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Assessment of Sediment Transport along Wadi Al-Gar

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Assessment of Sediment Transport along Wadi Al-Gar

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Dedication

I dedicate this thesis to my family for their endless support

To who pushed me to science, to my first supporter in life and with them increased pride (my father and my husband).

To who weaves my happiness with strings from her merciful heart (my mother)

Declaration

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged and that this thesis or any part of the same has not been submitted for a higher degree to any other University or institution.

Name: Salam Talal Abdel Al Fatah Dodeen

Signed: سلام دودين

Date: 05/05/2019

Acknowledgment:

As we take our last steps in this stage of education, I must express my thanks and gratitude to those who encouraged me and supported me in completing this thesis.

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اعداد: سلام طلال عبد الفتاح دودين

اشراف: د. جواد شقير

الملخص:

يعتبر تآكل التربة مشكلة عالمية بسبب تداعياته البيئية بما في ذلك الترسبات والتلوث في العديد من مناطق العالم. يمكن تقسيم آثار تآكل التربة إلى فئتين في الموقع وخارج الموقع . تعتبر التأثيرات في الموقع مهمة للحقل الزراعي وتسبب في انهيار بنية التربة وفقدان التربة الخصبة وفقدان الشتلات وتقليل عمق التربة. تشمل الآثار خارج الموقع الترسبات في اتجاه مجرى النهر ،وتلوث إمدادات مياه الشرب. تتضمن عملية تآكل التربة الناجم عن الماء فصل جزيئات التربة ثم نقلها عن طريق التدفق البري. هناك العديد من العوامل التي تؤثر على كمية جريان المياه السطحية مثل كثافة الأمطار وتدرج الميل وطول المنحدر. أجريت الدراسة على وادي الجار وهو أحد الروافد الكبيرة في الجانب الغربي من حوض البحر الميت. تستند هذه الدراسة البحثية إلى فهم انتقال الرواسب وترسبها في وادي الجار في اتجاه مجرى البحر فيما يتعلق بمصدر الرواسب . وتقديرات حجم الجريان السطحي لمنطقة الدراسة بواسطة التحكم الهندسي الهيدرولوجي - نظام الطراز الهيدرولوجي. أظهرت النتائج أن إجمالي كمية الأمطار في منطقة الدراسة لموسم الأمطار 2018/2017 كان 37 مليون متر مكعب ، 30 متر مكعب الجريان السطحي وكانت الخسارة الإجمالية 7 مليون متر مكعب. الجريان السطحي لوادي المصيده هو 21568300 متر مكعب و 8480100 متر مكعب في وادي المعزة.

تشير نسبة Na / Cl الأيونية لعينات وادي الجار في اعلى الواد واسفل الواد عام 2017 أقل من 0.7 إلى فقدان الصوديوم خلال هطول أملاح التبخر. وتتباين النسب في عينات اسفل الواد لعام 2018 ، حيث تجاوزت الواحد في بعض العينات . وتقع معظم العينات لنسبة المغنيسيوم / الكالسيوم > 0.9 المرتبطة بالطبقات الجوفية بالدولوميت وعادة ما تكون مصحوبة بمصادر إضافية لأيونات المغنيسيوم.

Abstract:

Soil erosion considered as a global problem because of its environmental consequences including sedimentation and pollution in many areas of the world. Effects of soil erosion may be divided into two categories on – site and out- site (off-site). On-site effects are important for agricultural field and cause breakdown of soil structure, loss of fertile soil, loss of seedling and reduction of soil depth. Off-site effects include sedimentation downstream, the salutation of a reservoir, and contamination of drinking water supplies. The process of water-induced soil erosion includes the detachment of soil particles and then transports it by overland flow. Many factors affect the amount of surface water runoff such as rainfall intensity, slope gradient, and slop length. The study was conducted on the Wadi Al-Gar is one of the large tributaries in the western side of the Dead Sea basin. This research study is based on understand the sediment transport and deposition at Wadi Al-Gar downstream in correlation to sediment source upstream. Study the slope variability and it's the influence of transmission of sediment along the Wadi Al-Gar. Study soil texture changes at upstream and downstream of the wadi to correlate its source of deposition. and Study the differences in the sediment profiles. and Estimations of the surface runoff volume for the study area by Hydrologic Engineering Control – Hydrologic Model System. Results showed the total precipitation volume on the study area for the rainy season 2017/2018 was 37 MCM, 30 MCM runoff and the total loss was 7 MCM. The runoff of Wadi Al-Mesyada is 21568300 m3 and 8480100 m3 in Wadi Al-Maaza.

Na/Cl ionic ratio of upstream and downstream 2017 samples of Wadi Al-Gar less than 0.7 indicate loss of Na through precipitation of evaporitce salts. and variability ratios in downstream samples 2018, Where it exceeded one in some samples there are characteristic of groundwater flowing through crystalline and are dependent on the nature of the feldspars and most of samples fail in the Mg/Ca ratio rang > 0.9 associated with dolomite or dolomitic aquifers and usually accompanied with additional sources of Mg ions. Aragonite precipitation also is favored, whereas the Mg/Ca ratio rise due to dolomite dissolution.

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Abbreviations

%	Percentage
Ca^2	Calcium
CEC	Cation Exchange Capacity
Cl^-	Chloride
EC	Electrical Conductivity
EDTA	Ethylenediaminetetraacetic Acid
HCO_3	Bicarbonate
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
K^+	Potassium
MCM	Million Cubic Meter
Meq/l	Milliequivalents per litre
Mg/l	Milligram/liter
Mg^{2+}	Magnesium
mm	Millimeter
Na^+	Sodium
OM	Organic Matter
PO_4^{3-}	Phosphate
SAR	Sodium Adsorption Ratio
SO^{2-}	Sulfate
SOP	Standard operating procedure
TNb	Total Nitrogen bound

TOC	Total Organic Carbon
μS/cm	Microsiemens/Centimetre

Chapter One:

This chapter contains a description of the current situation for soil erosion and sediment, the problem statement and research motivation of the study. In addition, the research questions, the goals for the study were also included.

1.1 Introduction

Soil is subject to natural weathering and erosion, natural or geological erosion occurs by water, wind, and ice at a relatively slow rate since the formation of the Earth, and natural erosion occurs slowly, leading to the formation of the landscape from century to century, while maintaining the ecological balance (Matthews,1972). Large-scale construction and land-moving projects contribute to erosion, mainly by exposing large areas of soils to rain and running water, if this flow is not properly treated, the result is often a serious trenching process in nearby waterways (Martínez et al., 2000).

Soil erosion is an important social and economic problem and an important factor in assessing the health and functioning of the ecosystem and it is one of the naturally occurring problems in soils. It will affect all landforms (Jiang et al., 2013). Also, may happen by forces associated with agricultural activities like tillage. Top soil, which has high fertility, rich in organic matter and soil life, is transported to other sites "on-site" where it accumulates over time or is transported off-site, where it fills in drainage channels. Soil erosion reduces cropland productivity, and contributes to the pollution of adjacent watercourses, wetlands and lakes (Matthews, 1972).

Sediment formed when solid particles (composed of compressed organic matter consists of fragments of rocks and minerals) carried out by rivers, oceans, winds and rain runoff force, and when the transportation energy lay down and become not strong enough to carry these particles, they drop out in the process of sedimentation which called clastic sedimentation which leads form what called sedimentary rocks. (Pant, 2010). Sediments transported through a stream represent a mixture of sediments from different locations and different types of sediment sources within the contributing basin. Knowledge of the source of sediment is an important condition of the examination of sediments routing and delivery and in the construction of catchment sediment budgets

The Dead Sea is located in one of the deepest continental depressions on the earth bordered by steep escarpments to the east and west of the basin. Due to this combination of extreme climatic and morphological gradients, the Dead Sea serves as a measure of rain with slight changes in precipitation on the drainage area, which is recorded sensitively by changing lake levels and sediments. In 2010 the Dead Sea Deep Drilling Project (DSDDP) drilled a core almost half a kilometer below the floor of the middle of the Dead Sea. The DSDDP core creating to reveals 200,000 years of climate history (Pleistocene-Holocene sedimentary record), and to study the sediment movement and the changes that get it until reach deep of the Dead Sea. This study will highlight the sediments coming from the region that passes through Wadi Al-Gar (upstream and downstream) which is one of the large tributaries in the western side of the Dead Sea basin. By taking soil, sediment, and runoff samples from this area, where flow water loaded with chemical elements (sediments) from these areas during the runoff to reach the Dead Sea.

Soil erosion is the removal of soil particles by water or wind affected by land slope, rainfall, vegetation cover and soil management (Vanmaercke et al., 2012). Soil erosion problems can differ from one place to another because of the variation of each factor, and the relationship of one factor to another can be achieved erosion control by understanding the nature of relationships. Climate and soil conditions are clearly uncontrollable by humans (Monke, 1965). However, proper planning can sometimes allow avoidance of construction in severely decomposed soils and under bad weather. It is easier and more effective to deal with vegetation and topographical conditions through practices erosion control (Wischmeier et al.,1971), Some soil erodes more readily than others. Although all factors are equal, physical and chemical soil properties affect its infiltration capacity, (Monsieurs et al., 2015). Soil erosion tends to increase with a greater content of silt and fine sand and decreases with a greater content of coarse sand, clay and organic matter (Salako F.K, 2003; Vanmaercke et al., 2016). Clay particles have a low probability due to the difficulty of separating them but once they do become separation they are easily transported and remains suspended throughout the time(Koiter et al., 2017)

Two important indicators of environmental quality are Soil erosion and sediment yield. Intensive soil erosion and excessive sediment indicate loss of manure, tillage, and destruction of agricultural land. Removal topsoil that is rich of nutrient (soil erosion) can lead to reduced soil productivity and soil biodiversity, reducing land productivity and limiting plant growth (Kang et al., 2001; Feng et al., 2010). Sediment deposition will decrease the capacity of water in river channels and reservoirs, raise the risk of flooding in rainstorms (Ouyang et al., 2010). In addition, filtration of the reservoir can lead to reduced water quality, resulting in increased demand for oxygen, accumulation of nutrients and pollutants, increased turbidity, etc (Tripathi et al., 2003). Contaminated sediments, from agricultural land, industrial sites, and residential area, carry contaminants in rivers. Both of these lead to the deterioration of the water ecosystem, pose a threat to the survival of living organisms in the reservoir and the safety of drinking water (Cai et al., 2007).

Physical processes and causes of erosion

1. Climatic Factors:

Rainfall is the major climate factor contributing to erosion (Sun et al, 2013). Causes of erosion in two ways: by raindrop impact, runoff. The ability of raindrops to separate soil particles when upon impact is a function of the size and velocity of each drop and intensity of rainfall (Imeson et al., 1998).

The second phase of erosion occurs due to rainfall occurs as runoff begins and rills begin to form (Meyer, 1981). Surface runoff occurs when rainfall exceeds the ability to infiltrate the soil and retain surface water (Vaezi et al., 2017). When the raindrops hit the surface of the bare soil, the slurry rapidly develops. As rainwater infiltrates the soil (Wei et al., 2017), clay particles are washed under the surface, thus closing the surface. This sealing process usually occurs within minutes of the beginning of an average rainfall (Chen et al., 2001; Oliveira et al., 2013).

2. Topographic Factors: Slope Length and Steepness

The length and steepness of the slopes affect the velocity of runoff water, so the main surface features affect erosion on the site (Michael et al., 2017). For practical field work, the common effects of length and steepness should be considered. It is important to think about the shape of the slope because the natural slopes may consist of convex, straight and concave sections all eroded at different rates (Monsieurs et al., 2015). The concave slopes are those that flatten towards the toe, or bottom end, where eroded soil particles are deposited, while the convex slopes become steeper at the toe (Gray et al., 1982).

3. Vegetation and surface cover

Overall, the accelerated erosion of soil at the construction site occurs due to the removal of protective vegetation. Thus, artificial assistance becomes necessary to replace natural control .(Weaver, 1989), (Snyman, 1999)

4. Runoff and nutrients

Soil transported with water erosion can reach receiving waters as streams, rivers and lakes (Martinez et al., 1999), causing sedimentation problems, often associated with nutrient loading (Lopez et al., 2007). The presence of nitrogen (N) and phosphorus (P) in surface water is a major environmental problem due to the risk of increasing nutrients (excessive growth of photovoltaic plants) resulting from these elements, (Casali et al., 2008,) Nutrient distribution is irregular on different sizes of sediment particles; fine sediments are usually richer in soil-sorbed nutrients than coarse sediment (Ettore, 2012).

Eroded soil deposited downslope is referred to as sedimentation. (Vaezi, et al., 2017). When heavy rains, wind events or soil disturbance occur because of human activities, the soil is transported off-site and deposited on land, in lakes, wetlands, and streams (Wu et al., 2016). Sediments, the largest source of undetermined pollutants, contribute to a reduction in the quality of surface water, endangering aquatic life and lead to increased erosion of banks and floods (Swenson et al., 1964).

The Sources of sediment in streams, increased sedimentation levels due to roads, residential and commercial development, timber harvesting, agricultural practices and any other disturbing land activity (Kinnell, 2016), (Grissinger et al., 1970)

Sediment yield is the amount of soil transferred to rivers and lakes in a given period above a specific area (Chen et al., 2007), Where the Sediment size distributions depend on many factors: soil properties and slope, rainfall characteristics, vegetation cover, hydraulic flow type (Marques et al., 2007). Among the factors affecting soil erosion, soil and surface characteristics are considered as fixed factors in the short term, while some climatic variables (e.g. daily rainfall, temperature, wind speed, etc). and land cover types are dominant influencing factors Change the short-term erosion process (Koiter et al., 2017).

Types of Sediment:

Most sediment is produced when rocks or minerals interact with the aquifer (and biosphere) near the Earth's surface. Sediments are generally transported through the Earth's system, and then settle under the force of gravity (Douglas et al.2003).

1. Clastic sediment:

Sediments consist of fragments or granules of rocks and minerals, the clastic sediments classified based on their grain size. The grain size reflects the amount of bumping and grinding. The larger clasts are found near the source of the sediments where they are difficult to transport. The farther away you go from the source, and they become smaller and smoother from the transportation process (Rachel et al., 2004). Mineral composition varies with increased transport, the strong and chemically stable metals stay in the more flight. Here the mineral properties of the hardness, cleavage, and types of bonds holding atoms together can affect the survivability of minerals (Chester et al., 2018)

2. Chemical sediments

Chemical sediments are not composed of weathering and erosion, they form from the precipitation of minerals out of a solution (Rosen et al, 1994), when the liquid containing dissolved ions evaporates. When the lake dries, the concentration of ions increases so that the remaining water is unable to carry the ions in the solution. They settle out of the solution and on the lake floor, large evaporation is the result of dry and/or hot climate and large salt deposits are indicative of these conditions, (Jones et al., 1978)

3. Biochemical

When organisms die, their shells fall to the bottom of the sea to form biochemical deposits (Dean, 1981). Many of these substances come from microorganisms, and Foraminifera and coccoliths produce calcium carbonate, diatoms and radiolaria produce silica. The basic biochemical rock is limestone. If the crust is not soft, the substance can be called bioclastic.(Meyers et al., 2001)

Transported sediments (Bed load, suspended, wash load): Soil erosion and sediment transfer are generally takes place through two natural processes that occur based on the morphology of the region. These processes are balanced based on soil composition rate, where sediments play an important role in conserving river environments, the balance of the natural environment can affects in the event of environmental interventions and human activities, the rate of transfer of sediments can also increase in line with the increase in the population and intensification of agriculture in the region based on studies conducted in 1900 (UNESCO, I. 2011). Transported sediments are important elements of the global geochemical cycle, depending on the local factors of the study; it can be shown that the sediments are useful or harmful to the environment, the negative effects of increased sedimentation can lead to increased flooding and resulting property damage, water supply contamination, crop loss, displacement and sometimes loss of life. Sediment movement is one of the important natural geochemical cycles and the movement of organic matter from the Earth to the oceans. Natural river tributaries remain in a morphological equilibrium where sediments flow at an average rate. Sediment can be disturbed by slowing or stopping water, thus preventing sediment movement. The climate mainly affects sediments so that it could be increased or decreased by climate change in terms of rainfall and runoff. Human factors such as agricultural production can also affect sediments by interacting with the climate. It is very difficult to control the management of sediments because each topographical character for each topographic environment is different from the other. Sediments can be controlled by studying the morphology of the area and conserving water, soil, wood cover and riparian land, so that misbehaving such as deforestation may lead to increased sediments (UNESCO,I. 2011).

Transport of sediment done by three major ways: (1) Bed load transport, (2) suspended-load transport or as (3) dissolved-load transport or wash load.

Bed load refers to the fine grains that moves along the bed of a flow, the fine grain consisting that material in particular that rolling and sliding by the flow, where suspended sediment load formed from compressed fine material that carried in suspension load and wash load which are finer compressed but larger than the suspended load and moving through water(UNESCO, I. 2011). This type of material is usually sand and gravels. (Michael et al., 2012).Suspended sediments are mainly affected by the force of flow and turbulence which elevate the concentration and produce coarser material. Suspended load constitute approximately 90% of transported sediment (Michael et al., 2012).The difference between suspended load and wash load that the wash load does not depend on the turbulence force, it can stand for long time in the suspension by the force of turbulence associated with molecule agitation of the water (Michael et al., 2012).

Sediment storage: As a result of soil erosion and the transfer of sediments from one place to another new layers have been produced in the place transferred to them, such as: (1) Rhythmic Layering which is composed of soft and rough parallel layers formed through the different seasons. (2) Cross Bedding is another type of layers that consist of a group of sediments associated by moving path or wind, the boundary between each layer represents the surface of the corrosion. (3) Graded bedding in which, the crust of water formed after a strong flow produces three types of dense sediments and then small particles followed by low density deposits that deposited on the density and low-density deposits remain stuck called turbines. (4) Non-sorted Sediment which consists of a mixture of different sediments of different sizes such as rocks and mud. (5) Ripple Marks: it consists of sand dunes and sedimentary rocks. (6) Mud cracks which resulted from the drying of the sediments on the ground which is considered as an indication of the level of the earth's surface. (7) Sole Marks they are soft deposits filled with mud. (8) Raindrop Marks resulting from the fall of rain, an indication of detection before burial. And (9) Fossils which is one of the most important signs of sedimentation since it is formed from the remains of living organisms (Pant, S. R. et al., 2010).

1.2 Problem statement:

Soil erosion by water runoff is still an important global issue because it’s adverse on-site and off-site impacts. It is one of the manifestations of environmental degradation in many areas of Palestine, including the areas through which passes of the Wadi Al-Gar in Hebron-Palestine, whether by nature or human forces where the surface topsoil loses many Dissolved ions and minerals by rain or wind, which reaches the Dead Sea. Due to variable sources of sediments researchers could not correlate, identify, or even date variable events.

1.3 Research motivation:

There are many studies conducted on the sediments in the Wadi Al-Gar in Hebron-Palestine, which indicate the climatic and tectonic history of the region, the upstream Wadi

Al-Gar is one of the areas where soil erosion occurs. Surface runoff loaded with dissolved ions and minerals deposited in downstream reaching the Dead Sea and deposited in the bottom.

In this area most of the research of others has been carried out at the downstream of Wadi Al- Gar, therefore studying sediment transport from the upstream to downstream provide a strong reason to lead researchers in such a trend

1.4 Research question:

1. What is the correlation between the transported sediment and its deposition downstream using geochemical ratios and soil texture?

2. What is the volume of surface runoff at Wadi Al-Gar to quantify the rate of eroded sediment?

1.5 Research goals:

The goal of this study is to understand the sediment transport and deposition at Wadi Al-Gar downstream in correlation to sediment source upstream. In order to achieve the main

Objective a set of specific objectives have been assigned as follow:

1. Study and analysis the sediment profiles downstream of Wadi Al-Gar

2. Study the slope variability and its influence on transmission of sediments along Wadi Al-Gar.

3. Analysis soil texture changes at upstream and downstream of the wadi and correlate its source of deposition

4. Estimations of the surface runoff volume using for Hydrologic Engineering Control-Hydrologic Model System (HEC-HMS)

Chapter Two:

This chapter contains a general background about soil erosion, sedimentation and runoff and the discussion was focused on the previous researches that were conducted in arid and Semi-arid regions

Literature Review

According to (Shi et al., 2012) Soil erosion is usually characterized by three actions, including soil loss, transport and deposition. These processes usually lead to the transfer of topsoil rich in organics , nutrients and soil life elsewhere in the site where they accumulate over time or transported off-site where it accumulate in drainage channels. It is usually severe on unprotected sloppy areas. Regarding to (Yujin Li et al., 2016) carbon loss and Soil erosion is closely related to plant species under rainstorm events. In grasslands Communities, higher soil loss and lower soil organic carbon (SOC) content, were less SOC loss. The shrubs communities were intermediate in the content and loss of SOC. Natural forest communities, with higher carbon concentrated soils and SOC storage capacity, can lead to further loss of SOC from water erosion in the rainstorms event (Wang Lei et al., 2018) describe the wood land erosion density is moderate, and grassland is essentially low. Soil erosion increases with increasing slope in the range from 0 to 15. Therefore the amount of bare soil at a site is a good indicator of soil exposure to erosion and degradation. Good soil coverage is an essential component of soil conservation programs. Vegetation protects the soil from eroding in different ways (Madeline, 2014). As for the (Adélia N, 2011) study Rainfall interception by the plant has two main results, the most important being that it reduces the erosive power that affects rain drops. It also reduces the volume of water that reaches the soil surface. Consequently, soil erosion can be controlled by changing land use and increasing ground coverage, which has proved to be one of the basic approaches to controlling soil erosion in all land use types. In relation to that (Mohammad et al., 2016) soil erosion by water as a natural phenomenon has direct and indirect effects on the environment and human life. It reduces land productivity and reduces the useful storage volume of rivers, reservoirs and the service life of many hydraulic structures, such as dams, by sediment deposition. According to (Adornis et al., 2014) the precipitation characteristics affect crust formation, infiltration rate and erosion depending on the intrinsic soil properties such as texture and minerals. Rainfall intensity is a contributing factor to the runoff and sediment generation (Martínez-Mena et al., 1999; Wei et al., 2017).

In relation to that (Lima De et al., 2011) the sediment grain size during runoff depends on the direction of the storm movement, and the downstream storms lead to more soil loss than the upstream storms. So that the sediment grain size in the upstream is coarser than in the downstream. Regarding to (Kinnell, 2005 ; Rasha et al., 2010) most of the coarse grains are moved by the pressure of the rain drop, while the soft grains pass without the help of rain drops, the sediment drainage of different sizes depends largely on the characteristics of the soil of the site and the state of rainfall and runoff, and that the results of a particular site may not be appropriate for circulation on another site. According to (Mahmood et al., 2016) climate changes associated with soil erosion mainly include changes in temperature and precipitation and accelerate the hydrological cycle, altering rainfall, and the magnitude and timing of runoff. As for the (Zhiying et al., 2016) there is a direct and indirect impact on soil erosion from climate change, the influencing factors are multiple. Increased rainfall amount, rainfall intensity and extreme rainfall event can directly increase soil erosion, while higher air temperatures can increase plant biomass, evapotranspiration rates, canopy density and residue decomposition Rate, even low precipitation falling as snow, which indirectly affects soil erosion.

(Shadeed, 2005) Semi-arid regions are associated with dry climate which are dominated by low annual rainfall, low soil moisture conditions, very high potential evapotranspiration levels and periodic droughts, in addition to different associations of vegetative cover and soils. (Ido et al., 2016) presented new insights from the Dead Sea on the role of seasonal thermohaline stratification and water balance in seasonal and depth variations of degree of halite saturation (salt) and halite growth rate along water column. The results of this study suggest the existence of a seasonal pattern of halite deposits, on the basis of spatiotemporal variations of the saturation of halite of the Dead Sea brine. In winter, halite deposited along the entire water column. This is due to the combination of continuous net evaporation (evaporation > infows), cooling and vertical mixing of the water column. In summer, the epilimnion is low saturated and dissolves salt, whereas hypolimnion is over saturated and precipitates salt. While (Yoav Ben Dor, 2018) Focused on a study Changing flood frequencies under opposing late Pleistocene eastern Mediterranean climates. Where he studied sections of sediment sheets located in the Dead Sea, so that it can be guessing of the floods that occurred and deposited during wet rainy seasons. The floods were triggered by strong rainstorms in the eastern and western parts of the Dead Sea. The classification of portable coarse sediments and the control of organic matter deposited on the surface of sediments, as well as the study of the method of production of Aragonite. From this, the geological and climatic conditions of the Mediterranean region can be used to predict the levels of the Dead Sea. As for the (Marieke Ahlborn, 2017) confirms the arrival of the sediment and its transfer to the Dead Sea because of the slopes of three main areas (Arugot, David, and Hever), Where they found that through the study of thin sections of the sediments that they moved to the Dead Sea due to heavy rainfall, and control the characteristics of sedimentary layers and soil types and texture. They then considered that the new flow quantities as evidence and indicator of the intensity of precipitation flowing to the region and study the previous changes in the pattern of the circulation of the atmosphere. (Adli Khalayleh, 2018) had established in his study about The Geochemical Characteristics of Wadi Al-Gar Stream Sediments as Indicator of their Source and Paleo-Weathering, which trace and major elements distribution and analyses that indicate stream sediments formed by the physical and chemical weathering of bedrock within the catchment area. The sediment geochemistry reflects that stream sediments are a combination of geomorphic elements and human uses. The isotopic analysis reflected influence from terrestrial organic matter to the sediment and its horizontal distributions indicate a pedogenic carbonate of the biotic and abiotic process and tectonic controls on sedimentation that is referred to a semiarid paleo-climate. On the other hand (Hussam Utair, 2013) studies the Quantifying the Surface Water Runoff to the Dead Sea under Different Climate Scenarios, Case Study Wadi Al-Gar Catchment. There was fluctuation in rainfall and runoff in Wadi Al-Gar in the dry and wet seasons, which in years was less than 200 mm while in other years it was about 1000 mm. In 2011 the precipitation amounts averaged about 475 mm. The modeled data shows that such events normally contribute with about 18-22 million cubic meter (MCM) annually to the Dead Sea. The percentage of surface runoff was still the same in three different scenarios as 40%.

Chapter Three

This chapter includes a full description of the study area such as its location, climate, rainfall, Topography, soil and geology of region

3.1.1 General View of the Study

Hebron district is located in the southern part of west bank bounded by Bethlehem district from the north and the 1948 cease-fire line from the other direction including the Dead Sea from the east. The total area of Hebron district is 1,050,000 dunums divided into built-up areas, closed area, nature reserves and cultivated area. There are 153 Palestinian built-up areas including 5 municipalities, 2 refugees camp, the other are villages or rural areas, these built up representing 3.6 % of the total area compared with 0.55 % for Israeli settlement and 19.4 % for closed area which are controlled by Israeli army(ARIJ-1995).

Wadi Arugot catchment is located to the southern middle part of the Hebron Governorate. Positioned over the Main Middle Mountains Chain of Palestine, and consist of two main sub-catchment these are Gar and Abu El Hayyat sub-catchment with total area of 375 km^2,Vegetation in this Wadi are very few except for some small areas covered with desert plants, which makes it easy to soil erosion, especially with a high slope. Wadi Al-Gar sub catchment with an area of 225 Km^2 and a length of 35 Km has a difference in the elevation from the west highlands going downwards to the Dead Sea level eastwards is more than 1200 m as shown as figure (3.1). The surface catchment area has a fan – shape border.

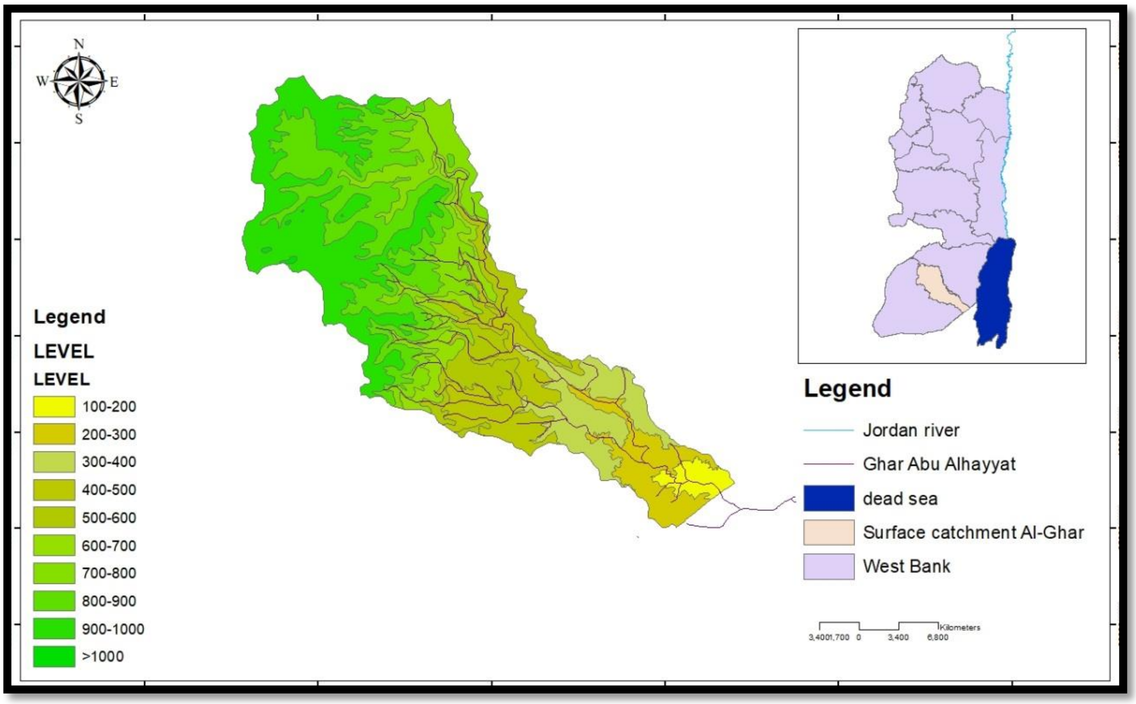

Figure (3.1): elevation distribution over Wadi Al-Gar catchment area.

3.1.2 Climate

The West Bank has a typical Mediterranean climate with two distinct seasons: dry hot season from June to October, and cold wet season from November to May. The monthly average temperature of the study area is 7 °C in the winter to 21°C in the summer. The minimum temperature is -3 °C in January and the maximum is 40 °C in August. Most of the rain falls during December through February although there may be rain in other periods of the year. The predominantly low-pressure area of the Mediterranean is centered between two air masses: the north Atlantic high pressure of North Africa and the Euro-Asian winter high pressure located over Russia. This is the primary cause of winter weather in the West Bank and the eastern Mediterranean in general (Husary et al., 1995). The rainfall ranges in this areas are 100-700 mm, and the average annual humidity is 60 % (GIS Unit - ARIJ, 2009).

3.1.3 Rainfall:

Rain is the main source of water in Palestine. It feeds groundwater, waterways, valleys, and floods. The rainy in Palestine fluctuates from one year to another and from one region to another depending on the topographical conditions in terms of altitude and drop from the sea. Rainfall in Palestine extends from September to May, peaking from December to March of each year.

Rainfalls are increased in the western slopes and decrease in the Jordan Valley. The amount of rain falling on the mountain highlands is more than the amount of rain falling on the coast. The average rainy in the West Bank ranges from 700 mm to 100 mm in the Dead Sea area.

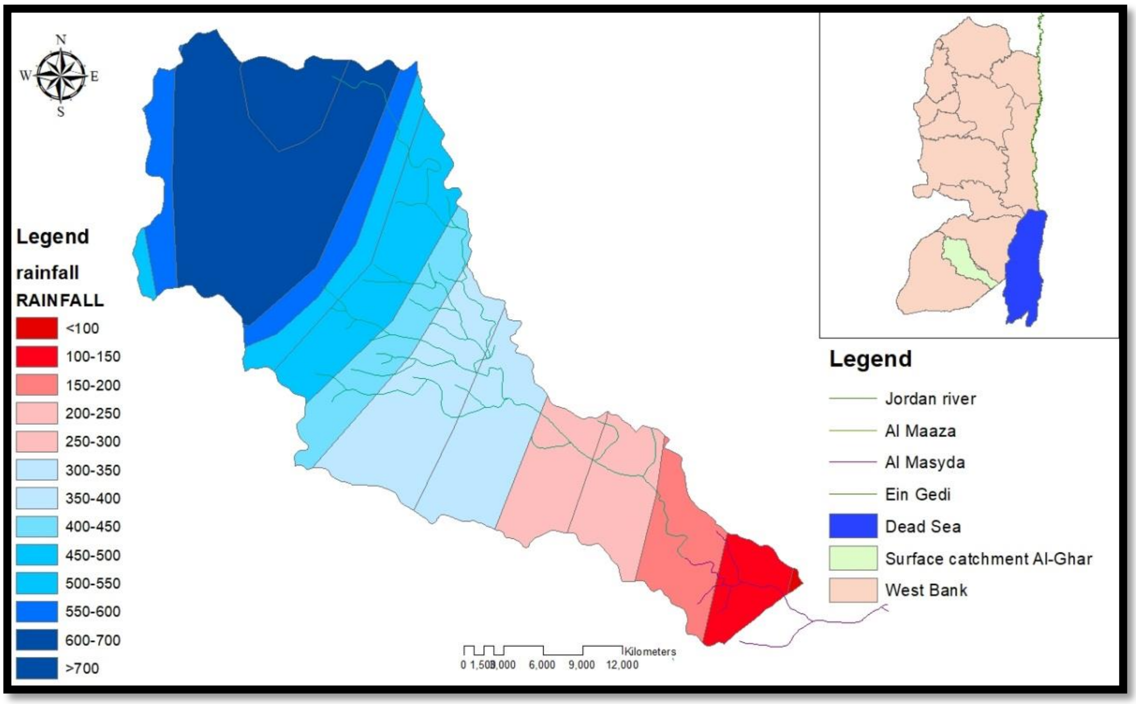

Figure (3.2): Simulated rainfall from the rain gage data over the study area suing GIS program.

3.1.4 Soil:

The soil is varied in the study area according to the origin of materials, the diversity of climatic conditions, and the composition of the soil is influenced by factors such as vegetation, topography, and erosion factors.

The major soil Association covering the study area and its Parent Material is: Brown Lithosols and Loessial Arid Brown Soils (Chalk, marl, limestone or conglomerate, loessial dust), Brown Rendzinas and Pale Renzinas (Soft chalk and marl covered partly Nari crust and hard chalk), Terra rossa (Hard limestones, dolomites with other inclusions of chalk and marl,) and Bar rocks and desert lithosols (Hard limestone, dolomite and chalk). Figure (3.1)

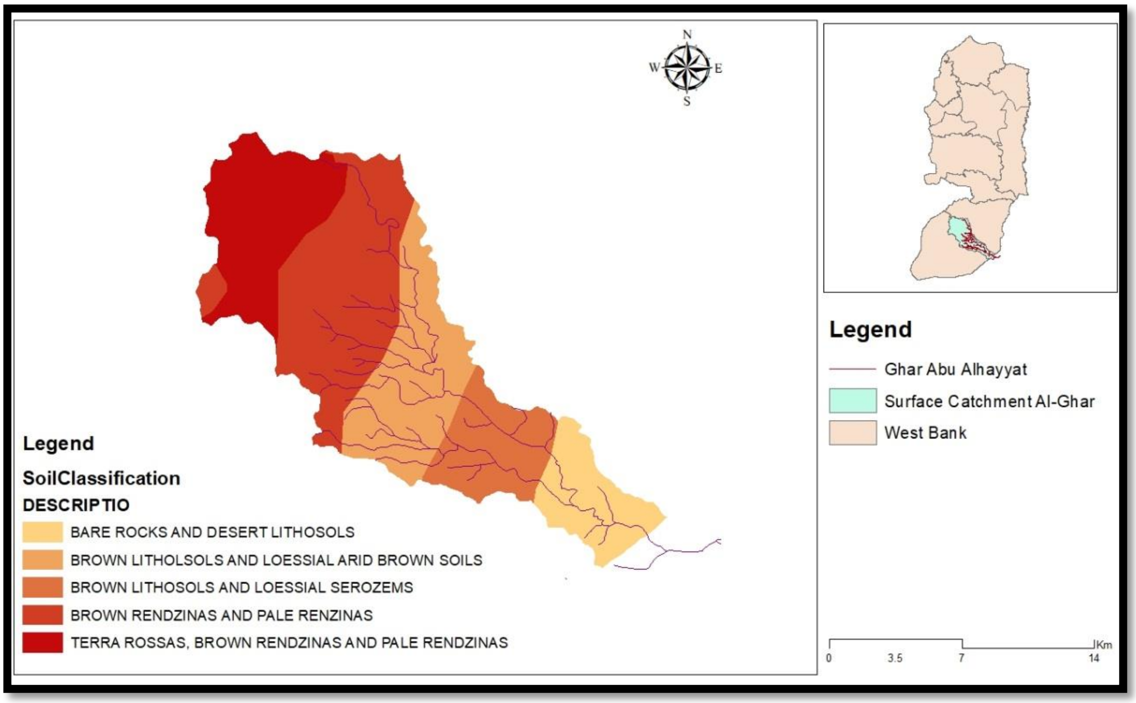

Figure (3.3): Description of the soil along Wadi Al-Gar stream.

3.1.5 Topography:

A large clear different in elevation were found in Hebron district from west to east , where the highest point in Halhul reaches 1011 m above sea level which considered as one of the highest point in west bank,and less to reach -400 m below sea level in the dead sea area with sharp slope.

3.1.6 Geology of the region

In Wadi Al-Gar, the oldest formation crop out at the axis of the anticline, whereas the younger Paleogene series (Senonian- Abu Dees) covers the flanks of the anticline in the southern and central part of the study area. Furthermore, the formation of the Upper and Lower Cretaceous are thick alternating sequences of limestone, dolomitic limestone, marls and marly limestone which make the aquifer system. On the other hand, a series of Senonian sequence of the Paleogene, consists mainly of thick chalk, chalky limestone with chert bands that compose the impervious cover of the aquifer system are found. The study area has various geologic formations as shown in figure (3.2). The main dominant formations are as follows as described by Rofe and Raffety in the hydrogeological survey they made of Palestine in 1963.

- Albian - Lower Beit Kahil Formation: This formation represents the lower part of the upper Albian . It is built of two sub formations, Kefira and Giva'tYearim. Kefira, the lower part of this formation, is made-up of Limestone with thin layers of porous dolomite interchanging with marly limestone. Gray Limestone layers alternating with layers of shale and marl are typical for the lower part of the Kefira Formation . On the other hand, Giv'at 13 Yearim, The upper part of the Lower Beit Kahil Formation, is made-up of gray to brown dolomite with clayey and marly limestone. The marly uppermost part of EinYorqe'am is equivalent to Moza marl .Generally, the Lower Beit Kahil is considered to be a moderate to good Aquifer (Hirtch, 1980).

- Albian- Upper BeitKahil Formation: Is ranging between 160 to 190 m of thickness. This formation is regarded as the upper part of the upper Albian. It has two sub formations that are; Soreq and Kesalon. The lower part of this formation (Soreq) consists of porous dolomite, marly dolomite, marl. The occurrence of the marl in this formation reduces its water bearing capability. On the other hand, the upper part of this formation (Kesalon) mainly consists of brittle dolomite and brittle limestone rich in fossils. This formation usually appears as a cliff and sometimes as a rocky landscape. This formation is considered to be the upper part of the lower aquifer.

- Cenomanian - Hebron Formation: The Middle Cenomanian Hebron Formation, (Aminadav in the Israeli terminology) is composed of brittle karistified gray dolomite, Dolomitic limestone and gray limestone. At its base it is formed of hard dolomite and Dolomitic limestone with some silicification. The lithology is uniform since Dolomite and Dolomitic Limestone are found throughout the sequence of Hebron Formation. The porosity of this Formation is mainly secondary because the rocks are well jointed and karstified. The Hebron Formation certainly is the most important aquifer within the West Bank, (Rofe and Raffety, 1963).

- Cenomanian – Bethlehem Formation: The Bethlehem formation is 30 to 115 m thick and underlies the Jerusalem formation. The Upper Cenomanian Bethlehem Formation is built of two formations: Weradim as its upper part and Kfar Shaul as its lower part. Kfar Shaul is made-up of limestone, Chalky Limestone and marl that act as a confining aquiclude for the Hebron Formation beneath. The Weradim Formation is made-up of hard Dolomite with some Limestone. Bethlehem Formation is frequently highly jointed and fractured making this formation a good aquifer. (Rofe and Raffety, 1963).

- Turonian - Jerusalem Formation: is approximately 70 to 130 m thick. Its lithology is characterized by karstified Limestone and Dolomite with marl and clay mainly near the bottom. Sometimes occurrence of chalk is evident on the top of this formation. Due to the fractures and joints of this formation turns out to be a good aquifer. This formation covers the middle part of the catchment of Wadi Ghar with an area of 94.3 Km^2. (Rofe and Raffety, 1963).

- Senonian – Abu Dis Formation: It is approximately 200 to 450 m thick. It consists of Chalk and Chert, the Chalk usually white but in some areas dark-colored due to the presence of bituminous materials. The formation is occasionally phosphatic with a distinctive twin band of chert beds. In general, Chalk often appears to be a fracture flow aquifer but because of its clayey nature, it is considered as an aquiclude. Abu Dees Formation covers the middle to lower section, about 58.7 Km^2, of the surface catchment area of Wadi Ghar. (Rofe and Raffety, 1963).

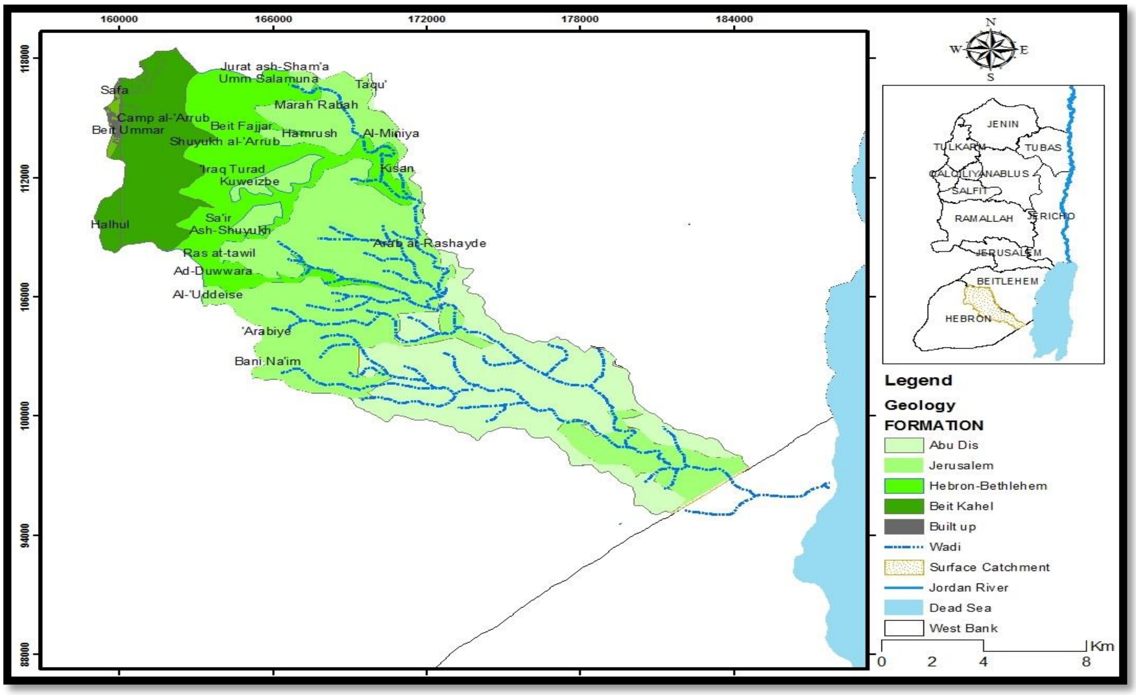

Figure (3.4): Geologic Formations tributaries covering the area of Wadi Al-Gar surface catchment.

Chapter Four:

Methodology

This chapter includes the site description and sampling, analysis, Description of HEC-HMS model and all the related laboratory work during the period of the study.

4.1 Site description:

Wadi Al-Gar is divide into two parts: Upstream were soil sample taken, include Halhol, Beit Ommar, Seir, and Taqu, at a depth of (0-10) cm as shown as figure (4.1), and Downstream (sediment sample), The samples were taken from many layers at different height were collected within Wadi Al-Ma'aza and Wadi Al-Masyada as shown as figure (4.2)

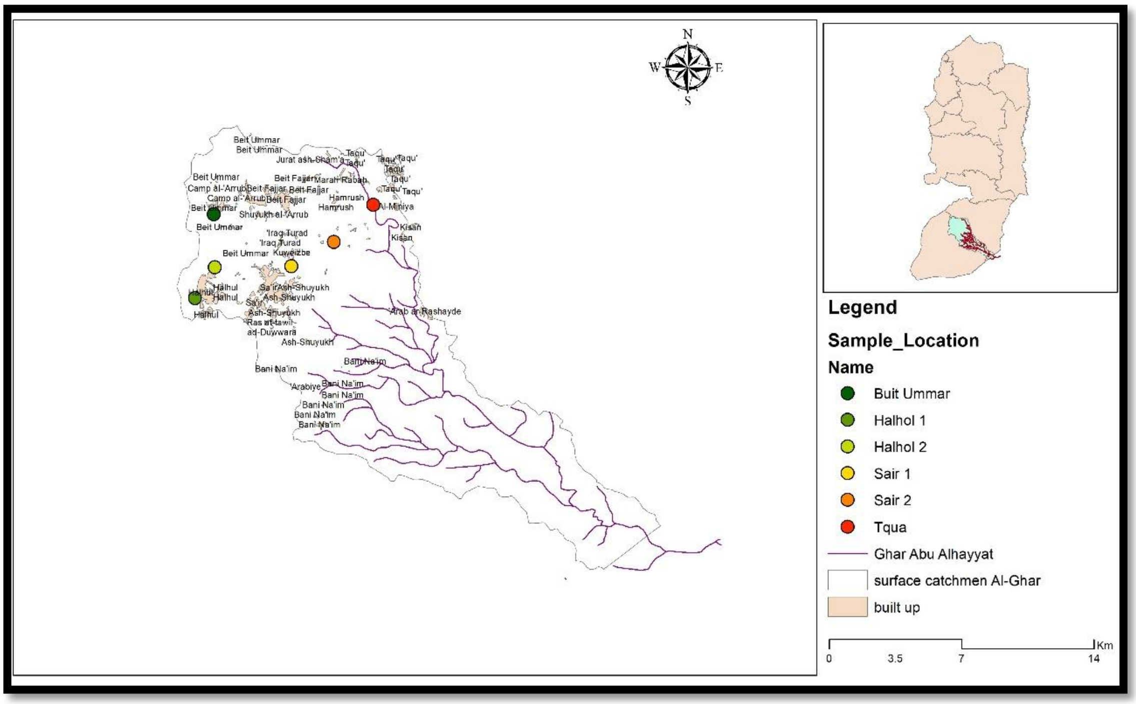

Figure (4.1): Location of Soil Samples in upstream of Wadi Al-Gar

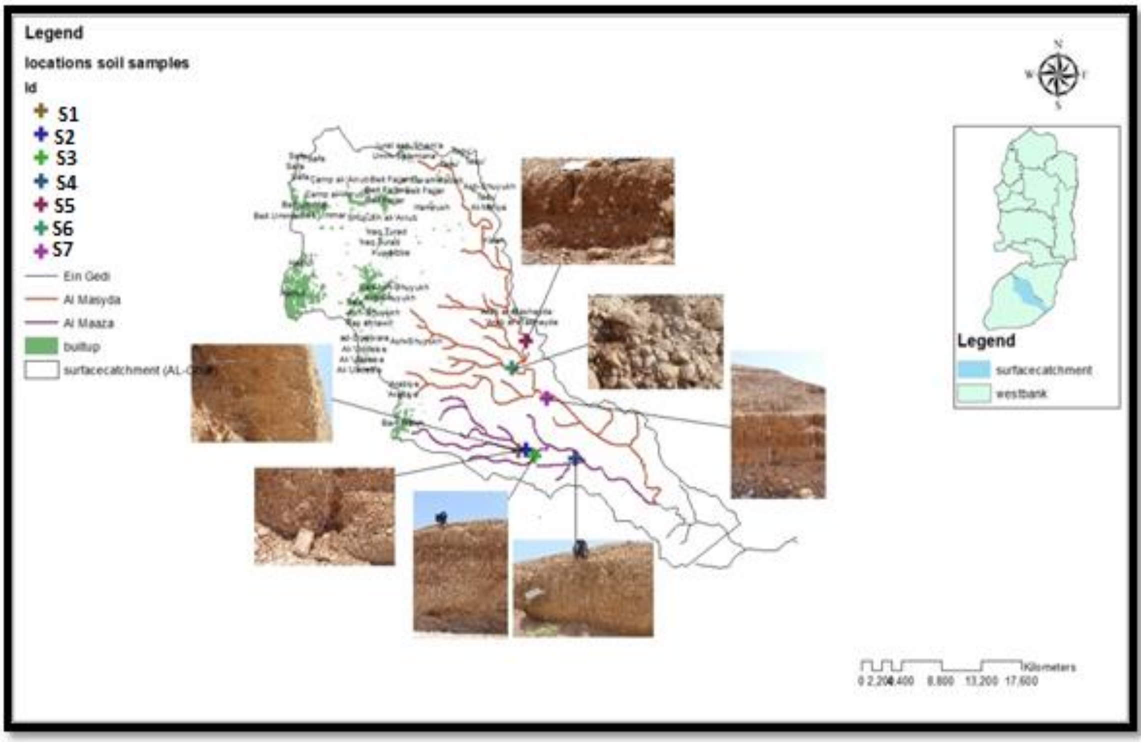

Figure (4.2): Location of sediment samples in downstream of Wadi Al-Gar (Wadi Al-Ma'aza and Wadi Al-Mesyada)

4.2 Soil and sediment sampling processing and analysis

- Soil and sediment samples: were collected in March 2018 from two parts. The sample coordinates were randomly selected, and using the shovel by drilling. Samples were placed in paper bags and brought to the laboratory, and dried in air at room temperature, crushed, homogenized, and passed through a 2 mm sieve.
- Runoff samples: were taken along the runoff of the Wadi Al-Gar from two location (Wadi Al-Ma'aza and Wadi Al-Masyada as shown as figure (4.3) to study the chemical properties of the runoff and to measure the sedimentation rate. (Use the Standard operating procedure)

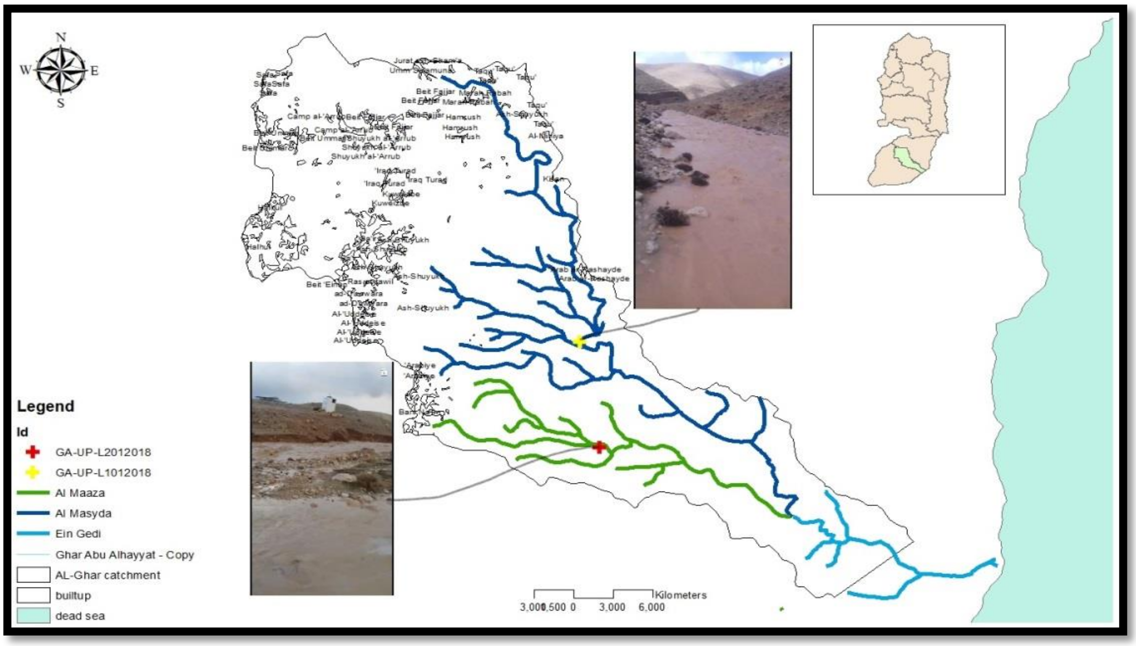

Figure (4.3): Runoff sample locations from Wadi Al-Ma'aza and Wadi Al-Masyada

- physical and Chemical Analysis:

All samples were analyzed for physical and chemical parameters. That include the Soil texture, pH , EC, chloride, alkalinity, Total Organic Carbon, Total Nitrogen bound, Sodium, Potassium, Calcium, Phosphate, Magnesium ,Three replicates of each sample were analyzed according to the methods recommended in Standard Operating Procedures (SOPs) using various analytical methods as shown in (Table 4.1) below.

Table 4.1: Analytical methods used in the determination of various parameters including: parameter analyzed, method of analysis (Al-Quds University).

Parameters	Chemicals	Method
Soil texture	sodium hexametaphosphate	Wet method
pH , EC		pH and EC meters
Cl^{-}	K_2CrO_4, $AgNO_3$	Titration
HCO_3^{-}	mixed indicator , $AgNO_3$	Titration
PO_3^{-4}	Potassium Persulfate , PhosVer 3	HACH
K^{+}, Na^{+}		flame photometer
Mg^{+2}	Erichrome Blake T, EDTA	Titration
Ca^{+2}	Murexide , EDTA	Titration
TOC and TNb	H_3PO_4, HCl	TOC device

4.3 Model Description:

This work is based on assessing the amount of runoff sarfuce contributed by wadi al-gar to the Dead Sea This model was built using HEC-HMS program and use Digital Elevation Model(DEM) to add different climatic, hydro-geological and topographical parameters. Surface geometry with computed slope curves and cross sections were prepared .Then the whole project file was exported as HEC HMS data, and then reopened with the HEC HMS program for simulation and detect the reaches points and accumulation points which depend in the previous DEM file (Fig. 4.4).Meteorological parameters such as daily rain event, estimated water losses, and SC-Curves were included in the model. Base flows for Al-Gar Stream were set to zero. The HEC-HMS program was used then for computation and simulation of storm-flow hydrographs.

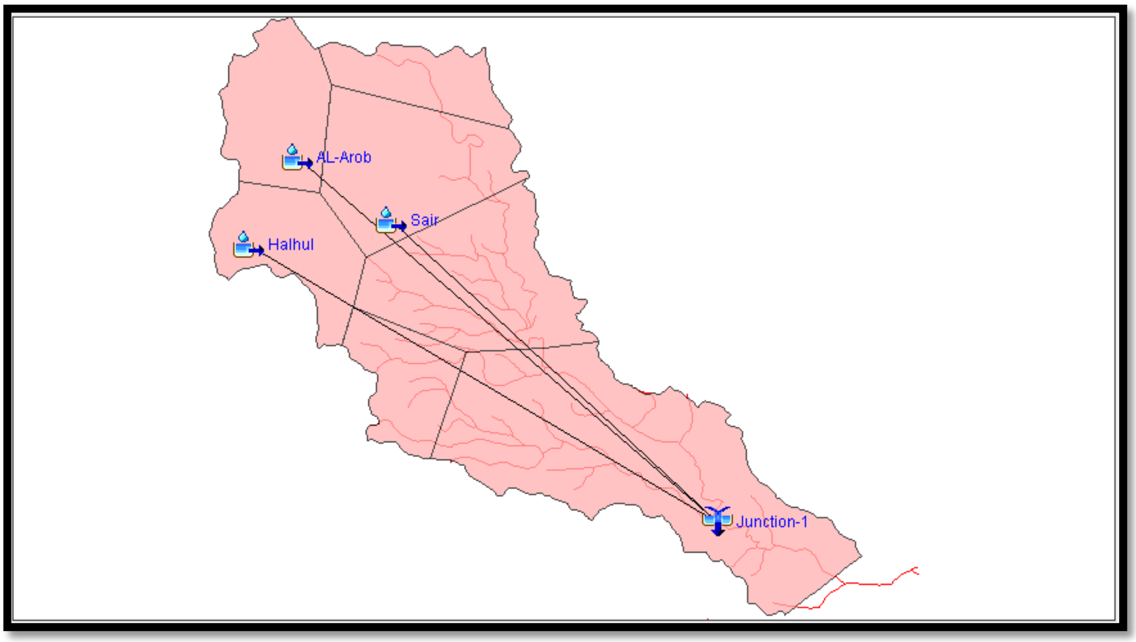

Figure (4.4): HEC-HMS basin, 3 sub-basin Halhol, Al-Arob and Sair that drained to the junction.

The old data for the year 2010/2011, were taken from Hussam Utair master thesis. The rainwater data from the year 2017/2018 were inserted in HEC-HMS runoff simulation model, to simulate a runoff model for the year 2017/2018, and then the model results were compared with previous study for 2010/2011

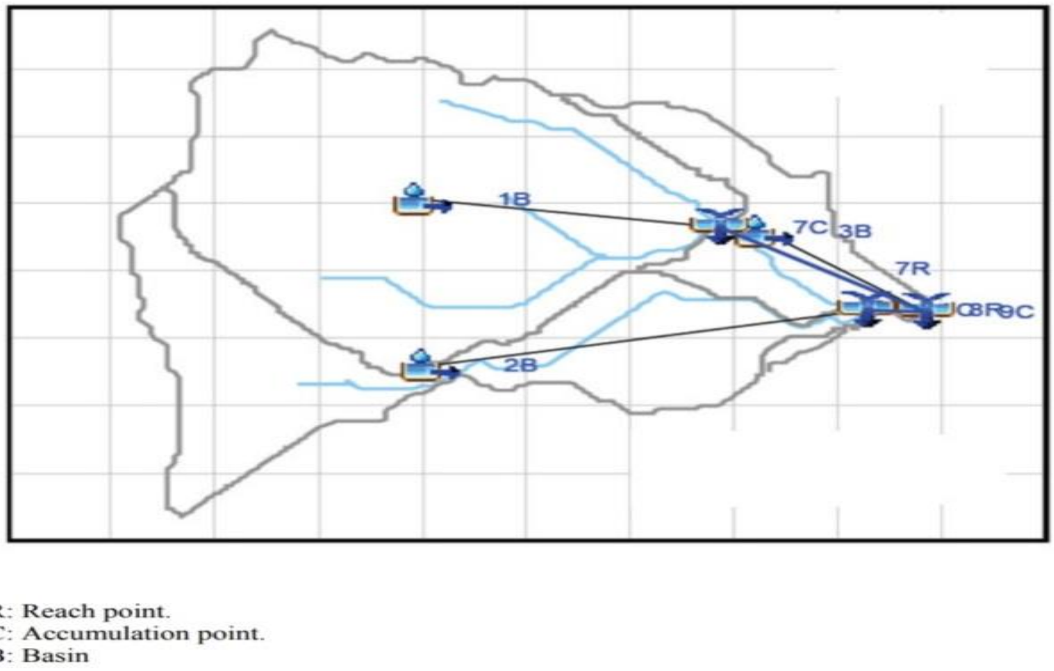

Figure (4.5): HEC-HMS basin. 3 sub basin 1B, 2B and 3B with different accumulation points that drained to the final Accumulation point to the Dead Sea. Adapted from Hussam Utier Thesis.

4.4 Sedimentation Rate:

The sedimentation rate was measured using numerical conical tubes, were 10 ml of runoff samples were placed. After one hour the sedimentation rate was registered. The information obtained was incorporated into the HEC-HMS model

Chapter Five:

Result and Discussion

The results and discussion chapter consists of five sections including the physical and chemical result (texture and ionic ratios), slope, runoff, HEC-HMS Result and sedimentation rate during the season.

5.1 Physical and chemical result of soil and sediment samples:

5.1.1 Soil texture:

The soil texture affects the likelihood that a soil particle will detach from the soil surface and be transported some distance from its initial position. It is an important property contributing to soil erosion. Soil with a high content of silt and fine sand or clay mineral expansion tends to be highly erodibility (Tulare, 2015). The silt % in all soil samples 2018 as shown as figure (5.3) is higher than 50% more than the sand and clay. The texture of soil samples is silt-loam and loam. Loamy soils (medium textured soils) tend to be more erodible because they contain large amounts of silt and fine sand. These soils tend to have moderate to low permeability and low resistance to particle separation. Erodibility is low for clay soils, with low shrink-swell capacity, because these clay particles block together into larger aggregates that resist separation and transport. The sandy soil containing large amounts of fine, medium or coarse sand particles (0.10 to 2.0 mm) also has a low erodibility. Sand particles lack the ability to assemble, but because they are very permeable, water runoff is low, so erosion is often slight. In addition, the large grain size of the sandy soil takes more energy to transport its particles than those containing soil with fine-textured soils. If disaggregated, silt and clay particles (small particles) are transported easily. Rock fragments can also prevent erosion by protecting the soil from the effect of raindrops (Ampontuah et al., 2006).

Table (5.1): Texture of sediment sample 2018 at Wadi Al-Gar

No. of sample(2018)	x-y	Height(cm)	texture	Sand %	Silt %	clay %
Wadi Al-Maaza						
1	0712563/3487627	240	Loam	38.9	45.9	15.2
2.a	0712563/3487627	10-60	silty loam	31.43	50.13	18.43
2.b	0712563/3487627	60-120	clay loam	43	26.83	30.16
2.c	0712561/3487629	120-140	Clay	29.76	39.5	30.73
3.a	0713074/3487338	0-70	clay loam	46.33	39.63	14.03
3.b	0713074/3487338	70-140	clay loam	28.73	37.03	34.23
3.c	0713071/3487340	140-240	clay loam	25.23	46.93	27.83
3.d	0713074/348734	240-305	Loam	42.66	36.46	20.86
3.e	0713074/348734	305-360	sandy loam	58.6	25.36	16.03
3.f	0713074/348734	360-394	Loam	42.6	41.7	15.7
3.j	0713074/348734	394-400	Loam	24.7	48.9	26.4
3.h	0713074/348734	400-500	Loam	39.3	34	26.7
4.a	0715347/3487221	0-90	Loam	34.7	42.4	22.9
4.b	0715347/3487221	90-170	Loam	48.93	33.4	17.66
4.c	0715347/3487221	170-220	silt loam	38.93	60.16	0.9
4.d	0715351/3487219	220-	sandy loam	59.06	38.16	2.76
Wadi Al-Mesyada						
5.a	0712485/3493439	0-40	sandy loam	59.66	27.4	12.93
5.b	0712483/3493438	40-70	sandy loam	75.73	15.83	8.43

6	0711716/3491984	140	sandy loam	71.7	21.9	6.4
7.a	0713674/3490390	130	silty loam	17.53	64.8	17.66
7.b	0713674/3490390	130-210	sandy loam	65.96	22.8	11.23
7.c	0713675/3490395	210-288	Loam	38.03	44.13	17.83

Table (5.2): Texture of sediment sample 2017 at Wadi Al-Gar

No. of sample (2017)	x-y	Height (cm)	Sand %	Silt %	caly %	soil type
Wadi Al-Maaza						
1	0712563/3487627	250 cm	45	36.13	18.86	Loam
2.a	0712567/3487622	125 cm	34.13	49.63	16.23	Loam
2.b	0712566/3487622	105 cm	52.13	33.83	14.03	sandy loam
2.c	0712567/3487630	35 cm	28.46	27.56	43.96	Clay
3.a	0713062/3487341	35 cm	26.5	40.36	33.13	clay loam
3.b	0713062/3487337	150 cm	41.16	26.2	32.63	clay loam
3.c	0713062/3487334	235 cm	23.83	33.13	43.03	Clay
3.d	0713062/2487338	320 cm	19.9	50.43	29.66	silty clay loam
4.a	0715344/3487221	100 cm	65.83	28.93	5.23	sandy loam
4.b	0715344/3487221	210 cm	42.23	53.73	4.03	silt loam
4.c	0715344/3487221	290 cm	43.3	48.03	8.66	Loam
4.d	0715344/3487221	350 cm	26.4	69.9	3.7	silt loam
Wadi Al-Mesyada						
5	0712485/3493439	45 cm	65.3	24.96	9.73	sandy loam
6	0711716/3491984	70 cm	82.33	14.53	3.13	loamy sand
7.a	0713674/3490390	40 cm	67.13	22.23	10.63	sandy loam
7.b	0713674/3490390	85 cm	64.93	24.93	10.13	sandy loam
7.c	0713675/3490395	117 cm	84.3	13	2.7	loamy sand

Table (5.3): Texture of soil sample 2018 at Wadi Al-Gar

Location	X-Y	Sand %	Silt %	Clay %	Texture
Halhol (Wadi Al-Geef)	699711-349546	13.5	62.6	23.9	Silt-Loam
Halhol(Wadi Al-Shenar)	700732-3497120	17.85	78.78	3.37	Silt-Loam
Taqu	709028-3500575	22.12	74.28	3.6	Silt-Loam
Sair	704772-3497255	30.07	49.28	20.65	Loam
Sair	706991-3498583	34.16	51.14	14.7	Silt-Loam
Beit Ommar	700611-3499920	30.62	62.78	6.6	Silt-Loam

The distribution of grain size is one of the most important properties of sediments. because grain size is a powerful tool for explaining the geomorphic importance of fluid dynamics in the natural environment, and describing site geomorphic setting and distinguishing between local and regional sediment transport mechanisms because grain size is the predominant controlling agent of sediment geochemistry. Watson et al. (2013). Sediment sample of 2017 and 2018 as shown as figure (5.1 and 5.2) was generally richer in silt and sand compared with the original soil. The texture of samples are sand, silt-loam, sandy loam, loam, clay, clay loam, and silty clay loam.

5.1.2 pH and EC:

The measurements of pH and EC can vary greatly and are influenced by many environmental factors, including climate and bedrocks, (plants and animals), geology, and local biota, as well as human impacts on land.

Appendix B- shows pH in upstream sample with ranging values from 7.3 to 8.57. This considered neutral and alkaline soil, Limestone is responsible for alkaline soil pH.

The pH in downstream samples differ from 2017 to 2018 , pH in most samples increased in 2018 , and was clearly shown in sample No 3.c,Where it has changed from 7.89 to 8.71 It was also the limestone that is responsible. the soil pH in the new layers is alkaline ,This is the result of irrigation water containing bicarbonate.

The electrical conductivity results of soil samples. Values ranging from (103.7-284) the soil is considered non-saline. In 2017, EC in downstream samples varied in the value. The lower value is 116.90 in sample No 5 and higher value 9520.00 in sample No 4.b, due to the high concentration of sodium and other minerals in the sample. and are considered saline. The EC of sample of 2018 between 99.20 in in sample No 6 indicate low available nutrients and 8516.67 in in sample No 4.c, is high due to the high concentration of sodium and other minerals in the sample.

5.1.3 Ionic ratios

- Sodium adsorption ratio:

Sodium Adsorption Ratio (SAR) which indicates a possible sodium hazard. It relates the amount of sodium relative to calcium and magnesium in water. In milliequivalents per liter (meq/L), which is used to determine soil salinity.

SAR= Na/√(Ca+Mg/2)

Figure (5.1) shows the SAR results for downstream samples 2017, the SAR values of the downstream samples are very low <3 the reason is that the concentration of sodium was low compared to the concentration of magnesium in samples.

In downstream samples we find the SAR result in 2017 is less than in 2018. Due to high sodium concentration in samples 2018 as shown as figure (5.4), In general, the SAR values in wadi Al-Ma'aza higher than wadi Al-Mesyada and appeared clearly in both samples 3.c increased from 0.03 to 3.49, and sample 3.d increased significantly from 0.08 to 10.24, soil structure can deteriorate, resulting in slower water infiltration and reduced soil aeration and severe risk of increasing soil sodicity on most soils. (Mohsen et al., 2008). Samples 3.(e,f,g,h) of the layers that appeared in 2018 in wadi Al- Ma'aza had SAR values higher than 3 where they are considered moderat salinity

- Sodium/chloride (Na/Cl):

The relationship between sodium and chloride was used to determine the process that controls salinity and salinity intrusion in arid and semi-arid zones. Na^+/Cl^- ionic ratio of upstream of Wadi Al-Gar less than 0.7 as shown as Figure (5.3) indicate loss of Na through precipitation of evaporitce salts .

All results of Na^+/Cl^- ionic ratio in Wadi Al Maaza and Wadi Al-Mesyada in 2017 less than 7 as shown as figure (5.1) because sodium tends to have greater adsorption on soil colloids than chloride because of its readiness to exchange with other cations. the Na^+/Cl^- ionic ratio increased in 2018 as shown as figure (5.4) for all samples The Na^+/Cl^- resulte in wadi Al-Maaza ranged from (0.22-1.22) the Na^+/Cl^- ratio range of sample 3.c (1.0-0.86) sodium deficiency relative to chloride is usually the result of positive ion exchange in which sodium is replaced by alkaline earth. Na^+/Cl^- ratio of samples 2. (a ,c) exceeding 1.0 are characteristic of groundwater flowing through crystalline and dependent on the nature of the feldspars the ionic ratio of wadi al mesyada ranged from (0.03-1.40) , sample 4.a and 7a is exceeding 1.0 and the rest sample less than 7.

- Magnesium/Calcuim (Mg/Ca)

The samples of upstream wadi fail in the Mg^{2+}/Ca^{2+} ratio rang > 0.9 as shown as Figure (5.3) the Mg/Ca ratio rise due to dolomite dissolution.

Sample 4.d in Wadi Al-Maaza in 2017 as shown as figure(5.2) fails in the Mg^{2+}/Ca^{2+} ratio range of < 0.5 ,that are indicative for dolomitization in which Ca+2 is released leading to an increase in Ca^{2+} ions in the solution .In Wadi Al-Mesyada, the sample 4.b decreased from 19.15 to 1.37 and sample 4.c decreased from 20 to 1.71 because increase in Ca^{2+} ions in the sample .

Sample 2.c in Wadi Al-Maaza increased from 3.33 to 14.14 usually indicative of the additional source of Mg^{2+} ions. With Mg- rich brined associated with evaporates or flow through Mg-rich silicate country rocks .

Figure (5.4) shown the Mg^{2+}/Ca^{2+} ratio of downstream sediment sample 2018, The sample 5.an in Wadi Al-Mesyada fail in the Mg^{2+}/Ca^{2+} ratio range of 0.5-0.7. Water flowing through chalky or limestone aquifers. Sample 2.b in Wadi Al-Maaza fail in rang (0.7-0.9) which might resembles associated with dolomite or dolomitic aquifers. and the rest sample of Wadi Al-Maaza and Wadi Al-Mesyada in 2017 and 2018 fails in the Mg^{2+}/Ca^{2+} ratio range of > 0.9 associated with dolomite or dolomitic aquifers and usually accompanied with additional sources of Mg ions.

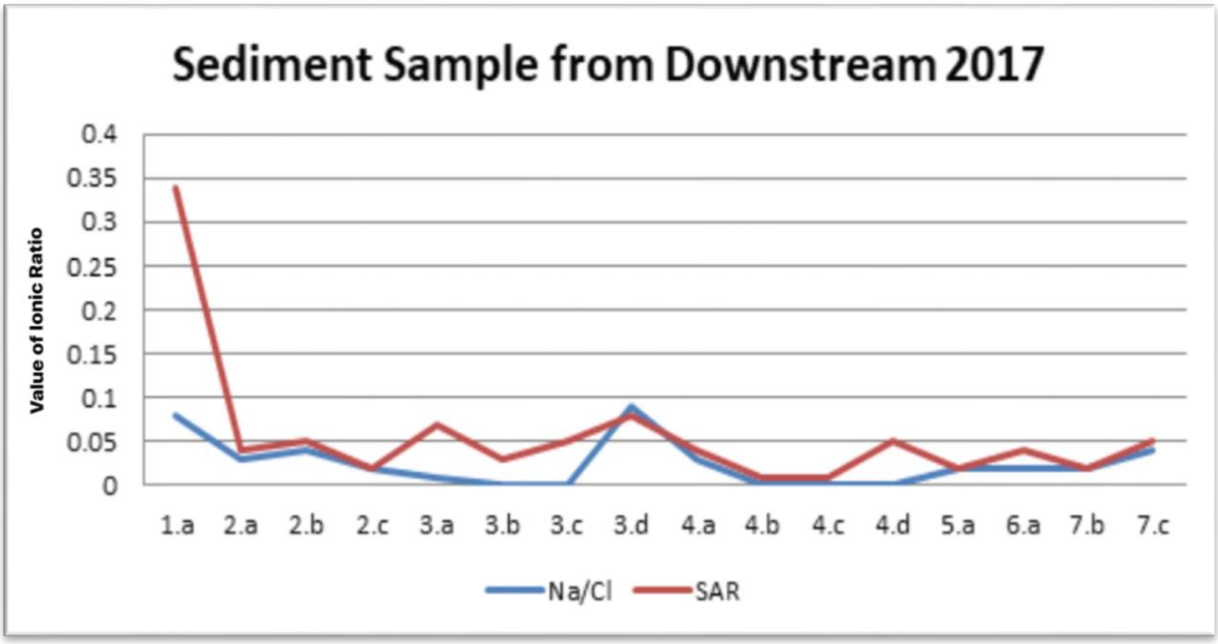

Figure 5.1: Ionic ratios (Na/Cl and SAR) of Sediment 2017 in Wadi Al-Gar downstream

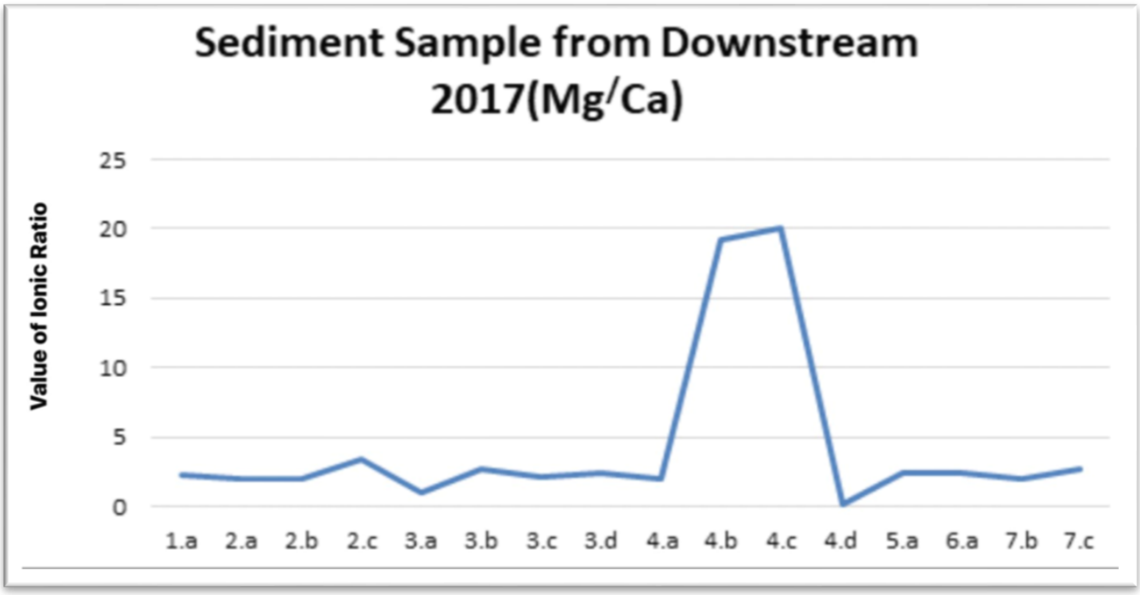

Figure 5.2: Ionic ratios (Mg/Ca) of Sediment 2017 in Wadi Al-Gar downstream

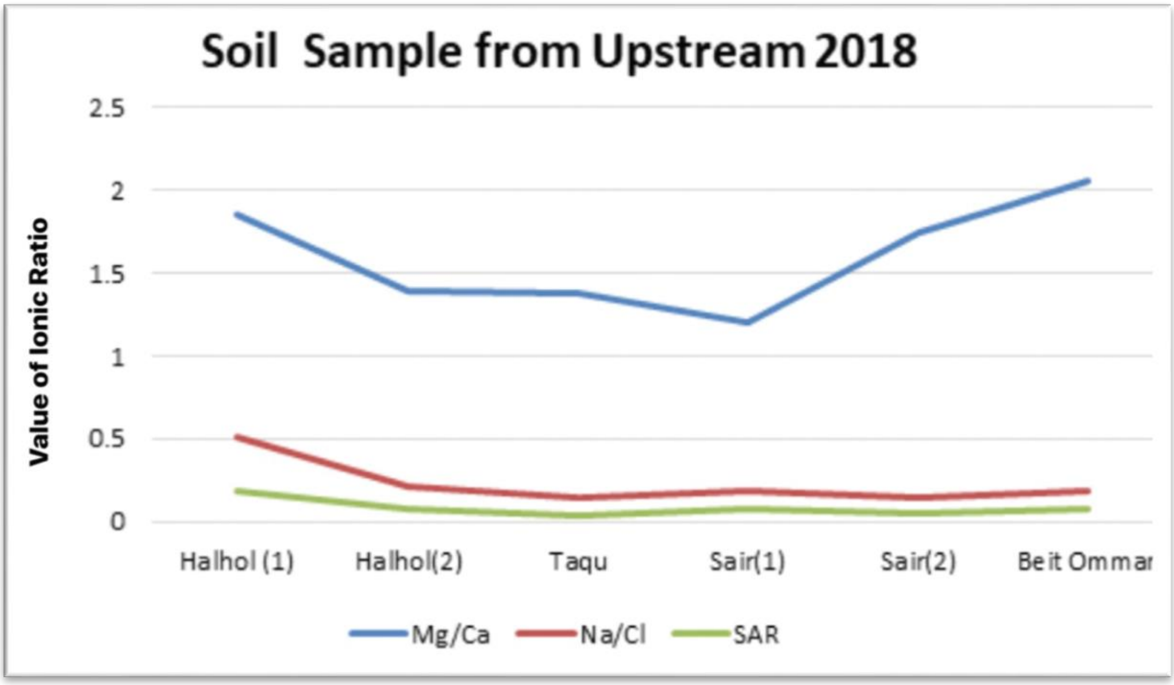

Figure 5.3: Ionic ratios (Mg/Ca, Na/Cl and SAR) of soil 2018 in Wadi Al-Gar upstream

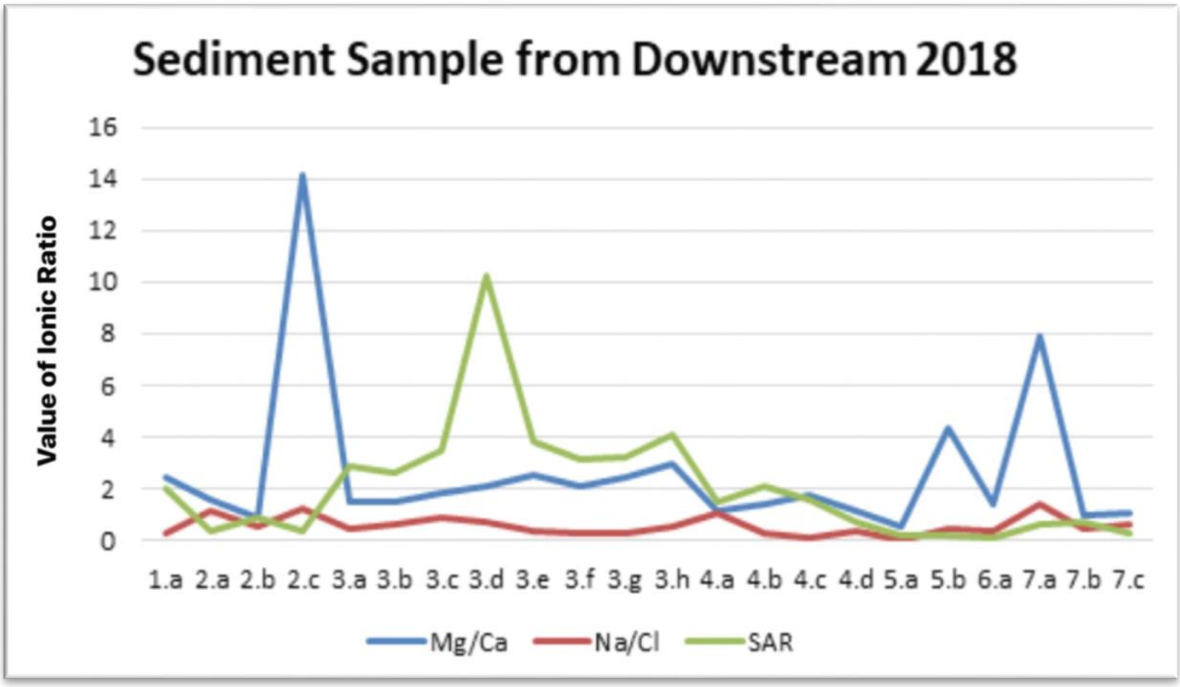

Figure 5.4: Ionic ratios (Mg/Ca, Na/Cl and SAR) of sediment 2018 in Wadi Al-Gar downstream

5.1.4 Total Organic Carbon and Total Nitrogen:

Total organic carbon 'TOC' and total nitrogen 'TN' contents are an important parameter for the environmental status estimation to distinguish marine and terrestrial sources of organic matter in soils and sediments. The sediments organic carbon and nitrogen are mainly derived by decomposition of the plants and animals or plankton or anthropogenic sources such as chemical contaminants, fertilizers or organic rich waste. The presence of the organic matter is an important constitute as it consists an index for the sediments depositional environments.

The TOC results of all samples are low while the TNb results are variable. The soil sample of upstream (Halhol 2) is low <2 as shown as figure (5.7)and the rest samples is medium fail in range (2-6). The sample (4.d, 3.d) 2017 as shown as figure (5.5) and sample 2.b, 7.a, 3.a) 2018 of Wadi Al-Maaza as shown as figure (5.6)is high >6 and the rest sample fail in medium to high range.

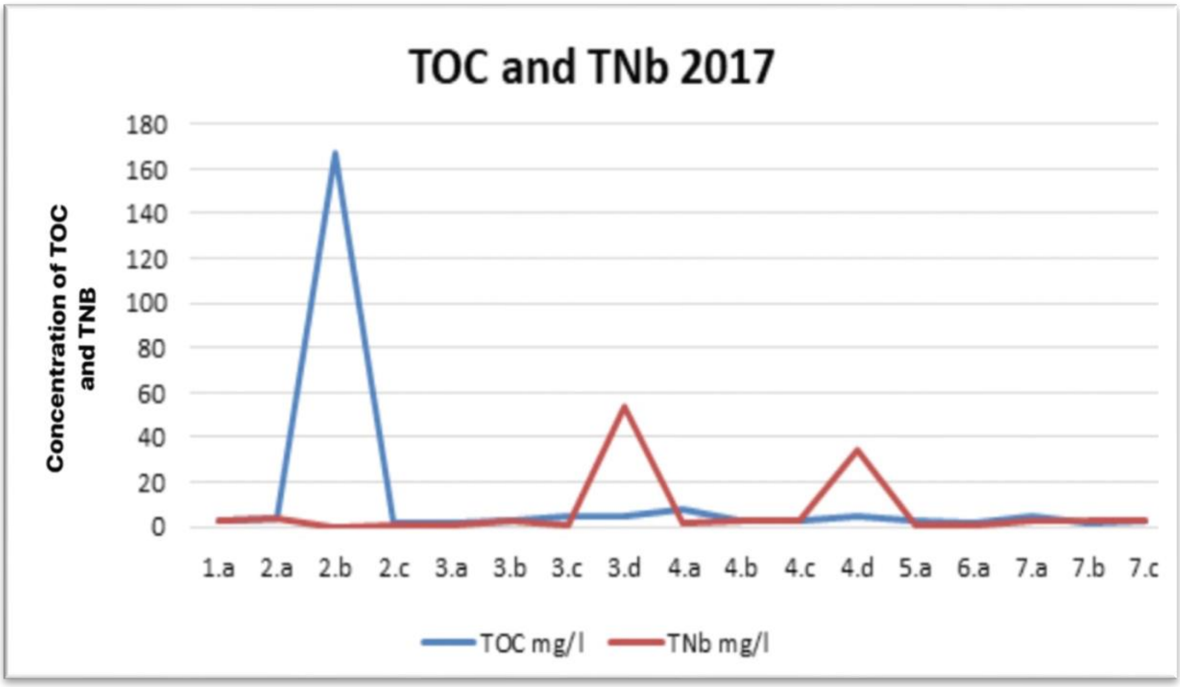

Figure (5.5): TOC and TNb of sediment 2017 in downstream of Wadi Al-Gar

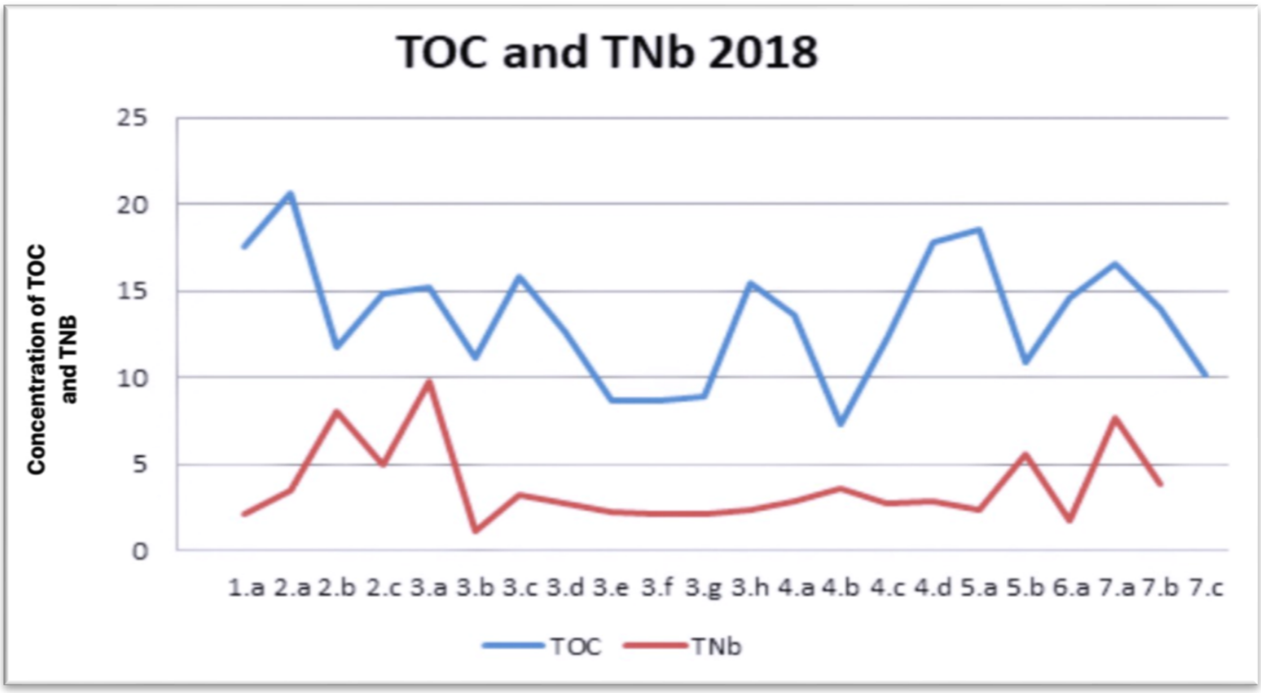

Figure (5.6): TOC and TNb of sediment 2018 in downstream of Wadi Al-Gar

*

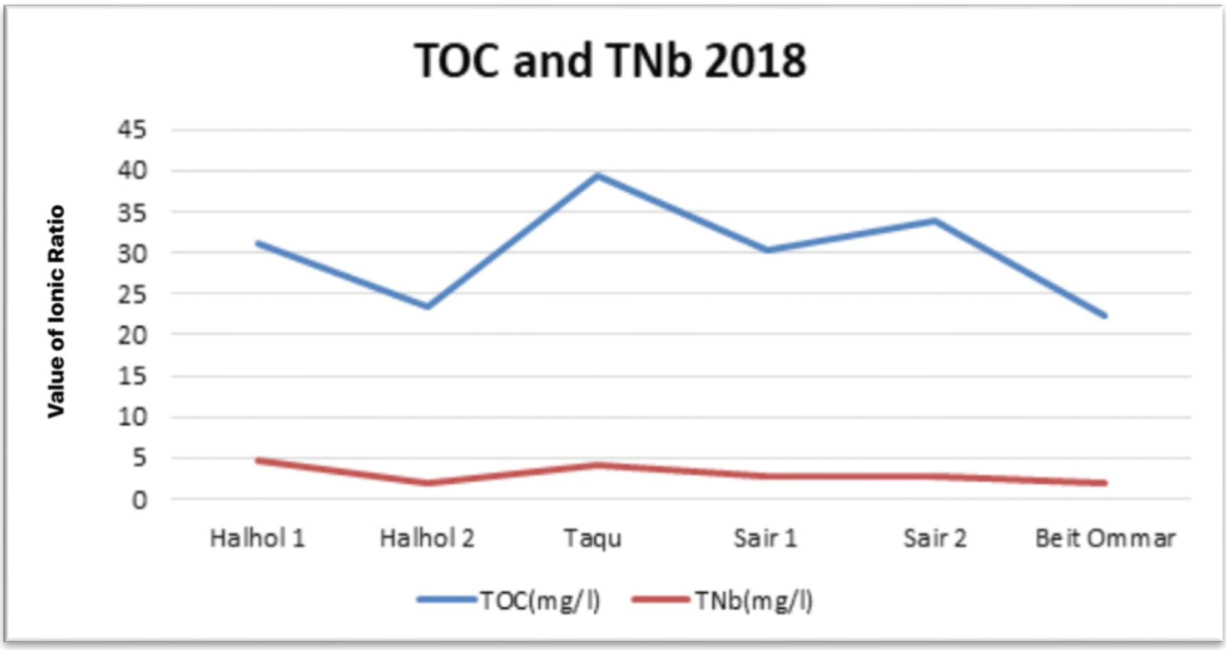

Figure (5.7): TOC and TNb of soil 2018 in upstream of Wadi Al-Gar

5.2 Slope:

Slope gradient as a major topography factor governing the amount of runoff and soil erosion.The soil loss increases exponentially with the slope steepness increasing as a result of the respective increase in the volume of surface runoff. The relationships between soil erosion and slope gradient different for different slope conditions, soil types, the condition of the land above the slope, and other factors (Ali et al. (2000)).

The study area locates over the eastern slope, where water flow direction is towards the east due to the acute difference in slope (0.02).changing from over 1000 m of altitude to - 400 m at its endpoint, the Dead Sea (calculated from the GIS database of AQU). Since the slop is steep it is natural that at some point there will be a natural discharge in form of springs in the Jordan Valley/Dead Sea areas. Wadi Al-Gar has very low to no vegetation cover where mainly natural small spine- bushes cover the slopes; the soil covering the area is very dry and can be eroded easily since the area has a very limited vegetation cover. Wadi Al-Gar has several gradients of slope, as shown as Figure (5.8) some areas have a slight slope and other has steepness. This has a strong effect on soil erosion and sediment transfer. The higher the slope of the area, the more susceptible of soil to erosion.

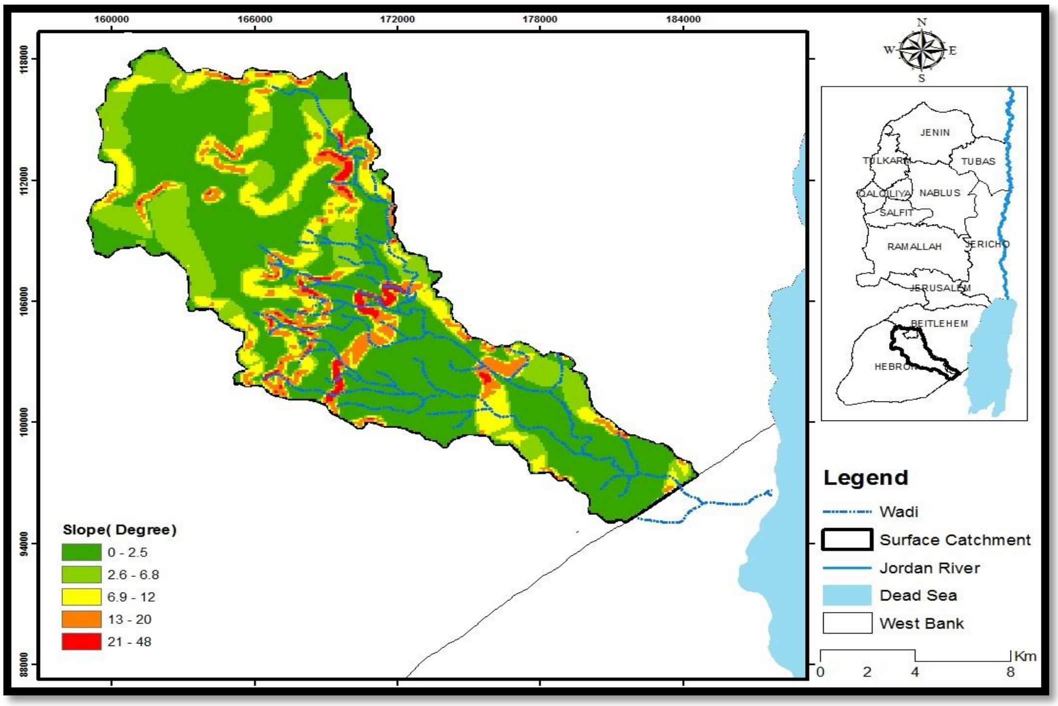

Figure (5.8): Slop of Wadi Al-Gar catchment area

5.3 Runoff:

The quantity of major ions (cations; Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} , and the anions; Cl^{-}, SO_4^{2-} , and HCO_3^{-}) in water depends primarily on the type of rocks or soil with which the water has been in contact and the length of time of contact. Irrigation drainage, Industrial effluents, septic tank, pesticide, fertilizers, and other sources that result from the anthropogenic activities are considered the additional sources of elements. Relative to the distribution of the highest concentration of major ions.

Table (5.4): Chemical properties of runoff sample (2018)

Flow Status	Time	pH	EC	Ca^{2+}	Mg^{2+}	Cl^{-}	HCO_3^{-}	Na^{+}	K^{+}	PO_4^{3-}	SO_4^{2-}	TOC	TNb
	pm		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Wadi al-mesyada													
Beginning of Stream	03:40	7.47	533.33	46.76	40.5	105.16	284.76	33.02	7.73	0.3	70	34.61	5
End of Stream	07:00	7.64	462.33	33.4	48.6	86.26	244.08	40.6	23.56	0.6	40	32.89	6.02
Wadi al-Ma'aza													
Beginning of Stream	03:20	7.51	523.33	58.78	46.17	98.07	305.1	37.35	12.3	1	30	31.97	6.64
Middle of stream	03:40	7.51	590.66	65.46	445.5	105.16	284.76	43.85	15.23	0.2	60	41.08	6.5
End of Stream	06:18	7.53	469.33	60.12	36.45	89.8	166.78	34.65	9.84	0.6	40	31.33	6.84
Middle of Stream	07:35	7.33	490.33	78.82	53.46	77.99	276.62	36.27	6.56	0.2	50	49.72	2.43
End of Stream	09:50	7.62	456.33	64.12	48.6	82.71	166.78	34.11	9.84	0.6	70	26.24	6.08

Table (5.4) shows the chemical properties of runoff which variation depending on the location and time of sampling (the samples taking in 26/04/2018). The EC in the beginning of stream of wadi Al-Mesyada was 533.33 µS/cm and Then decrease in the end of stream to 462.33 µS/cm The reason is the entry of un salinity water to the stream (the concentration of ions is low). In wadi Al-Maaza, was taken many samples from the beginning, middle and end of the stream Where the EC value at the beginning is 523.33 µS/cm, and then increase in the middle to 590.66 µS/cm due to enter one of the sources of ions, whether from irrigation water or From one of the sources of pollution such as Industrial effluents wastes or pesticide, then the value decreased at the end of the stream.

In another samples was taken from middle and end the EC in the middle higher than the end. The concentration of chloride at the beginning of stream of wadi AL-Mesyada higher than the end. Na^{+} and Cl^{-} as the main contributor to the salinity of surface water. Leaching from clay minerals and sediments is one of the sources of Na^{+} and Cl^{-}). Agricultural output (irrigation drains, pesticide, and fertilizer) and sewage effluent are other possible sources. The concentration of chloride at the beginning of the stream less than the middle, where the high concentration from one of the sources mentioned earlier. The concentration of Ca^{2+} at the beginning of stream of wadi Al-Masyada 46.76 mg/l then decrease to 33.4 mg/l. The Mg^{2+} concentration increased at the end of the stream. The concentration of Ca and Mg in wadi Al-Maaza sometimes increase and sometimes decrease. Ca^{2+} and Mg^{2+} concentrations indicate possible derivation from the dissolution of carbonate minerals. Leaching of Ca^{2+} and Mg^{2+} from clays of the Pleistocene sediments is the essential source of these ions. The highest concentration of Ca^{2+}, Mg^{2+} and is attributed to the effect of irrigation effluent, sewage water, pesticide, and fertilizers that used in irrigation. Can be considered as a source of Ca^{2+}, Mg^{2+}.

5.4 HEC-HMS:

5.4.1 Annual Rainwater:

The mean annual rainfall decreases from about 600 mm in the western part to less than 200 mm in the east, this decrease in precipitation is accompanied by an average maximum temperature increase from 26 to 32 C in August, and a minimum temperature in January (which is the coldest month) between 15 -12 C, respectively (Qannam, 2003).

Table 5.5: Rainfall data from October two April (2017-2018) from meteorological station.

Month(2017-2018)	AL-Arob (Precipitation mm)	Halhol (Precipitation mm)	Siar(Precipitation mm)
Oct	24	4.57	1.7
Nov	50.8	33.02	20.2
Dec	87	83.06	57.9
Jan	270.4	262.13	207.8
Feb	56.6	81.03	93.3
Mar	10.8	11.17	4.4
Apr	43.6	39.81	40.5
SUM	543.2	514.79	425.8

5.4.2 Surface Water modeling using HEC-HMS Program

These surface water modeling programs were used as mentioned in the methodology section, in order to assess the surface water contribution and the role of recharge excess to the Dead Sea. All the hydrological parameters were put to be fixed except the daily amount of rainfall for the years 2017/2018.

- The rainy season 2017/2018:

The rainy season 2017/2018 shows relatively normal rainwater with a total average of 494.59 mm. The calculated recharge volume over the study area of 132 km^2 is 30 Million Cubic Meter (MCM).

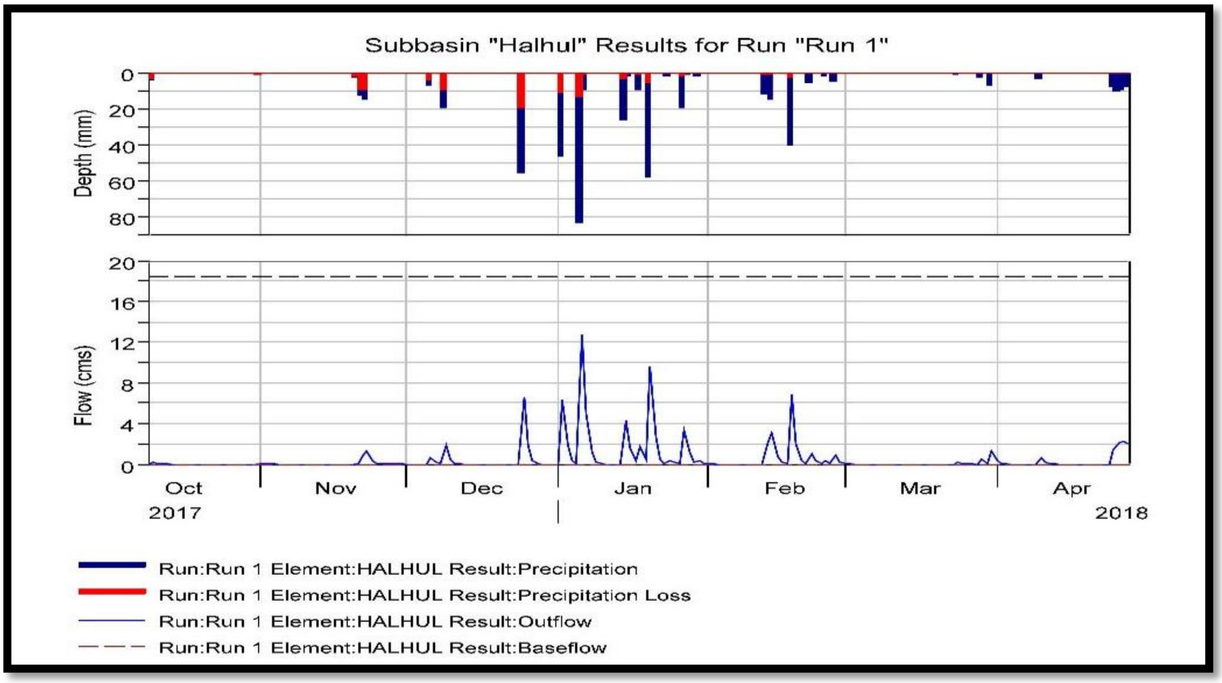

Figure (5.9): The modeled runoff in the Halhol sub-basin.

Figure (5.9) shows the modeled runoff in the first sub-basin of hahol. The discharge peak was 12.7 m^3/s in 5-jan -2018. This value was calibrated with the actual diver reading for the same date. The total precipitation at Halhol sub-basin for the year 2017/2018 was 10 MCM from which the model calculates the total loss as 2 MCM, where the total runoff from this sub-basin is around 8 MCM.

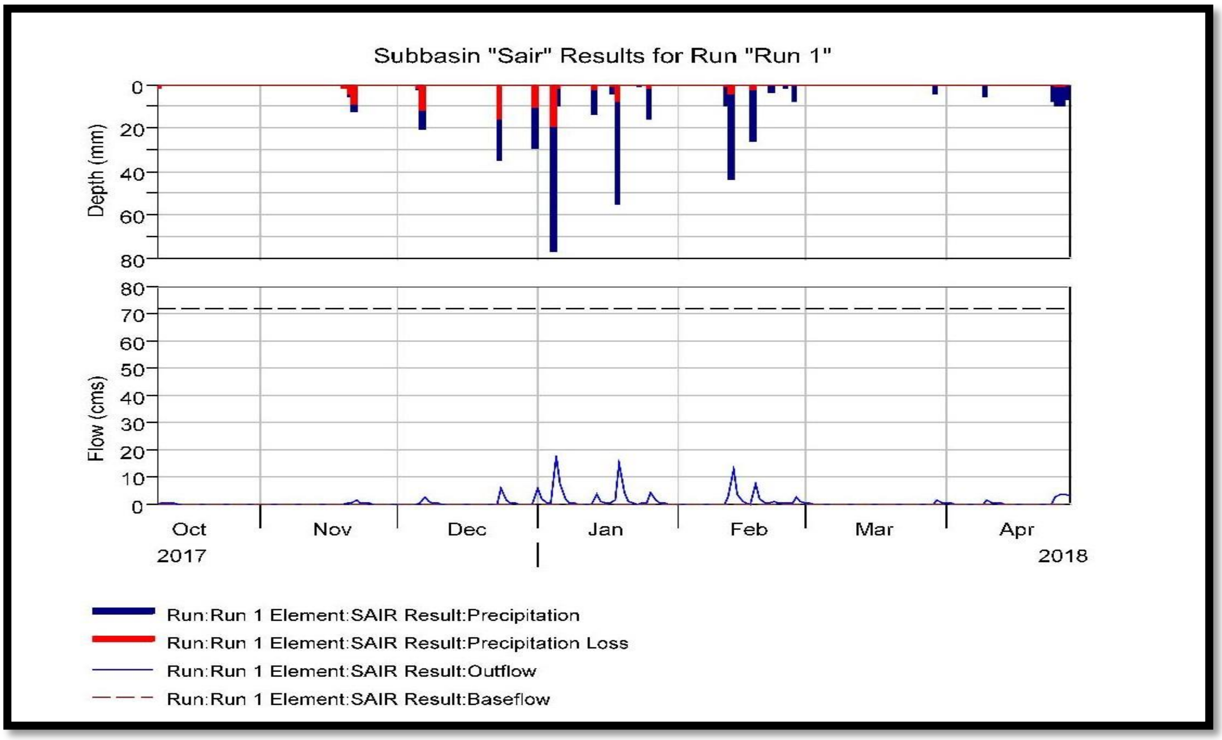

Figure (5.10): The modeled runoff in the Sair sub-basin.

Figure (5.10) shows the modeled runoff in the first sub-basin of sair. The discharge peak was 17.8 m^3/s in 5-jan-2018. This value was calibrated with the actual diver reading for the same date. The total precipitation at Sair sub-basin for the year 2017/2018 was 15 MCM from which the model calculates the total loss as 3.6 MCM, where the total runoff from this sub-basin is around 11.4 MCM.

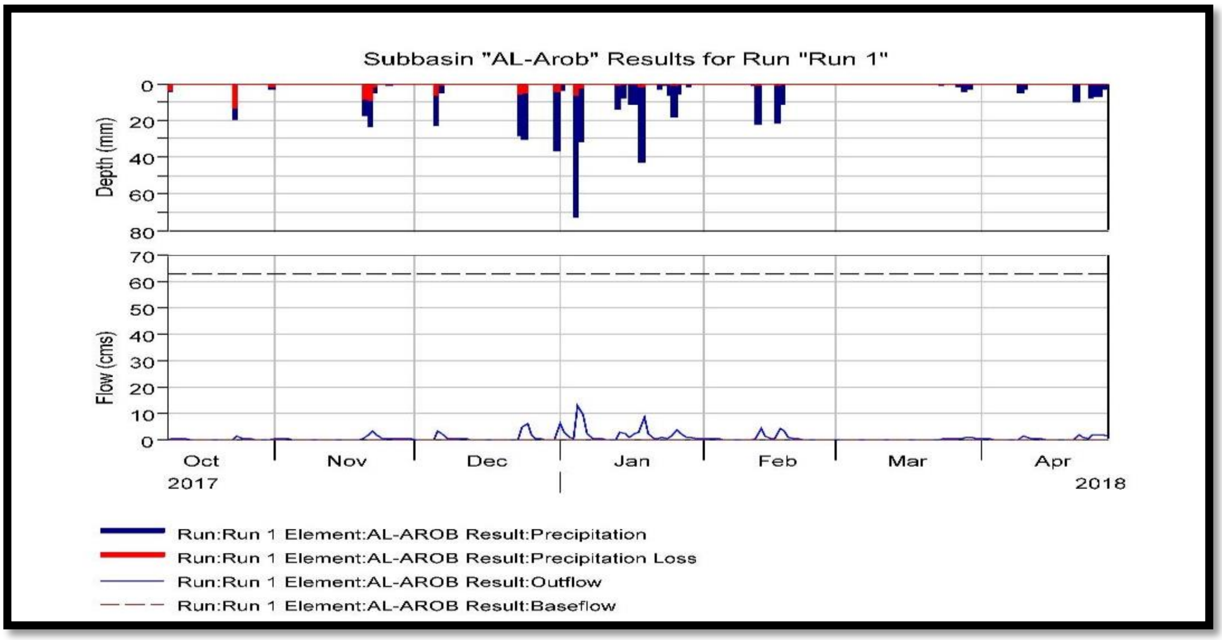

Figure (5.11): The modeled runoff in the Al-Arob sub-basin

Figure (5.11) shows the modeled runoff in the first sub-basin of al-arob. The discharge peak was 12.8 m^3/s in 5-jan-2018. This value was calibrated with the actual diver reading for the same date. The total precipitation at Al-Arob sub-basin for the year 2017/2018 was 12 MCM from which the model calculates the total loss as 2 MCM, where the total runoff from this sub-basin is around 10 MCM.

Table (5.6): The total runoff for the year 2017/2018 is the total sum of runoff from the 3 sub-basins.

Hydrologic Element	Drainage Area (KM^2)	Peak Discharge (M^3/S)	Volume (1000 M^3)
Sair	35.599	17.8	11278.8
AL-Arob	22.389	12.8	10289.5
Halhul	21.035	12.7	8480.1
Junction-1	79.023	30.6	30048.4

The total precipitation volume on the study area for the rainy season 2017/2018 was 37 MCM, and the total loss was 7 MCM.

The total runoff for the year 2017/2018 is the total sum of runoff from the 3 sub-basins that reach the Dead Sea at Junction-1which reach 30 MCM (Table 5.6).

In general for all of the 3 scenarios the total percentage of loss for the Al-Arob sub-basins was15% of the total amount of recharge, 20% for Halhol sub-basin, while it was 24% for the Sair sub-basin (Table 5.6). The amount of the surface water seepage for the three sub-basins could be high but in this case, the steep slope factor in the upper mountain help information more runoff rather than percolating of water to the ground.

- The rainy season 2010/2011:

The rainy season 2010/2011 shows relatively normal rainwater with a total average of 475 mm. The calculated recharge volume over the study area of 132 km2 is 21 Million Cubic Meter (MCM).

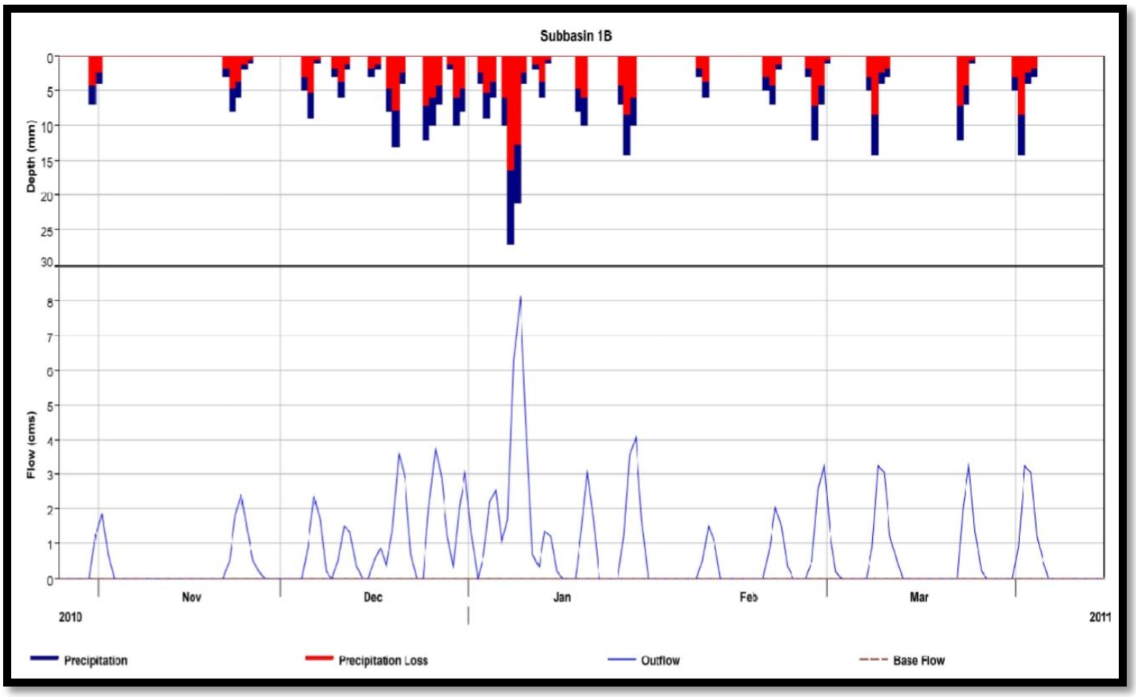

Figure (5.12): The modeled runoff in the sub-basin of 1B.

Figure (5.12) shows the modeled runoff in the first sub-basin of 1B. The discharge peak was 8 m3/s in 18 of January. This value was calibrated with the actual diver reading for the same date. The total precipitation at 1B sub-basin for the year 2010/2011 was 27 MCM, from which the model calculates the total loss as 16 MCM, where the total runoff from this sub-basin is around 11 MCM.

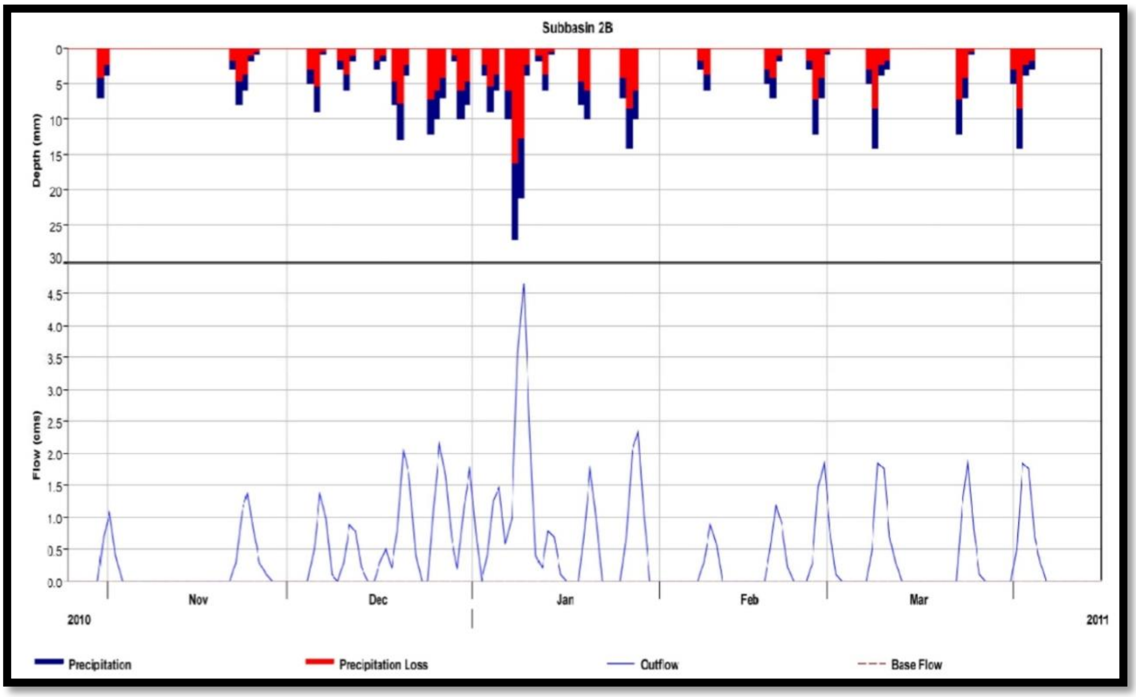

Figure (5.13): The modeled runoff in the sub-basin of 2B.

Figure (5.13) shows the modeled runoff in the sub-basin of 2B. The discharge peak was 4.7 m3/s in 18 of January. The total precipitation at 2B sub-basin for the year 2010/2011 was 15 MCM, from which the model calculates the total loss as 9 MCM, where the total runoff from this sub-basin is around 6 MCM.

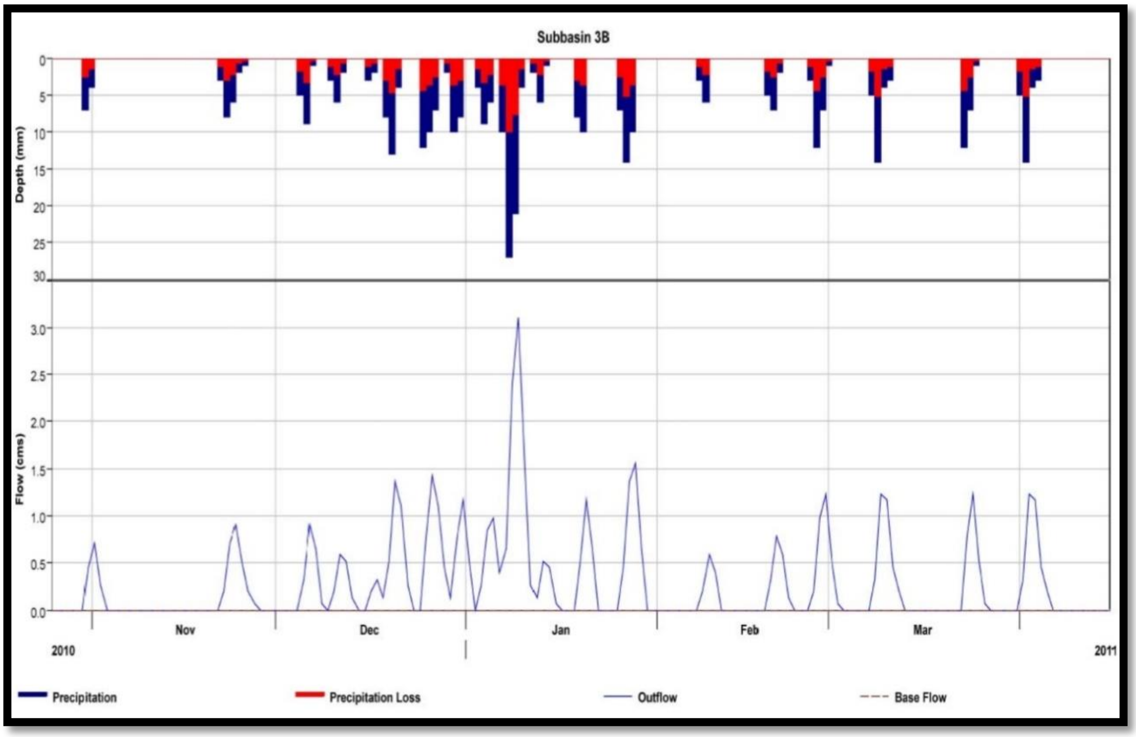

Figure (5.14): The runoff in the sub-basin of 3B.

Figure (5.14) shows the runoff in the sub-basin of 3B. The discharge peak was 3 m/s in 18 of January. The total precipitation at 3B sub-basin for the year 2010/2011 was only 6 MCM, from which the model calculates the total loss as 2 MCM, where the total runoff from this sub-basin is around 4 MCM.

Table (5.7): The total runoff for the year 2010/2011 is the total sum of runoff from the 3 sub-basins.

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Volume (1000 M3)
1B	73.1993	8.1	11506.9
2B	41.9490	4.7	6594.4
3B	17.7267	3.1	4389.0

The total precipitation volume on the study area for the rainy season 2010/2011 was 49.5 MCM, and the total loss was 28 MCM.

The total runoff for the year 2012/2011 is the total sum of runoff from the 3 sub-basins that reach the Dead Sea at point 9C which reach 22.5 MCM (Table 5.7).

5.5 Sedimentation rate:

The amount of sediment during 2017-2018 in Wadi Al-Mesyada is 4.637185 m^3 / 21568300 m^3 the amount of runoff and 1.7927 m^3 sediment and 8480100 m^3 runoff in Wadi Al-Maaza as shown as table (5.8)

Table (5.8): Total Runoff and Total sediment during the year 2017-2018 in Wadi Al-Mesyada and Wadi Al-Maaza

Location	sedimentation rate ml/h	Total Runoff m^3	Total sediment during 2017-2018 (sedimentation rate* Total Runoff)	Total sediment during 2017-2018(m^3)
Al-Mesyada	0.215	21568300	4637185	4.637185
Al-Maaza	0.2114	8480100	1792693	1.7927

Chapter Six:

6.1 Conclusion:

The year 2017 is considered to be drought, as there was no large surface runoff in Wadi Al-Ghar, so the amount of sediment was low compared to 2018. Where in 2018 new layers were discovered that did not exist in 2017 and each layer differs from the other for the same sample in its physical and chemical properties. Na/Cl ionic ratio of upstream and downstream 2017 samples of Wadi Al-Gar less than 0.7 indicate loss of Na through precipitation of evaporate salts. and variability ratios in downstream samples 2018, Where it exceeded one in some samples there are characteristic of groundwater flowing through crystalline and are dependent on the nature of the feldspars. Most of soil and sediment samples fail in the Mg/Ca ratio rang > 0.9 indicating the removal of Ca by precipitation of $CaCO_3$ and $CaSO_4$ .aragonite precipitation also is favored, whereas the Mg/Ca ratio rise due to dolomite dissolution.

The total precipitation volume on the study area for the rainy season 2017/2018 was 37 MCM, and the total loss was 7 MCM. The total runoff in Wadi Al-Gar during 2017-2018 is 30048400 m 3 ,where 21568300 m 3 in Wadi Al-Mesyada and 8480100 m 3 runoff in Wadi Al-Maaza.

The climatological factors of wadi al-gar affected runoff generation. Flash flood from single rainfall event exceeds runoff volume from a year.

6.2 Recommendation:

- In future studies, should be taken samples before and after each season at the upstream and downstream.

- added a larger number of basins to study runoff and compared with previous years

- added Parameters further and expanded to provide a deeper and more comprehensive explanation for the source of the sediment

- The HEC-HMS model should be calibrated and validated to be applicable for other catchments. Rainfall-runoff process in such arid and semi-arid environment could be investigated and understanding well.

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APPENDIX A:

Procedures:

pH: Among chemical indicators for soil quality, soil reaction (pH). This basic factor is known to influence nutrient availability and microbiological activity. These measurements were taken in the laboratory using a pH meter by method of extract for soil samples by mix 5 g of soil with 45 ml of distilled water in shaker for 1 hr (Ryan J et al., 1996).

Electrical Conductivity (EC): of the soil was measured by the extract method by mixing 5 g of soil with 45 distilled water and measuring by EC meter to measure the concentration of ions in the sample. It is generally used as an indicator of salinity (Ryan J et al., 1996).

Chloride (Cl^-): Measured chloride by titration sample preparation by extract method with 5 g and 45 distilled water, take 10 ml of the sample and add a few drops of $K2CrO_4$ also titrate with standard $AgNO_3$ titrate to the end point (color is pinkish yellow with stirring) (Ryan J et al., 1996).

Calculate it by Cl = (VT – VB) *NT*1000*35.45 / Vs

Bicarbonate (HCO_3^-): The procedure is applied to water samples to measure the sum of titratable bases measured HCO3 by titration through add 5 drops of mixed indicator and titrate with the same Cl standard until the indictor changes color from greenish blue to 0.1 N light brown (Eaton, A. D.; et al 1995).

HCO3 (mg/l) = (Vt * N *1000 * 61.02) / Vs

While Vs = volume of the sample used

N = Normality of the HCL nitrate used

(Potassium (K^+), Sodium (Na^+)): Transfer 5g soil (2mm soil) into a 250ml flask, add 50 ml distilled water using a graduated cylinder then shake about 1hr. Centrifuge for 10 min at 1000 rpm. Read K and Na concentration by a flame photometer (Eaton, A.D.; et al 1995).

Magnesium (Mg^+): Transfer 5g soil (2mm soil) into a 250ml flask, add 45 ml distilled water using a graduated cylinder then shake about 1hr, take 25 ml of the extract soil with 25 distilled water to and add a 1-2 drops of Erichrome Blake T to titrate it with 0.01 EDTA and shake continuously and keep titration slowly when reaching the end point at the color will change slowly from purple to blue.

Calculate it by: Mg mg/l = (A * N * 1000 * C) / B

Where:

A: volume of EDTA required for Mg titration

B: volume of sample

C: equivalent weight of Mg

N: normality of EDTA

Calcium (Ca^+): Transfer 5g soil (2mm soil) into a 250ml flask, add 45 ml distilled water using a graduated cylinder then shake about 1hr, take 25 ml of the extract soil with 25 distilled water and add a 2-3 drops of murexide as an indicator and titrate with 0.01 N of EDTA to change the color to purple.

Calculate it by:

Ca mg/l = (A * N of EDTA * 1000 *C) / B

Where:

A: volume of EDTA required for titration

B: volume of sample

C: equivalent weight of Ca

N: normality of the EDTA

Total organic carbon (TOC), Total Nitrogen Bound (TNb): Levels of total organic carbon and nitrogen reflect levels of total organic carbon. Total organic carbon and nitrogen measured by ratio TOC select device through dilution of the filter sample by 1:10 (manual of TOC device).

Soil texture: The concentration of aqueous HMP is increased to 3%, and shaking time reduced to 2 h. There is no collection of sand and POM of the 2.0- to 0.5-mm range, so only a 0.053-mm sieve is necessary to collect the sand fraction. A smaller original soil mass (15 g) can be used for the analysis, reducing the volume of liquid required to rinse the silt and clay particles through the sieve. This smaller volume of solution can be collected in a 600- or 800-mL beaker, and the sedimentation step carried out without sub sampling. The silt and clay solution is stirred thoroughly to suspend all particles, and then allowed to settle undisturbed at room temperature (18–24 °C) for a sedimentation period of at least 90 min but, 6 h. After the sedimentation period, the suspended clay fraction is decanted from the settled silt particles and discarded. The settled silt fraction is then dried in the beaker at 1058°C to constant weight the soil Sand% and Silt% are calculated based on their fraction of the original sample mass (T. A. Kettler, 2001).Calculate percent sand, silt clay from:

Sand (%) = (dry wt sand (g)/dry wt (g)) * 100%

Silt (%) = (dry wt silt (g)/dry wt (g)) *100%

The clay% is determined by calculating the difference of 100% minus the sum of the Sand% and Silt%

Clay (%) = 100% - (Sand (%) + Silt (%))

Appendix B: Results:

Sediment Sample 2018	pH	EC µS/cm	SO_4 (meq/l)	PO_4 (meq/l)	Na (meq/l)	K (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	Mg (meq/l)	Ca (meq/l)
Wadi Al-Maaza										
1	8.12	2940.00	40.00	0.00	6.32	0.01	2.00	27.49	13.67	5.68
2. a	8.85	106.30	10.00	0.00	0.57	0.03	2.40	0.50	2.78	1.77
2. b	8.59	308.67	7.00	0.00	1.15	0.05	2.27	2.33	1.67	1.87
2. c	8.52	191.37	10.00	0.00	1.02	0.03	3.00	0.83	14.18	1.00
3. a	8.45	1818.67	70.00	0.00	5.88	0.07	7.67	13.83	5.06	3.41
3. b	8.52	3813.33	720.00	0.00	8.37	0.06	2.80	14.61	12.66	8.52
3. c	8.71	1808.67	270.00	0.01	5.97	0.08	3.33	6.83	3.80	2.04
3. d	8.20	4186.67	80.00	0.00	24.51	0.15	2.00	35.30	7.76	3.67
3. e	8.68	2346.67	70.00	0.00	7.27	0.06	1.87	18.90	5.06	2.04
3.f	8.35	4026.67	80.00	0.01	8.45	0.07	2.00	35.30	10.13	4.91
3.g	8.31	5013.33	69.00	0.02	9.55	0.10	2.87	42.56	12.40	5.01
3.h	9.04	1304.33	70.00	0.00	5.42	0.04	2.00	10.33	2.63	0.90
4.a	8.23	902.67	180.00	0.00	2.90	0.06	1.93	2.73	3.80	3.47
4.b	8.05	3620.00	140.00	0.00	7.14	0.04	2.00	31.00	13.57	9.85
4.c	7.81	8516.67	50.00	0.00	9.26	0.05	2.00	79.79	43.03	25.12
4.d	8.05	592.00	19.00	0.00	1.35	0.12	2.30	4.20	4.05	3.54
Wadi Al-Mesyada										
5.a	8.81	110.27	9.00	0.00	0.25	0.06	4.60	7.47	1.62	3.01
5.b	8.54	202.53	16.00	0.00	0.37	0.06	3.67	0.80	5.06	1.17
6	8.65	99.20	3.00	0.00	0.19	0.06	3.20	0.53	11.14	8.18
7. a	8.47	416.33	35.00	0.00	1.68	0.04	3.33	1.19	12.66	1.60
7. b	8.69	190.70	16.00	0.00	0.70	0.06	2.73	1.53	1.11	1.14
7.c	8.56	141.80	13.00	0.00	0.33	0.09	4.13	0.53	2.03	2.00

Soil Sample	Mg(meq/l)	Ca(meq/l)	Na(meq/l)	K(meq/l)	HCO3(meq/l)	Cl-(meq/l)	PO4(meq/l)	**EC µS/cm**	**pH**
Halhol	11.1375	0.58116	0.52253	0.527742	1.500491803	0.54995346	0.02243	284	7.3
Halhol	11.1375	0.8016	0.222007	0.118267	2.000655738	0.69494119	0.00095	106.7	8.46
Taqu	15.1875	1.1022	0.205763	0.177982	4.401442623	0.624947113	0.00963	124.9	8.46
Sair	10.125	0.8517	0.211178	0.183411	2.500819672	0.574951344	0.01785	118.6	8.48
Sair	11.1375	0.6513	0.159737	0.200084	2.200721311	0.49995769	0.00096	103.7	8.57
Beit Ommar	10.3275	0.501	0.240959	0.116328	2.100688525	0.5499536	0.00134	109.3	8.37

Sample name 2017	Mg/Ca	Na/Cl	Mg/(Ca+Mg)	Ca/Mg	(Cl-Na)/Cl	Na/(Ca+Mg)
1.a	2.21	0.08	0.69	0.45	0.92	0.14
2.a	1.94	0.03	0.66	0.52	0.97	0.02
2.b	2.	0.04	0.67	0.5	0.96	0.02
2.c	3.33	0.02	0.77	0.3	0.98	0.01
3.a	1.	0.01	0.5	1	0.99	0.03
3.b	2.71	0.	0.73	0.37	1.	0.01
3.c	2.19	0.	0.69	0.46	1.	0.02
3.d	2.38	0.09	0.7	0.42	0.91	0.04
4.a	2.	0.03	0.67	0.5	0.97	0.02
4.b	19.15	0.	0.95	0.05	1.	0
4.c	20.	0.	0.95	0.05	1.	0
4.d	0.18	0.	0.15	5.59	1.	0.01
5.a	2.43	0.02	0.71	0.41	0.98	0.01
6.a	2.46	0.02	0.71	0.41	0.98	0.02
7.a	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
7.b	2.	0.02	0.67	0.5	0.98	0.01
7.c	2.67	0.04	0.73	0.38	0.96	0.03

Soil Sample	Mg/Ca	Na/Cl	Na/(Ca+Mg)	Mg/(Ca+Mg)	Ca/Mg	Na/√(Ca+Mg/2)
Halhol (1)	1.85	0.51	0.33	0.65	0.54	0.19
Halhol(2)	1.39	0.21	0.13	0.58	0.72	0.08
Taqu	1.38	0.14	0.06	0.58	0.73	0.04
Sair(1)	1.2	0.18	0.12	0.55	0.83	0.07
Sair(2)	1.74	0.15	0.08	0.63	0.58	0.05
Beit Ommar	2.06	0.19	0.14	0.67	0.49	0.08

Sample name 2017	Na+K-Cl	Na/Wurzel((Ca+Mg)/2)	Na/(Ca+Mg)	(Mg/(Ca+Mg))*100	(Na+K-Cl)/(Na+K-Cl+Ca)	HCO3/Cl
1.a	-4.64	0.34	0.14	0.69	1.26	0.42
2.a	-1.06	0.04	0.02	0.66	2.15	3.19
2.b	-1.12	0.05	0.02	0.67	2.88	1.63
2.c	-0.79	0.02	0.01	0.77	1.61	2.81
3.a	-5.5	0.07	0.03	0.5	1.28	0.44
3.b	-24.54	0.03	0.01	0.73	1.02	0.11
3.c	-21.45	0.05	0.02	0.69	1.06	0.09
3.d	-0.56	0.08	0.04	0.7	4.48	146.34
4.a	-1.98	0.04	0.02	0.67	2.66	1.53
4.b	-175.82	0.01	0	0.95	1.02	0.02
4.c	-37.9	0.01	0	0.95	1.03	0.09
4.d	-19.78	0.05	0.01	0.15	1.58	0.1
5.a	-0.76	0.02	0.01	0.71	2.57	3.92
6.a	-1.89	0.04	0.02	0.71	1.3	1.7
7.a	0.07	#DIV/0!	#DIV/0!	#DIV/0!	1	#DIV/0!
7.b	-0.89	0.02	0.01	0.67	2.09	2.94
7.c	-0.91	0.05	0.03	0.73	1.78	1.67

Soil sample	Na+K-Cl	Na/(Ca+Mg)	(Mg/(Ca+Mg))*100	HCO3/Cl	(Na+K -Cl)/(Na+K-Cl+Ca)	(Cl-Na)/Cl
Halhol (1)	0.54	0.33	64.95	2.73	0.47	-0.02
Halhol(2)	-0.23	0.13	58.15	3.33	-0.4	0.58
Taqu	-0.26	0.06	57.95	6.67	-0.31	0.73
Sair(1)	-0.2	0.12	54.61	3.33	-0.31	0.63
Sair(2)	-0.15	0.08	63.46	4	-0.32	0.71
Beit Ommar	-0.16	0.14	67.33	3.89	-0.47	0.62

Sediment Sample 2018	Na+K-Cl	Na/(Ca+Mg)	(Mg/(Ca+Mg))*100	HCO3/Cl	(Na+K-Cl)/(Na+K-Cl+Ca)	(Cl-Na)/Cl
1.a	-21.15	0.32	70.65	0.07	1.36	0.77
2.a	0.10	0.12	61.13	4.80	0.05	-0.13
2.b	-1.13	0.32	47.17	0.97	-1.64	0.50
2.c	0.22	0.06	93.39	3.60	0.18	-0.22
3.a	-7.88	0.69	59.77	0.55	1.73	0.57
3.b	-6.18	0.39	59.77	0.19	-2.71	0.42
3.c	-0.78	1.02	65.07	0.48	-0.66	0.12
3.d	-10.64	2.14	67.87	0.05	1.49	0.30
3.e	-11.57	1.02	71.30	0.09	1.20	0.61
3.f	-26.77	0.56	67.34	0.05	1.22	0.76
3.g	-32.92	0.54	71.22	0.06	1.17	0.77
3.h	-4.87	1.53	74.48	0.19	1.21	0.47
4.a	0.22	0.39	52.22	0.70	0.06	-0.06
4.b	-23.82	0.30	57.93	0.06	1.70	0.76
4.c	-70.47	0.13	63.14	0.02	1.55	0.88
4.d	-2.73	0.17	53.35	0.54	-3.96	0.67
5.a	-7.16	0.05	35.01	0.61	1.70	0.96
5.b	-0.37	0.05	81.24	4.58	-0.50	0.53
6.a	-0.28	0.01	57.64	6.00	-0.03	0.64

7.a	0.53	0.11	88.75	2.79	0.25	-0.40
7.b	-0.76	0.31	49.51	1.78	-2.48	0.54
7.c	-0.11	0.08	50.26	7.75	-0.06	0.38

No.of Sample 2017	Mg (meq/l)	Ca (meq/l)	Cl (meq/l)	HCO3 (meq/L)	Na (meq/l)	K (meq\L)	**pH**	**EC (µS/cm)**
Wadi Al-Maaza								
1	2.13	0.97	5.56	2.34	0.42	0.5	7.83	709
2.a	1.1	0.57	1.13	3.6	0.03	0.04	8.14	198.7
2. b	1.47	0.73	1.23	2	0.05	0.06	8.29	260
2. c	1	0.3	0.83	2.34	0.02	0.02	8.16	147.5
3. a	1.2	1.2	5.66	2.47	0.07	0.09	8.9	1752
3. b	1.27	0.47	24.59	2.8	0.02	0.03	8.58	2187
3. c	2.63	1.2	21.59	2	0.07	0.08	7.89	2058
3. d	1.03	0.43	0.7	102.41	0.07	0.08	8.15	134.1
4. a	2.47	1.23	2.1	3.2	0.06	0.07	8.03	311
4. b	60	3.13	175.95	2.74	0.06	0.07	7.32	9420
4. c	22	1.1	37.99	3.27	0.04	0.05	7.6	3990
4. d	1.3	7.27	19.99	1.99	0.1	0.12	7.52	2042
Wadi Al-Mesyada								
5	1.13	0.47	0.8	3.14	0.02	0.02	8.07	116.9
6	1.07	0.43	1.96	3.34	0.03	0.04	7.8	229
7. a	0	0	0	3.54	0.03	0.04	8.46	
7. b	0.93	0.47	0.93	2.74	0.02	0.02	8.35	166.8
7.c	1.07	0.4	1	1.67	0.04	0.05	8.26	126.1

Sediment Sample 2018	Mg/Ca	Na/Cl	Na/(Ca+Mg)	Mg/(Ca+Mg)	Ca/Mg	Na/√((Ca+Mg)/2)
1.a	2.40	0.22	0.32	0.70	0.41	2.03
2.a	1.57	1.13	0.12	0.61	0.63	0.37
2.b	0.89	0.49	0.32	0.47	1.11	0.86
2.c	14.14	1.22	0.06	0.93	0.07	0.36
3.a	1.48	0.42	0.69	0.59	0.67	2.85
3.b	1.48	0.57	0.39	0.59	0.67	2.57
3.c	1.86	0.87	1.02	0.65	0.53	3.49
3.d	2.11	0.69	2.14	0.67	0.47	10.24
3.e	2.48	0.38	1.02	0.71	0.40	3.85
3.f	2.06	0.23	0.56	0.67	0.48	3.08
3.g	2.47	0.22	0.54	0.71	0.40	3.23
3.h	2.91	0.52	1.53	0.74	0.34	4.07
4.a	1.09	1.06	0.39	0.52	0.91	1.51
4.b	1.37	0.23	0.30	0.57	0.72	2.08
4.c	1.71	0.11	0.13	0.63	0.58	1.58
4.d	1.14	0.32	0.17	0.53	0.87	0.69
5.a	0.53	0.03	0.05	0.35	1.85	0.16
5.b	4.33	0.46	0.05	0.81	0.23	0.20
6.a	1.36	0.35	0.01	0.57	0.73	0.06
7.a	7.89	1.40	0.11	0.88	0.12	0.62
7.b	0.98	0.45	0.31	0.49	1.01	0.66
7.c	1.01	0.61	0.08	0.50	0.98	0.23

APPENDIX C: Precipitation Results

Date	Beit Ommar Precipitation [mm]	Halhol Precipitation [mm]	Siar Precipitation [mm]
9/10/2017	4.2	4.57	1.7
24/10/2017	19.8	***	0
1/11/2017	2.8	1.02	***
20/11/2017	0.4	***	2
21/11/2017	17.6	2.54	5.7
22/11/2017	23.6	12.95	12.5
23/11/207	5	15.24	***
26/11/2019	1	0.76	***
27/11/2017	0.4	0.51	***
6/12/2017	23.2	7.37	2.6
7/12/2017	4.8	***	20.7
9/12/2017	0.2	19.56	***
24/12/2017	28.2	***	34.6
25/12/2017	30.6	56.13	***
1/1/2018	36.4	***	29.2
2/1/2018	4	46.23	***
5/1/2018	73	***	77
6/1/2018	31.8	83.82	10
7/1/2018	0.4	9.4	***
14/1/2018	14.2	***	14
15/1/2018	7.6	26.67	***
16/1/2018	0.4	2.03	0.6

17/1/2018	11.6	***	0.6
18/1/2017	11	9.91	4.2
19/1/2018	42.8	***	55
20/1/2018	0.2	57.91	***
23/1/2018	2.8	***	***
24/1/2018	1.2	2.29	1.2
25/1/2018	6.2	0.76	***
26/1/2018	18	***	16
27/1/2018	5.8	19.81	***
28/1/2018	0.4	1.27	***
29/1/2018	2	***	***
30/1/2018	0.2	2.03	***
31/1/2018	0.4	***	***
1/2/2018	0.4	***	***
12/2/2018	1.2	***	9.6
13/2/2018	22.2	12.19	44
14/2/2018	***	14.73	***
17/2/2018	21.2	***	***
18/2/2018	11.6	40.39	26.4
22/2/2018	***	6.1	3.7
25/2/2018	***	2.29	1.5
27/2/2018	***	5.33	8.1
24/3/2018	1	1.27	***
28/3/2018	1.6	***	***
29/3/2018	4.6	2.79	***

30/3/2018	3.4	***	4.4
31/3/2018	0.2	7.11	***
10/4/2018	5.2	3.81	5.7
11/4/2018	2.8	***	***
22/4/2018	10	***	***
25/4/2018	7.6	8.1	8.1
26/4/2018	7.4	10.1	9.8
27/4/2018	7.4	9.7	9.8
28/4/2018	3.2	8.1	7.1
Total	543.2	514.79	425.8