUT's are practiced in the study area:

- **Field and vegetable crops (LUT1):** Wheat, okra, onion and bean.
- **Olive and fruit trees (LUT2):** Olives and orchards.
- **Range and shrubs (LUT3):** This type of utilization is mostly practiced under semi-arid conditions or unfavorable soil properties or steep land, where the rainfall amounts or the soil moisture availability is not sufficient to satisfy the crop water requirements. Most of this type of utilization exists as open rangelands with some reserve areas.
- **Natural forest (LUT4):** This land utilization type dominates on governmental land, particularly high mountains area in the eastern part and high rainfall zone.
- **Surface irrigation (LUT5):** This land utilization is practiced on the down stream of the catchment, near spring, pomegranate (*Punica granatum*) is the main fruit trees.

3.2.4.4 Land suitability versus size of ownerships

Cadastral maps were scanned, georeferenced to the coordinates system of the study area (WGS84, projection: UTM zone 36) using a topographic map which was produced in 2004 at a scale of 1:10000. The cadastral map was overlapped with land covers, and land suitability, to evaluate the effect of land ownership size on land cover change (Figure 11). Figure 13 shows the cadastral map of Mazar Shamaliyyeh district villages. Figure 14 shows the cadastral villages of Al Korah district. Figure 15 shows Samoa village cadastral map as an example for the plots distribution and plots shapes.

3.2.5 Field work

The Wadi Ziqlab catchment was divided into different zones, according to elevation and land cover. By examining the satellite image 2008, and different land cover, sites which have different land cover and land cover change were selected, and then were validated. Forty sites were distributed overall the catchment are selected. Each site should represent the following: have 2-4 different land covers, and land cover change i.e. some sample has the same land cover since 1953 to 2008, and part of the land has changed it cover during the periods between 1953 to 1978, and/or 1978 to 2008.

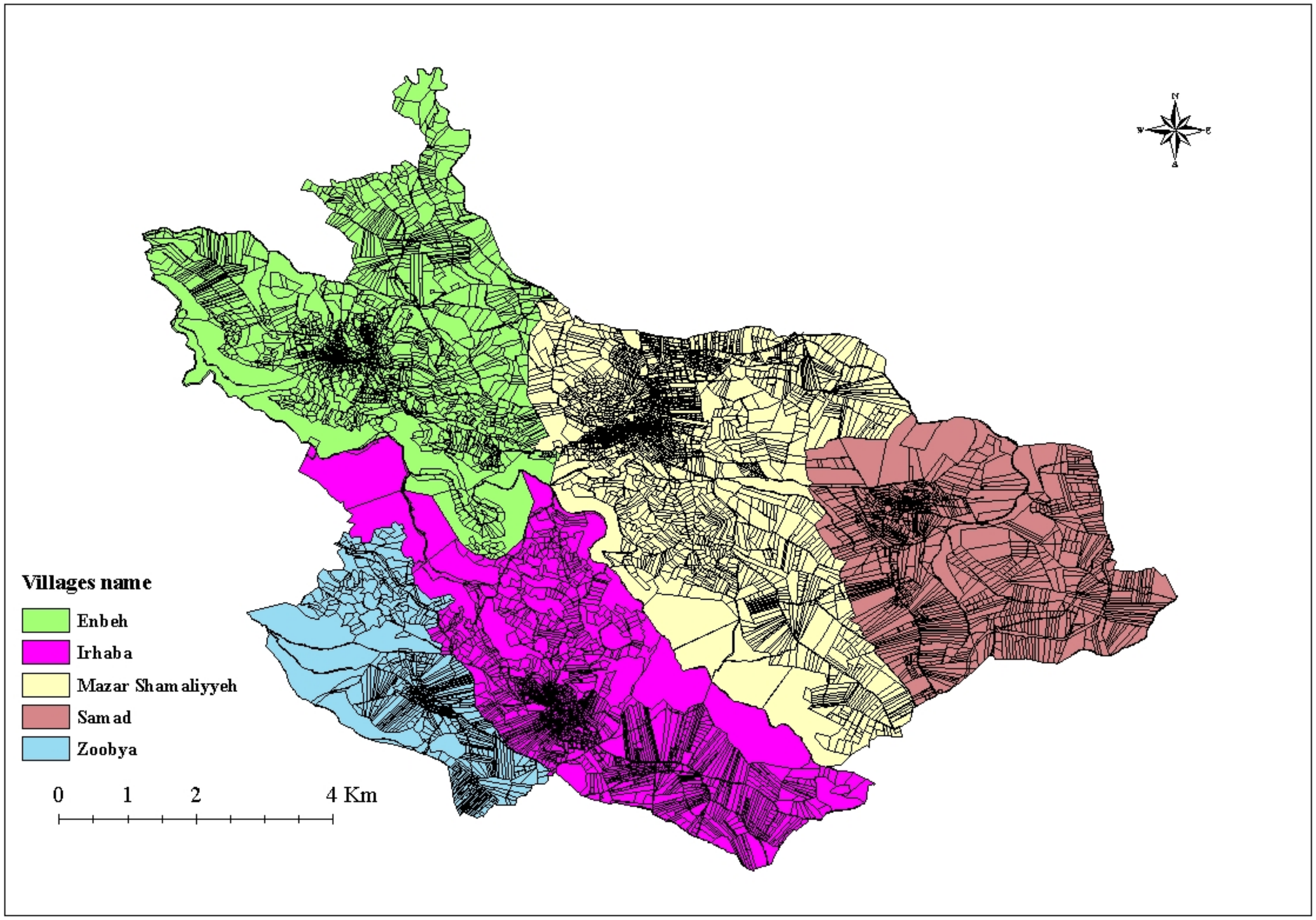

Figure 12: Cadastral map of Mazar Shamaliyyeh district villages.

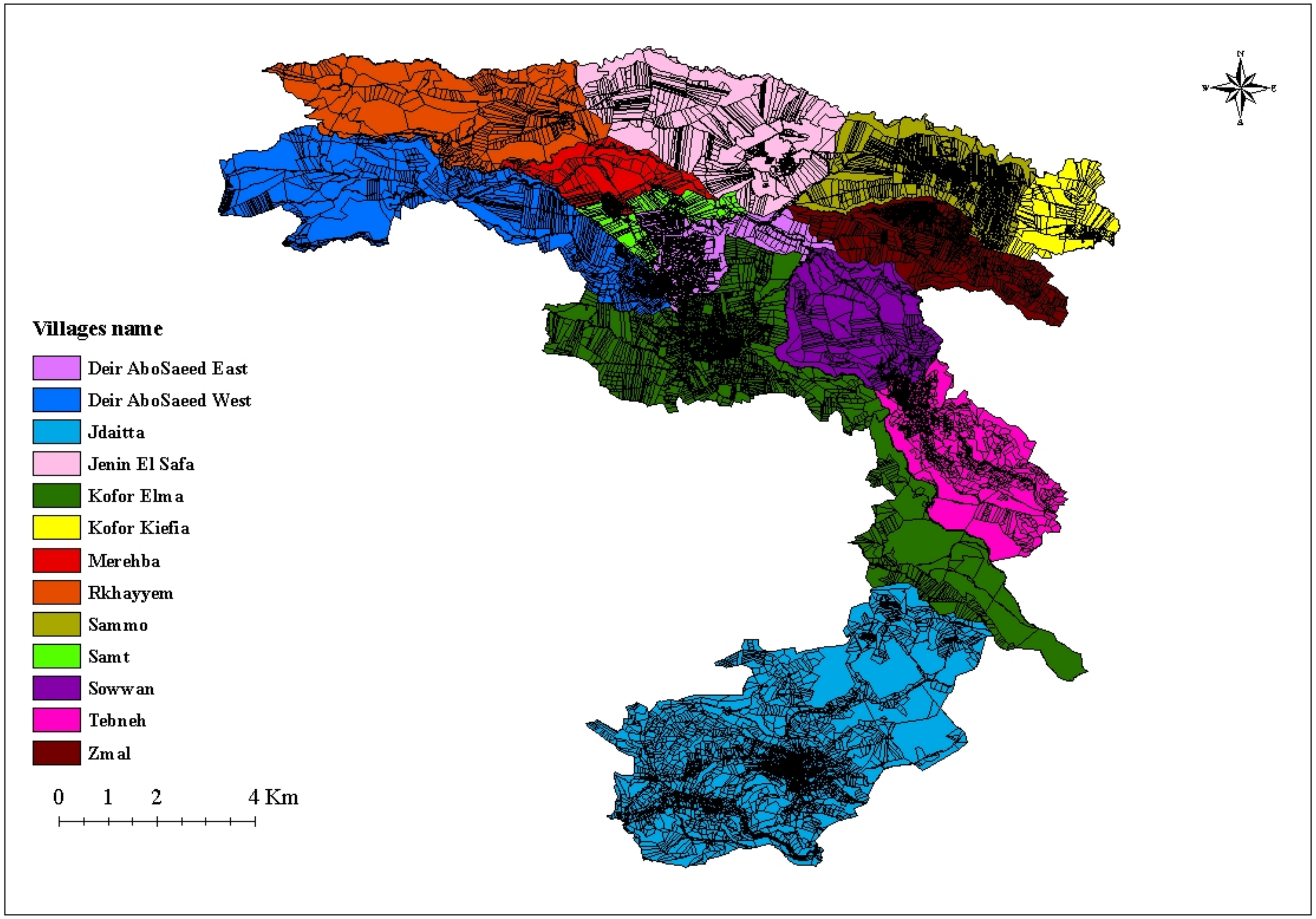

Figure 13: Cadastral map of Al Korah district villages.

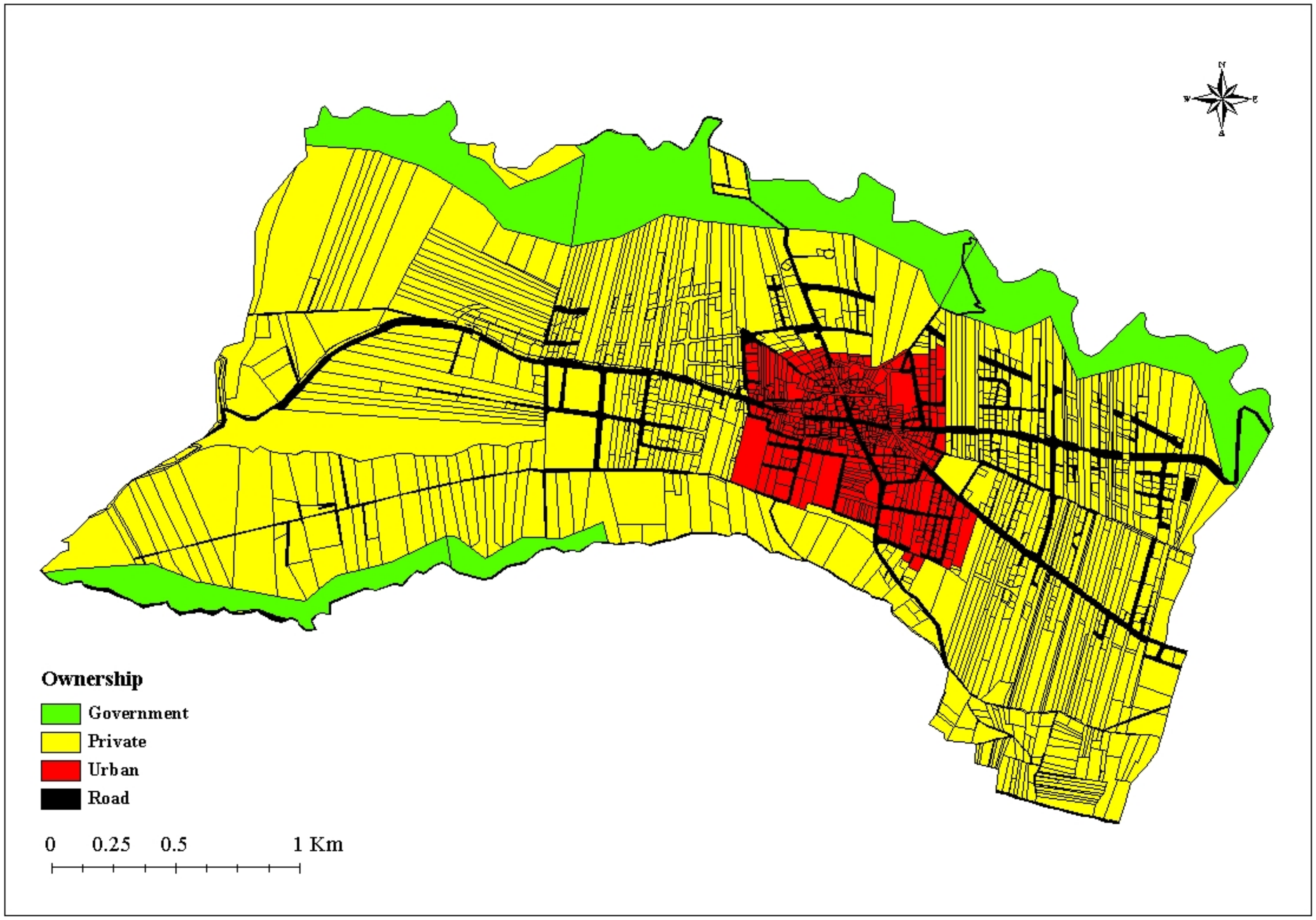

Figure 14: Cadastral map of Sammo villages.

Soil samples were collected from each land cover for all the 40 sites, each site included 2-4 different land covers. Total soil sample was 218. The objectives were to cover all the different land cover categories and land covers change during the period between 1953 and 2008, and to include all different soils in the study area. Each site represents different past and present land cover. Appendix D, Table 1, describes the land covers for soil samples in 1953, 1978 and 2008, thickness of A-horizon, soil texture, soil organic matter, availability of soil conservation measurements and number of samples for each land cover. Figure 15, shows the distribution and location of each site.

Surface soil samples (A-horizon) were collected. Thickness of A-horizon was measured in the field, soil texture and soil organic matter was analyzed in the laboratory.

3.2.6 Laboratory Analysis

The soil samples were air dried for 2-3 days under shade, sieved through a 2 mm mesh to remove stones, roots, and organic tissues, sealed in plastic bags, and carefully stored before analyses. Samples were analyzed as duplicated.

3.2.6.1 Particle size analysis:

Particle size distributions were determined by the hydrometer method (Bouyoucos, 1951).

3.2.6.2 Organic matter:

Organic carbon content was determined using Walkley-Black method (Nelson and Sommers, 1982).

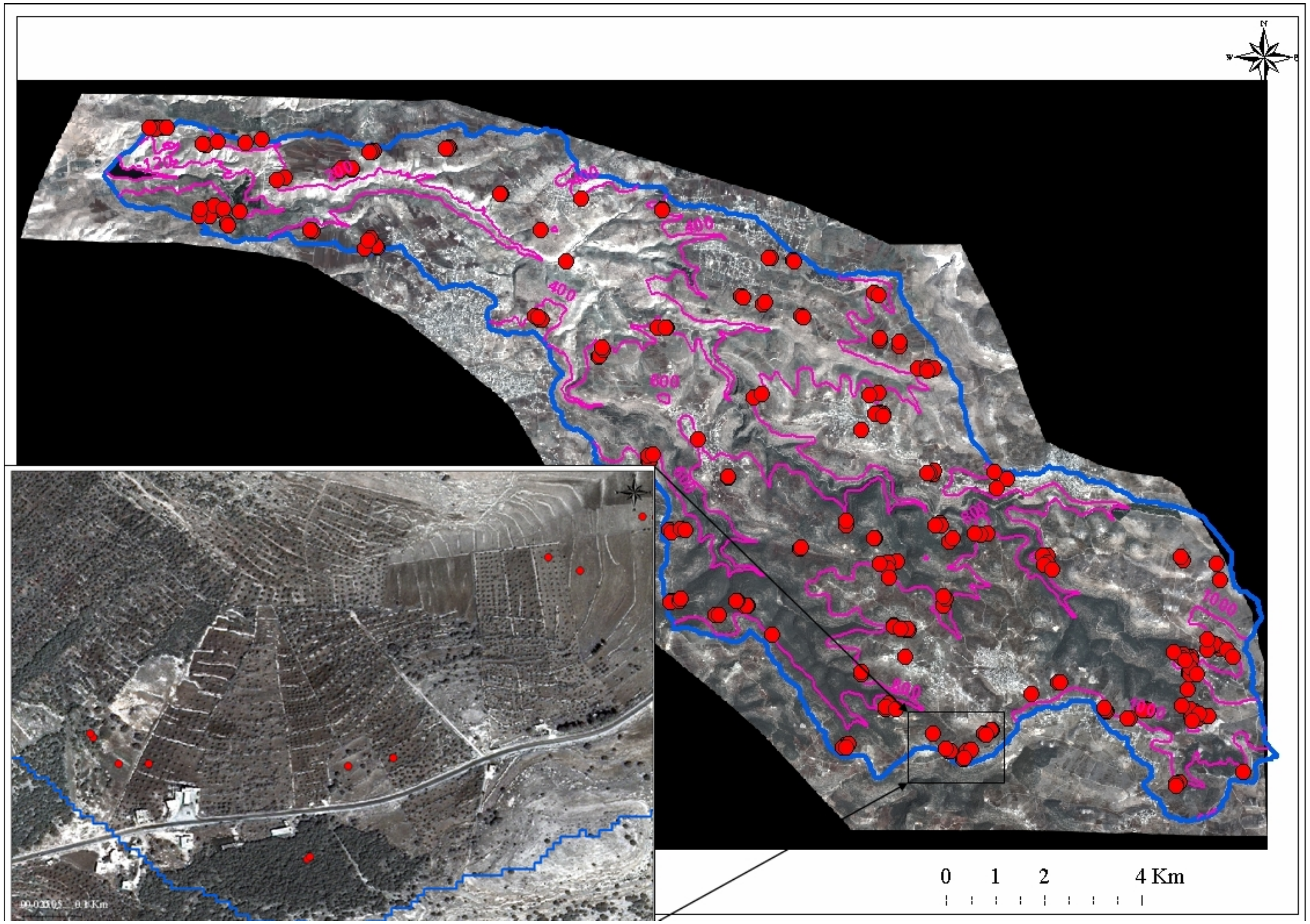

Figure 15: Location of soil samples.

3.2.6.3 Statistical analyses

A repeated measures, rainfall isohyets as blocking, soil conservation nested with land cover as independent variable, effects analysis (Unbalanced Treatment Structure, GenStat version 9.1), was employed to assess the effect of rainfall, land cover type, and soil conservation structures, their interaction on organic matter, soil texture, and thickness of A-horizon. Statistical significance was determined at levels 0.05 and 0.01.

T-test analysis of variance (SPSS version15) was used to determine the effect of land cover changes (forest vs. field crops, forest vs. orchard, forest vs. rangeland, field crops vs. orchard, field crop vs. rangeland, and orchard vs. rangeland) and (all possibility of land cover changes) on soil for organic matter, soil texture (clay, silt, and sand), and thickness of A-horizon.

3.2.7 Assessment of land degradation

The following were utilized to assess land degradation:

- Effect of change in land cover as of 1953, 1978, and 2008, on soil organic matter content, texture, and thickness of A-horizon.
- Effect of changing of land use on soil organic matter content, texture, and thickness of A-horizon.
- Effect of land fragmentation (plot size) on land use/land cover.
- Comparison between actual land cover and potential land suitability.

Note: Soil organic matter content, texture, and thickness of A-horizon were used as an indicator to assess land degradation.

Figure 16 is a flow chart that summarizes the steps used to assess land degradation. Software used for data entry, storing, analyzing, and output production include: Arc/GIS, as Geographical Informational System (GIS); ERDAS as image processing software and Microsoft Excel as work sheet software and SPSS , SAS and GenStat for statistical analyses.

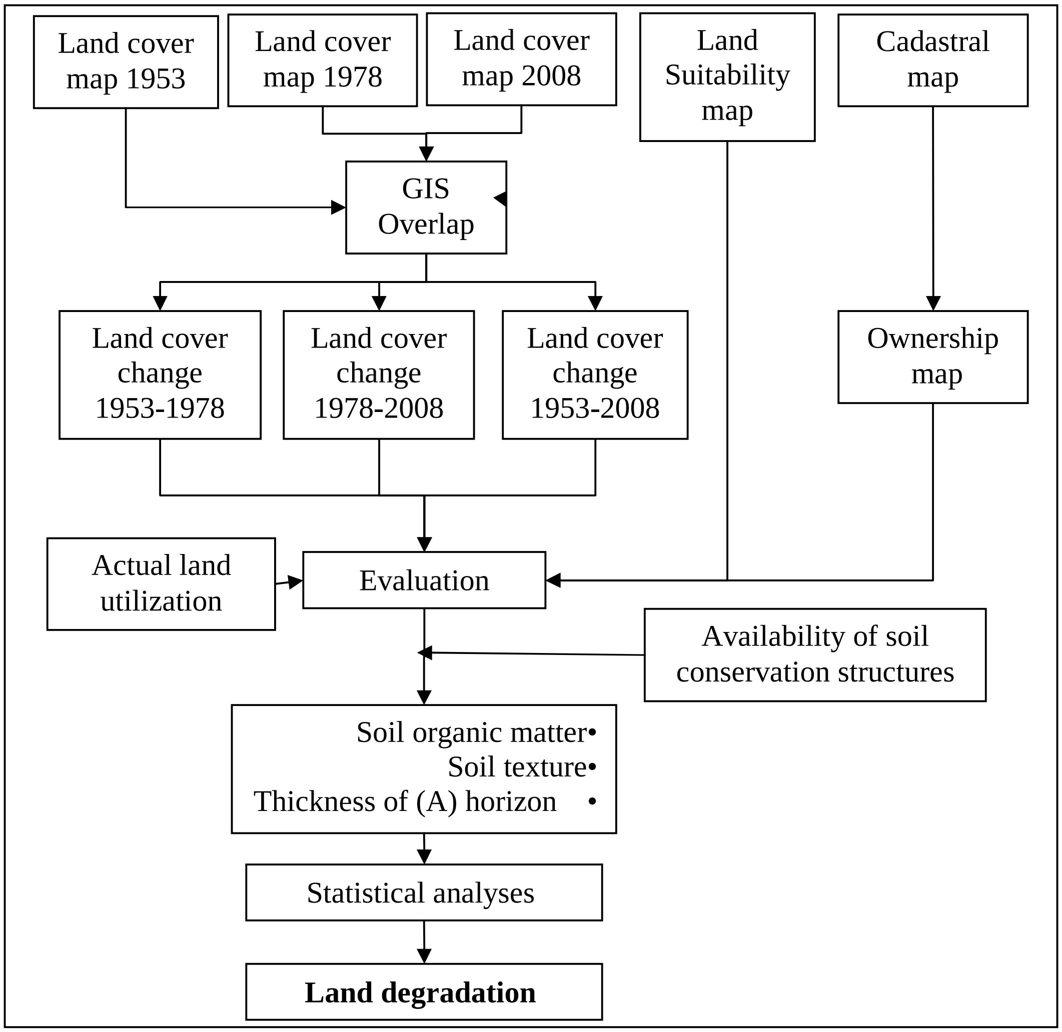

Figure 16: Flow chart showing steps used to assess land degradation.

4. RESULTS AND DISCUSSION

4.1 Land cover classification using CORINE system

The CORINE system was modified to suite the study area, especially at level 3. The modified CORINE system includes forest, urban area, field crops, and orchards trees. The main modifications for CORINE include: 1) forest area:-the forest area was classified according to canopy density. 2) urban area:- the scattered houses or (house at farm) is very popular 3) olive trees:- considered the main tree in study area.

The modified CORINE land cover classification divided Wadi Ziqlab catchment into four groups at level 1, seven groups at level 2, and fourteen groups at level 3. Table 7 and figure 17 show the distribution and area for each level and sub-sub-level.

- The main land cover was forest and semi natural areas. This class covers about 70% during 1953, which decreased to 67% in 1978, and 53% in 2008. Range and shrubs land exhibited the highest reduction within this class. It decreased from 37% in 1953 to 24% in 2008. Low density forest is rated the second. Low density forests were reduced from 11.5% in 1953 to 6% in 2008 (Table 7). Negligible increase was observed for the moderate and dense forest sub-subclasses.
- The second group of land cover was agricultural lands. Agricultural lands had increased from 29% in 1953 to 29.9% in 1978, and 39% in 2008 (Table 7). This increase was due to the increase in olive tree sub-subclass. Olive area increased from 3.8% in 1953, to 25.6% in 2008. On the other hand, field crops sub-subclass decreased from 25% in 1953 to 12% in 2008 (Table 7). This suggests that 50% of land used for field crops was converted to olive trees.

Table 7: CORINE land cover classification for Wadi Ziqlab during 1953-2008.

Level 1	Level 3	CORINE Code	1953		1978		2008	
			Area	%	Area	%	Area	%
Artificial Surface Area	Continuous urban	111	76	0.7	127	1.2	186	1.8
	Discontinuous urban	112	42	0.4	160	1.5	468	4.5
	House at farm	113	0	0	21	0.2	113	1.1
	Quarries	121	0	0	0	0	35	0.3
	Animal farms	122	0	0	0	0	10	0.1
Agricultural Land	Field crop	211	2646	25.2	2249	21.4	1301	12.4
	Irrigated	212	2	0	32	0.3	43	0.4
	Orchard	221	0	0	0	0	62	0.6
	Olive	222	399	3.8	855	8.2	2683	25.6
Forest and Semi Natural area	Low forest	311	1205	11.5	803	7.7	628	6.0
	Moderate forest	312	1090	10.4	1426	13.6	1175	11.2
	Dense forest	313	1117	10.6	1258	12.0	1278	12.2
	Shrub, range	321	3917	37.3	3539	33.7	2489	23.7
Water	Dam	411	0	0	25	0.2	25	0.2
Total			**10495**	**100**	**10495**	**100**	**10495**	**100**

-low forest cover <25%, moderate forest 25-50%, dense forest >50%.

- The third group was artificial surface, which covered 1.1% in 1953 and was increased to 7.7% in 2008 (Table 7). This increase was mainly as result of increasing discontinuous urban sub-subclass. No discontinuous urban was observed in 1953. However it covered 4.5% in 2008.
- The fourth group was water body. Sharhabeel dam was constructed in 1966 with a capacity of 4.4 MCM with a surface area of 25 ha.

Urban area within Wadi Ziqlab catchment was established long time ago. Most of the villages in Wadi Ziqlab catchment were established on or near archeological sites of ancient caves or around cisterns used for water harvesting.

The urban area expands every year. The new area around the villages is divided into 0.1 ha or less. Discontinuous urban sub-subclass increased to cover 4683 or 4.5% of total area in 2008.

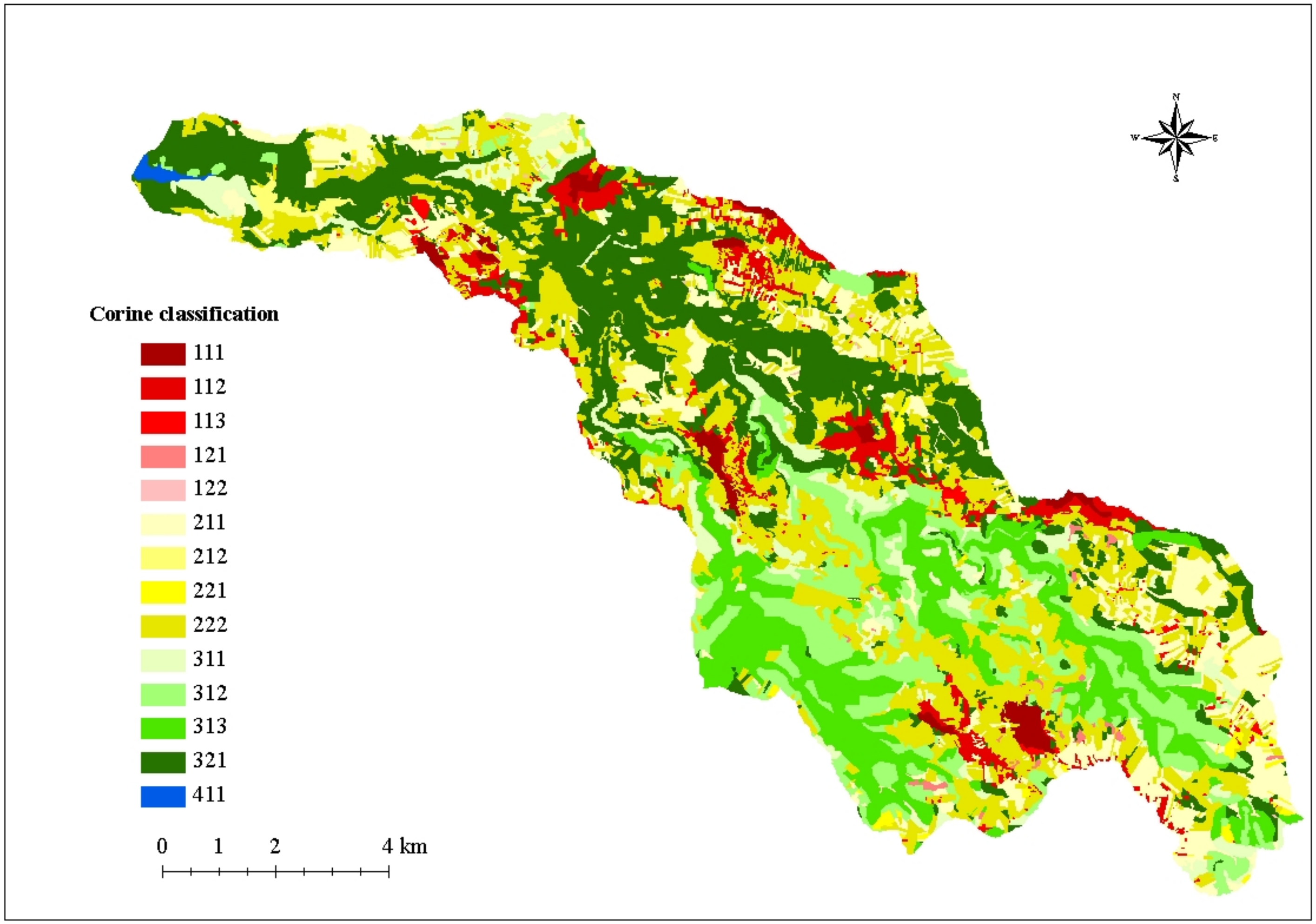

Figure 17. CORINE land cover classification during 2008.

The absence of a land use law that restricts the use of agricultural land for urban use, and responsibility of municipalities to connect electricity and water tab for each house encourages the people to build random houses at any farm or plot they own. Furthermore, fragmentation and division of agricultural land into 0.4 hectare enhanced the expansion of urban area. Table 7 shows that there are about 113 ha, or 1.1% of total area that can be considered as scattered houses (house at farm).

The CORINE land cover classification system classifies forests according to forest type, i.e. evergreen or deciduous. In the study area, forest lands are including both type, but the evergreen more dominant. Therefore, forests were classified according to canopy density; low, moderate, and dense forest (Table 7).

Low density forest covered 1205 ha (11.5%) in 1953 and decreased to 628 ha (6%) of total area in 2008 (Table 7). The low density forest usually decreased for many reasons. Some forest areas may develop to moderate forest, or might degrade by overgrazing and/or deforestation. Most of these areas are covered with shrubs, and/or young scattered forest trees.

Moderate density forest covered 1090 ha (10.4%) in 1953, and increased to 1426 ha (13.6%) in 1978, then decreased to 1175 ha (11.2%) in 2008 (Table 7). The moderate density forest increased during the period from 1953 to 1978, because some of tree grows to reach the dense forest category, while during the period of (1978 to 2008), it had decreased due to many reasons such as expansion of orchard (olive) on forest area, and/or degradation because of overgrazing and/or deforestation.

Dense forest covered 1117 ha (10.6%), in 1953 and increased to 1278 ha (12.2%) in 2008, (Table 7). The dense forest increased because some trees grow to reach the dense forest category. Usually the dense forests are far from residential area. Moreover, such forest is protected by the law.

4.2 Land use/cover changes

Changes of land cover influence the hydrology, and the climate of the earth. Studies that assessed changes of land cover, at the global scale, focused mostly on: deforestation, expansion of cropland, degradation of dry land, urbanization, expansion of pasture, and agricultural intensification (Hartemink et al, 2008).

The traditional cultivation systems practiced in the study area since the fifties include cultivation of winter field crops such as wheat (*Teriticum aestivum, T. turgidum*), barley (*Hordium vulgare*), lentil (*Lens culinaris*), chickpeas (*Cicer arietinum*), and summer vegetable as onion (*Allium cepa*), tomato (*Solanum lyccoerscum*), okra (*Abelmoschus esculentus*), and small areas planted with orchard trees such as olives (*Olea europacal*), figs, grapes (Vitis vinefera), apples (*Melus domestica*), pomegranate (*Punica granatum*) and stone fruit trees primarily around and within the urban area. Few patches of olive trees hundred years old can be found scattered within the catchment.

The objectives of land use/land cover mapping were to determine and delineate the spatial patterns of the current land use/land cover, and to determine the changes which took place between periods (1953 - 1978 and 1978 - 2008). Table11 and figure 18 show the distribution of different land use/land covers during there periods.

4.2.1 Land use/cover in 1953

The land use/land cover analyses for 1953, using aerial photos (Table 8, figures 18, and 19) showed that the majority of the study area was under range use, which accounted for 3917 ha (37.3%), followed by forest, 3412 ha (32.5%). Both rangeland and forest were natural plant cover. The forest area was dominated by oaks *Quercus agilops* and *Quercus calliprinus* forest trees. Area used for field crop, olive trees, and urban area covered 2646 ha (25.2%), 399 ha (3.8%), and 118 ha (1.1%), respectively.

Irrigated area covered 2 ha (less than 0.1%), irrigated pomegranate orchards were grown near main spring at the lower part of the catchment, which were established in 1940s (personal communication).

Table 8: Land use/cover pattern during different years (Area in hectare).

Land use/cover classes	1953		1978		2008		Digitizing Error %
	Area	%	Area	%	Area	%	
Field crop	2646	25.2	2249	21.4	1301	12.4	5.1
Orchard (olive)	399	3.8	855	8.2	2745	26.2	4.9
Forest	3412	32.5	3487	33.2	3081	29.4	3.4
Range	3917	37.3	3539	33.7	2489	23.7	3.6
Irrigated	2	0	32	0.3	43	0.4	2.2
Urban	118	1.1	308	2.9	767	7.3	4.4
Dam	0	0	25	0.2	25	0.2	3.8
Quarries	0	0	0	0	35	0.3	5.4
Animal farm	0	0	0	0	10	0.1	9.0
Total	10495	100	10495	100	10495	100	100

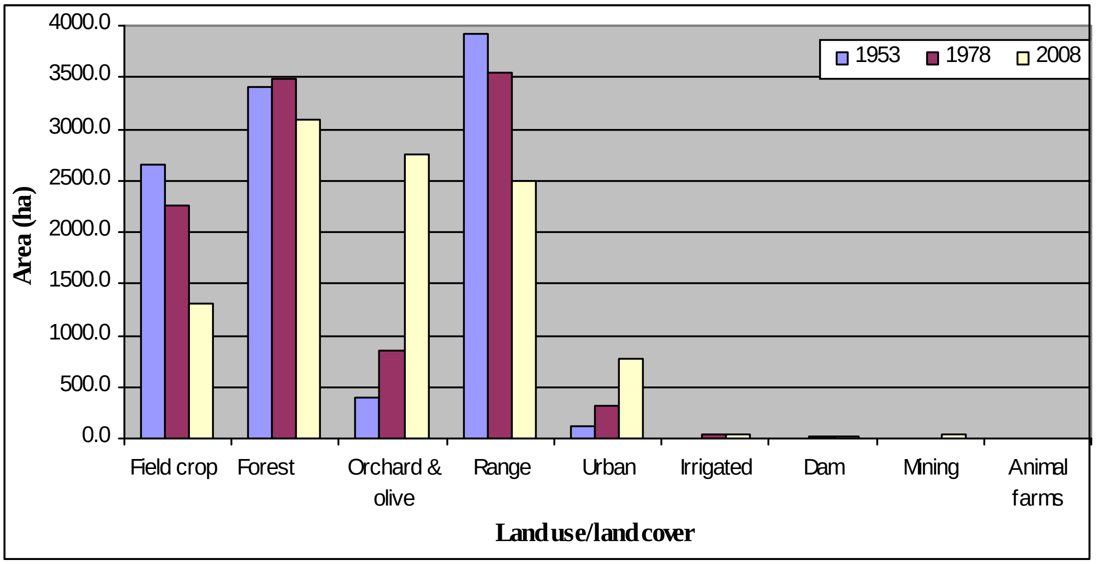

Figure 18: Changes of land cover during the period of 1953 to 2008.

The analyses of aerial photo, indicated that, mostly, before 1950s, all the steep, shallow, and rocky land, which covered about (7329 ha) or 70% of the catchment was not cultivated, and was covered with forest and range.

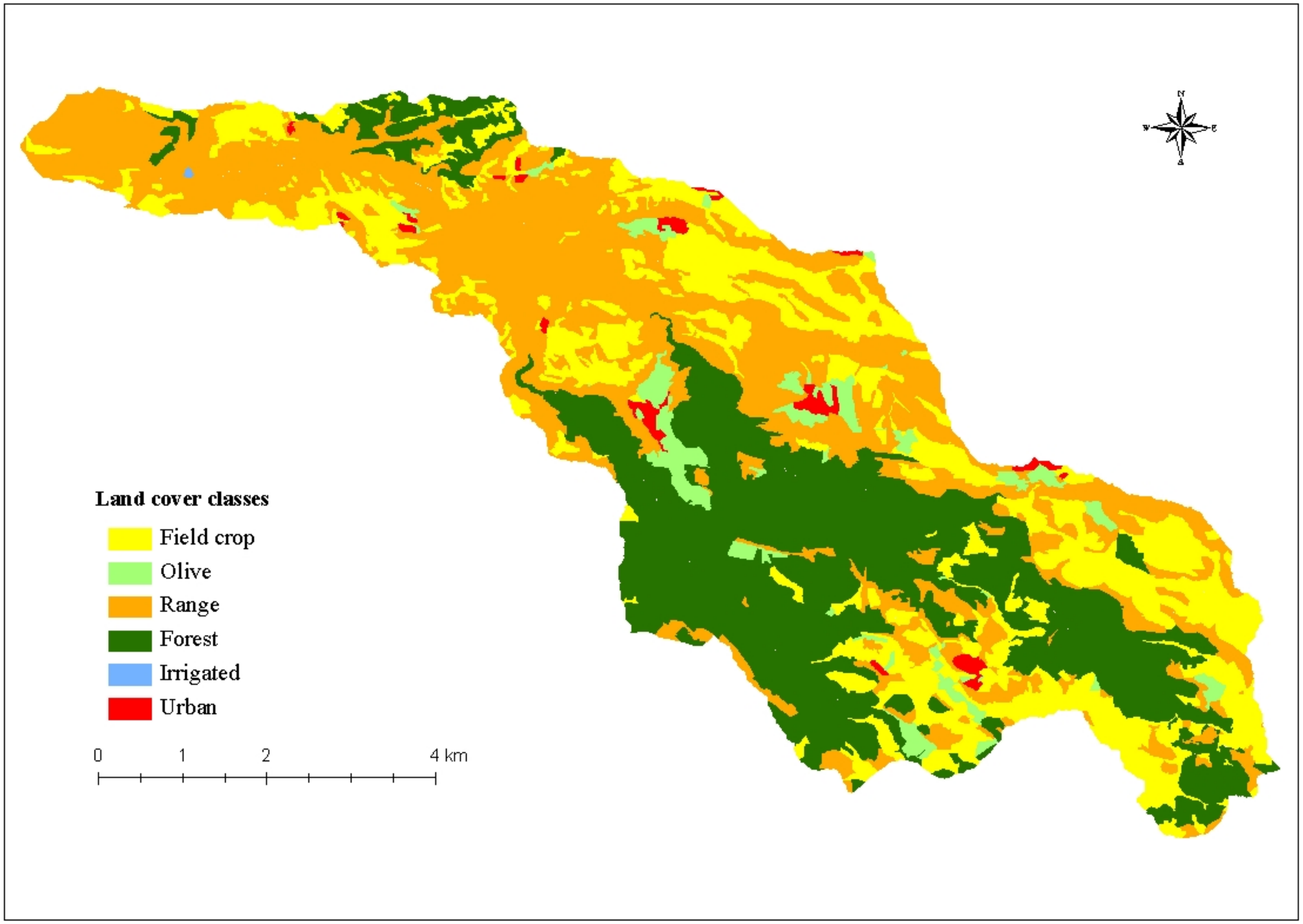

Figure 19. Land use/cover in 1953.

The population density was very low, no machinery was available, poor access to all areas, no transportation, and farmers were able to plant only summer or winter crops on flat area. In general, pressure on land before 1953 was low.

Field crop in 1953 was planted in a large area and covered 2646 ha (25%) of which only 4% of the catchment was classified as highly suitable, and about 21% was classified as moderately suitable. This area suffers from soil erosion, and/or improper plowing. Cultivation with field crops was to produce wheat enough to meet the local people demands. Olive trees mostly cultivated at wadies protected with soil conservation measure where danger of erosion is minimum.

4.2.2 Land use/cover in 1978

The land cover analyses for 1978, is given in table 8, and figures 18 and 20. The analysis showed that majority of the study area was used for range, which covered 3539 ha (33.7%), followed by forest, which covered 3487 ha (33.2%).

The analyses indicated that field crops, orchards (olive), and urban area covered 2249 ha (21.5%), 855 ha (8.2%), and 308 ha (2.9%), respectively. Irrigated area covered only 32 ha and were located near main springs and planted with pomegranates. Water body covered 25 ha, which represents Sharhabeel dam constructed at the lower part of catchment.

Few changes had been detected during 1953-1978 period, as compared with the period before 1953. The main changes included an increase in the urban area due to population increase from 11162 ha to 29711 ha in 1953 and 1978, respectively (Table 2). Forest areas increased because of the afforestation project were carried out (MoA, 1973). Area cultivated with olive trees also showed slight increase. The increase in urban, olive trees, and forest areas was on the expense of field crops and rang areas.

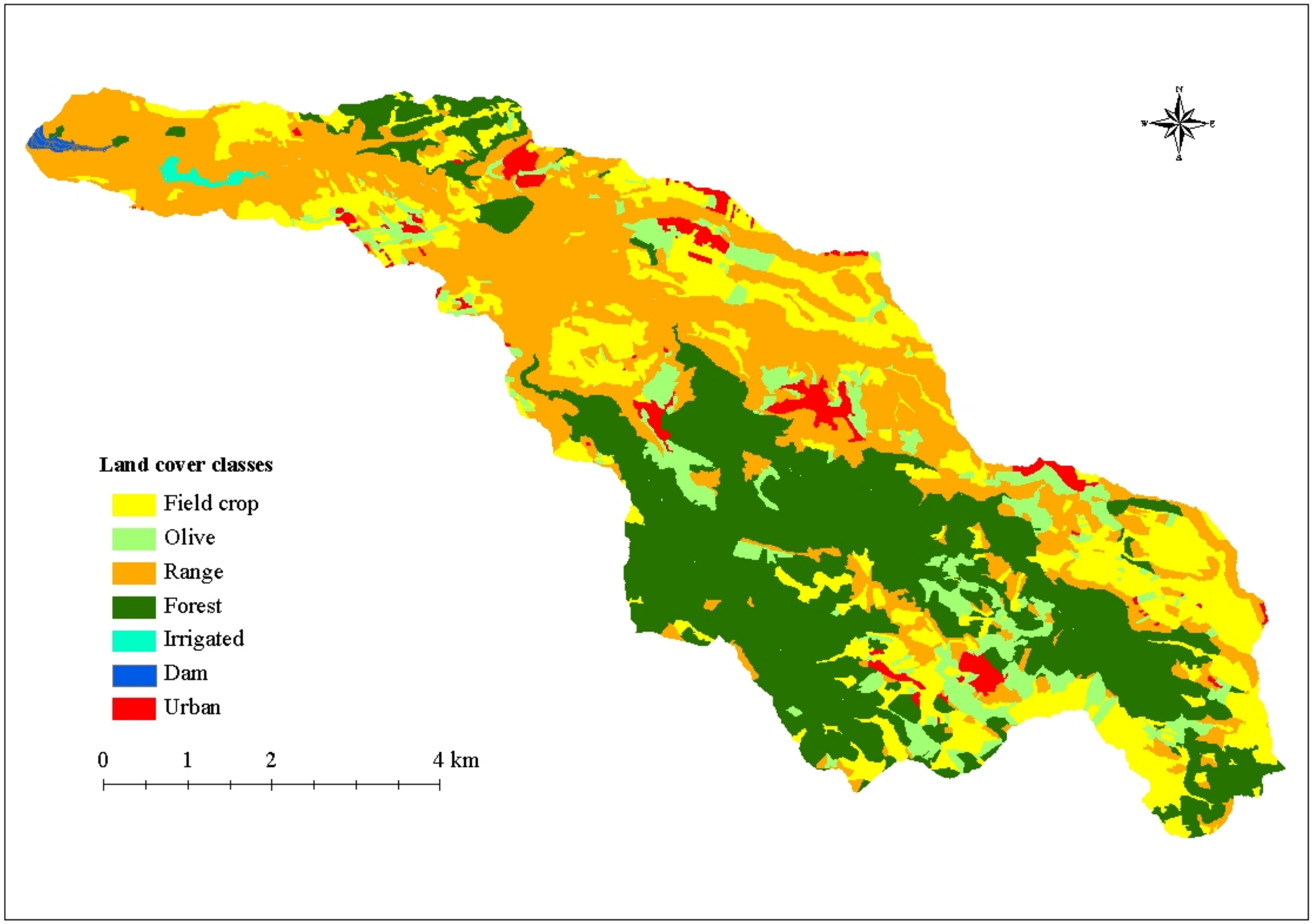

Figure 20. Land use/cover in 1978.

4.2.3 Land use/cover in 2008

High resolution satellite image for 2008 was used to determine land cover. Nine land use/land cover classes were identified (Table 8, figures 18 and 21). Out of the total area, forests covered the largest area (3081 ha or 29.4%). Forest area decreased from 3487 ha (33.2%), in 1978, to 3081 ha (29.4%) in 2008, due to deforestation and changes mainly within the private forest. Deforestation can be detected by aerial photo or satellite image when large spot are cleared. This type of deforestation occurred only on private forest when converted to another land use. Deforestation of private forest means all the area were cleared and can be measured. Other type of deforestation includes illegal cutting of scattered trees, randomly. This type of deforestation measured by the number of removed trees (Table 3).

The development of road network and availability of machineries provided the farmers with better access and facility to clear and cultivate their privately owned forest or replace it with olives trees or other orchard trees. Accordingly, area cultivated with orchard and olive trees increased from 855 ha (8.2%) in 1978 to 2745 ha (26.2%) in 2008.

Rangeland covered about 2489 ha (23.7%) in 2008, compared to 3917 ha (37.3%) in 1953, this decrease is due to pressure for the need of cultivated land, and was made feasible by the availability of facility to develop orchards. Field crop is currently confined to a very small area of about 1301 ha (12.5%), of the total area. Urban areas, irrigated orchard, quarry areas, and animal farms occupy 7.3%, 0.4%, 0.3% and 0.1%, respectively.

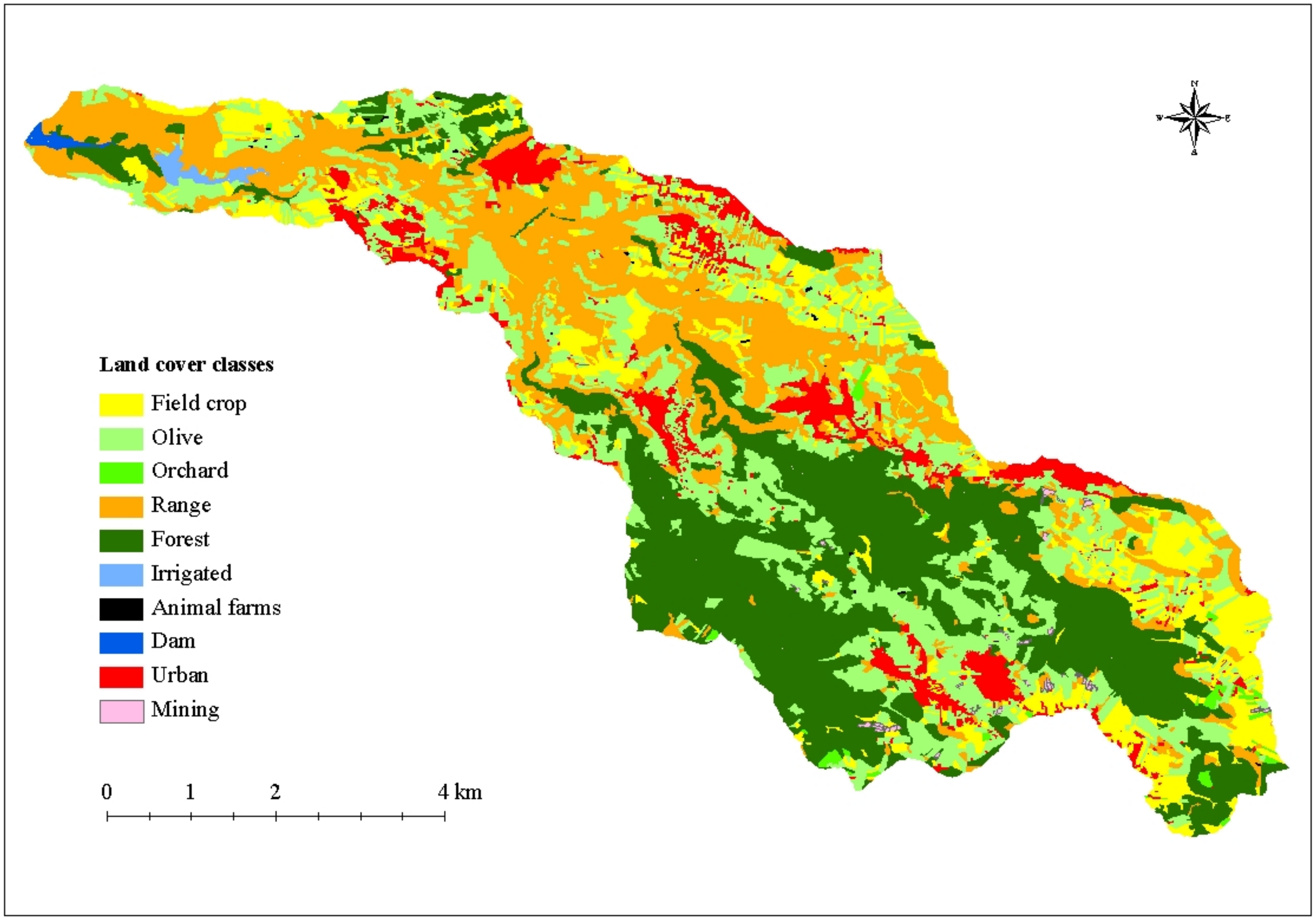

Figure 21. Land use/cover in 2008.

4.2.4 Unchanged land use/covers during the 1953-2008 period

During the period from 1953 to 2008, about 4414 ha (42%) was changed from one land use/cover to another, while 6081 ha (58%) of the land use was never changed since 1953. Table 9, and figure 22, show unchanged and changed land covers.

Table 9: Changed and unchanged land cover during the period of 1953 to 2008.

Land cover change	Area (ha)	%
Change land cover	4414	42.0
Unchange field crops	999	9.5
Unchange orchards	236	2.3
Unchange forest	2703	25.8
Unchange rangeland	2039	19.4
Unchange urban	105	1.00
Total	10495	100

The unchanged main land cover in 2008 was estimated at 9.7%, 2.3%, 25.8%, 19.4%, and 1% for field crops, orchards, forest, range, and urban area, respectively.

The main land cover change took place on the private land, which was converted to orchards and urban areas, estimated at 22.4% and 6.2%, respectively. Only few changes took place within government land between 1953 and 2008.

4.2.5 Dynamics of land use/cover change during the 1953-2008 period

Land use/land cover change during the last 55 years revealed that 3105 ha (29.6%) was changed from one land use to another (Table 10). The main change of land use was field crops, forest and rangeland, which have been drastically reduced from 25.2%, 32.5%, and 37.3% in 1953 to 12.4%, 29.4%, and 23.7% in 2008, respectively (Table 8).

Large portion of land covered with field crops, range, and forest, which covered 1345 ha, 1428 ha, and 332 ha, respectively, were replaced by 2284 ha of olive trees, and 6.2 ha of orchards in 2008 (Table 10). Some examples showing land converted from different land use to orchard or olive trees is given (Appendix F, Plates 1-3).

Table 10: Land cover changes for the period between 1953 and 2008, (Area in hectare).

Land cover classes	Changes during			% Change (1953-2008)
	(1953-1978)	(1978-2008)	(1953-2008)	
Field crop	-397	-948	-1345	-12.8
Orchard (olive)	+456	+1890	+2346	+22.4
Forest	+75	-407	-332	-3.2
Range	-379	-1050	-1428	-13.6
Irrigated	+29	+11	+41	+0.4
Urban	+190	+459	+649	+6.2
Dam	+25	0	+25	+0.2
Quarries	0	+35	+35	+0.3
Animal farms	0	+10	+10	+0.1

Orchards and olive trees can be cultivated on a steep, rocky, and stony area after some topographic modification, or soil conservation measures. All the conversion was confined to orchards or olive tree, because the converted area was not suitable for field crops, and since it generates better income or cash money than field crops.

Range area covered 37.3% in 1953, but decreased to 23.7% in 2008 (Table 8). Conversion of rangeland to orchards started during the last two decades because rangelands occur mostly on steep, shallow, rocky land. Such land is not easy to manage. However, the conversion was enhanced by the shortage of agricultural land.

Remarkably, urban area increased during the last 55 years from (118 ha) 1.1% in 1953 to (767 ha) 7.3% in 2008. Appendix F and plate 5 shows an example of expansion of urban area over agricultural land.

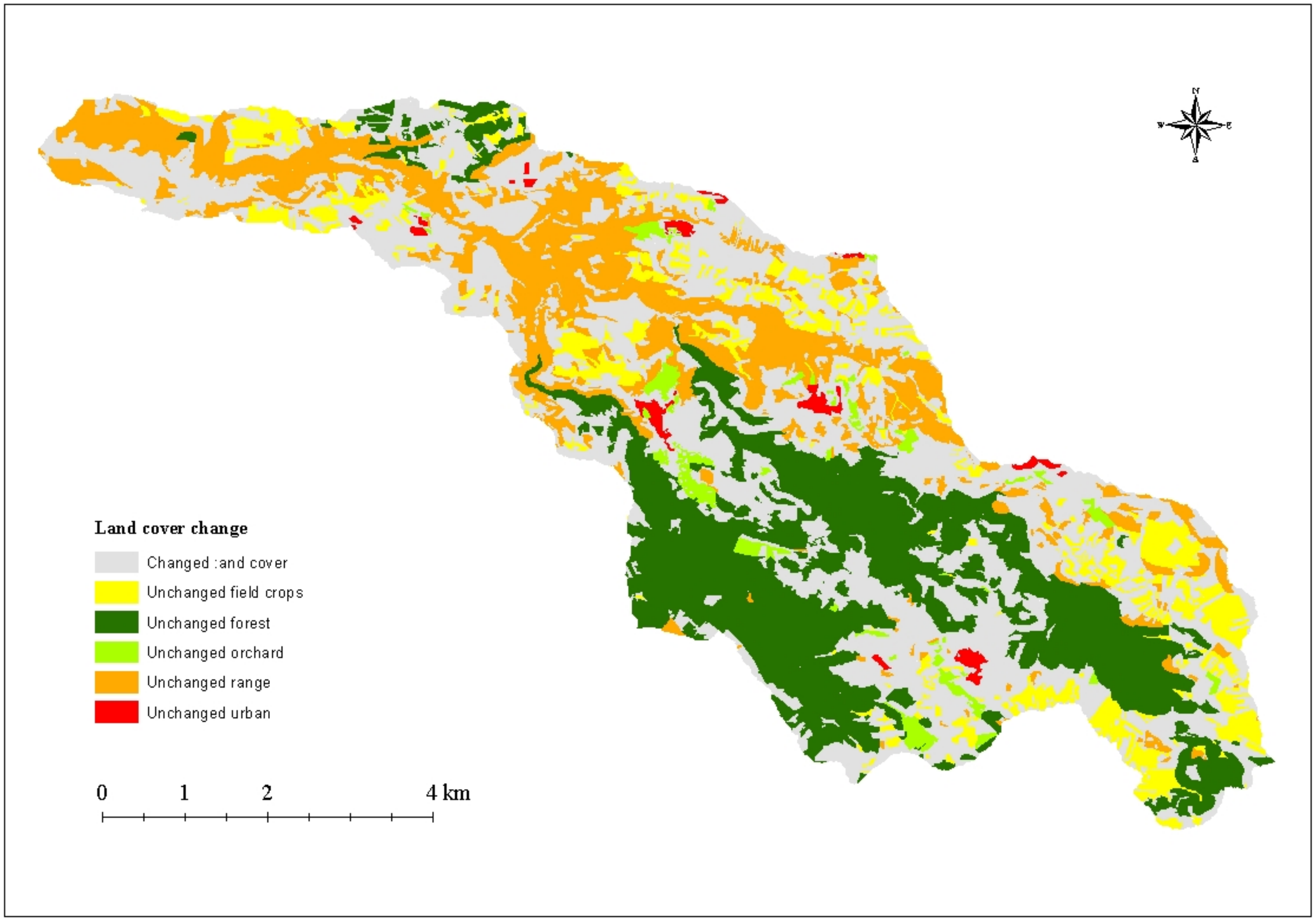

Figure 22. Changed and unchanged land use/cover during 1953-2008 periods.

Population growth affects the use of agricultural land (Ningal et al., 2008). Population of Wadi Ziqlab catchment and the area bordering the catchment was 11162 in 1952, and increased to 64387 in 2004. The population increase has affected the land use/land cover change, especially where urban areas were extended over land suitable for cultivation. Most of the people prefer the nuclear family and independent house more than extended family. The development of human culture encouraged the horizontal expansion of urban activities (DOS, 1952, 1978, 2004).

Local population within the study area depended completely on their farm products during the fifties. Production of wheat, barley, and vegetables was sufficient to satisfy the need of people and the animal. Family labour and farm animals (Oxen and Horses) were used to plow the land and sow the seeds. Population density varied according to the total population and area allocated to each village. The average population density was about (607 persons/km^2) in 2004. Tebneh had the high population density (214 persons/km^2) in 1952, which increased to (1379 persons/km^2) in 2004. Samad had the low population density, which was (49 persons/km^2) in 1952, and increased to 89 persons/km^2 in 2004. Table 2 shows the population and the population density for each village at different periods.

Other change in land use/land cover between 1953 and 2008 includes:

- Irrigated areas increased from 2 ha (0.02%) to 43 ha (0.4%). Development of irrigated area concentrated mainly on pomegranate trees. Surface irrigation depended on spring water sources. It is worth to indicate that only the northern part of Wadi Ziqlab stream areas is registered as irrigated area, while the southern part is not registered as irrigated area.
- Area of stone quarries covered 35 ha after 1978. Quarries excavation was practiced on forest and field crops lands. Privately owned lands were rented for

private companies for excavation and extraction of stones needed for construction. (Appendix F and plate 2, shows example of forest and field crop area destroyed or degraded by quarries activities).

- Sharhabeel dam was constructed in 1966 with a capacity of 4.4 MCM with a surface area of 25 ha. The dam provided supplementary water for irrigated agriculture in Al Ghor area. The dam depends on runoff during winter season and on base flow of springs through out the year.
- Areas of animal farms started at seventies, to cover about 10 ha (35 farms). Previously, farmers kept their animals (cows, sheep, goats and poultry) on their farmyard. Environment law (52/2006), issued in 2006, prohibited animal farm within 500 m from residential areas.
- National highways and roads occupied over than 3.7% of total area in 2008.
- Land use/land cover varied within different zones of the catchment according to elevation and rainfall distribution. The eastern zone was covered with forest of higher density due to higher rainfall and elevation compared with the western zone which receives less rain. Orchards were concentrated, mostly, around villages in 1953 and 1978. Meanwhile, in 2008, orchards can be found over all the catchment area.

4.2.6 Impacts of sustained land use change on soil properties

Soil properties selected to evaluate the impact of land cover change are:

- Organic matter content (OM) of the A-horizon.
- Soil texture (clay, sand, and silt) of the A-horizon.
- Thickness of the A-horizon.

T-Test was used to assess differences between combinations of two different land covers. The analyses indicated that the average OM content was 2.7%, 3.4%, 4.5%, and

3.5%, for field crop, orchard, forest, and rangeland area, respectively (Table 11). Significant differences in OM content exists between forest and field crops, forest and orchard, forest and rangeland, field crops and rangeland.

Table 11: Distribution of soil properties for areas where land use was not changed during 1953-2008.

Land use 1953-2008	Organic matter %	Thickness of A-horizon (cm)	Clay %	Silt %	Sand %	No. of samples
Field crop	2.7	14.6	57.5	31.3	11.2	53
Forest	4.5**	09.8**	50.4**	31.3	18.3**	55
Field crop	2.7	14.6	57.5	31.3	11.2	53
Orchard	3.4	12.7	60.4	26.3*	13.3	06
Field crop	2.7	14.6	57.5	31.3	11.2	53
Range	3.5**	10.3**	48.8**	34.9*	16.3*	24
Forest	4.5	09.8	50.4	31.3	18.3	55
Orchard	3.4**	12.7*	60.4	26.3**	13.3	06
Forest	4.5	09.8	50.4	31.3	18.3	55
Range	3.5**	10.3	48.8	34.9*	16.3	24
Orchard	3.4	12.7	60.4	26.3	13.3	06
Range	3.5	10.3	48.8*	34.9**	16.3	24

** Significant at the 0.01 level. * Significant at the 0.05 level.

Forest soils maintained the highest OM (4.5%) in comparison with soil continuously cultivated fields such as orchards (3.4%), and field crops (2.7%). Similar results were also reported by, Sanchez et al., 1983; Brown and Lugo, 1990; Fuller and Anderson, 1993; Funakawa et al., 1997; and Riezebos and Loerts, 1998. Littering is a major contributor to soil organic mater in the forest ecosystem (Chen et al., 2000).

No significant difference was found in OM content between orchards and field crops. The average OM content is higher for orchards as compared to field crops. This could be due to the fact that farmer plows their orchards at least twice a year and all the weed and grasses are mixed with the soil.

The average thickness of A-horizon is about 14.6 cm, 12.7 cm, 9.8 cm, and 10.3 cm, for field crops, orchards, forest, and rangeland, respectively. There were significant differences between field crops and forest, field crops and range, and forest and orchards (Table 11). Plowing orchards and field crops area results in mixing the soil surface, thus results in thicker A-horizon for cultivated land when compared to forest or rangeland. Field crop had thicker A-horizon as compared with orchards, because of tillage methods where farmers use horses or small tractors for plowing the orchards while usually they use heavy plowing machine for field crops, which resulted in thicker A-horizon.

Average surface clay content for soil of different land use was 57.5%, 60.4%, 50.4% and 48.8% for field crop, orchard, forest, and rangeland, respectively. Yao et al. (2010) reported that land use have a significant impact on soil texture. There are significant differences in clay content between field crop and forests, field crops and range, and between orchards and rangeland. The highest clay content was for orchard and field crops as compared with forest and rangeland (Table 11).

4.2.7 Impacts of changing land use on soil properties

During the last 55 years, 42% of the land use had been changed from one land use to another. The main change was converting forest, field crops, and/or rangeland to orchards, which took place during periods 1953 to 1978, and/or 1978 to 2008 (Table 12).

The analyses indicated that when the forest and rangeland was converted to orchards, OM content was significantly reduced and thickness of A-horizon is significantly increased (Table 12). However, when the field crop was converted to orchards, no significant difference in OM content, and thickness of A-horizon was observed. Similar results were reported by (Maitima et al., 2004: and Riezebos and Loerts, 1998) who indicated that the soil organic matter for forest decreases when the land was cleared for cultivation.

Concerning field crops land converted to orchard after 1953 or 1978 (Table 12), no significant difference in OM or thickness of A-horizon was observed. In general, the thickness of A-horizon for field crops is affected by the tillage practice and type of machinery used in the cultivation. Organic matter content for forests decreased with clearing of land for cultivation (Maitima et al., 2004). Riezebos and Loerts, (1998), reported that the OM content of the natural forest was significantly higher than the OM content for various field used for different agricultural uses.

Table 12: Distribution of soil properties for areas were land use was changed during 1953-2008.

Land use change during 1953, 1978, and 2008	Organic matter %	Thickness of A-horizon (cm)	Clay %	Silt %	Sand %	No. of samples
Field crop→ Field crop→ Field crop	2.7	14.6	57.5 *	31.3	11.2 *	53
Field crop→ Orchard → Orchard	2.7	14.4	63.4	30.7	06.0	16
Field crop→ Field crop→ Field crop	2.7	14.6	57.5	31.3	11.2	53
Field crop→ Field crop→ Orchard	2.7	14.3	56.1	31.3	12.5	35
Field crop→ Field crop→ Orchard	2.7	14.3	56.1 *	31.3	12.5 **	35
Field crop→ Orchard→ Orchard	2.7	14.4	63.4	30.7	06.0	16
Forest→ Forest → Forest	4.5 **	09.8 **	50.4 *	31.3 *	18.3 **	55
Forest→ Forest → Orchard	2.6	16.4	66.1	27.2	06.6	10
Forest→ Forest → Forest	4.5 **	09.8 *	50.4	31.3 *	18.3 *	55
Forest→ Orchard → Orchard	3.3	16.0	60.1	31.3	08.8	05
Forest→ Forest → Orchard	2.6	16.4	66.1	27.2	06.6	10
Forest→ Orchard → Orchard	3.3	16.0	60.1	31.3	08.8	05
Range→ Range → Range	3.5 *	10.3 **	48.8	34.9	16.3	24
Range→ Range → Orchard	2.8	14.6	52.8	34.1	13.1	14

** Significant at the 0.01 level. * Significant at the 0.05 level.

Clay and silt content were higher for land converted from field crops to orchard. The clay content increased according to the period of conversion. Area converted after 1953 had higher clay content as compared to area converted after 1978. This suggests that the length of period, since the land use was converted, affect soil texture.

4.2.8 Effect of climate and elevations

The analyses showed positive and significant correlation between OM content and clay with annual rainfall and elevation (Table 14). This agreed with results reported by many researchers (Burke et al., 1989; Hontoria et al., 1999; Ganuza and Almendros, 2003; Dai and Yao Huang, 2006).

Organic matter content varied in relation to annual rainfall. The organic matter content was 2.56%, 3.43%, and 3.45%, for different climatic zone with average rainfall <400 mm, 400-500 mm, and >500 mm, respectively. Higher rainfall produces more dense vegetation cover, especially for forest and orchards land (Table 13).

Table 13: Variation of soil properties according to rainfall isohyets.

Rainfall (mm)	Organic matter%	Thickness of A-horizon (cm)	Clay %	Silt %	Sand %	No. of samples
<400	2.56 **	13.2	52.47	34.12 **	13.45	40
400-500	3.43 **	13.5	57.59	30.33 **	12.03	72
>500	3.45 **	12.4	54.56	31.33 **	14.10	106

** Significant at the 0.01 level. * Significant at the 0.05 level.

Thickness of A-horizon also varied according to annual rainfall. Thickness of A-horizon was the highest (13.5 cm) for zone with average annual rainfall between 400-500. This could be due to dense land cover, although the eastern area is less steep and more intensively used. The thickness of A-horizon decrease to 12.4 cm when the average of the annual rainfall was greater than 500 mm, which could be due to soil erosion by water caused by higher rainfall. The thickness of A-horizon was 13.2 cm when the annual rainfall was less than 400 mm, because less rainfall and less erosion risk (Table 13).

Clay content was significantly different between rainfall isohyets. Higher clay was found at annual rainfall between 400 to500 mm, and decreased for area with higher rainfall, which could be attributed to higher rate of erosion.

Table 14: Correlation between organic matter, clay, silt sand, thickness of A-horizon, elevation, and rain isohyets.

	Thickness of A-horizon (cm)	Organic matter	Clay	Silt	Sand	Rain isohyets
Elevation	-.078	.188**	.139*	-.143**	-.081	.871**
Rain isohyets	-.105	.240**	.020	-.102	.037	1

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

4.2.9 Soil and water conservation practices

Soil conservation structures are quite costly to implement. Therefore, most of the time the are activities undertaken by the government (Ray, 2007). In Jordan, most of the soil conservation structures were carried out by the government.

Stone wall is one of the most poplar conservation measures in Highland area. Farmers in Wadi Ziqlab catchment used stone walls long time ago. Stone walls are mostly constructed on cultivated land. Area with stone walls covered 21% of the agricultural land in 1953, 1978, and increased to 31% in 2008 (Table 15).

Table 15: Cultivated area covered by stone walls.

Land use	Soil Conservation	1953		1978		2008	
		Area	%	Area	%	Area	%
Field crop	No stone wall	832	7.9	793	7.6	415	4.3
	Stone wall	1814	17.3	1456	13.9	886	8.4
Olive	No stone wall	125	1.2	180	1.7	329	3.1
	Stone wall	274	2.6	675	6.4	2416	23.0
Other		7450	71.0	7390	70.4	6449	61.1
Total		104945	100	10495	100	10495	100

The analyses indicated that area with stone walls was reduced for area used for field crops, and increased for areas used for orchards. This was associated with the reduction in total area used for field crops, and the increase in the area used for orchards.

Since large area of field crops was converted to orchard trees, stone walls covered about 66% of the area cultivated with field crops, and 88% of the area used as orchard and/or olive trees in 2008 (Table 15). Figure 23, 24 and 25, show the area developed with stone walls construction for different land use and different periods.

Implementations of soil conservation measures have great benefit for developing the land and improving soil properties. Organic matter content increased significantly with availability of stone wall and with time of construction. Organic matter content was 2.64%, for cultivated land without stone wall (Table 16). It increased to 2.66%, when stone wall was constructed after 1978, and 2.71% when wall constructed after 1953. Meanwhile, the OM was 3.15% when the stone wall was constructed before 1953.

The thickness of A-horizon had significantly increased with availability of stone wall, and had decreased when stone walls were destroyed and/or old and poorly maintained. The analyses indicated that the thickness of A-horizon was 15.12 cm when the stone wall constructed after 1953, 14.63 cm when the stone wall constructed after 1978, and 14.61 cm when no stone wall constructed (Table 16). However, the thickness of A-horizon was 14 cm when the stone wall was constructed before 1953, because no, or poor maintenance. Accordingly, area behind the stone walls was full with sediment, and the walls were not functioning to protect soil from erosion (Appendix F, plate 14A).

Table 16: Soil properties according to the year when stone walls were constructed.

Date of soil conservation			Organic matter%	Thickness of A-horizon (cm)	Clay %	Silt %	Sand %	No. of samples
1953	1978	2008						
No	No	No	2.64**	14.61**	58.82**	30.51	10.67**	33
No	No	Yes	2.66**	14.63**	56.16**	32.32	11.47**	43
No	Yes	Yes	2.71**	15.12**	60.56**	30.29	09.15**	34
Yes	Yes	Yes	3.15**	14.00**	57.56**	30.56	11.78**	29

** Significant at the 0.01 level. * Significant at the 0.05 level

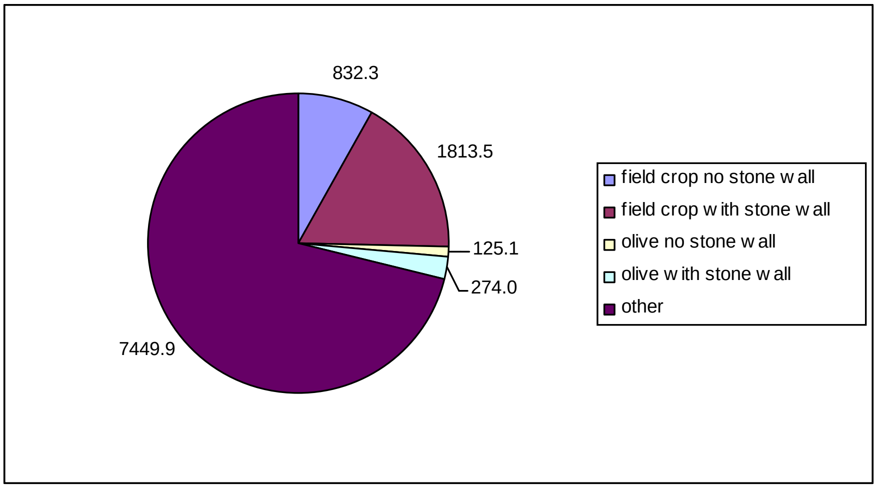

Figure 23: Distribution of cultivated land with or without stone wall in 1953.

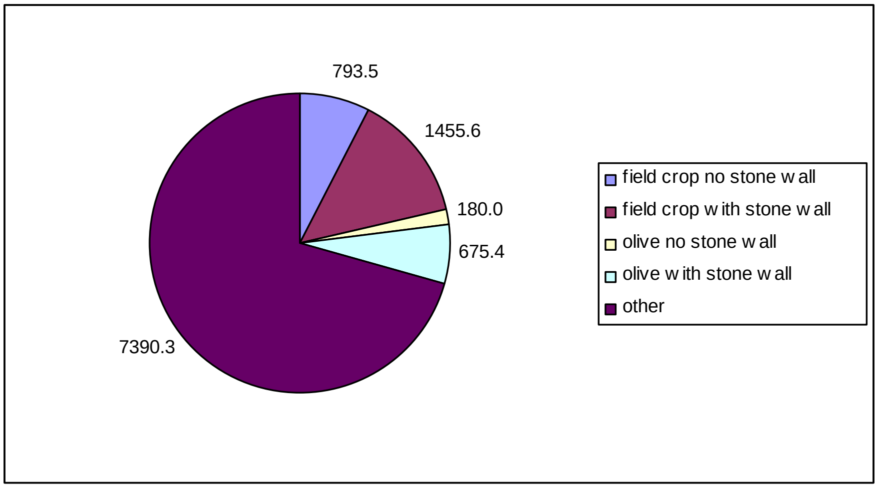

Figure 24: Distribution of cultivated land with or without stone wall in 1978.

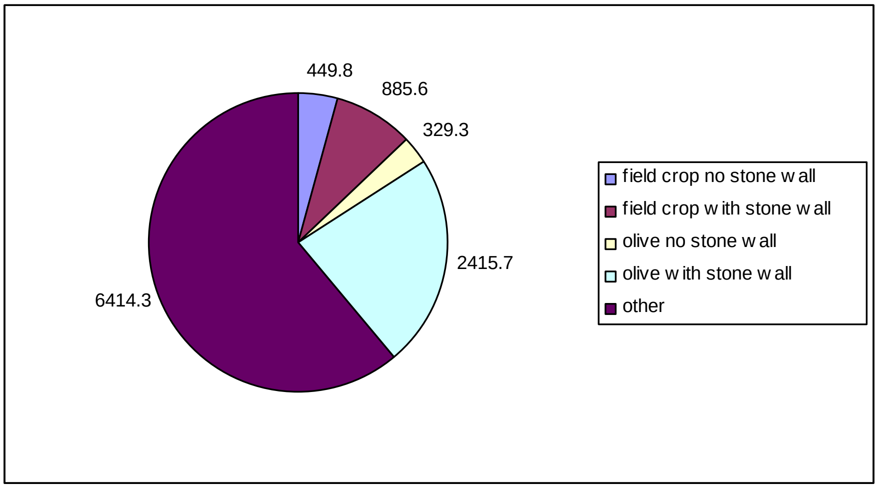

Figure 25: Distribution of cultivated land with or without stone wall in 2008.

4.2.10 Relationship between rainfall and land use change

The distribution of soil properties according to different rainfall zone, land use, and area covered with stone walls is given in table 17. The analyses indicated a significance difference in OM content between different rainfall zones (Appendix E, table 1). The OM content was 2.55%, 3.52%, and 3.49% for rainfall zone <400 mm, 400-500 mm, and >500 mm, respectively (Table 13). The analyses showed that within the rainfall zone of rainfall < 400mm), highest OM content was for forest area followed by rangeland. However, when the forest and rangeland, were converted to orchards, OM content had decreased. Moreover, when the field crop land was converted to orchards, OM content increased. Furthermore, OM content was even higher when soil conservation structures was implemented.

Regarding the thickness of A-horizon, no significance difference existed between different rainfall zone (Table 13). Thickness of A-horizon was higher for soil of lower rainfall, which could be due to lower soil erosion. The thickness of A-horizon was higher for land cultivated with field crops than forest or orchards.

Clay contents increased for area of higher rainfall. Clay content was higher within area converted from forest or range to olive in comparison with area cultivated with field crops, which could be due to lower soil erosion in orchards and better soil conservation measure, or due to the fact that most of soil conservation structure are new and in a good condition, while the stone walls within land used for field crops are old and suffer from poor maintenance.

Table 17: Distribution of soil sample and selected properties.

Rainfall (mm)	Land use change	Soil conservation 1953	1978	2008	Organic matter %	Thickness of A-horizon	Clay %	Silt %	Sand %	No. of cases
<400	Fc→ Fc→ Fc	No	No	No	2.3	16.1	55.2	32.8	12.0	12
<400	Fc→ Fc→ Fc	No	No	Yes	2.8	12.5	47.5	34.2	18.4	2
<400	Fc→ Fc→ O	No	No	No	2.4	14.5	48.5	36.2	15.3	6
<400	Fc→ Fc→ O	No	No	Yes	2.4	16.5	53.4	37.0	9.6	2
<400	Fc→ Fc→ O	Yes	Yes	Yes	2.0	13.5	46.2	37.7	16.6	2
<400	Fc→ O → O	No	No	No	2.0	13.7	61.2	31.5	7.4	3
<400	F→ F→ F	No	No	No	3.7	11.0	46.3	37.1	16.6	2
<400	R→ R→ O	No	No	Yes	2.1	13.3	55.5	34.9	9.6	3
<400	R→ R→ R→	No	No	No	3.1	9.1	48.4	34.7	16.8	10
400-500	Fc→ Fc→ Fc	No	No	No	3.8	12.3	56.3	33.8	10.0	4
400-500	Fc→ Fc→ Fc	No	No	Yes	2.9	14.5	56.8	33.4	9.7	6
400-500	Fc→ Fc→ Fc	No	Yes	Yes	2.5	14.5	57.5	32.3	10.2	4
400-500	Fc→ Fc→ Fc	Yes	Yes	Yes	2.5	14.0	64.0	26.6	9.4	3
400-500	Fc→ Fc→ O	No	No	No	3.7	11.7	69.0	22.6	8.5	3
400-500	Fc→ Fc→ O	No	No	Yes	2.9	15.5	61.3	30.6	8.1	2
400-500	Fc→ Fc→ O	No	Yes	Yes	3.2	14.3	56.4	28.8	14.8	4
400-500	Fc→ Fc→ O	Yes	Yes	Yes	3.6	17.0	58.9	30.1	9.8	3
400-500	Fc→ O→ O	No	No	No	3.5	24.5	18.3	34.5	48.0	2
400-500	Fc→ O→ O	No	No	Yes	3.8	14.0	44.0	41.3	14.7	3
400-500	Fc→ O→ O	No	Yes	Yes	1.4	13.0	58.5	35.3	6.2	2
400-500	F→ F→ F→	No	No	No	4.3	10.8	56.0	29.3	14.8	20
400-500	F→ F→ O	No	No	Yes	3.1	16.7	65.2	27.9	6.9	6
400-500	F→ O→ O	No	Yes	Yes	3.1	17.5	64.3	29.9	6.1	2
400-500	O→ O→ O	No	No	No	3.6	26.7	42.8	37.3	20.0	3
400-500	O→ O→ O	Yes	Yes	Yes	3.9	11.3	57.9	30.3	11.8	6
400-500	R→ R→ O	No	No	No	3.1	14.5	48.8	42.0	9.2	2
400-500	R→ R→ O	No	No	Yes	2.9	15.5	45.3	38.8	16.0	2
400-500	R→ R→ R	No	No	No	3.9	12.4	48.0	34.8	17.2	7
>500	Fc→ Fc→ Fc	No	No	No	3.2	15.3	48.6	32.9	18.5	3
>500	Fc→ Fc→ Fc	No	No	Yes	2.7	10.3	46.7	36.4	16.9	4
>500	Fc→ Fc→ Fc	No	Yes	Yes	2.8	15.2	55.8	33.6	10.6	14
>500	Fc→ Fc→ Fc	Yes	Yes	Yes	3.2	13.5	57.0	30.8	12.3	8
>500	Fc→ Fc→ O	No	No	Yes	2.0	12.3	44.6	35.6	19.7	4
>500	Fc→ Fc→ O	No	Yes	Yes	2.6	16.2	66.6	27.2	6.2	6
>500	Fc→ Fc→ O	Yes	Yes	Yes	2.6	14.0	45.8	34.7	19.4	4
>500	Fc→ O→ O	No	No	No	2.4	16.7	72.0	22.8	5.2	3
>500	Fc→ O→ O	No	Yes	Yes	2.2	10.3	59.2	34.4	6.4	3
>500	Fc→ O→ O	Yes	Yes	Yes	4.1	15.8	62.2	31.8	6.0	5
>500	F→ F→ F→	No	No	No	4.6	8.7	49.4	32.4	18.1	41
>500	F→ F→ O	No	No	Yes	2.0	16.0	67.6	26.2	6.1	4
>500	F→ O→ O	No	Yes	Yes	3.4	15.0	57.1	32.3	10.6	3
>500	R→ R→ O	No	No	Yes	3.1	14.9	54.9	30.2	14.9	7
>500	R→ R→ R	No	No	No	3.7	12.0	47.7	35.5	16.7	8

Land cover, Fc: field crops, F: forest, O: orchards, and R: range
Yes: year, when soil conservation measure introduced

The analyses showed significant difference in OM content within different rainfall and land use. No differences were obtained according to soil conservation availability (Appendix E, table 6).

Significant differences were obtained between thicknesses of A-horizon according to land use. No effect of rainfall or availability of soil conservation measure was obtained (Appendix E, table 7).

Significant differences were obtained between clay content according to land use. No effect of rainfall or availability of soil conservation measure was obtained (Appendix E, table 8-10).

4.3 Detailed land cover classification for Wadi Ziqlab catchment during 1953, 1978, and 2008

The classification of each land cover units included: description of land cover type, density of forest classes, rocks outcrops area, and land with or without soil conservation structure (Table 18).

The main changes that took place within the catchment can be summarized as follows:

- Urban area increased about 7.4% of total area in 2008, as compared to 1.1% in 1953. Discontinuous urban area showed the highest increase. Reason for such change is attributed to development of infrastructure, such as road network, electricity network, water tab network, and population increase. Land fragmentation had also enhanced the discontinuous urban development, since farmers can do anything on their farms.
- Olive trees with stone walls increased by 24% during the last 55 years. The increase is attributed to increasing need for agricultural land, awareness of farmers to the need for soil conservation, and availability of land development facilities.

- Field crops with soil conservation measures decreased by 13% during last 55 years. The reduction is due to land conversion to olive trees or urban activities.
- Forest area showed the lowest reduction. The reduction is due to degradation, overgrazing or deforestation. The main conversion of forest land was confined to private forest converted to orchards.

4.4 Land suitability analyses

Land suitability evaluation was performed according to the FAO framework for land evaluation. The assessment of land suitability was based on the simple limitation methods. The evaluation was carried for current land utilization types (LUTs) practiced in the study area. The study area includes 6 suitability groups (1, 1.1, 3, 3.1, 4, and 11) and 6 suitability subgroups (Ai, Aii, Aiii, Aii/s, Aiv/s, and Av/s) (Table 19 and figure 26). Description of each suitability groups is given in table 20. Only 3.8% (soil unit 1) of total area was found suitable for annual rainfed crops, if slope was <4%, and moderately suitable for tree crops when the slope was between 4-8%. Meanwhile 26.4% (soil units 7 and 10) of the area was classified as moderately suitable for field crops or trees with slope limitation. In general, only 30.2% (3172 ha) of Wadi Ziqlab catchment was classified as suitable for rainfed agriculture (soil units 1, 7, and 10), while about 58% (6082 ha) was classified as suitable for forest and rangeland (soil units 17, 23, and 25) (MoA, 1994).

Table 18: Detailed land use changes, during 1953-2008 (Area in hectare).

Land use	1953		1978		2008	
	Area	%	Area	%	Area	%
Urban, continuous	722	0.7	127	1.2	186	1.8
Urban, discontinuous	42	0.4	160	1.5	468	4.5
Urban, farm house	0	0	21	0.2	113	1.1
Quarries	0	0	0	0	35	0.3
Animal farm	0	0	0	0	10	0.1
Dam	0	0	25	0.2	25	0.2
Field crop	851	8.1	798	7.6	308	2.9
Field crop, (1)	0	0	0	0	95	0.9
Field crop, (1)(a)	0	0	0	0	27	0.3
Field crop, (2)	0	0	0	0	13	0.1
Field crop, (a)	1794	17.1	1452	13.8	859	8.2
Irrigated pomegranates	2	0	32	0.3	43	0.4
Orchard	0	0	0	0	10	0.1
Orchard, (a)	0	0	0	0	52	0.5
Olive	125	1.2	170	1.6	245	1.9
Olive, (1)	0	0	6.9	0.1	64	0.6
Olive, (1)(a)	0	0	73	0.7	327	3.1
Olive, (2)	0	0	0	0	37	0.3
Olive, (2)(a)	0	0	3	0	218	2.1
Olive, (3)	0	0	3	0	13	0.1
Olive, (3)(a)	0	0	0	0	9	0.1
Olive, (a)	274	2.6	599	5.7	1810	17.2
Low forest	1205	11.5	677	6.5	0	0
Low forest artificial	0	0	8	0.1	4	0
Low forest, (1)	0	0	48	0.5	405	3.9
Low forest, (2)	0	0	44	0.4	177	1.7
Low forest, (3)	0	0	26	0.2	43	0.4
Moderate forest	1090	10.4	1292	12.3	11500	11.0
Moderate forest, (1)	0	0	83	0.8	0	0
Moderate forest, (2)	0	0	52	0.5	0	0
Moderate forest artificial	0	0	0	0	25	0.2
Dense forest	1117	10.6	1234	11.8	1226	11.7
Dense forest artificial	0	0	24	0.2	52	0.5
Shrub range	3917	37.3	978	9.3	443	4.2
Shrub range, (1)	0	0	1030	9.8	432	4.1
Shrub range, (2)	0	0	1063	10.1	767	7.3
Shrub range, (3)	0	0	467	4.5	832	7.9
Shrub range, (a)	0	0	0	0	16	0.1
Total	10495	100	10495	100	10495	100

1: rock outcrop 25%. 2: rock outcrop 50%. 3: rock outcrop 75%. a: land with stone wall.
Low forest cover <25%, Moderate forest cover 25-50%, Dense forest cover >50%.

Table 19. Land suitability classes and subclasses for different potential land use.

Soil Unit	Suitability group *	Suitability Subgroup	Rainfed Annual crops	Rainfed tree crop	Drip irrigation	Range	Forest	Slope %	Area (ha)	Area %
1	1 1.1	1Ai, 1Aii	S1 S2t	S2s S2s	S1 S2t	S1 S1	S1 S1	0-8	400	3.8
7	3 3.1	7Aii 7Aiii	S2st S3st	S2s S2s	S2ct S3ct	S2c S2c	S1 S1	0-25	2070	19.7
10	3 3.1	10Aii 10Aiii	S2st S3st	S2s S2s	S2ctr S3ctr	S2c S2c	S1 S1	5-16	702	6.7
17	3.1 11	17Aiii 17Av/s	S3str NSstr	S2s NSst	S3ctr NScstr	S2c S3cst	S1 S3st	26-60	1976	18.8
23	3 11	23Aii 23Aiv/s	S2st N6st	S2s NSst	S2ctr NScstr	S2c S3cs	S1 S3s	9-16	4098	39.0
25	4 11	25Ai 25Aii/s	S3sr NSsetr	S3sr NSser	NSsr NSsetr	S2s S3se	S2s S3se	0-16	18	0.2
999	Urban								411	3.9
0	No Available Data (NDA)								821	7.8
	Total								10495	100

Source: National Soil Map and Land Use Project, MoA, 1994.
S1: highly suitable, S2: moderately suitable, S3: marginally suitable, NS: not suitable, and NDA: no available data.
A: refers to rainfall zone ranges >400 mm, and s: refers to soil (depth), c: climate, e: erosion,
t: topography, gradient or slope, and r: rock, stone or gravel on surface.
Number i-vi: refer to slope ranges 0-4, 5-8, 9-16, 17-25, 26-40, 41-60%.
* See table 8 for detailed description.

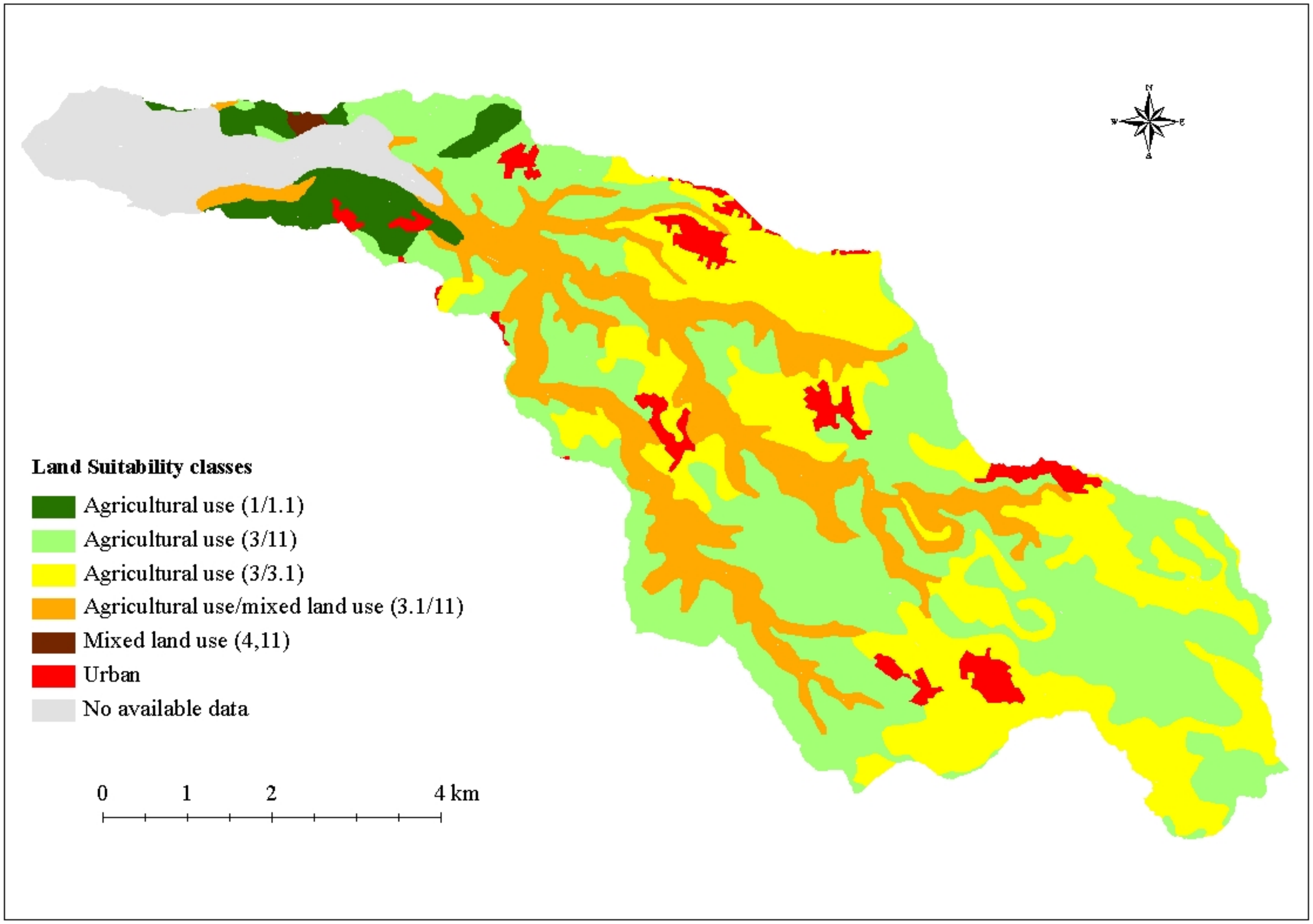

Figure 26: Land suitability groups for different potential land use, (Description of classes is given in table 20).

Table 20. Description of suitability groups for different potential land use.

Group	Land use recommendation	Descriptive of grouping
1	Zone for agricultural use	Good for rainfed field crops and Moderately good for tree crops
1.1	Zone for agricultural use	Moderately good for rainfed fruit tree crops Moderately good for rainfed field crops (slope limitation)
3	Zone for agricultural use	Moderately good for tree crops Moderately good for rainfed field crops
3.1	Zone for agricultural use	Moderately good for tree crops Marginal for rainfed field crops (slope limitation)
4	Mixed land use	Marginal for rainfed field crops Marginal for tree crops (mainly dry climate limitation)
11	Mixed land use	Unsuitable for rainfed or irrigation crops Marginal for range and forestry

Source: National Soil Map and Land Use Project, MoA, 1994.

4.4.1 Potential land suitability for annual rainfed crops

The distribution of different suitability classes for annual rainfed crops is given in table 21 and figure 27. Only 3.8% of the total area was classified as highly suitable (S1) for field crops, while about 26.4% of the total area was classified as moderately suitable (S2), due to soil shallowness and slope steepness, and 19% of the total area was classified as marginally suitable (S3), due to soil shallowness, slopes, and surface rockiness. Moreover, 39% of the total area was classified as not suitable (NS) because of soil shallowness, erosion, and slope steepness. Urban land use covered about 3.9% of the area (MoA. 1994).

The main cultivated field crops are: wheat, barley, and cowpea, grown entirely under rainfed condition. Appendix F, plate 6, show different annual field crops land with different suitability.

Table 21. Area of suitability classes and subclasses for different potential land use.

Suitability	Field crops		Tree crops		Drip irrigation		Range		Forest	
	Area	**%**	**area**	**%**	**Area**	**%**	**area**	**%**	**area**	**%**
S1	400	3.8	0	0	400	3.8	400	3.8	5148	49.1
S2s	0	0	5148	49.1	0	0	0	0	0	0
S2st	2772	26.4	0	0	0	0	0	0	0	0
S2c	0	0	0	0	0	0	4748	45.2	0	0
S2ct	0	0	0	0	2070	19.7	0	0	0	0
S2ctr	0	0	0	0	702	6.7	0	0	0	0
S3s	0	0	0	0	0	0	0	0	4098	39.0
S3se	0	0	0	0	0	0	18	0.2	18.0	0.2
S3str	1976	18.8	0	0	0	0	0	0	0	0
S3cs	0	0	0	0	0	0	4098	39.0	0	0
S3ctr	0	0	0	0	1976	18.8	0	0	0	0
NSst	4098	39.0	4098	39.0	0	0	0	0	0	0
NSser	0	0	18	0.2	0	0	0	0	0	0
NSsetr	18	0.2	0	0	18	0.2	0	0	0	0
NScstr	0	0	0	0	4098	39.0	0	0	0	0
Total *	9263	88.3	9263	88.3	9263	88.3	9263	88.3	9263	88.3

Source: National Soil Map and Land Use Project, MoA. 1994.
S1: highly suitable, S2: moderately suitable, S3: marginally suitable, NS: not suitable, and NDA: no available data, 821 ha (7.8%). urban 411 ha (3.9%).
c: climate, s: soil (shallowness), e: erosion, t: topography, gradient or slope, and r: rock, stone or gravel on surface.
Total*: Out of total area (10495 ha).

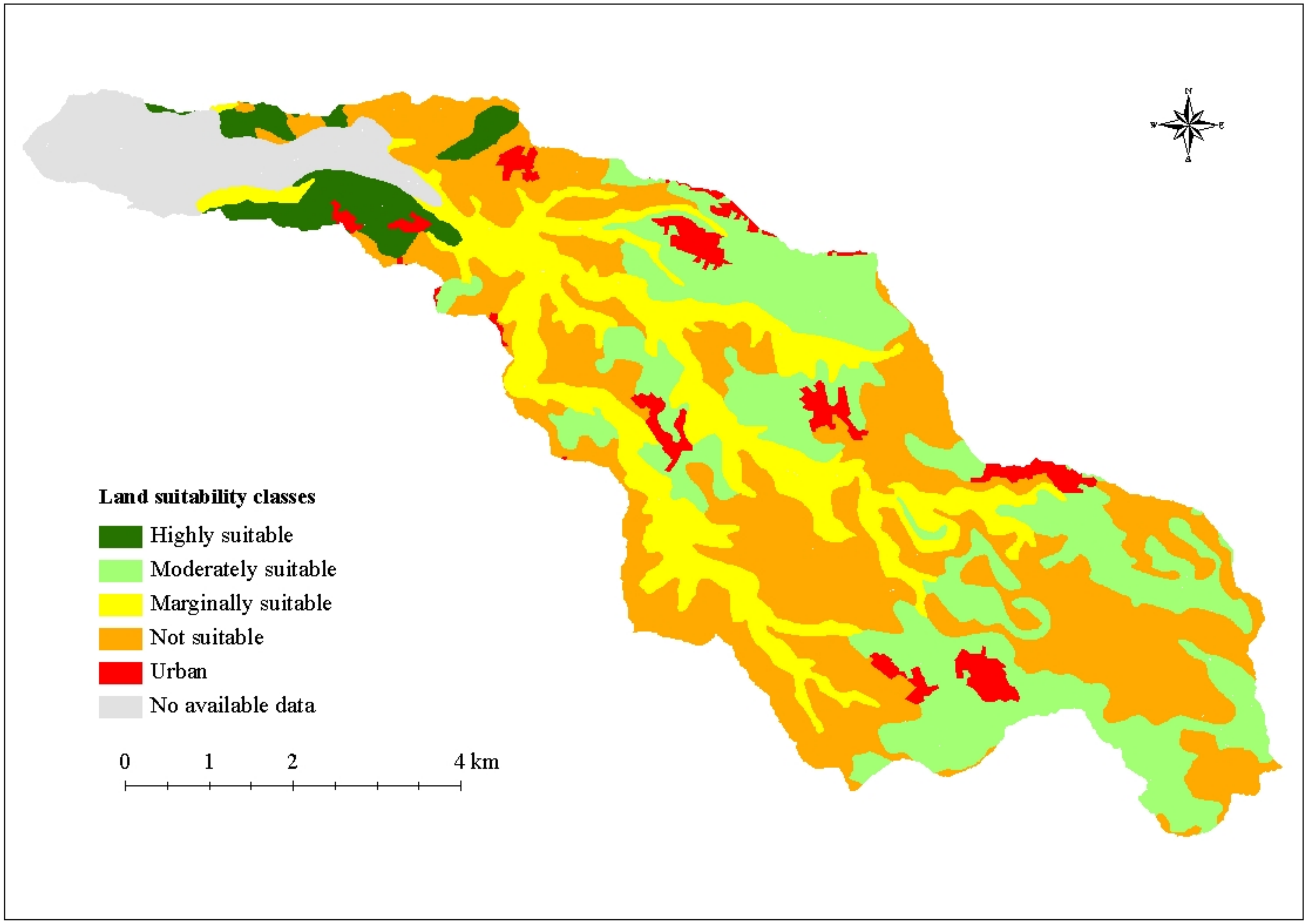

Figure 27: Distribution of land with different suitability classes for field crops.

Cultivated field crop within area which is not suitable for field crop can cause soil degradation such as soil erosion by plowing the land with slope, and in the absence of soil conservation measure to protect the soil.

4.4.2 Potential land suitability for rainfed fruit tree crops

The distribution of suitability classes for rainfed fruit trees is given in table 21 and figure 28. About 49% (5148 ha) of the total area was classified as moderately suitable (S2). The main limiting factor was soil depth, while 39% (4098 ha) of the total study area was classified as not suitable (NS) due to soil depth and slope steepness. Small areas, about 18 ha, have other limitations including soil erosion and surface rockiness.

The main cultivated orchards are: olives and Mediterranean fruit trees (peaches, figs, grapes). Areas cultivated with olive trees grown on different suitability classes are given in (Appendix F, plate 7).

Orchards or olive trees were the only alternative option available for developing the area, because of slope and stoniness limitation, which can also be controlled by soil conservation measure.

4.4.3 Potential land suitability for drip irrigation

The analyses indicated that only 3.8% (400 ha) of the total area was classified as highly suitable (S1) for drip irrigation (Table 21 and figure 29), while about 26% (2772 ha) of the total area was classified as moderately suitable (S2), due to low rainfall and slope steepness, among which 6.7% have additional surface rockiness limitations. Moreover, 18.8% (1976 ha) of the total area was classified as marginally suitable (S3), due to rainfall shortages, slope steepness, and surface rockiness. Meanwhile, 39.2% (4098 ha) of the study area was classified as not suitable (NS).

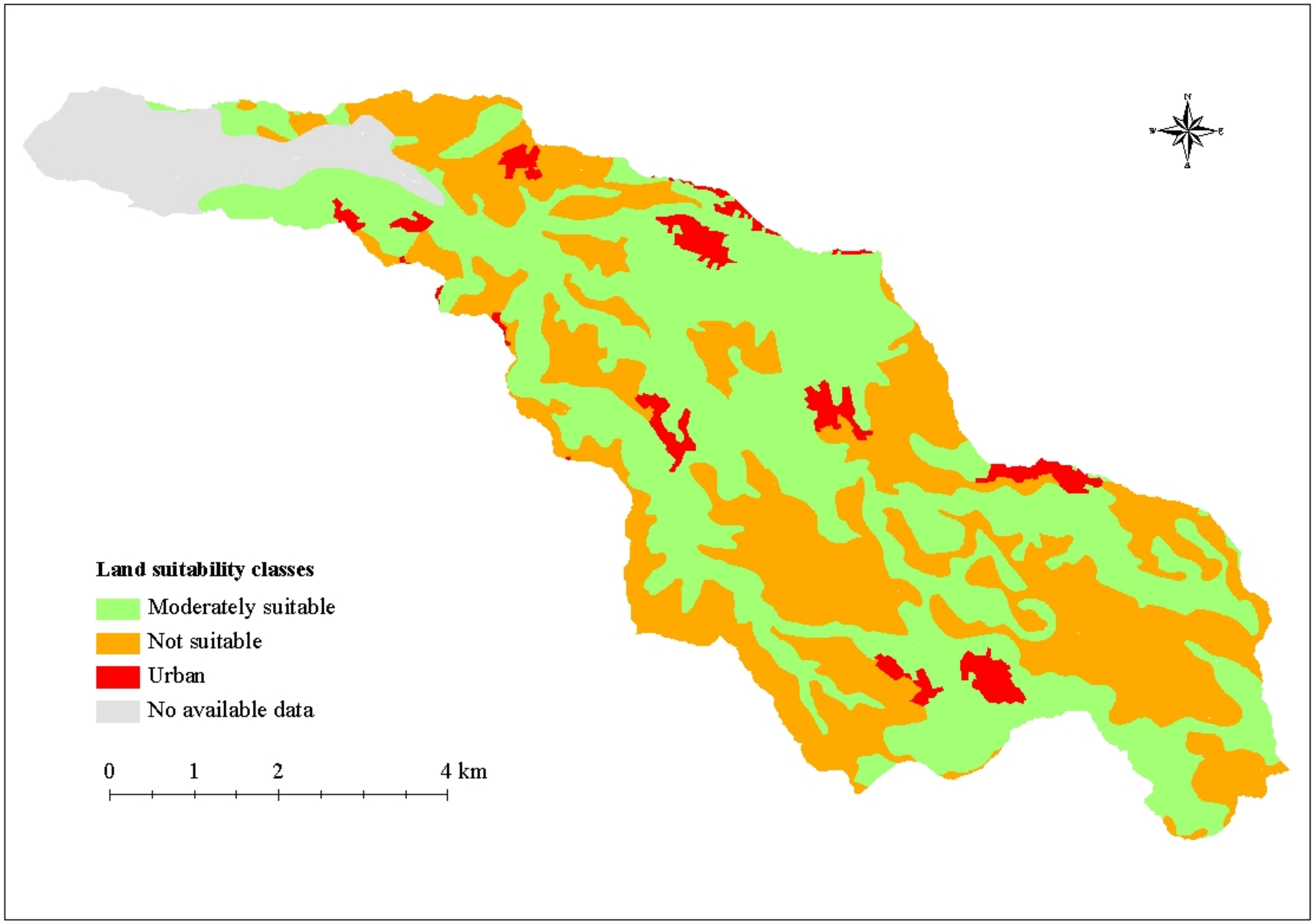

Figure 28: Distribution of land with different suitability classes for orchard.

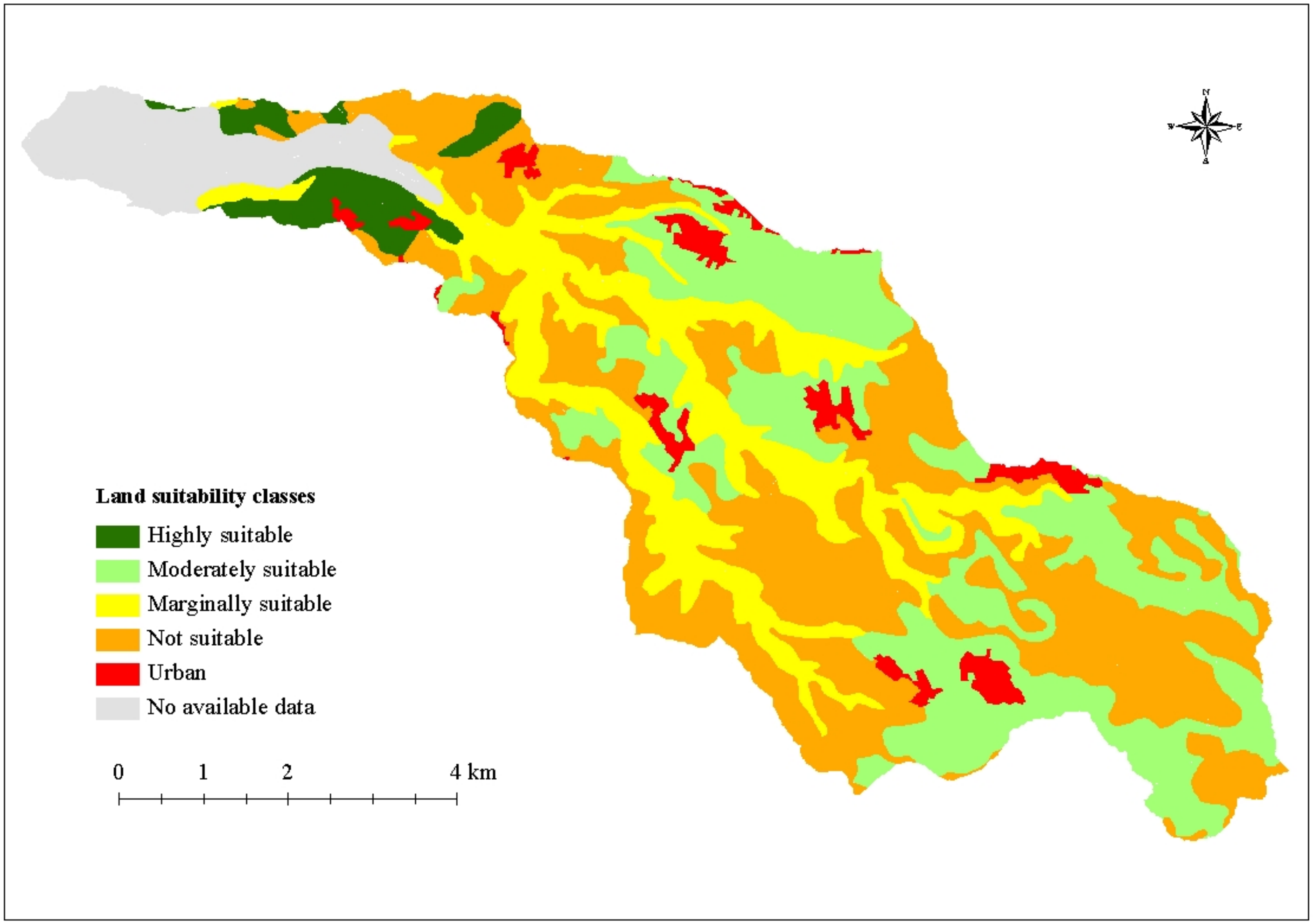

Figure 29: Distribution of land with different suitability classes for drip irrigation.

Main cultivated crops are: tomato, egg plant, cucumber, flower plants, and tree crops such as apple.

4.4.4 Potential land suitability for rangeland

The analyses indicated that only 3.8% (400 ha) of the total area was classified as highly suitable (S1) for range (Table 21 and figure 30). About 4748 ha (45.2%) was classified as moderately suitable (S2), due to rainfall limitations, while 39% (4098 ha) of the total area was classified as marginally suitable (S3), due to low rainfall and soil depth.

Natural grass species include: Poa, Carex, species and brush steppe species such as Artemesia, Retama, Salsola (MoA, 1994).

Rangeland in this area suffers from degradation because of overgrazing and poor management.

4.4.5 Potential land suitability for forest trees

The analyses indicated that 49.1% (5148 ha) of the total area was classified as highly suitable (S1) for forest trees, and 39% (4098 ha) of the total area was classified as marginally suitable (S3). Soil depth was the main limiting factor (Table 21 and figure 31).

Main forest tree species are: *Quercus Coccifera*, *Pistacia Palastina* and other deciduous broad leaves such as *Quevcus aegilops*. Evergreen forest species include *Pinus, halepensis* and *Juniperus Phoenicia* (MoA, 1994).

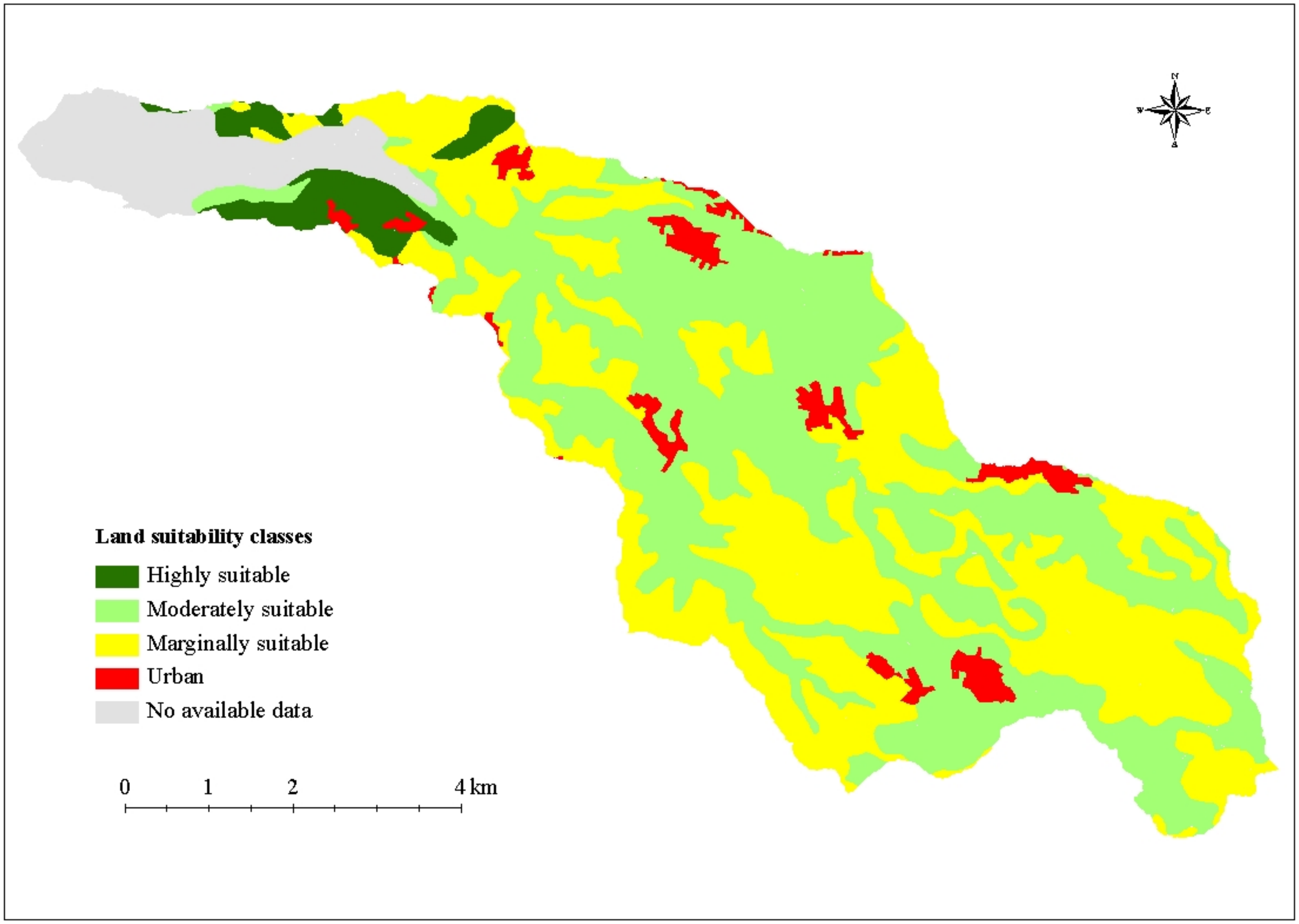

Figure 30: Distribution of land with different suitability classes for range.

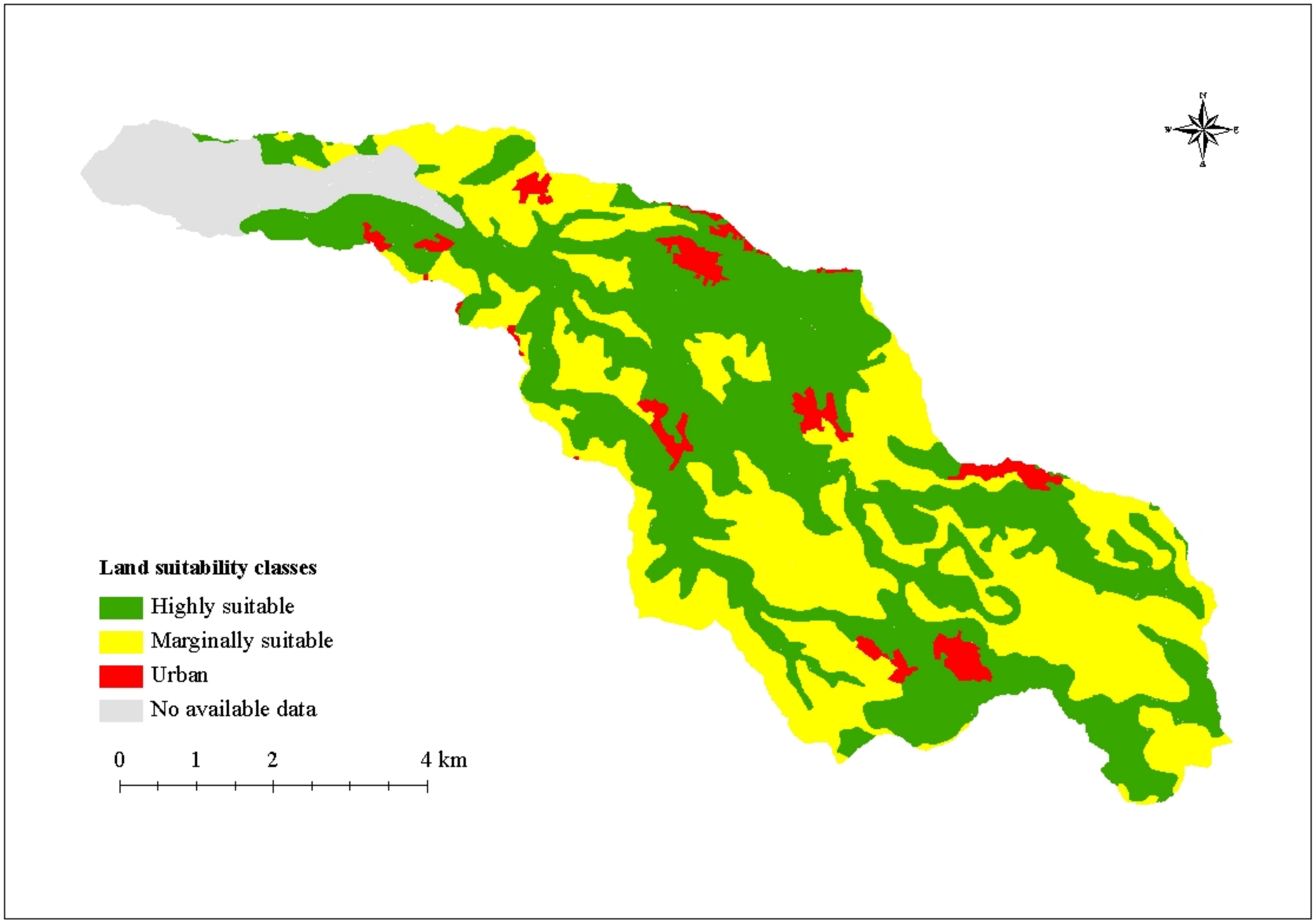

Figure 31: Distribution of land with different suitability classes for forest trees.

4.5 Comparison between current land use and potential land suitability

The objective of this evaluation was to examine whether the current land use/land cover was implemented according to optimal land use. When land use was not implemented according to land suitability, it would be reasonable to assume that land degradation would occur, unless measures such as soil conservation structures were implemented to control soil erosion especially on steep land.

The current land use was compared with potential land suitability using overlay technique of GIS. Tables 25, shows the land suitability compared with different land use for a different periods 1953, 1978, and 2008.

4.5.1 Comparison between current land use and potential land suitability for annual rainfed field crops

Generally, area of land suitable for annual rainfed crops was as follow: 3.8% was classified as highly suitable (S1), 26.4% moderately suitable (S2), 18.8% marginally suitable (S3) and 39.2% not suitable (NS). About 3.9% is used for urban activities while no available data for 7.8% of the area.

The comparison between potential land suitability, and annual rainfed area indicated that area used for annual rainfed crops was reduced with time. Area used for field crops was 25% in 1953, and was reduced to 21%, in 1978, and to 12% in 2008. Comparing areas used for annual rainfed field crops with the suitability classes indicated that majority of field crops were planted in moderately suitable (S2), and not suitable (NS) areas during different periods, (1953, 1978, and 2008), (Table 22, and figure 32).

Reduction of area used for field crop was higher in moderately suitable (S2) land as compared to not suitable (NS) class (Table 22), and highly suitable (S1) class. This means, when the land is fragmented, or divided, only few spots remain available for field crop in each plot, and farmer finds it unworthy to cultivate it with field crops. Other reasons might be attributed to land degradation by erosion, which increases stones on soil surface or rock might be exposed at the soil surface.

Table 22. Suitability classes compared with actual agricultural land use during the year of 1953, 1978, and 2008, (Area in hectare).

Land use/cover	Suitability classes	Total area		1953		1978		2008	
		Area	%	Area	%	Area	%	Area	%
Rainfed field crops	S1	400	3.8	250	9.4	240	10.6	162	12.5
	S2	2772	26.4	1415	53.5	1171	52.0	622	47.8
	S3	1976	18.8	69	2.6	51	2.3	33	2.5
	NS	4116	39.2	701	26.5	668	29.7	419	32.2
	Urban	411	3.9	139	5.3	73	3.2	12	1.0
	NAD	821	7.8	72	2.7	48	2.1	53	4.1
	Total	**10495**	**100**	**2646**	**100**	**2249**	**100**	**1301**	**100**
Rainfed tree crop	S2	5148	49.1	261	65.3	625	73.0	1627	59.3
	NS	4116	39.2	67	16.7	166	19.4	943	34.3
	Urban	411	3.9	72	17.9	65	7.6	51	1.9
	NAD	821	7.8	0	0	0	0	124	4.5
	Total	**10495**	**100**	**399**	**100**	**855**	**100**	**2745**	**100**
Drip irrigation	S1	400	3.8	0	0	0	0	0	0
	S2	2772	26.4	0	0	0	0	0	0
	S3	1976	18.8	0	0	0	0	0	0
	NS	4116	39.2	0	0	0	0	0	0
	Urban	411	3.9	0	0	0	0	0	0
	NAD	821	7.8	2	100	32	100	43	100
	Total	**10495**	**100**	**2**	**100**	**32**	**100**	**43**	**100**
Range	S1	400	3.8	113	2.9	91	2.6	35	1.4
	S2	4748	45.2	1661	42.4	1512	42.7	1166	46.9
	S3	4116	39.2	1352	34.5	1215	34.3	783	31.5
	NS	0	0	0	0	0	0	0	0
	Urban	411	3.9	94	2.4	41	1.2	16	0.6
	NAD	821	7.8	698	17.8	680	19.2	489	19.6
	Total	**10495**	**100**	**3917**	**100**	**3539**	**100**	**2489**	**100**
Forest	S1	5148	49.1	1369	40.1	1401	40.2	1214	39.4
	S3	4116	39.2	1984	58.1	2030	58.2	1781	57.8
	Urban	411	3.9	11	0.3	21	0.6	2	0.1
	NAD	821	7.8	48	1.4	36	1.0	84	**2.7**
	Total	**10495**	**100**	**3412**	**100**	**3487**	**100**	**3081**	**100**

S1: highly suitable, S2: moderately suitable, S3: marginally suitable, NS: not suitable, and NDA: no available data.

Main limiting factors for field crops were soil depth, steep, erosion, rocks and stones (Table 7). These limitations are very difficult to manage by soil conservation measures alone if land was used for field crops. Appendix F and plate 8, show area used for field crops converted to olive tree.

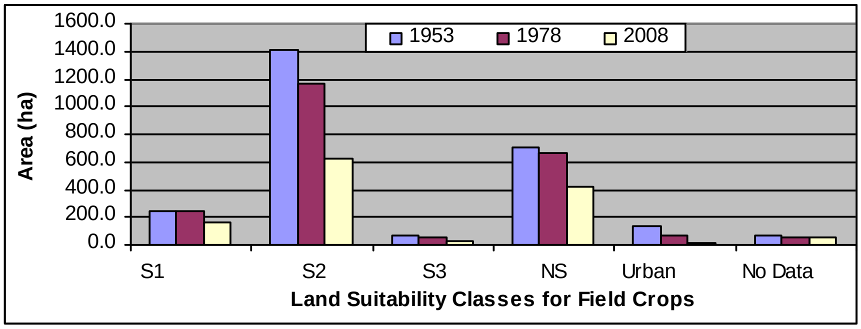

Figure 32. Area cultivated with field crop during different years and according to land suitability.

4.5.2 Comparison between current land use and potential land suitability for rainfed fruit trees

Generally, land suitable for rainfed fruit trees was classified as follow: 49.1% moderately suitable (S2) and 39.2% not suitable (NS) (Table 22). The comparison indicated that there was an increase in land cultivated with trees with time. Area used for tree crops was increased from 3.5% in 1953 to 8.2% in 1978 and to 26.2% in 2008 (Table 22 and figure 33). No area was classified as highly suitable (S1) because of many sever limitations such as: slope steepness, rock out crops, soil depth, and climate.

Comparing area cultivated with tree crops according to suitability classes, majority of the orchard trees were planted in moderately suitable (S2) and not suitable (NS) area during different periods (1953, 1978 and 2008) (Table 22). Area planted with orchard trees increased for both moderately suitable and not suitable classes, and decreased around urban area. Orchard areas increased more on not suitable (NS) as compared to moderately suitable (S2). Orchard trees covered 65.3% of moderately suitable (S2) area, and 16.7% of not suitable (NS) area in 1953. Orchard areas changed to cover 59.3% in moderately suitable class (S2), and 34.3% in not suitable (NS) class in 2008. The analyses indicated that orchard trees were planted more in not suitable (NS) class as compared with moderately suitable (S2) class.

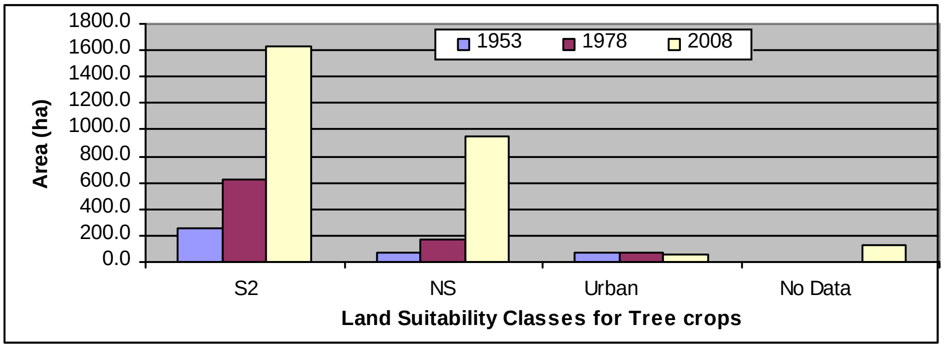

Figure 33. Area cultivated with orchard trees during different years and according to land suitability.

Planting of orchard and olive trees, continued with time on moderately suitable (S2), and not suitable (NS) classes, and decreased within urban area. This suggests, that when the farmer have a plot, he uses it in any way, even if it was not suitable. Socio-economic conditions within the catchment and low job opportunities had forced farmers to use any area to support their family livelihood.

4.5.3 Comparison between current land use and potential land suitability for drip irrigation

Drip irrigation in the study area is used as supplementary irrigation for orchards or to irrigate seedling during summer season for the first three years of plantation. Generally, land suitable for drip irrigation was as follows: 3.8%, 26.4%, 18.8%, and 39.2%, highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (NS), respectively (Table 22). Farmers within study area are not familiar with irrigation system and shortage of water.

4.5.4 Comparison between current land use and potential land suitability for rangeland

Rangeland within wadi Ziqlab, constitutes mainly natural shrubs, annual grasses, and wild plants. Activities regarding the development of the rangeland are not visible within study area. Generally, land suitable for range was as follows: 3.8%, 45.2%, and 39.2%, highly suitable (S1), moderately suitable (S2), and marginal suitable (S3), respectively, (Table 22).

The comparison indicated area covered with range was reduced since the 1953. Area covered with rangeland was 37.3% in 1953, and was reduced to 33.7%, and to 23.7% in 1978 and 2008, respectively. Area covered with range plants according to the land suitability is given in table 22, figure 34.

Comparison of rangeland area with different suitability classes, and actual land cover suggested that majority of range plant occur on moderately suitable (S2), and marginally suitable (S3), during different periods (1953, 1978, and 2008). Only 2.9%, of range occurred in highly suitable (S1) area in year 1953, which decreased to 1.4% in 2008. Rangeland privately owned was mostly converted to orchard trees, and protected with soil conservation measures as stone wall or terraces, (Appendix F, plate 111).

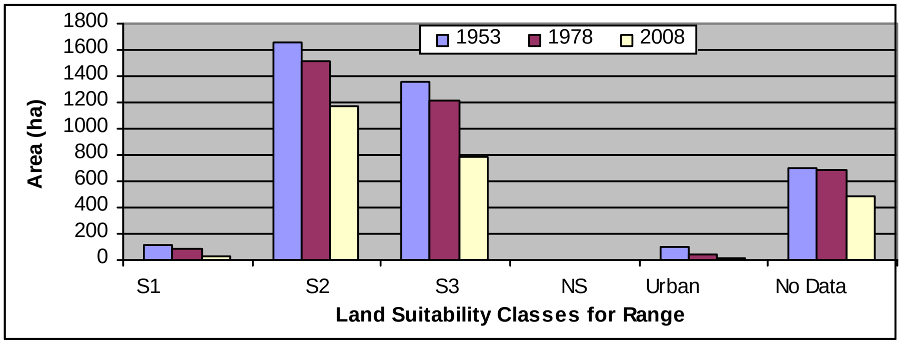

Figure 34. Area used for range during different years and according to land suitability.

4.5.5 Comparison between current land use and potential land suitability for forest trees

Forests within Wadi Ziqlab are mostly natural forests with natural grass underneath. There are few areas of artificial forest.

Generally, area suitable for forest was 49.1%, and 39.2%, classified as highly suitable (S1) and marginally suitable (S3), respectively. The comparison (Table 22, figure 35) indicated that the forest land increased during the period between 1953 and 1978. Forest area covered 32.5% in 1953, and increased to 33.2%, in 1978, but decreased to 29.4% in 2008. The analyses indicated that 39.4%, and 57.8% of forest in 2008 occurs on highly suitable (S1) and marginally suitable (S3), respectively, (Table 22).

The forest area increased during the period between 1953 and 1978, because during 1960's, afforestation projects were carried all over the Highland area in Jordan. The analyses indicated that about 81 ha was covered with artificial forest in 1978 (Table 8).

Deforestation is the main reason behind the reduction of forest areas between 1978 and 2008, specially in private forest, which was converted to orchard trees, or used for fuels (Appendix F, plates 3-5 show land that suffer from deforestation).

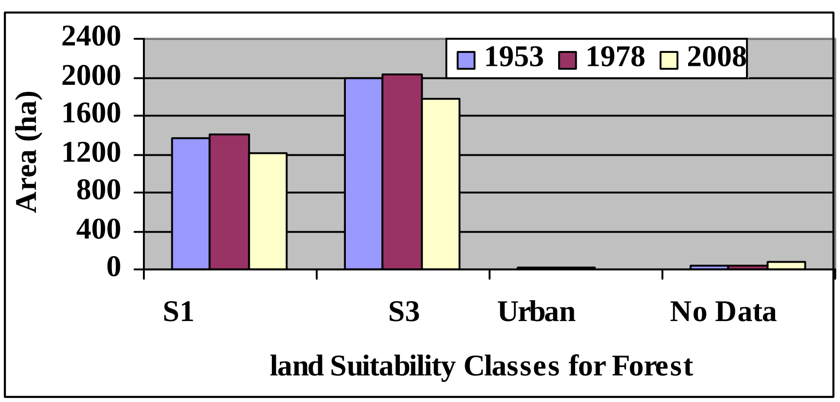

Figure 35. Area covered with forest during different years and according to land suitability.

4.5.6 Development of urban activity from 1953 to 2008

Wadi Ziqlab catchment occupied 46.4% of the total villages area that are located within or close to the villages. Government land within Wadi Ziqlab catchment covered 24.8%, while 71.5% is private land (Table 24 and figure 37).

Urban area increased to cover 118 ha, 308 ha, and 767 ha in 1953, 1978, and 2008, respectively. The expansion of urban area was carried according to clear pattern. It was uniformly carried around the old villages, and on farms far from the villages. The expansion was not according to land suitability. Therefore, most of the expansion took place on agricultural land. Urban area developed very fast because the population increased about 5.8 times within the period from 1953 to 2004. (Appendix F, plate 5, shows distribution of houses and expansion of urban area on agricultural land).

4.6 Land tenure

Land tenure is an important factor that controls land use and land management since the size and type of machines used govern production. The type of land tenure is also important in determining the availability of funds for financing of agricultural inputs. Land tenure also affects the scale of soil conservation investment.

Among the 21 villages located within Wadi Ziqlab catchment, 64% of areas allocated to these villages fall within Wadi Ziqlab catchment (Table 23 and figure 36). The total area of these villages is 22618 ha, of which 4729 ha (21%) is governmental forest and rangeland, and 17890 ha (79%) is private land. The distribution of area and population among the villages, area of each village as their ownership classification is given in table 24 and figure 37.

Table 23. Distribution of area by villages, population, and ownership in 2004 (Area in hectare).

Villages	Area (ha)*			Population**			Ratio (area/population)		
	Government	Private	Total	1952	1979	2004	1952	1979	2004
1. Ashrafiyyeh	311	1590	1901	-	-	-	-	-	-
2. Deir AboSaeed	211	1208	1420	1587	4780	14145	0.76	0.25	0.11
3. Deir El Berak	49	432	482	-	-	-	-	-	-
4. Enbeh	272	1372	1644	1198	2655	6662	1.15	0.52	0.21
5. Jdaitta	532	1607	2139	-	-	-	-	-	-
6. Jenien Essafa	208	721	929	801	1688	3752	0.90	0.43	0.19
7. Kofor Elma	351	1251	1602	-	-	-	-	-	-
8. Kofor Kiefia	44	213	257	147	384	618	1.45	0.55	0.34
9. Mazar Shamaliyyeh	283	1597	1880	2442	6642	12422	0.65	0.24	0.13
10. Merehba	46	227	273	238	699	***	0.95	0.32	-
11. Orjan	701	1208	1909.2	-	-	-	-	-	-
12. Irhaba	515	954	1470	1120	3250	7655	0.85	0.29	0.12
13. Rkhayyem	246	623	869	0	27	129	-	23.09	4.83
14. Samad	0	1214	1214	599	1128	1086	2.03	1.08	1.12
15. Sammo	92	518	610	796	2529	6213	0.65	0.20	0.08
16. Samt	0	158	158	204	785	***	0.78	0.20	-
17. Samta	239	1197	1435	-	-	-	-	-	-
18. Sowwan	83	475	558	0	8	12	-	59.4	39.58
19. Tebneh	275	421	696	900	2161	5805	0.47	0.19	0.07
20. Zmal	68	466	534	700	1602	2611	0.67	0.29	0.18
21. Zoobya	203	437	640	430	1381	2860	1.02	0.32	0.15
Total	4729	17890	22618			-	-	-	-

Source: *:- Land Survey Department. **:- Department of Statistics. - no available data, ***:-Villages are currently part of Deir AboSaeed.

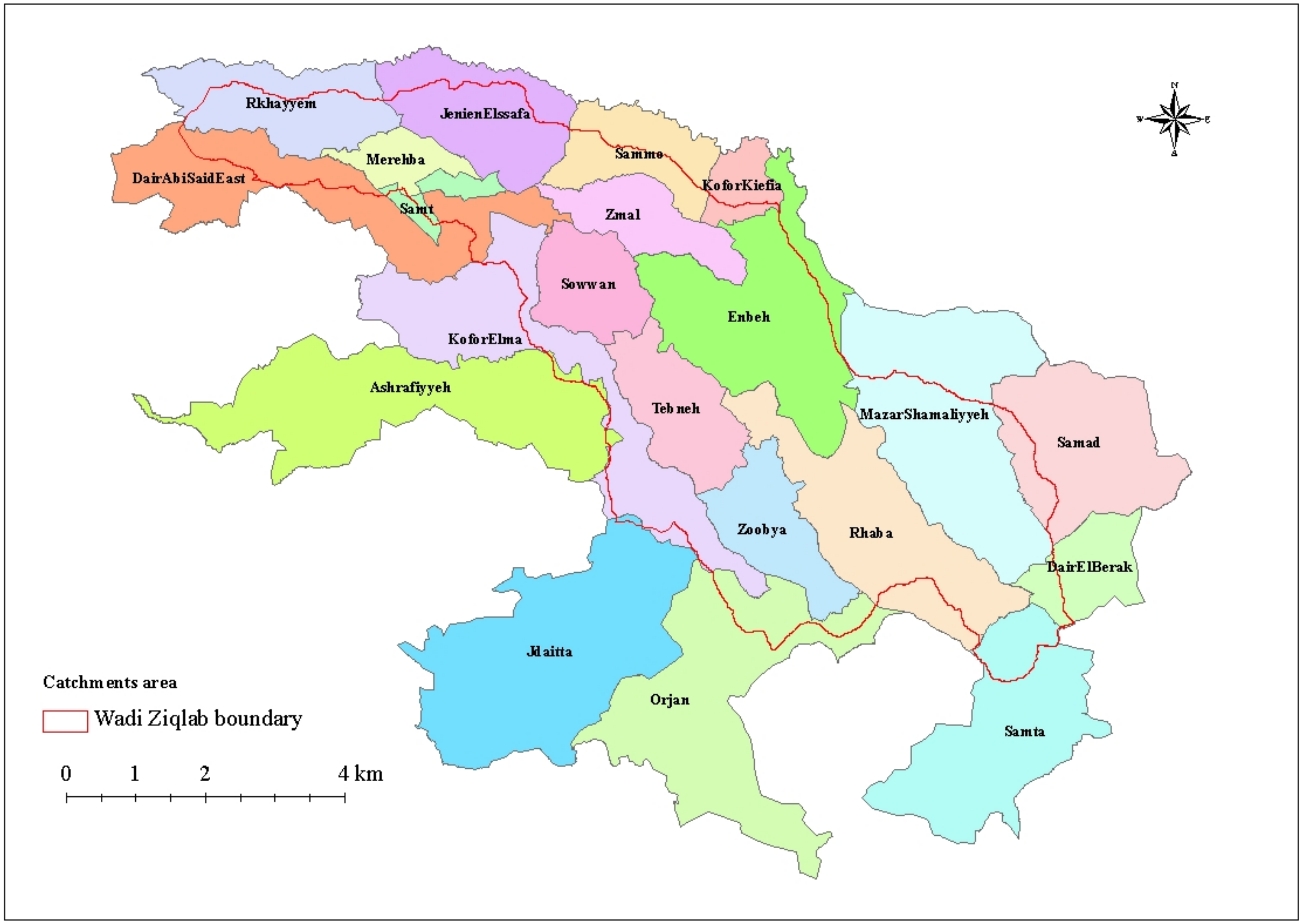

Figure 36. Villages boundary located within Wadi Ziqlab catchment.

Table 24. Distribution of land ownership by villages in 2004 (Area in hectare).

Village	Type of ownership				% of Government area
	Government	Private	Infrastructure	Total	
1. Ashrafiyyeh	8	32	2	42	19.8
2. Deir AboSaeed	75	417	40	531	14.1
3. Deir El Berak	6	91	5	102	5.8
4. Enbeh	272	1151	52	1475	18.4
5. Jdaitta	5	4	0.1	10	54.3
6. Jenien Essafa	105	504	24	633	16.6
7. Kofor Elma	351	476	32	858	40.9
8. Kofor Kiefia	33	30	3	65	50.3
9. Mazar Shamaliyyeh	283	807	41	1131	25.0
10. Merehba	46	215	10	271	16.9
11. Orjan	49	236	5	290	16.9
12. Irhaba	511	766	36	1313	38.9
13. Rkhayyem	151	360	11	521	28.9
14. Samad	0	150	5	155	0
15. Sammo	18	272	19	308	5.7
16. Samt	0	102	10	112	0
17. Samta	59	149	8	216	27.2
18. Sowwan	83	450	25	558	14.9
19. Tebneh	275	398	24	697	39.5
20. Zmal	68	477	20	565	12.0
21. Zoobya	204	420	20	644	31.7
Total	2601	7506	390	10496	24.8
Percent (%)	24.8	71.5	3.7	100	

Sources: Cadastral maps, Land and Survey Department (2004).

The data indicated that the size of ownership had decreased with time. Plot size per person was reduced from 0.7-1.5 ha, in 1952, to 0.08-0.3 ha in 2004 (Table 23). The population density ratio depends upon the area of the village and population. The area: population ratio varied according to the village, population, and years. Maximum ratio was 2.03 in 1952 and decreased to 1.12 in 2004 for Samad village. Minimum ratio was 0.47 in 1952, which decreased to 0.07 in 2004 for Tebneh village (table 23). The reduction of the population density ratio means that the fragmentation is a continuous process.

Most of privately owned agricultural land was kept under good management, while the governments land suffers from deforestation, overgrazing, and some time from fire during summer season, which cause land degradation.

4.7 Fragmentation and plot size

Generally, in Jordan, land fragmentation occurred on private land. Area of private land within Wadi Ziqlab catchment is 7506 ha, or 71.5% of total area. According to the cadastral map of 2004, private land can be classified, based on plot size, into eight classes, as follows: (1): <0.1 ha, (2): 0.1-0.2 ha, (3): 0.2-0.4 ha, (4): 0.4-1 ha, (5): 1-2 ha, (6): 2-3 ha, (7): 3-5 ha and (8): >5 ha. The distribution of land ownership and the plots number for each class is given in table 25, and figure 38.

Table 25. Distribution of private land according to plot size in 2004 (Area in hectare).

Land ownership	Plot size	Area	%	Number of plot	%
Private	**=<0.1**	293	3.9	11262	25.1
	0.1-0.2	282	3.8	4865	10.9
	0.2-0.4	440	5.9	4632	10.3
	0.4-1	1604	21.4	10125	22.6
	1-2	1874	25.0	7720	17.2
	2-3	964	12.8	2697	6.0
	3-5	1000	13.3	2139	4.8
	=>5	1050	14.0	1403	3.1
Total		**7506**	**100**	**44843**	**100**
Government		**2601**	**100**	**1625**	**100**
Roads		**390**	**100**	**7740**	**100**
Grand total		**10496**	**100**	**54208**	**100**

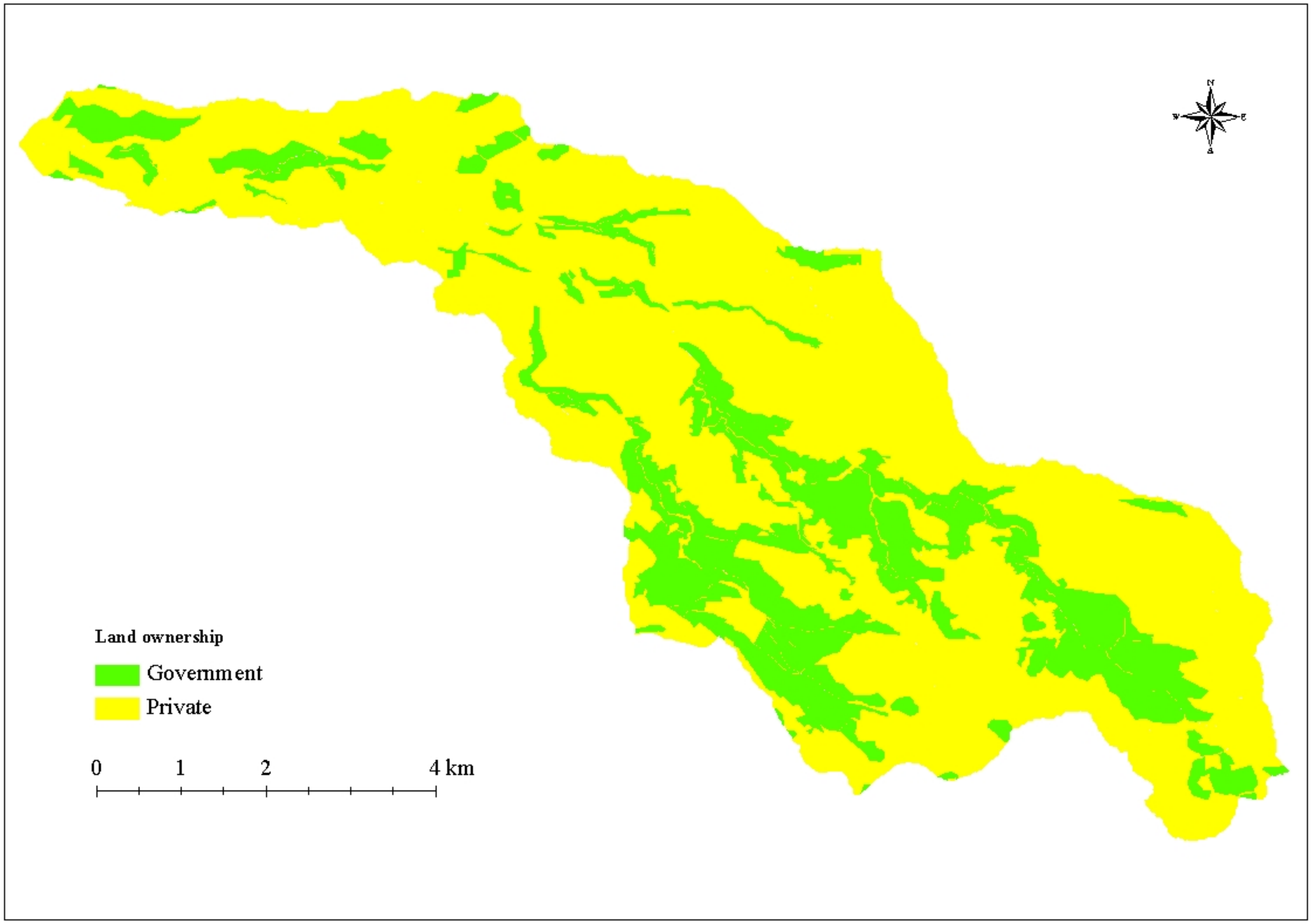

Figure 37. Distribution of private and government land.

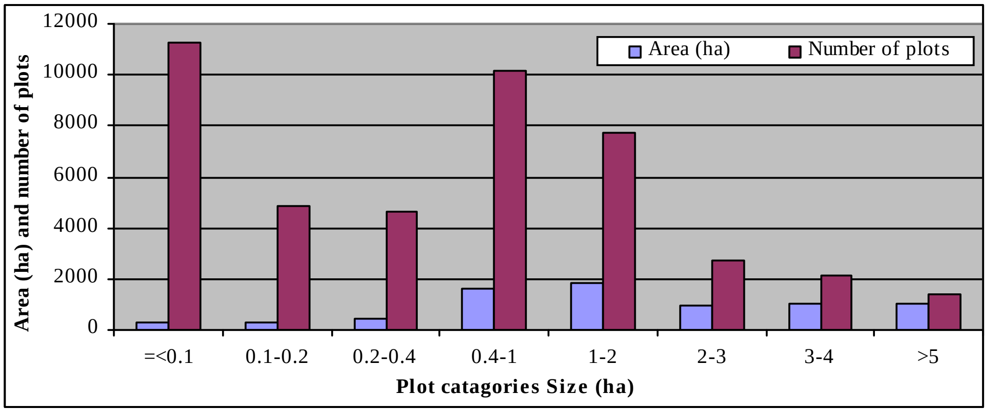

Figure 38. Distribution of private land according to plot size (2004).

The analyses indicated that private land suffers from sever fragmentation. The data indicated the presence of more than 44843 plots. The largest area (1874 ha, 25%) occurs within 1-2 ha category, followed by 1604 ha (21%), which occurs within 0.4-1 ha category. According to plot number, 11262 plots (25%) occurred within less 0.1 ha category, followed by 0.4-1 ha category, which included 10125 plots (22.6%).

Figure 38 and table 25 show the distribution of area according to plot size. The largest area of 1874 ha (25%) and 1604 ha (21.4%) occurred within plot size categories of 1-2 ha, and 0.4-1 ha, respectively. The analyses indicated that 11262 (25.1%) of the plots occurred within < 0.1 ha categories followed by 10125 plots (22.6%) which occurred within 0.4-1 ha categories. Most of the plots near or around the villages land occur on land with <0.1 ha category, while the other blocks are those far from the village usually divided by families not individuals.

Parcels are usually divided between partners according to criteria suitable for a farmer interest, and the economical value of the parcel. Division is carried in a manner which provides every plot with access to road. Division should equally include features such as: flat and steep slope, shallow and deep, and rocky area, etc. This explains why most plots have rectangular shape, i.e. few meters in width and hundreds of meters in length (Figure 39).

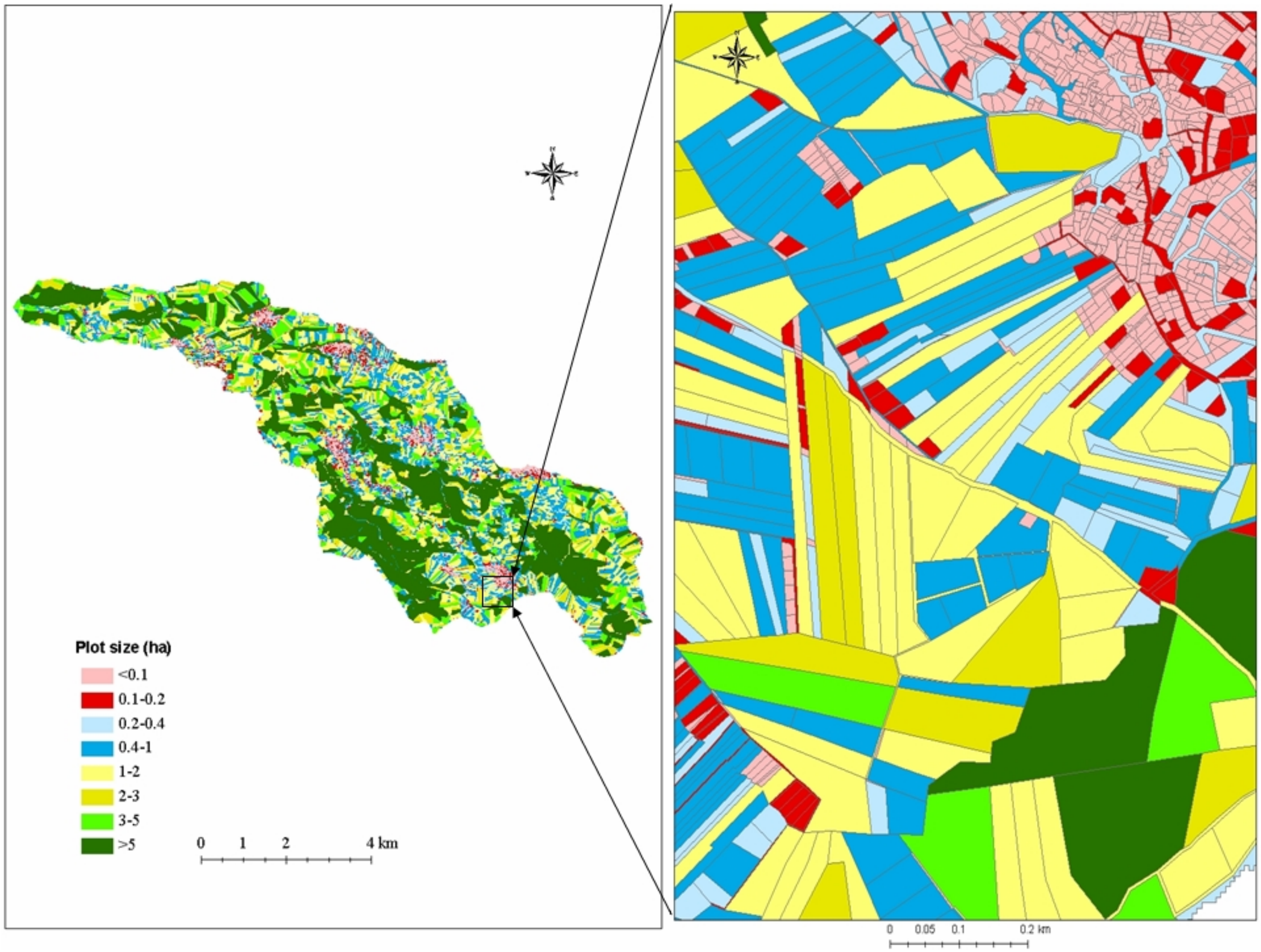

Figure 39. Distribution of land by plot size categories (Area in hectare).

The results of such division force farmers to neglect their land, or plant the whole plot without consideration of land suitability. Most plots are narrow in width and within long slope. Land with such plot shape is very difficult to plow across the slope because of its narrow width. Accordingly, land fragmentation has direct impacts on selecting suitable land use, and thus might be considered as a primary factor causing soil degradation, if land was not properly managed. Appendix F, plates 8, and 9 shows clearly how entire plots were changed in an improper way.

4.8 Land use/land cover vs. plot size of private land

Private land within Wadi Ziqlab catchment covers about 7506 ha. Orchards and olive trees were cultivated using different plot sizes and covered 376 ha (4392 plots) in 1953, and 1978. Orchards and olive trees covered 808 ha (7071 plots), and were planted in all different plot size, while in 2008, it covered 2616 ha or 15402 plots, mostly cultivated within 0.4-1 ha, and 1-2 ha categories, which covered 787 ha (4270 plots) and 772 ha (2941 plots). Orchards and olive trees was concentrated with plot size of 0.4-2 ha, because of land fragmentation, and conversion of rangeland to orchards (Table 26, 30, 31, 32, and figure 40, 41, 42).

Orchards and olive trees were developed on relatively large plot size for the following reasons:

- Areas converted to olive, mostly range, forest, and field crops land, are usually far from residential area, where the plots sizes are larger than the plots near villages.
- Most of lands within Wadi Ziqlab catchment are steep, shallow, and not suitable for field crops. Availability of machinery encourages farmers to rehabilitate their land and implement some soil conservation measures.
- Introduction of modern olive oil press and replacement of traditional old oil press.

- Plot size and plot shape encourages the farmer to use the entire plot for orchards, which induces land degradation, if soil conservation measure were not implemented. (Appendix F, plates 8 and 9). However, when the farmer owns a large plot, only few suitable patches are cultivated with field crops. When the land is divided, these patches are reduced or even disappear from the new plot. This forces farmers to convert all the plots to orchards.

Field crops was dominant land use in 1953 and covered 2538 ha (14426 plots), and was mostly practiced in land with plot size larger than 0.4 ha. After 1953, area cultivated with field crops was reduced to 2168 ha (10589 plots), and in 2008 were reduced to 1259 ha (5109 plots) (Tables 29, 30, and 31). Reduction was for all plot size categories. However, most of the reduction occurred for plots with size of <0.4 ha (Figure 42), since most of these plots occurred near urban area, and suffered from high level of fragmentation.

Generally, field crops are cultivated using parcels larger than 0.4 ha, because it is the only source of income for most families. Maximum area cultivated with field crops in 1953, was 674 ha, and 670 ha with plot size 0.4-1 ha, and 1-2 ha, and number of plot 3827 and 2662, respectively. Area planted with field crops, in 1978, decreased for all of categories to 517 ha and 625 ha, with number of plot 2917 and 2284 for categories 0.4-1 ha, and 1-2 ha, respectively. Area cultivated with field crops was continuously reduced, in 2008, to 255 ha, and 332 ha with number of plots 1499 and 1207 at plot size 0.4-1 ha and 1-2 ha, respectively, (Tables 29, 30, 31 and figures 40, 41, 42).

Table 26: Area covered by different plot size according to land use for 1953, (Area in hectare).

		<= 0.1 ha		0.1 to 0.2		0.2 to 0.4		0.4 to 1		1 to 2		2 to 3		3 to 5		> 5		Total	
Ownership	**Land use**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**
Private	**Field crop**	75	2779	89	1618	158	1618	674	3827	700	2662	320	927	257	592	266	403	2538	14426
	Olive	55	1898	64	934	69	649	103	540	49	260	22	60	11	35	3	16	376	4392
	Forest	13	557	26	419	59	613	224	1593	345	1538	174	481	211	509	265	353	1318	6063
	Range	79	3249	88	1583	141	1586	597	4087	778	3231	447	1227	522	1003	516	631	3167	16597
	Irrigated	0.0	1	0.2	1	1	6	1	8	0	1	0	0	0	0	0	0	2	17
	Urban	71	2778	15	310	11	160	5	70	3	28	0.1	2	0	0	0	0	105	3348
	Total	**293**	**11262**	**282**	**4865**	**440**	**4632**	**1604**	**10125**	**1874**	**7720**	**964**	**2697**	**1000**	**2139**	**1050**	**1403**	**7506**	**44843**
	%	**4**	**25**	**4**	**11**	**6**	**10**	**21**	**23**	**25**	**17**	**13**	**6**	**13**	**5**	**14**	**3**	**100**	**100**

Table 27: Area covered by different plot size according to land use for 1978, (Area in hectare).

		<= 0.1		0.1 to 0.2		0.2 to0. 4		0.4 to 1		1 to 2		2 to 3		3 to 5		> 5		Total	
Ownership	**land use**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**	**Area**	**No. plot**
Private	**Field crop**	37	1400	53	981	113	1138	517	2917	625	2284	303	843	247	581	273	445	2168	10589
	Olive	57	2127	76	1201	103	1025	274	1524	167	737	84	257	35	133	14	67	808	7071
	Forest	19	787	34	555	66	686	227	1689	342	1553	174	488	225	518	272	350	1359	6626
	Range	46	1910	72	1270	120	1350	538	3550	713	2949	394	1060	479	875	486	536	2848	13500
	Irrigated	1	21	2.2	24	6	29	11	55	5	17	3	3	0.4	1	0		29	150
	Urban	134	5016	44	830	31	401	35	382	19	175	7	46	2	19	0	3	271	6872
	Dam	0	1	0.4	4	0.3	3	2	8	3	5	0	0	12	12	6	2	23	35
	Total	**293**	**11262**	**282**	**4865**	**440**	**4632**	**1604**	**10125**	**1874**	**7720**	**964**	**2697**	**1000**	**2139**	**1050**	**1403**	**7506**	**44843**
	%	**4**	**25**	**4**	**11**	**6**	**10**	**21**	**23**	**25**	**17**	**13**	**6**	**13**	**5**	**14**	**3**	**100**	**100**

Table 28: Area covered by different plot size according to land use for 2008, (area in ha).

		<= 0.1		0.1 to 0.2		0.2 to 0.4		0.4 to 1		1 to 2		2 to 3		3 to 5		> 5		Total	
Ownership	land use	Area	No. plot	Area	No. Plot	Area	No. plot	Area	No. plot	Area	No. plot	Area	No. plot	Area	No. Plot	Area	No. plot	Area	No. plot
Private	Field crop	11	438	19	363	45	471	254	1499	331	1207	189.5	466	195	371	216	294	1259	5109
	Olive	57	2438	111	1784	207	1923	770	4189	753	2886	317.5	943	209	623	132	363	2557	15149
	Orchard	0.3	17	1	13	3	24	17	81	18	55	16.4	35	3	18	1	10	59	253
	Forest	6	321	11	227	31	407	137	1102	210	1011	122.6	347	199	404	245	239	961	4058
	Range	14	740	29	523	58	649	280	1828	445	1699	268.8	621	361	555	441	431	1896	7046
	Irrigated	1	27	2	27	6	32	14	72	10	31	5.6	11	1	2	0	0	39	202
	Urban	204	7266	109	1906	87	1081	120	1225	91	734	32.4	232	21	138	6	55	670	12637
	Dam	0	1	0.4	4	0.3	3	2	8	3	5	0.0		12	12	6	2	23	35
	Animal farm	0.2	11	0.2	9	0.4	9	3	44	3	36	1.5	9	0.2	5	1	7	9	130
	Quarrys	0	3	0.2	9	2	33	8	77	11	56	9.9	33	1	11	1	2	32	224
	Total	293	11262	282	4865	440	4632	1604	10125	1874	7720.0	964.1	2697.0	1000	2139	1050	1403	7506	44843
	%	4	25	4	11	6	10	21	23	25	17	12.8	6	13	5	14	3	100	100
Road	Total	27	1474	40	1172	66	1378	116	1984	64	910.0	33.2	377.0	23	215	20	230	390	7740
	%	7	19	10	15	17	18	30	26	16	12	8.5	5	6	3	5	3	100	100
Govern-Ment	Total	0.1	4	1	7	1	8.0	7	28	28	81.0	23.1	54.0	82	143	2460	1300	2601	1625
	%	0	0	0	0	0	0	0	2	0.1	5	0.1	3	0.3	9	10	80	10	100
Grand total		320	12740	322	6044	506	6018	1727	12137	1965	8711	1020.4	3128	1106	2497	3530	2933	10496	54208
%		3	24	3	11	5	11	17	22	19	16	9.7	6	11	5	34	5	100	100

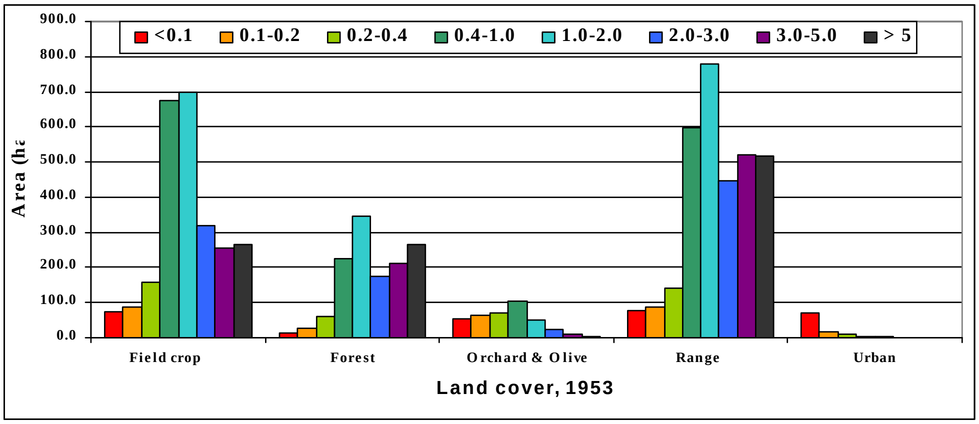

Figure 40. Distribution of private land in 1953 according to plot size.

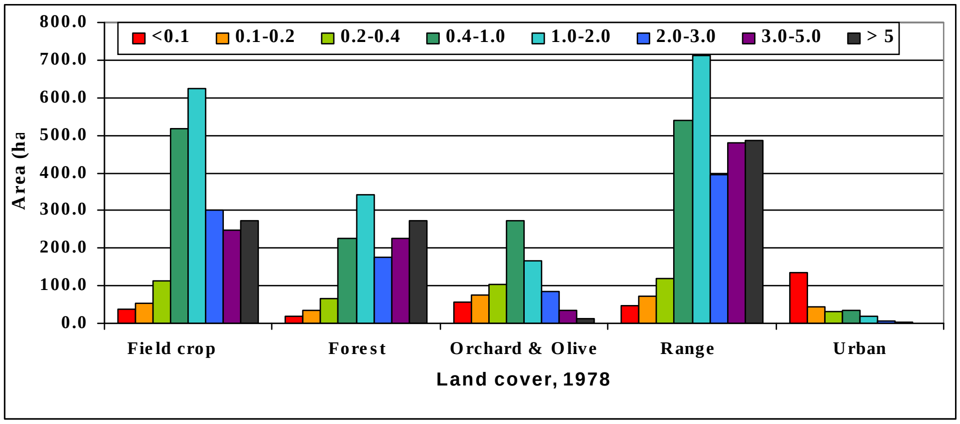

Figure 41. Distribution of private land in 1978 according to plot size.

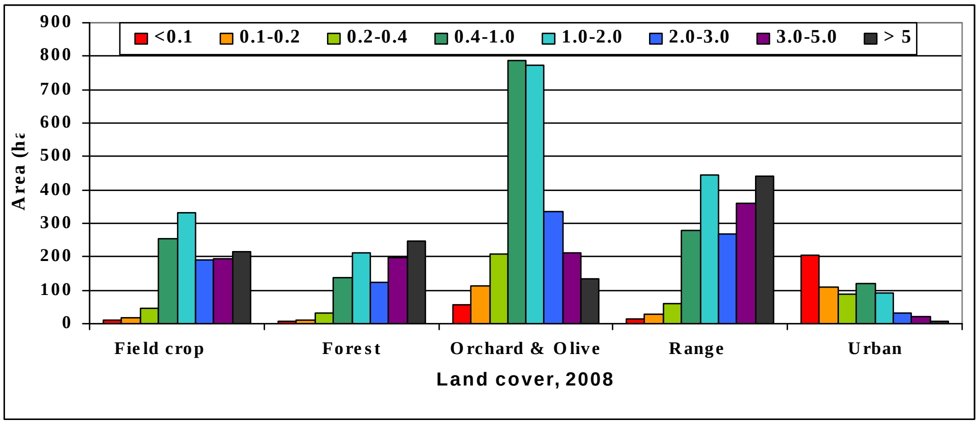

Figure 42. Distribution of private land in 2008 according to plot size.

Cultivation of field crops was stopped when the plots with size <0.4 ha were divided into smaller plots (Table 28), because it became difficult to cultivate such plot due to low return and mostly few patches left were suitable for field crops (See Appendix F, plate 8). Other important reasons for reduction of area cultivated with field crops are urbanization. New generation is educated, have job, and do not prepare bread at home. Furthermore, government started to import wheat, and sell it in prices cheaper than local production.

In the recent years, due to the shortage of agricultural land, farmer started to use intercropping system, including olives, and some other trees such as grape, apple, and stone fruit tree as secondary crops, or occasionally cultivates field crops as secondary crops under olive trees.

Urban areas are usually developed on small plots. Maximum area used for urban area was less than 0.1 ha, and covered 71 ha (2278 plots) in 1953. This area increased to 134 ha, (5016 plots), and to 204 ha, (7266 plots) in 2008 (Tables 29, 30, 31, and figure 40, 41, 42). Urban area expanded on all categories with time, even with plots larger than 5 ha. Reasons behind this are:

- The need to accommodate population growth.
- Fragmentation of private agricultural land.
- Development of infrastructure such as roads network, electricity, and portable water.

Private rangeland occurs in area with shallow soil, rocky, land with surface stone and steep area. Accordingly, land development is not easy and soil conservation structures are very difficult or expensive. Rangeland covers area with large size plots. Nevertheless, area of rangeland decreased with time for all different plot size categories (Table 26, 27, 28 and figure 40, 41, 42). Rangeland was mostly concentrated on plots larger than 0.4 ha. Total private area classified as rangeland was 3167 ha, in 1953, and decreased to 1896 ha in 2008. Rangeland decreased with time for the following reasons:

- Land fragmentation: when the number of owners of a single plot decreased, conservation of land becomes more feasible as compared to a plot which belongs to many owners.
- Availability of heavy machinery during last decades, and availability of government loan encouraged farmers to develop their lands.
- Increasing population and shortage of agricultural land, which forced them to develop rangeland, although with poor potential.
- Better economical return from olive tree, as compared with rangeland. This explains why most of rangeland was converted to orchards and olive trees.

Private forest areas were developed in large plots. The private forest area covered 1318 ha, in 1953, and decreased to 961 ha in 2008 (Table 26, 27, 28, and figure 40, 41, 42). Figure 44, shows that the highest conversion of forest area was within plot size between 0.4-2 ha. This suggests that when the large plots was divided into smaller plots, they become easy to clear and convert to other land use.

4.9 Land degradation within Wadi Ziqlab catchment

4.9.1 Land degradation within time as affected by land use change

The analyses of land cover since 1953 indicated that four main land use changes had occurred in the study area. There were field crops converted to orchards, forest to orchards, rangeland to orchard, and urban expansions. The following section discusses changes in OM, thickness of A-horizon, and soil texture as a result of these changes. The analyses also took into consideration whether the conversion of land use was associated with implementation of soil conservation measure or not, and if the time of conversion and construction of soil conservation is a factor causing degradation.

1. **Field crops to orchards**: Organic matter content was not affected by such conversion, but it increased when the soil conservation was implemented. OM for land continuously used for field crops was 2.7%, and increased to 3.0% when soil stone wall were implemented before 1953 (Table 29). Meanwhile, when the land was converted to orchards after 1978, the OM was reduced 2.8. Whereas, when the land was converted to orchard and stone wall was implemented before 1953, the OM increased to 3.8%.

   The thickness of A-horizon increased by converting the land used as field crops to orchards, because availability of stone wall and changes of plowing system. Clay content also changed (increased or decreased) but mostly depends on a site property, such as slope, shallowness, and availability of stone walls.

Table 29: Distribution of soil properties according to land use change and presence of soil conservation structures.

Land cover Change	Soil conservation			Organic matter %	Thickness of A-horizon	Clay %	Silt %	Sand %	No. of Cases
	1953	1978	2008						
Fc→ Fc → Fc	No	No	No	2.7	15.6	56.7	31.4	11.9	16
Fc → Fc → Fc	No	No	Yes	2.7	13.2	55.1	33.7	11.1	11
Fc → Fc → Fc	No	Yes	Yes	2.6	15.4	58.9	30.8	10.2	15
Fc → Fc → Fc	Yes	Yes	Yes	3.0	13.6	58.9	29.6	11.5	11
Fc → Fc → O	No	No	No	2.8	12.4	59.6	29.6	10.7	8
Fc → Fc → O	No	No	Yes	2.3	14.1	51.0	34.7	14.3	8
Fc → Fc → O	No	Yes	Yes	2.8	15.4	62.6	27.8	9.6	10
Fc → Fc → O	Yes	Yes	Yes	2.8	14.9	50.3	33.8	15.6	9
Fc → O→ O	No	No	No	2.2	15.2	66.6	27.2	6.3	6
Fc → O→ O	No	No	Yes	3.2	16.0	49.0	38.0	13.0	2
Fc → O→ O	No	Yes	Yes	2.0	12.3	62.4	33.2	4.4	4
Fc → O→ O	Yes	Yes	Yes	3.8	14.8	66.8	29.7	3.5	4
F→ F→ F	No	No	No	4.5	9.8	50.4	31.3	18.3	55
F→ F→ O	No	No	Yes	2.6	16.4	66.1	27.2	6.6	10
F→ O→ O	No	Yes	Yes	3.3	16.0	60.0	31.3	8.8	5
O→ O→ O	Yes	Yes	Yes	3.4	12.7	60.4	26.3	13.3	6
R→ R→ O	No	No	No	3.1	14.5	48.8	42.0	9.2	2
R→ R→ O	No	No	Yes	2.8	14.6	53.4	32.8	13.7	12
R→ R→ R	No	No	No	3.5	10.3	48.8	34.9	16.3	24

Land cover, Fc: field crops, F: forest, O: orchards, and R: range
Yes: year, when soil conservation measure introduced

2. **Forest to orchards:** The OM content was initially decreased when the land use was converted from forest to orchards, but later improved with time. The analyses

indicated that OM for continuous forest was 4.5% (Table 29). Meanwhile, when the forest was converted to orchard, after 1953, OM was reduced to 3.3%, and 2.6% when this conversion took place after 1978. Improvement of the OM content was observed when land was converted to orchards after 1953. This could be attributed to the implementation of stone walls, and the long term influence of stone wall.

The thickness of A-horizon for continuous forest area was 9.8 cm. It increased to 16.4 cm when the forest was converted to orchard after 1978, compared with 16 cm when the forest converted to orchard after 1953. Older stone walls were in poor conditions compared with those in areas converted after 1978, which again substantiate the positive role of stone walls.

Clay content of the soil surface increased when the forest area converted to orchards.

3. **Rangeland to orchards:** The OM content was 3.5% for land continuously used as rangeland, but decreased to 2.8% when the rangeland was converted to orchards. The thickness of A-horizon increased from 11 to 14.5 cm when the rangeland was converted to orchards. The implementation of stone wall increased the thickness of A-horizon to 14.6 cm.

4.9.2 Land degradation as affected by plot size and shape

Fragmentation of private land as a result of dividing large plots to small plots size can contribute to land degradation. Different plot sizes, plot shape and land suitability play a role in controlling land use and may cause land degradation due to several reasons such as improper land use, improper agricultural practices, and/or neglected land use.

Shortage of agricultural land within the study area, and population growth, forced farmers to cultivate all the area, without considering the land suitability. Farmer used most area for orchards as main land use and intercropping with other trees with summer or winter crops. These land use need more plowing, which can cause land degradation such as soil erosion, and depletion of soil fertility.

Plot shape plays a very important role in land degradation. Most of the area divided to form rectangular plot shape (low width and high length), and elongated with slope, which restricts plowing the land against the slope, since they use tractors for plowing. Practice can enhance soil erosion case the tractor will plow the plot with slope for their safety and easy. This method can develop soil erosion and cause land degradation.

4.9.3 Land degradation as affected by rainfall

The study area was divided to three agro-climatic zone according to rainfall, <400 mm, 400-500 mm, and >500 mm. Organic matter content was 2.56%, 3.43%, and 3.45% for rainfall <400 mm, 400-500 mm, and >500 mm, respectively (Table 13).

Organic matter varied according to land use and land use change, and according to agro-climatic zone. OM for a field crops was 2.5%, 2.9%, and 2.7% at rainfall <400 mm, 400-500 mm, and >500 mm, respectively. When land cultivated with field crops was changed to orchards, the OM decreased for climate zone <400 mm rainfall. At the same time, increased for some fields and decreased on others were rainfall between 400-500 mm or >500 mm, depending on field properties such as slope, soil depth and/or availability of soil conservation structure (Table 30).

Organic matter for forest area increased when rainfall increased. OM was 3.7%, 4.3%, and 4.6% for rainfall <400 mm, 400-500 mm, and >500 mm, respectively. Organic matter decreased when forest land was converted to orchard. Meanwhile it depended on time of conversion. Area converted after 1953 has higher OM than area converted after 1978 (Table 30). This means the OM increased for land used for orchards tree by time.

Organic matter for rangeland was 3.1%, 4.0%, and 3.7% were rainfall <400 mm, 400-500 mm, and >500 mm, respectively. Organic matter decreased for all climatic zones when the rangeland was converted to orchards. The highest OM was obtained for climate zone of rainfall between 400-500 mm, and decreased for climate zone >500 mm because mostly soil erosion, while lowest OM content for climate zone <400 mm rainfall was due to low vegetation cover.

The thickness of A-horizon was highest for land cultivated with field crop within climate zone <400 mm rainfall, because most of the land cultivated with field crops at these area occur on a very low slope.

The thickness of A-horizon was highest for orchard area or the area converted from forest or rangeland to orchards within area which receives rainfall between 400-500mm or rainfall >500mm.

Clay contents was higher for area within the climatic zone with rainfall >500mm or 400-500mm as compared with <400mm climatic zone, because more rainfall is responsible for better vegetation cover and more soil formation.

Table 30: Distribution of soil properties according to land use change and amount of rainfall

Rainfall (mm)	Land use change	Organic Mater %	Thickness of A-horizon	Clay %	Silt %	Sand %	No. of case
<400	Fc→ Fc → Fc	2.5	16.2	54.0	32.7	13.3	13
<400	Fc→ Fc → O	2.2	13.8	52.2	35.4	12.6	9
<400	Fc→ O → O	2.0	13.7	61.2	31.5	7.4	3
<400	F → F → F	3.7	11.0	46.3	37.1	16.6	2
<400	R→ R → O	2.1	13.3	55.5	34.9	9.6	3
<400	R→ R → R	3.1	09.1	48.4	34.7	16.8	10
400-500	Fc→ Fc → Fc	2.9	13.8	58.8	31.4	9.8	16
400-500	Fc→ Fc → O	3.4	14.5	61.0	27.9	10.8	12
400-500	Fc→ O → O	2.3	14.5	53.8	36.7	9.6	4
400-500	F→ F → F	4.3	11.8	55.2	28.1	16.7	16
400-500	F→ F → O	3.1	16.7	65.2	27.9	6.9	6
400-500	F→ O → O	3.1	17.5	64.3	29.9	6.1	2
400-500	O→ O → O	3.4	12.7	60.4	26.3	13.3	6
400-500	R→ R → O	3.0	15.0	47.0	40.4	12.6	4
400-500	R→ R → R	4.0	09.8	50.8	34.2	14.9	6
>500	Fc→ Fc → Fc	2.7	14.4	58.4	30.6	11.0	24
>500	Fc→ Fc → O	2.4	14.4	54.4	31.7	13.8	14
>500	Fc→ O → O	3.1	14.7	68.4	27.7	3.9	9
>500	F→ F → F	4.6	08.8	48.6	32.3	19.1	37
>500	F→ F → O	2.0	16.0	67.6	26.2	6.1	4
>500	F→ O → O	3.4	15.0	57.1	32.3	10.6	3
>500	R→ R → O	3.1	14.9	54.9	30.2	14.9	7
>500	R→ R → R	3.7	12.0	47.7	35.5	16.7	8

Land cover, Fc: field crops, F: forest, O: orchards, and R: range

5. CONCLUSIONS

1. The analyses of land cover changes between (1953 to 1978 and 1978 to 2008), indicated substantial expansion orchards and urban areas over field crop, forest, rangeland areas.
2. Conversion of field crop to orchards increases the organic matter content, if associated with soil conservation measures. While, converting forest and rangeland to orchard resulted in the reduction of organic matter.
3. Plowing of orchards and field crops resulted in mixing the soil surface, which was responsible for development of thicker A-horizon for cultivated area than forest or rangeland.
4. Clay content of the surface horizon was higher for land used for orchards and field crops due to associated cultivation practices and introducing soil conservation measures.
5. The influence of climate and elevation on soil properties varied as follows: Organic matter content increased as annual rainfall increases, the thickness of A-horizon, clay content were highest for areas which received annual rainfall between 400-500 mm. Lower clay values for area with higher rainfall amounts could be due to high soil erosion by water.
6. Organic matter content increased significantly with availability of stone walls and the period when the stone wall was constructed. Meanwhile, the thickness of A-horizon significantly increased with construction of stone walls, but decreased when stone walls were constructed before 1953, due to poor maintenance.
7. Assessment of land suitability indicated that about 49% (5148 ha) of the total area was classified as moderately suitable (S2) for rainfed fruit trees. The main limiting factors were soil depth, and slope steepness. Moreover, about 18 ha suffer from other

limitations including soil erosion and surface rockiness. Olive orchards were the only alternative available for developing the area under proper soil conservation measures and using small machines or plowing by animals, which can reduce soil erosion risk. Expansion of agricultural development seams to take place on land not suitable for specific practice, which forced farmers to take costly measure to convert the land to productive one.

8. Data indicated that the size of land ownership had decreased with time. Land fragmentation occurred primarily on private land. Land degradation seamed to be associated with land fragmentation.
9. Size of land used for orchards had decreased with time due to land fragmentation.

6. REFERENCES

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7. APPENDIX

Appendix A: Annual mean, minimum and maximum air temperature for four stations around Wadi Ziqlab catchment.

Years	Mean annual maximum air temperature (C°)				Mean annual minimum Air temperature (C°)				Mean annual air temperature (C°)			
	Baqura	Deir Alla	Irbid	Ras Muneef	Baqura	Deir Alla	Irbid	Ras Muneef	Baqura	Deir Alla	Irbid	Ras Muneef
1975	28.7	29.5	22.4	-	15.8	17.6	11.9	-	22.2	23.6	17.1	-
1976	28.5	29.3	22.4	-	15.7	17.4	11.6	-	22.1	23.4	17.0	-
1977	29.0	29.7	22.9	18.1	15.8	17.7	12.2	09.9	22.4	23.7	17.6	14.0
1978	28.9	30.1	23.4	18.9	15.8	17.8	12.7	10.5	22.4	24.0	18.0	14.7
1979	29.3	30.3	23.6	18.9	16.7	18.3	13.1	10.8	23.0	24.3	18.4	14.8
1980	28.5	29.4	22.7	18.3	16.0	17.7	12.3	10.4	22.2	23.6	17.5	14.3
1981	28.8	29.7	22.8	18.6	15.9	17.7	12.6	10.4	22.4	23.7	17.7	14.5
1982	28.1	28.7	21.9	16.9	15.4	17.2	12.1	09.7	21.7	23.0	17.0	13.3
1983	27.7	28.6	21.7	17.2	15.0	17.1	11.3	09.5	21.3	22.9	16.5	13.3
1984	28.8	29.8	22.5	18.3	15.6	17.5	12.3	10.1	22.2	23.6	17.4	14.2
1985	29.2	29.9	23.1	18.8	15.6	17.9	12.6	10.1	22.4	23.9	17.8	14.4
1986	28.8	29.7	22.5	18.2	15.4	17.7	12.6	09.9	22.1	23.7	17.6	14.1
1987	28.6	29.6	22.9	18.6	15.2	17.4	12.3	10.0	21.9	23.5	17.6	14.3
1988	28.8	29.4	22.5	18.1	15.5	17.5	12.7	09.7	22.2	23.4	17.6	13.9
1989	29.4	29.8	23.1	18.6	14.9	17.1	12.5	09.8	22.1	23.4	17.8	14.2
1990	29.2	29.9	22.9	18.5	15.4	17.6	12.4	09.7	22.3	23.7	17.7	14.1
1991	28.8	29.6	22.7	18.3	15.5	18.0	12.7	09.8	22.1	23.8	17.7	14.0
1992	27.6	28.0	21.3	16.8	14.7	16.9	11.2	08.6	21.1	22.4	16.2	12.7
1993	29.2	29.5	23.0	18.5	15.2	17.6	12.3	09.9	22.2	23.5	17.6	14.2
1994	29.5	30.0	23.4	18.6	16.3	18.5	13.3	10.5	22.9	24.3	18.4	14.6
1995	29.4	29.8	23.1	18.6	15.2	17.9	12.5	09.8	22.3	23.9	17.8	14.2
1996	29.4	30.2	23.3	18.8	16.2	18.3	12.9	10.4	22.8	24.2	18.1	14.6
1997	28.9	29.2	22.5	17.8	15.3	17.4	12.3	09.7	22.1	23.3	17.4	13.8
1998	30.2	30.8	23.9	19.3	16.4	18.7	13.4	11.0	23.3	24.7	18.6	15.1
1999	30.7	31.2	24.3	19.6	16.4	18.9	13.4	10.9	23.5	25.1	18.8	15.2
2000	29.7	30.0	23.5	18.6	15.9	18.2	12.9	10.1	22.8	24.1	18.2	14.3
2001	30.7	31.0	24.4	19.5	16.5	19.0	13.7	10.8	23.6	25.0	19.1	15.1
2002	30.1	30.4	23.9	19.0	16.4	18.6	13.3	10.4	23.3	24.5	18.6	14.7
2003	29.5	30.1	23.6	18.6	16.3	18.4	13.2	10.4	22.9	24.2	18.4	14.5
2004	29.6	30.4	23.9	19.3	15.4	17.9	13.0	10.5	22.5	24.1	18.4	14.9
2005	29.3	30.2	23.5	18.7	15.3	18.0	13.1	10.1	22.3	24.1	18.3	14.4
2006	29.4	30.1	23.3	18.6	15.2	17.8	13.0	10.0	22.3	24.0	18.2	14.3
2007	29.6	30.6	23.7	19.0	15.9	18.3	13.4	10.5	22.7	24.4	18.5	14.8
2008	30.3	31.0	24.2	19.4	15.9	18.6	13.5	10.7	23.1	24.8	18.8	15.1
Mean	29.2	29.9	23.1	18.5	15.7	17.9	12.7	10.1	22.4	23.9	17.9	14.3

Source: Ministry of Transportation, Jordan Metrology Department.
- No available data.

Appendix B: Mean annual rainfall (mm) for six stations within and around Wadi Ziqlab catchment.

Year	Baqura	Deir Alla	Deir AboSaeed	Irbid	Irhaba *	Ras Muneef
1975	326	216	-	428	-	-
1976	379	220	383	399	425	489
1977	375	311	480	472	813	444
1978	312	176	293	342	376	613
1979	499	335	547	517	583	375
1980	459	323	501	571	673	609
1981	337	209	362	333	422	656
1982	335	307	257	442	275	419
1983	395	318	487	566	263	526
1984	356	225	398	540	499	638
1985	321	240	342	413	520	498
1986	537	386	550	660	761	464
1987	330	193	377	399	522	800
1988	443	362	552	564	785	594
1989	238	246	280	272	339	784
1990	445	206	332	399	432	390
1991	681	487	700	646	798	430
1992	823	501	922	878	987	915
1993	211	141	230	260	259	1038
1994	577	469	638	586	-	384
1995	232	118	264	253	-	838
1996	367	274	470	380	-	310
1997	447	480	580	558	-	571
1998	366	192	441	400	-	849
1999	168	120	249	214	-	506
2000	444	371	590	447	-	257
2001	329	247	379	301	-	700
2002	485	408	608	618	-	418
2003	512	353	700	746	-	773
2004	393	246	432	448	-	818
2005	345	248	497	448	-	608
2006	274	322	363	372	-	625
2007	356	220	426	379	-	494
2008	193	167	304	298	-	558
Mean	391	283	453	457	541	588
Max.	823	501	922	878	987	1038
Min.	168	118	230	214	259	258

Source: Ministry of Transportation, Metrology Department-Jordan.

- No available data.

Appendix C: Summary of properties for different soil mapping units.

Map Unit	Sub-Groups	Area (ha)	Elevation (m)	Slope (%)	Geomorphology and parent material	Land use	Stones within A-horizon	Stones at surface	Rock outcrop	Depth (cm)
1	ChromicHaploxererts*	400	300-670	0-8	Undulating terrain; deep colluviums, weathered to shrinking soil	Very intensive rainfed fruit tree and field crops; irrigated horticulture	2%	1%	No rock outcrop	>80
	TypicHaploxererts									>80
	VerticHaploxerepts									>80
	LithicHaploxerepts									<50
7	TypicHaploxerepts	2070	400-1150	0-25	High, rolling plateau and terrace; moderately deep colluvium	Intensive rainfed field crops and tree crops, minor irrigation	4%	4%	<5%	50-80
	VerticHaploxerepts									>80
	LithicHaploxerepts									<50
10	TypicHaploxerepts	702	450-1100	5-16	Colluvial foot slopes on bench positions deep and moderately deep colluvium	Intensive rainfed field crops and tree crops	17%	35%	<2%	50-80
	VerticHaploxerepts									50-80
	LithicXerorthents									<50
	LithicHaploxerepts									<50

Source: National Soil Map and Land Use Project, semi detailed 1:50000, MoA, 1994
Soil depth: shallow < 50 cm, moderately deep 50-80 cm, and deep > 80 cm.
* Modified from MOA 1994

- **Appendix C:** (Continued).

Map Unit	Sub-Groups	Area (ha)	Elevation (m)	Slope (%)	Geomorphology and parent material	Land use	Stones within A-horizon	Stones at surface	Rock outcrop	Depth (cm)
17	TypicHaploxerepts	1976	400-1000	26-60	Very steep mass-movement slopes in major and deeply dissected valleys	Brush range, forest and reforestation, some irrigation	15%	10% and boulders	10%	50-80
	LithicHaploxerolls*									<50
	LithicHaploxerepts									<50
	LithicXerorthents									<50
23	LithicHaploxerepts	4098	600-1100 250-600	9-16	Convex ridge tops and upper slops; shallow colluvium	Brush range, forest, some tree crops.	6%	5% and boulders	5%	>80
	TypicHaploxerepts									>80
	LithicXerorthents									>80
	LithicHaploxerolls*									<50
25	LithicHaploxerepts	18	660-690	0-16	Undulating to rolling rocky plain on hard sandstone; some shallow and stony colluvium	Brush range, plasticulture, rainfed field crops, construction.	5%	5%	15%	<50
	TypicHaploxerepts									50-80
	LithicXerorthents									<50
Urban		411								
No Data		821								

Source: National Soil Map and Land Use Project, semi detailed 1:50000, MoA, 1994.
Soil depth: shallow < 50 cm, moderately deep 50-80 cm, and deep > 80 cm.
*Modified from MoA, 1994

Appendix D: Description of soil samples according the land cover at (1953, 1978, and 2008).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
1	1	Field crop, new stone wall	Field crop	Field crop	Field crop	12	2.8	47.5	34.2	18.4	<400
2	1	Field crop, new stone wall	Field crop	Field crop	Field crop	13	2.8	47.5	34.2	18.4	<400
3	1	Olive 10 years , no stone wall	Field crop	Field crop	Olive	12	1.9	45.3	38.2	16.5	<400
4	1	Olive 10 years , no stone wall	Field crop	Field crop	Olive	10	2.6	59.1	33.4	7.5	<400
5	1	Olive, old stone wall	Field crop	Field crop	Olive	13	1.9	45.4	38.4	16.3	<400
6	1	Olive, old stone wall	Field crop	Field crop	Olive	13	1.9	45.4	38.4	16.3	>500
7	1	Olive, old stone wall	Field crop	Field crop	Olive	14	2.1	47.0	37.0	17.0	<400
8	1	Olive, no stone wall	Field crop	Olive	Olive	11	2.2	65.0	31.5	3.9	<400
9	1	Range	Range	Range	Range	7	1.9	67.8	30.7	1.4	<400
10	1	Range	Range	Range	Range	5	2.2	41.0	36.9	22.1	<400
11	1	Range	Range	Range	Range	9	3.4	64.9	31.4	3.7	<400
12	1	Range	Range	Range	Range	7	2.5	34.6	37.1	28.3	<400
13	2	Range, field crop, no stone wall	Field crop	Field crop	Field crop	13	1.2	59.6	32.4	8.0	<400
14	2	Olive 20 years no stone wall	Field crop	Field crop	Olive	19	1.9	49.8	40.0	10.2	<400
15	2	Forest	Forest	Forest	Forest	15	3.9	48.5	34.3	17.2	<400
16	3	Field crop, no stone wall	Field crop	Field crop	Field crop	25	2.8	47.0	35.4	17.5	<400
17	3	Field crop, no stone wall	Field crop	Field crop	Field crop	23	2.7	47.0	35.4	17.6	<400
18	3	Field crop, no stone wall	Field crop	Field crop	Field crop	25	2.4	47.0	35.0	18.0	<400
19	3	Olive 20 years, no stone wall	Field crop	Olive	Olive	16	1.9	70.0	28.6	1.3	<400
20	3	Olive, no stone wall	Field crop	Olive	Olive	14	1.9	48.5	34.5	17.0	<400
21	3	Olive, no stone wall	Field crop	Field crop	Olive	16	1.6	48.0	34.0	18.0	<400
22	4	Field crop, no stone wall	Field crop	Field crop	Field crop	14	2.7	55.4	34.2	10.4	<400
23	4	Field crop, no stone wall	Field crop	Field crop	Field crop	13	3.0	55.4	30.0	14.6	<400
24	4	Olive, no stone wall	Field crop	Field crop	Olive	14	2.9	57.0	33.9	9.1	<400

Appendix D: (continued).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
25	4	Olive 10 years , no stone wall	Range	Range	Olive	15	3.2	57.8	34.4	7.9	<400
26	4	Range	Range	Range	Range	9	3.1	50.1	27.6	22.3	<400
27	4	Range	Range	Range	Range	9	2.3	50.2	31.9	17.9	<400
28	5	Field crop, no stone wall	Field crop	Field crop	Field crop	16	3.0	52.3	31.5	16.3	<400
29	5	Field crop, no stone wall	Field crop	Field crop	Field crop	15	2.4	51.0	32.0	17.0	<400
30	5	Olive, no stone wall	Field crop	Field crop	Olive	14	2.9	57.0	33.9	9.1	<400
31	5	Range	Range	Range	Range	9	4.2	43.2	36.8	20.0	<400
32	5	Range	Range	Range	Range	11	4.1	43.5	37.0	19.5	<400
33	6	Field crop, no stone wall	Field crop	Field crop	Field crop	15	2.2	64.3	30.5	5.2	<400
34	6	Field crop, no stone wall	Field crop	Field crop	Field crop	9	2.1	64.3	30.0	5.7	<400
35	6	Field crop, no stone wall	Field crop	Field crop	Field crop	17	2.0	64.3	30.5	5.2	<400
36	6	Olive 20 years, no stone wall	Field crop	Field crop	Olive	12	2.1	60.8	29.8	9.4	<400
37	6	Olive, new stone wall	Range	Range	Olive	13	1.8	59.6	32.4	8.0	<400
38	6	Range	Range	Range	Range	16	3.7	44.0	36.0	20.0	<400
39	7	Field crop, no stone wall	Field crop	Field crop	Field crop	15	3.3	59.3	36.2	4.5	400-500
40	7	Low forest	Forest	Forest	Forest	17	4.9	62.0	30.0	8.0	400-500
41	7	Low forest	Forest	Forest	Forest	17	4.8	66.2	27.8	6.0	400-500
42	7	Olive, old stone wall	Forest	Forest	Olive	15	3.9	61.4	34.0	4.6	400-500
43	8	Forest	Forest	Forest	forest	7	3.6	44.0	40.0	16.0	<400
44	8	Olive no stone wall	Range	Range	Olive	12	1.2	49.0	38.0	13.0	<400
45	8	Range	Range	Range	Range	9	3.2	45.0	42.0	13.0	<400
46	9	Field crop, stone wall	Field crop	Field crop	Field crop	17	2.3	57.6	38.6	3.8	400-500
47	9	Field crop, stone wall	Field crop	Field crop	Field crop	17	1.8	59.6	34.2	6.2	400-500
48	9	Olive 30 years, stone wall	Field crop	Olive	Olive	13	1.5	57.4	36.4	6.2	400-500

Appendix D: (continued).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
49	9	Olive 30 years , stone wall	Field crop	Olive	Olive	13	1.4	59.6	34.3	6.1	400-500
50	10	Field crop, old stone wall	Field crop	Field crop	Field crop	12	2.4	60.0	29.0	11.0	400-500
51	10	Olive, old stone wall	Field crop	Field crop	Olive	12	3.0	61.0	30.0	9.0	400-500
52	10	Olive, no stone wall	Range	Range	Olive	14	3.2	49.1	42.0	8.9	400-500
53	10	Olive, no stone wall	Range	Range	Olive	15	2.9	48.5	42.0	9.5	400-500
54	10	Range	Range	Range	Range	13	3.3	55.9	35.6	8.7	400-500
55	11	Field crop, old stone wall	Field crop	Field crop	Field crop	14	1.5	66.3	23.8	9.9	400-500
56	11	Field crop, old stone wall	Field crop	Field crop	Field crop	13	1.7	66.3	23.8	9.9	400-500
57	11	Olive 10 years, stone wall	Field crop	Field crop	Olive	10	2.3	66.0	22.0	12.0	400-500
58	11	Olive 10 years , old stone wall	Field crop	Field crop	Olive	25	2.2	65.0	21.0	14.0	400-500
59	12	Olive, no stone wall	Range	Range	Olive	11	2.3	33.3	47.7	19.0	400-500
60	12	Range	Range	Range	Range	8	3.1	32.8	48.0	19.0	400-500
61	13	Field crop, stone wall	Field crop	Field crop	Field crop	14	3.4	65.7	30.7	3.5	>500
62	13	Field crop, no stone wall	Field crop	Field crop	Field crop	10	3.7	64.9	30.4	4.6	400-500
63	13	Field crop, no stone wall	Field crop	Field crop	Field crop	9	3.3	65.0	30.0	5.0	400-500
64	13	Olive 10 years, no stone wall	Field crop	Field crop	Olive	9	4.4	64.6	25.1	10.3	400-500
65	13	Olive 10 years, stone wall	Field crop	Field crop	Olive	10	4.3	65.0	25.0	10.0	400-500
66	13	Dense forest	Forest	Forest	Forest	3	5.5	47.1	35.4	17.5	>500
67	13	Olive 50 years , old stone wall, good management, stone wall	Forest	Olive	Olive	19	3.8	70.0	28.6	1.3	>500
68	14	Field crop, stone wall	Field crop	Field crop	Field crop	15	4.2	59.5	32.3	8.2	400-500
69	14	Field crop, stone wall	Field crop	Field crop	Field crop	15	3.1	63.7	28.0	8.3	400-500
70	14	Field crop, old stone wall	Field crop	Field crop	Field crop	16	2.4	62.6	28.5	8.5	400-500
71	14	Olive 40 years , new stone wall	Field crop	Field crop	Olive	17	3.7	61.5	32.2	6.3	400-500
72	14	Olive, new stone wall	Field crop	Field crop	Olive	16	2.8	63.6	30.1	6.3	400-500

Appendix D: (continued).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
73	14	Olive, new stone wall	Field crop	Field crop	Olive	15	3.1	59.0	31.0	10.0	400-500
74	15	Forest	Forest	Forest	Forest	8	3.5	55.0	32.0	13.0	400-500
75	15	Olive, old stone wall	Olive	Olive	Olive	13	2.1	60.0	21.0	19.0	400-500
76	17	Dens forest, 1cm O.M	Forest	Forest	Forest	12	5.3	48.6	37.3	14.1	400-500
77	17	Dens forest, 1cm O.M	Forest	Forest	Forest	12	5.2	50.6	39.3	10.1	400-500
78	17	Olive, new stone wall, intercropping	Forest	Forest	Olive	19	2.5	67.5	28.6	3.9	>500
79	17	Olive, new stone wall, intercropping	Forest	Forest	Olive	19	2.4	69.7	24.3	6.0	>500
80	18	Field crop, new stone wall	Field crop	Field crop	Field crop	15	3.5	60.2	32.9	6.9	>500
81	18	Field crop, new stone wall	Field crop	Field crop	Field crop	15	3.0	60.1	33.0	6.8	>500
82	18	Dense forest	Forest	Forest	Forest	15	4.8	61.0	18.0	21.0	>500
83	18	Forest	Forest	Forest	Forest	4	4.1	58.5	33.1	8.4	>500
84	18	Dense forest	Forest	Forest	Forest	12	2.2	28.6	24.1	47.2	>500
85	19	Olive 50 years, 23 cm, fine root, worm, no stone wall	Field crop	Olive	Olive	21	2.8	64.0	33.0	3.0	>500
86	19	Dense forest	Forest	Forest	Forest	10	5.3	38.6	42.6	19.0	>500
87	19	Dense forest	Forest	Forest	Forest	17	4.0	65.5	31.0	3.5	>500
88	19	Dense forest	Forest	Forest	Forest	11	3.4	64.3	30.5	5.2	>500
89	19	Dense forest	Forest	Forest	Forest	17	4.3	50.9	18.1	31.0	>500
90	19	Dense forest	Forest	Forest	Forest	7	4.4	50.9	18.1	31.0	>500
91	19	Dense forest	Forest	Forest	Forest	10	3.6	65.1	26.4	8.5	>500
92	19	Olive 50 years, 23 cm, fine root, worm, no stone wall	Forest	Olive	Olive	23	2.8	65.1	32.7	2.2	>500
93	19	Olive 15 years, new stone wall	Forest	Forest	Olive	18	3.2	64.8	26.3	8.7	>500
94	19	Olive 15 years, new stone wall	Forest	Forest	Olive	18	3.3	64.6	26.3	9.1	>500
95	19	Field crop among forest, no stone wall	Range	Range	Range	12	3.3	67.0	26.3	6.8	>500
96	20	Dense forest	Forest	Forest	Forest	10	4.4	52.8	23.1	24.2	>500

Appendix D: (continued).

Sample number	Site number	Description	Land cover 1953	Land cover 1978	Land cover 2008	Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
97	20	Dense forest	Forest	Forest	Forest	7	4.8	50.2	23.1	26.7	>500
98	20	Olive orchard 30 years new stone wall	Forest	Forest	Orchard	18	1.5	69.8	21.0	9.2	>500
99	20	Olive orchard 30 years new stone wall	Forest	Forest	Orchard	20	1.6	74.0	21.8	4.2	>500
100	21	Olive, new stone wall	Field crop	Field crop	Olive	16	3.0	55.0	33.0	12.0	>500
101	21	Dense forest	Forest	Forest	Forest	12	5.6	59.0	31.0	10.0	>500
102	22	Field crop, old stone wall	Field crop	Field crop	Field crop	16	2.1	48.1	34.7	17.2	>500
103	22	Field crop, new stone wall	Field crop	Field crop	Orchard	16	2.7	54.3	32.6	13.0	>500
104	22	Dense forest	Forest	Forest	Forest	12	4.0	53.0	29.0	18.0	>500
105	22	Range	Range	Range	Range	17	2.3	51.4	29.0	19.7	>500
106	23	Field crop, new stone wall	Field crop	Field crop	Field crop	22	3.0	66.6	30.8	2.6	>500
107	23	Field crop, old stone wall	Field crop	Field crop	Field crop	17	1.4	66.2	29.1	4.7	>500
108	23	Field crop, old stone wall	Field crop	Field crop	Field crop	23	4.6	66.6	30.8	2.6	>500
109	23	Field crop, old stone wall	Field crop	Field crop	Field crop	19	1.2	59.9	33.4	6.8	>500
110	23	Olive, new stone wall	Field crop	Olive	Olive	15	4.2	66.5	30.7	2.8	>500
111	23	Olive, new stone wall	Field crop	Field crop	Olive	14	2.2	60.4	32.5	7.1	>500
112	23	Olive, grape, fig, almond, new stone wall	Field crop	Field crop	Orchard	23	3.1	72.8	24.4	2.8	>500
113	23	Apple 15 years, old stone wall	Field crop	Field crop	Orchard	13	2.1	55.4	38.4	6.2	>500
114	23	Moderate forest	Forest	Forest	Forest	4	3.6	50.2	31.1	18.7	>500
115	23	Forest	Forest	Forest	Forest	4	3.5	50.2	31.1	18.7	>500
116	23	Moderate forest	Forest	Forest	Forest	16	4.3	67.0	31.0	2.0	>500
117	23	Forest	Forest	Forest	Forest	15	5.5	67.0	31.0	2.0	>500
118	24	Field crop, old stone wall	Field crop	Field crop	Field crop	15	4.2	67.4	26.5	6.1	>500
119	24	Dense forest	Forest	Forest	Forest	4	5.1	58.9	33.3	7.7	>500
120	24	Dense forest	Forest	Forest	Forest	16	4.6	56.5	41.6	1.9	>500

Appendix D: (continued).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
121	24	Olive 7 years, new stone wall	Range	Range	Olive	15	3.5	66.0	25.0	9.0	>500
122	24	Olive 30 year, new stone wall	Range	Range	Olive	15	3.6	65.0	24.0	11.0	>500
123	24	Olive, new stone wall	Range	Range	Olive	12	4.7	69.5	24.3	6.2	>500
124	24	Range old stone wall	Range	Range	Range	10	4.9	69.7	24.4	6.0	>500
125	24	Range	Range	Range	Range	12	4.3	58.8	39.7	1.5	>500
126	25	Moderate forest	Forest	Forest	Forest	11	5.4	58.5	20.0	22.0	400-500
127	25	Dense forest, O horizon	Forest	Forest	Forest	4	5.9	31.5	28.7	39.8	>500
128	25	Dense forest	Forest	Forest	Forest	4	5.8	35.6	30.7	33.7	>500
129	25	Dense forest, A-horizon	Forest	Forest	Forest	6	3.8	41.5	28.2	30.2	>500
130	25	Dense forest	Forest	Forest	Forest	6	3.5	35.0	29.0	36.0	>500
131	25	Olive 20 years, stone wall	Forest	Olive	Olive	16	3.1	55.9	30.1	14.0	>500
132	25	Olive, stone wall	Forest	Olive	Olive	12	3.5	63.5	27.0	10.0	400-500
133	25	Olive, no stone wall	Range	Range	Olive	15	2.7	51.5	34.1	14.4	>500
134	26	Field crop, old stone wall	Field crop	field crop	Field crop	10	3.6	56.3	36.7	7.0	>500
135	26	Field crop, old stone wall	Field crop	field crop	Field crop	9	3.0	55.8	36.2	8.0	>500
136	26	Dense forest	Forest	Forest	Forest	13	4.7	38.8	30.5	30.7	>500
137	26	Dense forest	Forest	Forest	Forest	9	4.3	59.0	21.0	20.0	400-500
138	26	Moderate forest	Forest	Forest	Forest	13	4.3	58.0	34.0	8.0	>500
139	26	Olive new stone wall	Forest	Forest	Olive	11	3.1	63.0	27.8	9.0	400-500
140	26	Olive, old stone wall	Forest	Forest	Olive	11	1.7	57.0	35.0	8.0	>500
141	26	Range	Range	Range	Range	9	5.6	58.5	34.6	7.0	>500
142	27	Field crop, old stone wall	Field crop	Field crop	Field crop	12	3.4	52.7	27.3	19.8	400-500
143	27	Field crop, old stone wall	Field crop	Field crop	Field crop	11	2.2	35.0	42.0	23.0	400-500
144	27	Olive 25 years, stone wall, historic area	Field crop	Field crop	Olive	10	5.3	33.8	42.2	24.0	400-500

Appendix D: (continued).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
145	27	Olive 25y, stone wall, historic area	Field crop	Olive	Olive	11	3.7	34.0	43.0	23.0	400-500
146	28	Olive 25 years, stone wall	Field crop	Field crop	Olive	17	3.3	55.2	28.0	13.0	400-500
147	28	Olive 25 years, stone wall	Field crop	Field crop	Olive	17	3.8	60.0	30.0	10.0	400-500
148	28	Olive 700 years, stone wall	Olive	Olive	Olive	17	3.5	62.4	30.3	7.4	400-500
149	28	Olive 25 years, stone wall	Range	Range	Olive	20	3.4	57.3	29.8	12.9	400-500
150	28	Range, no stone wall	Range	Range	range	12	4.6	39.4	39.5	21.1	400-500
151	29	Field crop, stone wall	Field crop	Field crop	Field crop	15	4.8	48.2	31.6	20.2	400-500
152	29	Olive 700 years, stone wall	Olive	Olive	Olive	11	3.2	58.0	32.0	10.0	400-500
153	29	Olive 40 years, stone wall	Olive	Olive	Olive	10	4.9	59.6	32.1	8.4	400-500
154	29	Olive 700 years, good management	Olive	Olive	Olive	12	3.6	61.2	21.3	17.6	400-500
155	29	Olive 700 years, good management	Olive	Olive	Olive	13	3.3	61.1	21.2	17.7	400-500
156	29	Range	Range	Range	Range	7	5.5	54.9	27.6	17.5	400-500
157	29	Range	Range	Range	Range	7	4.3	55.0	28.5	16.5	400-500
158	30	Field crop, old stone wall	Field crop	Field crop	Field crop	7	4.3	47.0	36.4	16.5	>500
159	30	Olive 30 years, new stone wall	Field crop	Olive	Olive	13	4.7	64.5	32.4	3.1	>500
160	30	Olive 30 years, new stone wall	Field crop	Olive	Olive	14	3.7	63.0	32.0	5.0	>500
161	30	Forest, old stone wall	Forest	Forest	Forest	11	4.7	60.5	32.5	7.0	>500
162	31	Field crop old stone wall	Field crop	Field crop	Field crop	13	3.2	30.0	30.0	40.0	>500
163	31	Field crop old stone wall	Field crop	Field crop	Field crop	12	3.1	31.0	32.0	37.0	>500
164	31	Olive 20 years with stone wall	Field crop	Field crop	Olive	14	1.8	16.4	37.2	46.0	>500
165	31	Forest	Forest	Forest	Forest	13	3.7	13.8	36.9	49.4	>500
166	31	Forest	Forest	Forest	Forest	13	4.5	14.0	36.5	49.5	>500
167	31	Forest	Forest	Forest	Forest	8	4.1	15.1	35.1	49.3	>500
168	31	Range	Range	Range	Range	11	2.4	15.0	35.9	49.0	>500

Appendix D: (continued).

Sample number	Site number	Description	Land cover 1953	Land cover 1978	Land cover 2008	Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
169	32	Field crop, no stone wall	Field crop	Field crop	Field crop	14	3.3	45.9	33.5	20.7	>500
170	32	Range	Range	Range	Range	15	4.7	40.9	34.6	24.5	>500
171	33	Field crop, old stone wall	Field crop	Field crop	field crop	14	2.7	65.0	19.0	16.0	>500
172	33	Olive new stone wall	Field crop	Field crop	Olive	13	3.1	64.0	21.0	15.0	>500
173	33	Dense forest	Forest	Forest	Forest	10	4.4	60.0	28.0	12.0	>500
174	34	Olive, old stone wall	Field crop	Field crop	Olive	13	2.5	42.0	33.0	25.0	>500
175	34	Olive, old stone wall	Field crop	Field crop	Olive	14	2.8	40.9	34.6	24.5	>500
176	34	Dense forest, 1cm O.M	Forest	Forest	Forest	11	3.9	45.9	33.5	20.7	>500
177	34	Low forest	Forest	Forest	Forest	8	4.3	47.0	36.4	16.5	>500
178	34	Olive, stone wall, no management	Range	Range	Olive	13	3.2	13.8	36.9	49.4	>500
179	35	Field crop, old stone wall	Field crop	Field crop	Field crop	16	2.8	75.4	19.7	4.9	>500
180	35	Olive, field crop as intercropping, no stone wall	Field crop	Field crop	Olive	18	2.6	77.3	17.5	5.1	>500
181	36	Field crop, old stone wall	Field crop	Field crop	Field crop	14	2.6	75.4	19.7	4.9	>500
182	36	Field crop, no stone wall	Field crop	Field crop	Field crop	17	1.8	75.4	19.7	4.9	>500
183	36	Field crop, old stone wall	Field crop	Field crop	Field crop	17	2.1	75.4	19.7	4.9	>500
184	36	Olive, field crop as intercropping, no stone wall	Field crop	Field crop	Olive	16	2.4	77.3	17.5	5.1	400-500
185	36	Olive, no stone wall	Field crop	Olive	Olive	17	2.5	73.1	23.9	3.1	>500
186	36	Olive, no stone wall	Field crop	Olive	Olive	16	2.4	72.0	22.0	6.0	>500
187	36	Olive, old stone wall	Field crop	Olive	Olive	17	2.8	73.1	23.9	3.1	>500
188	36	Olive, no stone wall	Field crop	Olive	Olive	17	2.5	71.0	22.5	6.5	>500
189	37	Field crops new stone wall	Field crop	Field crop	Field crop	9	1.5	45.4	38.2	16.5	>500
190	37	Field crops new stone wall	Field crop	Field crop	Olive	9	1.2	47.8	37.5	14.8	>500

Appendix D: (continued).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
191	38	Moderate forest	Forest	Forest	Forest	13	3.9	69.8	27.0	3.2	>500
192	38	Moderate forest	Forest	Forest	Forest	13	4.6	70.0	29.2	0.8	>500
193	38	Olive 25 years, new stone wall	Range	Range	Olive	17	2.7	59.3	33.6	7.0	>500
194	38	Field crop, new stone wall	Range	Range	Orchard	17	1.1	59.2	33.5	7.3	>500
195	38	Range	Range	Range	Range	11	3.0	60.7	35.3	4.0	>500
196	38	Range	Range	Range	Range	11	2.3	27.0	50.7	22.3	>500
197	39	Field crop, new stone wall	Field crop	Field crop	Field crop	12	2.6	65.0	31.1	3.9	>500
198	39	Field crop old stone wall	Field crop	Field crop	Field crop	15	1.0	27.0	50.7	22.3	>500
199	39	Field crop, old stone wall	Field crop	Field crop	Field crop	12	2.1	60.2	32.5	7.2	>500
200	39	Field crop, new stone wall	Field crop	Field crop	Field crop	13	4.0	60.7	35.3	4.0	>500
201	39	Field crop, new stone wall	Field crop	Field crop	Field crop	15	2.3	70.0	28.0	2.0	>500
202	39	Olive 20 years, new stone wall	Field crop	Field crop	Olive	10	2.3	60.0	35.0	5.0	>500
203	39	Olive 15 years, good management, new stone wall	Field crop	Field crop	Olive	16	2.6	70.0	29.2	0.8	>500
204	39	Moderate forest	Forest	Forest	Forest	13	4.2	59.4	33.6	7.0	>500
205	39	Dense forest	Forest	Forest	Forest	2	5.5	46.5	29.3	24.3	>500
206	39	Dense forest	Forest	Forest	Forest	8	4.4	59.1	33.4	7.5	>500
207	39	Dense forest	Forest	Forest	Forest	10	4.2	55.2	32.0	12.8	>500
208	39	Dense forest	Forest	Forest	Forest	11	5.1	59.2	33.5	7.3	>500
209	39	Olive 15 years , good managements	Forest	Forest	Olive	15	3.3	69.5	27.0	3.2	>500
210	40	Olive 50 years, old stone wall, bad management, stone wall	Field crop	Olive	Olive	12	2.9	67.8	30.7	1.5	>500
211	40	Olive 50 years , old stone wall, bad management, stone wall	Field crop	Olive	Olive	11	2.4	64.9	31.4	3.7	>500
212	40	Dense forest	Forest	Forest	Forest	3	5.3	47.0	35.4	17.6	>500

Appendix D: (continued).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
191	38	Moderate forest	Forest	Forest	Forest	13	3.9	69.8	27.0	3.2	>500
192	38	Moderate forest	Forest	Forest	Forest	13	4.6	70.0	29.2	0.8	>500
193	38	Olive 25 years, new stone wall	Range	Range	Olive	17	2.7	59.3	33.6	7.0	>500
194	38	Field crop, new stone wall	Range	Range	Orchard	17	1.1	59.2	33.5	7.3	>500
195	38	Range	Range	Range	Range	11	3.0	60.7	35.3	4.0	>500
196	38	Range	Range	Range	Range	11	2.3	27.0	50.7	22.3	>500
197	39	Field crop, new stone wall	Field crop	Field crop	Field crop	12	2.6	65.0	31.1	3.9	>500
198	39	Field crop old stone wall	Field crop	Field crop	Field crop	15	1.0	27.0	50.7	22.3	>500
199	39	Field crop, old stone wall	Field crop	Field crop	Field crop	12	2.1	60.2	32.5	7.2	>500
200	39	Field crop, new stone wall	Field crop	Field crop	Field crop	13	4.0	60.7	35.3	4.0	>500
201	39	Field crop, new stone wall	Field crop	Field crop	Field crop	15	2.3	70.0	28.0	2.0	>500
202	39	Olive 20 years , new stone wall	Field crop	Field crop	Olive	10	2.3	60.0	35.0	5.0	>500
203	39	Olive 15 years, good management, new stone wall	Field crop	Field crop	Olive	16	2.6	70.0	29.2	0.8	>500
204	39	Moderate forest	Forest	Forest	Forest	13	4.2	59.4	33.6	7.0	>500
205	39	Dense forest	Forest	Forest	Forest	2	5.5	46.5	29.3	24.3	>500
206	39	Dense forest	Forest	Forest	Forest	8	4.4	59.1	33.4	7.5	>500
207	39	Dense forest	Forest	Forest	Forest	10	4.2	55.2	32.0	12.8	>500
208	39	Dense forest	Forest	Forest	Forest	11	5.1	59.2	33.5	7.3	>500
209	39	Olive 15 years, good managements	Forest	Forest	Olive	15	3.3	69.5	27.0	3.2	>500
210	40	Olive 50 years, old stone wall, bad management, stone wall	Field crop	Olive	Olive	12	2.9	67.8	30.7	1.5	>500
211	40	Olive 50 years, old stone wall, bad management, stone wall	Field crop	Olive	Olive	11	2.4	64.9	31.4	3.7	>500
212	40	Dense forest	Forest	Forest	Forest	3	5.3	47.0	35.4	17.6	>500

Appendix D: (continued).

Sample number	Site number	Description	Land cover			Thickness of A-horizon (cm)	Organic matter (%)	Clay %	Silt %	Sand %	Rainfall (mm)
			1953	1978	2008						
213	40	Dense forest	Forest	Forest	Forest	10	4.0	46.9	36.0	17.1	>500
214	40	Moderate forest	Forest	Forest	Forest	4	5.3	35.2	38.6	26.2	>500
215	40	Dense forest	Forest	Forest	Forest	4	5.0	47.5	34.2	18.4	>500
216	40	Moderate forest	Forest	Forest	Forest	6	5.0	45.4	38.4	16.3	>500
217	40	Dense forest	Forest	Forest	Forest	6	4.6	47.5	34.2	18.4	>500
218	40	Olive 50 years, stone wall, chalk rock	Forest	Olive	Olive	10	3.2	45.3	38.2	16.5	>500

Appendix E. Table 1: Analyses of variance (ANOVA) for organic matter.

Source of variation	df	F value
Rain isohyets	2	0.001**
Error	215	
Total	217	

** Significant at the 0.01 level. * Significant at the 0.05 level.

Appendix E. Table 2: Analyses of variance (ANOVA) for thickness of A-horizon

Source of variation	df	F value
Rain isohyets	2	0.216
Error	215	
Total	217	

** Significant at the 0.01 level. * Significant at the 0.05 level.

Appendix E. Table 3: Analyses of variance (ANOVA) for clay

Source of variation	Df	F value
Rain isohyets	2	0.099**
Error	215	
Total	217	

** Significant at the 0.01 level. * Significant at the 0.05 level.

Appendix E. Table 4: Analyses of variance (ANOVA) for sand

Source of variation	Df	F value
Rain isohyets	2	0.421
Error	215	
Total	217	

** Significant at the 0.01 level. * Significant at the 0.05 level.

Appendix E. Table 5: Analyses of variance (ANOVA) for silt

Source of variation	Df	F value
Rain isohyets	2	0.006**
Error	215	
Total	217	

** Significant at the 0.01 level. * Significant at the 0.05 level.

Appendix E. Table 6: Analyses of variance (ANOVA) for organic matter.

Source of variation	Df	F value
Rain isohyets	**2**	**0.001****
Land cover	**8**	**0.001****
Land cover. soil conservation	**11**	**0.038***
Error	**196**	
Total	**217**	

** Significant at the 0.01 level. * Significant at the 0.05 level.

Appendix E. Table 7: Analyses of variance (ANOVA) for thickness of A-horizon.

Source of variation	Df	F value
Rain isohyets	**2**	**0.126**
Land cover	**8**	**0.001****
Land cover. soil conservation	**11**	**0.483**
Error	**196**	
Total	**217**	

** Significant at the 0.01 level. * Significant at the 0.05 level.

Appendix E. Table 8: Analyses of variance (ANOVA) for clay

Source of variation	Df	F value
Rain isohyets	**2**	**0.073**
Land cover	**8**	**0.001****
Land cover. soil conservation	**11**	**0.254**
Error	**196**	
Total	**217**	

** Significant at the 0.01 level. * Significant at the 0.05 level.

Appendix E. Table 9: Analyses of variance (ANOVA) for sand

Source of variation	Df	F value
Rain isohyets	**2**	**0.391**
Land cover	**8**	**0.001****
Land cover. soil conservation	**11**	**0.940**
Error	**196**	
Total	**217**	

** Significant at the 0.01 level. * Significant at the 0.05 level.

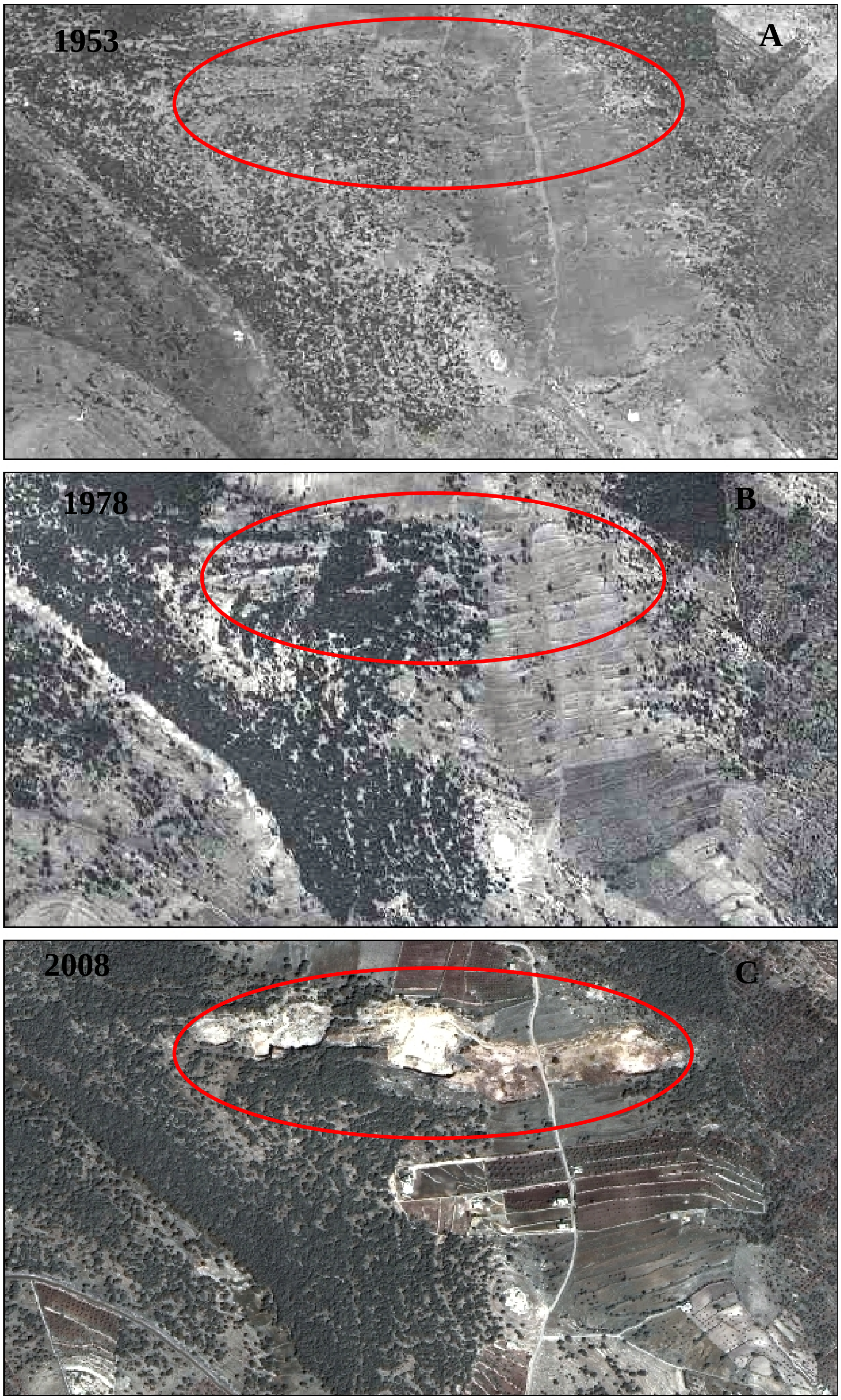
Appendix E. Table 10: Analyses of variance (ANOVA) for silt

Source of variation	Df	F value
Rain isohyets	**2**	**0.003****
Land cover	**8**	**0.039***
Land cover. soil conservation	**11**	**0.003****
Error	**196**	
Total	**217**	

** Significant at the 0.01 level. * Significant at the 0.05 level.

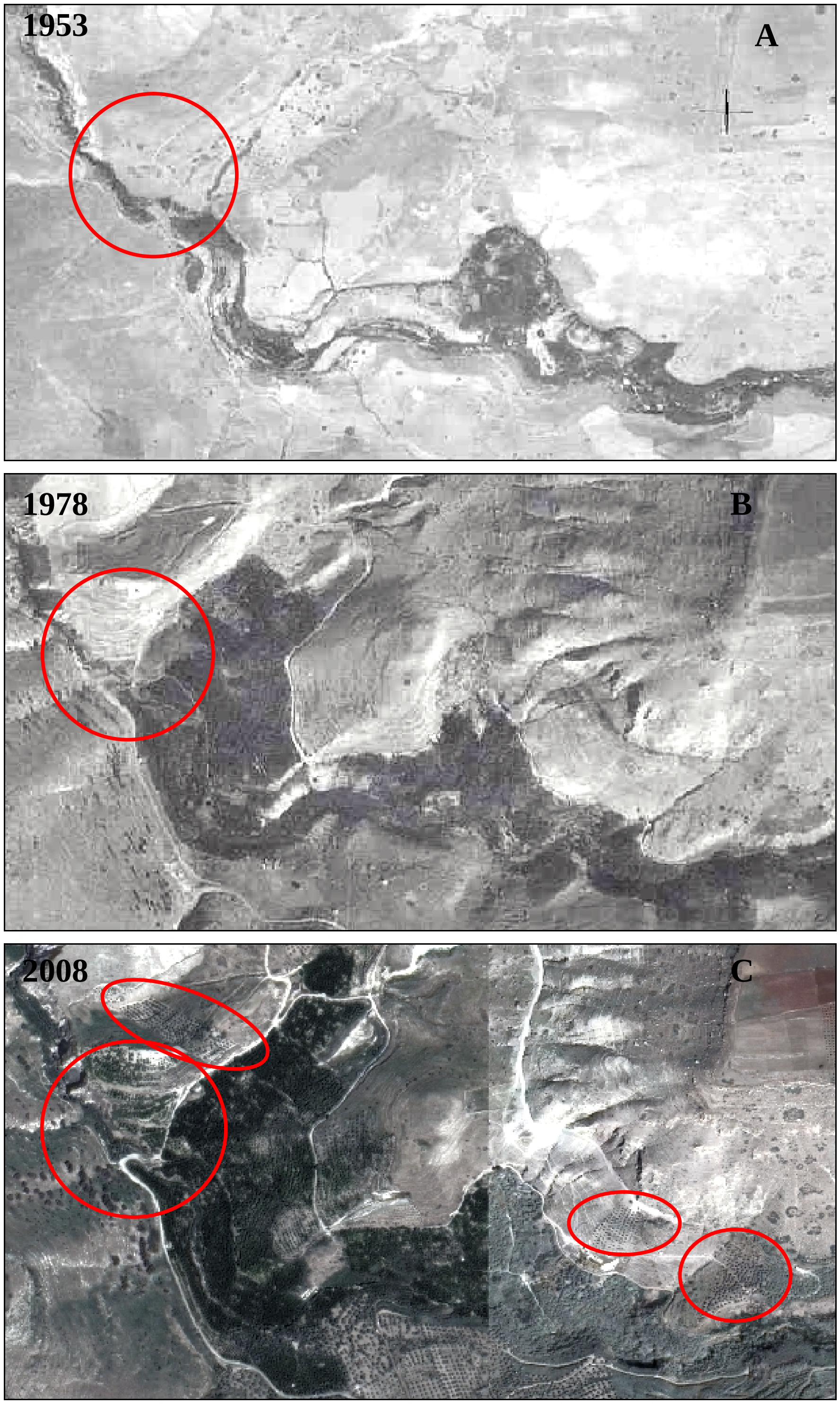
APPENDEX F

Appendix F. Plate 1: Land use change, forest area converted to orchard trees with a proper soil conservation structure (stone walls), stone wall are clear on plate 9b (1978) and new stone wall on plate 9c (2008).

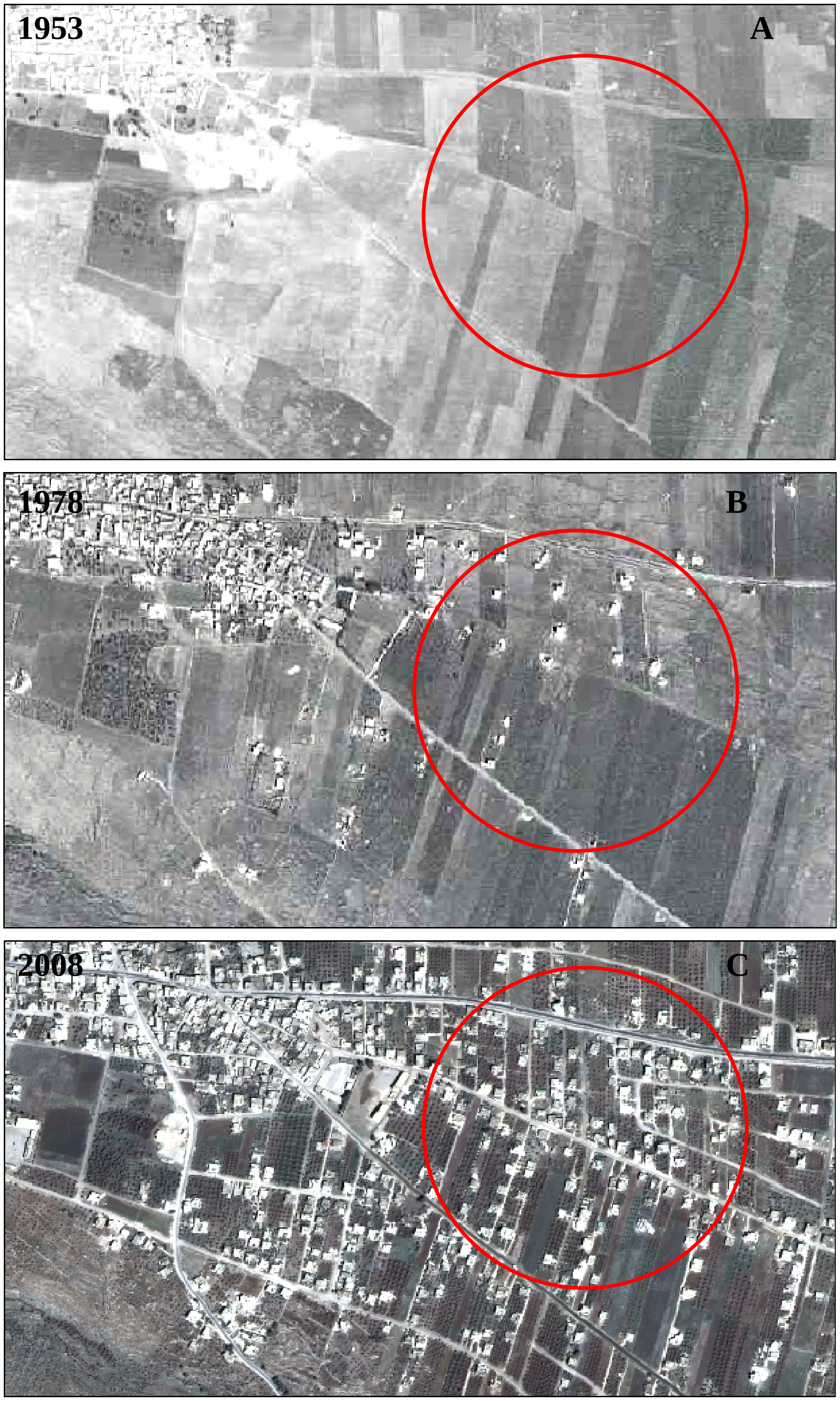


Appendix F. Plate 2: Land use change, forest area and field crops used as quarries.

Appendix F. Plate 3: Land use change, forest and range area converted to orchard trees with a proper soil conservation structure (stone walls).

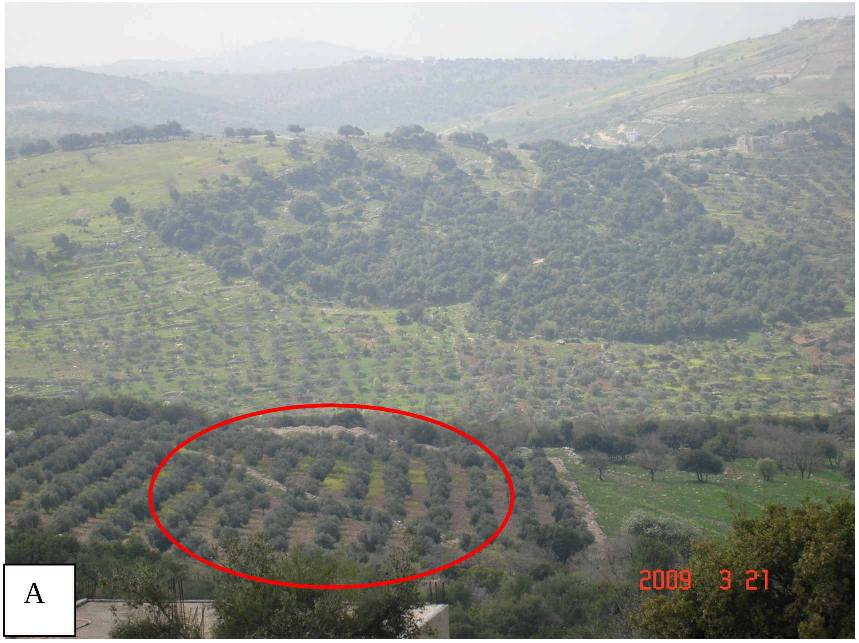


Appendix F. Plate 4: Land use change, range, field crops, and vegetables area converted to irrigated orchards (pomegranate and olive trees).



Appendix F. Plate 5: Land use change, field crops converted to urban and orchard trees.

Appendix F. Plate 6: Annual field crops planted on different land.
a- proper land use:- deep soil, low slope.
b- poor land use:- shallow, steep land.



Appendix F. Plate 7: Orchards planted on different land.
a- proper land use:- deep soil, moderate slope, and proper stone wall.
b- poor land preparation:- shallow soil, steep land, and rocky land.

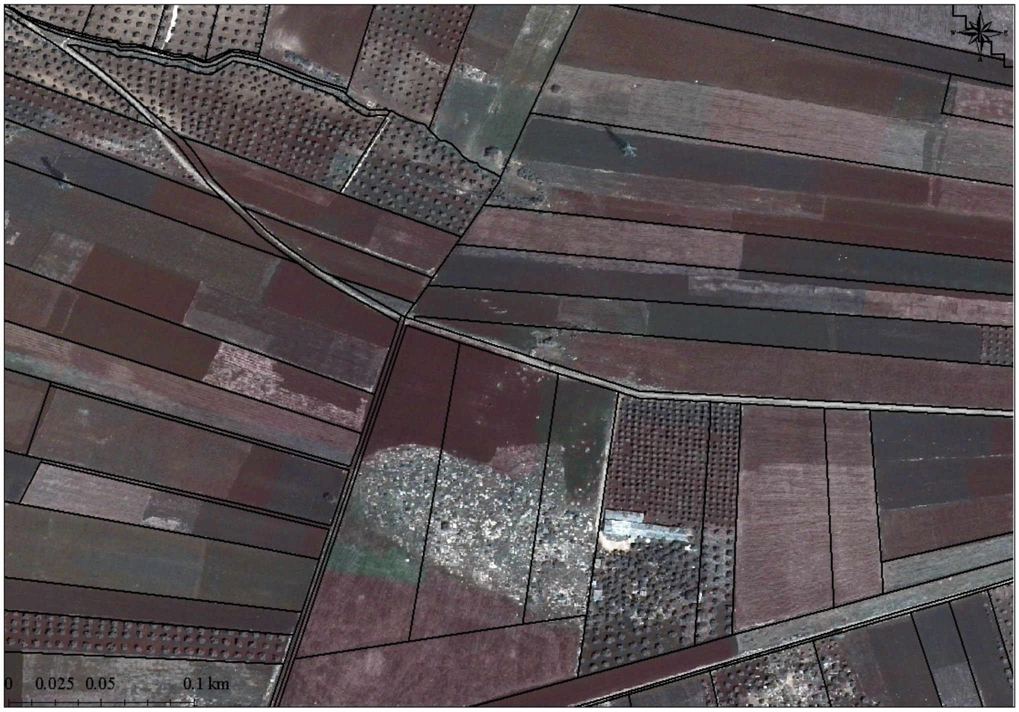
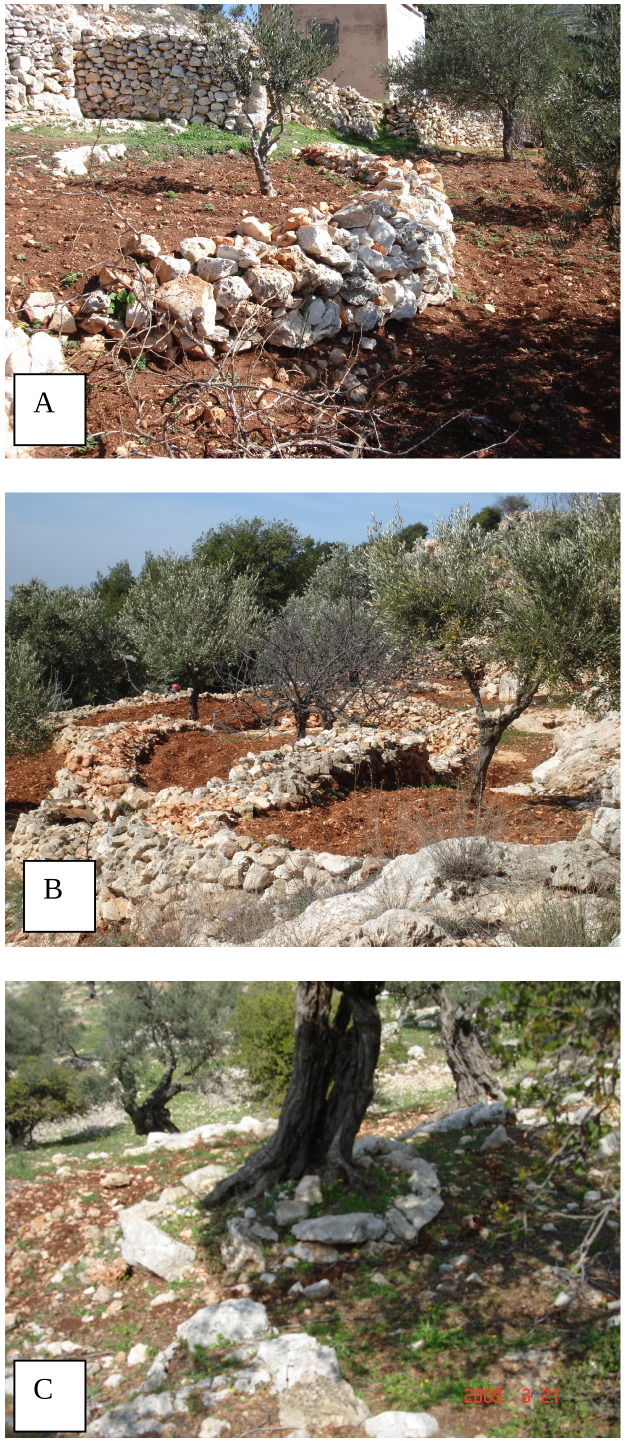


Plate 8. Fragmentation of field crop area force land use change to orchard.

Appendix F. Plate 9: Unsuitable land (shallow and rocky land), used for olive tree

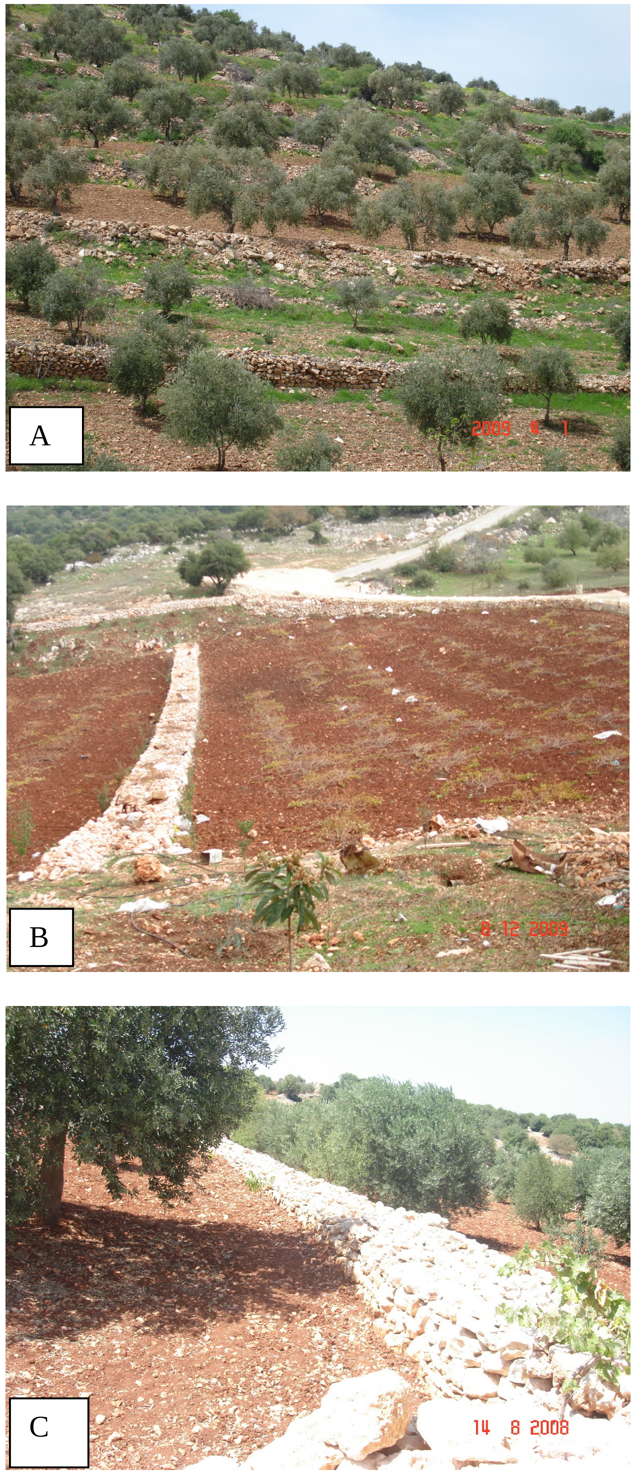
Appendix F. Plate 10: Fragmentation expansion of urban area. Few houses build on one plot.

Appendix F. Plate 11: Intensification of agriculture.
a- intercropping of wheat between olive trees.
b- planting apple trees between olive tree.



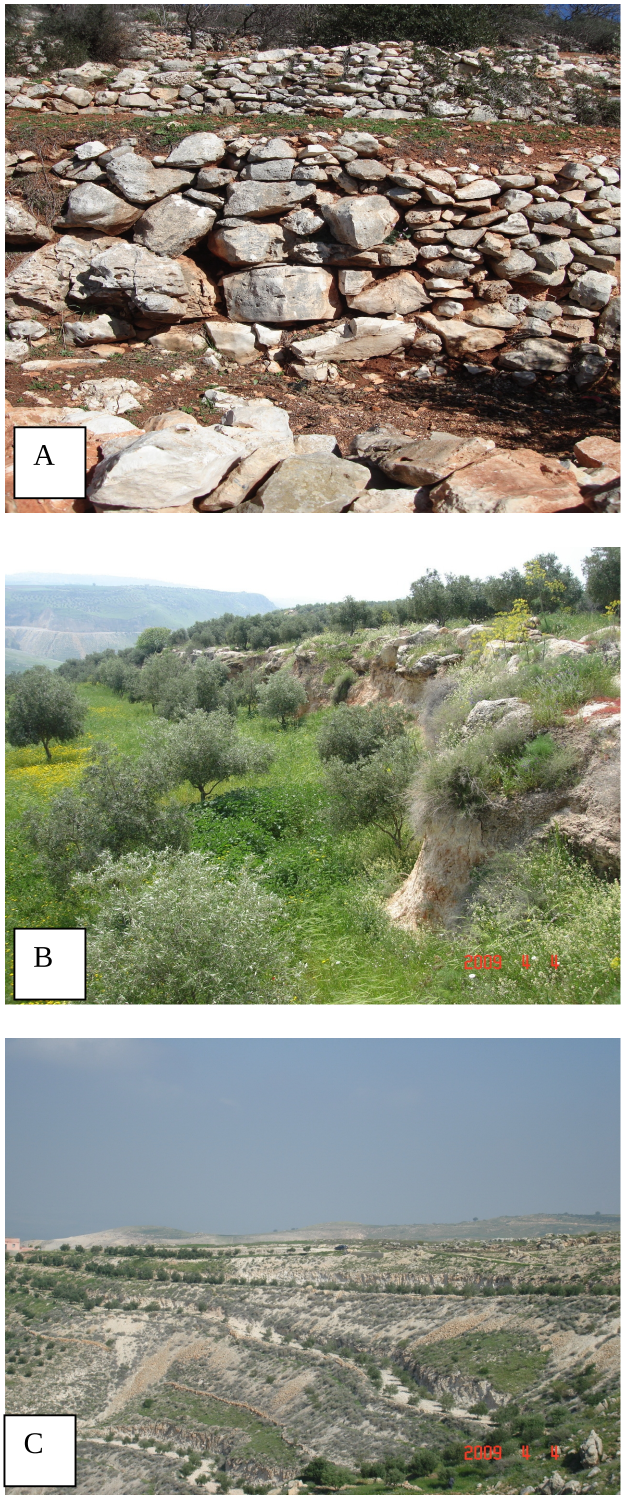
Appendix F. Plate 12: Soil conservation structure, stone tree basin (STB).
a- single STB for single tree.
b- STB for more than one tree.
c- old stone tree basin.

Appendix F. Plate 13: Effect of stone tree basin.
a- old single stone tree basin for single tree.
b- tree with same age without STB,
(tree mound clear and more than 50 cm height).

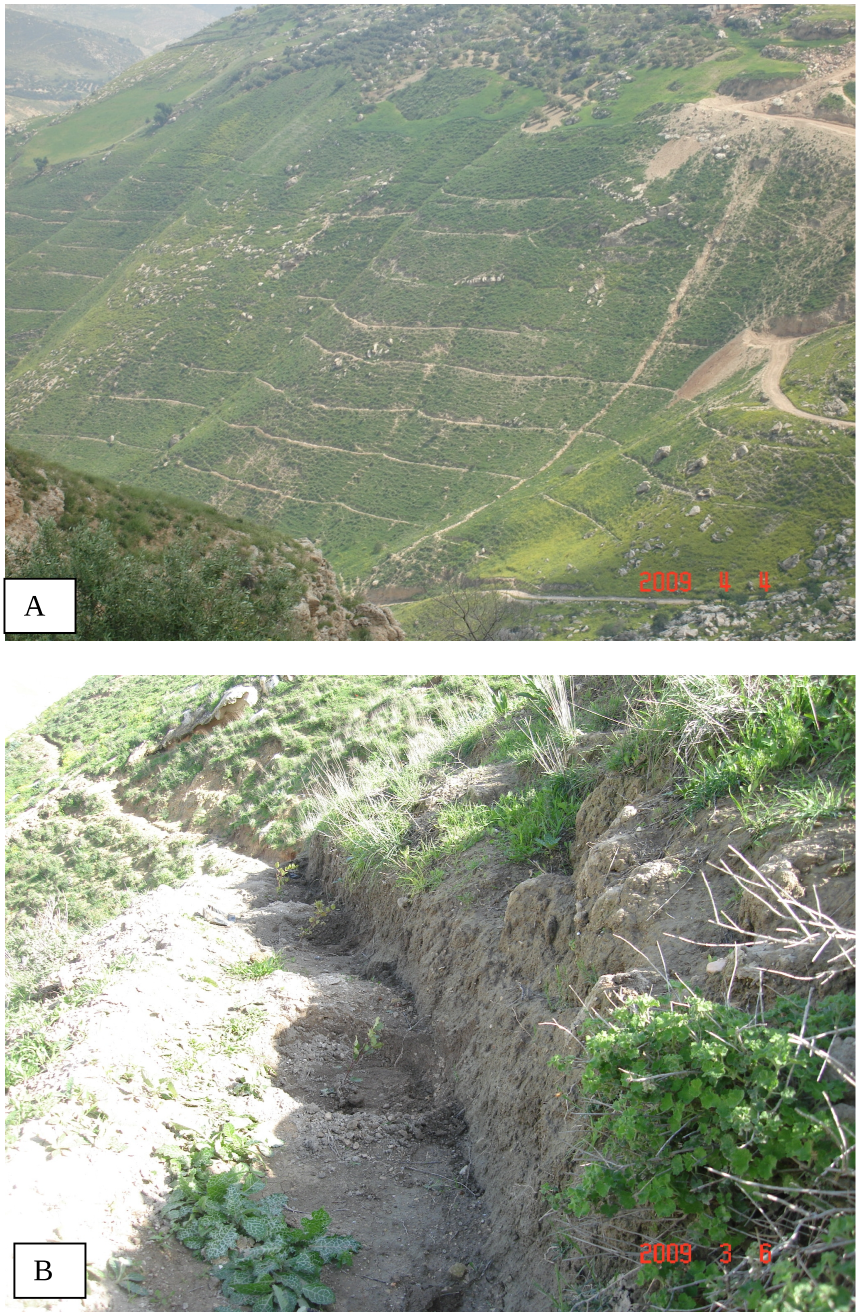


Appendix F. Photo 14: Soil conservation structure (stone wall).
a- unmaintained stone wall.
b- new stone wall.
c- maintained stone wall

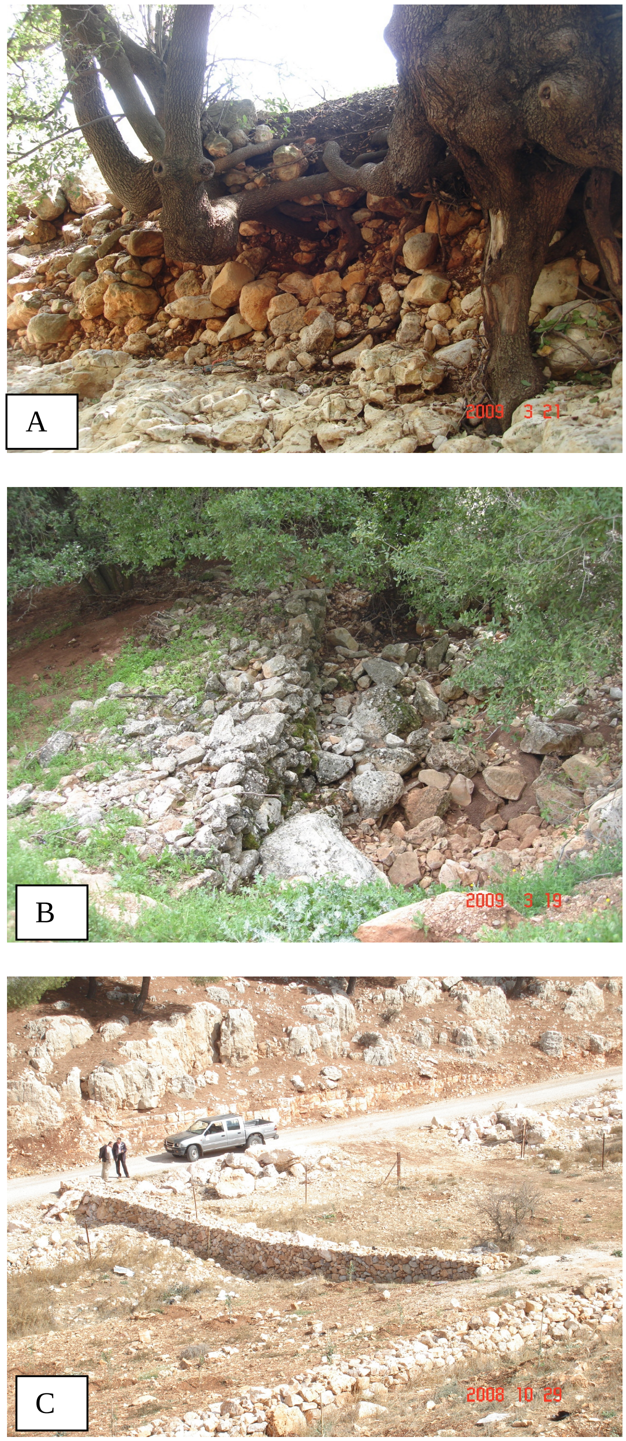
Appendix F. Photo 15: Soil conservation structure (stone wall).
a- olive tree with stone wall.
b- olive tree without stone wall



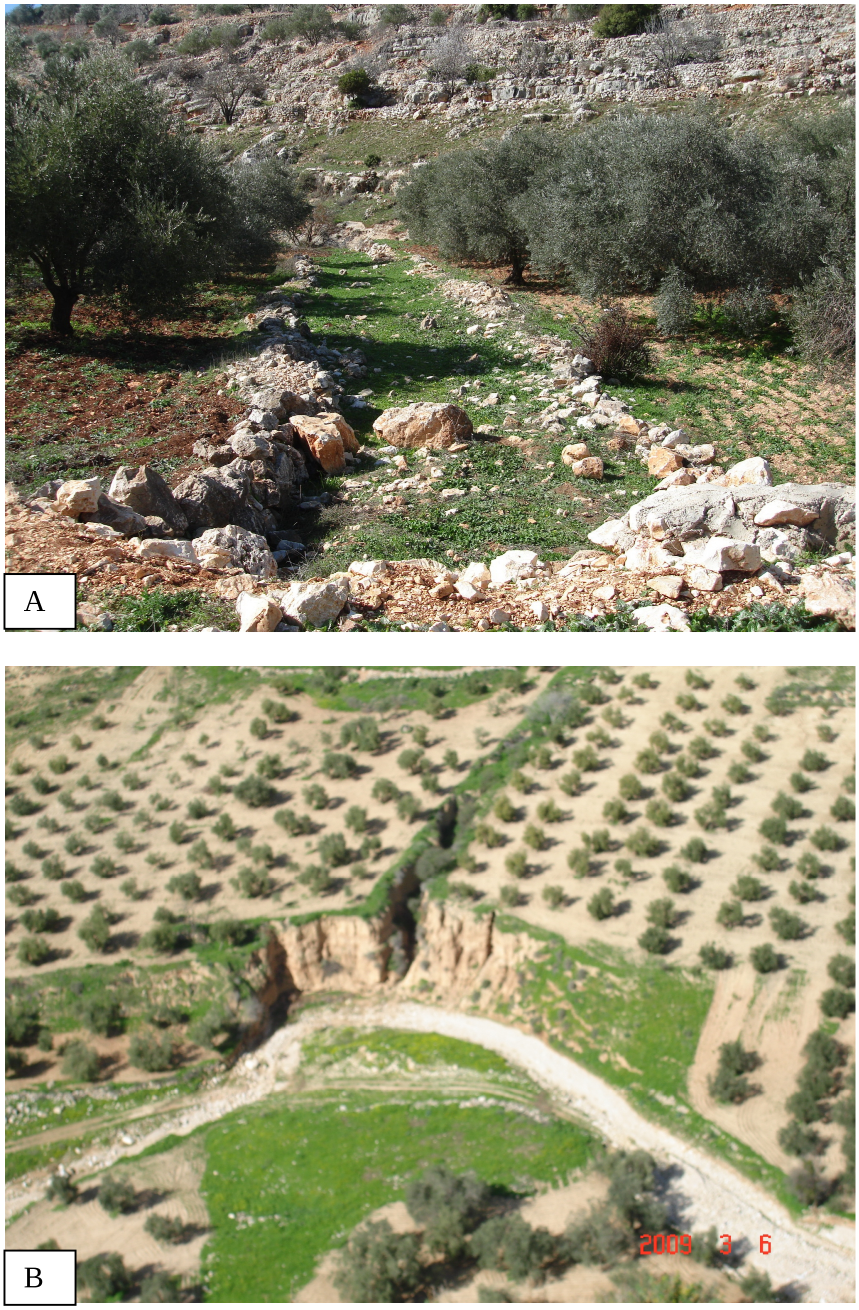
Appendix F. Photo 16: Soil conservation structure (terraces).
a- stone terraces.
b- and c- leveling terraces using heavy machines.



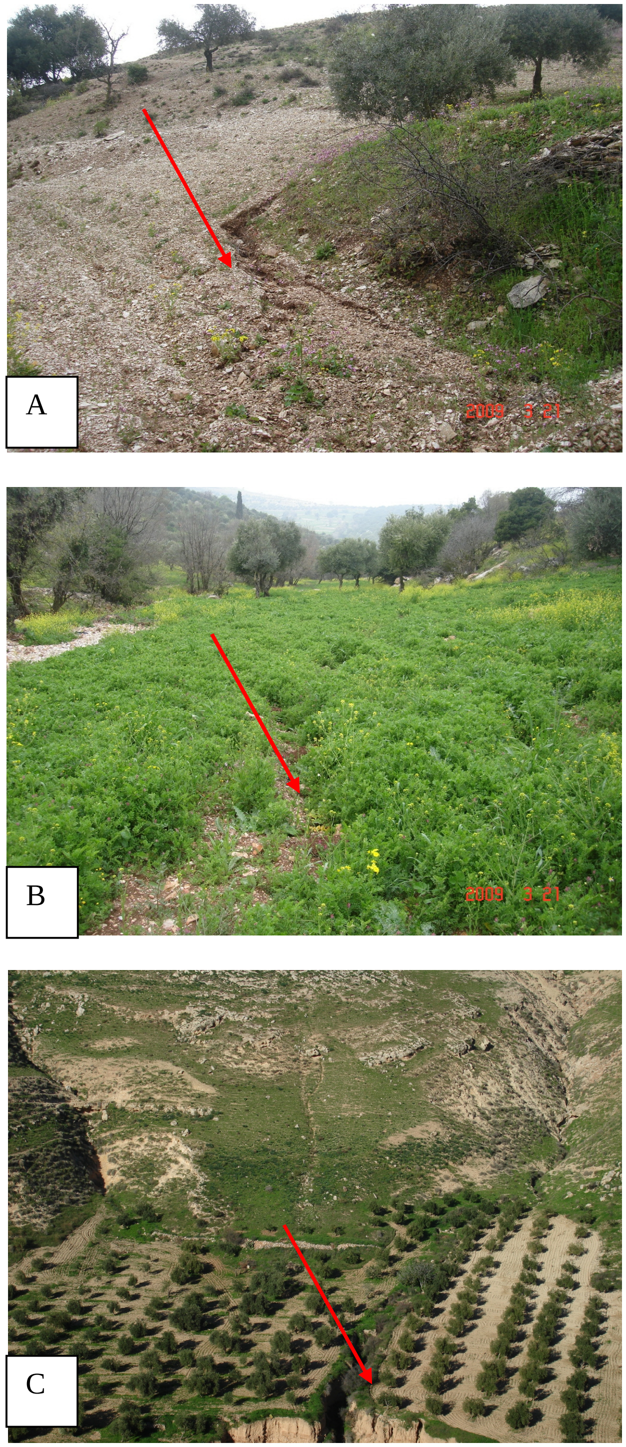
Appendix F. Plate 17: Soil conservation structure (contour line – gradoni). This method can be used for afforestation or shrubs for grazing.
a- general view of land suitable for Gradoni.
b- gradoni planted with forest seedling



Appendix F. Photo 18: Soil conservation structure (dike) across the wadi.
a- no dike.
b- old and full with sediment dike.
c-. new constructed dike



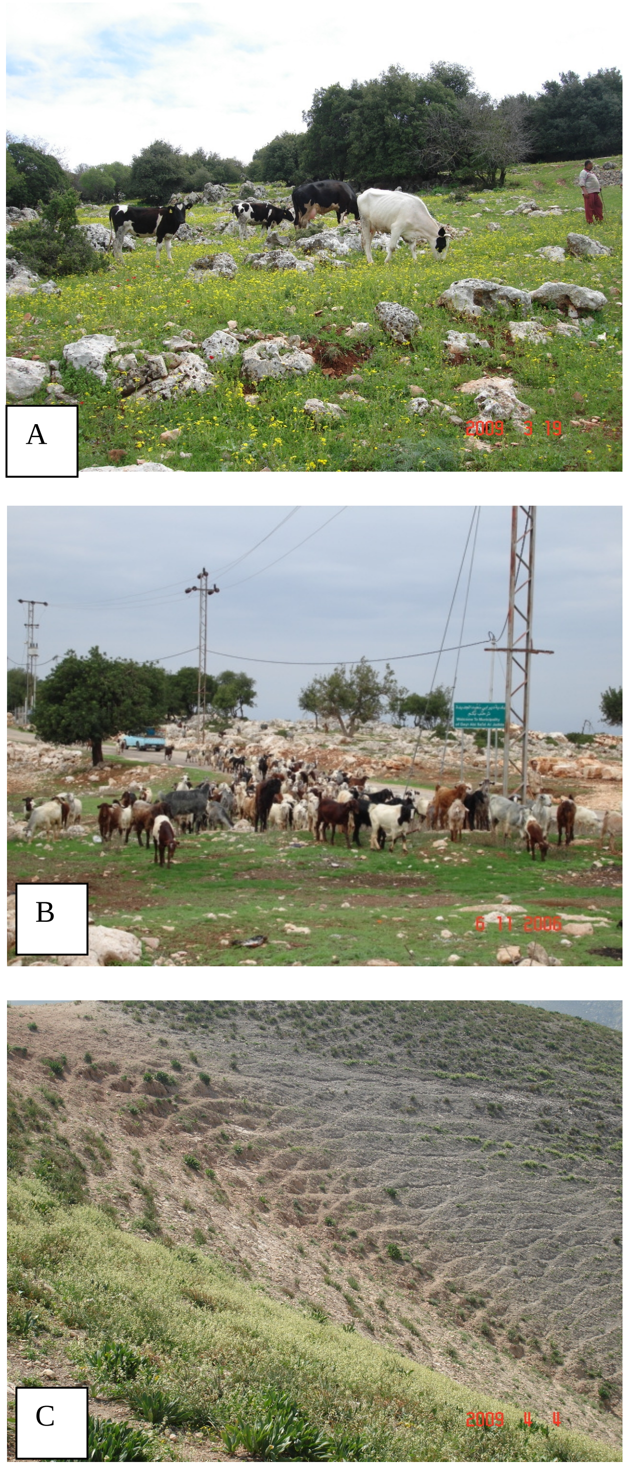
Appendix F. Plate 19: Soil conservation structure (wadi width control).
a- controlled wadi sides.
b- uncontrolled wadi side



Appendix F. Plate 20: Soil erosion (rill erosion).
a- soil erosion caused by absences of soil conservation structure (stone wall).
b- soil erosion caused improper agriculture practices (plowing with slope).
c- absence of soil conservation.

Appendix F. Plate 21: Land slide and soil flow.
a- sudden land slide which took place in 1992.
b- accumulative earth flow.

Appendix F. Plate 22: Deforestation.
a- injured tree.
b- damaged tree.



Appendix F. Plate 23: Overgrazing.
A- caw grazing among the forest.
B- sheep grazing at early season, when the grass is very small.
C- effect of overgrazing on steep land.

تقييم تدهور الأراضي في مسقط مائي وادي زقلاب

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المشرف المشارك
الدكتور فراس زيادات

الملخــص

أجريت هذه الدراسة في المسقط المائي لوادي زقلاب بهدف تقييم تدهور الأراضي الناتج عن تغير كلا من استعمالات الأراضي والغطاء النباتي خلال الفتره من 1953- 2008، حيث تم إستخدام الصور الجوية التي التقطت خلال عامي (1953، 1978) و صورة القمر الصناعي كويك بيرد للعام 2008. وقد تم استخدم نظم المعلومات الجغرافية والاستشعار عن بعد في تحليل و دراسة تغير الغطاء النباتي خلال فترة الدراسة وتم تدقيق النتائج من خلال العلومات الميدانية التي تم جمعها. كما اشتملت الدراسة أيضا على تقييم ملكية وحجم الحيازات الزراعية ومدى ملائمة الأراضي للإستعمالات الزراعية السائده في المنطقة (زراعة المحاصيل الحقلية (الشتوية والصيفية)، زراعة الأشجار المثمرة، الغابات، والمراعي) وذلك بإستخدام نظام استعمالات الأراضي المتبع من قبل منظمه الاغذية والزراعة الدولية (الفاو).

بينت الدراسة على أن هنك تغير في استعمالات الأراضي من محصولي الى آخر شمل 4414 هكتار وبما يعادل (42%) من المساحة الاجمالية لموقع الدراسة، في حين لم يتغير استعمال الاراضي في المساحة المتبقيه والبالغه6081 هكتار (58%) من مجمل مساحة موقع الدراسة والبالغ 10495 هكتار.

وقد دلت نتائج تقييم تغير استعمالات الأراضي بأن المساحة المزروعة بالاشجار المثمرة قد ازدادت زيادة ملحوظة في حين تناقصت مساحه الاراضي المزروعة بالمحاصيل الحقلية و الغابات والمراعي. وكذلك ازدادت رقعة أراضي العمران على حساب الأراضي الزراعية وخاص حول القرى، بسبب الازدياد المستمر بالسكان وتطور خدمات البنيه التحتية في المنطقة.

وقد تم تقييم تأثير تغير استعمالات الأراضي على تدهور الاراضي من خلال دراسة وتحليل وتقييم عدد من خصائص التربة مثل محتوى التربة من المواد العضوية، قوام التربة السطحية ومحتواها من الطين، سماكة الطبقة السطحية للتربة حيث تم جمع 218 عينة تربة من 40 موقع وإشتمل كل موقع على استعمالات مختلفة من الأراضي.

دلت التحليلات على انخفاض المساحة المزروعة بالمحاصيل الحقلية من 25.5% في عام 1953 إلى 12.4% في عام 2008. كما انخفضت المساحة المزروعة بالغابات من 32.5% في عام 1953 إلى 29.4% في عام 2008. أما مناطق المراعي فقد انخفضت من 37.3% إلى 23.7% خلال الفترة 1953-2008. في حين ان التغيير الرئيسي كان في ازدياد المساحات المزروعة بالأشجار المثمره والزيتون من 3.8% إلى 26.2% خلال الفترة 1953- 2008. هذا بالإضافة إلى الازدياد في المساحات العمرانية بنسبة 6.2%. أما مساحة المناطق المروية فقد ازدادت من ما يقارب 2 هكتار في عام 1953 إلى 43 هكتار في عام 2008.

أظهر التحليل الإحصائي وجود فروق معنوية في محتوى المادة العضوية بين مختلف الزراعات السائدة، حيث تم الحصول على أعلى قيمه ومقدارها 4.5% في أراضي الغابات المعمره. كما وجد أيضا فروق واضحة في معدل سماكة الطبقة السطحية من التربة لكل من المحاصيل الحقلية (14.6سم) ، والأشجار المثمرة (12.7 سم)، والمراعي (10.3 سم) والغابات (9.5 سم). ويعود سبب زيادة الطبقة السطحية في الأراضي المزروعة بالأشجار المثمرة والمحاصيل الحقلية مقارنة بأراضي الغابات والمراعي نتيجة خلط الطبقة السطحية من التربة مع الطبقة تحت السطحيه جراء عمليات الحراثة.

أما محتوى الطين في استعمالات الأراضي المختلفة فكان 57.5%، 60.4%، 50%، و 48.4%، لكل من المحاصيل الحقلية، الأشجار المثمرة، الغابات والمراعي، على التوالي. لم يكن هناك فرق معنوي في محتوى الطين بين أراضي المحاصيل الحقلية والغابات، أوالمحاصيل الحقلية والمراعي، أو مابين الأشجار والمراعي. وقد تم الحصول على أعلى محتوى للطين في المناطق المزروعة مقارنة بأراضي الغابات والمراعي. أدى التحويل في مناطق الغابات و المراعي إلى الأشجار المثمره إلى نقص محتوى المادة العضوية وزيادة سماكة الطبقة السطحية. وأضهرت الدراسة أن للمناخ ودرجة الإنحدار اثراً واضحاً في زيادة كثافة الغطاء النباتي ومحتوى المادة العضوية حيث كانت الزيادة تتناسب طرديا مع زيادة الهطول المطري.

غطت تدابير صيانة التربة في عام 2008 ما يقارب 66% من الأراضي المزروعة بالمحاصيل الحقلية، وحوالي 88% من الأراضي المزروعة بالأشجار المثمره. ووجد أن هناك فروق معنويه في زيادة محتوى المادة العضوية عند وجود جدران حجرية كنتورية، رغم إختلاف عمر الجدران الحجرية. كما زادت كثافة الطبقة السطحية بوجود الجدران الحجرية، لكنها قلت مع قدم الجدران وذلك يعود لعدم وجود صيانة جيدة لها.

إزداد محتوى الطين في الطبقة السطحية بإزدياد معدل الامطار، وكان أعلى في المناطق التي تحولت من غابات ومراعي إلى أشجار مثمره مقارنة بتلك التي زرعت بالمحاصيل الحقلية وذلك نتيجة وجود تدابير صيانة للتربة.

أشارت البيانات الخاصة بحجم الحيازات الزراعية، بأن حجم الحيازة يتناقص مع الزمن. ففي عام 1953، تراوح معدل مساحة الحيازة الزراعية من 0.7 -1.5 هكتار/ شخص، ولكنها تراوحت ما بين 0.08 إلى 0.3 هكتار/شخص عام 2004. وجد أن اكثر مساحة هي للملكيات التي تقل عن 0.1 هكتار، تليها المساحات من 0.4 -1 هكتار والمساحات من 1 -2 هكتار. وتقع معظم هذه المناطق في محيط القرى، حيث وجد أن تفتت الملكيات و عدم إستخدام نظام لإستعمالات الأراضي في البناء له الأثر الكبير على تغير استعمالات الأرضي/ والغطاء النباتي في الأراضي المملوكه.