<u>**Impacts of different soil and water conservation measures on physical soil properties in the Negev, Israel**</u>

MSc Thesis by Vinay Suresh Waghdhare
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Impacts of different soil and water conservation measures on physical soil properties in the Negev, Israel

By

Vinay Suresh Waghdhare

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Student registration number:
850312924110

Subject:
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Supervisor(s):
Dr. Eli Argaman

Examinator:
Prof.dr.ir. L. Stroosnijder

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Wageningen University, Land Degradation and Development Group

Soil Erosion Research Station (Israel)

Abstract

Afforestation provides suitable spots for outdoor recreation to growing population. The locally developed infiltration basins known as *limans* and terraces are used as soil and water conservation (SWC) structures in combination with afforestation for mitigation of desertification. This combination improves the soil structure and hence enhances the water use efficiency. Jewish National Fund (JNF) took an initiative to combat desertification, thereby creating desert rehabilitation works. Current research was conducted at Negev desert in Israel with an objective to study dynamics of soil and water properties under rehabilitation through forests in combination with *limans* and terraces. The study basically compared the impact of these SWC structures on soil physical proprieties and water use efficiency. Soil samples were collected from nine plots and carefully analyzed. Soil properties including texture, organic matter, bulk density, aggregate size distribution, and hydraulic conductivity were improved significantly with increase in the ages of SWC structures. The oldest *liman* plots showed higher water use efficiency (hydraulic conductivity: new plots 1.3 cm h^{-1} and old plots 5.9 cm h^{-1}). Further studies are needed on run-off and evapo-transpiration in this study area.

Keywords: Afforestation, terraces, *limans*, soil texture, organic matter, bulk density, soil moisture content, aggregate size distribution, hydraulic conductivity.

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1. Introduction

Soil and water conservation (SWC) structures are mainly used to conserve rain water. These structures retain organic matter, soil structure, and soil depth. Improvement in soil physical properties namely retention of soil structure and organic matter leads to increased water infiltration and storage of water in soil profile (Pimentel, 1993). This not only results in reduction of run-off but also helps in reduction in soil erosion. Apart from SWC structures afforestation also helps to conserve soils on degraded land by reducing soil erosion (Oscar, 2001). Moreover, afforestation increases soil organic matter, implying in better soil structure, aggregation of soil and soil porosity (Cornelis et al., 2002 and Jackson et al., 2002). Improved soil structure, aggregates, and porosity promotes increased infiltration and storage of water in the soil. Additionally, afforestation provides habitat for wildlife by improving the landscape (Franco et al., 2003).

In the coming decades, global climate change is expected to produce large shifts in vegetation distributions at historically unprecedented rates (Allen and Breshears, 1998 and Woodwell, 2002). These shifts are expected to be most rapid and extreme within the ecotones at the boundaries between ecosystems, particularly in arid and semiarid landscapes. This is a particular problem in agricultural areas. Significant scientific advances and regulatory, technological, and policy changes will be needed to control the environmental impacts of agricultural expansion (Tilman et al., 2001). However, drought is a major constraint worldwide to the establishment of vegetation (Schume et al., 2004), particularly for trees, which often have a relatively low water-use efficiency (Wang et al., 2004 and Zhao & Li, 2005).

Water use efficiency (WUE) is a broad concept that can be defined in many ways; for farmers and land managers, WUE is the yield of harvested crop product achieved from the water available to the crop through rainfall, irrigation and the contribution of soil water storage (White, 1961). Whether under dry or irrigated conditions, successful crop production depends on storing adequate soil water to sustain the crop until the next precipitation or irrigation event. In semi-arid and also in sloping areas, rain water is conserved by constructing soil and water conservation measure like terraces. Our research deals with relationship between the soil properties and the effectiveness of local afforestation process at farm level in semi arid area, Ambassadors forest (Israel).

My thesis topic was a small part of project carried out by Jewish National Fund (JNF) called as Combating Desertification and Desert Rehabilitation or afforestation in Negev desert, Israel. The JNF is a non-profit corporation owned by the World Zionist Organization and possesses quasi-government powers that are responsible for the implementation of afforestation and forest management. In 2006, the JNF signed a 49-year lease agreement with the State of Israel which gives it controls over 30,000 hectares of Negev land for the development of forests (Leon, 2005). One of the main objectives of afforestation and forest reclamation in Israel is to provide the rapidly growing and densely settled population with suitable spots for outdoor recreation, i.e. areas with a comfortable microclimate (Schiller, 2001). It also helps in preventing the process of desertification and water conservation measures like terraces and *limans* improves soil structure leading to water use efficiency by plants.

2. Problem statement

The major problem in this area was that there is very less rainfall (200mm/year). The major soil categories in this area are loamy sand, loess sandy loam and sandy loam or loess soils. These soils are loosely structured and coarse textured and thereby are highly susceptible to erosion by water and wind (Dan, 2006). In fact, less than 50% of rainfall water infiltrate through these soils and most of them flows, leading to runoff i.e. loss of water (Orlovsky, 2008). SWC measures were built by JNF. But less study was carried out about their impacts on physical soil properties. There was not much knowledge on soil physical properties related to water use efficiency. My work was to see how conservation measures affect the soil physical properties in terms of water use efficiency. For that, I carried out some field measurements (for physical soil properties, EC and soil temperature) at different locations in terraces and *limans* which had no, less or dense vegetation, to study the interactions between soil, water and vegetation. By collecting the information and analyzing the data I wanted to see for which situation the conservation measures (CM) like *Limans* and terraces, are suitable so that the water will be used by the plants more instead it was being lost due to evaporation or by runoff.

3. Overall objective

To study the impacts of different soil and water conservation (SWC) measures on physical soil properties in Ambassador Forest, Israel

3.1. Specific objective

1. To measure the physical soil properties of different SWC measures
2. To examine the relation between physical soil properties and hydraulic conductivity
3. To analyze the difference between terraces and *limans* of different ages

4. Conceptual Frame Work

In arid and semi-arid areas with erratic rainfall patterns WUE is very important. Rainfed areas faces loss of soil water, from soil surface through evaporation or through uptake by plants and subsequently lost via openings on plant leaves. Water can also be lost through run-off or deep infiltration through the soil. Amount of total soil water lost due to both soil evaporation and plant transpiration is referred to as evapotranspiration. In case of irrigation, water is usually lost because of mismanagement of irrigation right from the lifting of the water to the roots of the crops. 50% of irrigation water is “lost” for the crop at the farm level (IAEA, 1998). However, at the watershed level it might be less, due to possible recoveries from the subsoil and groundwater (Orlovsky, 2008). These off-site losses of water can result either from inappropriate land management practices to capture a substantial part of the rainfall within an agricultural landscape and retain it in the plant rooting zone or excessive use of irrigation water.

Soil physical properties, which deteriorate agricultural soils, are equally variable. These can be explained by following examples. Low rates of infiltration can lead to high run-off, Compaction of the soil reduces water infiltration, Low water holding capacity maybe due to sandy soils (Valentin, 1985) and better aggregation of soil can lead to increased water infiltration.

Storage of water in the root zone may decline due to a) low moisture-holding capacity of sandy soils and b) the limitation on root pro- liferation at depth by natural soil hardness (Bhardwaj, 2007). Management techniques like *limans* which prevent run-off during the rainy season may cause ponding and over-wet conditions particularly at early stages of growth. Even complete infiltration at the starting phase of the crop plantation may lead to crop under stress due to unpredicted rainfall or low holding capacity of soil. Chemical soil problems include low fertility which may be inherent or caused by leaching or by past soil erosion (Condon, 2002).

5. Study Area

The study area was located in the Ambassadors Forest of JNF near Beer Sheva city at Negev desert in Israel which receives 200mm of average rainfall (Cohen, et. al., 1997). Over the last few decades numerous small plot "*limans*" (from the Greek limne, meaning a pool of standing water) and terraces (soil and water conservative measures) were constructed in the region and planted with various tree species. This practice imitated ancient agricultural systems based on methods of harvesting water from hill slopes and runoff from small streams. The *limans* were built at suitable hydro topographic locations in dry river beds, and each plot consists of 0.1 – 3.0 ha of leveled land encircled by a low earth dam (about 1 m in height), erected to harvest runoff water from small catchments, with a 1:10 to 1:20 ratio of cultivated land to catchments area (Yair 1983; Yair and Shachak 1987). *Limans* and terraces plays very important role in reducing the run-off water and allows infiltration in the soil, and also reduces soil erosion. *Limans* hold water throughout their whole area while terraces collect water at their end next to the edge where the trees are planted.

Figure 1: Left- terrace system with new trees and Right- *liman* with old trees

The site selection and plot selection was done with the help of local expertise from Israel. The total size of the study area was 15 sq. km.; it was difficult to take samples from all the points. The area was divided into few plots which represented whole study area.

Study area had basically two different conservative measures such as terrace and *liman*. Terraces were further divided into

- Terrace new - no plantation (TNOP) = plot no. 16
- Terrace- new plantation (TNEP) = plot no. 17
- Terrace- old plantation (TOP) = plot no. 24 & 25

Limans were divided into

- Liman new - no plantation (LNOP) = plot no. 7
- Liman- new plantation (LNEP) = plot no. 11
- Lima- old plantation (LOP) = plot no. 19, 21 & 23.

The old plantation in terraces or *limans* was done in the February 2005, new plantation in the February 2009, and new terraces or *limans* were constructed in February 2009. Thus, the study area was relatively new. The field and lab work in Israel was carried in the month of July, August and September 2009. Based on the presence of green leafs, condition of trees/shrubs in the above plots during my thesis work was as follows:

Table 1: Conditions of trees and shrubs in different plot

Plots	Condition of trees	Condition of shrubs
TNOP	No	No
TNEP	Good	No
TOP - 24	Moderate	Bad/dried
TOP - 25	Moderate	Bad/dried
LNOP	No	No
LNEP	Good	No
LOP - 19	Good	Good
LOP - 21	Good	Good
LOP - 23	Good	Good

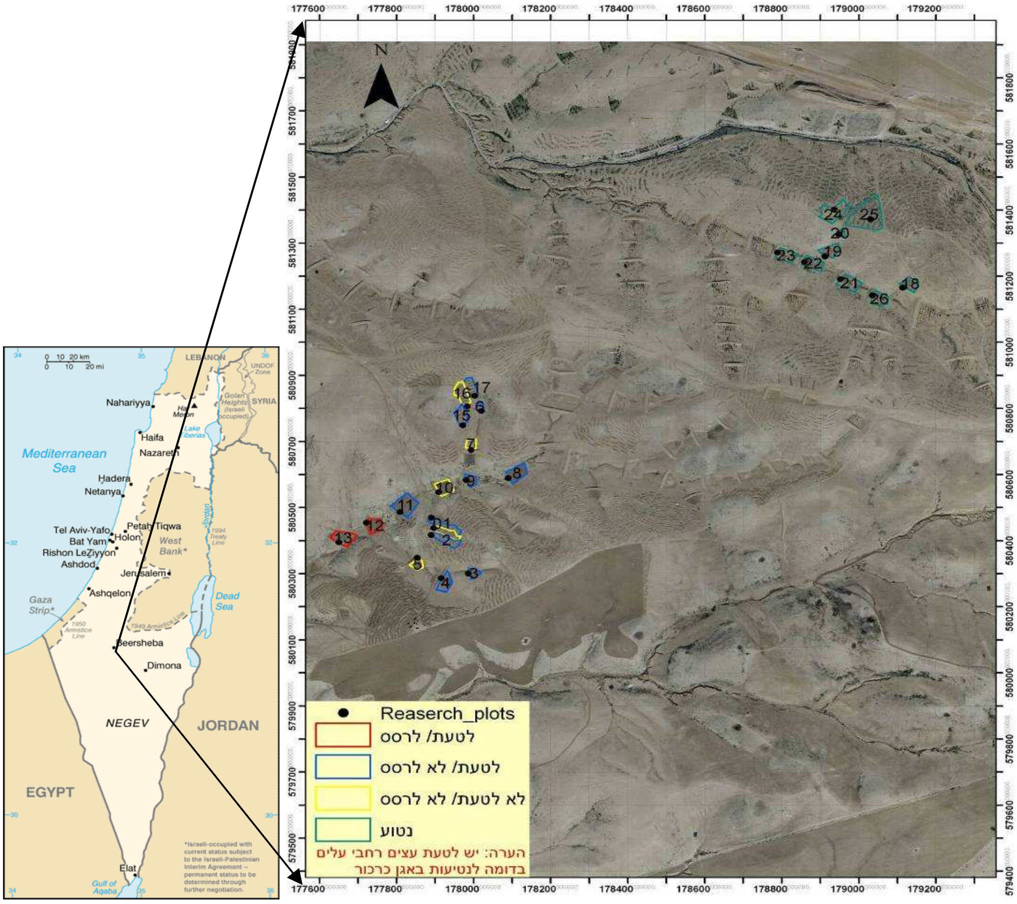

Figure 2: Location of Study area/Ambassadors forest in Israel

N. B. =

Indicates terraces and limans with old plantation

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Indicates new terraces and limans with no plantation.

Indicates terraces and limans with new plantation

Indicates terraces and limans with new plantation treated with herbicide.

Since the study area was far away and red colored plots were only once treated with herbicide, these plots (red color) were not considered for my thesis.

6. Materials and Methods

In order to measure soil physical properties of the selected plots in Ambassadors forest, Israel, an assessment of soil physical properties was carried out for Soil texture, Organic matter, Bulk density, Dry aggregates stability and Infiltration rate. Additional assessment was also done to get information on Soil temperature, Soil moisture and Electrical conductivity (EC).

Figure 3: Soil sampling with the help of spade

Soil samples were taken from the top 0-5cm using a spade at three different spots in each plot and then average reading was considered to analyze the data. During the first visit it was found that the shrubs were absent in the contributing area and were present near the wall of the terrace and *liman*. Thus, to find out the reason behind this phenomenon we decided to divide each plot into two sections namely Up and Down and soil samples were taken from these spots. Up means the “contributing area” for terraces and “higher part” for *Limans*. Down means the “area near the wall” of the terraces and *limans*. Further onwards Up and Down terminology is used in this thesis.

Figure 4: Showing presence (Down) and absence (Up) of shrubs in the terrace

These samples were used to determine soil texture, organic matter, and aggregate size distribution, and also to determine EC and soil moisture. For bulk density the samples were taken with help of soil core sampler and for infiltration rate mini disk infiltrometer was used.

6.1. Soil texture

To determine the texture of the soil, Pipette method was used. It was however time consuming but accurate to determine soil texture. The sample was processed similarly by dispersion, sedimentation and decantation, as in the separation of sand and coarse silt. The remaining suspension, containing medium and fine silt and clay, was then analyzed at a constant temperature by taking samples with a pipette. The suspension was first transferred to a 1 liter cylinder, which was placed in a water bath at room temperature (25^{o}C). After dispersion, the volume was made up to 1 liter with distilled water. The suspension was stirred thoroughly. Afterwards, sedimentation was allowed to occur for 4 minutes (Kilmer and Alexander, 1949), a portion was drawn with a 50ml pipette at a depth of 10cm. The content, containing the medium silt fraction (20-5 micron), is dispensed into a pre weighed porcelain crucible, dried and weighed. A second portion is drawn after 68 minutes of sedimentation time, dried and weighed. This process determines the fine silt fraction (5-2 micron). The clay fraction is obtained by pipetting a portion at a depth of 7cm after a sedimentation time of 5 hours.

6.2. Soil organic matter

Two grams of soil sample and 5 ml of potassium dichromate solution were added in each digestion tube and mixed for few seconds. While mixing, 10ml of sulphuric acid was added to each tube. After addition of all the acid, further mixing was continued for 30 sec. Then the tubes were placed in preheated block digester. Exactly, after 30 minutes, tubes were removed, allowed to cool, water was added to half way and mixed. After further cooling, the tubes were filled to graguated mark with water and increased 3-4 times for thorough mixing. After the settlement of the suspension, the same amount from each digest solution was decanted into centrifuge tube and centrifuged for 15 minutes. Similarly, the standards were also prepared. Eventually, absorbances for sample and standard supernatant solution were measured using spectrophotometer at 610nm (Heans, 1984).

6.3. Bulk density

The bulk density has been determined using the Core Method as described by Anderson and Ingram (1993). It was very difficult to take the soil samples into the cylinder, as the soil was very dry and lose. First of all, distilled water was poured into the soil and allowed soil to get wet. After that the soil core sampler was used to take the samples (figure-5 left).

Figure 5: Left - sampling with soil core sampler, Right - sample removed from the cylinder

Soil core sampler was hammered into the soil applying an impact absorbing hammer, and guide cylinder, the sample was trimmed using a small frame saw, and at the end we poured the sample into carry bag, this procedure was repeated for different readings. Wet samples were weighed then oven dried at 105℃ f or 24 hours and weighed again after oven drying. (NB: For the bulk density, samples were taken at the depth 0-5 cm).

6.4. Aggregate size distribution (ASD)

Nest of sieves with screens having 2, 1.4, 1, 0.5, 0.25, 0.18, 0.13, 0.09 and 0.06 mm was used. A rotary shaker was used to sieve the samples. The weighted soil was transferred to the top sieve. Top sieve was covered with the lid and sieves were tightened with the help of screws on a rotary shaker. Shaker was switched on for 10minutes and then sieves were removed to collect the soil aggregates retained on each screen in the pre weighed aluminum cans.

Figure 6: Pouring the sample on the top nest for sieving

The soil aggregates retained were weighed. Percentage of each group was calculated by using the formula stated below.

Calculation of aggregates in each size group after sieving:

$$\text{Distribution of aggregates (\%)} = \frac{\text{weight of aggregates}}{\text{total weight}} \text{x100}$$

6.5. Infiltration rate

The infiltration rate was determined with the help of mini disk infiltrometer (MDI). MDI consists of two chambers namely upper and lower, which has to be filled with water. Upper chamber was filled first. Once it was full, the suction control tube was pushed down and the infiltrometer was inverted to remove the bottom elastomer with the porous disk to fill the water reservoir. The bottom elastomer was replaced to make sure the porous disk is firmly in place. Suction had to be chosen according to the soil texture. In case of sandy soils suction of 6 cm was chosen and for clayey soils suction of 2 cm was chosen based on literature (Kirkham, 2005), whereas for medium textured soils experimentally optimum suction of 4 cm was found in the field. After adjusting the suction the infiltrometer was held vertically and checked for water leak proof to avoid error in measured reading.

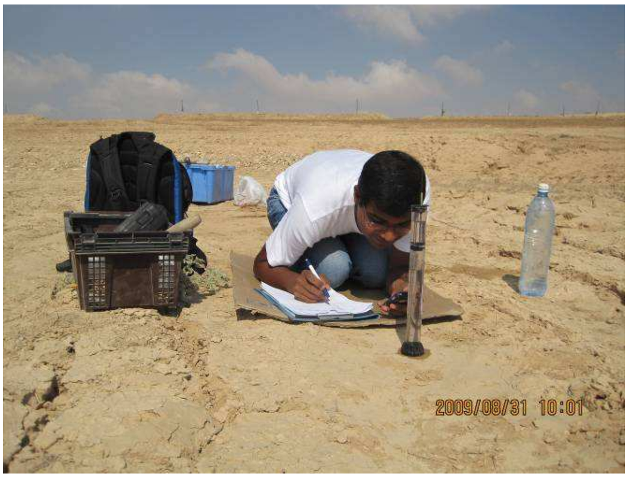

Figure 7: Taking reading for the infiltration rate

The infiltrometer was placed on a smooth spot, if it was not smooth then fine silica sand was used to make the surface smooth. Initial water volume was noted at time zero, and then the infiltrometer was placed on the surface. The volume was recorded at regular intervals of 30 seconds. Water was allowed to infiltrate until same difference between the two readings was obtained for three times. The method proposed by Zhang (1997) was used to calculate hydraulic conductivity. Zhangs method includes the use of spreadsheet named Macro, to evaluate curve slope of cumulative infiltration against square root of time, based on the data gathered from the above steps. Curve slope and van Genuchten parameters (for a given soil type, suction rate and radius of the infiltrometer disk) were used to calculate Hydraulic conductivity (K).

6.6. Additional information

6.6.1. Soil moisture

Moisture contents were determined by gravimetric method (Hesse, 1971). Fresh soil sample were weighed and then samples were dried in the oven at 105℃ for 24 hours. After drying samples were removed from the oven and weighed. Soil moisture was determined by the following formula,

$$\text{Soil moisture (\%)} = \frac{\text{weight of fresh soil - weight of oven dry soil}}{\text{weight of oven dry soil}} \text{x100}$$

6.6.2. Soil temperature (ST)

The data for soil temperature was collected from the website of a weather station. A weather station is built in the Ambassadors forest to give detailed information of all weather parameters. A soil temperature probe was also installed to measure the ST at different depths. In this research, ST at 0 – 10 cm of depth was noted.

6.6.3. Electrical conductivity (EC)

The collected soil sample was first air dried. After drying it, a sieve with approximate 2mm spacing was used to remove any large soil clumps. Half a cup of dried soil and distilled water were poured into glass beaker. Mixture was gently stirred for 30 seconds. Soil water suspension was allowed to stand for 30 seconds. Before taking the EC measurements the soil water was stirred gently again. EC meter was then inserted into the beaker and was swirled gently around in the soil water extract. After approximately 30 – 60 seconds or after EC reading has stabilized, digital readings on the EC meter were noted down (Rhoades, 1982).

7. Results and discussion

7.1. Soil Texture

From the table 2 (soil texture-Up), it is seen that in case of terraces- Up TNOP had sandy loam soil, where as TNEP and TOP had Loam soil. So, it was clear that the soil texture changes (becomes more fine) as the plots become Older (in terms of the age of the trees and terraces or *limans*). Older plots mean "there must be erosion of soil due to factors like slope of terrace/*liman*, erosion due to wind and/or water". In case of *limans*-Up, the LNOP had silt loam soil, LNEP had loam soil and LOP had clay loam soil mostly. In *limans* the soil texture changes as the plots gets older.

Table 2: Soil texture- Up and Down for different plots

Plots	Soil texture	%			Soil texture	%		
	Up	Sand	Silt	Clay	Down	Sand	Silt	Clay
*TNOP	Sandy loam	54.4	27.9	17.7	Silt Loam	46.4	31.8	21.8
TNEP	Loam	50.4	31.8	17.8	Clay loam	40.9	31.7	27.4
TOP - 24	Loam	42.7	33.7	23.5	Loam	44.9	32.3	22.8
TOP - 25	Loam	46.6	35.3	18.1	Loam	47.2	34.7	18.1
LNOP	Silt loam	29.2	51.6	19.2	Silt loam	17.2	63.6	19.2
LNEP	Loam	48.9	32.4	18.7	Sandy loam	52.9	32.4	14.7
LOP - 19	Clay loam	29.4	36.4	34.2	loam	41.4	32.4	26.2
LOP - 21	Clay loam	41.4	28.4	30.2	Clay loam	37.4	32.4	30.2
LOP - 23	Loam	45.4	36.4	18.2	Clay loam	41.4	26.4	32.2

***TNOP = Terrace new - no plantation, TNEP = Terrace new plantation, TOP = Terrace old plantation, LNOP = *Liman new -* no plantation, LNEP = *Liman* new plantation, LOP = *Liman* old plantation.**

From table 2 (soil texture- Down), in case of terraces- Down it is observed that TNOP had Silt loam soil, TNEP had clay loam soil, TOP had loam soil. Thus, in this case there was a change observed in soil texture as the plots become older. In case of *limans*, LNOP- Down had silt loam soil, LNEP had sandy loam soil, and LOP had mostly clay loam. Thus, we can say that there was a change in soil texture in case of *limans* also as the plots turns older.

To study the difference in soil texture, Up and Down were compared. The difference was observed in case of terraces, TNOP-Up had sandy loam soil where as TNOP- Down had silt loam soil and TNEP- Up had loam soil where as TNEP- Down had clay loam soil. No difference was seen in case of TOP- Up and TOP- Down as they both had loam soil. LNOP- Up and LNOP- down both had silt loam soil, LOP 21- Up and LOP 21- Down both had clay loam soil, therefore no difference was observed, may be there was no transport of soil (fine particle) from Up to Down. It was generally observed that soil texture was finer in Down than Up, while it was not observed in some cases such as LNEP- Up had loam soil, LNEP- Down had sandy loam, and LOP 19- Up had clay loam soil and LOP 19- Down had loam soil. This was due to transport of soil (fine particles) from neighboring area of the plot to the Up- 19 (figure-8).

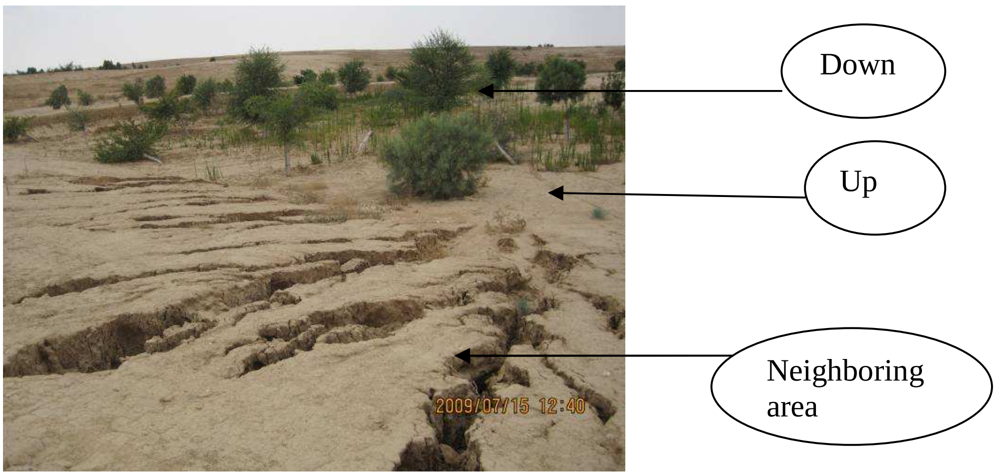

Figure 8: Transport of soil from neighboring area of the plot to the Up - 19

Texture is one of the most important soil characteristic. It influences many other properties significantly to land-use and management (Brown, 1995). The soil properties that are influenced by texture are drainage, water holding capacity, aeration, susceptibility to erosion, organic matter content, etc. Medium textured soils (clay loam & loam) are most suitable for plant growth (WSU, 2004). Plots having medium texture soils in my case are TOP- Up & Down and LOP- Up & Down. It is true that these plots had healthy trees but among these two, LOP- Up & Down had more healthy plants and shrubs than TOP- Up & Down (figure-9).

Figure 9: left = LOP and right = TOP with healthy trees

7.2. Organic matter (OM):

The results of soil analysis for organic matter are as follows:

Table 3: Percentage of organic matter for different plots

Plots	Organic matter (%)		*SD
	Up	Down	
***TNOP**	0.59	0.53	0.04
TNEP	0.52	0.44	0.06
TOP - 24	0.40	0.44	0.09
TOP - 25	0.61	0.57	0.07
LNOP	0.57	0.89	0.23
LNEP	0.38	0.54	0.11
LOP - 19	0.26	0.77	0.36
LOP - 21	0.36	0.85	0.35
LOP - 23	0.50	0.52	0.01

*** TNOP = Terrace new - no plantation, TNEP = Terrace new plantation, TOP = Terrace old plantation, LNOP = *Liman new -* no plantation, LNEP = *Liman* new plantation, LOP = *Liman* old plantation. SD = standard deviation**.

Organic matter plays crucial role in water holding capacity of the soil and improving soil structure aggregation that help in water infiltration and reducing erosion. Organic matter is an essential component of intensive rehabilitation of arid lands and deserts (Fuller, 1991).The content of total organic matter in desert soils ranges from 0.3 to 0.8% (Lobova, 1967). Table - 3 shows the results of organic matter (OM) as varies from different plots in the range of 0.26 to 0.89 %. The lower OM was seen in plot LOP-19 Up which was not expected as this being an old *Liman*, this may be due to sample was collected very far away from trees and higher OM was observed in plot LNOP Down which was also not expected because this plot did not had trees and shrubs (figure-10). Such types of unexpected results may be also due to the human activity in this area. Human activity such as use of earth movers/bulldozers to build CM, which can lead to disappearance of the litter layer (as it was a grassland before building CM) in combination with a significant reduction in number and variety of soil organisms and ultimately in the percentage of organic matter (Curry and Good, 1992).

Figure 10: Plot LNOP - 7 indicating no trees and shrubs in it

Generally, higher OM was seen in the plots LOP - Down which seem true because here trees as well as shrubs were healthy. The LOP which had higher OM (0.55 to 0.85%) was more efficient than other plots (which have 0.4 to 0.6%).

Differences in Up and Down were compared. In case of terraces, there was no large difference in Up and Down for TNOP, TNEP & TOP (e.g. TNOP- Up had 0.59 % and TNOP - Down had 0.53 % of OM).

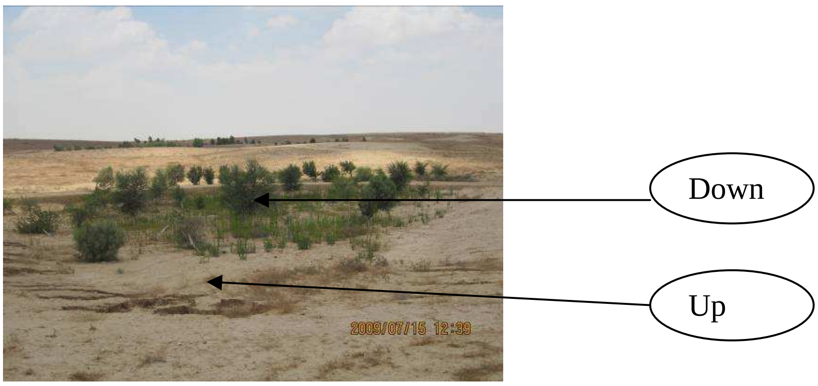

Figure 11: Indicating absence (Up) and presence (Down) of trees and shrubs in LOP - 21

On the other hand in case of all limans OM was observed more in Down than in Up, such as LOP – 21 had more OM in Down (0.85 %) than in Up (0.35 %). This was due to absence of shrubs and trees (no plant residues) in Up while shrubs and trees were present in Down (figure-11).

7.3. Bulk Density (BD)

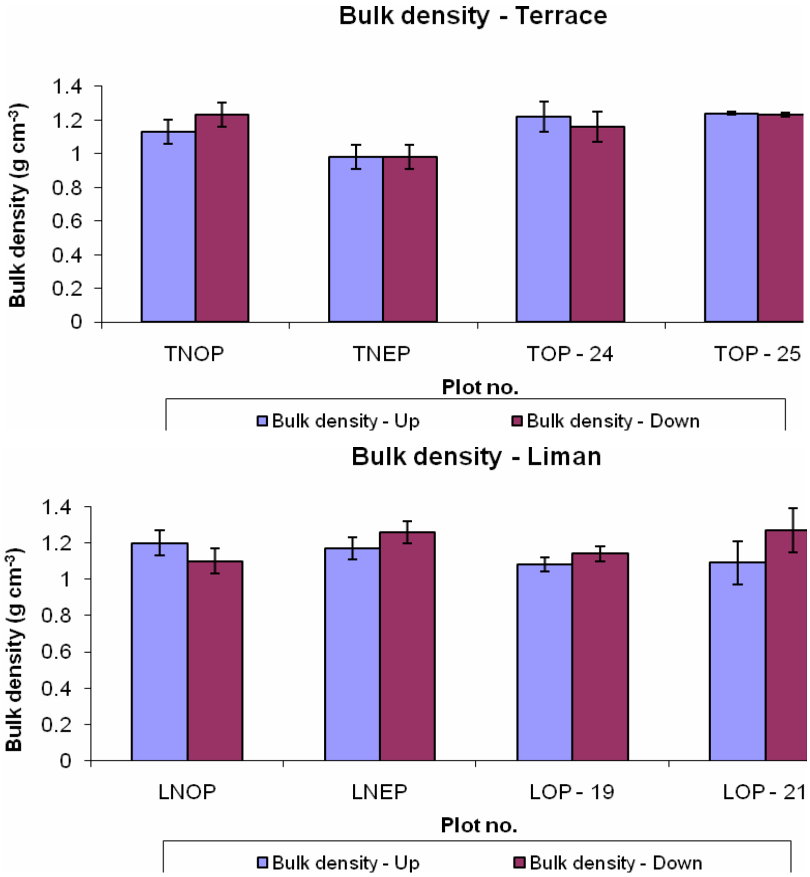

Figure 12: Bulk density in g cm^{-3} for different plots

X- axis: TNOP = Terrace new - no plantation, TNEP= Terrace new plantation, TOP = Terrace old plantation, LNOP = Liman new - no plantation, LNEP = Liman new plantation, LOP = Liman old plantation. Error bars represent standard deviations between means.

Figure-12 illustrates that, in different plots of the study area values of bulk density (BD) vary in the range of 0.98 to 1.27 g cm^{-3}. BD varies with the packing of the soil particles (Skopp, 2002). Higher bulk density is an indication of low soil porosity and soil compaction. Compaction results in reduced infiltration, which can lead to increased run-off and erosion from sloping land or water logged soils in flatter areas (USDA, 2008).

In case of terrace- Up, BD for TNOP was 1.13 g cm^{-3}, TNEP was 0.98 g cm^{-3} and for TOP were 1.24 g cm^{-3}. TNOP and TNEP had lower values than TOP. According to Skopp (2002) higher values are indication of compaction, so we can say that the soil was compacted in TOP. In case of *liman* Up, LOP (1.08 & 1.09 g cm^{-3}) and LNEP (1.17 g cm^{-3}) had lower values of BD than LNOP (1.2 g cm^{-3}). The values are very low for compaction, therefore shows no indication of compaction.

Differences in Up and Down were compared. In case of terrace, TNOP Up had 1.13 g cm^{-3} and TNOP Down had 1.23 g cm^{-3}, which indicates that TNOP Down was compacted. In rest of the plots, there was no much difference. In case of *limans*, LNEP and LOP Down had higher values (1.26 & 1.27 g cm^{-3} resp.) of BD than LNEP & LOP Up (1.08 & 1.09 g cm^{-3} resp.), which indicate that soil was compacted in Down part than in Up, except for the plot LNOP which does not show any compaction.

BD for *limans* and terraces were compared, it was observed that TNOP and TNEP Up had 1.13 and 0.98 g cm^{-3} respectively and LNOP and LNEP Up had 1.2 and 1.17 g cm^{-3} respectively where as TOP Up had higher value (1.24 g cm^{-3}) than LOP Up (1.08 g cm^{-3}). This means in case of new plots, *limans* and terraces were not compacted where as in case of old plots terraces were compacted than *limans*.

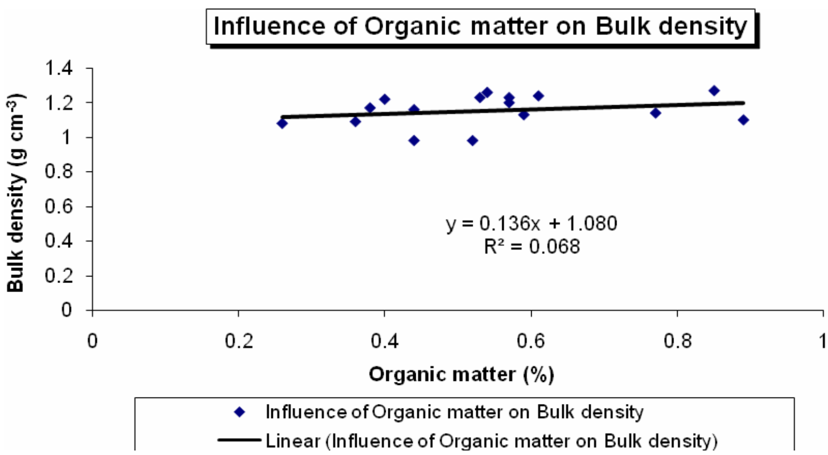

Figure 13: Influence of Organic matter on Bulk density for different plots

Figure-13 shows that there was no significant influence (R^2= 0.07) of organic matter on BD. The value of BD should decrease with the increase in the value of OM (Adams, 1973), but results indicates otherwise. It may be due to the lack or less percentage of organic matter which is not sufficient to have strong effect on bulk density. Therefore, values of OM particularly in arid environment do not have an impact on soil BD.

7.4. Aggregate size distribution (ASD)

ASD gives an indication of soil stability against the rainfall (Marquez, et. al., 2004). According to Alan & Byron (2000), more proportion of small aggregates (< 0.5 mm) reflects poor soil structure and has potential to increase soil erosion and more proportion of large aggregates (> 1mm) reflects good structure and has less potential for soil erosion.

Table 4: Aggregate size distribution (Up and Down) for different plots

Plots	Up (%)		Down (%)	
	Large aggregates	Small aggregates	Large aggregates	Small aggregates
*TNOP	18.53	66.43	36.64	56.23
TNEP	38.78	53.17	59.07	32.89
TOP - 24	46.53	45.41	56.33	37.08
TOP - 25	35.24	57.52	46.34	47.1
LNOP	24.79	61.07	53.21	40.63
LNEP	18.53	66.43	36.64	56.23
LOP - 19	45.64	49.26	48.94	40.51
LOP - 21	56.77	33.21	44.73	44.62
LOP - 23	58.63	29.35	55.18	33.18

*** TNOP = Terrace new - no plantation, TNEP = Terrace new plantation, TOP = Terrace old plantation, LNOP = *Liman new -* no plantation, LNEP = *Liman* new plantation, LOP = *Liman* old plantation.**

In case of terrace- Up, mostly it was observed that proportion of small soil aggregates (< 0.5 mm diameter) was more than proportion of large soil aggregates (> 1 mm diameter) except for the TOP-24 where no major difference was observed in the proportion of large and small soil aggregates. In case of *limans*- Up, more proportion of small aggregates was observed in LNOP & LNEP except for the plot LOP-19 where no major difference was observed in the proportion of large and small aggregates. On the contrary, for LOP-21 & 23 more proportion of large aggregates was observed than proportion of small aggregates. Thus, in case of terraces most of plots had potential for soil erosion except for TOP-24 and in case of *Limans* LNOP and LNEP had the potential for soil erosion, where as LOP had less potential for soil erosion.

In case of terraces- Down, most of the plots had more proportion of large aggregates than proportion of small aggregates except for TOP- 25 where no major difference was found between small and large aggregates. In case of *limans*- Down, most of the plots had more proportion of large aggregates except for LOP- 21 where no difference was observed between sizes of aggregates. On the contrary for LNEP more proportion of small aggregates was observed. Thus, in case of terraces most of the plots had less potential for soil erosion except for TOP-25 and in case of *limans* also most of the plots had less potential for soil erosion except for LNEP.

Differences in Up and Down were compared, it was found that Down (TNOP, TNEP, LNOP & LOP) had better structure (large aggregates) except for TOP & LNEP. LOP 21 & 23- Up also had good structure. Good structure indicates that it had less potential for soil erosion. It was observed that only LOP- Up & Down and TOP- Down had good structure, which indicates that they had less potential for soil erosion.

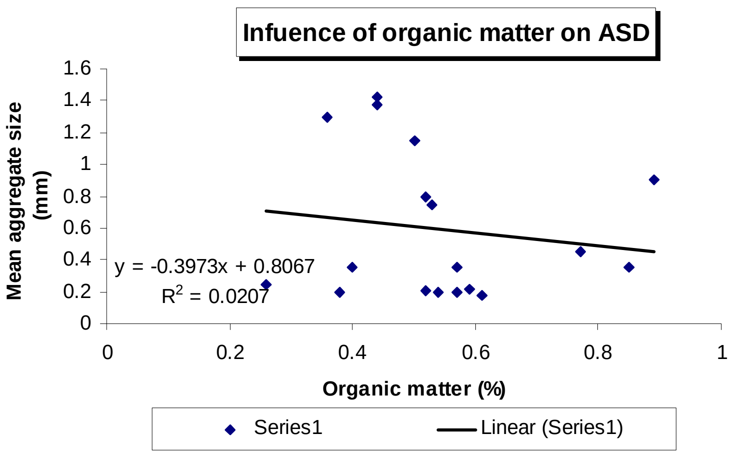

Figure 14: Influence of Organic matter on Aggregate size for different plots

Figure - 14 shows that there was no correlation (R^2 = 0.02) between OM and ASD. Aggregate size should increase with increase in the percentage of OM (Chaney, 1984), but it was not observed in this case. It was observed that the values of organic matter were unexpected, due to human activities. Therefore, we can conclude that due to construction of CM aggregate are also distributed in such a way that no correlation is found between OM and ASD in the Ambassadors forest.

7.5. Hydraulic conductivity (K)

K is calculated from the infiltration rate.

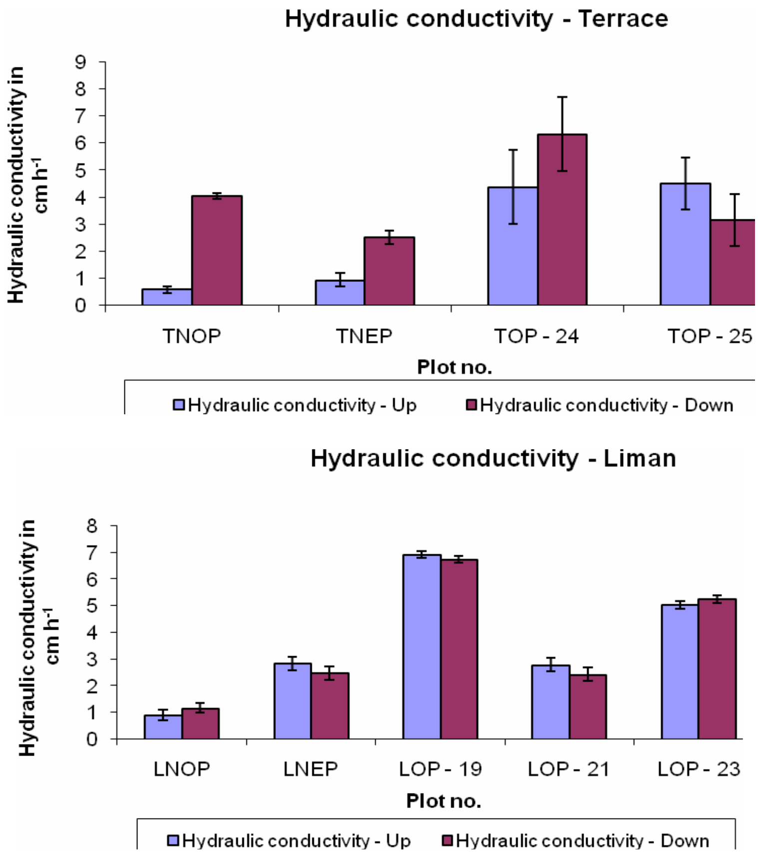

Figure 15: Hydraulic conductivity in cm h^{-1} for different plots.

X- axis: TNOP = Terrace new - no plantation, TNEP= Terrace new plantation, TOP = Terrace old plantation, LNOP = *Liman new -* no plantation, LNEP = *Liman* new plantation, LOP = *Liman* old plantation. Error bars represent standard deviations between means.

Figure- 15 shows that the graph of hydraulic conductivity varied from 0.58 to 6.9 cm h^{-1} for different plots. In case of terrace- Up, TOP (4.38 and 4.51 cm h^{-1}) had higher K than the TNOP (0.59 cm h^{-1}) & TNEP (0.94 cm h^{-1}). In case of *Liman*- Up, LOP (6.93 and 5.26 cm h^{-1}) had higher K than LNOP (1.17 cm h^{-1}) and LNEP (2.47 cm h^{-1}) which indicates that old plots had higher K than the new plots for both terraces and *limans*. In case of terrace- Down and *liman*- Down, the old plots had higher K than for the new plots.

Differences for hydraulic conductivity in Up and Down were compared, in case of *limans* there was no significant difference between Up and Down. Higher K was observed in plots TNOP, TNEP & TOP (4.05, 2.52 & 6.34 cm h^{-1} resp.)- Down than TNOP, TNEP & TOP (0.59, 0.94 & 4.38 cm h^{-1} resp.) -Up.

Differences for hydraulic conductivity was compared between *Limans* and terraces, the LOP- Up & Down had higher K values than TOP- Up & Down. Therefore *limans* especially LOP had higher hydraulic conductivity in the study area.

Figure-16 shows that there was no correlation (R^2= 0.09) between OM and K. K should increase with the increase in OM (Attila et. al., 2005), but it was not observed in this case. Moreover, figure-17 shows that no correlation (R^2= 0.02) exits between BD and K. Increase in OM may not immediately lead to beneficial changes in soil physical and hydraulic properties. The effect of plant residues/OM may be delayed due to dry soil surface conditions that occur for extended periods of time in this climate. A greater monthly soil temperature reduces the microbial biomass carbon (Natasja, et. al, 2007). Moreover, the area is newly constructed for forest development therefore the results might have been affected.

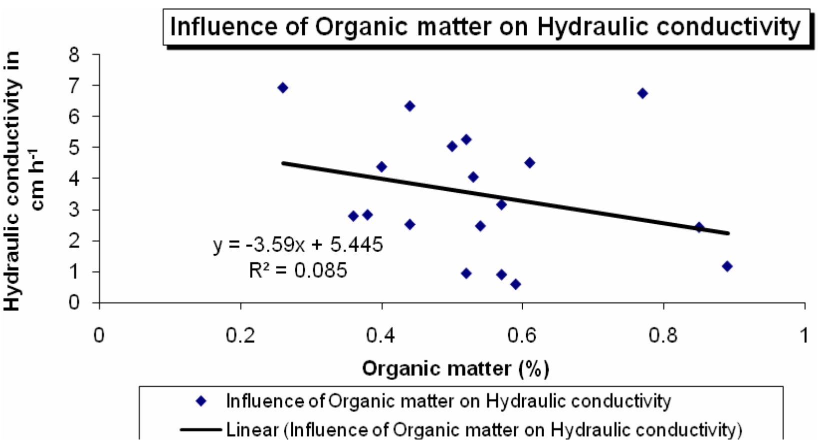

Figure 16: Influence of Organic matter on Hydraulic conductivity for different plots

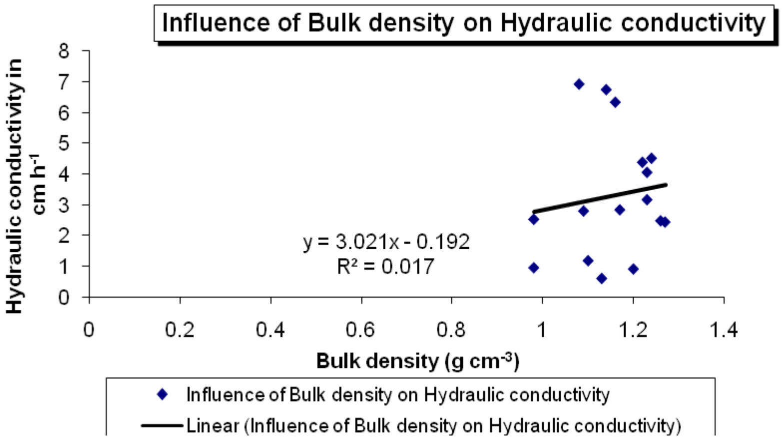

Figure 17: Influence of Bulk density on Hydraulic conductivity for different plots

7.6. Additional information

Influence of soil moisture content, soil temperature and Electrical conductivity (EC) on Hydraulic conductivity:-

The soil water content can significantly impact infiltration by (1) increasing the K, which shows increase in infiltration and (2) reducing the surface tension that draws moisture into the soil, which shows decrease in infiltration (Paul, 2003). Figure- 18 shows good correlation (R^2= 0.55) between soil moisture content and saturated hydraulic conductivity. The infiltration capacity is a maximum rate, that soil in a given condition can absorb water and generally decreases as soil moisture increases (Paul, 2003). It is observed that the saturated hydraulic conductivity increases with the low soil moisture content and decreases with increase in soil moisture content. This unexpected effect may be due to an error during the measurements in the lab for soil moisture content.

Soil temperature influences infiltration through its effect on the viscosity of water (ASCE, 1996). Figure-19, shows that there was no correlation (R^2= 0.12) between soil temperature and hydraulic conductivity.

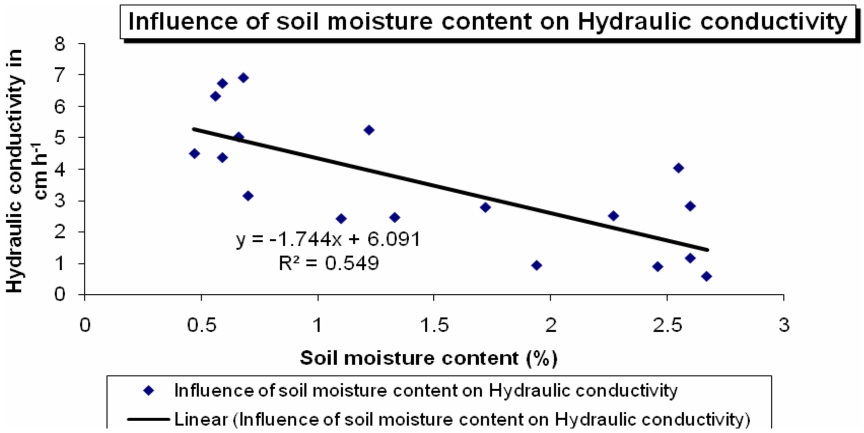

Figure 18: Influence of Soil moisture content on Hydraulic conductivity

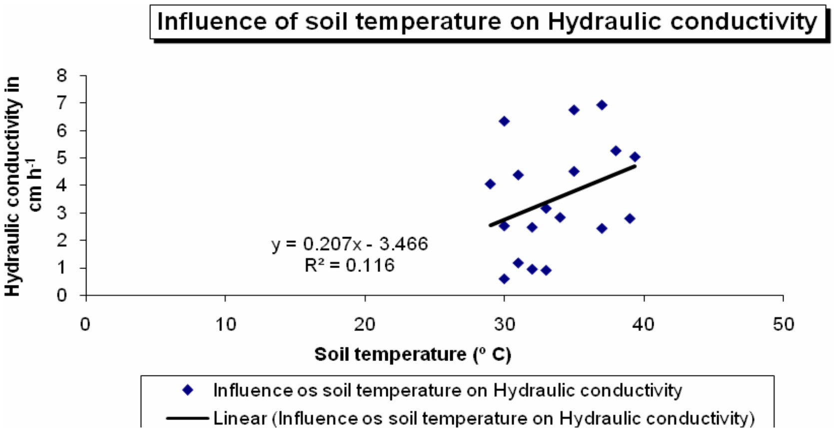

Figure 19: Influence of Soil temperature on Hydraulic conductivity for different plots

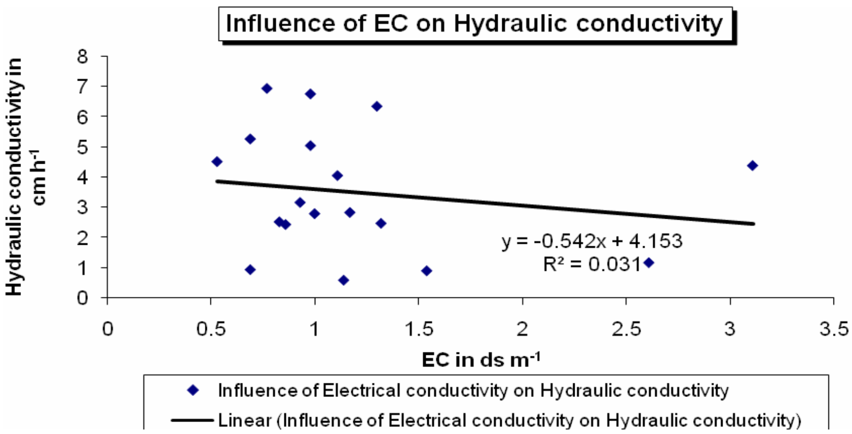

Figure 20: Influence of Electrical conductivity on Hydraulic conductivity

EC of samples was analyzed to determine the amount of salts in the sediment. With this parameter it could be confirmed if plot suffers from salinization issues. EC can be the cause of water stress. EC of the soil can be affected by moisture content or organic matter of the soil (Doolittle et. al., 1994). It is observed from figure-20 that there was no correlation (R^2 = 0.03) between EC and K. EC does not has any correlation with organic matter and moisture content, therefore no co-relation was found with hydraulic conductivity.

8. Conclusion

Upon closer study of soil physical properties with the ages of conservation measures in the Negev in Israel, the following conclusions could be drawn.

- Conservation measures such as terraces and *limans* were found to be important not only to mitigate the soil erosion due to water and wind erosion but also to maintain the soil texture. The soil textural fractions were most fine under plots that were treated with terraces and *limans* for several years (older structures).
- The organic matter content was higher under plots treated with *limans* for many years than the new plots. Similarly, plots with no tree and shrubs had revealed higher organic matter values than those with plantations. This could be attributed to the manipulation by human beings in the area particularly associated with the use of bull dozers to built conservation measures. Mostly, higher OM was observed in LOP especially in Down parts, which is true as they had healthy trees and shrubs.
- Bulk density was higher in some terraces and *limans* implying compaction. The compaction was more prevalent in the down part sections. For the newly constructed *limans* and terraces, there was no any indication of compaction where as for old terraces showed compaction.
- In case of Up, *limans* with the treatment of many years had less potential of erosion and in case of Down, most of the terraces and *limans* had less potential of erosion.
- Hydraulic conductivity of the soils with older *limans* was higher than the new once. The hydraulic conductivity of the soils with *limans* was higher than those with terraces implying *limans* are more efficient in increasing water infiltration.

Above all, the effect of conservation measures and plantations in improving the soil physical properties increased with the ages. Hence, this study implied for more application of these measures for improved water conservation and sustainable use of the fragile soils in the Negev.

9. Recommendations

This study focused on the analysis of the physical soil properties following the development of soil water conservation measures. Hence, further studies are needed in the following aspects.

- Quantification of the rainwater use efficiency of the agricultural systems in the presence of conservation measures.
- Examining the amount of rainwater that can be changed from non-productive evapo-transpiration loss to productive transpiration due to the application of conservation measures is needed.
- As this study focused mainly on the biophysical aspects of the soil and water conservation measures, the socio-economic and institutional aspects of the measures should also be studied further.

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