بسم الله الرحمن الرحيم

# Hebron University
## College of Graduate Studies

## *Evaluating Soil Properties Along a Climatological Transect and under Different Land Uses*

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## *Dedication*

*There are moments of sadness, there are moments of joy, but I find peace and comfort because I know you are with me forever. I can hear your voice saying how proud you are of me. I can smile and simply say I love you and thank you for all the words of encouragement throughout my life. Thank you for teaching me to rely on my faith in good times and bad. Thank you for giving me life. To say I love you does not seem to be enough, but it will do until I see you again. Until then, I will love you forever …mother.*

*For my Family, my father, brothers & my sister*

*For my kids Zuhair, Rand & Abdul Rahman*

*Special thanks to my wife Maysson who has been the wind beneath my wings until I completed this thesis.*

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# Abstract

This study attempts to evaluate the soil properties at different land use and different slope in a climatic gradient at southern part of West Bank. The study was conducted in three sites at Hebron district (Nuba, Halhoul, and Al-Shyoukh), which represent different climatic conditions. To asses the effect of three different slopes, gently slope (S1: 3%-8%), moderately slope (S2: 8%-18%) and moderately steep slope (S3: 18%-32%), and within each slopes three land use where evaluated, cultivated trees, range land, and arable land which cultivated by field crops.

The research findings showed that soil properties significantly different along the climatic gradiant. However, Nuba and Halhoul sites, which had semi arid to semi humid, have more clay content and organic matter compared to Al-Shyoukh site which had moderately arid to semi arid climatic zone. In addition, sand content is higher at Al-Shyoukh site compared to Nuba and Halhoul sites, so it was increased as climate oriented to aridity. Also, calcium carbonate is not statistically different between the three sites.

There is no statistical difference between most of the soil properties (clay content, bulk density,..etc) due to the difference in slopes of the three sites. In addition, sand content at moderately slope in Al-Shyoukh was higher than gently and moderately steep slope. However, water content at gently slope in Halhoul was significantly higher than moderately and moderately steep slopes. At the same time, electrical conductivity at moderately steep slopes in Nuba was significantly higher than gently and moderately slopes.

In addition, data showed that soil texture is similar under the three-land use at the three sites. Influence of range land was appearing on bulk density, since bulk density was significantly higher in range land than cultivated trees and arable land. In addition, higher organic matter content was found at range land use in comparison with cultivated trees and arable land. Cation exchange capacity and sodium adsorption ration had no statisticall difference between the three-land uses at the three sites.

# Introduction

Soil is a natural resource that must be sustainably managed for the future of human kind, and soil is one of the major components of the agro-biodiversity concept, in conjunction with climate and other environmental factors. Although, West Bank represents relatively a small geographic area (about 5,600 $km^2$), the soils in this area are remarkably diverse in origin and characteristics. The major causes of this variety are the extreme conditions which form the soils in West Bank/palestine: climate (arid in the south and wet in the north), parent materials (sedimentary rocks, sand dunes, alluvium,..etc.), and different topographic circumstances (a West-East 40 km transect shows topography varying from 1000 m (above sea level) to -400 m (below sea level). Also, physical weathering from water, wind and gravity, which modifies the soils of this area. Therefore, taking this diversity in consideration is of paramount importance when planning for sustainable agriculture development.

The study area was located at the southern part of West Bank at Hebron district. In Nuba, Halhul, and Al-Shyoukh, these areas were characterized by a strong climatological gradient from East to West.

Study the variation of soil properties under different climatic conditions, land use and different slopes at the southern part of West Bank will serve to get accurate and useful predictions to be made for management purposes, the conservation and sustainable use of soil at the study sites; it would be the main practical purpose of evaluating soil properties. The information about the soils in the three study sites would be directed to help in realizing the effect of climate, slopes, and land use on the soil properties, wherever, climate is one of the most important factors determining soil development and type, flora and fauna (Margalef, 1986) and the changes in climate implicate modifications of the pedological processes, and as a consequence results in different soil types (Duchafour, 1975). Thus understanding the effect of climate, slopes, and land use acting as indicators of the soil, and hence give a clear qualitative and quantitative indication of the rate and status of the soil. For this reason, there is a need to study these relationships in different regions to define the role of each of these factors (climate, slope, and land use) on soil properties in a given location in the future. Lavee et al., (1991) found, in the Eastern Mediterranean, a clear relationship between climate and almost all of the erosional response parameters that they measured.

The overall objective is studying the soil properties at different land use and different slopes in a climatic gradient at southern part of West Bank. Particularly, there are three main detailed objectives in this study:

1- Evaluate the soil properties along a climatologically transect in the three sites, Nuba, Halhoul, and Al-Shyoukh.
2- Evaluate soil properties at different slopes along a climatic gradient.
3- Evaluate soil properties at different land uses along a climatic gradient.

# CHAPTER ONE

## 1. Literature review

## 1.1. Soil in Palestine

Mediterranean regions, which occupy an area of 4,300,000 km2 (Yaalon, 1997), are known for their hot dry summers and cool wet winters (Sousa, 1999). In addition, this area has undergone a complex geological evolution (Stanley and Weezel, 1985). It is a relic of many landforms, and has been affected by a long history of land use, which may explain why it is more diverse than other climatic regions (Iba´n˜ez et al., 1995). In fact, the term "Mediterranean soil" includes a wide variety of parent material, drainage conditions, and seasonal water regimes (Bech et al., 1997; Darwish and Zurayk, 1997).

Despite the small area of Palestine, a variety of soils can be found (Qannam, 2003). The major causes of this variety are the extreme conditions which form these soils: climate, arid in the east and wet in the mountainous ridge; variable geology: sedimentary rocks, sand dunes, alluvium, etc.; and different topographic circumstances: topography varying from 400 meter above sea level at the western edge to 1000 meter above sea level at the mountain ridge to 410 meter below sea level at the Dead Sea area. In addition, physical weathering from both water and wind are involved in modifying the soils (Ghanem, 1999).

It should be borne in mind that soil pattern in this region, fairly confined in terms of space, represents an extraordinary typological diversity, ranging from humid Mediterranean soils to typical hot desert soils, from landscapes with steep slopess, to low-lying, level ones (Arieh, 2007).

## 1.2. Climate

The West Bank has a typical Mediterranean climate with two distinct seasons: dry hot season from June to October, and cold wet season from November to May (Qannam, 2003). The predominantly low pressure area of the Mediterranean is centered between two air masses: the north Atlantic high pressure of North Africa and the Euro-Asian winter high pressure located over Russia. This is the primary cause of winter weather in the West Bank and the eastern Mediterranean in general (Husary et al. 1995).

### 1.2.1. Rainfall

In the West Bank, the dominant travel direction of air masses is from the Mediterranean Sea towards the east; rainfall varies from 716 mm to 49 mm, 70% of rainfall amounts accumulated between November and March (Badia Workshop, Amman, Jordan, 2009). Rainfall increases eastwards with elevation, with the heaviest rain falling near the ridge of the Central Highlands (800-1000 masl) (Qannam, 2003). Further, to east, there is a rapid decline in rainfall amounts as the air is heated, decreasing the relative humidity and establishing a rain-shadow, particularly in the Dead Sea area 410 m below sea level and the central Jordan Valley (Qannam, 2003). Rainfall amounts also decline from north to south, particularly at the eastern ridge of the West Bank. The isohyetal map (figure 1) shows the long-term annual average rainfall all over the West Bank.

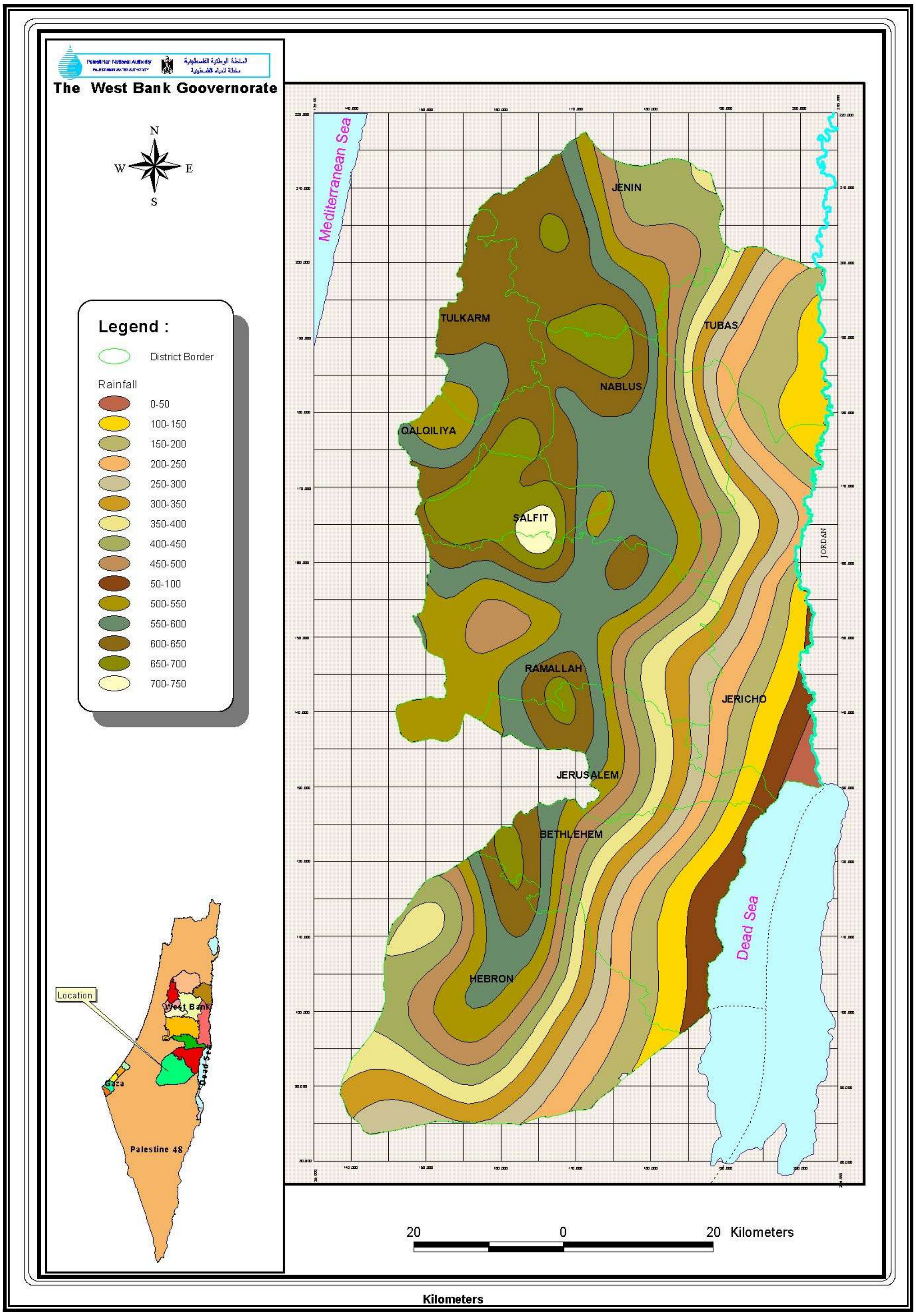



Figure 1: Isohyetal contour map of the long term annual rainfall averages of the West Bank (PWA, 2009)

Rainfall distribution, amount, intensity, span and intermittence vary considerably. The rainfall duration vary from less than few minutes to a few days with intensities of less than 1 mm to more than 100 mm in an event, and they vary in time span between each rain event from few days up to several weeks (Ayalon et al. 1998).

In Hebron, most of the rain falls during December through February, although winter season extends from mid- of October to the end of April. The mean annual rainfall is 596 mm, the mean annual rainfall in Hebron varies from year to year, while the rainfall reaches 1027 mm in the wet years, and drops to 200 mm/year during the dry years (Hebron meteorological station). The amount of rainfall decrease from 638.4 mm at Al- Arroub in the north to 383 mm at Al-Dhahriya in the south, and 200 mm at the eastern boundaries. During the wet year 1979/1980, rainfall reaches up to 876 mm and in 1991/1992 reached 1027 mm (Kessler, 1994).

### 1.2.2. Temperature

The average summer temperature, in the West Bank varies between 20 and 23 °C, reaching a maximum of 43 °C (Qannam, 2003). The average long-term winter temperature is 10 to 11 °C with a minimum of 3 °C. These variations are expected because of the differences in position, elevation, and distance from the coast and the environment around the stations (Ghanem, 1999). The temperature increases from north to south and from west to east on contrary to the altitude.

In Hebron district, the monthly average temperature ranges from 7.5-10 $C^o$ in the winter to 22 $C^o$ in the summer. The minimum temperature is -3 $C^o$ in January and the maximum is 40 $C^o$ in August. The air temperature ranges from a minimum of -5 $C^o$ in January, to a maximum of 42 $C^o$ in the summer season (Kessler, 1994).

### 1.2.3. Relative humidity

In the West Bank, temperature, the elevation as well as the distance from the coast are the main factors controlling the atmospheric moisture content e.g. expressed as relative humidity (RH %) (Qannam, 2003). The driest locations are in the Jordan Valley, while a more temperate climate can be experienced at the highest summits of the mountain ridge. The relative humidity in the West Bank varies from north to south. It ranges from 60-65 % in the north and 50 % in the south during summer. During winter, it ranges from 65-70 % in the north and 70-75 % in the south (Ghanem, 1999).

In Hebron district, the mean range of annual relative humidity is 60-75%. The relative humidity reaches 40% in mid-day and increases gradually to reach 80-100% as an average at night (Kessler, 1994).

### 1.2.4. Wind

Hebron District experience western winds from the Mediterranean Sea. Humidity of these winds is the significant factor in determining the possibilities of rainfall occurrence (Qannam, 2003). In summer (June, July and August), this area is being prevailed by northwest winds, while in winter by southwest, west and occasionally northwest winds. From late April to mid-June the area is often affected by very hot dry, dusty winds, which are blowing from the Arabian Desert. The average monthly wind speed during the meteorological period (1965-1969) show that the average wind speed in the wet season is 9.5 km/h, while in the dry season it is 5.3 km/h (Qannam, 2003).

### 1.2.5. Sun shine duration

The longest sunshine duration occurs in the summer months, which is almost cloudless. During winter, even in the rainy days few hours of sunshine can be recorded. According to Ministry of Transport, Meteorological Office-PNAMO (1998 and 1999), the annual sun shine duration in the West Bank is ranging between 3000-3300 hours. The overall daily average sunshine duration at Al-Arroub Meteorological Station is 8.8 hour for the period 1961-1990 (PNAMO, 1998) with a summer average of 10.6 h/day and 7.5 h/day during winter. The maximum monthly sunshine durations are 11.8 h/day recorded in June, while the minimum average is 6.2 h/day recorded in January and February.

### 1.2.6. Potential evaporation

The 1980-1989 potential evaporation contour map of the West Bank (figure 2) shows that the central highlands have the lowest potential evaporation records (1400-1800 mm/yr) (Qannam, 2003). Further to east, there is a rapid increase in potential evaporation due to lower elevation, higher temperature, and lower relative humidity particularly in Dead Sea area (2800 mm/yr). From north to south less evaporation variations could be noticed and that could be attributed to less variation in elevation.

In Hebron, mean daily evaporation varies from 2 mm/day in December to 8.5 mm/day in August. The average monthly evaporation of Al-Arroub weather station is 230 mm/month in the summer and 80 mm/month in the winter. Actually, there are only three months of the year where rainfall exceeds evaporation (Kessler, 1994).

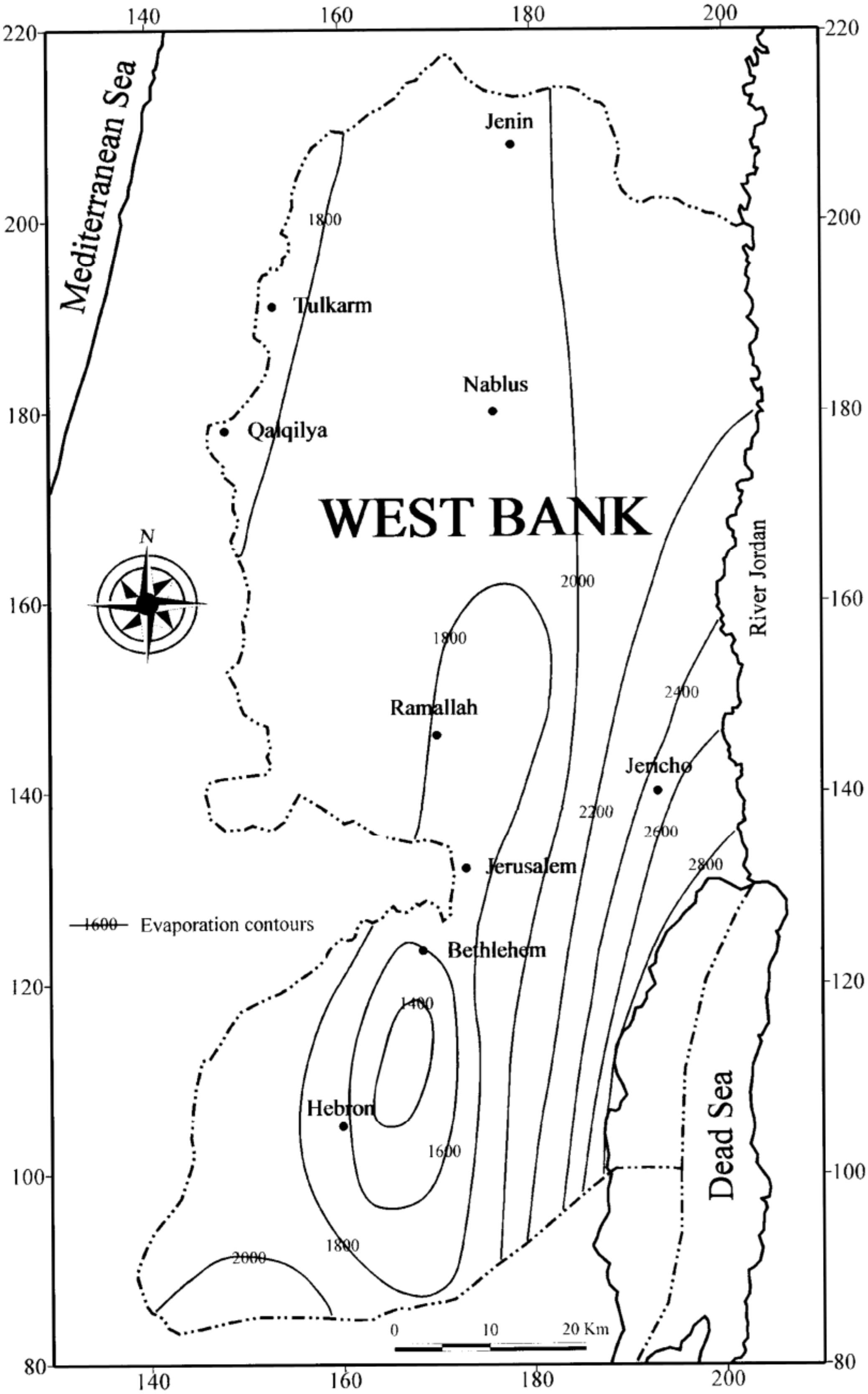



Figure 2: 1980-1989 Class-A pan evaporation contours map for the West Bank (modified after the Israeli Meteorological Service 1990)

So, the climate of the Hebron district ranges from arid to semi-arid with an increase in aridity towards Negev desert in the south and the Jordan valley in the east (ARIJ, 1995).

## 1.3. Geomorphology

Generally, the West Bank morphology is a result of folding, faulting and subsequent denudation (Qannam, 2003). The dominant geomorphological features of the West Bank are the Hebron Mountains, rising to an elevation of 1020 m, turning over northwards into the Jerusalem Mountains, Nablus Mountains and to the 300-400 m high Jenin Hills. Roughly parallel to this north-south trending line of hills the Rift Valley with the Jordan River flowing southwards into the Dead Sea terminal lake is the most significant and unique geomorphological feature. The bottom of the Jordan Valley in the West Bank falls from an elevation of 200 masl to 410 mbsl as it enters the Dead Sea (Qannam, 2003).

The hilly-mountains areas may be considered as four distinct units, as shown in (figure 3); the Mountain Plateau, the Semi-Coastal Plain, the Western slopes, and the Eastern Slopes (MOPIC, 1999). The three mountain blocks of Hebron, Jerusalem and Nablus are referred to as the Mountain Plateau, to the east of which the hills of the Eastern slopes descend including the Jerusalem Desert from a height of 600 m. The semi coastal plain is a hilly area with an elevation of 50-300 m above sea level, 3-12 km wide and about 70 km long. It is an extension of the Palestinian Mediterranean coastal region, limited to the northwestern part of the West Bank and comprises parts of Jenin and Tulkarm districts. The hilly transition zone between the Semi Coastal Plain and the Mountain Plateau is referred to as the Western Slopes that have an elevation of 300-600 masl and an average slope of 2.5%. In the southern West Bank, these slopes are sometimes referred to as the Jerusalem foothills (Qannam, 2003).

Hebron district is characterized by great variation in its topography and altitude (ARIJ, 1995). The highest elevation of approximately 1020 m above sea level is found in Halhoul area. In the eastern part of the district characterized by sharp slope, which called eastern slopes, since the elevation drops from 1020 to 100 m above sea level.

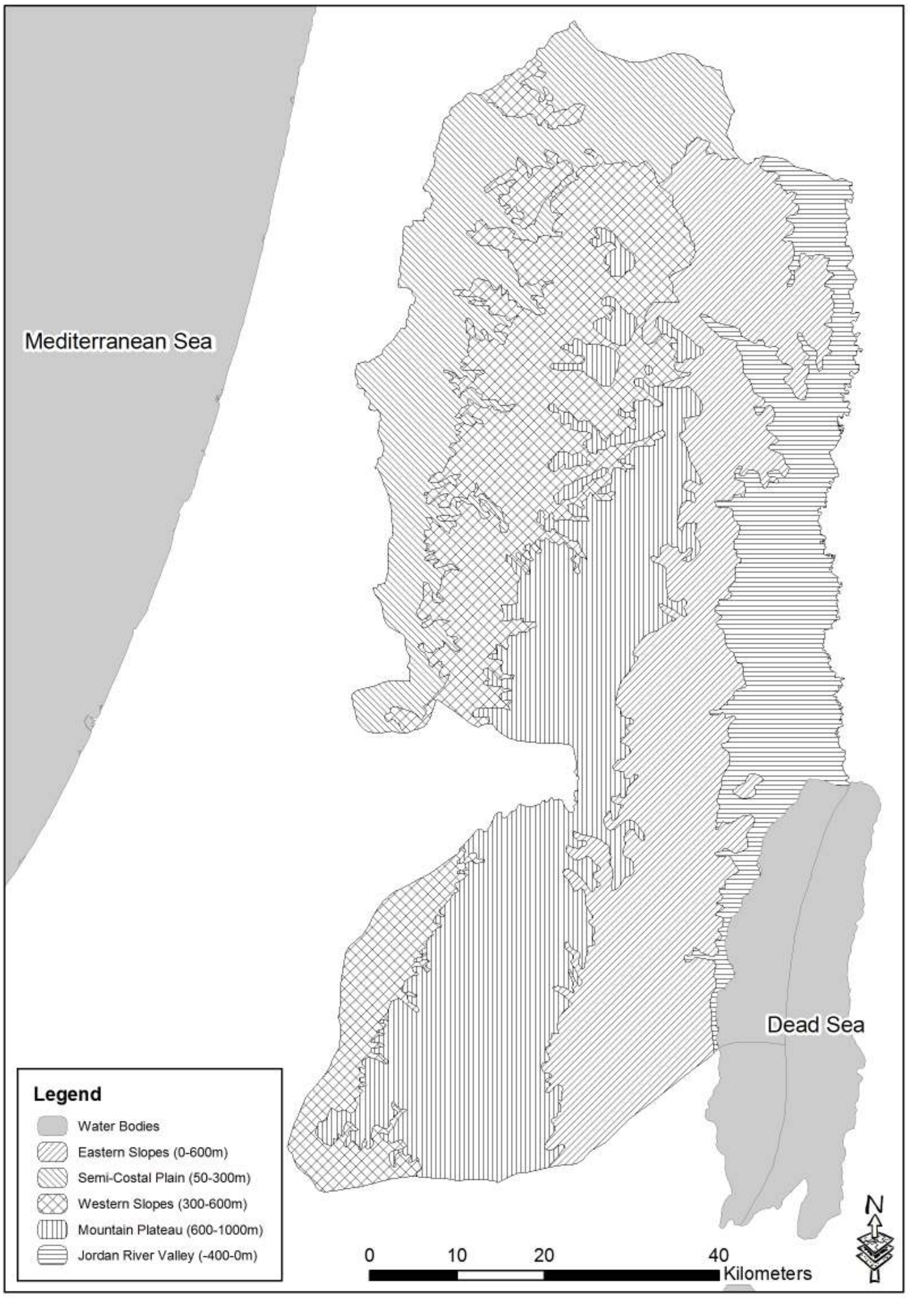



Figure 3: Geomorphological map of the West Bank (MOPIC, 1999).

### 1.3.1. Agro-ecological zones

Five agro-ecological zones determined by location, rainfall and altitude can be distinguished in the Palestinian Territories are shown in Table (1).

Table 1: Agro-ecological Zones of Palestinian Territories

| Location | Area ($km^2$) |
|---|---|
| Central Highlands | 3,500 |
| Semi Coastal Region | 400 |
| Eastern Slopes | 1,500 |
| Jordan Valley | 400 |
| Sub-total West Bank | 5,800 |
| Coastal Zone (the Gaza Strip) | 360 |
| Grand Total | 6,160 |

Source: ESCWA and FAO, Prospective Development of the Agricultural Institutions in the Occupied Territories - Proposed Action Programs for the Restructuring of the Palestine Agriculture Public Institutions, 1994.

## 1.4. Influence of climate on soil properties

Soil formation greatly depends on the climate, and soils from different climate zones show distinctive characteristics (Department of Agriculture, US). Temperature and moisture affect weathering and leaching. Wind moves sand and other particles, especially in arid regions where there is little plant cover. The type and amount of precipitation influence soil formation by affecting the movement of ions and particles through the soil, aiding in the development of different soil profiles. The most relevant factors for the occurrence of carbonate loss are a combination of slope, aspect, latitude and potential evapotranspiration (Rubio and Escudero, 2005).

Seasonal and daily temperature fluctuations affect the effectiveness of water in weathering parent rock material and affect soil dynamics, freezing and thawing is an affective mechanism to break up rocks and other consolidated materials. Temperature and precipitation rates affect biological activity, rates of chemical reactions, and types of vegetation cover.

The production and accumulation or decomposition of organic matter and humus is greatly dependent on climatic conditions. Temperature and soil moisture are the major factors in the formation or decomposition of organic matter, they along with topography determine the formation of organic soils. Soils high in organic matter tend to form under wet or cold conditions where decomposer activity is impeded by low temperature (Wagai et al, 2008) or excess moisture (Minayevs et al, 2008).

Sarah (2004), Kutiel, et al., (1999), and Al-Seikh, (2006) found that the organic matter increases from arid zone to Mediterranean zone. On the other hand, Khresat, et al., (1998) reported that organic matter content increased as the precipitation increased, as will as the clay content and vegetation cover increase.

There are high correlation exists between climatic conditions and pedo-geomorphic variables, such as organic matter content, aggregate stability and soil moisture, and processes, such as infiltration and overland flow. ( Lavee H. and Sarah P. 2009).

## 1.5. Influence of slope on soil properties

Moreover, landscape attributes (slope, aspects, and altitude) are affecting the amount and distribution of almost all chemical and physical soil properties (Rezaei et al., 2005 a, b; Fu et al., 2003; Fu et al., 2004). Landscape position directly affected water storage (Tomer et al., 2006) and interacted with management to affect spatial water redistribution (da Silva et al., 2001). In a cropped soil landscape, da Silva et al. (2001) found that soil moisture was affected significantly by the spatial distribution of clay content and organic matter along a slope under different tillage systems. The spatial and temporal variability of soil moisture result from the effect of different topography, soil type, vegetation and land use (Fu. et al., 2003; Salve, 2001; Al-Kharabsheh 2004; Sarah, 2004, Al-Seikh, 2006, Adam, 2007).

Rezaei, et al (2005) and Oztas, et al (2003), found that in the mountainous areas, clay content was lowest in up slopes compared to down slopes, and the values steadily increased with increasing slope gradient. Moreover, as water flow velocity increases with increasing slope, chances of infiltration from surface run-off decrease (Chaplot and Le Bissonnais, 2000). Lateral movement of soil moisture through surface and surface flow are considered the engine for clay illuviation and carbonate fluxes forming catenary soil changes with slopes (Yaalon, 1997).

Changes of various parameters along toposequence in mountainous areas have been already investigated in different climates of the world, mainly with respect to the influence of crop cultivation on hillslopes (McConkey et al., 1997; Rockstro¨m and de Rouw, 1997). For semiarid environments in particular, only little information is available about changes of different parameters along toposequences with natural vegetation (Ludwig and Tongway, 1995), and nothing has been published, so far about the impact of different grazing intensities on soil and vegetation parameters along toposequences on hill-slopes.

## 1.6. Influence of land use on soil properties

In addition to variation in climate and topography, soil characteristics are also important factors that lead to variation in plant species, vegetation type, and plant communities (Rezaei et al., 2005 a, b).
Empirical studies are deficient in Palestine, but others conducted elsewhere in the world have attempted to evaluate the effects of changes in land use and land cover on physical and chemical properties of soils. Al-Seikh (2006) found in his study at Soreif, Bane Noeim, and Dura at Hebron district in the West Bank, that soil properties significantly different by climate condition, topography, land use, and conservation methods. Also he reported that range lands, mainly the shrub land, have significantly more soil organic matter and nutrients compared to cultivated bare land.

Lumbanraja et al. (1998) found out that with conversion of primary forests to secondary forests, coffee plantations and cultivated land in south Sumatra, Indonesia, soil organic carbon, total N, available P, total P and exchangeable cations contents and cation exchange capacity (CEC) of the soil decreased significantly. In a study in the Zagrous Mountains of Iran, Hajabbasi et al. (1997) reported an increase in bulk density, and decreases in soil organic matter (SOM), total N and soluble ion contents following deforestation. In addition, Sahani and Behera (2001), Shrestha et al. (2007), reported higher bulk density in deforested and continuously cultivated lands. In Orissa, India, conversion of forest into farmland led to a significant reduction in organic carbon, total N and C/N ratios, but not in total and available P levels (Saikh et al., 1998 a). Similarly, Lal (1996) concluded that soils in western Nigeria deteriorated in chemical properties after deforestation and with cultivation time, regardless of differences in cropping systems. So existing land cover affects soil physical and chemical properties by supplying nutrient elements and microclimate for development of soil properties (Seyed and Robert, 2005).

On the other hand, in their study in Orissa, India, Saikh et al. (1998 b) reported that deciduous forest, grassland and cultivated soils have statistically similar contents of exchangeable $Ca^{2+}$ , $Mg^{2+}$, $K^{+}$ and $Na^{+}$. In a comparison of soil samples collected in 1969 and 1996 in eastern Burkina Faso, there was no indication of declining fertility of the soils that could be ascribe to agricultural land use (Mazzucato and Niemeijer, 2000).

Bulk density is a dynamic property that varies with the structural condition of the soil. This condition can be altered by cultivation; trampling by animals; agricultural machinery; and weather; i.e., raindrop impact (Arshad et al., 1996). Compacted soil layers have high bulk densities, restrict root growth, and inhibit the movement of air and water through the soil.

Grazing is the most economical way of evaluating rangeland vegetation. Nevertheless, overgrazing or uncontrolled grazing always reduces plant cover that protects the soil and finally causes soil erosion and compaction (Oztas et al. 2000). Overgrazing and its attendant effect of depletion of plant cover and litter and trampling of the soil is the most important factor contributing to erosion (Branson et al. 1981).

Soil organic matter and soil texture are the principal determinants of physical properties such as bulk density and aggregate stability (Young, 1988). The degree of association of soil organic carbon with particle sizes is a qualitative indicator of the impact of land use and soil management. Farming practices affect soil organic carbon concentration and physical properties (Hao et al., 2001). In addition, organic matter had an effect on soil aggregate stability and in turn affected soil erosion (Abu Hammad 2004).

Vance (2000) found that, tillage operations disrupt soil structure and accentuate soil organic matter oxidation by increasing aeration, which stimulates microbial activity. In contrast, conservation tillage or no-till have less deleterious effects on soil structure, and maintain or increase soil organic carbon concentration (Lal and Kimble, 1997).

McVay et al.,(2006) found that no-till systems has the potential to increase organic matter in the soil profile both by increasing carbon additions to the system and by decreasing oxidation caused by tillage. In cultivated land, manuring increases the organic input to soil and consequently enhances soil organic carbon concentration (Jarecki and Lal, 2003).

Organic matter in cultivated soils has less physical protection than that in uncultivated soils because of removal of large quantities of biomass during land clearing, a reduction in the quantity of organic inputs to the soil and increasing soil organic matter decomposition rates (Abbasi et al., 2007). These decomposition rates are due to enhance biological activities by tillage practices, break up macro-aggregate and exposes soil organic matter to decomposition (Dunjo et al., 2003). Adam (2007), Al-Seikh (2006) and

Fu et al. (2004) found that in cultivated land, the amount of organic matter was lower than that in natural vegetation.

## CHAPTER TWO

# 2. Materials and methods

## 2.1 Study sites

The study area was located at the southern part of West Bank (Nuba, Halhul and Al-Shyoukh) (figure 4). Three sites were selected to carry out the study. The area is characterized by a strong climatological gradient from west to east with respect to the annual rainfall. From western slopes to eastern slopes, the elevation raises gradually until it reaches its highest point in Halhoul site (950 m above sea level with 600 mm annual precipitation), and then it goes down gradually towards Al-Shyoukh site until it reaches its lowest point (450 m above sea level with 250 mm annual precipitation).

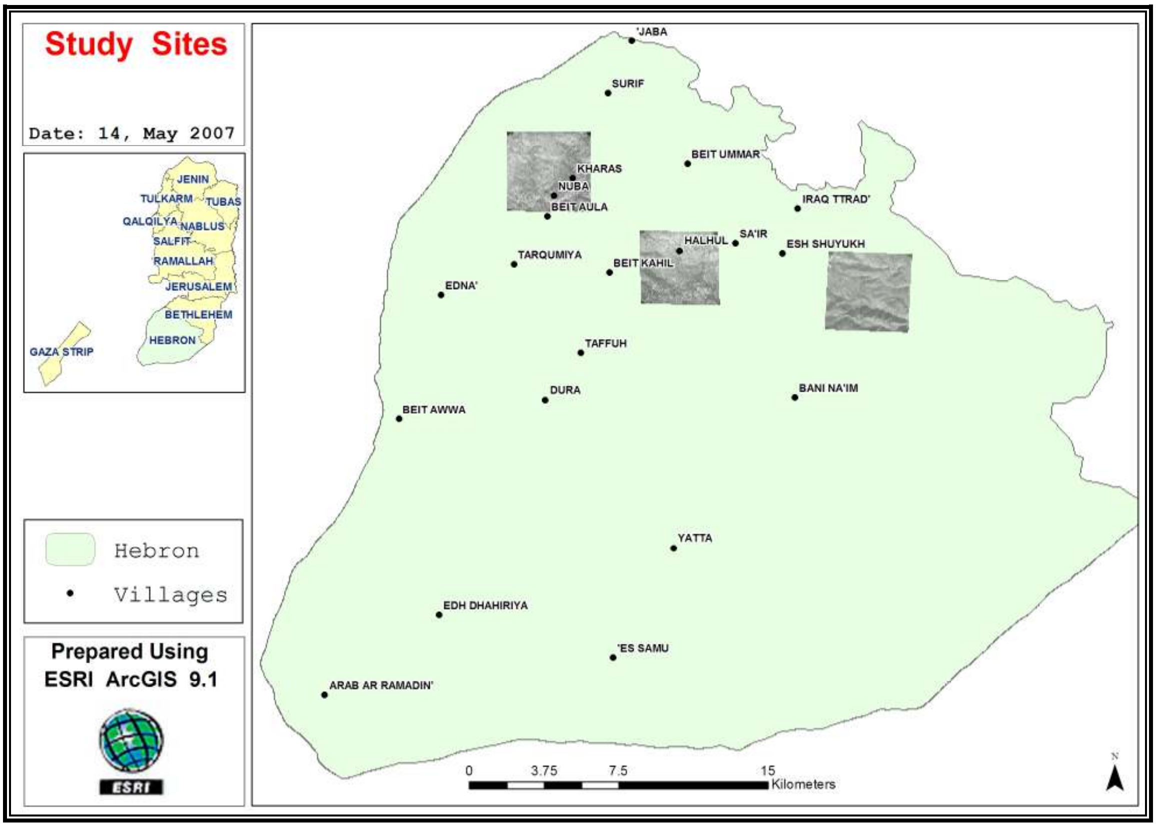



Figure 4: Map of the study sites

### 2.1.1. Nuba site

The area comprises hills descending from central heights (east) to coastal plain (west). The geographical positions for the site in Palestinian Coordinates are from 152.211 Km to 155.136 Km East and from 112.110 Km to 115.693 Km North. It is about (11) Km north-west of Hebron city (figure 4). Its topography is Hilly with maximum altitude (640 m above the sea level) measured on the south-east part of the site and the minimum altitude (430 m above the sea level) measured on the north-west part of the site (Land Research Center, 1999).

This area considered as semi-arid to semi-humid Mediterranean climate with a long hot dry summer and short cool rainy winter. Average annual rainfall is about 432.8 mm falling during winter season from November to April. Figure 5 presents the annual rainfall between 2000-2008 years at Beit Awla site station that is located close to the study site in Nuba.

Soil classified as dark brown soil, brown rendzinas and pale rendzinas (Dan et al, 1975). The parent materials of Brown rendzinas and pale rendzinas are soft chalk and marl covered partly by nari crust and hard chalk (Dan J. et al. 1962) and it is classified as *Lithosols* and *rendzinas* in FAO classification and *Xerorthents*, *haploxerolls* in USDA classification (Land Research Center, 1999).

Terrarossa soil is derived from hard limestone and dolomites of Upper Cretaceous and Eocene formation (Zohary, 1947). These hills has different land use, in the foot-slopes, they are covered with non irrigated arable land, in the valley flats and summit surfaces are occupied by olive groves and non irrigated arable land. Grassland covered some part of hill-slopes, which are cultivated with olive groves and fruit trees.

### 2.1.2. Halhoul site

The area is considered as part of the central heights of the West Bank. The longitude of the site in Palestinian Coordinates is 157.656 Km to 161.342 Km, and latitude is 108.582 Km to 110.587 Km. It is about (5) Km north of Hebron city (figure 4). Its topography is mountainous with elevation range from 850 to 980 m above sea level. The maximum altitude of 980 m above the sea level, which is measured on the western part of the site and the minimum altitude, is 850 m above the sea level, which is measured on the south- west part of the site.

This area is considered as semi-arid to semi-humid Mediterranean climate with a long hot dry summer and short cool rainy winter. Average annual rainfall is about 595.9 mm falling during winter season from November to April. Figure 5 presents the annual rainfall between 2000-2008 years at Halhul station.

Soil is classified as Terrarossa, brown rendzinas and pale rendzinas (Dan et al, 1975). The parent materials of terrarossa soils are hard limestones, dolomites with inclusions of chalk and marl and calcareous shales. For brown rendzinas and pale rendzinas soils, the parent materials are soft chalk and marl covered partly by nari lime crust, hard chalk (Dan J. et al. 1962).

Cenomanian-turonian sedimentary formations provide the most extended exposures of rocks in these mountains (Arieh, 2007).

This site has different land uses, footslope and summit surfaces and valley flats are always cultivated. Vineyards, fruit trees and olive groves represent the most important land use with natural vegetation. Hillslopes and hillcrests normally are covered by pastures seasonal natural grassland.

### 2.1.3. Al-Shyoukh site

The area is considered as part of the Eastern slopes of West Bank, which descending from central heights (west) to Jordan valley (east). The longitude of the site in Palestinian Coordinates is 168.084 Km to 171,136 Km, the latitude is between 106,684 and 108,950. It is about (8.5) Km northeast of Hebron city (figure 4). Its topography is mountainous and hills with elevation range from 570 to 880 m above sea level. The maximum altitude is measured on the north-west part of the site and the minimum altitude is measured on the south-east part of the site.

This area is considered as moderately arid to semi-arid Mediterranean climate; most of the rain falls as short with high intensity rainstorms. Average annual rainfall is about 250-300 mm. Figure 5 shows the annual rainfall between 2000-2008 years at Bani Noem station, which is the closest station for Al-Shyoukh site.

Soil classified as brown rendzinas and pale rendzinas, brown lithosols and loessial arid brown soils (Dan et al, 1975). The parent materials of brown rendzinas and pale rendzinas soil are soft chalk and marl covered partly by nari lime crust and hard chalk. And for brown lithosols and loessial arid brown soils are underlying rocks may be chalk, marl, limestone or conglomerate, most of which are covered by a hard lime crust, most of the soils are affected by loessial dust which is deposited mainly on flat or moderately sloping areas (Dan J. et al. 1962). Cenomanian-turonian sedimentary formations provide the most extended exposures of rocks in these mountains (Arieh, 2007).

Hillslopes and hillcrests normally covered by seasonal natural grassland used as pastures. Summit surfaces and valley flats are cultivated with olive groves and fruit trees.

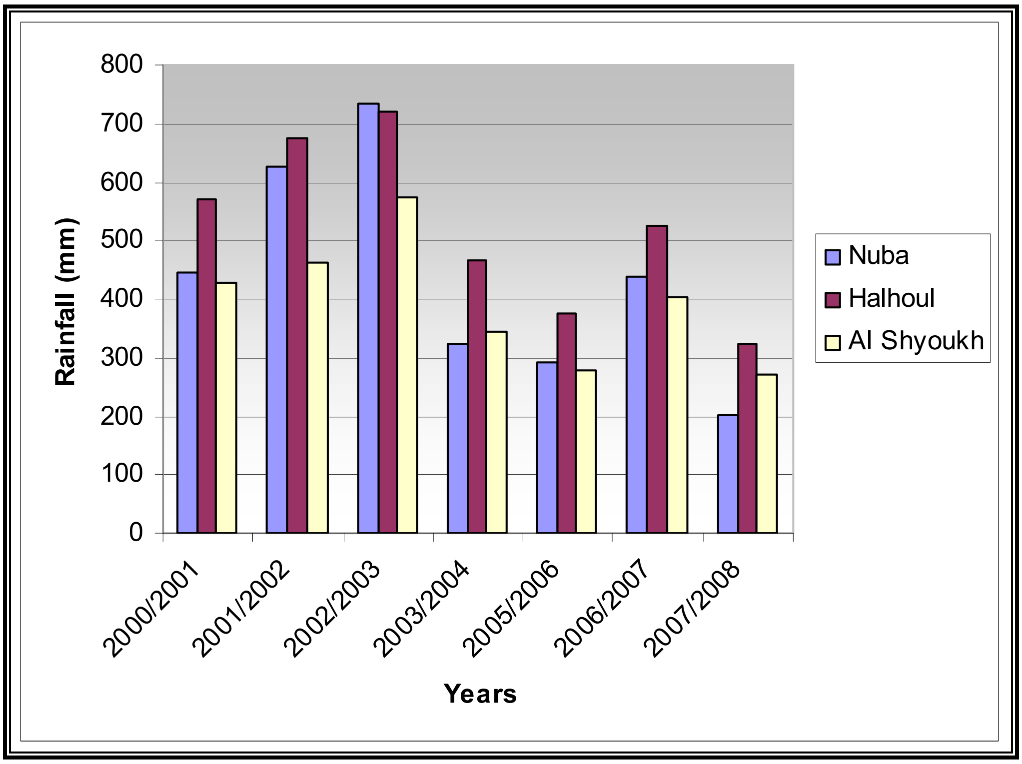



Figure 5: Rainfall at the study sites during 2000-2008

## 2.2. Treatments and sample collection

The study includes three sites (Nuba, Halhoul, and Al-Shyoukh), at each site three slopes where studied, gently slope, S1 (3%-8%), moderately slope, S2 (8%-18%) and moderately steep slope, S3 (18%-32%), and within each slopes three land uses where evaluated, cultivated trees, range land, and arable land (figures 6, 7).

The combination of different site-slope treatments were arranged in a completely randomized design (CRD) with factorial treatment with three replications; and the combination of different site-land use were arranged in a completely randomized design. Figure (10) show the collection design for the three sites with three slopes and three-land uses.

In total eighty-one soil samples were taken randomly distributed on the three sites during October 2007, {(3 site (Nuba, Halhoul, Al-Shyoukh) X 3 slopes (S1, S2, S3) X 3 land use (Cultivated trees, arable land, range land) X 3 replicates}

With uniformity in north slope aspect for all the collected samples. A global positioning system (GPS) used to determine the coordinates of sampling points, and some variables were defined before sampling: local slope, using a clinometer (figure 9). Soil samples was taken from the surface (10 cm depth) by a shovel, the collected samples were immediately placed in plastic bags (figure 8), well closed, and then taken to the laboratory, weighed and oven-dried at 105 $C^o$ over 48 hours. The dried samples were crushed using a pestle and mortar, then it passed through a 2 mm sieve and the following chemical and physical analyses were conducted.

Figure 6: Photo show different
land uses in Al-Shyoukh site

Figure 7: Photo show different
land uses in Halhoul site

Figure 8: Soil sample collection in Al-Shyoukh site

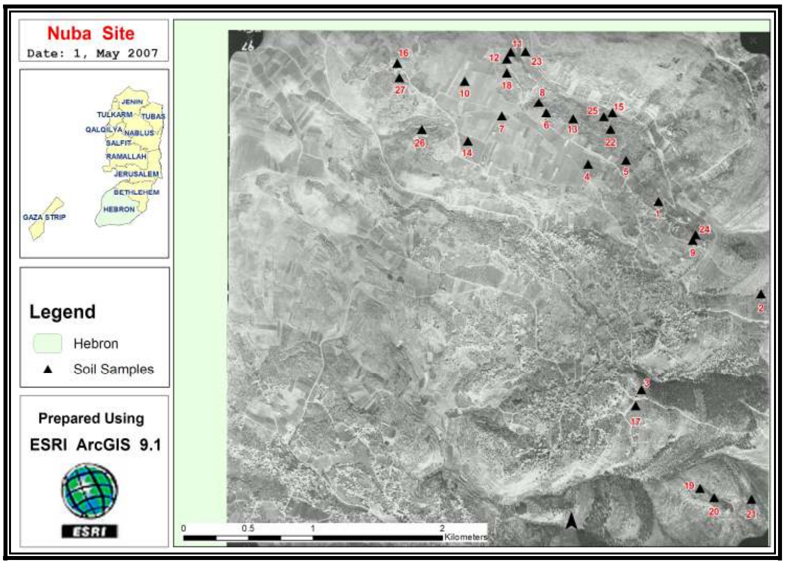
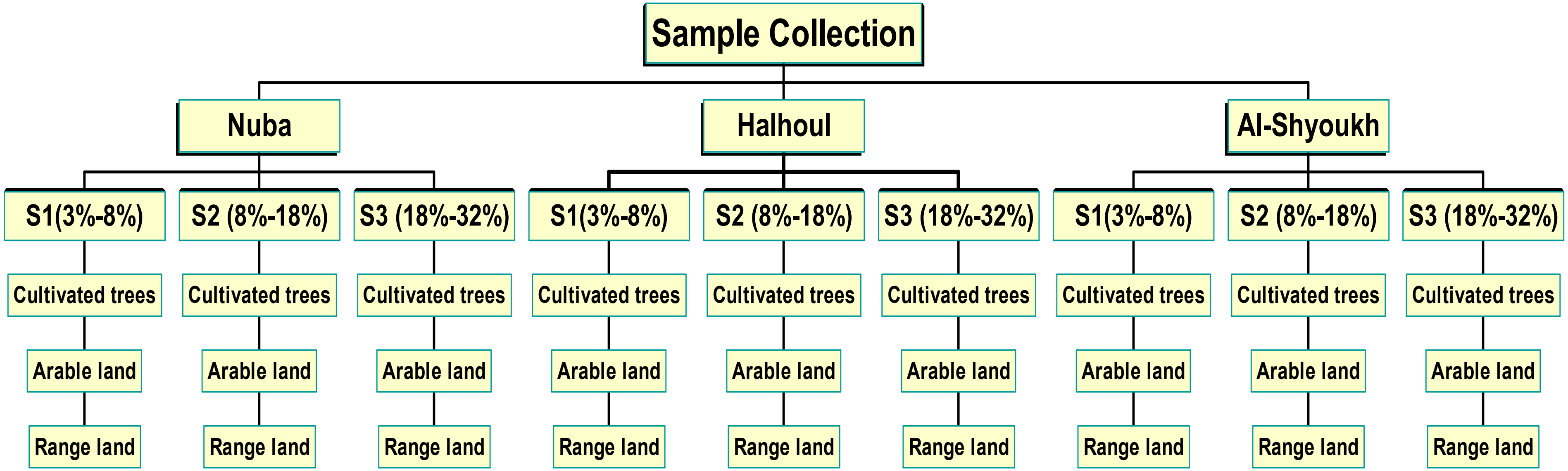



Figure 9: Arial photo presents soil sample distribution in Nuba site

Figure 10: Sample collection design for the three sites with three land uses and three slopes



Organic matter (OM%), soil (pH), electrical conductivity (EC), calcium carbonate ($CaCO_3$), calcium ($Ca^{++}$), magnesium ($Mg^{++}$), available potassium ($K^+$), sodium ($Na^+$), soil texture (%clay, %silt, %sand), bulk density, meniral density, and Porosity.

### 2.3. Soil physical analysis

Soil particle size distribution was determined using the pipette method (Bouwer, 1986). Soil moisture content was measured using gravimetric method. Bulk density determined by clod method (Kim, 1996). Mineral density was measured based on finding the volume of the particles contained in a known weight of oven-dry soil by measuring the volume of a liquid displaced by these particles.

### 2.4. Soil chemical analysis

Soil pH determined by using an electrode pH-meter for a saturated soil past (1:2.5) using distilled water, the electrical conductivity (EC) was measured in a saturated past (1:2.5) (Skoog and West, 1976; FAO 1980).

Organic matter contents were determined by using the Walkey and Black method (Nelson and Sommers, 1982). Extractable bases ($Ca^{++}$, $Mg^{++}$, $K^+$, $Na^+$) were determined following displacement with 1M $NH_4OAc$ (Thomas, 1982). $CaCO_3$ content determined by using the calcimeter instrument.

## CHAPTER THREE

# 3. Results

## 3.1. Influence of climate on soil properties

### 3.1.1. Soil physical properties

#### 3.1.1.1. Soil texture

The results of soil texture analysis from the three sites (Nuba, Halhoul, and Al-Shyoukh) in the north transect are shown in table (2).

Table 2: Means of soil texture (Clay; Silt; and Sand %) between three sites

| Site | %Sand | %Silt | %Clay | Soil Type |
|---|---|---|---|---|
| **Nuba** | 31.70[b*] | 31.50[c] | 36.80[a] | Clay loam |
| **Halhoul** | 30.10[b] | 39.80[ab] | 30.10[b] | Clay loam |
| **Al-Shyoukh** | 37.40[a] | 40.50[a] | 22.00[c] | Loam |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at p ≤0.05.
*In each site, mean for 27 soil sample (different slopes and land uses).

The results indicate that soil particles distribution (sand, silt, and clay) is different between the three study sites. The clay content in Nuba (36.80%) was significantly higher than (30.10%, 22.00%) in Halhoul and Al-Shyoukh, respectively, and the lowest clay content was measured in Al-Shyoukh, which considered as moderately arid to semiarid climate. The results show other trend for sand content since, in Al-Shoyukh (37.40%), it was the highest content and show significant difference compared to Nuba and Halhoul (31.70%, 30.10%), respectively, so it was increased as climate oriented to aridity.

The result of silt content, show some significant variation between the three sites, since, the highest silt content was measured in Al-Shyoukh (40.50 %) with significant difference compared to Nuba (31.50%). The content of silt in Nuba and Halhoul is generally similar. From the above data, the soil type in Nuba and Halhoul is classified as clay loam soil, and in Al-Shyoukh is loam.

### 3.1.1.2. Bulk density, mineral density and porosity

The results in table (3), show that the bulk density is statistically significantly different between the three sites. The highest bulk density was in Al-Shyoukh (1.25 gm/cm$^3$), which had lowest clay content, with significant difference compared to Nuba (1.17 gm/cm$^3$), and Halhoul (1.20 gm/cm$^3$), since these two sites had more clay and organic matter content.

Table 3: Means of soil bulk density, mineral density and porosity percentage between three sites:

| Site | Bulk Density (g/cm$^3$) | Mineral Density (g/cm$^3$) | %Porosity |
|---|---|---|---|
| **Nuba** | $1.17^{b*}$ | $2.69^{a}$ | $56.50^{a}$ |
| **Halhoul** | $1.20^{b}$ | $2.65^{ab}$ | $54.80^{ab}$ |
| **Al-Shyoukh** | $1.25^{a}$ | $2.59^{c}$ | $51.80^{c}$ |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site, mean for 27 soil samples (different slopes and land uses).

The results between porosity and mineral density show the same trend, since the highest porosity was in Nuba (56.50%) with significant difference compared to Al-Shyoukh (51.80%), also for the mineral density, Nuba had the highest value (2.69 gm/cm$^3$) with significant difference compared to Al-Shyoukh (2.59 gm/cm$^3$). The relation between porosity percentage and bulk density is inverse, and generally in the three sites porosity percentage has positive relation with mineral density, as porosity increases mineral density increase, which shown by figure (11). In addition to that, as clay content increasing, the porosity percentage increase.

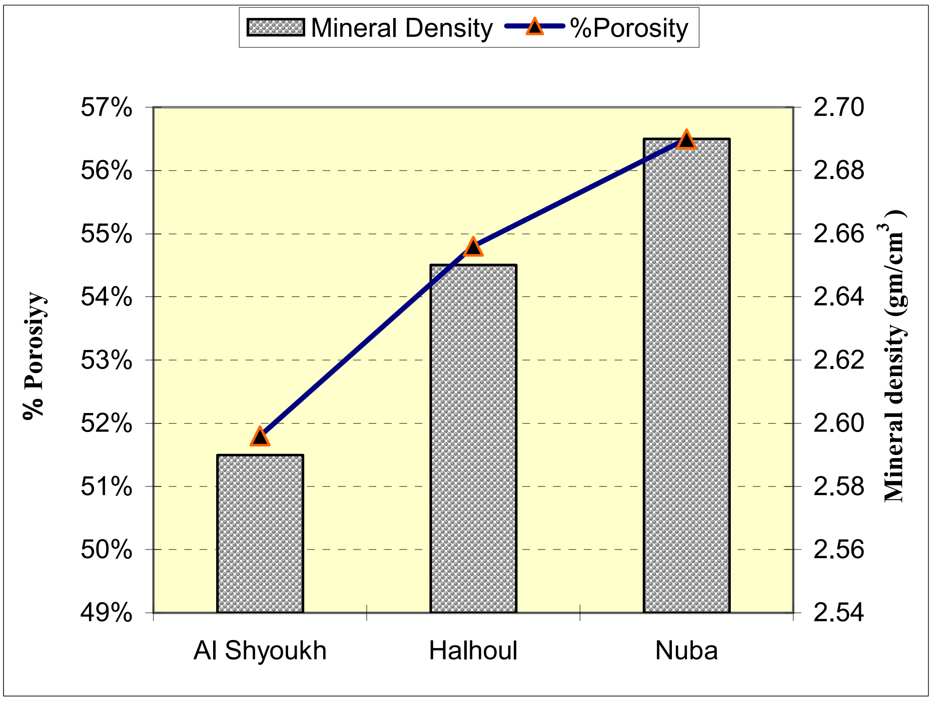



Figure 11: Relation between porosity and mineral density in the three sites.
*In each site, mean for 27 soil samples (different slopes and land uses).

### 3.1.1.3. Soil moisture content

Soil moisture content exhibited different variability at the three sites. However, data showed that soil moisture content was significantly higher in Halhoul (7.21 %) – semi arid to semi humid - compared to Al-Shoukh sites (5.00%) – moderately arid to semi arid, which has the lowest water content between the three sites. For water content in Nuba (6.70 %), it has no significant difference compared to Halhoul, (figure 12).

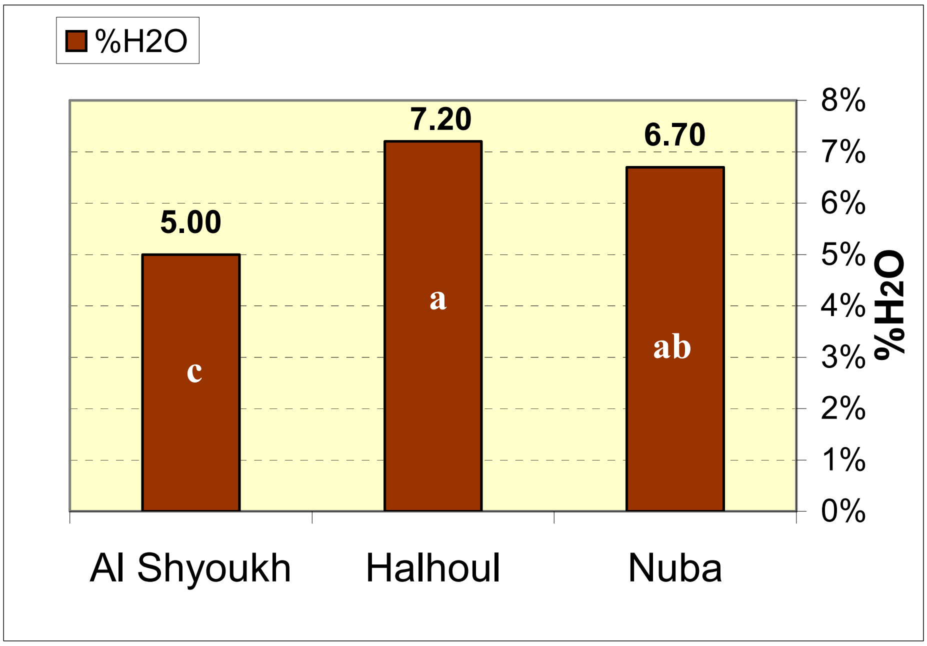



Figure 12: Means of water content percentage in the three sites.
- Columns followed by the same letter are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
- In each site, mean for 27 soil samples (different slopes and land uses).

### 3.1.2. Soil chemical properties

#### 3.1.2.1. Organic carbon and organic matter percentage

Data showed that organic matter content (OM %) in Nuba site (3.00 %) was the highest value and is significantly different compared to Al-Shyoukh (2.00 %) which had the lowest content percentage. Between Nuba (2.80 %) and Halhoul, there was no statistically difference (Table 4).

Table 4: Means of (%$CaCO_3$, pH, EC (mmho $cm^{-1}$), Organic Carbon percentage, Organic matter percentage) in the three sites

| Site | %Organic Carbon | %OM | %$CaCO_3$ | pH | EC (mmho*$cm^{-1}$) |
|---|---|---|---|---|---|
| **Nuba** | $1.80^{a}$ | $3.00^{a}$ | $32.10^{a*}$ | $7.28^{b}$ | $1.34^{a}$ |
| **Halhoul** | $1.60^{ab}$ | $2.80^{ab}$ | $30.00^{a}$ | $7.30^{b}$ | $1.16^{b}$ |
| **Al-Shyoukh** | $1.20^{c}$ | $2.00^{c}$ | $24.70^{a}$ | $7.44^{a}$ | $0.79^{c}$ |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site, mean for 27 soil samples (different slopes and land uses).

Also for the organic carbon, which has the same trends, since Nuba site organic carbon percentage (1.80 %) significantly higher than Al-Shyoukh site (1.20 %), which has the lowest organic carbon percentage. However, organic carbon percentage between Nuba (1.80 %) and Halhoul (1.60 %) had no statistically difference.

### 3.1.2.2. pH, calcium carbonate and electrical conductivity

The soil pH, calcium carbonates, and electrical conductivity are among the major important soil chemical properties, because they have a major role in controlling the solubility of the most essential elements of plant growth.
Data in table (4) showed that soil reaction (pH) in Al-Shyoukh site (7.44) was the highest, since this area had lowest amount of rainfall, it was significantly different compared to Halhoul site (7.30), and the lowest pH in Nuba site (7.28), both Nuba and Halhoul sites had more amount of rain.
According to Marx et al, (1999) the soil of Nuba and Halhoul is neutral, and in Al-Shyoukh is moderately alkaline. Calcium carbonate content has no statistically difference between the three study sites (Table 4).

Nuba site electrical conductivity (1.34 mmhos/cm) has the highest EC and it was significantly different compared to Halhoul site (1.16 mmhos/cm) and the lowest EC in Al-Shyoukh site (0.795 mmhos/cm). According to Marx et al, (1999) the soil of the three sites has medium electrical conductivity.

### 3.1.2.3. Cation exchange capacity, calcium, magnesium, and potassium

Cation exchange capacity (CEC) is the amount of negative charge in soil that is available to bind positively charged ions (cations) (Camberato, 2001). Cation Exchange Capacity values were generally similar (16.62, 16.15, 16.79 meq/100g), respectively for the three sites (Nuba, Halhoul, and Al-Shyoukh) (Table 5).

Table 5: Means of cation exchange capacity, calcium, magnesium, and potassium in the three sites:

| Site | CEC | Ca | K | Mg |
|---|---|---|---|---|
| | (meq/100g) | | | |
| **Nuba** | 16.62$^{a*}$ | 12.20$^{a}$ | 0.72$^{c}$ | 3.51$^{a}$ |
| **Halhoul** | 16.15$^{a}$ | 11.94$^{a}$ | 0.90$^{ab}$ | 3.20$^{a}$ |
| **Al-Shyoukh** | 16.79$^{a}$ | 12.32$^{a}$ | 0.90$^{a}$ | 3.36$^{a}$ |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at p ≤0.05.
*In each site, mean for 27 soil samples (different slopes and land uses).

The extractable soil *Calcium* from the study sites soils were statistically not significant (12.20, 11.94, and 12.32 meq/100gm) which equivalent to (2440, 2388, and 2464 ppm) for the three sites Nuba – semi arid to semi humid , Halhoul – semi arid to semi humid, and Al-Shyoukh moderately arid to semi arid, respectively. And according to Marx et al, (1999) these soils have high level of calcium concentration.

The extractable soil *magnesium* between the study sites were statistically not significant (3.51, 3.20, and 3.36 meq/100gm) that are equivalent to (424.71, 387.20, and 406.56 ppm) for the three sites Nuba, Halhoul, and Al-Shyoukh, respectively. And according to Marx et al, (1999) these soil have high level of magnesium concentration.

The extractable soil *potassium* between the study sites were statistically significantly different. The results were (0.72, 0.89, and 0.90 meq/100gm) that are equivalent to (280.8, 350.6, and 352.8 ppm) for the three sites (Nuba, Halhoul, and Al-Shyoukh), respectively. The extractable soil potassium was the highest in Al-Shyoukh site and significantly different compared to Nuba site, which has the lowest extractable soil potassium and according to Marx et al, (1999) these soil have high level of potassium concentration.

### 3.1.2.4. Sodium and Sodium Adsorption Ratio

The results of extractable soil *sodium* were (0.20, 0.17, and 0.21 meq/100gm) that are equivalent to (46, 39.1, and 48.3 ppm) for the three sites Nuba, Halhoul, and Al-Shyoukh, respectively. Sodium content in Al-Shyoukh site is significantly higher than that for Halhoul site (Table 6).

Table 6: Means of sodium concentration (meq/100g) and Sodium Adsorption Ratio (SAR) in the three sites:

| Site | Na (meq/100g) | SAR |
|---|---|---|
| **Nuba** | $0.20^{ab*}$ | $0.84^{ab}$ |
| **Halhoul** | $0.17^{b}$ | $0.76^{b}$ |
| **Al-Shyoukh** | $0.21^{a}$ | $0.88^{a}$ |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site, mean for 27 soil samples (different slopes and land uses).

The same trends for sodium adsorption ratio, the results were (0.84, 0.76, and 0.88) for the three sites Nuba, Halhoul, and Al-Shyoukh, respectively (Table 6). Sodium adsorption ratio in Al-Shyoukh site is significantly higher than that for Halhoul site, $SAR = Na/(Ca+Mg/2)^{1/2}$.

## 3.2. Influence of slopes on soil properties

### 3.2.1. Soil physical properties

#### 3.2.1.1. Soil texture

The soil texture analysis results (Table 7) for S1 (3%-8%), S2 (8%-18%), and S3 (18%-32%) in the north aspect of the three study sites, indicate that clay content between the three slopes inside the same site is generally similar at Nuba and Halhoul. Nevertheless, this trend was different in Al-Shyoukh, since clay content in S3 was significantly higher in comparison with S1 and S2.

Table 7: Means of soil texture (Clay; Silt; and Sand %) in three sites and three slopes.

| Site | Slope | %Sand | %Silt | %Clay | Soil Type |
|---|---|---|---|---|---|
| Nuba | S1 | 28.8[cd*] | 34.9[c] | 36.3[ab] | clay loam |
| | S2 | 30.2[cd] | 35.0[c] | 34.8[abc] | clay loam |
| | S3 | 36.2[abc] | 24.5[d] | 39.3[a] | clay loam |
| Halhoul | S1 | 28.4[cd] | 39.1[abc] | 32.6[bcd] | clay loam |
| | S2 | 34.1[bcd] | 38.7[abc] | 27.2[de] | clay loam |
| | S3 | 27.9[d] | 41.6[ab] | 30.5[cde] | clay loam |
| Al-Shyoukh | S1 | 37.9[ab] | 41.9[ab] | 20.1[f] | loam |
| | S2 | 43.5[a] | 36.5[bc] | 20.0[f] | loam |
| | S3 | 30.9[bcd] | 43.1[a] | 26.0[e] | loam |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site slope, mean for 9 soil samples with three different land uses.

In addition, Nuba S3 had the highest clay content with significantly difference compared to Al-Shyokh and Halhoul moderately steep slopes (S3). In addition, clay content was statistically different between the three moderately slopes (S2), and moderately steep slope (S3), through the three study sites.

Moreover, corresponding, sand content at Al-Shyoukh S2 was significantly highest than S3 inside the site slopes. Sand content at S1, S2, and S3 was not statistically different inside the same site at Nuba and Halhoul. Sand content at S1 at Al-Shyoukh was significantly higher than S1 in both Nuba and Halhoul, and the same trend for S2. Sand content at Halhoul S3 was the lowest, and had statistically different compared to S3 at Nuba.

Silt content at Halhoul slopes is generally similar, in contrast with Nuba and Al-Shyoukh slopes. Since Nuba S1 and S2, silt content was significantly higher than S3, and Al-Shyoukh S3 had significantly higher than S2. The higher content of silt was measured at Al-Shyoukh S3, which was statistically different compared to Nuba S3. Silt content on Al-Shyoukh S1 was significantly higher than Nuba S1. In addition, silt content at S2 between the three sites was relatively similar.

### 3.2.1.2. Bulk density, mineral density and porosity

The results (Table 8) show that bulk density at the three slopes in Nuba and Halhoul were generally similar.

Table 8: Means of soil bulk density, mineral density, porosity, and %$H_2O$ at the three sites and three slopes.

| Site | Slope | Bulk Density ($g/cm^3$) | Mineral Density ($g/cm^3$) | %Porosity | %$H_2O$ |
|---|---|---|---|---|---|
| Nuba | S1 | 1.16[c*] | 2.70[a] | 57.1[a] | 6.7[b*] |
| | S2 | 1.17[c] | 2.68[a] | 56.4[ab] | 6.6[b] |
| | S3 | 1.18[bc] | 2.67[a] | 55.9[ab] | 6.9[ab] |
| Halhoul | S1 | 1.20[abc] | 2.65[abc] | 54.5[ab] | 8.4[a] |
| | S2 | 1.20[abc] | 2.66[ab] | 54.8[ab] | 6.3[bc] |
| | S3 | 1.19[bc] | 2.65[abc] | 55.1[ab] | 6.7[b] |
| Al-Shyoukh | S1 | 1.28[a] | 2.59[cd] | 50.6[d] | 4.8[d] |
| | S2 | 1.26[ab] | 2.57[d] | 51.1[cd] | 5.0[cd] |
| | S3 | 1.21[abc] | 2.61[bcd] | 53.6[bc] | 5.2[cd] |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at p ≤0.05.
*In each site slope, mean for 9 soil samples with three different land uses.

Al-Shyoukh slopes had higher bulk density than other two sites. The highest bulk density was measured in Al-Shyoukh gently slopes (S1) (1.28

g/cm$^3$), which was statistically different with the same slope in Nuba site (1.16 gm/cm$^3$), (Table 8). In addition, bulk density on moderately slopes (S2) at Al-Shyoukh was significantly higher than the same slope at Nuba site. The relation between bulk density and clay content according to slope slope at the three sites was evidently shown, since as clay content increase, bulk density decrease (figure 13).

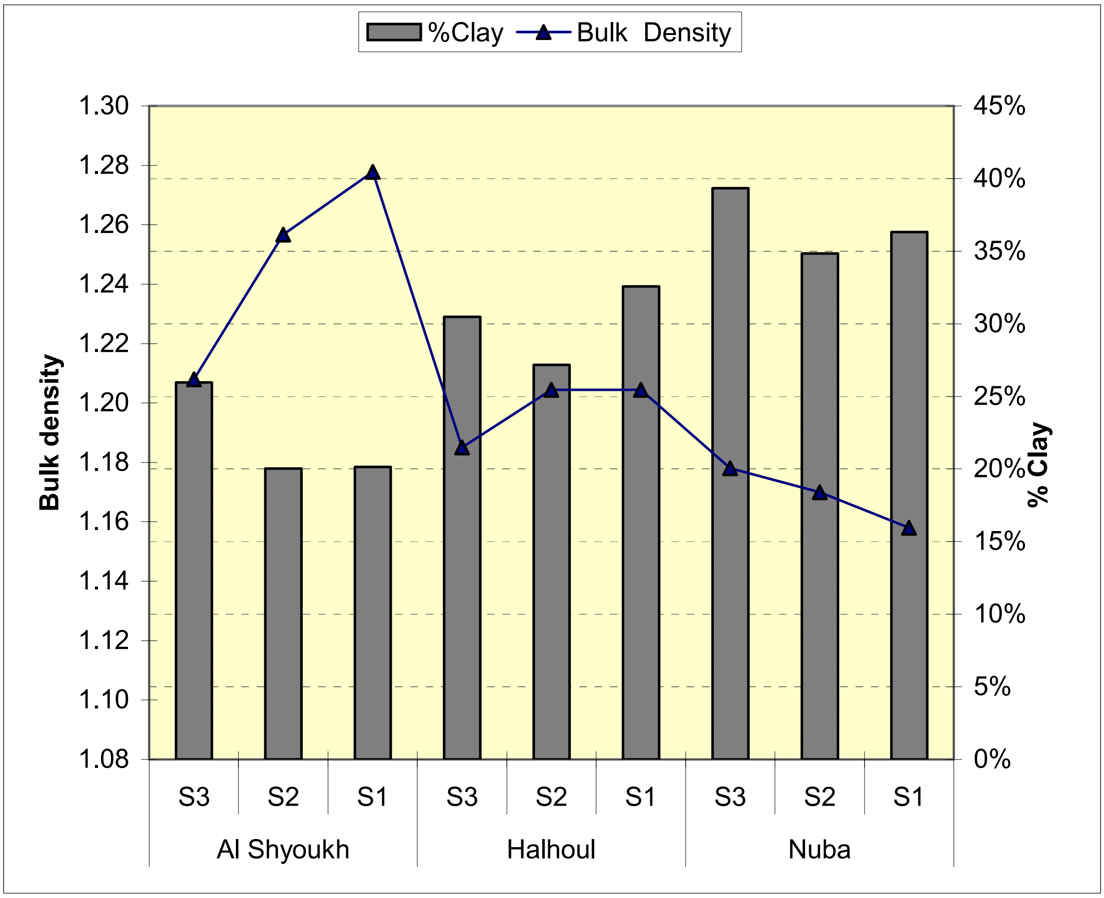



Figure 13: Percentage of clay content and bulk density (g/cm$^3$) of soil from the three slopes in the three sites
*In each site slope, mean for 9 soil samples with three different land uses.

Data (Table 8), show that, mineral density had higher values in Nuba slopes compared to Al-Shyoukh slopes. Nuba gently (S1), moderately (S2), moderately steep (S3) slopes were significantly higher than Al-Shyoukh slope. Similar porosity result trend was shown between Nuba and Halhoul slopes (S1, S2, and S3), since the value were higher compared to Al-

Shyoukh slopes. Moreover, porosity percentage on gently slopes (S1) at Nuba was significantly higher than porosity percentage on gently slopes (S1) at Al-Shyoukh. On the other hand, porosity percentage at Nuba slopes increased as slope decreases. Porosity of moderately steep slopes (S3) at Al-Shyoukh was significantly higher than gently slopes (S1) at the same site.

Data showed that there are close relationships between mineral density and porosity (figure 14). However, soil mineral density increased as porosity percentage increases, since mineral density only takes into account the volume occupied by the solid particles. It excludes the volume occupied by air and water. Percent porosity calculated as follows:

% Porosity =1 - ((Bulk density / Mineral density) X 100)

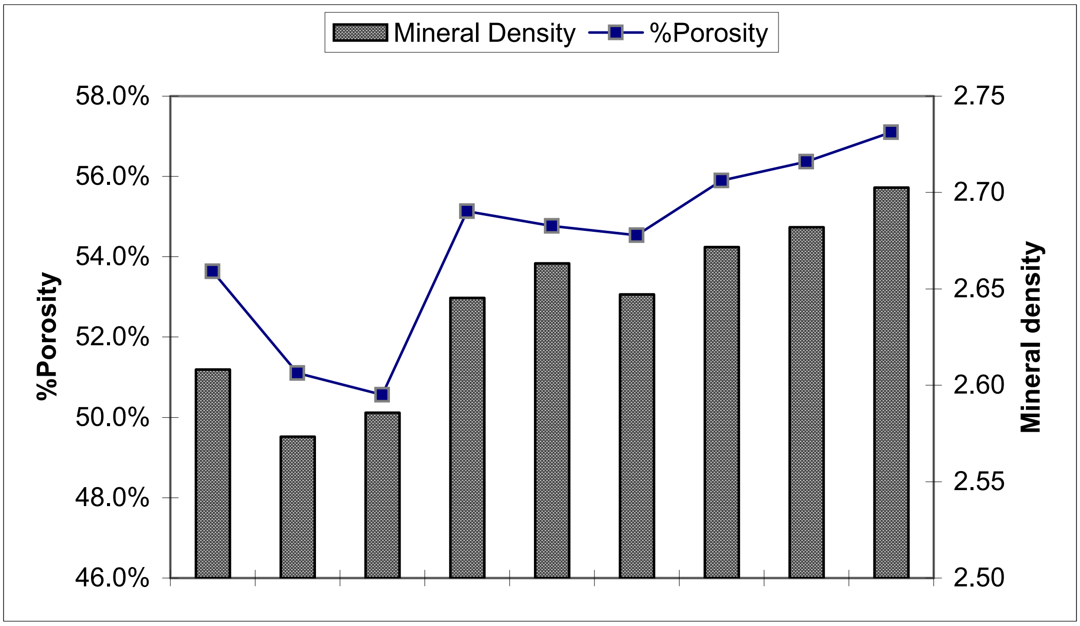



Figure 14: Relationship between mineral density and porosity percentage among three slopes at three sites

*In each site slope, mean for 9 soil samples with three different land uses.

#### 3.2.1.3. Soil moisture content

The volumetric soil moisture content is defined as the ratio, which expressed in percentage of the weight of water in a given soil mass to the weight of solid particles.

In table (8), data show that soil moisture content was higher at semi arid to semi humid area slopes, which represented by Nuba and Halhoul slopes, compared to Al-Shyoukh slopes, soil moisture content at Halhoul gently slopes (S1) was significantly higher than moderately (S2) and moderately steep (S3) slope at the same site slopes, although, it is significantly higher than the same slopes at Nuba and Al-Shyoukh site. However, generally, soil moisture content between the three slopes at Nuba and Al-Shyoukh slopes are similar at the same site.

### 3.2.2. Soil chemical properties

#### 3.2.2.1. Organic carbon and organic matter percentage

Data showed that organic matter (OM %) in Nuba and Halhoul slopes had the highest content compared to moderately arid – semi arid slopes which represented by Al-Shyoukh slopes (Table 9).

Table 9: Means of soil (%$CaCO_3$; pH; EC (mmho*$cm^{-1}$); %Organic Carbon; and %Organic matter) in three sites and three slopes.

| Site | Slope | %$CaCO_3$ | pH | EC (mmho*$cm^{-1}$) | %Organic Carbon | %OM |
|---|---|---|---|---|---|---|
| **Nuba** | S1 | $32.9^{ab*}$ | $7.28^{b}$ | $1.36^{ab}$ | $1.6^{ab}$ | $2.8^{ab}$ |
| | S2 | $28.9^{ab}$ | $7.30^{b}$ | $1.16^{bc}$ | $1.7^{ab}$ | $3.0^{ab}$ |
| | S3 | $34.5^{ab}$ | $7.28^{b}$ | $1.52^{a}$ | $1.9^{a}$ | $3.3^{a}$ |
| **Halhoul** | S1 | $22.7^{b}$ | $7.26^{b}$ | $1.25^{bc}$ | $1.6^{ab}$ | $2.8^{ab}$ |
| | S2 | $36.7^{a}$ | $7.27^{b}$ | $1.10^{cd}$ | $1.5^{abc}$ | $2.6^{abc}$ |
| | S3 | $30.6^{ab}$ | $7.36^{ab}$ | $1.16^{bc}$ | $1.8^{a}$ | $3.0^{a}$ |
| **Al-Shyoukh** | S1 | $23.8^{b}$ | $7.44^{a}$ | $0.72^{e}$ | $1.1^{cd}$ | $2.0^{cd}$ |
| | S2 | $23.3^{b}$ | $7.45^{a}$ | $0.85^{de}$ | $1.0^{d}$ | $1.7^{d}$ |
| | S3 | $27.0^{ab}$ | $7.43^{a}$ | $0.81^{e}$ | $1.3^{bcd}$ | $2.3^{bcd}$ |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site slope, mean for 9 soil samples with three different land uses.

At the three sites, moderately steep slopes (S3) organic matter were higher than gently (S1) and moderately (S2) slopes without statistically difference. Inside the same site, there were no statistically different between S1, S2, and S3. Nuba and Halhoul gently (S1), moderately (S2), and moderately steep (S3) were significantly higher than Al-Shyoukh slopes (S1, S2, S3), respectively. Organic carbon content had the same trend at all sites and the three slopess.

### 3.2.2.2. pH, calcium carbonate and electrical conductivity

Soil pH values in Al-Shyoukh slopes were higher than Nuba and Halhoul slopes (Table 9). In Nuba slopes, soil pH values were (7.28, 7.30, to 7.28), respectively for gently (S1), moderately (S2), and moderately steep (S3) slopes (Table 9). There was no statistically significant difference between the three slopes withen each study site. On the other hand, gently (S1) and moderately (S2) slope at Al-Shyoukh are significantly higher than the gently and moderately slope, respectively, at Nuba and Halhoul slopes. According to Marx et al, (1999) the soil slopes at Nuba and Halhoul classified as neutral soils and as moderately alkaline for Al-Shyoukh slopes soils. In general, data showed that soil pH increasing while organic matter decreasing (figure 15).

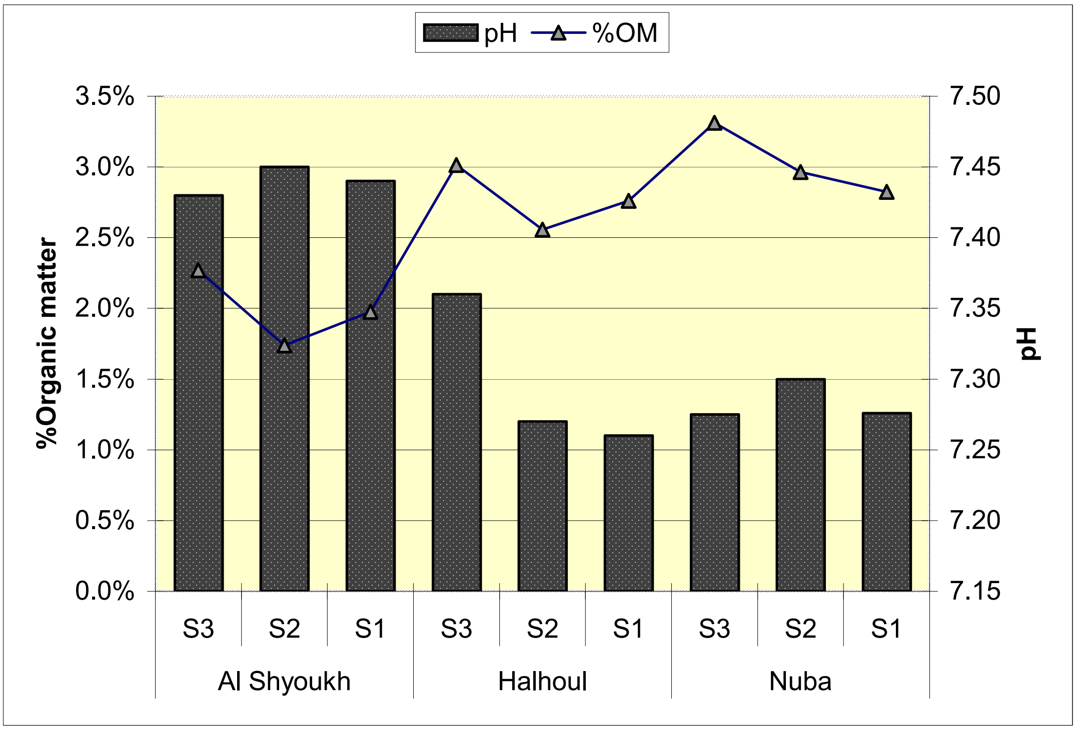



Figure 15: Organic matter and pH of soil from the three slopes at three sites.
*In each site slope, mean for 9 soil samples with three different land uses.

In general, data showed that calcium carbonate content at Nuba and Halhoul slopes were higher than Al-Shyoukh slopes (Table 9). There were no statistically difference between the three slopes at Nuba and Al Shyoukh. Calcium carbonate content at Halhoul moderately slopes (S2) were significantly higher than gently (S1) slopes.

In general, data showed that soil pH increasing and electrical conductivity decreasing from Al-Shyoukh to Nuba and Halhoul (Table 9). However, soil electrical conductivity values at moderately steep (S3) (1.52 mmhos/cm) slope in Nuba were statistically higher than moderately (S2) slope ( 1.16 mmhos/cm) (Table 9). The highest electrical conductivity is recorded in S3, and followed by S1. Although, electrical conductivity at Halhoul gently (S1) (1.25 mmhos/cm) has the highest electrical conductivity compared with S2 (1.08 mmohs/cm) and S3 (1.14 mmohs/cm), but there are no statistically difference between the three slopes.

The same trend was shown for the EC values at Al-Shyoukh slopes, since there were no statistically difference among the three slopes ( 0.72, 0.85, and 0.81 mmhos/cm) for S1, S2, and S3, respectively. The highest electrical conductivity is recorded in S2 and S3.
However, soil electrical conductivity of moderately steep (S3) slope at Nuba was significantly higher than (S3) at Halhoul and Al Shyoukh.

### 3.2.2.3. Cation exchange capacity, calcium, magnesium, and potassium

Generally, cation exchange capacities at the three site slopes were similar (Table 10). In Nuba, cation exchange capacity values of the three slopes were similar (16.67, 16.80, 16.39 meq/100g) for S1, S2, and S3, respectively. The highest cation exchange capacity was recorded in moderately slopes (S2). Also at Halhoul slopes cation exchange capacity values (16.49, 16.26, 15.71 meq/100g) for S1, S2, and S3, respectively. The highest cation exchange capacity is recorded in gently slopes (S1), and the lowest is recorded in moderately steep slopes (S3), with out statistically difference between the three slopes. Although, in Al-Shyoukh slopes, cation exchange capacity values generally similar (17.07, 16.96, 16.35 meq/100g) for S1, S2, and S3, respectively. The highest cation exchange capacity is recorded in gently slopes (S1), and the lowest is recorded in moderately steep slopes (S3), but statistically there is no difference between the slopes.

Table 10: Means of soil cation exchnage capacity (CEC (meq/100g)), calcium (Ca (meq/100g)), potassium (K (meq/100g)), and magnesium (Mg (meq/100g)) in three sites and three slopes:

| Site | Slope | CEC (meq/100g) | Ca (meq/100g) | K (meq/100g) | Mg (meq/100g) |
|---|---|---|---|---|---|
| Nuba | S1 | 16.67$^{ab*}$ | 12.30$^{ab}$ | 0.76$^{bcd}$ | 3.38$^{ab}$ |
| | S2 | 16.80$^{ab}$ | 12.40$^{ab}$ | 0.74$^{cd}$ | 3.46$^{ab}$ |
| | S3 | 16.39$^{ab}$ | 11.85$^{ab}$ | 0.66$^{d}$ | 3.69$^{a}$ |
| Halhoul | S1 | 16.49$^{ab}$ | 12.20$^{ab}$ | 0.95$^{a}$ | 3.18$^{ab}$ |
| | S2 | 16.26$^{ab}$ | 12.10$^{ab}$ | 0.89$^{ab}$ | 3.11$^{b}$ |
| | S3 | 15.71$^{b}$ | 11.60$^{b}$ | 0.86$^{abc}$ | 3.30$^{ab}$ |
| Al Shyoukh | S1 | 17.07$^{a}$ | 12.40$^{ab}$ | 0.95$^{a}$ | 3.50$^{ab}$ |
| | S2 | 16.96$^{a}$ | 12.60$^{a}$ | 0.90$^{ab}$ | 3.25$^{ab}$ |
| | S3 | 16.35$^{ab}$ | 11.95$^{ab}$ | 0.86$^{abc}$ | 3.33$^{ab}$ |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site slope, mean for 9 soil samples with three different land uses.

The extractable soil calcium, magnesium, and potassium from Nuba, Halhoul, and Al-Shyoukh slopes soils were similar between the three slopes at the same site (Table 10). However, calcium content at Al-Shyoukh moderately slope (S2) soils were significantly higher than Halhoul moderately steep slopes (S3) soils. In addition to that, magnesium at Nuba moderately steep slope (S3) soils was significantly higher than Halhoul moderately slope (S2) soils.

Although, where as both Halhoul and Al-Shyoukh gently slopes (S1) soils, potassium were significantly higher than gently slopes (S1) at Nuba (Table 10). In addition, potassium at Halhoul and Al-Shyoukh moderately slope (S2) soil, was significantly higher than moderately slope (S2) at Nuba site.

Moreover, for potassium moderately steep slopes (S3) soils of Halhoul and Al Shyoukh, it had the same trend toward Nuba moderately steep slopes soils. It was clear that inside the same site (Nuba, Halhoul, and Al Shyoukh) slopes, potassium concentration increasing from moderately steep slope soils to moderately and gently slope soils, respectively. And according to Marx et al, (1999), all these soil have high level of calcium, magnesium, and potassium concentration.

### 3.2.2.4. Sodium and Sodium Adsorption Ratio

Data showed in table (11), that as other cations, inside the same site slope soils, the extractable soil sodium were similar, for example, at Nuba site slopes, Na at the three slopes were similar (0.20, 0.21, and 0.18 meq/100gm) for S1, S2, and S3, respectively. And for sodium adsorption ratio the results from the three slopes were statistically not significant (0.84, 0.89, and 0.79) for S1, S2, and S3, respectively. While Na at Al-Shyoukh gently slopes, (S1) soil was the highest and significantly different in comparison with Halhoul gently slopes.

Table 11: Means of soil sodium (Na (meq/100g)) and sodium adsorption ratio (SAR) in three sites and three slopes.

| Site | Slope | Na (meq/100g) | SAR |
|---|---|---|---|
| **Nuba** | S1 | $0.20^{ab*}$ | $0.84^{ab}$ |
| | S2 | $0.21^{ab}$ | $0.89^{ab}$ |
| | S3 | $0.18^{ab}$ | $0.79^{ab}$ |
| **Halhoul** | S1 | $0.17^{b}$ | $0.75^{b}$ |
| | S2 | $0.18^{b}$ | $0.77^{ab}$ |
| | S3 | $0.17^{b}$ | $0.75^{b}$ |
| **Al Shyoukh** | S1 | $0.22^{a}$ | $0.94^{a}$ |
| | S2 | $0.20^{ab}$ | $0.84^{ab}$ |
| | S3 | $0.20^{ab}$ | $0.88^{ab}$ |

*Means followed by the same letter in the same column are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site slope, mean for 9 soil samples with three different land uses.

### 3.3. Influence of land use on soil properties

### 3.3.1. Soil physical properties

#### 3.3.1.1. Soil texture

The soil texture analysis results for cultivated trees, range land, and arable land in the north aspect of three study sites are shown in table (12).

Table 12: Means of soil texture (Clay; Silt; and Sand %) between three land uses in each site:

| Soil particle distribution | Nuba land use | | | Halhoul land use | | | Al-Shyoukh land use | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cultivated trees | Range Land | Arable Land | Cultivated trees | Range Land | Arable Land | Cultivated trees | Range Land | Arable Land |
| **%Sand** | 32.1[a]* | 31.7[a] | 28.6[a] | 32.2[a*] | 30.6[a] | 28.3[a] | 38.1[a*] | 38.4[a] | 35.2[a] |
| **%Silt** | 32.1[a] | 29.4[a] | 37.1[a] | 39.4[a] | 41.3[a] | 39.0[a] | 38.7[a] | 37.7[a] | 45.7[a] |
| **%Clay** | 35.8[a] | 38.9[a] | 34.3[a] | 28.5[a] | 28.1[a] | 32.7[a] | 23.3[a] | 23.9[a] | 19.2[a] |

*Means followed by the same letter in the same row on each site land use are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site land use, mean for 9 soil samples with three different land slopes.

The results indicate that soil particles distribution is similar between the three land uses of Nuba site. The highest clay content was in range land (38.9 %) compared with cultivated trees (35.8 %) and arable land (34.3 %) without any significant difference. The same trend showed in Al-Shyoukh site, since the highest clay content in range land is (23.9 %) compared with (23.3 %, 19.3 %) in cultivated trees and arable land, respectively. But this trend differs in Halhoul, where the clay content in arable land (32.7 %) was the highest in comparison with cultivated trees and range land (28.5 %, 28.1 %), respectively, without statisticall differences.

Silt content has higher value in arable land (37.1%) in both Nuba and Al Shyoukh, respectively in comparison with other land uses in the same sites without any statistically difference. In addition, it has the lowest value in arable land (39.0%) in Halhoul site, without statistically difference compared with range land (41.3 %) which has the highest amount and cultivated trees (39.4 %) in the same site.

Nuba and Halhoul site had the same pattern of sand particle distribution, whereas cultivated trees had the highest value compare with range land and arable land without statistically difference. Similarily, sand content in arable land had the lowest in both site, Nuba and Halhoul (28.6 %, 28.3 %), respectively. The trend changed in Al Shyoukh, since the highest sand content value was in range land (38.4 %) in comparison with cultivated trees (38.1 %) and arable land (35.2 %) without statisticall differences.

### 3.3.1.2. Bulk density, mineral density and porosity

The results in (Table 13) show that the bulk density is statistically significant between the three-land uses of the three-study sites. The bulk density in range land is significantly higher than cultivated trees and arable land in the three sites.

For the mineral density, there were no significant difference between the three land uses in Nuba and Al-Shyoukh sites, since in Nuba, the higher value was in range land (2.72 $gm/cm^3$), and in Al-Shyoukh was in arable land (2.61 $gm/cm^3$). At the same time, the situation was different in

Halhoul, where the highest mineral density was in range land (2.68 gm/cm$^3$) with significant difference compared to cultivated trees (2.61 gm/cm$^3$), (Table 13).

Table 13: Means of soil bulk density, mineral density, porosity percentage and water content between three land use in each site:

| | Nuba land use | | | Halhoul land use | | | Al-Shyoukh land use | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Cultivated trees** | **Range Land** | **Arable Land** | **Cultivated trees** | **Range Land** | **Arable Land** | **Cultivated trees** | **Range Land** | **Arable Land** |
| **Bulk density (g/cm$^3$)** | 1.12$^b$ | 1.26$^a$ | 1.11$^b$ | 1.17$^b$ | 1.27$^a$ | 1.14$^b$ | 1.19$^b$ | 1.34$^a$ | 1.21$^b$ |
| **Mineral Density (g/cm$^3$)** | 2.68$^a$ | 2.72$^a$ | 2.67$^a$ | 2.61$^b$ | 2.68$^a$ | 2.66$^{ab}$ | 2.58$^a$ | 2.58$^a$ | 2.61$^a$ |
| **%Porosity** | 58.2$^{ab}$ | 53.4$^c$ | 58.3$^a$ | 55.3$^{ab}$ | 52.5$^c$ | 57.0$^a$ | 53.8$^a$ | 47.9$^c$ | 53.6$^{ab}$ |
| **%$H_2O$** | 6.4$^a$ | 7.0$^a$ | 6.8$^a$ | 5.9$^b$ | 7.1$^{ab}$ | 8.4$^a$ | 5.2$^a$ | 5.2$^a$ | 4.6$^a$ |

*Means followed by the same letter in the same row on each site land use are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site land use, mean for 9 soil samples with three different land slopes.

Porosity percentage has the same trend in Nuba and Halhoul, since in Nuba, arable land (58.3 %) was significantly higher than range land (53.4 %), as well as in Halhoul, arable land (57.0 %) was significantly higher than range land (52.5 %). But in Al-Shyoukh site, cultivated trees (53.8 %) was significantly higher than range land (47.9 %), which had the lowest porosity in Al Shyoukh.

### 3.3.1.3. Soil moisture content

Soil moisture content (Table 13) exhibited slight difference between land uses in Nuba and Al-Shyoukh sites without any statistically difference, since in Nuba, the measurements was (6.4 %, 7.0 %, and 6.8 %) for the three land uses (cultivated trees, range land, and arable land uses), respectively, and in Al-Shyoukh was (5.2 %, 5.2 %, and 4.6 %) for cultivated trees, range land, and arable land uses, respectively.

In Halhoul land use, data showed that soil moisture content was significantly higher in arable land (8.4 %) compared to cultivated trees (5.9 %).

## 3.3.2. Soil chemical properties

### 3.3.2.1. Organic carbon and organic matter percentage

Range land had the highest organic matter content in the three land uses within the three sites (Table 14). Nuba land use data showed that organic matter content (OM %) in range land (3.6 %) was significantly higher than cultivated trees (2.9 %) and arable land (2.5 %). Also, Halhoul land use data showed that organic matter content (OM %) in range land (3.3 %) was significantly higher than cultivated trees (2.2 %), which was the lowest value between the three land uses. Al-Shyoukh land use organic matter content exhibit statistically different in range land (2.6 %) compared to arable land (1.6 %),(Table 14).

Table 14: Means of (%$CaCO_3$, pH, EC (mmho*$cm^{-1}$), Organic Carbon percentage, Organic matter percentage) between three land use in each site:

| | Nuba landuse | | | Halhoul landuse | | | Al-Shyoukh land use | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cultivated trees | Range Land | Arable Land | Cultivated trees | Range Land | Arable Land | Cultivated trees | Range Land | Arable Land |
| **%Organic carbon** | 1.7$^{b}$ | 2.1$^{a}$ | 1.4$^{b}$ | 1.3$^{c}$ | 1.9$^{a}$ | 1.7$^{ab}$ | 1.1$^{ab}$ | 1.5$^{a}$ | 0.9$^{b}$ |
| **%Organic matter** | 2.9$^{b}$ | 3.6$^{a}$ | 2.5$^{b}$ | 2.2$^{c}$ | 3.3$^{a}$ | 2.9$^{ab}$ | 1.9$^{ab}$ | 2.6$^{a}$ | 1.6$^{b}$ |
| **pH** | 7.29$^{a}$ | 7.23$^{a}$ | 7.34$^{a}$ | 7.29$^{a}$ | 7.3$^{a}$ | 7.32$^{a}$ | 7.42$^{a}$ | 7.38$^{a}$ | 7.54$^{a}$ |
| **EC (mmho*$cm^{-1}$)** | 1.21$^{b}$ | 1.58$^{a}$ | 1.13$^{b}$ | 1.008$^{a}$ | 1.257$^{a}$ | 1.186$^{a}$ | 0.85$^{a}$ | 0.84$^{a}$ | 0.70$^{a}$ |
| **%$CaCO_3$** | 32.0$^{a}$ | 31.5$^{a}$ | 31.8$^{a}$ | 24.7$^{a}$ | 26.1$^{a}$ | 38.8$^{a}$ | 28.7$^{a}$ | 20.5$^{a}$ | 24.6$^{a}$ |

*Means followed by the same letter in the same row on each site land use are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site land use, mean for 9 soil samples with three different land slopes.

Organic carbon content in range land at Nuba land use (2.1 %) was significantly higher than cultivated trees (1.7 %) arable land (1.4 %). In Halhoul organic carbon of range land (1.9 %) was significantly higher than cultivated trees (1.3 %), which was the lowest value between the three lands. For the organic carbon of range land (1.5 %) in Al-Shyoukh land use, it was significantly higher than arable land (0.9 %).

### 3.3.2.2. pH, calcium carbonate and electrical conductivity

The pH values exhibit slight variability under different land uses in the three sites (Table 14). The higher values of pH were in arable land in all land uses without statistically difference. According to Marx et al, (1999) the soil is classified as neutral to moderately alkaline soils in Nuba and Halhoul land uses, and moderately alkaline soils in Al-Shyoukh land use.

Calcium carbonate content showed the same trend between the land uses of Nuba and Al Shyoukh, since the highest content was in cultivated trees and the lowest in range land, without statistically difference between land uses. In Halhoul the higher value was in arable land and the lower value in cultivated trees.

The electrical conductivity value was higher in Nuba and Halhoul land use in comparison with Al-Shyoukh land use (Table 14). Electrical conductivity of range land (1.58 mmhos/cm) in Nuba land use was significantly higher than cultivated trees (1.21 mmhos/cm) and arable land (1.13 mmhos/cm). According to Marx et al, (1999) these soils have medium electrical conductivity.

### 3.3.2.3. Cation exchange capacity, calcium, magnesium, and potassium

Cation exchange capacity data showed that, there were no statistically difference between Nuba, Halhoul, and Al-Shyoukh land uses (Table 15). However, Nuba and Al-Shyoukh land uses show the same trend, since arable land had the highest value of cation exchange capacity compared with cultivated trees and range land.

Table 15: Means of (cation exchange capacity, calcium, magnesium, potassium) between three land use in each site:

| | Nuba landuse | | | Halhoul landuse | | | Al-Shyoukh land use | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Cultivated trees** | **Range Land** | **Arable Land** | **Cultivated trees** | **Range Land** | **Arable Land** | **Cultivated trees** | **Range Land** | **Arable Land** |
| **CEC (meq/100g)** | 16.61[a] | 16.47[a] | 16.95[a] | 16.22[a] | 16.12[a] | 16.07[a] | 16.66[a] | 16.33[a] | 17.36[a] |
| **Ca (meq/100g)** | 12.17[a] | 12.2[a] | 12.43[a] | 12.16[a] | 11.72[a] | 11.93[a] | 12.02[a] | 12.30[a] | 12.62[a] |
| **Mg (meq/100g)** | 3.52[a] | 3.44[a] | 3.47[a] | 3.24[a] | 3.27[a] | 3.08[a] | 3.55[a] | 3.0[c] | 3.50[ab] |
| **K (meq/100g)** | 0.738[a] | 0.646[a] | 0.823[a] | 0.941[a] | 0.867[a] | 0.89[a] | 0.894[ab] | 0.81 8[b] | 0.998[a] |

*Means followed by the same letter in the same row on each site land use are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site land use, mean for 9 soil samples with three different land slopes.

The extractable soil *Calcium* values from Nuba, Halhoul, and Al-Shyoukh land uses were not statistically different between types of land uses (Table 15). However, Nuba and Al-Shyoukh land uses type, had the same trend, since calcium of arable land use had the highest concentration compared to range land and cultivated trees.

The extractable soil *magnesium* and *potassium* between the three land uses in Nuba and Halhoul, did not statistically difference. In contrast with magnesium of Al-Shyoukh land use type, since in cultivated trees (3.55 meq/100 g) it was significantly higher than range land 3.0 meq/100 g), also for potassium of arable land (0.998 meq/100 g), which was significantly higher than range land (0.818 meq/100 g)- (figure 16).

And according to Marx et al, (1999) the soils of Nuba, Halhoul, and Al-Shyoukh land uses have high level of calcium, magnesium, and potassium concentration.

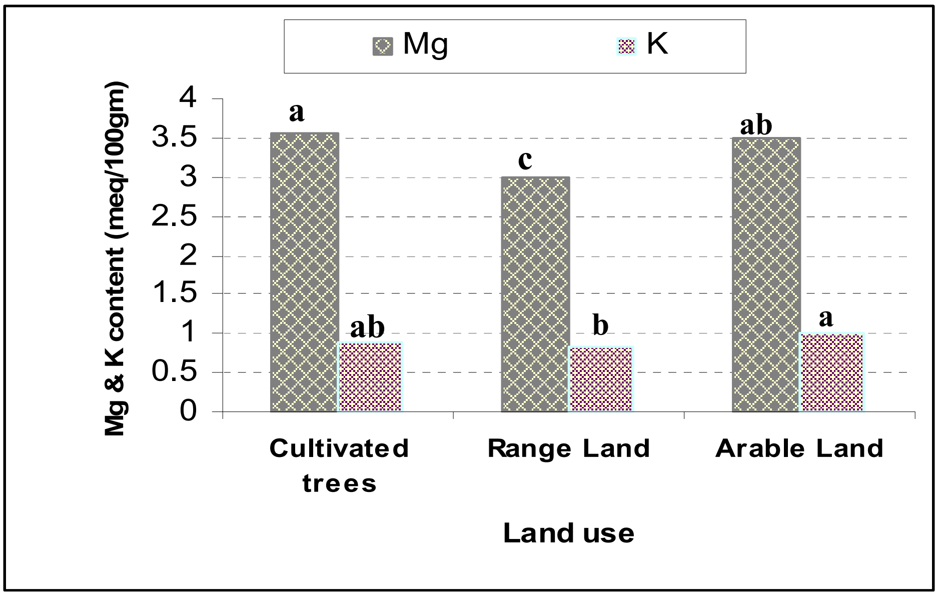



Figure 16: Means of soil content of Mg and K in Al-Shyoukh Land uses.
- Columns followed by the same letter are not significantly different, according to Fisher LSD test at p ≤0.05.
- In each site land use, mean for 9 soil samples with three different land slopes.

### 3.3.2.4. Sodium and Sodium Adsorption Ratio

The extractable soil *sodium* values of the three land uses in Nuba, Halhoul, and Al-Shyoukh did not statistically difference (Table 16). Moreover Nuba and Al-Shyoukh land use types, showed the same trend, since sodium of arable land use had the highest values compared with range land and cultivated trees. In contrast with Halhoul land use types, sodium of range land use (0.190 meq/100 g) had the highest value compared with arable land (0.169 meq/10 g) and cultivated trees (0.157 meq/100 g). For sodium adsorption ratio, the results of the three land use types have the same orientation of sodium.

Table 16: Means of sodium and Sodium Adsorption Ratio between three land use in each site:

| | Nuba landuse | | | Halhoul landuse | | | Al-Shyoukh landuse | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cultivated trees | Range Land | Arable Land | Cultivated trees | Range Land | Arable Land | Cultivated trees | Range Land | Arable Land |
| **Na (meq/100g)** | 0.183[a] | 0.189[a] | 0.228[a] | 0.157[a] | 0.190[a] | 0.169[a] | 0.184[a] | 0.207[a] | 0.228[a] |
| **SAR** | 0.789[a] | 0.815[a] | 0.976[a] | 0.68[a] | 0.83[a] | 0.74[a] | 0.796[a] | 0.898[a] | 0.966[a] |

*Means followed by the same letter in the same row on each site land use are not significantly different, according to Fisher LSD test at $p \leq 0.05$.
*In each site land use, mean for 9 soil samples with three different land slopes.

## CHAPTER FOUR

# 4. Discussion

### 4.1. Soil Physical properties

#### 4.1.1. Soil texture

Results of soil texture analysis (Table 2) showed that Nuba and Halhoul sites, have more clay content (36.8 % and 30.1 %, respectively) and less sand content (31.7 %, 30.1 %), respectively) than Al-Shyoukh site (22 % for clay and 37.40% for sand). Such difference express the change in the intensity of the chemical weathering, which mainly controlled by the long term influence of the different amount of precipitation along a climatic transect, which transferred from semi arid – semi humid to moderately arid – semi arid zones in Mediterranean region. This agrees with Zehetner and Miller (2006), Al-Seikh (2006), who found that, soils show significant variations along the studied climatic gradient. Also as Sarah (2004) reported that clay content in the soil increases from about 10% in the arid zone to about 50% in the Mediterranean zone. Although, the history of land use and the long term effect of the land degradation process as runoff and soil erosion which considered the main reasons affected the particle size distribution (Al-Seikh, 2006). In addition, higher clay content especially in Nuba site might be due to the site morphology, since it considered lower land compared to Halhoul and Al Shyoukh, which is affecte by soil depositional process at this site.

Al-Kharabsheh (2004) reported that surface runoff varied according to rainfall amount, intensity, and duration and soil moisture content. So the importance of soil texture as a fundamental property affecting many processes in the soil environment is widely recognized. It has been adopted as a central variable in scientific soil classification systems, including the “fertility capability soil classification” (Sanchez et al., 2003).

Schlecht, et al., (1994) found that increased clay contents were associated with increased aggregation or aggregate stability. In increasing soil aggregation, soil clay content indirectly affects soil carbon storage by occluding organic materials, making them inaccessible to degrading organisms and their enzymes. Therefore, soil texture (particularly soil clay content) plays direct and indirect roles in chemical and physical protection mechanisms (Alain et al. 2006).

The results of soil texture analysis (Table 7) indicate that clay content between the three slopes, gently (S1), moderately (S2), and moderately steep (S3) inside the same site at Nuba and Halhoul is general similar. Nevertheless, this trend was different in Al Shyoukh, since clay content in S3 was significantly higher in comparison with S1 and S2, which may be due to eroding clay from upper parts to lower parts.

No significant difference in sand content at S1, S2, and S3 inside the same site at Nuba and Halhoul, whereas, sand content at Al-Shyoukh moderately slopes (S2) was significantly higher than moderately steep slopes (S3), since (S3) is upper slopes and runoff processes are dominant in such attribute. The trends for higher sand contents in the moderately slope positions to some extent is in concurrence with the result of Franzmeier et al. (1969) study which reported that on the mid-slope positions the soils were coarser than those above or below, sand particles are relatively loosely aggregated, they are too heavy to be transported down the slope unless sufficient velocity of water is applied which is however not attained due to high infiltration rate. Surface sealing and low infiltration rate are the main reasons for runoff initiation and for sediment transport (Mamedov et al., 2000).

Sand, silt, and clay contents did not exhibite any significant difference between the three land uses (cultivated trees, range land, and arable land) inside the three sites, Nuba, Halhoul, and Al-Shyoukh (Table 12). Since such difference may be more visible if the soil samples were collected from deep soil, as a result of transportation of clay particles from surface to subsurface soil, which make the sub soil has more clay content because of tillage and cultivation processes.

### 4.1.2. Bulk density, mineral density and porosity

The results in table (3), show that, the bulk density in Al-Shyoukh (1.25 $gm/cm^3$) was significantly higher than Halhoul (1.20 $gm/cm^3$) and Nuba (1.17 $gm/cm^3$). This may due to the lowest clay content (22 %) and organic matter (2 %) at Al Shyoukh.

The bulk density of the soil mainly related to soil texture, organic matter, organic carbon content, and soil management, when the values of clay, organic matter, organic carbon content were higher, this lead to lower bulk density and higher porosity and vice versa. And this agree with Wilcox et al., (1988), who found that increases the soil organic carbon content, reduces bulk density, and increases hydraulic conductivity (Balliette et al., 1986). The increase in soil organic carbon may enhance biological activity, which in turn results in increased porosity and therefore decreased bulk density (Kay, 1998).

The soil bulk density did not differ significantly in Nuba and Halhoul, it is worth mentioning, that soil with high bulk density indicate very poorly physical condition, especially for plant growth, and this soil are very compacted with moderately pore space, also the infiltration rate will be very low.

Jiang et al. (2007), mentioned that, among landscape positions, bulk density was the highest at the foot-slope position. This agree with our results in Halhoul and Al Shyoukh, since the highest bulk density was measured in Al-Shyoukh gently slopes (S1) (1.28 g/cm$^3$) in comparison to moderately (S2) (1.26 g/cm$^3$), and moderately steep (S3) (1.21 g/cm$^3$) slope in the same site. Also in Halhoul gently (S1) and moderately (S2) slope in comparison with moderately steep (S3) slopes. Since Al-Shyoukh moderately steep (S3) slopes had higher clay content (26 %) and higher organic matter content (2.3 %) compared with gently (S1) and moderately (S2) slopes. In Halhoul moderately steep slope (S3), had the lowest bulk density (1.9 g/cm$^3$) compared to gently (S1) and moderately (S2) slopes, due to higher organic matter content. The effects of clay and organic matter content on bulk density were not visible between Nuba slopes. Generally, the relation between bulk density, clay content and organic matter content according to slope slope at the three sites was evidently shown, since as clay and organic matter content increase, bulk density decrease.

Bulk density is a dynamic property that varies with the structural condition of the soil (Daraghmeh et al., 2008). This condition can be altered by cultivation; trampling by animals; agricultural machinery; and weather; i.e., raindrop impact (Arshad et al., 1996). Compacted soil layers have high bulk densities, restrict root growth, and inhibit the movement of air and water through the soil (Arias et al., 2005).

In the three sites (Nuba, Halhoul, and Al Shyoukh) soil bulk density showed different variability between range land, cultivated trees, and arable land uses (Table 13). The bulk density in range land, which used for grazing, is significantly higher than cultivated trees and arable land in Nuba, Halhoul, and Al-Shyoukh (1.26, 1.27, and 1.34 $gm/cm^3$) respectively, compared to cultivated trees (1.12, 1.17, and1.19 $gm/cm^3$) and arable land (1.11, 1.14, and 1.21 $gm/cm^3$). This could be related to intensity and frequency of grazing, since high bulk density of the top horizon in the overgrazed range site may be resulted from soil compaction due to extreme compaction by heavy grazing. In accordance with that, clay content in Nuba was the highest in range land uses (38.91 %) compared with the other uses, and in range land at Halhoul study site has high clay (28.1), and Al-Shyoukh range land uses (23.94 %). Stephenson and Veigel (1987) indicate that increasing the stocking rates increasing the bulk density. On the other hand, Van Haveren (1983) found that the degree of soil compaction depend on the texture of the soil as will as on the soil moisture at the time of grazing and on the level of organic matter in the surface soil. Grazing is the most economical way of evaluating range land vegetation. But, overgrazing or uncontrolled grazing always reduces plant cover that protects the soil and finally causes soil erosion and compaction (Oztas et al. 2000). Overgrazing and its attendant effect of depletion of plant cover and litter and trampling of the soil is the most important factor contributing to erosion (Branson et al. 1981). Livestock affects soil properties by trampling which compacts the soil and increases bulk density (Trimble and Mendel, 1995); and Herbivors which reduce plant cover (Coughenour, 1991). However, soil bulk density, and soil structure are sensitive to the soil formation factors and land management factors (Rezaei et al., 2005 a).

The porosity of the soil mainly related to soil texture and organic matter content, when the values of clay and organic matter content was higher, this lead to get higher porosity. Between the three sites, the relation between porosity percentage and bulk density is inverse, as porosity increases bulk density decrease. Figure (11) shown that, generally mineral density of soils are positive related to porosity this may be due to clay mineralogy which exist. The role of clay content and organic matter content with their effect on porosity and mineral density was clear between sites, since Nuba site, which has high content of clay (36.8 %) and has a significant difference compared to Halhoul and Al Shyoukh, also it had higher porosity and mineral density with significant difference compared to the two other sites.

Results showed that, the relation between porosity percentage and mineral density is positively, as porosity increases mineral density increase which shown by figure (14). In addition to that, as clay content increasing, the porosity percentage increase, since Nuba (2.69 $gm/cm^3$) and Halhoul (2.65 $gm/cm^3$) had the higher mineral density in comparison to Al-Shyoukh (2.59 $gm/cm^3$) (Table 3). In the same context, these results interpreted through the fact that, clay content and organic matter had the same trend between the three sites, which play the major role in mineral density values. Gently (S1), moderately (S2), moderately steep (S3) slopes had similar values at the same site without statistically different (Table 8).

Mineral density in range land at Nuba and Halhoul (2.72 $gm/cm^3$, 2.68 $gm/cm^3$ ), respectively, had the higher value compared to cultivated trees and arable land as a result of high clay and organic matter content. At the same context, the situation was different in Al Shyoukh, wherever the highest mineral density was in arable land (2.61 $gm/cm^3$) compared with cultivated trees and range land (Table 13). This might be as a result of high silt content compared to other land use, and in addition to effect of sodium, since arable land had the higher value of sodium content in comparison to cultivated trees and range land.

On the other hand, porosity percentage at Nuba slopes increased as slope decreases. The footslope position receives runoff water, lateral flow, and seepage from upper slope positions with eroded fine particles, so from the data on table (8), the clay and silt percentage at Nuba gently (S1) slope higher than moderately (S2) and moderately steep (S3) slopes. And these types of slopes are more stable than S2 and S3 related to degradation processes. This might be the reason for higher porosity and mineral density in S1 compared to S2 and S3. However, the data did not exhibit statistically different between the three slopes inside the same site.

In Nuba, Halhoul and Al-Shyoukh land uses, porosity in range land were lowest and had statistically different compared to cultivated trees and arable land, this agree with Breland and Hansen (1996), who observed that, compaction reduces the total soil porosity and alters pore size distribution, favoring a rise in the percentage of smaller pores, in which organic material can be physically protected from microbial action. So, disturbances of grazing and trampling by livestock lead to soil compaction due to extreme pressure by heavy grazing.

### 4.1.3. Soil moisture

Soil moisture is one of the primary limiting factors for plant growth in semiarid regions. However, variability and the change in soil moisture content were measured for the soil samples in each site, land use and slope, the spatial and temporal variability of soil moisture result from the effect of different topography, soil type, vegetation and land use (Fu. et al., 2003; Al-Kharabsheh 2004; Sarah, 2004, Al-seikh, 2006, Adam, 2007).

Soil moisture content in Halhoul site was significantly higher than Al-Shyoukh site, water content in Nuba hasn't statistically different compared to Halhoul (figure 12). This might be due to geomorpholigical nature of the study sites since Nuba site located on the western slopes of the West Bank and Halhoul which located on the Central Hights of the West Bank, most of the rainfall reached western slopes from west side before reach the central hights, also Halhoul site is higher in elevation than Nuba site, so runoff water may goes to the down area of Nuba. In addition to that, these results might be due to high amount of precipitation in Halhoul (figure 5), in addition Halhoul is located in semi-arid Mediterranean which have low amount of evapotranspiration compared to Al Shyoukh, which represent the moderately arid-semi-arid climate. Moreover Halhoul have more vegetation cover. In addition, the high clay content and organic matter content in Halhoul might be another reason related to high moisture. This agrees with Slave and Allen-Diaz (2001), who found that soil moisture increases as clay content increase. Also, moisture content at Nuba site was significantly higher than Al-Shyoukh site, this may be due to the same reasons, rainfall, clay content, and organic matter, with the same explanation that there are a high correlation exists between climatic conditions and pedo-geomorphic variables (such as organic matter content, aggregate stability and soil moisture) and processes (such as infiltration and overland flow), (Lavee H. and Sarah P. 2009). However, some researchers (Calvo-Cases et al., 2005) have indicated that the variability in climate pattern has consequences for the eco-geomorphological system of hillslopes (defined as the integrated system of climate, soil, water, vegetation and erosion), soil water–plant relationships and soil surface properties.

Soil moisture content at Halhoul gently slopes (S1) were significantly higher than moderately (S2) and moderately steep (S3) slopes (Table 8). This agree with Mlot (1990) who mentioned that hilltops and slopes tend to have less organic matter and moisture than valleys and flat areas because water carries these nutrients downhill. These results might be due to high clay content at gently slopes (32.6 %) in comparison to moderately and moderately slopes, since clay particles have large surface area and a high power of water holding capacity. Generally, the capacity of landscapes to store water is related to soil texture (Ludwig et al., 2005). Although, sandy or coarse-textured soils have higher infiltration rates but lower ability to retain moisture than clayey or fine textured soils. In the same context, landscape position directly affected water storage (Tomer et al., 2006) and interacted with management to affect spatial water redistribution (da Silva et al., 2001). In a cropped soil landscape, da Silva et al. (2001) found that soil moisture was significantly affected by the spatial distribution of clay content and organic matter along a slope under different tillage systems. However, the footslope position receives runoff water, lateral flow, and seepage from upper slope positions. Soil at the footslope positions may remain wetter for more extended time periods (Jiang et al., 2007).

Soil moisture content at arable land in Halhoul site was significantly higher than cultivated trees land use (Table 13). These results might be due to higher clay content (32.7 %) and higher porosity (57 %), since clay can absorb more water has high retention. Also, cultivated land use exposed to intensive farming practices like ploughing and cleaning which expose soil surface to aeration that lead to loos moisture from the soil surface, but in arable land use, soil surface ploughed one time at the beginning of planting seasone, and after harvesting crop residues remain on the surface which prevent water evaporation and save soil moisture from loosing. On the other hand, soil moisture content at range land and arable land uses has the highest value compared to cultivated trees, this might be due to high amount of organic matter in range land and arable land (3.3 %, 2.9 %), respectively, compared to cultivated trees (2.2 %), since organic matter increase the efficiency of the soil to capture the water in the soil for long time. In addition, soil physical properties may change with the loss of organic matter. Bowman et al. (1990) measured lower water content at field capacity and lower cation exchange capacity associated with the loss of organic matter. In accordance with land use, these agree with Parienteh (2002), Al-Seikh (2006), and Fu et al. (2004), who mentioned that in the shrub area, the soil water content is relatively higher than in cultivated and grass site.

## 4.2. Chemical properties

### 4.2.1. Organic carbon and organic matter percentage

According to Marx et al., (1999) accurate measurement of soil organic matter is difficult. The analysis of three sites show that, the higher amount of organic matter content were measured in Nuba and Halhoul site (3 %, 2.8 %), respectively which significantly different compared to Al-Shyoukh site (Table 4), this is explained by the difference in climatic zone, since from arid to semi arid, organic matter content increase due to the vegetation characteristics and microorganism activities. This results agree with Sarah (2004) and Al-Seikh, (2006) results where they found that the organic matter increases from arid zone to Mediterranean zone. On the other hand, Khresat et al., (1998) reported that organic matter content increased as the precipitation increased, as will as the clay content and vegetation cover increase.

It is necessary to mention that soil structure and soil organic matter concentration are among the most dynamic properties of soil, and depend on land use and management (Blanco-Canqui and Lal, 2004). Also, dissolved soil organic matter behaves differently in different climates ( Zech et al., 1997). On the basis of these observations, we would expect inverse relationship between soil erodibility with, texture and organic matter.

Therefore, knowledge of aggregate stability is useful in the evaluation of soil properties with regard to degradation processes and land use systems. So factors such as soil organic matter and clay content can also affect aggregate stability (Victor et al., 2006). Since, clay content at Nuba and Halhoul higher than Al-Shyoukh site. However, the organic matter contents of arid and semiarid region, are low, and aggregate stability in such soils is not highly correlated with organic matter content (Levy et al., 2003), but positively correlated with clay content (Boix-Fayos et al., 2001; Levy et al., 2003).

Also soil structure is nominated as a key soil property because of its critical role in soil water dynamics, plant growth and development, and the suitability of habitat for soil biota. Soil structure dynamics therefore influences hydraulic properties (Daraghmeh et al., 2008), agricultural productivity and environmental impact at the catchment scale, and vice versa (Southorn and Cattle, 2004). According to Bronick and La1 (2005), soil structure exerts important influences on the edaphic conditions and environment. It can be significantly modified through management practices and environmental changes. Soil structure and aggregation are strongly influenced by processes such as tillage, cropping system and climate (Guerif et al., 2001; Daraghmeh et al., 2009). So soil organic matter accumulation improves soil quality and fertility and contributes to sequestration of carbon (Mikha and Rice, 2004).

Organic matter content withen the same site had no statistical difference between the three slopes, and in each site, organic matter content at moderately steep slopes (S3) were higher than gently (S1) and moderately (S2) slopes (Table 9), these results may be due to the fact that moderately (S2) to moderately steep slopes (S3) usually used for grazing with the consequent addition of animal manure.

Also for organic carbon content, which had the same trend at all sites and the three slopes. In general, from our data, a strong and expected positive correlation was observed between clay and water content and also between clay and organic matter and negative between clay and pH. This agree with Bosatta and Agren (1997), who found that soil organic matter content is often positively correlated with the clay content of the soil. Although, textural composition moderates the behavior of several soil processes, including soil organic matter dynamics and carbon sequestration (Kettler et al., 2001).

Physical fractionation of soil particles into size and density classes can provide information on the importance of interactions between organic and inorganic soil components and the turnover of soil organic matter (Christensen, 2001). The degree of association of soil organic carbon with particle sizes is a qualitative indicator of the impact of land use and soil management. The soil organic carbon associated with the coarse fraction is commonly less decomposed material and has a higher C/N ratio than that associated with the fine fraction. In contrast, soil organic carbon adsorbed to clay is mostly of humic nature with a low C/N ratio (Christensen, 2001).

Farming practices affect soil organic carbon concentration and physical properties (Hao et al., 2001). Our results show conformity with what mentioned above, since the lowest organic matter content in the three sites was found in arable land and cultivated trees, both are cultivated land (Table 14). In Nuba land uses, the range land organic matter content and organic carbon percentage were significantly higher than cultivated trees and arable land uses, which subjected to farming practices like ploughing and cleaning, this agree with Vance (2000), who found that, tillage operations disrupt soil structure and accentuate soil organic matter oxidation by increasing aeration, which stimulates microbial activity. In contrast, conservation tillage or no-till have less deleterious effects on soil structure, and maintain or increase soil organic carbon concentration (Lal and Kimble, 1997).

The same trend was found in Halhoul land uses, since the data show that organic matter content in cultivated trees (2.2 %) was significantly lower in comparison with range land uses (3.3 %) and arable land uses (2.89 %) (Table 14). Organic matter in cultivated trees soils had less physical protection than that in range land and arable land soils because of removal of large quantities of biomass during extensive land ploughing and clearing, a reduction in the quantity of organic inputs to the soil and increasing soil organic matter decomposition rates. These decomposition rates are due to enhance biological activities by tillage practices, break up macro-aggregate and exposes soil organic matter to decomposition (Dunjo et al., 2003). Also tillage disrupts soil aggregates and decreases soil organic matter (Plante and McGiII, 2002).

According to Six et al. (2000), soil disturbance by tillage is a major cause of organic matter depletion and reduction in the number and stability of soil aggregates when native ecosystems are converted to agriculture. Also Six et al. (2000) reported that cultivation reduces soil carbon content and changes the distribution and stability of soil aggregates.

In Al-Shyoukh site, the highest organic matter content was measured in range land uses (2.6 %) and significantly difference with arable land uses (1.56 %), and there were a difference with cultivated trees uses (1.88 %), but not statistically difference. In Al Shyoukh, the range land is considered as natural vegetation which dominated with *S. spinosum*; in this case the organic matter is high probably due to the dominance of the shrubs, which increase the amount of organic matter by adding and decomposition of plant litter. Similar results obtained by Al-Seikh (2006) and Adam (2007), who found that organic matter content in the shrub land dominated with *S. spinosum* was the highest compared with other treatment. In addition to that, significantly higher organic matter in range land uses might be explained by the vegetation types (shrubs), which increase the amount of organic matter by creating suitable climatic condition, deposition material, and protecting the area from the effects of erosion (Xie, and Steinberger, 2001; Casermeiro et al., 2004). However, in other land uses, the content of organic matter is lower due to the fact that cultivated land has lower organic matter as a result of ploughing, in addition to that, during cultivation practices most of the vegetation cover was cleared and removed which is the source of the organic matter. Similar results also found by (Adam 2007, Al-Seikh 2006 and Fu et al. 2004), where they found that in cultivated land the amount of organic matter was lower than that in natural vegetation.

The same trends, occurred for the organic carbon which has significantly different between the three land uses, cultivated trees, range land , and arable land in the three sites, also when comparing the results between the sites (Table 14). As the farming practices increase, the organic carbon decrease, this result agree with McVay et al. (2006), they found in no-till systems has the potential to increase organic carbon in the soil profile both by increasing carbon additions to the system and by decreasing oxidation caused by tillage. In cultivated land, manuring increases the carbon input to soil and consequently enhances soil organic carbon concentration (Jarecki and Lal, 2003).

Also, soil organic carbon concentrations and soil texture probably influenced aggregate stability. The magnitude of soil disturbance and the amount of residue incorporated into the soil impact aggregates and the associated carbon pool (Blanco-Canqui and Lal, 2004).

### 4.2.2. pH, calcium carbonate and electrical conductivity

Soil pH is an important parameter, where the extreme values affected the solubility of most elements necessary for plant growth. According to Marx et al. (1999) soil pH in the three sites was not extreme and within the range for optimal plant growth and it is classified neutral to moderately alkaline.

In Al-Shyoukh site pH value (7.44) was significantly higher than Halhoul site (7.3) and Nuba site (7.28). These results may be due to the type of climate and organic matter content, since Al-Shyoukh had less annual precipitations and organic matter content compared to Nuba and Halhoul. However, this might be related to low soil moisture and low amount of organic matter (Rezaei et al. 2005), and there are high correlation exists between climatic conditions and pedo-geomorphic variables (such as organic matter content, aggregate stability and soil moisture) and processes (such as infiltration and overland flow) (Lavee H. and Sarah P. 2009). So at sites with high rainfall, the carbonates may even be entirely leached from the soil profile (Yaalon, 1982; Retallack, 1994). Even in Halhoul site the rainfall is higher than Nuba, the pH value in Halhoul was higher than Nuba site, and this may be due to the higher percent of organic matter in Nuba site. According to Marx et al, (1999) the soils at Halhoul and Nuba slopes have medium electrical conductivity and soils of Al-Shyoukh slopes have low electrical conductivity.

In Nuba and Halhoul slopes, pH values (Table 9) close together in the three slopes and in all slopes it was neutral (Marx et al. 1999). But Al-Shyoukh slopes had moderately alkaline soils, soil pH was higher in Al-Shyoukh slopes, this may be due to the nature of climate which found in Al-Shyoukh with low rainfall, and aridity factors which exist in the study site. In general, data showed that soil pH increasing while organic matter decreasing (figure 15), this may due to the fact that organic matter contain carboxylic and phenolic groups which behave as weak acids by releasing $H^+$, in addition to organic and inorganic acids which formed from organic matter mineralization that provide $H^+$ to the soil. The same trends in pH values occurred between land use, since the pH in Al-Shyoukh land use was the higher compared to Nuba and Halhoul land uses without statistically difference (Table 14).

Dissolution and redistribution of carbonates tradeoff govern the level of soil carbonates in a wide variety of soil types, and has been considered an important soil shaping process in Mediterranean soils (Yaalon et al., 1966; Yaalon, 1996). The results which present in (Table 4), showed that soil calcium carbonate is relatively similar in the three sites with out any statistically difference and the soils were calcareous. This might be because of soil in all the three sites derived from carbonate – rich rocks. Lithological parent materials with calcite and/or dolomite are usually the initial source of soil carbonates. However, Rubio and Escuderos (2005) found that the most relevant factors for the occurrence of carbonate loss are a combination of slope, aspect and latitude and an estimated climatic demand for water depending on temperatures and several soil forming factors mainly related to water availability are responsible for this process.

Our results indicate that the most relevant factors for the occurrence of carbonate loss are a combination of slope, aspect and latitude and an estimated climatic demand for water depending on temperatures (annual potential evapotranspiration) (Rubio and Escudero, 2005). However, data showed (Table 9) that calcium carbonate content at Nuba and Halhoul slopes were higher than Al-Shyoukh slopes. This might be due to tillage practices on the surfaces which mixed the subsurface with surface soil. Calcium carbonate content at Halhoul moderately slopes (S2) were significantly higher than gently (S1) slopes. This might be due to $CaCO_3$ content was higher at the top and upper slope positions compared to positions down the slope. Differences in pH were very small and insignificant (Wezel A. 2006). The results which present in (Table 14), showed that soil calcium carbonate had relatively similar content in the three land uses with out any statistically difference between the three sites.

Nuba site soils electrical conductivity were significantly higher than Halhoul and Al-Shyoukh sites (Table 4), this is because greater soil porosity, clay and silt content in Nuba soils compared to Halhoul and Al Shyoukh, the more easily electricity is conducted. Soil with high clay content has higher porosity than sandier soil (Tom, 1999). This agree with Mucller et al. (2003), who mentioned that electrical conductivity was significantly positively correlated with clay content, in contrast, EC was negatively correlated with silt content.

Data showed in table (9) that soil electrical conductivity at Al-Shyoukh and Halhoul had no statistically different between the three slopes, gently (S1), moderately (S2), and moderately steep (S3) slope. But soil electrical conductivity of moderately steep (S3) values at Nuba were statistically different compared to moderately (S2) due to high clay and low silt content. Since, physical contact between soil particles allows for higher electrical conductivity and is known to be greater with clay than with sand- or silt-sized particles (Corwin and Lesch, 2003).

For the land use the electrical conductivity has range from low to medium in all sites, in Halhoul and Nuba it was medium. An electrical conductivity value was higher in Nuba and Halhoul land use in comparison with Al-Shyoukh land use (Table 14) as a result of higher clay content at Nuba and Halhoul land use. Electrical conductivity of range land in Nuba land use was significantly higher than cultivated trees (1.21 mmhos/cm) and arable land (1.13 mmhos/cm) this may due to high clay content and low silt in comparison to cultivated trees and arable land uses. Since clays greatly impact electrical conductivity because of their exchangeable cations and the water film associated with them (McNeill 1980). In addition to excreted salts on the grazing animal urine.

### 4.2.3. Soil exchangeable cations and cation exchange capacity

Parent material composition strongly influences soil and soil-solution chemistry (Hornung et al., 1990), which in turn regulates soil fertility. In particular, the nutrient status of a soil largely depends on its pool of exchangeable base cations (Reynolds et al., 1988).

The most common cations in arid and semi-arid areas are calcium, magnesium, and sodium. Each of these cations is base-forming, meaning that they contribute to an increased $OH^-$ concentration in the soil solution and a decrease in $H^+$ concentration. They typically dominate the exchange complex of soils, having replaced aluminum and hydrogen. Soils saturated with calcium, magnesium, and sodium has a high base saturation and typically high pH values (Miller and Donahue, 1995). For that reason, the study sites with different slopes and land uses show high values of calcium, magnesium, and potassium.

Cation exchange capacity had no statistically difference between the three sites, with higher value at Al Shyoukh. Data showed that Al-Shyoukh had the highest content of calcium, potassium, and sodium content, which have more arid than Halhoul (Table 5). This might be the reason for this trend, in addition to high pH at Al Shyoukh, since soil pH is important for cation exchange capacity because as pH increases, the number of negative charges on the colloids increase, thereby increasing cation exchange capacity, even though Al-Shyoukh had low clay and organic matter content..

Generally, cation exchange capacity at the three sites slopes were similar (Table 10). Moderately slope (S2) at Nuba had the highest cation exchange capacity, this may due to higher pH in comparison to gently (S1) and moderately steep (S3) slopes. Also at Halhoul slopes, the highest cation exchange capacity are recorded in gently (S1) slopes, this may be due to high clay content compared to other slopes (S2, S3). Although, in Al-Shyoukh slopes, gently (S1) slopes had the highest cation exchange capacity with high content of calcium, potassium, and sodium content which reflect low weathering processes.

Cation exchange capacity data showed that, there were no statistically difference between Nuba, Halhoul, and Al-Shyoukh land uses Nuba (Table 15). However, arable land at Nuba and Al-Shyoukh had the highest cation exchange capacity in comparison with cultivated trees and range land uses, since both had high content of calcium, potassium, and sodium content, in addition to high pH at this type of land use. In the contrary, cultivated trees at Halhoul had higher cation exchange capacity compared to range and arable land uses, this may due to high calcium and potassium content, and extensive farming practices such as fertilization.

In Al-Shyoukh land uses the higher amount of Mg in cultivated trees which has a significant different compared to range land, this result may due to addition of fertilizers and type of parent materials which subjected to low weathering to consist this soils. The same reason for the significant different of potassium in arable land at the same site compared to range land.

Between the sites, extractable sodium at Al-Shyoukh was the highest and has significance difference compared to Halhuol, this might be related to low weathering which related to type of climat in Al Shyoukh. And as a result of nearby Al-Shyoukh to the eastern highest and Jordan valley which has a unique characteristics, since Jordan valley was covered with the sea water thousand of years ago, and lacustrine was the dominant parent material (Land Research Center, 1999). Therefore, sodium can accumulate in areas inundated by seawater, in arid areas where salts naturally accumulated (Bohn et al. 1979). Thus, soil dispersion which is the primary physical process of soil structure degradation is associated strongly with sodium concentration (Bauder and Brock, 2001; van de Graaff and Paterson, 2001). Also, soil structure alteration is the primary soil response to an excess of exchangeable sodium in combination with low salinity, which results in a decline in soil air and water permeability (Oster and Shainberg, 2001) and consequently, diminishes agricultural soil productivity and increase water runoff and soil erosion.

Between the three slopes and three land uses, there were no statistically different in SAR. Related to sodium level, the SAR in Al-Shyoukh site has higher level and significantly different compared to Halhoul, which affect on the dispersion and slaking of soil particles, and lead to more erosion. Abu-Sharar et al. (1987) concluded that the extent of slaking depends on

SAR and total electrolyte concentration. As electrolyte concentration decreased and SAR increased, clay dispersion increased and hydraulic conductivity decreased correspondingly (Yousaf et al. 1987).

# Conclusions and Recommendations

- This study indicate that there was a variation in soil properties along a climatological transect, particularly clay content, bulk density, pH and organic matter and how these properties oriented with aridity. This will give the ability to kow-how to maintain soil resources and work on the conservation and promotion of these soil resources to avoid soil degradation.

- Some soil properties such as texture, calcium carbonates and soil moisture, varied between the three slopes. But different slope had not clearly affected on other soil properties. However, in the study sites, we need further studies to understand the processes taking place at the landscape and soil changes. However, management effects on soil properties which varied with landscape position.

- Land use types had been used to assess their effect on soil properties, since these results give a clear view about characteristics of soil how we can manage with each type of land use. The study show that range land use influence bulk density and organic matter, by compaction risks which need to be balanced through controlling grazing and reduce intensity to maintain plant cover and protect soil from compaction and degradation.

- More studies should be concentrated on the compination of soil properties and soil degradation processes like aggregate stability and infiltration rate.

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# Abstract (Arabic)


**الخلاصة**

## تقييم خواص التربة على طول مقطع مناخي و اختلاف استخدام الاراضي

تهدف هذه الدراسة إلى تقييم خواص التربة في استخدامات أراضي مختلفة وانحدارات مختلفة في مناطق ذات تباين مناخي جنوب الضفة الغربية. تم إجراء الدراسة في ثلاثة مواقع في محافظة الخليل ( نوبا، حلحول، الشيوخ )، والتي تمثل ظروف مناخية مختلفة. و ذلك لتقييم تأثير ثلاثة انحدارات (انحدار سهل ( S1:3-8%)، انحدار متوسط ( S2:8-18% ) وانحدار متوسط – شديد ( S3:18-32% )) كل انحدار يحتوي على ثلاث استخدامات للأراضي ( أراضي شجرية، أراضي مراعي، أراضي محاصيل حقلية).

أظهرت نتائج البحث أن لتباين المناخ تأثير ذو دلالة إحصائية معنوي على خصائص التربة . حيث أن محتوى الطين والمادة العضوية في موقعي نوبا وحلحول ذات المناخ شبه جاف – شبه رطب أكثر مقارنة مع موقع الشيوخ الذي يتصف بمناخ متوسط جاف– شبه جاف. إضافة إلى أن محتوى الرمل في موقع الشيوخ كان أكثر مقارنة مع موقعي نوبا و حلحول، حيث أن زيادة محتوى الرمل في التربة كانت مرتبطة مع زيادة الجفاف، ولم يكن لكربونات الكالسيوم أي تأثير ذو دلالة أحصائية في المواقع الثلاث.

إن اختلاف نسبة الانحدار في موقعي نوبا وحلحول لم يكن له تأثير ذو دلالة إحصائية على خواص التربة مثل محتوى الطين، الكثافة الظاهرية، المسامية، المادة العضوية، والتبادلية الأيونية. من ناحية أخرى كان للانحدار المتوسط (S2) في الشيوخ تأثير ذو دلالة إحصائية معنوي على محتوى الرمل في الانحدار البسيط (S1) و المتوسط – شديد (S3). كذلك كان للانحدار البسيط (S1) في حلحول تأثير معنوي على المحتوى المائي بين الانحدارين المتوسط (S2) ومتوسط – شديد (S3)، وكذلك الايصالية الكهربائية (EC) في الانحدار متوسط – شديد (S3) مقارنة مع الانحدار البسيط (S1) و المتوسط (S2) .

كذلك أظهرت النتائج أن قوام التربة كان متشابها في استخدامات الأراضي الثلاثة في مختلف المواقع، وكان لاستخدام المراعي تأثيرا على الكثافة الظاهرية، حيث كان استخدام تأثيرا معنويا على الكثافة الظاهرية مقارنة مع الأراضي الشجرية والحقلية .

كان محتوى المادة العضوية أعلى في أراضي المراعي مقارنة مع الأراضي الشجرية والحقلية، و لا يوجد أي اختلاف للسعة التبادلية الأيونية (CEC) و نسبة ادمصاص الصوديوم (SAR) ضمن استخدامات الأراضي الثلاثة .