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Effect of water harvesting techniques on vegetation characteristics (natural and planted), runoff and sedimentation at semi-arid area

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List of Abbreviations:

- Area (A) Area administered by the Palestinian Authority.
- Area (B) Administered by both the Palestinian Authority and Israel
- Area (C) Area administered by Israel.
- CL Contour Lines.
- CWANA Central and West Asia and North Africa**.**
- GS Gaza Strip.
- mcm Million Cubic Meters.
- Opt Occupied Palestinian Territories.
- PCBS Palestinian Central Bureau of Statistics.
- P-S-P Plowing – Sowing – Plowing.
- RWH Rain Water Harvesting .
- SC Strip cropping.
- S-P Sowing – Plowing.
- UNEP United Nations Environment Program.
- WB West Bank.
- WHTs Water Harvesting Techniques.

DEDICATION

To my parents, for their love, prayers, and inspiring me love of education.

To my wife, for her love, patience,

full support and sincere

encouragement to complete this work.

To my wonderful brothers and sisters,

I wish them peace, joy, and great futures.

To our stead fasten Palestinian farmers on their land.

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Abstract

Agriculture production in Palestine depends on rainfall which is highly variable spatially and temporally. Water is the key environmental factor that determines plant growth at the Eastern slopes, and because of the characteristics of rainfall, in general, and low precipitation in particular the productivity of plants is very low (MOA, 2012). Therefore, this study was conducted at Al-Ubeidiya in Bethlehem governorate to evaluate the effect of using water harvesting techniques on the productivity of barley and natural vegetation through its influence on runoff and soil sedimentation during 2013, 2014 and 2015. Split plot design was used to compare between treatments. the results showed the positive effects of water harvesting practices on barley productivity where the spike and straw weight increased significantly compared with the conventional cultivation, spike, straw weights and plant height gave the best results in strip planting followed by P-S-P then the contour ridges while the lowest values were in the traditional planting (S-P). In natural vegetation study, surface runoff was decreased significantly by 49.5% and 45.4% in gentle slope (10%) by using contour ridges at 3m and 5m distances, respectively, compared with control area, as well as water runoff in steep slope (20%) reduced by 43.6% and 32.2% in contour ridges at 3m and 5m distances. Also the data showed the positive effects of contour ridges at 3m and 5m distances in the two slopes (gentle 10% and steep 20%) on natural vegetation characteristics. Results showed that plant biomass was recorded the highest values in area treated by contour ridges at 5m distance in gentle and steep slopes, it was 203.4kg/dunum and 174.8 kg/dunum, respectively, and it was significantly increased by 158.9 kg/dunum and 113.1kg/dunum in area treated with contour ridges at 3m

distance in gentle and steep slopes respectively. In addition plant density increased significantly in contour ridges with 3 m and 5 m distances in gentle slope were it recorded the highest plant density (49.4 plants/0.25m^2 and 52.7 plants/0.25m^2, respectively) compared with the other treatments. In addition plant cover result showed no significantly difference between all treatments.

Using simple way to enhance field crops production and improve rangeland performance is possible, but it needs previous planning and period of time to see the positive effects on the land.

Chapter one

1. Introduction:

Water is the main factor for successful plant growth and increasing the survival rate of plants, especially in arid and semi-arid areas; Palestine, as many countries around the world, has a problem in water availability. Israeli occupation, climatic change and misuse of water resources, all of these factors caused a severe shortage of water in Palestine which currently considered as the main limiting factor for agriculture, forest and rangeland development.

The main source of water for the Palestinians in the West Bank (WB) and Gaza Strip is the groundwater; it provides more than 90% of all water supplies. The Israeli occupation in 1967 controls all water resources including surface and groundwater and utilizes more than 85% of these resources, leaving less than 15% for Palestinian use (Palestinian Water Authority, 2012).

According to the National Agriculture Sector Strategy "Resilience and Development" (2014), 146 million cubic meters (mcm) of water was available for agriculture, which constitutes 44% of the total available water; 60 mcm was distributed in the West Bank and 86 mcm in the Gaza Strip, 228 thousands dunum can be irrigated by this amount of water which is representing 19% from the total cultivated lands. Because of this lack of water for irrigated agriculture the most cultivation pattern in West Bank and Gaza strip is rain-fed cultivation, which occupying 81% of all plant producing lands (National Agriculture Sector Strategy "Resilience and Development", (2014), and PCBS/ Agricultural Census, 2010/2011). Rain fed agriculture is the dominant cropping worldwide. According to

Scheierling and others (2012), 80% of cropped areas in the world depend on rainfall alone. However, in many semi-arid areas, tropical and arid regions, as well as in some temperate regions the crop production is relatively low, and water management is suggested to be the key for improving agricultural production in these lands (Scheierling, *et al.*, 2012).

Rangeland areas in Palestine cover about 2.02 million dunums, which considered important habitat for natural vegetation (PCBS/ Agricultural Census, 2010/2011). The largest proportion of the rangeland area is located in the Eastern Slopes region in West Bank. The Eastern Slopes characterized by its arid to semi-arid environment, transitional from Mediterranean to arid with moderate to high temperature, low relative humidity and low annual rainfall which varied between 50 and 400 mm / year (Palestinian Water Authority, 2012).

The escalating demand for forage by grazing animals overtakes the potential productivity of rangeland area. The increase in grazing pressure and cultivation of traditional and fragile grazing lands has led to severe degradation of these rangelands (Mudabber, *et al.*, 2011). In addition, climate change increases the negative impacts of aridity on rangeland vegetation. These impacts include low levels of emergence of annual species, changes in phenology and the timing of reproduction, reduced biodiversity, low levels of plant cover, and a decline in productive capacity in pastoral systems (Belgacem and Louhaichi, 2013) as well as climatic changes lead to a shortage of water resources, widespread land degradation, and increased desertification. These threats would impact negatively rangeland biodiversity, the life cycle of plants, and crop/livestock productivity (Louhaichi, *et al.,* 2016).

Field crops and forages are the main cultivated and natural rain-fed crops in rangeland areas in occupied Palestinian Territories (oPt) (Isaac, 1994). According to the PCBS web site and the agriculture censuses since 2012, the cultivated area of field crops in Palestine is about 245400 Dunums, from these, in Bethlehem governorate approximately 4438 Dunums, with very low field crops productivity (98 kg/Dunum).

Low precipitation and poor soil quality are the main factors effects on growth of plants in the rangelands. Maximizing the use of micro water harvesting techniques might be practical to increase forage production which is essential to feed the sheep and goats of rangeland areas (Karrou, *et al.*, 2011). Scheierling (2012) mentioned that, the need to improve water management in rain-fed areas is often emphasized, in particular by increasing timely water availability and the water uptake of crops, yields can be significantly enhanced and agricultural productivity improved.

Water harvesting techniques (WHTs) is one option that can increase the amount of water per unit cropping area, reduces drought effects and enables use of runoff beneficially (Zhang and Oweis *et al*., 1999).

Oweis and Hachum (2009) stated that the principle of WHT is based on the concept of depriving part of the land of its share of precipitation, which is usually small, non-productive and giving it to another part to increase the amount of water available to the latter part. While Critchly and Sigert (1991) defined WHT as collection of runoff for its productive use.

Water harvesting systems established in many parts of the world since thousands of years. Contour terracing were used in the central highlands of Mexico since 1000 years ago (UNEP (1983); water harvesting structures in Jordan, have been constructed since 9000 years ago (Prinz, 1996); and run-off-irrigation systems have been found in the semi-arid to arid Negev desert region since 5000 years (Evenari *et al*., 1971).

WHT has become an effective way to fight against droughts for arid and semi-arid region (Zhang, *et al.*, 2007). According to Rebeka (2006), rainwater harvesting techniques can be applicable in all agro climatic zones. However, it is more suitable in arid and semi-arid areas where the average annual rainfall is from 200 to 400 mm (Mohammad, 2008).

Therefore, this study was carried out in Al-Ubeidiya Town (sh'ab alshouk) at Bethlehem district, in semi-arid area (eastern slope). With a general objective of evaluating the efficiency of different water harvesting techniques in decreasing surface rain water runoff and increasing the barley and rangeland vegetation growth and yield.

Chapter Two

2. Literature Review

2.1. Palestinian Environment:

Palestine is characterized by a great variation in topography and altitude, especially in the West Bank where the variation ranges between 1,020 meters above sea level to 420 meter below sea level. This variation is directly reflected on the climate and the distribution and diversification of agricultural patterns, from irrigated agriculture in the Jordan Valley to rain-fed farming in the mountains (Applied Research Institute –Jerusalem 2015).

The climate in the Palestinian territory is Mediterranean in its basic pattern, and varies from semi-arid in the west to extremely arid in the east and southeast. Generally, the climate of Palestine is characterized by a long, hot, dry summer and short, cool, wet winters (Hadid, 2002).

According to the Frenken (2009), West Bank and Gaza strip were divided into five major zones (Fig. 1) based on several factors including climate, topography, soil types and farming systems:

1. The Jordan Valley Region lies 75-90 m above sea level with an annual rainfall of only 100–200 mm.
2. The Eastern Slopes Region is a transitional zone between the Mediterranean and desert climate with rainfall of 150–300 mm/year and lies 100 – 450 m above sea level.
3. The Central Highlands Region extends along the West Bank from south to the north with mountains ranging from 400–1000 m above

sea level. Annual rainfall varies between 300 mm / year in the south to 600 mm / year in the north.

4. The Semi-Coastal Region has an elevation of 100–300 m above sea level. Rainfall varies from 400–700 mm/year.
5. The Coastal Plain (Gaza Strip) lies at sea level and It has a rainfall of 200–400 mm/year.

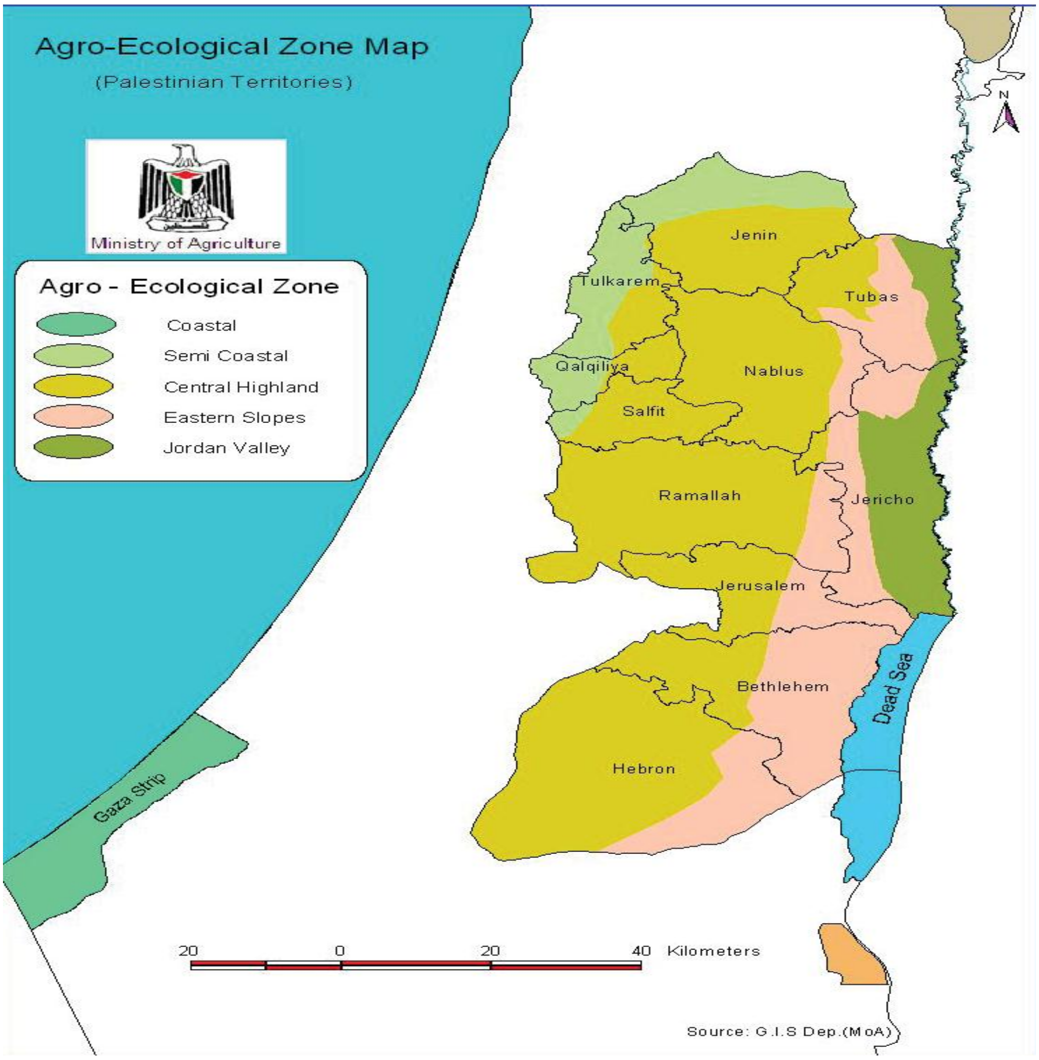


Figure (1): Agro ecological zones in West Bank and Gaza strip (GIS Dep.(MOA)).

Rainfall is the major resource for ground and surface water in Palestine. In Palestine, precipitation shows considerable spatial and temporal variation, with an annual average rainfall of 450 mm/y in the West Bank and 327 mm/y in the Gaza Strip (Palestinian Water Authority report, 2013). In addition, the annual rainfalls in the West Bank are also highly variable (figure 2) and it ranged from 700 mm in western part to less than 100 mm in eastern parts.

The rainy season usually starts in the middle of October and continues until May, where most of the rainfalls during the period between November and March.

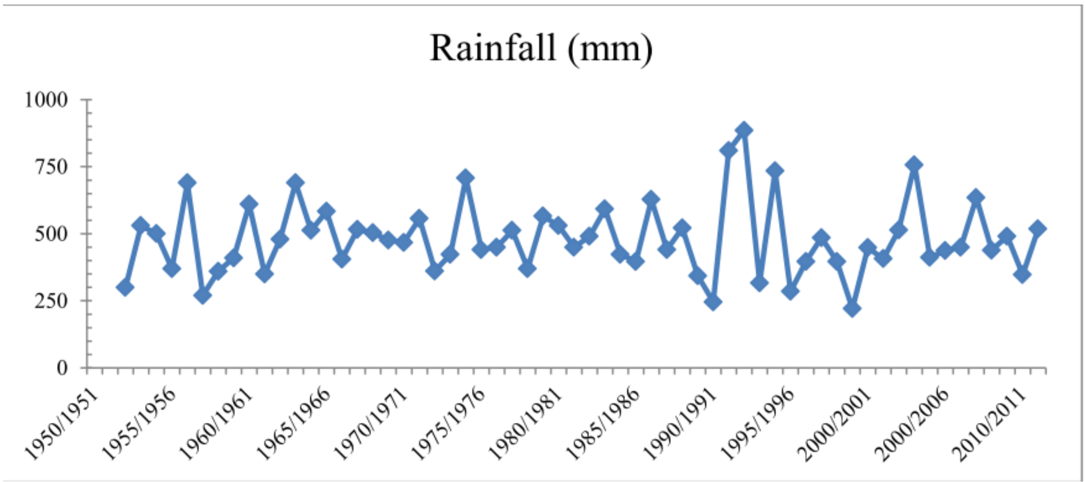


Figure (2): West Bank long-term average rainfall, hydrological years (1950-2010) (Palestinian Water Authority, 2012).

On the other hand, temperature in Palestine is relatively high especially in summer months with mean temperature 20.8C^{o} and 30C^{o} in July and August, respectively, while in winter months the mean temperature range from 8.7C^{o} to 14.7C^{o} (Isaac and Rishmawi, 2015).

2.2.Vegetation covers in Palestine:

Palestine as the Mediterranean lands is a major world center of plant diversity (Heywood, 1999).

According to the National Agricultural Sector Strategy “Resilience and Development” (2014); "The total area of cultivated land is estimated at 1.2 million dunums, of which 90% is in the West Bank and 10% in the Gaza Strip. 81% of the area is rain-fed; the remaining 19 % is irrigated. While rangeland area is 2.02 million dunums, the area available for grazing is only 621,000 dunums. In addition, forests stretch over an area of 94,000 dunums. About 62.9% of the arable land is located in Area C; 18.8% in Area B; and 18.3% in Area A".

Esse (1991) reported that, there are four climatic zones which ‘converge in Palestine: the Mediterranean, Irano-Turanian, Saharo-Sindian and enclaves of Sudano-Deccanian’. These zones together create the best habitat for plant diversity.

Danin (1988) said that, the plant communities that occur in a particular place are influenced by their phytogeographical position, climatic factors, soil, and human activities. Therefore, due to high variability in its topography, climate (ranging from Mediterranean to desert), and soil and due to its geographical position (located between the continents of Africa, Asia and Europe), all of these factors were interacts and contributes to make Palestine a very rich in flora and fauna. Various sources estimated plant variety at 2953 species belonging to 126 families (Environment Quality Authority, 2006). Rare species account for 27.8% and those classified as very rare account for 25.6%. Palestine has a high number of plant species comparing with many other countries; Deist (2000) mentioned that, there are 718 plant species endemic to the area.

The number of threatened plants in the West Bank is about 334 species that belong to 222 genera from 81 families. Among the threatened species there are 33.8% annuals and 18% are trees (Ali and Jamous, 2002). Alkhouri, (2012) found that about 16% of West Bank shows a decreasing rate of vegetation with time, and that clear in the northern part of WB and 3% from WB area showed increase of vegetation with time, while 81% shows no difference in vegetation.

Natural resources especially soil, water and vegetation in Palestine are exposed to sever damage such as: overgrazing, deforestation and fire for a long period of time as a result of absent or mismanagement for these resources especially during the occupation period. All these factors have increased the risk of loss the vegetation cover and soil, and finally led to land degradation and the threat of desertification (Mohammad, 2000).

2.3. Rangeland conditions in Palestine:

Most of the arid and semi-arid area of the central and West Asia and North Africa (CWANA) regions are rangelands and are characterized by wide variability in rainfall and temperature. Droughts are common, resulting in low forage production and crop productivity as well as water scarcity (Karrou, *et al*., 2011).

Rangeland area in Palestine concentrated in the eastern slopes of West Bank. A large part of rangelands are inaccessible for grazing (most rangeland area located in area C) because these areas under full Israeli occupation control and measures (MOA, 2012). It was estimated that 80-90% of the rangeland in the West Bank are located in the area affected by water scarcity, these grazing fields are generally used by shepherds to graze their sheep for a period of four months (between mid-February and May) to be followed by an additional two months in which the sheep graze on harvest by-products. As for the remaining six months, shepherds feed their sheep with fodder like barley, vetch and alfalfa (OCHA oPt, 2009). On the other hand the livestock herders derive only about 14% of the total feed requirements from rangeland areas (Mohammad, 2008).

The decrease of plant cover leads to soil erosion, less water infiltration, heavy surface water runoff and desertification. Many shrubs, grasses and forbs such as *Ratem sp, Artimisia sp, Papilionaceas* family (*Vice sp* and *Trifolium sp)* and *Graminea* family (*Hordeum spp*), have been depleted and nearly lost, because of the absence of rangeland management (Mohammad, 2008). In addition Israeli occupation, tree cut for fuel, overgrazing and mismanagement of rangeland, all of these led to lands degradation and presently producing much below their potential (Mohammad, 2000).

Al-joaba (2006), found that plant dry biomass and density decreased as a result of overgrazing in southern part of West Bank. On the other hand Braighith (1995) found that the amount of available forage is about 60, 80 and 40 kg/Dunum in eastern slopes, Jordan valley area and mountains area, respectively. Mahmoud (2003) mentioned that the vegetation cover of the pasture in Eastern slopes is enough only for 10% of livestock reared.

Mohammad (2000 and 2005) assessed the vegetation productivity and plant botanical composition in the rangeland area in southern part of WB (Eastern slope, Al-Dahria and Al-Samoo), the data showed that the range productivity was low (98.5 kg/dunum in eastern slope, 71.1 kg/dunum in Al-Dahria and 92.9 kg/dunum in Al-Samoo), and he found that the total plant cover percentage were 83%, 54% and 57% in Eastern slope, Al-Dahria and Al-Samoo, respectively.

2.3.1. Natural Vegetation in rangeland area:

Climatic variation, topography, cultivation, livestock grazing and other factors affects on rangeland vegetation in Palestine. Compared with the past were it used to support six months grazing cycles, but currently animals are grazed for only 2-3 months per year (Sholi, *et al.*, 2010).

The main factors that affect on land degradation in Palestine are classified as human activities and natural factors (Dudeen, 2008). Rangeland condition at the Southern part of West Bank is classified as poor because of sever overgrazing that led to soil erosion, low vegetation cover, low soil fertility, and presence of large percentage of weeds (Mohammad, 2000; and 2005).

Mohammad (2008) concluded that sever overgrazing reduced the rangeland potential for high vegetation production in semi-arid and semi humid areas at the southern part of West Bank (WB).

On the other hand, a plant survey carried out by the Ministry of Agriculture (2012) to estimate the rangeland vegetation characteristics and rangeland productivity in WB, data showed that rangeland condition at the northern parts of WB is generally better than that at the southern rangelands in WB. In the same study they reported the presence of large number of different plant species that grow naturally in rangeland, 59 plants in Mar Saba Site (Al-Ubeidiya) and 104 plants in Atouf. They identified 8 plant species as dominant species at each site. The dominant plant species are varies greatly from one area to another. Mohammad (2005) and Al-Joaba (2006) identified the following species as dominant at the southern parts of West Bank: *Sarcopoterium spinosum, Asphodelus* *aestivus, Eryngium crecum, Stiba bulbosa, and Anthemis spp and Bromus spp*.

On the other hand, Al-joaba, (2006) and Mohammad, (2008), found that the dominant plant species in natural vegetation in eastern slope (BaniNoem rangeland) are *Torilis tenella*, *Poa bulbosa*, *Anthemis spp*, *Vivia sp*, *Crithopsis delileana*, *Medicago sp* and *Helianthemum salicifolium*.

Al-joaba (2006) and Ministry of Agriculture (2012) found that plant dry biomass and plant density are different between years; this variation reflects mainly the difference in precipitation, soil fertility, and grazing levels.

Not only the locations form a source of variation in dominant plant species, slope aspects are also among other sources that cause this variation. Mohammad (2008) studied the effects of slope aspects on vegetation characteristics, the results gave that total dry biomass, density and cover are higher in north aspects compared to south aspect. Auslander and other (2003), reported that south facing slope (SFS) are warmer and dryer and may receive six times the amount of solar radiation received by north facing slope (NFS). On the other hand Rezaei and Gilkes (2005), proved that soil nutrient pool and general fertility on NFS was greater than that on SFS which lead to a high variability in plant species, vegetation type and plant community.

The real difference between the locations or the slope aspect are amount of precipitation, soil, temperature, and other environmental factors that finally express a difference in vegetation characteristics.

2.4.Rain-fed Farming:

A large part of the surface of the earth is arid, characterized as too dry for conventional rain-fed agriculture (Creswell, *et al.,* 1998). Rain-fed agriculture is the predominant farming system in these areas, but aridity and climatic uncertainty are major challenges faced by farmers who rely on rain-fed farming (Ammar, *et al*., 2016). Although, Field, *et al*., (2014), said that plant production in rain-fed agriculture could be reduced by up to 50% in some regions by 2020, Rain-fed agriculture will continue to produce the bulk of the world's food. It is already practiced in 80% of the world physical agricultural area and generates 62% of the world's staple food (FAOSTAT 2005; Rockstrom *et al*., 2007; and FAO, 2006).

The importance of rain-fed agriculture varies regionally, but most food for poor communities in developing countries is produced in rain-fed agriculture, about 93% of farmed land is rain-fed in Sub-Saharan Africa, 87% in Latin America, 67% in the Near East and North Africa, 65% in East Asia, and 58% in South Asia (FAO 2002). Most countries depend primarily on rain-fed agriculture for their grain food. The challenge in arid and semi- arid regions is the low and uneven distribution of rainfall throughout the season, which makes rain-fed agriculture a risky enterprise (Aydrous, *et al*., 2015).

In arid and semi-arid regions water management is the key challenge for improving food production in rain-fed agriculture due to the extreme variability of rainfall, long dry season and recurrent droughts, floods and dry spells. Water management should be directed towards the reduction of water-related risks posed by high rainfall variability rather than coping with an absolute lack of water (Trisorio and Hamdy, 2008).

Rain-fed farming in Palestine represents an important component of the agricultural production system, it made up of field crops and forages particularly wheat, barley, chickpeas, lentils, sorghum, vetch, and vegetables. And fruit trees such as, olives, almonds, other nuts, plums, apricots, peaches, pears, cherries and grapes (Leipzig, 1996).

The field crops and forages are grown in the winter (rainy season), and many farmers follow with vegetables grown on residual water in the spring. According to the PCBS Agriculture census (2010/2011) the area and production of field crops in Palestine by type of irrigation and governorate are shown in Table (1).

Table (1): The area and production of field crops in Palestine by type of irrigation and governorate, (2010/2011) (BCBS, 2010).

Governorate	**Type of Irrigation**				**Total**	
	Rain-fed		**Irrigated**			
	Area (Dunum)	**Production(ton)**	**Area (Dunum)**	**Production (ton)**	**Area (Dunum)**	**Production (ton)**
Palestine	**230,815**	**31,385**	**14,599**	**13,019**	**245,414**	**44,404**
West Bank	212,683	28,112	8,199	8,409	220,882	36,521
Jenin	58,264	15,852	733	1,347	58,997	17,199
Tubas	31,615	2,815	125	178	31,740	2,993
Tulkarm	5,130	890	910	643	6,040	1,533
Nablus	28,992	3,674	342	518	29,334	4,192
Qalqiliya	10,779	1,166	642	471	11,421	1,637
Salfit	1,988	301	6	8	1,994	309
Ramallah & Al-Bireh	7,745	558	-	-	7,745	558
Jericho & Al-Aghwar	416	29	5,428	5,242	5,844	5,271

Jerusalem	1,061	43	-	-	1,061	43
Bethlehem	**4,438**	**98**	**-**	**-**	**4,438**	**98**
Hebron	62,255	2,686	13	2	62,268	2,688
Gaza Strip	18,132	3,273	6,400	4,610	24,532	7,883
North Gaza	2,709	732	1,365	2,116	4,074	2,848
Gaza	3,795	272	2,305	589	6,100	861
Deir Al-Balah	1,606	326	180	251	1,786	577
Khan Yunis	5,164	1,036	1,064	341	6,228	1,377
Rafah	4,858	907	1,486	1,313	6,344	

According to table (1) most field crops production is rain fed agriculture, therefore, rainfall characteristics have great effects on the productivity of field crops. It appeared that cultivated area of field crops and productivity in Jenin governorate higher than other governorates in Palestine. Most wheat and barley crops cultivated as rain-fed agriculture with 202kg/dunum and 111kg/dunum respectively (MOA, 2012/2013).

Low precipitation and irregular distribution of rainfall is a permanent threat to agriculture in many semi-arid areas (Beernaerts, 2003). Under arid and semi-arid conditions, the low rainfall and the high temporal and spatial variability the field crop yield is low and varies from one year and region to another (Al-Suhaibani, 2011). Since agricultural production of rain-fed farming in the semi-arid regions is much dependent on rainfall and its distribution, water harvesting might be an effective way to improve field crop productivity in semi-arid areas and decrease drought effect. Rockstrom (2001) reported that, only 15 to 30 % of rainfall is productively been used by the crops. In semi-arid area, yield of rain-fed crops can be improved by increase water availability to the crops, maximize water holding capacity of the soils and improve plant water uptake capacity (Beernaerts, 2003), and by providing more balanced soil moisture during the growing season through water harvesting techniques (Mohammad (2008); Alseekh and Mohammad (2010)).

RWH and management techniques have a significant potential for improving and sustaining the rain-fed agriculture in the semi-arid areas (Lasage and Verburg 2015; and Ibrahim, 2012). According to Proud (1988), the strategies to improve the availability of soil moisture for use by trees and crops can be enhanced by managing the supply of water so that losses through run-off and evaporation are minimized and provide more efficient use of rainfall water by trees and crops.

Water harvesting techniques have the positive impact of improved soil moisture, runoff and ground water recharge; and increased agriculture production, which in turn reduces risks and deliver positive impacts on other ecosystems (Yosef and Asmamaw, (2015); Ngigi, *et al.*, (2005); Abu-Zreig, *et al*., (2000); Liang and Van Dijk (2011); Oweis, (2016))**.**

Zhang and other (2006) reported that contour ridge and furrow planting and gradually constructed contour terrace all can intercept runoff, collect rainwater, and thus increase soil moisture, affects on promoting crop growth and increasing crop production.

2.5. Water Harvesting Techniques (WHT)

2.5.1. Concepts, Components, Types and Benefits:

In the past, water harvesting was the backbone of agriculture in arid and semi-arid areas world-wide (Prinz, 1996). Since thousands of years ago mankind has lived in semi-arid areas and cultivated many agricultural crops, also they practiced some kind of water harvesting (Evenari *et al.*, 1971). As stated by Beckers, and others (2013) different water harvesting methods constructed during the Bronze Age or earlier and some of these methods stay in use even today.

Prinz (1996) stated that WHT is applied in arid and semi-arid regions where rainfall is either insufficient to sustain a good crop and pasture growth or where, due to the erratic nature of precipitation, the risk of crop failure is very high. Water harvesting can significantly increase plant production in drought prone areas by concentrating the rainfall/runoff in parts of the total area. On the other hand, Ibraimo and Munguambe (2007) reported that, the aim of the rainwater harvesting is to mitigate the effects of temporal shortages of rain to cover both household needs as well as for productive use. The interest in WHT has increased during the last centuries, national and international associations developed programs to investigate the potential of WHT and to expand its use.

The term “water harvesting” has many definitions according to the method and purpose of water storage. The essence of water harvesting is the collection and storage of water for livestock drinking, domestic uses and growing of plants. Proud (1988) defined the water harvesting as the interception and concentration of rainfall run-off and its storage in the soil profile for use by crops, grasses or trees. The method of rainwater harvesting in general entails concentrating, diverting, collecting, storing, utilizing, and managing runoff for productive purposes (Ngigi, 2003).

The main components of water harvesting systems; catchment area where runoff is collected, storage facility which is the place where runoff water is held from the time it is collected until it is used (storage can be in surface reservoirs, subsurface reservoirs such as cisterns, in the soil profile as soil moisture, and in groundwater aquifers), target area where the harvested water is used. In agricultural production, the target is the plant or the animal (Oweis, *et al*., 2001).

Water harvesting techniques had been developed and improved to keep pace with the growing needs for water for agricultural and domestic purposes (Hamid, 2004). There are two main types of water harvesting techniques, namely: micro and macro catchment systems (Ali Abu Nukta, *et al*., 2009). Micro catchment systems include: contour bunds, semi-circular and trapezoidal, small pits, diamond shape, strip cropping and rooftop systems. Macro catchment systems on the other hand, include small farm reservoirs, wadi bed cultivation, jessour, and off wadi (water spreading systems, large bunds, tanks and cisterns) systems (Ali Abu Nukta, *et al*., 2009).

Prinz (2001) classified WHTs into two major groups (1) Rainwater Harvesting, which is the collection of runoff and its use for the irrigation of crops, pastures and trees and (2) Floodwater Harvesting, also called 'Spate Irrigation', which uses the floodwater of ephemeral streams and rivers.

Strip cropping is based on the principle of depriving part of the land of its share of rain, which is usually small and non-productive, and adding it to the share of another part. Strip cropping is a multi-purpose practice that has one or more of the following effects: reduce sheet and rill erosion; reduce wind erosion; increase infiltration and available soil moisture; reduce dust emissions into the air; improve visual quality of the landscape; improve wildlife habitat; improve crop growth, and improve soil quality (Chepil and Woodruff, 1963; and Carman 2005). According to Abu – Nukta (2009), the strip cropping technique is a good method for barley production for seed production, green biomass and/or pastured for sheep and goat and that strip cropping helps preventing or reducing the surface runoff, and soil erosion. By using this technique, surface runoff from the uncultivated land can be used to supplement the rainfall to the cultivated land.

Contour ridge is a micro catchment technique used to collect runoff from the uncultivated strip between ridges and stored in a furrow just above the ridges (fig. 3). The system is simple to construct – by hand or by machine and can be even less labor intensive than the conventional tillage of a plot.

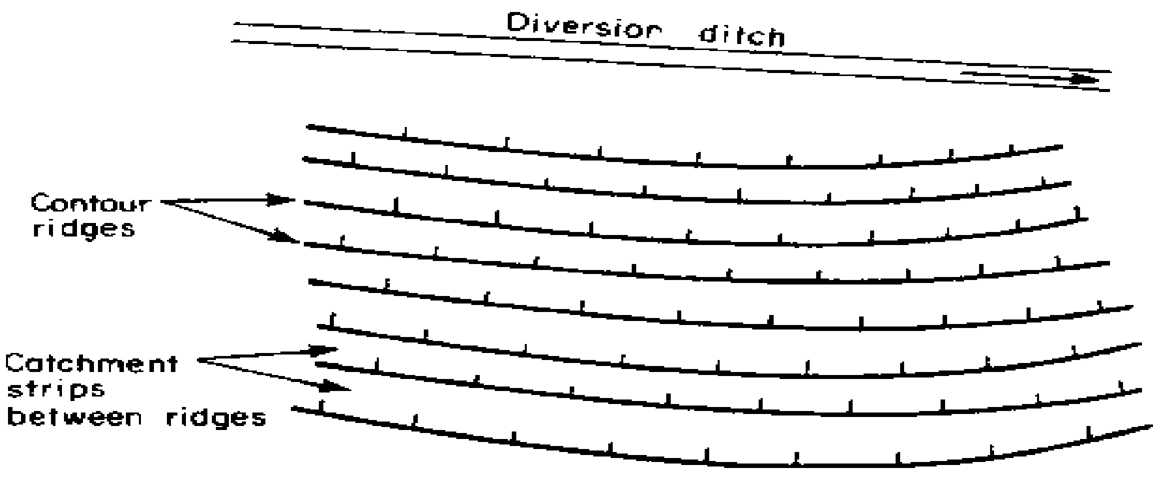


Figure (3): Contour ridges field layout (Critchley & Siegert 1991).

According to Al-seekh and Mohammad., (2009); and Xiao-yan *et al.*, (2004); Owies *et al.*, (2001), WHT have many effects as reducing soil erosion and sedimentation and increasing soil water storage and soil fertility. A good characters for some water harvesting techniques that is worth to consider are that it is simple, cheap, replicable, efficient and adaptable (Reij and others 1988).

Hamid (2015) reported that, the main purposes for collecting rain water can be to provide adequate water for arable lands, range land, fishing industries, domestic uses, animal consumption, strategic purposes (defensive purposes), recreational purposes and wildlife consumption.

Prinz, (2001) and Fidelibus and Bainbridge (1995) mentioned some of the important parameters to be taken into consideration in choosing a water harvesting technique in any area and in determining the suitable size of the catchment area (such as distance between contour ridges) are:

- Rainfall distribution and Rainfall intensity.
- Topographical condition.
- Runoff / Infiltration characteristics of the location.
- Water storage capacity of soils.
- Socio-economic conditions.

2.5.2. WHTs and Plant Production in Rangeland Area:

Water is important to all life forms, human, animal and plant. In arid and semi-arid area rainfall is irregular and most of rain lost as surface runoff (Hatibu *et al.*, 1999) or through evaporation which finally lead to low production in semi-arid areas (Yosef and Asmamaw, 2015).

Many studies in the world, shows the effect of WHTs on field crop production, and fruit tress growth. On the other hand many experiments applied in rangeland area to evaluate the effect of many WHTs on vegetation characteristics. Alamerew *et al*., (2002) and Mohammad (2008) stated that RWHTs increase the amount of water stored in the soil profile by trapping or holding the rain where it falls. When the harvested runoff is used for providing the soil water required for plant growth the system is called runoff farming (Gowing *et al*., 1996).

Rango and Havstad (2011) stated that the basic goal of water harvesting on rangeland is to intercept the flow of surface water. It should be clear that water harvesting techniques alone might be not effective in improving the rangeland vegetation without being associated with a suitable management to the rangeland. Mohammad (2008) reported that using simple WHTs and prevents grazing, for a period of time, possibly plant biomass and plant density will be enhanced, as well as Mohammad (2011) proved that grazing reduced the amount of dry biomass and plant density by 36% and 37% respectively. Oweis (2009); and Adham, *et al*., (2016), found that micro-catchment WH improve the vegetation cover and plant biomass, and increase the carrying grazing capacity of rangeland.

Almost, all the studies that evaluated the efficiency of using water harvesting techniques found a positive effect for these techniques on increasing yield of field crops. However, the results for the most efficient methods were variable; this variability might due to the involvement of many factors on the role of these techniques.

In Al-majjediah village, Al-Satari (2013) found that, number of tillers in barely increased by strip cropping and contour ridges compared with traditional method. Also barely production was 517.47kg/ha in contour lines, 422.23 kg/ha in traditional method and 351.73 kg/ha for strip method, while the straw yield was 447.70, 315.36 and 253.23 kg/ha for contour ridges, traditional and strip methods, respectively. while Abu – Nukta *et al*., (2009) found that barely production was highest using strip cropping compared with conventional cultivation, in addition the barely lengths were highest in different ratios in strip cropping ranging between 26-28 cm compared to 23 cm in the conventional cropping system (Abu – Nukta *et al*., 2009). RWHT in field has been shown to improve the yield of maize and sunflower in South Africa (Henslley *et al*., 2000).

In addition, in experiment carried out by Saoub, *et al*., (2011), to investigate the effect of three water harvesting methods on establishment of three forage shrubs and productivity of natural vegetation at Tal Rimah (North- Eastern Badia of Jordan), contour farrows gave higher shrub biomass when compared to the crested and V – Shaped techniques, also biomass production of forage shrubs under contour furrows was 25 and 30% higher than that in crescent – shape and V – shape, respectively. Also Ali Akhtar and other (2007) evaluated the effect of micro-catchment water harvesting on soil-water storage and shrub establishment in Syrian rangelands, they found that the contour ridges increased water storage in soil layers after 24-36 hours of rainfall as well as shrub survival rate was highest for *Atriplex halimus* (71%) followed by *Salsola vermiculata* (56%) and *Atriplex leucuclada* (31%). Zhang and other (2007) found that, the contour ridge and furrow planting can increase crop production by 74.2%, and gradually constructed contour terrace can increase crop production by 37.1%. In a study at central mountains of West Bank, Abu Hammad (2004) found that the plant biomass was higher by 3.5 to 6 times in terraced area compared with non-terraced area.

In Experiment carried out by Mohammad (2008) to evaluated the effects of different land reclamation practices on vegetation characteristics in semi-arid to semi-humid conditions of the southern part of the West

Bank, stone terrace plots and semi-circle bund plots increased plant biomass and plant density significantly, plant biomass increased significantly by 80 % and 45 % in stone terraces and semi-circle bunds respectively, while plant density increased significantly by 15% and 52% in stone terrace and semi-circle bund.

Mohammad and Adam (2010) said that keeping suitable vegetative cover, as a natural water harvesting method, should be considered for soil and water conservation in forests and rangeland, and any cultivation or brush control should be carefully practiced to avoid retrogressive trends in these lands.

2.5.3. Water Harvesting Techniques and Water Runoff:

The Palestinian areas characterized by mountainous topography and fragile semi-arid climate as the Mediterranean region, this area subjected to many environmental problems as loss of natural vegetation cover and fluctuation of rainfall amount and intensity, which causes high water runoff, soil erosion and overland flow (AL-Seekh and Mohammad, 2009). Rainfall in arid and semi-arid areas is characterized by short duration, high intensity and poor distribution. These properties of low rainfall duration with high rainfall intensity combination are contributed to high runoff production.

Quantity of surface runoff depends on many factors such as: land topography and slope, nature of soil surface, land cover and their type, period and intervals of rainfall, density of rainfall, and other climatic factors as evapotranspiration, temperature, moisture, wind, *etc* (Abu – Nukta *et al*., 2009; Mohammad and Adam 2010). Mohammad and Adam, (2010) found that the runoff amount was low in forest and natural vegetation dominated by *S. spinosum* compared with natural vegetation where *S. spinosum* was removed.

Ibraimo (2007) said that, the threshold amount of rainfall required to generate runoff on slopes in arid zones is rather low, for example 3-5 mm on stony soils in the Negev.

Hai, (1998) said that, rapid runoff in the rainy season is due to soil erosion, vegetation degradation and decrease in soil fertility. Abu – Nukta *et al*., (2009) found that the runoff was 96.93m^3/ha in uncultivated land, 36.74 m^3/ha in rangeland and 12.86 m^3/ha in cultivated land. Taye *et al*., (2013) found that seasonal runoff coefficient and seasonal soil loss were higher in rangeland compared to cropland.

Many researchers found the positive effects of WHTs to reduce water runoff by intercept and give water the time to infiltrate in the soil (Oweis and Hachum, 2009; Ali *et al*., 2010; Alseek and Mohammad, 2009).

In the arid sites at the southern part of West Bank, Alseekh and Mohammad (2009) found that contour ridges significantly reduced the amount of total runoff by 73% compared to the control. And they noted that the water harvesting structures reduced the negative impacts of high runoff intensity and subsequently increasing soil moisture storage from rainfall. Most WHTs such as soil bunds and contour ridges were very effective in reducing runoff, soil erosion and nutrient depletion (Adimassu *et al.*, 2017). Ali *et al*., (2010) found that the unit runoff yield was 280 and 413 m^3/ha for 6m spacing and between 198 and 312m^3 /ha for 12 m spacing between contour ridges. The suitable size of catchment area or the distance between contour ridges varies greatly according to many factors that include: the runoff producing potential, the soil surface condition (cover, vegetation, crust and stoniness), the gradient and evenness of slope and the water retention capacity of the soil in the root zone profile (Fidelibus and Bainbridge, 1995), in addition, they found that the runoff threshold coefficient is a key factor effect on the optimum size for a micro catchment.

Many studies reported that, WHTs reduced the negative effect of intense rainfall and decrease the amount of water runoff and soil erosion compared with control area (Abu Hammad *et al.*, 2004; Yosef and Asmamaw 2012; Mudabber et al., 2011; Al-Seekh and Mohammad 2009).

2.5.4. Water Harvesting Techniques and Soil sedimentation:

Soil erosion is the most destructive degradation process to soils and its productivity potential in West Bank. It caused by the combination of climate, harsh topography (steep to very steep slopes), and thin low vegetation cover and poor agricultural practices (Dudeen, B. 2001). Abu – Nukta *et al.*, (2009) found that when the rainfall is about 12 mm per day, with a density between 2-3 mm/hr, and a surface runoff coefficient between 5-10%, the sediment reaches between 0.2 to 0.6 kg/ha.

Also Abu – Nukta *et al*., (2009) found that the average value of sediment was 8.28 kg/m^3 in cultivated, 8.41kg/m^3 range land, and 21.49 kg/m^3 in uncultivated land. These results show that soil erosion can be controlled or reduced by using simple methods of water harvesting techniques for the purpose of improving and developing the agricultural environments as vegetation land cover, organic matter, and biodiversity.

Abu – Nukta (2009) found that the ploughing against the slope with planting barley can reduce the runoff and soil sediment, and increasing soil moisture and reducing soil erosion. Al-Seekh and Mohammad (2009) found that the sedimentation in contour ridges was 12.9g/m^2 while the sedimentation in stone terraces was 25.7g/m^2. Mudabber and other (2011), found that continuous and intermittent contour ridges implemented with a 4-m spacing reduced soil erosion within the treated area, and they stated that the higher land slope treatment resulted in higher runoff and higher water productivity regardless of the spacing between planted rows and WHTs used.

Grum and other (2016) found that tied ridges and straw mulch, significantly reduced average soil loss, tied ridges alone reduced average soil loss by 60%, however, they found that *in situ* water harvesting techniques can effectively reduce soil and nutrient losses from farmland and they were more efficient when the techniques were combined.

2.6. Research Objectives:

The overall objective of this study is to evaluate the efficiency of using water harvesting techniques on rehabilitation of rangeland and improving the productivity of barley under semi-arid conditions.

The detailed objectives are:

1. To Study the effects of different WHTs on barley production (spikes weight, hay production and height of the barley).
2. To study the effects of the distance between the contour lines at different slopes on runoff, soil sedimentation and natural vegetation characteristics (biomass, cover, and density).

Chapter Three

3. Materials and Methods

This study was a part of project entitled as dry land rehabilitation through water harvesting techniques funded by US forest service – International Program and implemented by College of Agriculture at Hebron University.

3.1. Study Site (Al-Ubeidiya Town):

Al-Ubeidiya is a Palestinian town in Bethlehem Governorate located 8.4 km east of Bethlehem City and 10 km Southeast Jerusalem.

Al-Ubeidiya is located at an altitude of 532 m above sea level with a mean annual rainfall of 250-300 mm (MOA, 2016). The average annual temperature is 18.5 C^o, and the average annual humidity is about 58 percent (ARIJ GIS, 2009).

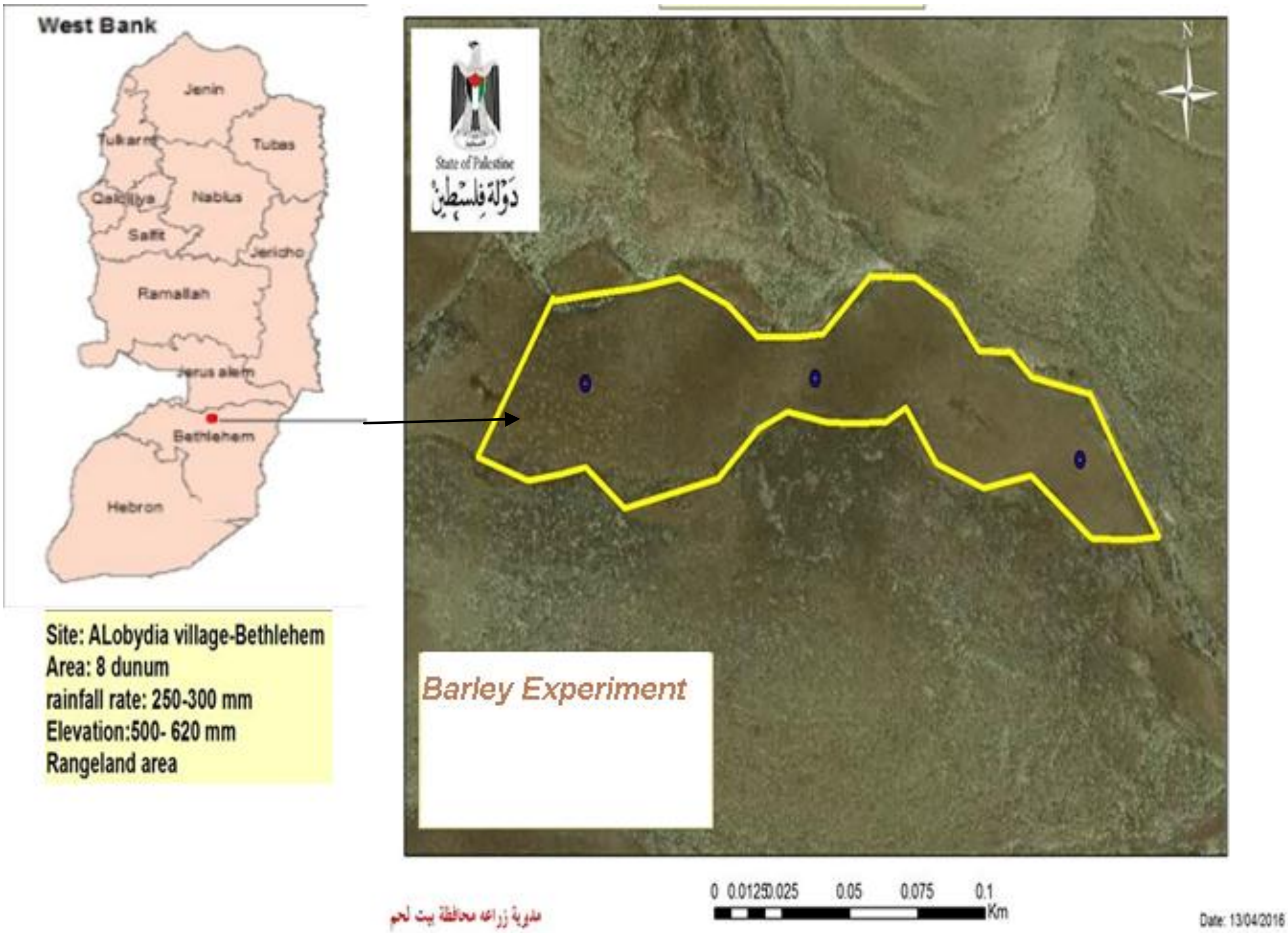
Al-Ubeidiya lies on a total area of about 97,232 dunums of which 96,032 dunums are considered arable land, and 563 dunums are residential land. Agriculture production in Al-Ubeidiya depends mostly on rainwater.

The field crops and forage in Al-Ubeidiya in particular, wheat and barley, are the most cultivated crops with an area of about 750 dunums, barely is the main crop which is commonly planted in the study area while forage crops, such as bitter vetch and common vetch are the next most cultivated crops.

The site is characterized by a semi-arid climate with a long, hot dry summer, and the rainfall in winter, it characterized by strong storms.

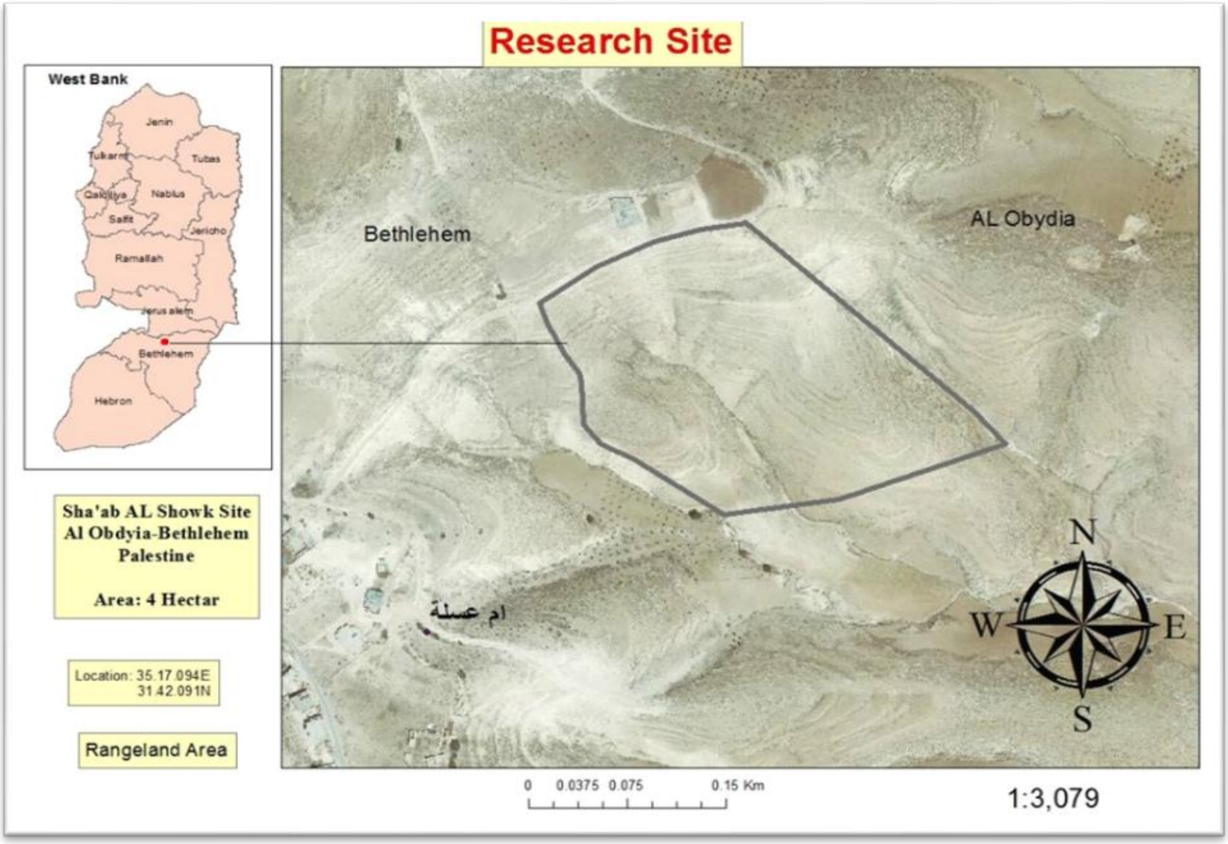
The study was implemented at two sites in Al-Ubeidiya village, specifically in sha'b Alshouk area.

The area of the first site is 8 dunums (map 1), usually planted with field crops. This site was used to evaluate the effect of different WHTs on barley production (spikes weight, straw production and height of the barley).



Map (1): Barley study site at Al-Ubeidiya village (GIS).

The second experiment was implemented on the rangeland near to the barley site (sha'b Alshouk), the total area is 40 dunums (map 2), historically used for grazing of sheep and goats. This site was used to evaluate the effects of water harvesting techniques on different rangeland characteristics.



Map (2): Rangeland study site at Al-Ubeidiya village (GIS).

The second site was used for many years as rangelands, and due to overgrazing, vegetation cover is very low and the land degraded. According to Ministry of Agriculture (2012), the dominant plant species in khalet dar safi (sha'b Alshouk) are *Aegilops sp*, *Anthemis palestina*, *Avena sterilis*, *Bromus sp*, *Echinops polyceras*, *Crithopsis delileana*, *Sinapis arvensis*, and *Maresia pygmaea*.

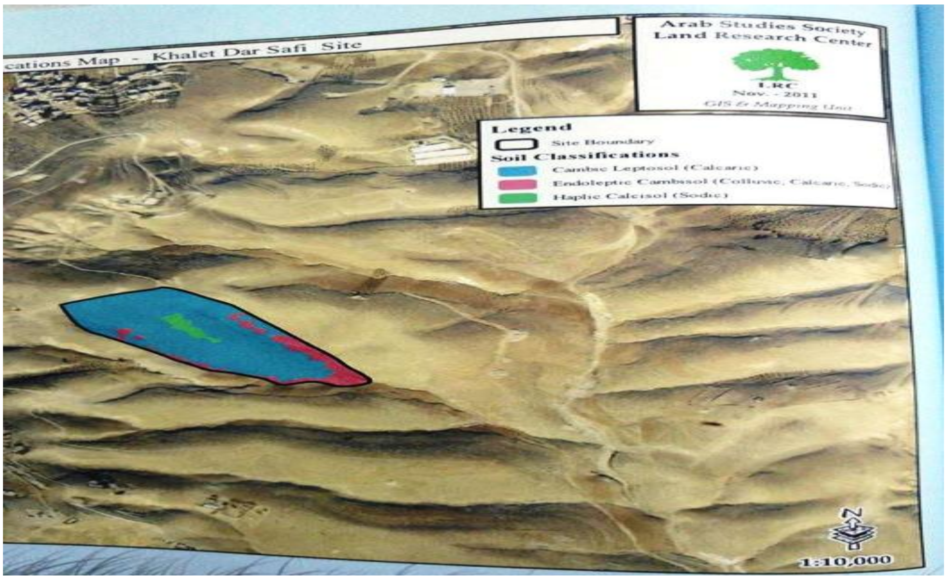
Soil in the study sites is composed of four soil associations classified according to Dan, *et al*., (1976). These soil associations are:

- Terra Rossas, Brown rendzians and pale rendzians.
- Grumosols
- Brown lithosols and loessial arid brown soils
- Brown rendzians and pale rendzinas.

According to the Ministry of Agriculture (2011), Soil in khalet Dar Safi (sha'b Alshouk) was classified into 3 types (map 3):

- Haplic Calcisol (sodic)
- Cambic Leptosol (calcaric).
- Endoleptic cambiosol (colluvic, calcaric , sodic).

This classification was according to the FAO – World reference base for soil resources (2006).



Map (3): Soil classification map – Khalet Dar Safi site (sha'b Alshouk) Al-Ubeidiya (MOA, Soil survey, 2011).

3.2. Treatments and Experimental Design:

Rain gauge was placed in the study site to record the amount of rainfall during the study period (fig 4).

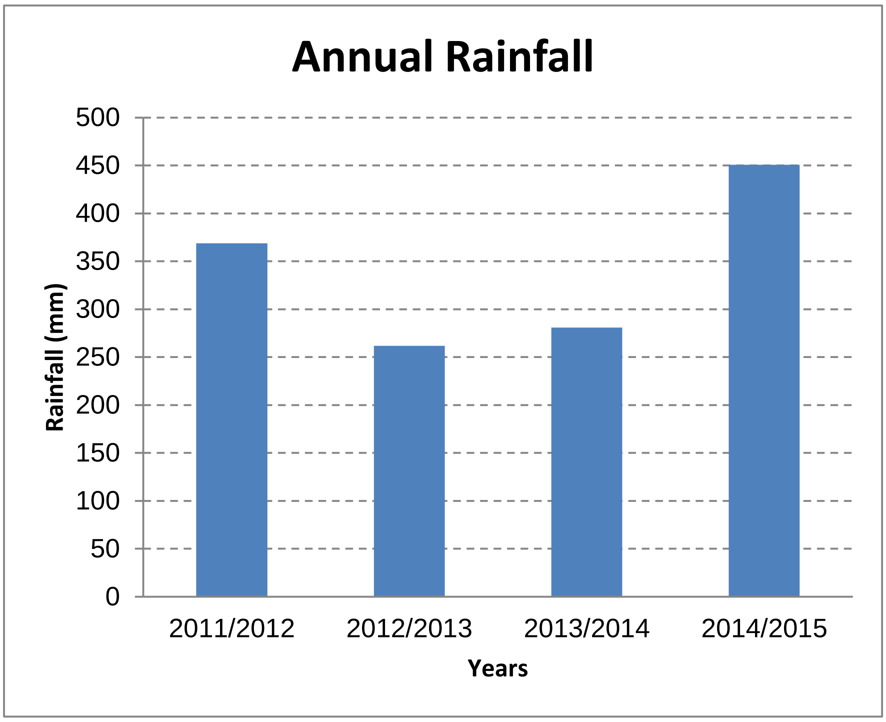


Figure (4): Annual rainfall (mm) at Al-Ubeidiya 2011/2012 to 2014/2015.

3.2.1. Experiment (A):

The aim of this experiment was to evaluate the effects of different WHTs (Strip cropping (Fig 5), Contour Lines (Fig 6), and Plowing-Sowing-Plowing (Fig 7)) on barley production (Spike weight, straw weight and plant height) compared with traditional method (barley seed sown and then plowed by animal). We sowed barely (Qenare 6 rows) 12 kg/dunum in all treatments during two years (December 2012-2013 and December 2013-2014). Each treatment was repeated three times (three replicates, the area of each replicate was 650 m^2). Split plot design was used to compare between treatments, where the years as the main plot and the water harvesting technique as the sub- plot.

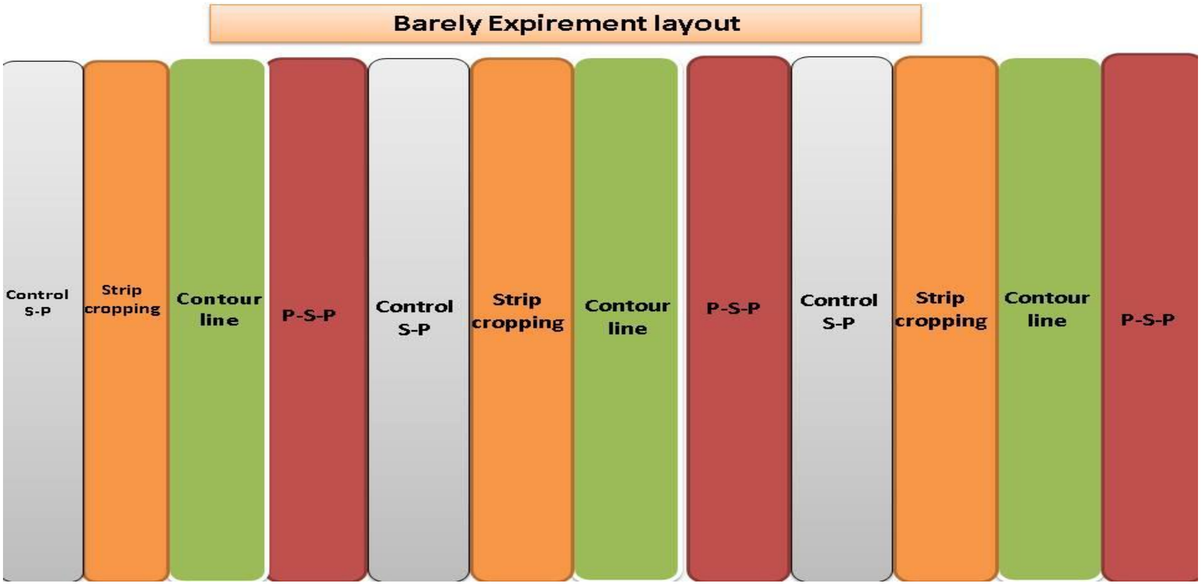


Figure (5): Barely experiment layout at the field (8 Dunums).

- **Strip Cropping (SC):** tilling strips of land along crop rows (1.5m cultivated) and leaving appropriate sections (1m) of the inter-row space uncultivated so as to release runoff.

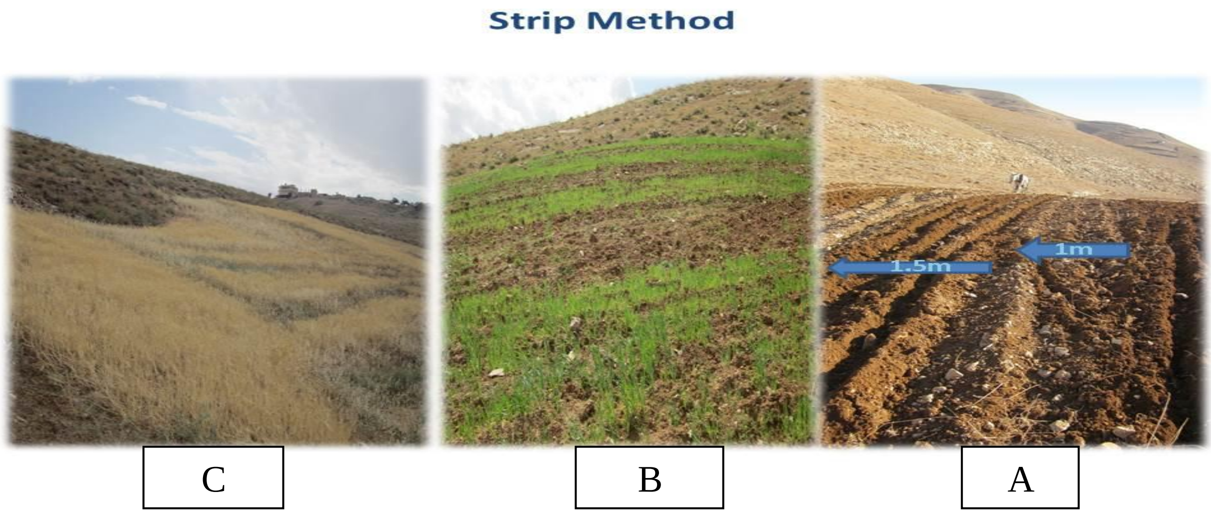


Figure (6): Strip cropping.

- **Contour ridges (CL):**

The contour ridges were established by using the animal then manually manipulated, after that barley seed were sown inside the furrows.

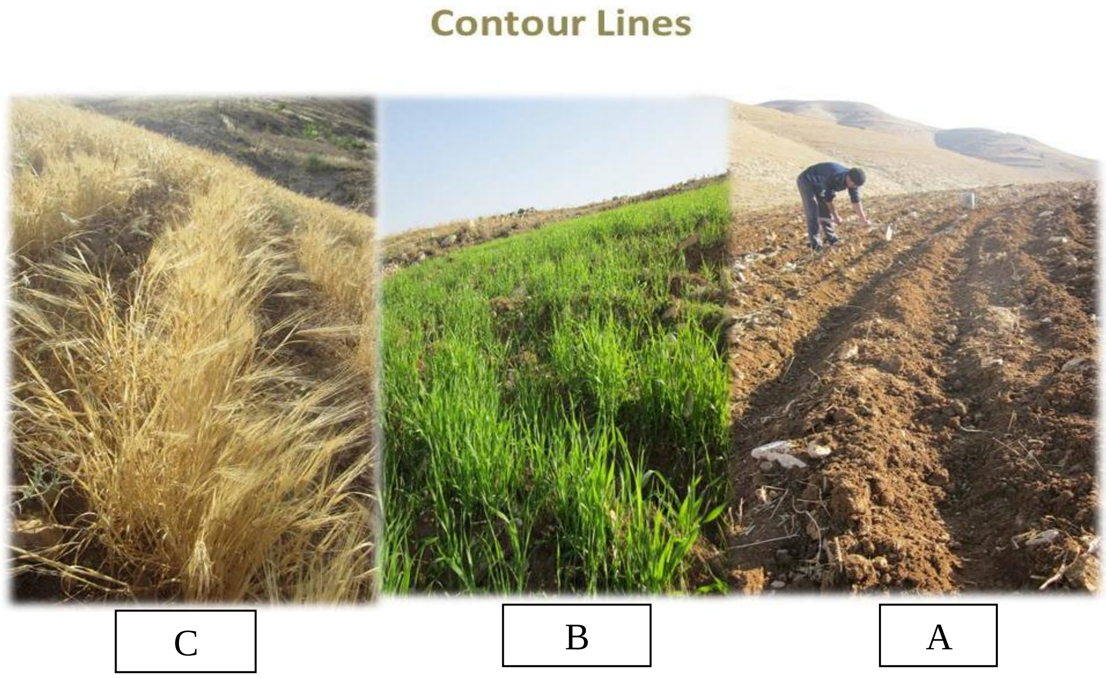


Figure (7): Contour lines.

- **Plowing-Sowing-Plowing (P-S-P):**

In this treatment, the soil plowed before barley seed sown after that when the sufficient amount of rainfall participate the barley seeds sowed then some tillage were practiced mainly to cover the seeds.

Figure (8): Plowing-Sowing-Plowing.

- **Traditional Method (TM):**

This treatment used to compare with the other treatments which considered as the control , which represent the local way of barley growing in Al-Ubeidiya village where the barley seed broad casted then some tillage were practiced mainly to cover the seeds.

3.2.2. Experiment (B):

The aim of this experiment was to evaluate the effects of the distance between the contour lines at different slopes on runoff, soil erosion and natural vegetation characteristics (biomass, cover, and density) during study years (2013/2014 and 2014/2015). Split plot design was used in this experiment with slope as main plot and the distance between the contour line as sub-plot.

- **Gentle slope 10%**: Three treatments were applied within this slope. Each treatment was repeated three times (three micro-catchments with an area of 30 m^2 as in fig. 8):
  - ✓ 1st Plot: (Control plot).
  - ✓ 2nd Plot: 3 meters between the contour ridges.
  - ✓ 3rd Plot: 5 meters between the contour ridges.
- **Steep Slope 20%:** the same treatments and replications as above. We built 3 catchment (plot) area each plot area was 90 m^2 and in each plot three micro-catchment were built (3 replicates) each of 30m^2.
  - ✓ 1st Plot: (Control plot).
  - ✓ 2nd Plot: 3 meters between the contour ridges.
  - ✓ 3rd Plot: 5 meters between the contour ridges.

At each treatment 3 replicate's micro-catchment (3*10 m^2 each replicate) were constructed to evaluate and measure surface water runoff and sedimentation. Cement block (20 cm height) was used to bind each runoff plot (micro-catchment) to prevent runoff from the adjacent area. Plastic pipe was used to convey the runoff water to 100 liters tank.

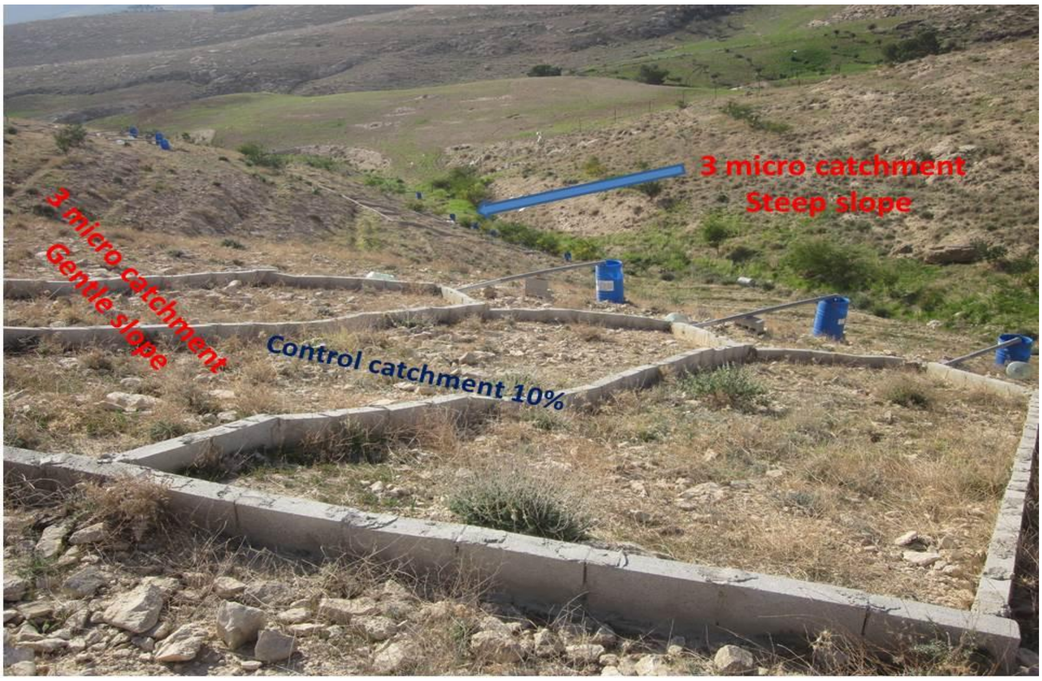


Figure (9): Micro-catchments for Runoff and Sedimentation measurements (for each treatment 3 micro-catchments were established as replicates).

3.3.Data Collection:

3.3.1. Experiment (A): Evaluation the effects of different WHTs on barely productivity.

Barely was sowed in November and the samples were collected for all treatments in June. With the aim to estimate barely productivity, ten 0.25m^2 square quadrates were allocated randomly in each replicate in all treatments (fig 9). In each quadrate all part of plant was collected and placed in labeled paper bags. The air dried weight of the spike and straw were measured separately. Barley production (spike and straw) determined directly as weight g/0.25m^2. Then multiplied by a given factor to obtain the barley production in kg/dun.

Barley production (Straw and Spike weight) (Kg/dun.)= ((1000m^2* Value g/0.25m^2)/0.25m^2).

In the field the heights of 10 plants that chosen randomly were measured in each replicates for all treatments.

Figure (10): Barely data collection.

3.3.2. Experiment (B):

This experiment was conducted to evaluate the effects of the distance between the contour lines at different slopes on runoff, soil sedimentation and natural vegetation characteristics.

3.3.2.1. Runoff and Sedimentation:

The amount of runoff was measured after each main rainstorm event by using a 5 liters beaker. The soil sedimentation also measured after each main rainstorm event, were after shacking the water tanks a 3 samples (replicates) each of 50 ml were collected. These samples were taken to the lab and dried in the oven at 105 C$^{\circ}$ for 24 hours and weighed to determine the average weight of sediment for each treatment replicate

(fig 11) A rain gauge was used to measure the amount of rainfall in the study site during the study period.

Figure (11): Runoff and soil sediment sampling.

3.3.2.2. Natural vegetation characteristics:

For each treatment, vegetation measurements were carried out in April during the peak development stage of the plants (Tedmor *et al*., (1974); Mohammad (2008); and Gutman and Seligman, (1979)). All plant species were identified during the study period according to (Zohary 1966, Oril *et al*. 1999, Al-Eisawi 1998, Burnie 1995, Alsheikh *et al*., 2000 and Botanical garden of Israel (www.flora. Israel).

3.3.2.2.1. Plant Cover :

To estimate the ground cover percentage in each treatment, step-point method was used according to (Bonham 1989). In each treatment three transects (100 step in each transect) were established across each experimental plot (fig 12). Whatever (plant by species, rock or bare soil) found under the tip of the boot was recorded.

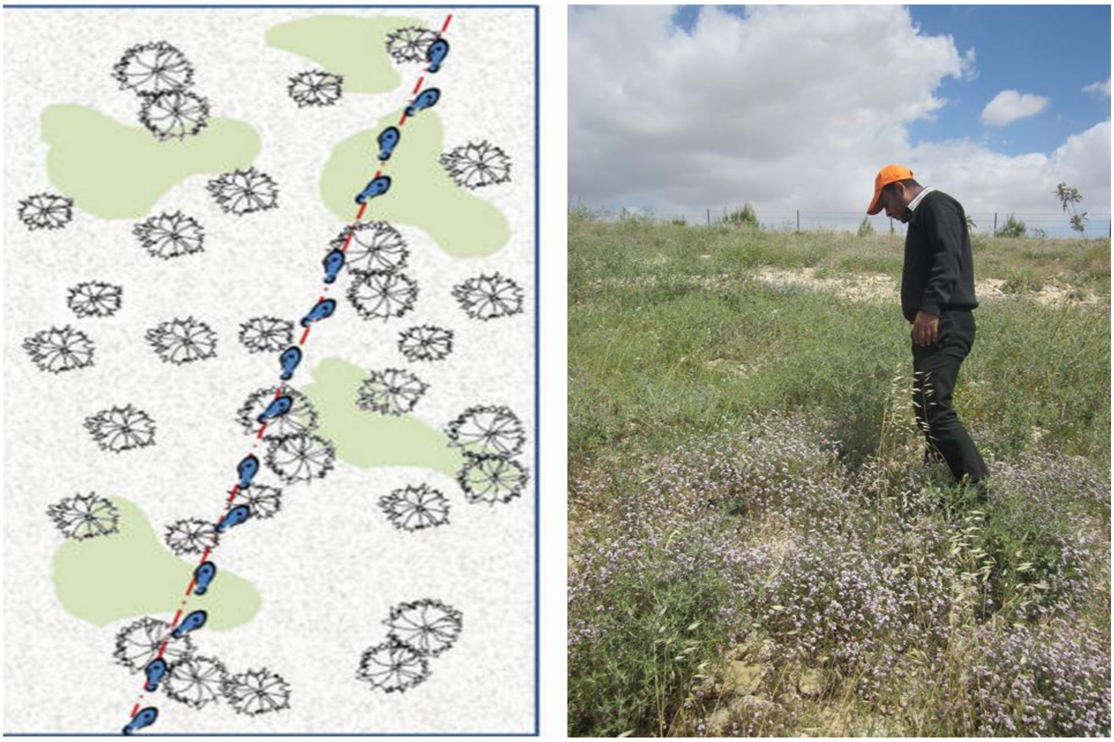


Figure (12): Step-point method.

3.3.2.2.2. Plant Density:

Plant density defined as the number of individuals per unit area. With the aim to estimate plant density, ten 0.25 m² square quadrates were allocated randomly in each treatment (Fig 13). In each quadrate, the number of individuals of each species was documented.

Figure (13): Quadrate $0.25m^2$ to determine plant density.

3.3.2.2.3. Plant Biomass:

For each treatment, ten 0.25 m^2 square plot quadrates were used to estimate plant biomass in each treatment. The square plots were randomly allocated and all part of plant (current year growth) of each species were cut at soil surface and placed in labeled paper bags. To assess dry biomass all samples were taken to the lab. The samples were then placed in the oven to dry at 105 C^o for 24 hours and dry weight was recorded. Plant biomass was determined in Kg/dunum.

3.3.2.2.4. Species richness and diversity

Species richness is the number of different species represented in an ecological community, landscape or region (Barbour *et al*., (1987); and Al-Joaba, (2006)). The Shannon-Weiner index was used as diversity index, this index assumes that individuals were sampled from a very large population and that all species are represented in the sample (Guervitch *et al*., 2002) .

The Shannon Diversity Index is calculated by multiplying a species proportional abundance by the natural log of that number:

$$H' = \sum_{i=1}^{s} pi * lnpi$$

H'= diversity index

Where *s* is the number of species, *Pi* is often the proportion of individuals belonging to the ith species.

Ln= Natural logarithms.

Chapter Four

4. Results

4.1.Rainfall:

The experimental site sha'b alshouke (Al-Ubeidiya) received 262 mm, 280.8 mm, and 450.7 mm annual rainfall in 2012/2013, 2013/2014 and 2014/2015 years. The variability in the amount of rainfall between years is a normal character of rainfall in arid and semi-arid region that also become more clear as affected by the climate change. In 2012/2013 the rainy days was 20 days, 2013/2014 the rainy days was 16 days and 2014/2015 the rainy days was 29 days. The results from fig (14) show the rainfall distribution during the growing seasons from 2012/2013 until 2014/2015. In 2012/2013 most of the rainfall events were during the period from November to March, on the other hand 2013/2014 it was during December and March, rain gauge was not recorded any amount of rain during January. Most of the rainfall on year 2014/2015 was during the period from November until April with good distribution.

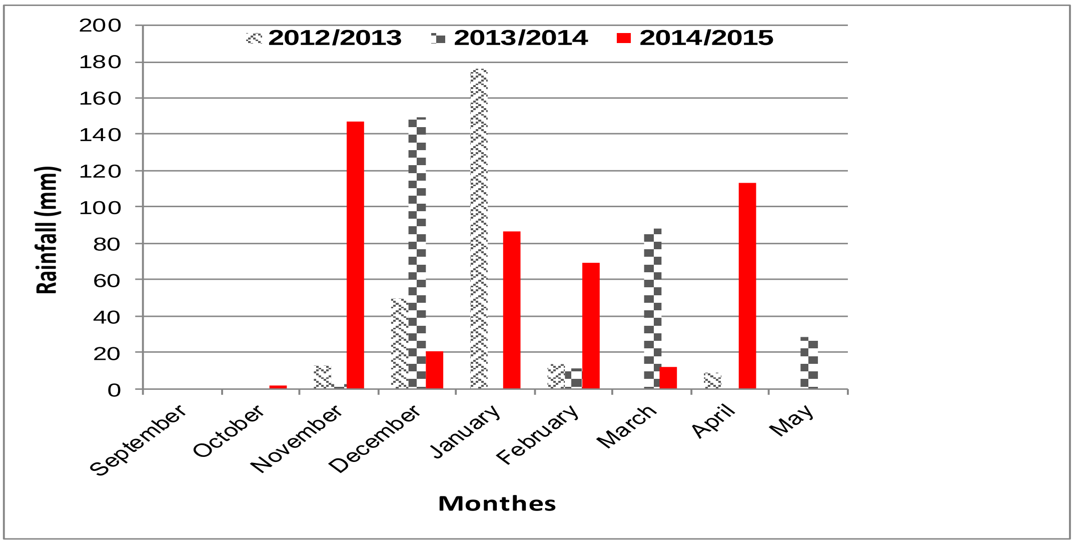


Figure (14): Monthly Rainfall at Al-Ubeidiya site during 2012/2013, 2013/2014 and 2014/2015 years.

4.2. Barely Study:

4.2.1. Barely productivity:

Barely productivity data were measured during the growing seasons of 2012/2013 and 2013/2014. We evaluated the effect of strip cropping, contour lines, and Plowing-Sowing-Plowing on spike weight , straw weight and plant height (tables 2 and 3) compared with traditional method.

4.2.1.1. Spike Weight:

The data in table (3) showed that water harvesting techniques when averaged over years gave a higher spike weight (yield) than the traditional planting method. The spike weight were increased significantly ($p \leq 0.05$) by 62.2, 55.9 and 62.6 kg/dunum by using the strip, contour lines and plowing-sowing-plowing methods, respectively, compared with the traditional method. Data showed no significant difference between the water harvesting treatments. As for the interaction between years and planting methods (table 2), only contour lines during the first year gave significantly higher spike weight (251.1 kg/dunum) than the traditional method (168.9 kg/dunum). Although other treatment combinations gave higher value but not significant difference compared with the traditional method.

Table (2): Average barely production (spike weight (Kg/Dunum), Straw weight (Kg/Dunum) and Plant height (cm/plant) in Al-Ubeidiya during 2012/2013 and 2013/2014 study years.

Treatment combination	Spike weight (kg/dun.)	Straw weight (kg/dun.)	Plant height (cm)
Year1**/strip	**246.8ab*±16.12**	352.4a±16.5	55.9a±2.5
Year2/strip	215.38ab±16.12	365.1a±16.5	45.7 ab±2.5
Year1/Contour lines	251.1a±12.02	271.8bc±12.3	47.8ab±1.9
Year2/Contour lines	198.5ab±16.12	279.4abc±16.5	40.7bc±2.5
Year1/Plowing-sowing-plowing	226.1ab±12.75	295.3abc±13.1	48.9ab±1.9
Year2/Plowing-sowing-plowing	237ab±14.72	331.6ab±15.1	40.1bc±2.3
Year1/ traditional	169b±14.72	184.8d±15.1	44.6ab±2.3
Year2/traditional	168.9b±16.12	223.8cd±16.5	28.1c±2.5

* Means followed by the same letter in the same column are not significantly different, according to Tukey's test at $P \leq 0.05$.

** Year1 (2012/2013) and Year 2 (2013/2014).

Table (3): Average barely production (spike weight (Kg/Dunum), Straw weight (Kg/Dunum) and Plant height (cm/plant) in Al-Ubeidiya study area over two years.

treatment	Average over years		
	Spike weight (kg/dunum)	Straw weight (kg/dunum)	Plant height (cm)
Strip	**231.1a* ±11.40**	358.8 a±11.7	50.8 a±1.8
Contour	224.8a ±10.06	275.6b±10.3	44.2b±1.6
p-s-p	**231.5a ±9.74**	313.5b±9.97	44.5ab±1.5
traditional	168.9b ±10.92	204.3c±11.2	36.3c±1.7

* Means followed by the same letter in the same column are not significantly different, according to Tukey's test at P ≤0.05.

4.2.1.2. Straw Weight:

Straw weight was significantly increased by applying water harvesting technique (table 3) when data averaged over the years. Strip method showed the highest straw weight (358.8 kg/dunum) which is significantly higher than other treatments. The traditional method gave the lowest straw weight (204.3 kg/dunum).

While the results showed high significant differences (P≤0.05) for the interaction between years and planting methods (table 2). The strip method recorded the highest value in the two study years followed by P-S-P and contour lines. The traditional method recorded the lowest value in the two study years (184.75 kg/dunum in 2012/2013 and 223.8 kg/dunum in 2013/2014).

4.2.1.3. Plant Height:

The data in table (2) showed high significant differences ($P \leq 0.05$) for the interaction between years and planting method on plant height. Strip method in 2012/2013 recorded the highest plant height (55.9 cm/plant) followed by P-S-P in 2012/2013 (48.9 cm/plant) and contour lines (47.8 cm/plant) during the same year while the traditional method recorded the lowest value (28.1cm/plant). On the other hand the plant height increased significantly ($P \leq 0.05$) by 17.6 cm, 12.6 cm and 12 cm by using the strip, contour lines and plowing-sowing-plowing methods, respectively, compared with the traditional method.

However the data in table (3) showed that strip method over years gave a highest plant height (50.8 cm/plant) followed by P-S-P (44.5 cm/plant) and contour lines (44.2 cm/plant) while the traditional method gave the lowest height (36.3 cm/plant). The strip method increased plant height significantly ($P \leq 0.05$) compared with contour ridges and traditional method, otherwise the strip method gave no significant difference ($p \geq 0.05$) when compared with P-S-P treatment.

4.3. Runoff, Sedimentation and Plant characteristics Study:

Runoff, sedimentation and plant characteristics data were measured during winter and spring seasons of 2013/2014 and 2014/2015. The total amount of surface runoff in all treatments over study years over slope gradients represented in table (4) and table (5), respectively. And the average natural vegetation biomass, density and plant cover over study years, represented in table (6).

4.3.1. Surface Runoff and Soil Sedimentation:

The data in table (4) showed that water runoff decreased significantly ($P \leq 0.05$) by 49.5% and 45.4% in gentle slope (10%) by contour ridge at 3m and 5m distances, respectively, compared with control plot in the same slope when averaged over years.

While the contour ridges in steep slope (20%) reduced water runoff by 43.6% and 32.2% at 3m and 5m distances, respectively compared with control area in the same slope.

On the other hand, the data in table (4) showed that the amounts of sedimentation in all treatments were low compared with control plots. The highest sedimentation amount was in control plot (steep slope) 78.5 kg/dunum. Water harvesting techniques decreased the amount of sedimentation in gentle slope by 25.4% and 37.3% in contour ridge with 3m and 5m distances, respectively, compared with control plot in the same slope. On the other hand the amount of soil sedimentation in steep slope was higher than that in gentle slope.

Table (4): Interaction effects (Slope and Distance) on Runoff (Liters/Dunum) and Sedimentation (Kg/Dunum) over Study years at Al-Ubeidiya study area over study year.

Treatment combination	Runoff (Liters/dun.)	Sedimentation (Kg/dun.)
G 3m*	4365.5c**±338.7	9.4b±7.8
G 5m	4722.9bc±338.7	7.9b±7.8
G C	8642.1a±338.7	12.6b±7.8
S 3m	4686.9c±338.7	28.9b±7.8
S 5m	5633.44b±338.7	16.6b±7.8
SC	8305.83a±338.7	78.5a±7.8

* G: gentle slope, 3 m: 3 meter distance, 5 m: 5 meter distance, S: steep slope, C: control.

** Means followed by the same letter in the same column are not significantly different, according to Tukey's test at P ≤0.05.

The effect of water harvesting structure in decreasing surface water runoff and soil sedimentation was very clear. Our data (table 5) showed that contour ridges when averaged over slope gradient gave a lower water runoff and soil sedimentation amount than the control plots. Contour ridge at 3m and 5m distances over slope gradients reduced significantly (P ≤0.05) water runoff by 46.6% and 38.9%, respectively, compared with control plot. In addition, a highly significant difference (P ≤0.05) were also resulted in soil sedimentation over slope gradients, when contour ridges were used at 3m (19.2 kg/dunum) and at 5m (12.3 kg/dunum) distances compared with the control plots (45.6 kg/dunum).

Table (5): Average amount of water runoff (Liters/Dunum) and Average amount of soil sedimentation (kg/dun.) in contour ridges at 3m and at 5m distances and control plot over slope gradients at Al-Ubeidiya study area.

Treatments combination	Runoff (liters/dun.)	Sedimentation (kg/dun.)
Contour 3 m	4526.2b*±244.6	19.2b±6.5
Contour 5 m	5178.12b±244.6	12.3b±6.5
Control plot	8473.9a±244.6	45.6a±6.5

* Means followed by the same letter in the same column are not significantly different, according to Tukey's test at P ≤0.05.

Figures (14) and (15) showed the relationship between surface runoff and amount of soil sedimentation during the study years, the data showed that the amount of sediment directly related to the amount of water runoff during the two study years 2013/2014 and 2014/2015.

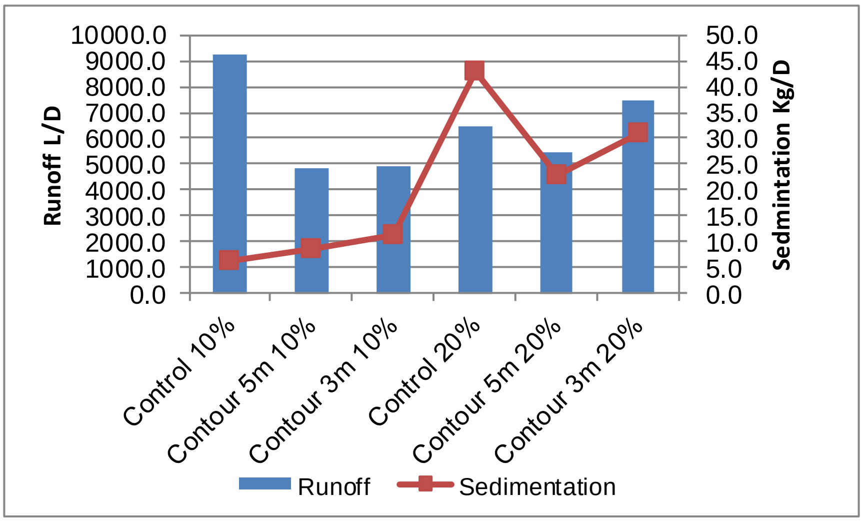


Figure (15): Relationship between surface runoff (L/D) and sedimentation (Kg/D) at study site in 2013/2014.

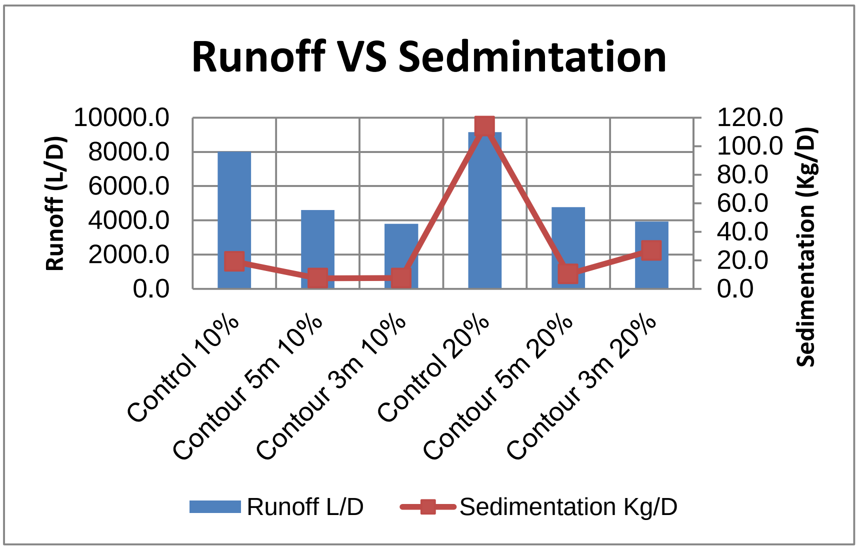


Figure (16): Relationship between surface runoff (L/D) and sedimentation (Kg/D) at study site in 2014/2015.

4.3.2. Plant Characteristics:

Natural vegetation characteristics (plant biomass, plant density and plant cover (tables 6 and 7) were measured during spring seasons of 2013/2014 and 2014/2015.

4.3.2.1. Plant Biomass:

The data in table (6) showed that water harvesting techniques when average over years gave a higher plant biomass than the control area in the two slopes. The plant biomass were increased significantly ($P \leq 0.05$) by 49 and 93.5 kg/dunum by using contour ridge at 3m and at 5m distances in gentle slope, respectively, compared with control area in the same slope. In addition contour ridges at 3m and 5m distances in steep slope increased significantly ($P \leq 0.05$) plant biomass by 23.8 kg/dunum and 85.5 kg/dunum, respectively compared with control area in steep slope. At both slopes, the data showed that plant biomass was higher with contour ridges at 5m than that at 3m distance. And plant biomass generally higher in contour ridges at the gentle slopes than that at steep slope.

On the other hand, the data in table (7) showed that water harvesting techniques increased plant biomass significantly by 36.5% and 89.9% of contour ridge at 3m and at 5m distances, respectively compared with control area over slope gradient.

Table (6): Interaction effects (slope and distance) on plant dry biomass (Kg/dunum), plant density (plants/0.25m^2) and plant cover % over the study years at Al-Ubeidiya study site.

Treatment combination	Plant Biomass (Kg/dun.)	Plant Density (plants/0.25m^2)	Plant Cover%
G 3m*	158.9b**±12.9	49.4a±2.85	0.96a±0.022
G 5m	203.4a±12.9	52.7a±2.85	0.94a±0.022
G C	109.9c±12.9	22.3c±2.85	0.94a±0.022
S 3m	113.1c±12.9	34.6b±2.85	0.92a±0.022
S 5m	174.8ab±12.9	28.0bc±2.85	0.97a±0.022
SC	89.3c±12.9	29.8bc±2.85	0.92a±0.022

* G: gentle slope, 3 m: 3 meter distance, 5 m: 5 meter distance, S: steep slope, C: control.

** Means followed by the same letter in the same column are not significantly different, according to Tukey's test at P ≤0.05.

4.3.2.2. Plant density and plant cover percentage:

The data in table (6) showed high significant differences ($P \leq 0.05$) when plant density averaged over the study years, contour ridges at 3 m and at 5 m distances in gentle slope recorded significantly the highest plant density (49.4 plants/0.25m^2 and 52.7 plants/0.25m^2 , respectively) compared with the other treatments. At steep slope, the distances between contours have no significant effects on plant density compared with the control.

In general contour ridge treatments gave higher plant cover compared with control treatment but the difference was not statistically significant. The highest plant cover was 97% in contour ridge at 5 m distance in steep slope followed by 96% in contour ridge at 3m distance in gentle slope while the lowest value recorded 92% in control area in steep slope.

On the other hand, the data in table (7) showed that water harvesting techniques increased plant density, and it recorded the highest value in contour ridge at 3m distance (42 plants/0.25m^2) and at 5m distance (40.4 plants/0.25m^2), while the lowest value was in control plot (26.1 plants/0.25m^2). As for the plant cover percent the data showed no significantly difference ($p \geq 0.05$), the highest plant cover percentage was in contour ridge at 5m distance (96%) followed by contour ridge at 3m distance (94%) while the lowest value was in control area (93%).

Table (7): Average amount of plant biomass, plant density and plant cover % averaged over the two slopes at Al-Ubeidiy study area.

Treatment combination	Plant Biomass (Kg/dun.)	Plant Density (plants/0.25m^2)	Plant Cover%
Contour 3 m	136b*±12.4	42a±2.8	0.94a±0.016
Contour 5 m	189.1a±12.4	40.4a±2.8	0.96a±0.016
Control plot	99.6c±12.4	26.1b±2.8	0.93a±0.016

* Means followed by the same letter in the same column are not significantly different, according to Tukey's test at P ≤0.05.

4.3.2.3. Vegetation composition:

The plant species list sampled in this study is shown in Annex B. The total number of identified plant species during the study years 2013/2014 and 2014/2015 was 42 species and 45 species, respectively.

The data in Annex (B) showed the number of each plant species in each treatment. In general, the tables showed some differences in the dominant species between the treatments, and it showed that *Sinapis arvensis*, *Hordeum spontanum*, *Bromus scorparins*, *Aegilops geniculate* and *Avena sterilis* were the dominant species in all treatment areas except in control area at gentle slope during 2013/2014 just *Sinapis arvensis* was the dominant plants, furthermore new species appeared as a dominant plants during 2014/2015 as *Hippcrepis unisilquosa* at area treated by contour ridges at 5m distance also *Trifolium sp* was appeared as a dominant plant in control area at steep slope. Forbs were the most species grown in the study area while the most dominant species were the grasses. Although, some changes in vegetation composition were detected, it is well known that under semi-arid conditions the changes require many years.

4.3.2.3.1. Species diversity

4.3.2.3.1.1. Species richness

Our results showed that species richness varied between treated areas, and it ranged between 15 and 28 species per 2.5 m^2.The data showed no consistent results for the change in species richness during the study years (Table 8). But still our results showed a high value for the species richness for all treatments.

Table (8): Species richness at treated area in 2013/2014 and 2014/2015:

Treatments	**Richness (no. of species/2.5 m^2)**		
	2014	2015	**AVG**
G 3m*	25	23	24
G 5m	27	21	24
G C	15	28	21.5
S 3m	17	18	17.5
S 5m	23	23	23
SC	20	24	22

* G: gentle slope, 3 m: 3 meter distance, 5 m: 5 meter distance, S: steep slope, C: control.

4.3.2.3.1.2. Diversity

Using Shannon-Weiner index to evaluate the species diversity in study area, results showed that the plant diversity ranged between 1.2 and 2.6 (Table 9). At steep slope, establishing the contours seems to decrease the diversity which might be due to the disturbance in soil. At gentle slope the diversity was 2.4 and 2.1 at 3 m and 5 m distances while at steep slope the diversity was 1.7 and 1.9 at 3m and 5 m distances.

Table (9): Shannon-Weiner index H' at the treated area during 2013/2014 and 2014/2015

Treatments	**Shannon index**		
	2014	2015	AVG
G 3m*	2.3	2.4	2.4
G 5m	2.1	2.1	2.1
G C	1.2	2.6	1.9
S 3m	1.7	1.7	1.7
S 5m	1.6	2.1	1.9
SC	2.1	2.4	2.3

* G: gentle slope, 3 m: 3 meter distance, 5 m: 5 meter distance, S: steep slope, C: control.

Chapter Five

5. Discussion

5.1. Experiment A (barley productivity):

Barley is mainly grown as a rain-fed crop in Palestine, the planted area of barley in Palestine is about 92806 dunum and produces 10318 ton (MOA, 2014). The average barley yield is lower in southern parts than northern parts of West Bank as the average barley yield in Jenin is 270 kg/dunum while in Bethlehem and Hebron it is about 100kg/dunum (PCBS, 2010/2011., MOA 2012/2013). This difference is related to many edaphic and climatic factors.

Using the traditional method may not help to conserve enough water for barley production, high intensity rain events leads to increase water runoff and soil erosion. Barley growth conditions may further be hampered by a number of climatic factors, as low and erratic rainfall, low relative humidity levels and high temperature during the growing season. There are several options to improve barley production at southern parts of West Bank, one of these options is the use of WHTs. Oweis and Hachum, (2009) said that field crop yield in the cropped area with WHTs should be at least twice that purely rain-fed area.

This study evaluated the effects of water harvesting techniques on spike weight, straw weight and height in rain-fed area, where rainfall is low and poorly distributed. The data were collected during 2012/2013 and 2013/2014, the rainfall rate (fig 3) was 262 mm with 20 rainy days and 280.8 mm with 16 rainy days respectively, the monthly rainfall distribution is shown in figure (14). The rainfall during the study years were around the long term average of Al-Ubeidiya town (250-300mm).

5.1.1. Spike weight, Straw weight and Plant height:

Results show that WHTs (Strip planting, P-S-P, and contour lines) have significant effect on spike weight, straw weight and plant height compared with the traditional method (tables 2 and 3). Generally, these results provide a promising possibility of increasing the barley productivity under hard environmental conditions by using new planting methods.

The three water harvesting techniques that were under investigation gave significantly higher spike weight, straw weight and plant height compared to the control (traditional method), and the data showed no significant difference between these techniques for spike weight while for straw weight and plant height the strip method gave highest value than P-S-P and contour methods. These results indicated that using the strip, P-S-P, or contour method is effective in storing moisture in the soil profile and yet provide more moisture for barley during the growing season that might make soil moisture more balanced mainly during the periods of no precipitation or incase were precipitation distribution within the season is poor. In addition, these techniques also might extended the growing season since soil moisture is expected to be higher for longer period at the end of the rainy season. This result is consistent with Al-seekh and Mohammad (2009) and Karrar *et al*., (2012) conclusions where the soil moisture retention increased when they used conservation practices as stone terraces, semi-circular bunds and contour ridges and furrow, and hence crop yield also increased. In addition, Li and Gong (2002) reported that rainfall harvesting systems, as furrow and ridges, increased water availability for crops and enhance agriculture production in loess Plateau in northwest china. Similar results also obtained by Hatibu and Mahoo

(1999) were they mentioned that WHTs used to enhance barely productivity through increasing the amount of water stored in the soil profile by trapping and intercepting the runoff. Ngigi (2003) and Barron and Okwach (2005) were they concluded that poor distribution of rainfall due to dry spells together with low nutrient input during critical growth stages lead to low yields or crop failure.

There was low interaction between study years and planting method which might be due to similarity of precipitation characteristics during the study years.

In 2012/2013 all treatments gave higher values of spike weight, straw weight and plant height, compared with traditional planting. These results attributed to effective rainfall collection when using strip, P-S-P and contour lines as water harvesting techniques. This mean that these techniques were collected a satisfactory amount that meet barley water requirement.

Our results are in agreement with those of Al-Satari *et al.*, (2013) who showed that the vital role of WHTs in improving barley yield in low rainfall areas. Increased plant height and tillers number of contour ridges and strip methods in comparison with traditional method were attributed to the effective collection of rainfall in barley plants root zones area. In addition Ali Abu-Nukta *et al*., (2009) found that plant height, barley grain and straw weight were increased by using strip cropping and plowing opposite to the land slope.

Soil and water conservation practices have ability to intercept rain water and enhance the soil moisture contents for crop use and minimized the soil sediment loss (Rashid *et al* 2016).

Chapman and carter (1976) indicated that the effectiveness of rainfall in promotion plant growth depended on three factors: amount of moisture, distribution of moisture and soil texture, our results showed that by using water harvesting techniques we can manipulate the effectiveness of rainfall on plant growth through increasing soil moisture and decreasing the variation in soil moisture during the growing seasons.

WHTs as contour ridges increasing the infiltration rates and reducing the surface runoff by providing surface micro-relief or roughness which helps in temporary storage of rain water, thus providing more time for infiltration, this reflected on barley growth and barley production.

5.2. Experiment B (Surface Runoff, Sedimentation and Natural Vegetation Characteristics):

5.2.1. Surface Runoff and Soil Sedimentation:

Runoff and sedimentation data were collected during winter seasons of 2013/2014 and 2014/2015 (tables 4 and 5). Runoff data showed high significant difference between treatments when data averaged over years, and soil sedimentation was decreased by using contour ridges at 3m and 5m distances. When data averaged over slope gradients contour ridges at 3m and 5m distances were significantly decreased water runoff and soil sedimentation compared with control area. The effect of contour ridges in decreasing surface water runoff and soil sedimentation was reported earlier by many researchers (Alseekh and Mohammad (2009); Mudabber *et al*., (2011); Al-Kharabsheh (2004); Mohamoud, (2012); Rashid *et al.*, (2016) and Taye *et al*., (2013)).

Generally, the contour ridges at 3m and 5m distances in gentle slope (10%) reduced water runoff by 49.5% and 45.35%, respectively, compared with control plot in same slope while the contour ridges at 3m and 5m distances in steep slope reduced water runoff by 43.6% and 32.17%, respectively, compared with control area in the same slope. Our data showed that at 10% slope there was no significant difference between the contour ridges at 3 m and 5 m distances. While at 20% slope closer distances between the contour ridges was more efficient in decreasing the water runoff. As for the soil sedimentation, slope have a great effects on the amount of sediment, and at 20% slope the sediment was significantly higher than all other treatments, with no difference between the other treatments and the control at 10% slope. Similar results were obtained by (Al-Kharabsheh 2004; Yair and Yassif 2004). These data showed the effects of slope on runoff and soil sedimentation which is among other factors mentioned by other studies such as rain fall characteristics and distribution (Alseekh and Mohammad (2009); Oweis (2015)), soil characteristics (Alseikh, 2006; and Morgan, 1995), vegetation cover (Zuazo *et al*., 2008; and Mohammad and Adam, 2010).

On the other hand the control plots at the two slopes gave high water runoff during the study periods.

The data showed that the amount of sedimentation is related to the amount of surface runoff, degree of slope and the disturbance of the soils (figures 15 and 16). In addition our results showed that WHTs reduced the amount of surface runoff and losses of soil compared with control area.

According to Al-kharabsheh (2004); and Ali ., *et al* (2010), the differences in the amount of surface runoff is due to rainfall amount, rainfall intensity and duration.

In addition, the data showed in figures (15 and 16) that the relationship between the amount of sedimentation and surface runoff at 20% slope is higher than that at low slope (10%), which might indicate that at high slope, controlling the surface runoff could be more efficient in controlling soil erosion than that at low slopes.

The slope clearly increased water runoff and sedimentation rate especially in control plot with high effects of spacing between contour to reduce runoff and sedimentation. At 3m spacing between contour ridges was better than 5m spacing between contours at two slopes. These results agreed with Mudabber results (2011) the runoff was higher with slope and higher with spacing between contours. The higher amount of sedimentation in contour ridges (although statistically is not significant) with 3m distance probably due to the construction of bounded plot that leads to soil surface disturbance which increases the probability of soil erosion mainly during the early years of contour establishment.

Data of this study showed no significant difference between the 3m and 5m distances of contour ridges on runoff and sedimentation at low slopes while at steep slope the 3m distance resulted in lower runoff than at 5m distance therefore the use of 5m distance might be advised at low slope to the farmers since it decrease the cost and labor work while as slope increase the use of 3m distances is more effective.

5.2.2. Plant characteristics:

The data of natural vegetation were collected during winter seasons of 2013/2014 and 2014/2015.

5.2.2.1. Plant Biomass:

When averaged over years plant biomass (table 6) increased significantly ($P \leq 0.05$) when contour ridges were used compared with the control treatment. Also plant biomass recorded the highest value (189.1 kg/dunum) in contour ridges with 5m distance over slope gradients followed by contour ridges with 3m distance (136kg/dunum) while the control area recorded the lowest value (99.6 kg/dunum).

Plant biomass in gentle slope responded much higher than that in steep slope to contour ridges, where at 10% slope the increase of plant biomass with contour ridges was significant compared to the control while at 20% slope the increase in dry biomass with contour ridges was not significant compared with control. These results might be due to other factors that affects on vegetation growth such as soil characteristics (depth and fertility), since the soil erosion at high slopes is higher than that at low slopes, it mean that the fertile topsoil removed with sediment and the amount of soil moisture in the higher slope lower than in gentle slope leads to the differences between plant biomass at two slopes.

The dry biomass showed highly significant difference between treatments and control area. It seems that the contour ridges give the water longer time to infiltrate into the soil, and increased the amount of water stored for use by the natural vegetation. Saoub., *et al* (2011) found that using the contour farrows increased shrub and vegetation biomass compared to the crested and V-shaped techniques. Plant biomass was increased with harvesting rainfall in West Asia from 533kg/ha to 651 kg/ha, Abu-Zanat *et al*, (2003); Mohammad (2008) and (2011); and Al-joaba (2006); Ezzat et al., (2016) found that the contour ridges and other water harvesting techniques increased vegetation biomass.

Zhang., **et al** (2005) reported that the contour ridge and furrow planting can increase crop production by 74.2% and gradually constructed contour terrace can increase crop production by 37.1%, due to intercept runoff, and yet increased soil moisture.

5.2.2.2. Plant Density and Plant Cover percentage:

Results of the vegetation measurements showed that the percentage of natural vegetation cover at the study sites generally was high, whether in treatments or control area. This might be due to excluding grazing in the site, and the presence of the plant seeds in the soil, when these plants have the opportunity they grow, and this reflected also on the presence of large number of different plant species. These results indicate that there are high opportunities for natural vegetation in these areas either by controlling grazing alone or with applying some water harvesting structures, and it should be considered in the improvement projects and activities that planned for such areas.

Al-Shawahneh (2009) found that the contour ridges increased plant cover% more than the untreated area, due to more moisture conserved in contour ridges.

Data in table (6) showed that contour ridge with 5m distance in slope 10% has the highest plant density and this data reflected also on plant dry biomass, also the lower disturbance for the soil in contour ridge with 5m distance compared with that in contour ridge at 3m distances affects on plant biomass and plant density. These results indicated that contour ridges contributes in increasing the available water content for vegetation growth in the soil by increasing the time of water infiltration in the soil and yet increased plant growth and seed germination. In addition decreasing the soil erosion provides the soil a chance to conserve organic matter and improve its fertility. Aljoba (2006) found that plant density was increased in contour ridges area at Bani-Naim site, Singh *et al.*,

(2010) reported that water harvesting structures significantly increased the plant density, species number, richness and productivity compared to control.

The dominant plant of *Aegilops geniculate* in contour ridges at 5m distance in slope 10% during the two study years might indicate that this treatment was increased the water requirement's availability for this plant. According to Breqiuth (personal communication, he is expert in terrestrial plants) *Aegilops geniculate* needs large amount of water for good growth.

Plant density and plant biomass increased in area treated with contour ridges regardless of the distance between contour and slope gradients which mean that the contour ridges slowed down the rate of runoff and gave the water more time to infiltrate into the soil, and become available for use by vegetation. This results agreed with Mohammad (2009); and Mohammad and Adam (2010).

Avena sterilis was found as one of the dominant plants in all treatments, this is probably due to the presence of deep soil at the study site. Kutiel and Noymeir (1986); and Al-seekh (2006), found that soil depth strongly affected *Avena sterilis* distribution, phenology and productivity.

5.2.2.3. Species diversity

Our results show high plant diversity in the study site (Tables 8 and 9). This is a very encouraging result and indicated the high potential for range improvement and increasing the productivity of rangeland at these sites. It seems that controlling the grazing have direct effects on vegetation growth in addition to other range improvement activities such as water harvesting techniques can accelerate the improvements. And under semi-arid conditions the changes between the treatments require long period of times. These results in agreements with (Mohammad, (2008); Vallentine, (1983); Aljoba, A., and Mohammad (2008)).

Singh et al., (2010); and Mohammad, (2011) reported that water harvesting techniques increased the plant density, species number, richness and productivity compared with control area.

Al-Joaba (2006) found the higher richness between many study sites as the highest richness and shannon index was in Dura site compared with Bani-Noe'm site this differences might be related with the difference in land use.

Chapter Six

6. Conclusion and Recommendations:

6.1.Conclusion:

Application of water harvesting techniques in semi-arid area have the potential to improve the field crops productivity and enhance the rangeland performance by increase the natural vegetation biomass production also resulted in improved plant density, through reducing the water runoff and soil sedimentation. Topography and land use play an important role in determine the best water harvesting techniques.

Under semi-arid conditions, using water harvesting techniques can improve barley productivity. As the slope gradient increased the water runoff and soil sedimentation also increased. Using WHTs with suitable design and method is efficient in decreasing rain water runoff and soil erosion and increasing the soil moisture content and improved the natural vegetation attributes (biomass, density and plant cover).

6.2.Recommendations:

Depending on our results the following recommendation should be taken into considerations:

1. In arid and semi-arid conditions, barley productivity can be improved by using the suitable water harvesting technique.
2. Further studies are recommended to examine the barley productivity using water harvesting techniques for several years.
3. Further studies are recommended to examine the effects of different water harvesting techniques on soil characteristics.

4. Using WHTs for rangeland development, it reduces surface runoff and soil erosion, beside that increase rangeland productivity, thus increasing livestock productivity and improving livelihoods in semi-arid environments.

5. The distance between contour ridges should be closer as the slope is increased. Rainfall characteristics and topography should be taken into consideration for choosing and designing any WHTs especially in arid and semi- arid area.

References:

1. Abrisqueta, J. M., Plana, V., Mounzer, O. H., Mendez, J., and Ruiz-Sanchez, M. C. (2007). Effects of soil tillage on runoff generation in a Mediterranean apricot orchard. *Agricultural water Management*, *93*(1), 11-18.

2. Abu Hammad, A. (2004). Soil erosion and soil moisture conservation under old terracing system in the Palestinian central mountains. PH.D Thesis, Agricultural University of Norway.

3. Abu-Nukta, A., Sertyesilisik, B., & Alkhaddar, R. (2009). Cropping systems as water harvesting techniques for barley production in arid and semi-arid areas in Jordan. *Journal of Facilities Management*, *7*(4), 319-331. Amman, Jordan.

4. Abu-Nukta, A., Sertyesilisik, B., and Alkhaddar, R. (2009). Cropping systems as water harvesting techniques for barley production in arid and semi-arid areas in Jordan. *Journal of Facilities Management*, 7(4), 319-331.

5. Abu-Zreig, M., Attom, M., and Hamasha, N. (2000). Rainfall harvesting using sand ditches in Jordan. *Agricultural Water Management*, *46*(2), 183-192.

6. Adham, A., Riksen, M., Ouessar, M., and Ritsema, C. J. (2016). A methodology to assess and evaluate rainwater harvesting techniques in (semi-) arid regions. *Water*, *8*(5), 198.

7. Adimassu, Z., Langan, S., Johnston, R., Mekuria, W., and Amede, T. (2017). Impacts of Soil and Water Conservation Practices on Crop Yield, Run-off, Soil Loss and Nutrient Loss in Ethiopia: Review and Synthesis. *Environmental Management*, *59*(1), 87-101.

8. Ahmad, S., Islam, M., and Mirza, S. N. (2012). Rangeland degradation and management approaches in Balochistan, Pakistan. Pak J Bot, 44, 127-36.

9. Al sheikh, B., Salman, M., Masalha, J., Salem, K., Ron, M. and Shmida, A. (2000). Preliminary Checklist and Ecological Data-Base of Plants of the West Bank. Al Quds University. *Faculty of Science and Technology*, *Department of life science*, Abu Deis, West Bank.

10. Alamerew, E., Fentaw, B., and Ali, S. (2002). Traditional rainwater harvesting systems for food production: The case of Kobo Wereda, Northern Ethiopia. Addis Abeba: ERHA.

11. Al-Eisawi, D. (1998). Field guide to wild flowers of Jordan and neighboring Countries, Amman. Jordan.

12. Ali, A., and Yazar, A. (2007). Effect of micro-catchment water harvesting on soil-water storage and shrub establishment in the arid environment. *International Journal of Agriculture & Biology*.

13. Ali, A., Yazar, A., Aal, A. Oweis, T., and Hayek, P. (2010). Micro-catchment water harvesting potential of an arid environment. *Agricultural water management*, *98*(1), 96-104.

14. Ali-Shtayeh, M., and Jamous, R. (2002). Red list of threatened plants of the West Bank and Gaza Strip and the role of botanic gardens in their conservation. *Biodiversity and Environment Sciences Studies 2*, *Environmental Research center*. Til, Nables, Palestine.

15. Al-Joaba, O. (2006). Studies of natural vegetation characteristics at different environment and range improvement practices at southern West Bank. M.Sc thesis, Hebron University.

16. Aljoba, A., and Mohammad, A. (2008). Influence of excluding grazing on vegetation attributes at the eastern slopes of West bank. *An-Najah University Journal for Research*, *22*, 43-66.

17. Al-Kharabsheh, A. (2004). *Effect of rainfall and soil surface management on soil water budget and erosion in arid areas* (Doctoral dissertation, M. Sc. thesis, University of Jordan, Amman).

18. Alkhouri, S. I. G. (2012). Monitoring of land condition on the occupied Palestinian territory (2000-2010). Applied Research Institute- Jerusalem.

19. Al-Satari, Y. A., Mhawish, Y. M., Al-Kabneh, A. K., and Khreisat, Z. S. (2013). The Impact of Water Harvesting Techniques on Barley Productivity under Rangelands Conditions in Jordan. *International Journal of Agricultural Science and Research*, 3 (4), 65-70.

20. Al-Seekh, S. H., and Mohammad, A. G. (2009). The effect of water harvesting techniques on runoff, sedimentation, and soil properties. *Environmental management*, *44*(1), 37-45.

21. Al-Suhaibani, N. A. (2011). Better forage and grain yield quality of pearl millet (Pennisetum glaucum L.) under different irrigation water supplies and plant densities. *World Applied Sciences Journal*, *15*(8), 1136-1143.

22. Al-Suhaibani, N. A. (2011). Yield production of some barley genotypes related to irrigation management under low rainfall conditions in Saudi Arabia. *Middle East Journal of Scientific Research*, *8*(1), 191-197.

23. Ammar, A., Riksen, M., Ouessar, M., and Ritsema, C. (2016). Identification of suitable sites for rainwater harvesting structures in arid and semi-arid regions: A review. *International Soil and Water Conservation Research*, *4*(2), 108-120.

24. Applied Research Institute – Jerusalem (ARIJ). (2015). Status of the Environment in the State of Palestine. Bethlehem, Palestine.

25. Auslander M., Nevo E., and Inbar M. (2003). The effect of slope orientation on plant growth, developmental instability and susceptibility to herbivores. *Journal of arid environments*. 55:405-416.

26. Aydrous, E, A., Mohamed, E,A,M., Abdelbagi, A,A., Salih, R,S,A., and Elsheik, M, M, A. (2015). Effect of Micro-catchment water harvesting techniques on soil moisture content. *International conference on chemical, civil and environmental engineering*. Istanbul, Turkey.

27. Barbour, M., Burk, J., and Pitts, W. (1987). Terrestrial plant ecology. 2nd edition. The Benjamin/ Cummings Publishing Company, Inc. California.

28. Barron, J., and Okwach, G. (2005). Run-off water harvesting for dry spell mitigation in maize (Zea mays L.): Results from on-farm research in semi-arid Kenya. *Agricultural Water Management*, 74: 1-21.

29. Beckers, B., Berking, J., and Schutt, B., (2013). Ancient Water Harvesting Methods in the Drylands of the Mediterranean and Western Asia. *Journal for Ancient Studies*. Berline. Germany. Volume 2 . pp.145-164.

30. Beernaerts, I. (2003). Water harvesting for improved rain-fed agriculture in Sub-Saharan Africa: potential, constraints and opportunities. *11th International Rainwater Catchment Systems Conference. International Rainwater Catchment Systems Association. Texcoco, Mexico.*

31. Belgacem, A. O., and Louhaichi, M. (2013). The vulnerability of native rangeland plant species to global climate change in the West Asia and North African regions. *Climatic Change*, *119*(2), 451-463.

32. Bennie, J., Hill, M., Baxter, R. and Huntley, B. (2006). Influence of slope and aspect on long-term vegetation change in British chalk grasslands. J. Ecol. 94:355–368.

33. Biswas, A. K. (1983). Rain and storm water harvesting in rural areas. *Water Resources Series, (United Nations Environment Programme)*. Dublin, Ireland.

34. Bonham, C. (1989). Measurement for Terrestrial vegetation. John Wiley & Sons, Inc. *United States of America.*

35. Braighith, A. (1995). Forest and Woodland in Palestine from 1950 to 1995. Palestinian Ministry of Agriculture.

36. Burnie, D. (1995). Wild Flower of the Mediterranean. Dorling Kinderrley Limited, London.

37. Creswell, R., and Martin, F. W. (1998). Dryland farming: crops and techniques for arid regions. *ECHO technical note, Fort Myers, Fl, USA.*

38. Cristofoli S., Monty A. and Mahy G. (2010). Historical landscape structure affects plant species richness in wet heathlands with complex landscape dynamics. Landscape Urban Plann. 98:92–98.

39. Critchley, W., Siegert, K., and Chapman, C. (1991). Water Harvesting: A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production, *Food and Agriculture Organization of the United Nations*, Rome AGL. MISC/17/91.

40. Danin, A. (1988). Flora and vegetation of Israel and adjacent areas. *The zoogeography of Israel*, 129-158.

41. Deist, F.E., (2000). The material culture of the Bible: an introduction. Sheffield: *Sheffield Academic Press*.

42. Dudeen, B. (2001). The soils of Palestine (The West Bank and Gaza Strip) current status and future perspectives. *Soil Resources of Southern and Eastern Mediterranean Countries*, 203-233.

43. Dudeen, B. (2008). Land Degradation in Palestine: Main Factors, Present Status and Trends, Recommended Actions. Jerusalem: Land Research Center: *Soil and Environment Department*.

44. Environment Quality Authority (2006), Third National Report on Biodiversity Conservation.

45. Esse, D.L., (1991). Subsistence, trade, and social change in Early Bronze Age Palestine.Chicago: *The Oriental Institute of the University of Chicago.*

46. Evenari, M., Shanan, L. and Tadmor, N.H. (1971). the Negev, the Challenge of a Desert. *Harvard University Press*, Cambridge, Massachusetts, USA.

47. Ezzat, S., Omer, M. A., & Fadlalla, B. (2016). Effect of water harvesting and re-seeding on forage biomass production from rangelands in Sheikan Locality, North Kordofan State, Sudan. *Journal of Agricultural and crop Research*. Vol. 4(8), pp. 117-123.

48. FAO – World reference base for soil resources (2006) classifications. *World Soil Resources Reports, 103*.

49. FAO (Food and Agriculture Organization). (2002). World Agriculture: Summary Report. Rome.

50. FAO. (2005). Database. Food and Agriculture Organization, Rome. Accessed November 2005. http://faostat.fao.org.

51. Fidelibus, M. W., & Bainbridge, D. A. (1995). Microcatchment water harvesting for desert revegetation. *Soil Ecology and Restoration Group*.

52. Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., and White, L. L. (2014). IPCC, 2014: climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the Fifth (p. 1132) Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

53. Fleskens, L., Stroosnijder, L., Ouessar, M., and De Graaff, J. (2005). Evaluation of the on-site impact of water harvesting in southern Tunisia. *Journal of Arid Environments*, 62(4), 613-630.

54. Frenken, K. (2009). Irrigation in the Middle East region in figures AQUASTAT Survey-2008. *Water Reports*, (34).

55. Gowing, J. W., and Young, M. D. B. (1996). Evaluation and Promotion of Rainwater Harvesting in Semi-Arid Areas. *Final Technical Report*. University of Newcastle. p84.

56. Grum, B., Assefa, D., Hessel, R., Woldearegay, K., Kessler, A., Ritsema, C., and Geissen, V. (2016). Effect of In Situ Water Harvesting Techniques on Soil and Nutrient Losses in Semi-Arid Northern Ethiopia. Land Degradation & Development.

57. Gutman, M., and No'Am G, S. (1979). Grazing management of Mediterranean foothill range in the Upper Jordan River Valley. *Journal of Range Management*, 86-92.

58. Hadid, M. (2002). Architectural styles survey in Palestinian territories. Energy Codes for Building (www. molg. pna. ps).

59. Hai, M. T. (1998). Water harvesting: an illustrative manual for development of microcatchment techniques for crop production in dry areas.

60. Hamid, A. R. M. N. (2015). Rainwater harvesting techniques for soil moisture conservation on the upper terraces of the White Nile state (Sudan) (Doctoral dissertation, UOFK).

61. Hatibu, N., and Mahoo, H. (1999). Rainwater harvesting technologies for agricultural production: A case for Dodoma, Tanzania. *Conservation tillage with animal traction*, 161.

62. Hensley, M., Botha, J. J., Anderson, J. J., Van Staden, P. P., and Du Toit, A. (2000). Optimizing rainfall use efficiency for developing farmers with limited access to irrigation water. *Water Research Commission*, South Africa, Report, (878/1).

63. Heywood, V. H. (1999). The Mediterranean region a major center of plant diversity. *Wild food and non-food plants: Information networking. Chania: CIHEAM-IAMC*, 5-13.

64. Hussein, A. R., Marwan, G., and Ibrahim, S. (2010). Rainfall trends in the district of Ramallah and Al-Bireh, Palestine. *Journal of Water Resource and Protection.*

65. Ibrahim, I. A. (2012). Investigation of rainwater harvesting techniques in Yatta district, Kenya.

66. Ibraimo, N., and Munguambe, P. (2007). Rainwater harvesting technologies for small scale rainfed agriculture in arid and semi-arid areas. *Department of Rural Engineering, Faculty of Agronomy and Forestry Engineering, University Eduardo Mondlane,* Maputo, Mozambique.

67. Isaac, J., and Rishmawi, K., (2015). Status of the Environment in the state of Palestine. Publications of the Applied Research Institute – Jerusalem (ARIJ).

68. Isaac, J., Istanbuli, D., Yousef, O., Laham, A., Hosh, L., Hrimat, N., Shalaldeh, J., Qumsiyeh, R., Saba, D., and Al-Dajani, N., (1994). Dryland Farming in Palestine.

69. Karrar, A. B., Mohamed, H. I., Elramlwai, H. R., Saeed, A. B., and Idris, A. E. (2012). Effects of some in-situ water harvesting techniques on soil moisture and sorghum (Sorghum bicolor (L.) Moench) production in northern Gedaref state. *Glob J Plant Ecophysiol*, *2*, 54-66.

70. Karrou, M., Oweis, T., Ziadat, F., and Awawdeh, F. (2011). Rehabilitation and integrated management of dry rangelands environments with water harvesting. Community-based optimization of the management of scarce water resources in agriculture in Central and West Asia and North Africa. Aleppo, Syria: ICARDA.

71. Komariah., and Senge, M. (2013). The development of water harvesting research for agriculture. *Reviews in Agricultural Science*, *1*, 31-42.

72. Kutiel, P., and Lavee, H. (1999). Effect of slope aspect on soil and vegetation properties along an aridity transect. *Israel Journal of Plant Sciences*, *47*(3), 169-178.

73. Kutiel, P., and Noy-Meir, I. (1986). The effects of soil depth on annual grasses in the Judean Hills. I: The effect of soil depth on individual plant species. *Israel journal of botany*, *35*(3-4), 233-239.

74. Lasage, R., and Verburg, P.H. (2015). Evaluation of small scale water harvesting techniques for semi-arid environments. J. *Arid Environ.* 118, 48–57.

75. Leipzig. (1996). Country report to the FAO international technical conference on plant genetic resources, The Palestinian Institute for Arid Land and Environmental Studies (PIALES).

76. Liang, X., and Van Dijk, M. P. (2011). Economic and financial analysis on rainwater harvesting for agricultural irrigation in the rural areas of Beijing. *Resources, conservation and recycling*, *55*(11), 1100-1108.

77. Louhaichi, M., Ziadat, F., Ates, S., and Zucca, C. (2016). Rangeland rehabilitation in the southern part of the Mediterranean basin. *International Center for Agricultural Research in the Dry Areas*, PO Box 950764, Amman (Jordan).

78. Mahmoud, N. (2003). Pastures in the eastern slopes of Palestine. M.Sc thesis, of Environmental Science, Faculty of Graduate Studies, at *An-Najah National University*, Nablus, Palestine.

79. Marini, L., Scotton, M., Klimek, S., Isselstein, J., and Pecile, A. (2007). Effects of local factors on plant species richness and composition of Alpine meadows. *Agriculture, Ecosystems & Environment*, *119*(3), 281-288.

80. Ministry of Agriculture, (2014). National Agriculture Sector Strategy “Resilience and Development”. Prepared with technical support from the *Food and Agriculture Organization* of the United Nations (FAO) and financial support from the European Union.

81. Ministry of Agriculture. (2011). Soil survey and classification of the communal Rangeland in the West Bank.

82. Ministry of Agriculture. (2012). Inventory for vegetation properties of the communal Rangeland in the West Bank. Seasons 2011 and 2012.

83. Mohammad, A, G. (2008). The Effect of Slope Aspect on Soil and Vegetation Characteristics in arid Mediterranean region. *Bethlehem University Journal, vol.27.* Bethlehem, West Bank, Palestine.

84. Mohammad, A, G. (2008). The impact of land reclamation on natural vegetation. *Hebron University Research Journal.Vol.(5), pp.(77 – 91).* Hebron, West Bank, Palestine.

85. Mohammad, A. (2008). Growth and development of range plants at Southern West Bank. *Hebron University Research Journal, 3*, 1-21.

86. Mohammad, A. G., and Adam, M. A. (2010). The impact of vegetative cover type on runoff and soil erosion under different land uses. *Catena*, *81*(2), 97-103.

87. Mohammed, A. (2000). Vegetation cover and productivity of the rangeland in the Southern part of West Bank. *Bethlehem University Journal* 19: 75- 87.

88. Mohammed, A. (2005). Rangeland condition at southern West Bank. *Hebron University Research Journal* 2:42-54.

89. Mohamoud, Y. M. (2012). Effect of contour ridging on runoff and soil loss. *African Journal of Agricultural Research*, *7*(46), 6115-6124.

90. Morgan, R.P.C. (1995). Soil Erosion and Conservation, second edition. Longman Scientific and Technical, Longman Group Ltd., New York.

91. Mudabber, M., Oweis, T., Suifan, M., Shawahneh, N., Sattar, Y., Ziadat, F., and Karrou, M. (2011). Effect of water harvesting techniques on water productivity and soil erosion. *Rehabilitation and integrated management of dry rangelands environments with water harvesting*, 31.

92. Mudatenguha, F., Anena, J., Kiptum, C. K., and Mashingaidze, A. B. (2014). In Situ Rain Water Harvesting Techniques Increase Maize Growth and Grain Yield in a Semi-arid Agro-ecology of Nyagatare, Rwanda. *International Journal of Agriculture & Biology*, *16*(5), 996-1000.

93. Nefzaoui, A., and El-Mourid, M. (2008). Rangeland improvement and management in arid and semi-arid Environments of West Asia and North Africa.

94. Ngigi, S, N. (2003). What is the limit of up-scaling rainwater harvesting in a river basin? *Physics and Chemistry of the Earth*, 28: 943-956.

95. Ngigi, S.N., J. Rockstrom and C.K.K. Gachene. (2005). Hydro-economic evaluation of rainwater harvesting and management technologies: Fanners' investment options and risks in semi-arid Laikipia district of Kenya. *Physics and Chemistry of the Earth*, 30:772-782.

96. Office for the coordination of humanitarian affairs occupied Palestinian territory (OCHA oPt). (2009). *Water Scarcity Response Strategy for West Bank* - Version 14.

97. Oril, F., Plitmann. U., Heller, D., and Shmida, A. (1999). checklist and ecological data base of the flora of Israel and its surroundings. *Department of Evolution, Systematics and Ecology*. The Hebrew University of Jarusalem.

98. Oweis, T. and Hachum, A. (2009). Water harvesting for Improved Rainfed Agriculture in the Dry Environment. *Integrated Water and Land Management Program, International Center for Agricultural Research in the Dry Areas (ICARDA).* Aleppo, Syria.

99. Oweis, T. Y. (2016). Rainwater harvesting for restoring degraded dry agro-pastoral ecosystems: a conceptual review of opportunities and constraints in a changing climate. *Environmental Reviews*, (999), 1-15.

100. Oweis, T., D. Prinz and Hachum, A. (2001). Water Harvesting: Indigenous Knowledge for the Future of the Drier Environments. *ICARDA*, Aleppo,Syria. 40 pages.

101. Palestinian Central Bureau of Statistics (PCBS). *Agricultural Census* 2010/2011.

102. Palestinian Water Authority. (2012). Annual status report on water resources, water supply, and wastewater in the occupied State of Palestine, *Ramallah*, *13*.

103. Prinz, D. and Malik, A. H. (2002). Runoff farming. Article prepared for WCA infoNet. *Institute of Water Resources Management, Hydraulic and Rural Engineering, Dept. of Rural Engineering,* University of Karlsruhe, D-76128 Karlsruhe, Germany.

104. Prinz, D., (2001). Water harvesting for afforestation in dry areas. In Proceedings, *10th international conference on rainwater catchment systems, Mannheim* (pp. 195-198).

105. Proud, K.R.S. (1988). Manual on soil and water conservation techniques FAO, *Forestry Division*, Rome.

106. Rango, A., and Havstad, K. (2011). Review of Water-Harvesting Techniques to Benefit Forage Growth and Livestock on Arid and Semiarid Rangelands. *INTECH Open Access Publisher*.

107. Rashid, M., Alvi, S., Kausar, R., and Akram, M. I. (2016). The effectiveness of soil and water conservation terrace structures for improvement of crops and soil productivity in rainfed terraced system. *Pakistan Journal of Agricultural Sciences*, *53*(1).

108. Rebeka, A. (2006). Impact assessment of rainwater harvesting ponds: the case of alaba woreda, Ethiopia, Addis Ababa.

109. Reij, C., Mulder, P., and Begeman, L. (1988). Water harvesting for plant production. *World Bank Technical paper 91*. World Bank, Washington.

110. Rezaei, S.A., and Gilkes, R.J. (2005). The effects of landscape attributes and plant community on soil chemical properties in Rangelands. *Geoderma* .125:167-176.

111. Rockstrom, J. (2002). Potential of rainwater harvesting to reduce pressure on freshwater resources. *Paper prepared for the Dialogue on Water for Food and Environment, International Water Conference*, 14-16. p 24.

112. Rockstrom, J., Hatlbu, N., Owels, T. Y., and Wani, S. P. (2007). Managing water in rainfed agriculture.

113. Saoub, H. M., Al Tabini, R., Al Khalidi, K., and Ayad, J. Y. (2011). Effect of three water harvesting techniques on forage shrub and natural vegetation in the Badia of Jordan. *International Journal of Botany*.

114. Scheierling, S. M., Critchley, W. R. S., Wunder, S., and Hansen, J. W. (2012). Improving water management in rainfed agriculture: Issues and options in water-constrained production systems. *Water Paper, Water Anchor. The World Bank, Washington DC Water harvesting for crop production in Sub-Saharan Africa*, 31.

115. Senge, M. (2013). The development of water harvesting research for agriculture. *Reviews in Agricultural Science,* 1, 31-42.

116. Sholi, N., Karam,F and Christiansen, S. (2010). Improving rural livelihoods through sustainable water and land use management in the middle east: Egypt, Iraq, Jordan, Lebanon, Palestine, Syria, and Yemen. *ICARDA and USAID project*.

117. Singh, G., Rani, A., Bala N., Shukla S., Baloch S., and Limba, N. (2010). Resource availability through rainwater harvesting influence vegetation diversity and herbage yield in hillslope of Aravalli in India. *Frontiers of Agriculture in China* 4 (2):145-158.

118. Sperber, D. (1974). Drought, Famine and Pestilence in Amoraic Palestine. *Journal of the Economic and Social History.*

119. Tadmor, N. H., Eyal, E., and Benjamin, R. W. (1974). Plant and sheep production on semiarid annual grassland in Israel. *Journal of Range Management*, 427-432.

120. Tarhouni, M., Ben Salem, F., Tlili, A., Ouled Belgacem, A., Neffati, M., and Louhaichi, M. (2016). Measurement of the aboveground biomass of some rangeland species using a digital non-destructive technique. *Botany Letters*, *163*(3), 281-287.

121. Tawaha, A. M., Turk, M. A., and Maghaireh, G. A. (2002). Response of Barley to Herbicide Versus Mechanical Weed Control

Under Semi-Arid Conditions. *Journal of Agronomy and Crop Science*, *188*(2), 106-112.

122. Trisorio-Liuzzi, G., and Hamdy, A. (2008). Rain-fed agriculture improvement: Water management is the key challenge. In XIIIth World Water Congress “Global Changes and Water Resources: confronting the expanding and diversifying pressures”- *International Water Resources Association*, (Vol. 4, pp. 1-4).

123. UNEP (United Nations Environment Programme). (1983). Rain and Stormwater Harvesting in Rural Areas. UNEP Report. *Tycooly International Publishing*, Dublin, Ireland.

124. Vallentine, J. F. (1983). Range Improvements: Getting Going Again. *Rangelands*. Academic press. Inc. U.S.A. 113-115.

125. Xiao-yan, L., Xie, Z., and Yan, X. (2004). Runoff characteristics of artificial materials for rainwater harvesting in the semiarid regions of China. *Agriculture Water Management* 65:211–224.

126. Yair, A., and Kossovsky, A. (2002). Climate and surface properties: hydrological response of small arid and semi-arid watersheds. *Geomorphology*, *42*(1), 43-57.

127. Yosef, B. A., and Asmamaw, D. K. (2015). Rainwater harvesting: An option for dry land agriculture in arid and semi-arid Ethiopia. *International Journal of Water Resources and Environmental Engineering*, 7(2), 17-28.

128. Zhang, H., & Oweis, T. (1999). Water–yield relations and optimal irrigation scheduling of wheat in the Mediterranean region. Agricultural Water Management, 38(3), 195-211.

129. Zhang, J., Zheng, D., Wang, Y., Duan, Y., and Su, Y. (2006). Two within-field rainwater harvesting measures and their effects on increasing soil moisture and crop production in north china. *College of Resources and Environment, China Agricultural University, Beijing, China.*

130. Zohary, M. (1982). Vegetation of Israel and adjacent areas. Wiesbaden: Reichert.

131. Zuazo, V. H. D., and Pleguezuelo, C. R. R. (2008). Soil-erosion and runoff prevention by plant covers. A review. *Agronomy for sustainable development*, *28*(1), 65-86.

132. Flora of Israel. http://www.botanic.co.il.

133. http://www.pmd.ps, Palestinian metrological department.

Annex (A)

Table (10): Daily rainfall amount during 2012/2013 winter season in Al-Ubeidiya study site:

NO	Date	Rainfall amount (mm)	Accumulation (mm)
1	12/11/2012	7	7
2	23/11/2012	6	13
3	04/12/2012	12	25
4	06/12/2012	3	28
5	11/12/2012	3	31
6	12/12/2012	4.5	35.5
7	21/12/2012	21	56.5
8	22/12/2012	6.2	62.7
9	05/01/2013	2	64.7
10	06/01/2013	4	68.7
11	07/01/2013	53	121.7
12	08/01/2013	40	161.7
13	09/01/2013	37.5	199.2
14	29.1.2013	4	203.2
15	30.1.2013	14	217.2
16	31.1.2013	21.8	239

17	1.2.2013	9	248
18	6.2.2013	5	253
19	5.4.2013	4	257
20	20.4.2013	5	262

Table (11): Daily rainfall amount during 2013/2014 winter season in Al-Ubeidiya study site.

No	Date	Rainfall amount (mm)	Accumulation (mm)
1	07/11/2013	2.5	2.5
2	05/12/2013	10	12.5
3	08/12/2013	1.5	14
4	11/12/2013	77	91
5	12/12.2013	31	122
6	13/12/2013	25.5	147.5
7	14.12.2013	3	150.5
8	29.12/2013	2	152.5
9	2.2.2014	0.5	153
10	15.2.2014	5	158
11	16.2.2014	6	164
12	9.3.2014	33	197

13	11.3.2014	10.5	207.5
14	12.3.2014	16.8	224.3
15	13.3.2014	28	252.3
16	7.5.2014	28.5	280.8

Table (12): Daily rainfall amount during 2014/2015 winter season:

No	Date	Rainfall amount (mm)	Accumulation (mm)
1	19/10/2014	2	2
2	01/11/2014	25	27
3	02/11/2014	13	40
4	04/11/2014	13	53
5	05/11/2014	2	55
6	17/11/2014	9	64
7	18/11/2014	4	68
8	23/11/2014	3	71
9	24/11/2014	4	75
10	26/11/2014	19.2	94.2
11	27/11/2014	44	138.2
12	28/11/2014	11	149.2

13	06/12/2014	2.5	151.7
14	13/12/2014	6	157.7
15	14/12/2014	3	160.7
16	15/12/2014	4	164.7
17	27/12/2014	5	169.7
18	08/01/2015	35	204.7
19	09/01/2015	16	220.7
20	10/01/2015	3.5	224.2
21	11/01/2014	17	241.2
22	15/01/2015	9	250.2
23	16/01/2015	6	256.2
24	19/02/2015	11.5	265.7
25	20/02/2015	25	292.7
26	21/02/2015	33	325.7
27	21/03/2015	12	337.7
28	14.4.2015	18	355.7
29	16.4.2015	95	450.7

Annex (B)

Table (13): Number of individuals of each plants species in each 0.25m^2 quadrate in control area in slope 10%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2013/2014.

	Plot A Control 10%	***Number of individual for each species in every plots 2013/2014***													
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM (2.5m^2)**
1	ارث	*Echinops polyceras*	Compositae	2	0	3	1	1	0	0	1	0	1	0.9	9
2	**لفيتة**	*Sinapis arvensis*	Brassicaceae	**24**	**19**	**6**	**11**	**0**	**17**	**21**	**7**	**11**	**3**	11.9	119
3	قوص	*Carthamus tenuis*	Compositae	2	0	2	2	0	0	0	0	0	0	0.6	6
4	منثور	*Matthiola aspera*	Brassicaceae	1	0	0	0	0	0	0	0	0	0	0.1	1
5	بالوته	*Ballota undulata*	Labiatae (Lamiaceae)	0	1	0	0	0	0	0	0	0	0	0.1	1
6	بصيل	*Bellevalia warburgii*	Liliaceae	0	1	2	0	3	2	0	0	2	2	1.2	12
7	اقحوان	*Anthemis sp*	Asteraceae	0	3	2	0	4	0	0	0	0	0	0.9	9
8	ورد الشمس	*Helianthemum vesicarium*	Cistaceae	0	0	0	0	1	0	0	0	0	1	0.2	2
9	جريس ثلاثي	*Astragalus hamosus*	Papilionaceae	0	0	0	0	1	0	0	0	0	0	0.1	1
10	عدسية	*Helianthemum salicifolium*	Cistaceae	0	0	0	0	1	0	0	0	0	0	0.1	1
11	سعيسعة	*Lathyrus cicero*	Leguminosae	0	0	0	0	1	0	0	0	0	0	0.1	1
12	شعير بري	*Hordeum spontaneum*	Poaceae	0	0	0	0	0	2	0	0	0	0	0.2	2
13	شخيخ	*Halopeplis amplexicaulis*	*Chenopodiaceae*	0	0	0	0	0	0	0	1	0	0	0.1	1
14	ربحلة	*Lactuca orientalis*	*Compositae (Asteraceae)*	0	0	0	0	0	0	0	0	1	0	0.1	1
15	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	0	0	0	0	0	0	0	0	1	0.1	1
SUM				29	24	15	14	12	21	21	9	14	8	16.7	167

Table (14): Number of individuals of each plants species in each 0.25m^2 quadrate in area treated with contour at 5m distance in slope 10%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2013/2014.

	Plot B contour 5m 10%	***Number of individual for each species in every plots 2013/2014***													
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	
1	مرار بنفسجي	*Centaurea eryngioides*	*Compositae (Asteraceae)*	1	0	0	0	0	0	0	0	0	0	0.1	SUM 2.5m^2
2	ارث	*Echinops polyceras*	*Compositae*	2	0	0	1	1	0	1	0	0	1	0.6	6
3	عنجد	*Scorpiurus muricatus*	*Fabaceae*	2	0	0	0	0	0	0	0	0	0	0.2	2
4	مدك	*Medicago orbicularis*	*Fabaceae*	3	0	0	0	0	0	0	0	0	0	0.3	3
5	**شوفان**	*Avena sterilis*	*Poaceae*	**9**	**7**	**9**	**5**	**4**	**3**	**0**	**3**	**0**	**15**	5.5	55
6	**اغلوبس**	*Aegilops geniculate*	*Poaceae*	**16**	**9**	**4**	**42**	**48**	**36**	**14**	**9**	**3**	**9**	19	190
7	عين جمل	*Anagallis arvensis*	*Primulaceae*	2	0	0	0	0	2	0	0	0	0	0.4	4
8	برومس	*Bromus scoparius*	*Poaceae*	5	0	0	0	0	0	0	0	0	0	0.5	5
9	قطينة	*Evax contracta*	*Compositae (Asteraceae)*	2	0	0	0	0	3	0	0	0	0	0.5	5
10	صفيرة	*Crepis aspera*	*Compositae / Asteraceae*	0	2	0	0	0	0	0	0	1	0	0.3	3
11	عدسية	*Helianthemum salicifolium*	*Cistaceae*	2	0	0	0	0	0	0	0	0	3	0.5	5
12	**شعير بري**	*Hordeum spontaneum*	*Poaceae*	**0**	**5**	**25**	**4**	**0**	**0**	**22**	**11**	**3**	**0**	7	70
13	قوص	*Carthamus tenuis*	*Compositae*	0	3	0	0	0	0	0	0	0	2	0.5	5
14	بصيل	*Bellevalia warburgii*	*Liliaceae*	0	1	0	0	0	2	0	0	1	2	0.6	6
15	**لفيتة**	*Sinapis arvensis*	*Brassicaceae*	**0**	**0**	**23**	**2**	**0**	**0**	**13**	**0**	**12**	**5**	5.5	55

16	منثور	*Matthiola aspera*	*Brassicaceae*	0	0	0	3	0	0	0	0	0	0	0.3	3
17	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	0	0	2	2	0	2	0	0	3	0.9	9
18	ركيبة	*Lomelosia palaestina*	*Dipsacaceae*	0	0	0	0	2	0	0	0	0	0	0.2	2
19	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	0	0	2	3	2	3	0	0	1	10
20	سعيسعة	*Lathyrus cicera*	*Leguminosae*	0	0	0	0	2	0	0	2	0	0	0.4	4
21	ابرة عجوز	*Erodium acaule*	*Geraniaceae*	0	0	0	0	1	0	0	0	0	0	0.1	1
22	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	0	0	0	0	2	0	2	0	0	0	0.4	4
23	شعير	*Hordeum vulgare*	*Poaceae*	0	0	0	0	0	3	0	0	0	0	0.3	3
24	حمحم مصري	*Anchusa aegyptiaca*	*Boraginaceae*	0	0	0	0	0	0	1	0	0	0	0.1	1
25	دحريجة	*Medicago scutellata*	*Fabaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
26	بلانتاجو افرا	*Plantago afra*	*Plantaginaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
27	برومس احمر	*Bromus tectorum*	*Poaceae*	0	0	0	0	0	0	0	0	0	13	1.3	13
SUM				44	27	61	59	64	52	57	28	24	53	46.9	469

Table (15): Number of individuals of each plants species in each 0.25m^2 quadrate in area treated with contour at 3m distance in slope 10%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2013/2014.

	Plot C contour 3m 10%	***number of individual for each species in every plots 2013/2014***													
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	اغلوبس	*Aegilops geniculate*	*Poaceae*	18	8	0	0	3	0	8	9	6	47	9.9	99
2	قوص	*Carthamus tenuis*	*Compositae*	7	7	0	0	0	2	0	3	0	2	2.1	21
3	لفيتة	*Sinapis arvensis*	*Brassicaceae*	13	0	0	26	14	23	17	14	0	13	12	120
4	دنبان	*Brachypodium distachyon*	*Poaceae*	9	0	0	0	0	0	0	0	0	0	0.9	9
5	اقحوان	*Anthemis sp*	*Asteraceae*	2	0	4	0	0	3	0	2	0	0	1.1	11
6	قرصعنة	*Eryngium creticum*	*Umbelliferae / Apiaceae*	1	0	0	0	0	0	0	0	0	0	0.1	1
7	سعيسعة	*Lathyrus cicera*	*Leguminosae*	1	0	1	0	2	0	0	0	1	0	0.5	5
8	برومس	*Bromus scoparius*	*Poaceae*	4	0	0	0	0	0	33	14	0	0	5.1	51
9	شوفان	*Avena sterilis*	*Poaceae*	5	6	7	0	8	9	8	20	0	3	6.6	66
10	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	1	0	0	0	0	0	0	0	0	0.1	1
11	ارث	*Echinops polyceras*	*Compositae*	0	2	2	0	0	1	2	2	1	0	1	10
12	شعير بري	*Hordeum spontaneum*	*Poaceae*	0	15	19	0	4	0	0	0	45	4	8.7	87
13	مدك	*Medicago orbicularis*	*Fabaceae*	0	2	2	0	3	3	0	0	3	0	1.3	13
14	عدسية	*Helianthemum salicifolium*	*Cistaceae*	0	3	0	0	0	0	0	0	0	2	0.5	5

15	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	2	0	3	2	2	0	0	0	0	0.9	9
16	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	0	2	2	0	2	0	0	0	0	0	0.6	6
17	صفيرة	*Crepis aspera*	*Compositae / Asteraceae*	0	1	2	0	0	0	0	0	0	0	0.3	3
18	بصيل	*Bellevalia warburgii*	*Liliaceae*	0	0	2	0	0	0	1	2	0	0	0.5	5
19	ركيبة	*Lomelosia palaestina*	*Dipsacaceae*	0	0	0	1	0	0	0	0	0	0	0.1	1
20	برومس احمر	*Bromus tectorum*	*Poaceae*	0	0	0	0	6	0	0	0	0	0	0.6	6
21	عين جمل	*Anagallis arvensis*	*Primulaceae*	0	0	0	0	2	0	0	0	0	0	0.2	2
22	قطينة	*Evax contracta*	*Compositae (Asteraceae)*	0	0	0	0	3	0	0	0	0	0	0.3	3
23	منثور	*Matthiola aspera*	*Brassicaceae*	0	0	0	0	0	2	2	0	0	0	0.4	4
24	كتان	*Linum strictum*	*Linaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
25	عنجد	*Scorpiurus muricatus*	*Fabaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
SUM				60	49	41	30	49	45	71	66	60	71		542

Table (16): Number of individuals of each plants species in each 0.25m^2 quadrate in area treated with contour at 5m distance in slope 20%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2013/2014.

	Plot D contour 5m 20%	***number of individual for each species in every plots 2013/2014***													
No	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	شوفان	*Avena sterilis*	*Poaceae*	37	7	21	10	8	4	6	17	33	23	17	166
2	لفيتة	*Sinapis arvensis*	*Brassicaceae*	4	5	16	0	9	11	9	5	0	4	6.3	63
3	شعير بري	*Hordeum spontaneum*	*Poaceae*	5	0	0	0	0	0	0	0	0	0	0.5	5
4	مدك	*Medicago orbicularis*	*Fabaceae*	1	2	2	1	0	0	1	0	0	0	0.7	7
5	صفيرة	*Crepis aspera*	*Compositae / Asteraceae*	1	0	0	3	0	0	0	0	0	0	0.4	4
6	ركيبة	*Lomelosia palaestina*	*Dipsacaceae*	0	1	0	0	0	0	0	0	0	0	0.1	1
7	ارث	*Echinops polyceras*	*Compositae*	0	1	0	0	1	0	1	0	0	0	0.3	3
8	عين جمل	*Anagallis arvensis*	*Primulaceae*	0	1	0	0	0	0	0	0	0	0	0.1	1
9	اغلوبس	*Aegilops geniculate*	*Poaceae*	0	2	7	9	0	8	0	0	0	0	2.6	26
10	خويخة	*Salvia syriaca*	*Labiatae (Lamiaceae)*	0	0	1	0	0	0	0	0	0	0	0.1	1
11	منثور	*Matthiola aspera*	*Brassicaceae*	0	0	0	2	0	0	0	0	0	0	0.2	2
12	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	0	0	1	0	0	0	0	0	0	0.1	1
13	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	0	0	3	0	0	0	0	0	0	0.3	3
14	برومس	*Bromus scoparius*	*Poaceae*	0	0	0	3	0	0	0	0	0	0	0.3	3

15	قوص	*Carthamus tenuis*	*Compositae*	0	0	0	0	2	2	0	0	0	0	0.4	4
16	عدسية	*Helianthemum salicifolium*	*Cistaceae*	0	0	0	0	0	2	0	0	0	0	0.2	2
17	هيليوتروبيوم	*Heliotropium digynum*	*Boraginaceae*	0	0	0	0	0	0	1	0	0	0	0.1	1
18	خرفيش	*Notobasis syriaca*	*Compositae (Asteraceae)*	0	0	0	0	0	0	1	0	0	0	0.1	1
19	دحريجة	*Medicago scutellata*	*Fabaceae*	0	0	0	0	0	0	0	1	0	0	0.1	1
20	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	0	0	0	2	2	1	1	2	0.8	8
21	بلانتاجوافرا	*Plantago afra*	*Plantaginaceae*	0	0	0	0	0	0	0	0	3	0	0.3	3
22	بصيل	*Bellevalia warburgii*	*Liliaceae*	0	0	0	0	0	0	0	0	1	1	0.2	2
23	حمرة	*Carlina hispanica*	*Compositae*	0	0	0	0	0	0	0	0	0	1	0.1	1
	SUM			48	19	47	32	20	29	21	24	38	31	31	309

Table (17): Number of individuals of each plants species in each 0.25m^2 quadrate in area treated with contour at 3m distance in slope 20%, and the average number of each plants species per 0.25m2 and the total number of individuals of each plant species 2013/2014.

	Plot E contour 3m 20%	***number of individual for each species in every plots 2013/2014***													
No	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	لفيتة	*Sinapis arvensis*	*Brassicaceae*	26	7	13	0	3	5	12	0	14	9	8.9	89
2	شوفان	*Avena sterilis*	*Poaceae*	2	12	7	2	14	10	9	8	11	13	8.8	88
3	اغلوبس	*Aegilops geniculate*	*Poaceae*	9	3	3	0	0	23	0	11	4	7	6	60
4	جريس	*Onobrychis caput-galli*	*Fabaceae*	2	0	0	0	0	4	0	0	0	2	0.8	8
5	ارث	*Echinops polyceras*	*Compositae*	0	2	0	1	0	1	2	2	0	0	0.8	8
6	قوص	*Carthamus tenuis*	*Compositae*	0	1	2	0	3	1	1	0	0	0	0.8	8
7	جريس ثلاثي	*Astragalus hamosus*	*Papilionaceae*	0	0	2	0	0	0	0	0	0	1	0.3	3
8	بصيل	*Bellevalia warburgii*	*Liliaceae*	0	0	1	0	0	0	0	0	2	0	0.3	3
9	مرار بنفسجي	*Centaurea eryngioides*	*Compositae (Asteraceae)*	0	0	0	2	0	0	0	0	0	0	0.2	2
10	سعيسعة	*Lathyrus cicera*	*Leguminosae*	0	0	0	0	1	0	0	0	0	0	0.1	1
11	دحريجة	*Medicago scutellata*	*Fabaceae*	0	0	0	0	0	1	0	0	0	0	0.1	1
12	خويخة	*Salvia syriaca*	*Labiatae (Lamiaceae)*	0	0	0	0	0	0	1	0	0	0	0.1	1
13	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	0	0	0	0	0	0	1	0	0	0.1	1
14	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	0	0	0	0	0	2	0	0	0.2	2
15	شعير بري	*Hordeum spontaneum*	*Poaceae*	0	0	0	0	0	0	0	2	0	0	0.2	2
16	مدك	*Medicago orbicularis*	*Fabaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
17	صفيرة	*Crepis aspera*	*Compositae / Asteraceae*	0	0	0	0	0	0	0	0	0	2	0.2	2
	SUM			39	25	28	5	21	45	25	26	33	34	28	281

Table (18): Number of individuals of each plants species in each 0.25m2 quadrate in control area in slope 20%, and the average number of each plants species per 0.25m2 and the total number of individuals of each plant species 2013/2014.

	Plot F Control plot 20%	*number of individual for each species in every plots 2013/2014*													
NO	Arabic name	*Scientific Name*	*Family Name*	1	2	3	4	5	6	7	8	9	10	AVG	SUM 2.5m2
1	لفيتة	*Sinapis arvensis*	*Brassicaceae*	12	0	4	0	9	9	0	0	23	7	6.4	64
2	اغلوبس	*Aegilops geniculate*	*Poaceae*	11	3	2	4	14	0	11	4	23	2	7.4	74
3	شوفان	*Avena sterilis*	*Poaceae*	0	8	6	0	4	6	22	8	2	3	5.9	59
4	مرار بنفسجي	*Centaurea eryngioides*	*Compositae (Asteraceae)*	0	3	3	1	2	2	0	3	0	2	1.6	16
5	بصيل	*Bellevalia warburgii*	*Liliaceae*	0	1	0	2	2	2	0	1	1	5	1.4	14
6	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	0	1	0	0	3	0	0	1	0	0.5	5
7	ارث	*Echinops polyceras*	*Compositae*	0	0	1	1	1	0	0	0	0	1	0.4	4
8	مدك	*Medicago orbicularis*	*Fabaceae*	0	0	2	0	0	0	2	0	0	0	0.4	4
9	قوص	*Carthamus tenuis*	*Compositae*	0	0	2	2	0	0	0	0	0	0	0.4	4
10	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	0	0	4	2	0	0	0	0	0.6	6
11	عدسية	*Helianthemum salicifolium*	*Cistaceae*	0	0	0	0	2	0	0	0	0	0	0.2	2

12	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	0	0	0	0	1	0	0	0	0	0	0.1	1
13	سعيسعة	*Lathyrus cicera*	*Leguminosae*	0	0	0	0	0	1	0	0	0	0	0.1	1
14	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	0	0	0	0	3	0	2	2	0	0.7	7
15	شعير بري	*Hordeum spontaneum*	*Poaceae*	0	0	0	0	0	4	0	0	0	0	0.4	4
16	حمحم مصري	*Anchusa aegyptiaca*	*Boraginaceae*	0	0	0	0	0	0	0	1	0	0	0.1	1
17	ورد الشمس	*Helianthemum vesicarium*	*Cistaceae*	0	0	0	0	0	0	0	1	0	0	0.1	1
18	صفيرة	*Crepis aspera*	*Compositae / Asteraceae*	0	0	0	0	0	0	0	0	12	0	1.2	12
19	ابرة العجوز	*Erodium gruinum*	*Geraniaceae*	0	0	0	0	0	0	0	0	1	0	0.1	1
20	خويخة	*Salvia syriaca*	*Labiatae (Lamiaceae)*	0	0	0	0	0	0	0	0	0	1	0.1	1
	SUM			23	15	21	10	39	32	35	20	65	21	28	281

Table (18): Number of individuals of each plants species in each 0.25m^2 quadrate in control area in slope 10%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2014/2015.

	Plot A Control 10%	***Number of individual for each species in every plots 2014/2015***													
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	ابرة الراعي	*Scandix pecten-veneris*	*Apiaceae*	2	0	0	0	0	0	0	0	0	0	0.2	2
2	برومس	*Bromus scoparius*	*Poaceae*	13	2	0	0	3	0	0	3	4	0	2.5	25
3	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	2	1	2	2	2	0	2	0	2	0	1.3	13
4	جريس ثلاثي	*Astragalus hamosus*	*Papilionaceae*	1	1	1	1	0	0	0	0	0	0	0.4	4
5	ارث	*Echinops polyceras*	*Compositae*	2	0	0	0	1	0	2	0	1	0	0.6	6
6	ربحلة	*Lactuca orientalis*	*Compositae (Asteraceae)*	1	0	0	0	0	0	0	0	0	0	0.1	1
7	قوص	*Carthamus tenuis*	*Compositae*	2	1	0	3	5	1	0	3	3	1	1.9	19
8	حمرة	*Carlina hispanica*	*Compositae*	1	0	0	0	0	0	0	0	0	0	0.1	1
9	مدك	*Medicago orbicularis*	*Fabaceae*	1	0	0	0	0	0	0	0	0	0	0.1	1
10	اقحوان	*Anthemis sp*	*Asteraceae*	3	0	1	0	0	0	5	2	0	0	1.1	11
11	اغلوبس	*Aegilops geniculate*	*Poaceae*	4	0	5	0	12	0	0	0	0	0	2.1	21
12	رويص	*Rhagadiolus stellatus*	*Compositae (Asteraceae)*	1	0	0	0	0	0	0	0	0	0	0.1	1
13	شوفان	*Avena sterilis*	*Poaceae*	8	0	6	0	0	0	0	6	2	0	2.2	22
14	لفيتة	*Sinapis arvensis*	*Brassicaceae*	5	3	0	15	9	9	4	2	6	12	6.5	65

15	ورد الشمس	*Helianthemum lippii*	*Cistaceae*	0	1	0	0	0	0	0	0	0	1	0.2	2
16	حمحم	*Anchusa sp.*	*Boraginaceae*	0	2	0	0	0	0	0	0	0	0	0.2	2
17	بهمة	*Stipa capensis*	*Gramineae (Poaceae)*	0	2	0	4	0	0	0	0	0	0	0.6	6
18	شعير بري	*Hordeum spontaneum*	*Poaceae*	0	0	8	11	0	0	0	0	16	0	3.5	35
19	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	0	1	1	0	0	0	0	0	0	0.2	2
20	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	0	1	0	0	0	0	0	0	0	0.1	1
21	شبيه دبيقة	*Ononis orthopodiodes*	*Papilionaceae*	0	0	0	0	1	0	0	0	0	0	0.1	1
22	عين جمل	*Anagallis arvensis*	*Primulaceae*	0	0	0	0	2	0	2	0	0	0	0.4	4
23	قطينة	*Evax contracta*	*Compositae (Asteraceae)*	0	0	0	0	22	0	0	0	0	0	2.2	22
24	طرخشقون	*Taraxacum officinale*	*Asteraceae*	0	0	0	0	0	0	2	2	2	0	0.6	6
25	علك خيل	*Sonchus oleraceus*	*Asteraceae*	0	0	0	0	0	0	0	2	0	0	0.2	2
26	خويخة	*Salvia syriaca*	*Labiatae (Lamiaceae)*	0	0	0	0	0	0	0	1	0	0	0.1	1
27	بلانتاجو افرا	*Plantago afra*	*Plantaginaceae*	0	0	0	0	0	0	0	2	0	0	0.2	2
28	صر	*Noaea mucronata*	*Chenopodiaceae*	0	0	0	0	0	0	0	0	1	0	0.1	1
		SUM		46	13	25	37	57	10	17	23	37	14	28	279

Table (19): Number of individuals of each plants species in each 0.25m^2 quadrate in area treated with contour at 5m distance in slope 10%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2014/2015.

	Plot B contour 5m 10%	***number of individual for each species in every plots 2014/2015***													
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	لفيتة	*Sinapis arvensis*	*Brassicaceae*	5	12	13	12	5	3	5	0	11	0	6.6	66
2	شوفان	*Avena sterilis*	*Poaceae*	6	10	7	15	2	8	21	12	14	6	10	101
3	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	12	0	4	4	6	6	7	11	6	4	6	60
4	تريفوليوم	*Trifolium sp.*	*Fabaceae*	5	0	0	0	2	0	3	7	7	2	2.6	26
5	اغلوبس	*Aegilops geniculate*	*Poaceae*	26	9	10	0	36	35	8	37	17	19	20	197
6	دنبان	*Brachypodium distachyon*	*Poaceae*	0	5	0	0	0	0	3	0	5	0	1.3	13
7	عدسية	*Helianthemum salicifolium*	*Cistaceae*	0	2	0	0	0	3	1	0	0	0	0.6	6
8	شعير بري	*Hordeum spontaneum*	*Poaceae*	0	3	5	0	3	0	0	0	0	8	1.9	19
9	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	2	0	0	0	2	0	0	2	0.6	6
10	برومس	*Bromus scoparius*	*Poaceae*	0	0	8	22	0	9	0	0	0	0	3.9	39
11	بلانتاجوافرا	*Plantago afra*	*Plantaginaceae*	0	0	0	3	2	0	0	3	0	0	0.8	8
12	قوص	*Carthamus tenuis*	*Compositae*	0	0	0	5	3	0	3	5	0	0	1.6	16
13	ارث	*Echinops polyceras*	*Compositae*	0	0	0	0	1	0	0	0	0	0	0.1	1
14	مدك	*Medicago orbicularis*	*Fabaceae*	0	0	0	0	0	1	0	0	3	0	0.4	4

15	دحريجة	*Medicago scutellata*	*Fabaceae*	0	0	0	0	0	0	2	0	0	0	0.2	2
16	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	0	0	0	0	0	2	0	0	0	0.2	2
17	حمرة	*Carlina hispanica*	*Compositae*	0	0	0	0	0	0	0	1	0	0	0.1	1
18	برومس احمر	*Bromus tectorum*	*Poaceae*	0	0	0	0	0	0	0	13	0	0	1.3	13
19	طرخشقون	*Taraxacum officinale*	*Asteraceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
20	عين جمل	*Anagallis arvensis*	*Primulaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
21	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	0	0	0	0	0	0	0	0	1	0.1	1
		SUM		54	41	49	61	60	65	57	89	67	42	59	585

Table (20): Number of individuals of each plants species in each 0.25m^2 quadrate in area treated with contour at 3m distance in slope 10%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2014/2015.

	Plot C contour 3m 10%	***number of individual for each species in every plots 2014/2015***													
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	لفيتة	*Sinapis arvensis*	*Brassicaceae*	14	9	3	8	3	8	7	0	0	0	5.2	52
2	تريفوليوم	*Trifolium sp.*	*Fabaceae*	5	3	0	0	0	0	0	10	2	0	2	20
3	قوص	*Carthamus tenuis*	*Compositae*	2	3	2	3	0	1	0	0	0	4	1.5	15
4	شوفان	*Avena sterilis*	*Poaceae*	6	7	4	0	19	9	3	26	17	5	9.6	96
5	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	3	0	5	4	4	0	7	3	3	9	3.8	38
6	اغلوبس	*Aegilops geniculate*	*Poaceae*	6	2	27	9	5	27	5	8	0	0	8.9	89
7	دنبان	*Brachypodium distachyon*	*Poaceae*	4	0	0	0	12	6	2	4	6	0	3.4	34
8	شعير بري	*Hordeum spontaneum*	*Poaceae*	3	3	0	5	3	5	3	0	0	4	2.6	26
9	ارث	*Echinops polyceras*	*Compositae*	0	1	0	1	0	0	1	2	0	0	0.5	5
10	بروميس احمر	*Bromus tectorum*	*Poaceae*	0	10	0	0	8	0	0	0	0	0	1.8	18
11	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	2	0	0	2	0	0	0	0	0	0.4	4

12	حنون كبير / دحنون/حنون ابو قرون	*Glaucium aleppicum*	*Papaveraceae*	0	0	0	1	0	0	0	0	0	0	0.1	1
13	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	0	2	0	3	2	0	0	0	0.7	7
14	برومس	*Bromus scoparius*	*Poaceae*	0	0	0	6	0	0	0	0	0	0	0.6	6
15	شبيه دبيقة	*Ononis orthopodiodes*	*Papilionaceae*	0	0	0	0	0	1	0	0	0	0	0.1	1
16	بلانتاجوافرا	*Plantago afra*	*Plantaginaceae*	0	0	0	0	0	4	4	0	3	0	1.1	11
17	عين جمل	*Anagallis arvensis*	*Primulaceae*	0	0	0	0	0	3	0	0	0	0	0.3	3
18	سعيسعة	*Lathyrus cicera*	*Leguminosae*	0	0	0	0	0	0	0	1	0	0	0.1	1
19	عدسية	*Helianthemum salicifolium*	*Cistaceae*	0	0	0	0	0	0	0	0	4	1	0.5	5
20	مدك	*Medicago orbicularis*	*Fabaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
21	قرصعنة	*Eryngium creticum*	*Umbelliferae / Apiaceae*	0	0	0	0	0	0	0	0	1	0	0.1	1
22	مرار	*Centaurea hyalolepis*	*Compositae (Asteraceae)*	0	0	0	0	0	0	0	0	0	3	0.3	3
23	تريفوليوم احمر	*Trifolium stellatum*	*Papilionaceae*	0	0	0	0	0	0	0	0	0	8	0.8	8
		SUM		43	40	41	39	56	67	34	54	38	34	45	446

Table (21): Number of individuals of each plants species in each 0.25m^2 quadrate in area treated with contour at 5m distance in slope 20%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2014/2015.

	Plot D contour 5m 20%	***number of individual for each species in every plots 2014/2015***													
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	لفيتة	*Sinapis arvensis*	*Brassicaceae*	4	0	9	0	3	0	16	5	5	3	4.5	45
2	شوفان	*Avena sterilis*	*Poaceae*	22	16	7	5	9	18	0	9	11	8	11	105
3	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	3	2	0	0	3	0	0	0	0	0	0.8	8
4	بهمة	*Stipa capensis*	*Gramineae (Poaceae)*	8	0	0	0	0	0	0	0	0	0	0.8	8
5	مدك	*Medicago orbicularis*	*Fabaceae*	3	1	0	0	2	0	0	0	2	4	1.2	12
6	قوص	*Carthamus tenuis*	*Compositae*	1	1	0	0	0	2	0	0	2	0	0.6	6
7	ارث	*Echinops polyceras*	*Compositae*	1	1	2	1	1	0	0	0	0	0	0.6	6
8	بصيل	*Bellevalia warburgii*	*Liliaceae*	0	1	0	0	0	0	0	0	0	0	0.1	1
9	اغلوبس	*Aegilops geniculate*	*Poaceae*	0	4	0	0	5	6	0	5	0	0	2	20
10	دحريجة	*Medicago scutellata*	*Fabaceae*	0	1	0	0	0	0	0	0	0	0	0.1	1

11	حنون كبير / دحنون/حنون ابو قرون	*Glaucium aleppicum*	*Papaveraceae*	0	0	0	1	0	0	0	0	0	0	0.1	1
12	بلانتاجوافرا	*Plantago afra*	*Plantaginaceae*	0	0	0	3	0	0	0	6	0	0	0.9	9
13	قطينة	*Evax contracta*	*Compositae (Asteraceae)*	0	0	0	5	4	0	0	0	0	0	0.9	9
14	ابو حربي	*Minuartia decipiens*	*Caryophyllaceae*	0	0	0	0	2	0	0	0	0	0	0.2	2
15	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	0	0	0	2	0	0	0	0	0	0.2	2
16	طرخشقون	*Taraxacum officinale*	*Asteraceae*	0	0	0	0	2	0	0	0	0	0	0.2	2
17	حمرة	*Carlina hispanica*	*Compositae*	0	0	0	0	0	1	0	0	0	0	0.1	1
18	مرار بنفسجي	*Centaurea eryngioides*	*Compositae (Asteraceae)*	0	0	0	0	0	0	2	0	0	0	0.2	2
19	عين جمل	*Anagallis arvensis*	*Primulaceae*	0	0	0	0	0	0	0	3	0	0	0.3	3
20	هيليوتروبيوم	*Heliotropium digynum*	*Boraginaceae*	0	0	0	0	0	0	0	0	1	0	0.1	1
21	شبيه دبيقة	*Ononis orthopodiodes*	*Papilionaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
22	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	0	0	0	0	0	0	0	2	0.2	2
23	تريفوليوم	*Trifolium sp.*	*Fabaceae*	0	0	0	0	0	0	0	0	0	3	0.3	3
		SUM		42	27	18	15	33	27	18	28	23	20	25	251

Table (22): Number of individuals of each plants species in each 0.25m^2 quadrate in area treated with contour at 3m distance in slope 20%, and the average number of each plants species per 0.25m^2 and the total number of individuals of each plant species 2014/2015.

	Plot E contour 3m 20%	***number of individual for each species in every plots 2014/2015***														
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	شوفان	*Avena sterilis*	*Poaceae*	13	13	3	4	6	0	0	9	6	7	6.1	61
2	لفيتة	*Sinapis arvensis*	*Brassicaceae*	2	9	0	4	13	5	0	0	0	6	3.9	39
3	اغلوبس	*Aegilops geniculate*	*Poaceae*	33	11	43	14	12	15	25	27	9	22	21	211
4	قوص	*Carthamus tenuis*	*Compositae*	0	2	0	0	2	2	1	8	1	4	2	20
5	مرار بنفسجي	*Centaurea eryngioides*	*Compositae (Asteraceae)*	0	1	0	0	0	0	2	0	0	1	0.4	4
6	ارث	*Echinops polyceras*	*Compositae*	0	0	2	1	0	0	0	0	0	0	0.3	3
7	شبيه دبيقة	*Ononis orthopodiodes*	*Papilionaceae*	0	0	2	0	0	2	0	3	0	0	0.7	7
8	جريس ثلاثي	*Astragalus hamosus*	*Papilionaceae*	0	0	1	0	0	0	0	0	1	0	0.2	2
9	بصيل	*Bellevalia warburgii*	*Liliaceae*	0	0	1	0	0	0	0	0	0	0	0.1	1
10	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	0	0	0	5	2	0	0	0	4	4	1.5	15
11	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	0	0	3	0	0	0	0	0	0	0.3	3

12	تريفوليوم	*Trifolium sp.*	*Fabaceae*	0	0	0	0	3	2	8	0	2	12	2.7	27
13	حمحم	*Anchusa sp.*	*Boraginaceae*	0	0	0	0	1	0	0	0	0	0	0.1	1
14	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	0	0	0	1	0	0	0	0	0.1	1
15	حمرة	*Carlina hispanica*	*Compositae*	0	0	0	0	0	0	1	0	0	0	0.1	1
16	مدك	*Medicago orbicularis*	*Fabaceae*	0	0	0	0	0	0	2	2	2	0	0.6	6
17	عنجد	*Scorpiurus muricatus*	*Fabaceae*	0	0	0	0	0	0	0	0	2	0	0.2	2
18	دنبان	*Brachypodium distachyon*	*Poaceae*	0	0	0	0	0	0	0	0	0	7	0.7	7
19		*SUM*		48	36	52	31	39	27	39	49	27	63	41	411

Table (23): Number of individuals of each plants species in each 0.25m2 quadrate in control area in slope 20%, and the average number of each plants species per 0.25m2 and the total number of individuals of each plant species 2014/2015.

	Plot F Control plot 20%	***Number of individual for each species in every plots 2014/2015***													
NO	**Arabic name**	***Scientific Name***	***Family Name***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**AVG**	**SUM 2.5m^2**
1	ترايفوليوم	*Trifolium sp.*	*Fabaceae*	8	17	3	0	0	0	3	7	0	4	4.2	42
2	مرار بنفسجي	*Centaurea eryngioides*	*Compositae (Asteraceae)*	1	0	1	0	0	0	2	0	0	0	0.4	4
3	شوفان	*Avena sterilis*	*Poaceae*	3	4	7	6	13	7	6	4	2	13	6.5	65
4	جريس مخزق	*Hippocrepis unisiliquosa*	*Papilionaceae*	5	1	5	0	2	0	3	3	1	0	2	20
5	اغلوبس	*Aegilops geniculate*	*Poaceae*	12	15	0	6	0	0	9	13	7	6	6.8	68
6	لفيتة	*Sinapis arvensis*	*Brassicaceae*	3	0	6	2	0	4	0	4	7	0	2.6	26
7	مدك	*Medicago orbicularis*	*Fabaceae*	0	5	0	0	0	0	0	0	0	3	0.8	8
8	ارث	*Echinops polyceras*	*Compositae*	0	1	0	2	0	0	0	0	0	1	0.4	4
9	دنبان	*Brachypodium distachyon*	*Poaceae*	0	4	0	0	0	9	7	0	3	0	2.3	23
10	قوص	*Carthamus tenuis*	*Compositae*	0	2	1	0	1	2	0	2	2	2	1.2	12
11	خويخة	*Salvia syriaca*	*Labiatae (Lamiaceae)*	0	0	1	0	0	0	0	0	0	0	0.1	1

12	حنون كبير / دحنون/حنون ابو قرون	*Glaucium aleppicum*	*Papaveraceae*	0	0	1	0	0	0	0	0	0	0	0.1	1
13	اقحوان	*Anthemis sp*	*Asteraceae*	0	0	2	0	0	0	1	0	2	0	0.5	5
14	غيصلان	*Asphodelus aestivus*	*Liliaceae*	0	0	1	0	0	0	0	0	0	0	0.1	1
15	جريس	*Onobrychis caput-galli*	*Fabaceae*	0	0	2	0	0	0	2	0	0	0	0.4	4
16	صوفان	*Phagnalon rupestre*	*Compositae (Asteraceae)*	0	0	0	1	0	0	0	0	0	0	0.1	1
17	برومس	*Bromus scoparius*	*Poaceae*	0	0	0	5	4	0	5	0	0	0	1.4	14
18	صر	*Noaea mucronata*	*Chenopodiaceae*	0	0	0	0	1	1	0	0	0	0	0.2	2
19	جريس ثلاثي	*Astragalus hamosus*	*Papilionaceae*	0	0	0	0	0	2	0	1	0	0	0.3	3
20	عنجد	*Scorpiurus muricatus*	*Fabaceae*	0	0	0	0	0	0	0	2	0	0	0.2	2
21	شبيه دبيقة	*Ononis orthopodiodes*	*Papilionaceae*	0	0	0	0	0	0	0	2	0	0	0.2	2
22	برومس احمر	*Bromus tectorum*	*Poaceae*	0	0	0	0	0	0	0	0	5	0	0.5	5
23	ربحلة	*Lactuca orientalis*	*Compositae (Asteraceae)*	0	0	0	0	0	0	0	0	1	0	0.1	1
24	عين جمل	*Anagallis arvensis*	*Primulaceae*	0	0	0	0	0	0	0	0	1	0	0.1	1
		SUM		32	49	30	22	21	25	38	38	31	29	32	315

تأثير استخدام طرق الحصاد المائي على الخصائص النباتية (الطبيعية والمزروعة)، الجريان السطحي وانجراف التربة في المناطق شبه الجافة

تعتمد الزراعة في فلسطين على كميات الامطار الهاطلة سنويا والتي تتغير كثيرا من حيث الزمان والمكان، كما وتعتبر المياه العامل المحدد لنمو النباتات في مناطق المنحدرات الشرقية. تم تنفيذ الدراسة في منطقة العبيدية التابعة لمحافظة بيت لحم وتعتبر جزء من منطقة المنحدرات الشرقية حيث تتراوح كمية الامطار فيها من 250-300 ملم سنويا.

هدفت الدراسة الى قياس مدى تأثير استخدام طرق الحصاد المائي على انتاجية الشعير (وزن السنبلة، وزن القش وطول النبات) مقارنة بالطرق التقليدية في الزراعة وايضا تقييم استخدام الخطوط الكنتورية بأبعاد مختلفة في ميلان 10% و 20% على الخصائص النباتية الطبيعية وعلى الجريان السطحي وانجراف التربة في سنوات 2013، 2014، 2015.

اظهرت النتائج ان استخدام طرق الحصاد المائي زادت من انتاجية الشعير بشكل معنوي مقارنة بالطرق التقليدية، حيث سجلت طريقة Strip Cropping اعلى نتائج على صعيد وزن السنبلة والقش وطول النبات تبعها P-S-P ومن ثم Contour lines بينما سجلت الطرق التقليدية اقل انتاجية لنبات الشعير. كما واظهرت النتائج ان الجريان السطحي وانجراف التربة قلت بشكل معنوي في المناطق المعاملة بالخطوط الكنتورية وعلى مسافة 3م و5م بمعدل 49.5% ، 45.5%، و 43.6% و 32.2% في الميلان 10% و 20% بالمقارنة مع المناطق غير المعاملة. كما ودلت النتائج على ان استخدام الخطوط الكنتورية بأبعاد 3م و5م في ميلان 10% و 20% له تأثير جيد في تحسين الخصائص النباتية (الغطاء النباتي، كمية المادة الجافة و كثافة النباتات). وعليه فان استخدام طرق الحصاد المائي البسيطة له تأثير ايجابي في تحسين انتاجية المحاصيل الحقلية وخصائص الغطاء النباتي الطبيعي كما ويساهم في تقليل الجريان السطحي وانجراف التربة مما يساهم في تحسين انتاجية المناطق الواقعة في المناطق الشبه جافة ولكن يجب التخطيط مسبقا لتطبيق التدخل المناسب في المنطقة وايضا الحاجة الى فترة زمنية لإظهار النتائج الايجابية على الارض.