PLANNING LANDUSE AROUND SELECTED WASTEWATER TREATMENT PLANT USING REMOTE SENSING AND GIS.

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Committee Decision

This thesis **(Planning Land Use Around Selected Wastewater Treatment Plant Using Remote Sensing and GIS)** was successfully defended and approved on 4th of August 2008.

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تعتمد كلية الدراسات العليا
هذه النسخة من الرسالة
التوقيع .... التاريخ ....

Dedication

This research is dedicated to:

The memory of my mother.

My husband Tareq for his love, patience and his continuous support

My daughter Salma.

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I would like to express my deepest thanks to my advisor Dr. Jawad Al-Bakri for his guidance, continuous support, and encouragement throughout the research.

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ABSTRACT

This study was carried out to evaluate and assess land use around two wastewater treatment plants (As-Samra and Jerash) using both remote sensing data coupled with GIS. The main objective was to identify the most suitable areas for alfalfa production around both wastewater treatment plants, based on parameters, such as water quality, crop, soil salinity, and crop water requirements.

Satellite imageries were visually interpreted, verified in the field to analyze existing land use, and to plan a sampling scheme. Soil samples were randomly taken along the study area at two different soil depths (0-20cm and 20-40cm) after the growing season. Samples were brought to the laboratory for both chemical and physical analysis. Chemical analysis was carried out to measure the concentration of macro nutrient (N, P, and K), EC and pH. Physical analysis included soil texture, while other physical properties were predicted using USDA hydraulic property model. Results obtained from laboratory analysis were interpolated using Inverse Distance Weighted (IDW) to map different soil properties.

Obtained data indicated that enrichment of nutrient resulted from the reuse of treated wastewater around the two wastewater treatment plants, especially, in the area near As-Samra. Comparing those results with the alfalfa requirements, treated wastewater was satisfying the need of alfalfa crop and it could reduce applied fertilizers. In the other

hand, assessment of water quality was carried out using long term monthly averages of wastewater treatment plants based on properties of water such as BOD_5, COD, TDS and pH. While soil suitability for alfalfa was based on average soil salinity.

Cross tabulation analysis between existing land use and soil suitability maps indicated that 23% of the area with mixed agricultural was highly suitable for alfalfa. Rainfed arable and forage compromises 33% of moderately suitable area and 33% of marginally suitable areas. The possibility of replacing other crop with alfalfa was possible for 33 % of area. Most of the non-cultivated areas where pumping of water was needed were not suitable for forage cultivation.

Although, the most suitable area for alfalfa was higher along direction close to Jerash and few locations around As-Samra, cropping pattern was against soil potential and so the research recommends a shift program toward alfalfa cultivation and this can be done according to the resulted maps from the study. Finally, the study clearly showed the usefulness of the preliminary approach in identifying the most suitable areas and crop water requirements for alfalfa production around selected wastewater treatment plants.

1. INTRODUCTION

In arid and semi-arid countries where water is becoming an increasingly scarce resource for agriculture and industrial development, resources planners are forced to take into consideration treated wastewater as a choice in their water management strategies. This source of water might increase pollution of other water sources and soil. However, reuse of reclaimed wastewater if properly managed not only alleviate pollution of water resources and sensitive receiving surface bodies, but also allows the release of fresh water to higher value uses and can largely reduce the water shortage problem and take the advantage of the nutrients contained in treated wastewater to growing crops.

In most countries of the eastern Mediterranean region, including Jordan, there is an increasingly and an urgent need to conserve and protect water resources (Al-Hennawi, 2004). Consequently, the reuse of wastewater for agriculture is highly encouraged (Al-Salem, 1996). Jordanian standards permitted the use of treated wastewater in irrigating fruit trees, field crops, cooked vegetables, cut flowers and trees on sides of roads (MTI, 2006). However, the ultimate use depends on quality of the treated wastewater. Alternative to irrigating vegetable crops and fruit trees the treated wastewater can be used for forage to support livestock production in Jordan were the contribution of rangelands and agricultural by- products to the feeding calendar of small ruminants does not exceed 35% (Abu-Zanat, 2002; Abu-Zanat and Tabbaa, 2004).

Proper solutions to overcome the shortage in forage production, is the reuse of treated wastewater. Preliminary results of different research done in Jordan using different wastewater treatment plants (Mohsen, 1987; Kattari and Jamjoom, 1988;

Mahasneh et al., 1989; Fardous and Jamjoom, 1996) were promising, and showed that about 50% of imported barely and an equal quantity of alfalfa can be produced by reuse of treated wastewater. Given that the value of imported forages in Jordan for the year 2000 was 216 million JD.

Since the early 1980s, Jordan has worked to manage irrigation with trated wastewater by either discharging it to the environment where it mixes with freshwater or indirectly reused downstream along the wadis, or to irrigate restricted crops such as cereal, fodder, forest trees and fruits. Official records of Ministry of Water and Irrigation (MWI, 2001) showed that more than 100 thousand donums are irrigated with treated wastewater effluent of the existing treatment plants. Most of the irrigated areas are cultivated with olive trees and illegal plantation of vegetables. The largest areas of olive trees and irrigated forest are close to As Samra and Aqaba. Less than 10% of the onside cultivation in As-Samra is forage.

Long term use of excess treated wastewater for irrigation than plant use, the more water that will percolate below the root zone, carrying with it a portion of accumulated salts in the surface layer of the soil. Consequently, soil salinity will cause physical problems; limiting infiltration, soil chemistry; problems limiting nutrient uptake, and reduces plant ability to absorb water. The only practical way to reduce soil salinity is through leaching.

In Jordan, managing and operating the reuse of treated wastewater seem to be less efficient either in the term of ultimate end of the reuse process, cost of discharge to the nearest farms, crop type and pattern, and water quality and quantity needed by the crop

(Duqqah, 2000). So, agricultural reuse of wastewater has to be integrated into a comprehensive land and water management plans (Bahri, 1999). Issues; such as, the effect of using treated wastewater on soil, accumulation of heavy metals in forage tissues, animals and the overall effect on human health should be studied before any recommendation concerning the use of treated wastewater in forage production. Therefore, this study aims to evaluate and assess land use between As-samra and Jerash wastewater treatment plants using soil, water and climatic data. The specific objectives of this study are:

- To identify the most suitable areas around the selected plants, for irrigating forage crops.
- To map, analyze and evaluate suitability of the area for alfalfa using interpolated soil properties.

2. LITERATURE REVIEW

2.1. Reuse of treated wastewater

The benefits of promoting wastewater reuses as a mean of supplementary water resources had been early recognized in the U.S.A and by the European Union (Asano, 1998).The indication for utilization of treated wastewater for agricultural irrigation extended back to ca.3000-1100 B.C (Angelakis et al., 1996 as quoted by Konstantinos et al. 2001).

New projects for reclamation and reuse of treated wastewater were reported almost every year in countries all over the world (Friedler, 2001), including Middle East and Mediterranean countries (Mills et al., 1992; Salgot et al., 1996; Angelakis et al., 1999; Bahri, 1999; Bonomo et al., 1999; Faby et al., 1999).

Several studies and research indicated the usefulness of treated wastewater reuse for crop production by reducing the requirement of commercial fertilizers and improving nutrient balance of the soil (Fitzpatrick et al.,1986; Hayes et al.,1990; Abderrahman et al., 1991; Pescod, 1992; Hussain and Saati., 1999; Duqqah, 2000; Boom, 2000; Angelakis et al., 2001; Meli et al., 2002; Ramirez et al., 2002; Al-Lahham et al., 2003; Gori et al., 2004).

Al Salem, (1992) reported that it was possible to get rid of 90% of the phosphate and of 85% of organic substances and suspended matter in effluent by using treated wastewater on the adjacent outlets of the treatment plants for farm irrigation. Vallentin, (2005) calculated the average content of macro nutrient in south Jordan valley in the season 2003/2004 and found that farmers can get of 1.356 ton of N in the form of nitrate and ammonium, 202 ton of P and 1.938 ton of K.

Ramirez et al.(2002) reported that wastewater contained large concentration of valuable nutrients, such as NH_4, total P and K which will increase not only crop production, but also the root development and amount of residues left in the field.

On the other hand, the use of treated wastewater for forage production is commonly accepted as a worldwide practice. Day et al. (1974) indicated that wheat plant irrigated with municipal wastewater had higher hay yield, clums diameter and total fiber content than in plants irrigated with fresh water.

2.2 Effects of treated wastewater reuse on crop yield in Jordan

Several studies and research in Jordan indicated the potential use of treated wastewater for forage crops (Jamjoum and Khattari 1986), reported that stalk yield of corn plants was significantly higher in plants treated with wastewater by sprinkler irrigation than regular water. Mohsen (1987) conducted a field experiment to study the effect of treated wastewater on corn yield and some soil physical properties using treated wastewater from Queen Alia airport treatment plant. Results indicated that corn yield components were slightly increased for two years compared to those irrigated by fresh water.

Experiment conducted at Ramtha wastewater treatment plant, on maize (*Zea mays*) and vetch (*Vicia sativa*), indicated that secondary treated wastewater could be a source of plant nutrients and can be reused for irrigation to increase forage crop production. (Mohammad and Mohammad 2004),

2.3 Impacts of treated wastewater reuse on soil

Reuse of treated wastewater can create real or perceived problems including nutrient and sodium concentrations, accumulation of heavy metals, and the presence of contaminants and human and animal pathogens (Toze, 2006; Duqqah, 2000). They concluded that soil salinity should be checked regularly regardless of the irrigation method.

2.4 Use of remote sensing and GIS in planning the use of treated wastewater.

The use of tools such as remote sensing and GIS can contribute to planning the reuse of treated wastewater, the classification of the study area into different land use/cover types is one of the primary objectives of studies that use remote sensing technology (Silva and Blanco, 2003). Remote sensing can be used as a tool to gather data for the use in geographic information systems (GIS), which are very useful for processing and manipulating spatial database. On the other hand, GIS can facilitate the storing and processing of the geo-referenced data derived from remotely sensed images for studying land use (Lillesand and Kiefer, 2000).

Both of GIS and remote sensing could be used for site selection of areas such as: service facilities, recreational activities, retail outlets, hazardous waste disposal sites and critical areas for specific resources management and control practices (Jankowski, 1995). A comprehensive review on remote sensing applications for agricultural water management was presented by several researches (Choudhury et al., 1994; Vidal et al., 1995; Rango et al., 1998; Stewart et al., 1999).

Several studies in Jordan (e.g. Findlay and Maani, 1999; Millington et al., 1999 ; Al-Bakri et al., 2001; Al-Tamimi, 2005; Al-Tamimi and Al-Bakri, 2005;) indicated the potential of remote sensing and GIS in providing and analyzing land use/cover using different algorithms and procedures.

Nagarajan et al. (2002) have reported that synergistic use of orbital satellite images along with ground based information of land use, slope and drainage networks could be integrated for identifying the potential areas for cultivation. The study indicated that temporal satellite images could be effectively used in rapid performance assessment of water resources projects for decision making.

2.5 Treated wastewater in Jordan

Due to an increase of water demand in Jordan around 70% of the total water demand is used for irrigation (MWI, 2004), treated wastewater became an important source of irrigational purposes. The quality of the treated wastewater is of vital importance as it becomes in contact with the food chain. Therefore, intensive investigation concerning the quality of the effluents, the effect of these effluents on soil properties such as EC, pH and plants irrigated with wastewater must be performed in Jordan.

The major receiving streams for wastewater have very low flow with wastewater comprising a significant portion of stream flow. Much of Amman's wastewater treated effluent is discharged in the Zarqa River and is impounded by the King Talal Dam where it gets blended with fresh floodwater and is subsequently released for irrigation use in the Jordan Valley (McCornick et al., 2002).

2.6 Land evaluation as a tool for land use planning.

The assessment of land potential component for land use planning requires a comprehensive exercise in land evaluation. Such exercise involves detailed data on physical, chemical and morphological characteristics of land resources (Rossiter, 1996).

Land evaluation is defined as the process of assessment of land performance when used for specific purpose (FAO, 1985). A general purpose of land evaluation is to assess the suitability of an area for all relevant forms of use, including existing uses and new ones. Quantitative and qualitative evaluations are two approaches to evaluate land. A qualitative evaluation is the one in which the suitability of land for alternative purpose is expressed in qualitative terms only, such as highly, moderately, or marginally suitable or not suitable for a specified use and this approach is employed mainly in surveys at a reconnaissance scale. The quantitative evaluation is the one in which provides quantitative estimates of the prediction or other benefits to be expressed and it is the most frequently carried out as the bases for economic evaluations (Dent and Young, 1981).

Many systems have been used to evaluate landuse for specific purpose.examples on these systems is: USDA land capability classification (Klingebiel and Montgormery, 1961); land suitability for irrigation; soil survey interpretation; yield estimate; and the FAO framework for land evaluation (FAO, 1976). Each method has its own advantages and limitations when used for intended purpose. The most important factor in selecting one of these systems is the availability of data and collecting of new ones (Rossiter, 1996).

The FAO framework for land evaluation (FAO, 1976) consists of basic concepts, principles and procedures for land evaluation. The FAO framework is an approach of assessing land suitability evaluation for crops in term of suitability rating from highly suitable to not suitable based on climate, terrain data and soil properties. The framework has been followed by series of guidelines for rainfed agriculture (FAO, 1983), forestry (FAO, 1984) and irrigated agriculture (FAO, 1985).

The FAO framework for land evaluation has been applied in Jordan in two national projects: the National Soil Map and Landuse Project (NSMLUP) (MOA, 1995), and the Jordan Arid Zone Productivity Project (JAZPP) (JAZPP, 2001). In addition, other research was applied land suitability evaluation for different land utilization types (Mazahreh, 1998; Al-Shoubaki, 1999; Rashdan, 1999; Sultan, 2005; Abu-Sarhan, 2008). These studies evaluated the different land utilization types in different study area within the arid to semi arid of Jordan. Conclusions from the above studies indicated that accuracy of land suitability results would depend soil mapping units and density of observations. Alternative to these approaches soil properties could be spatially interpolated between observation points collected from ground survey. The other factor related to the selection of land properties would be the criteria for rating limiting land properties for certain use.

2.7 Soil survey and land suitability

Soil survey can be defined as all practices required assessing the properties of soils and their response to management for specific purpose (Dent and Young, 1981). Conventional soil surveys rely on qualitative analysis of landscape where it assumed the properties of modal profile apply to the entire soil mapping unit. So, these surveys are usually limited in providing quantitative information on spatial variability of soil properties that are used in many environmental studies (Florinsky et al., 2002). Therefore interpolated soil properties can provide more detailed soil information for modern land evaluation, land suitability analysis and landuse planning (Phillips, 2002; Ziadat, 2005). Another factor that should be considered in using soil map evaluation is their availability at large scale and cost of producing these maps (Mckenzie et al. 2000; Daigle et al. 2005).

3. MATERIALS AND METHODS

3.1 Study area

The study area is about 50-70 km north of Amman (Figure 1). It extends from As-Samra waste water treatment plant, Al-Hashmiya village, and the cultivated areas within along the banks of the Zarqa River to King Talal Dam (KTD) (Figure 2). It covers Zarqa and Jerash governorates.

3.1.1 Land use

The study area encompasses varied terrain. Most of the area consists of a plateau undulating between 500-1000m in altitude and it includes a mixture of urban, agricultural and non agricultural activities. Agricultural activities include forest, olive trees, mixed agriculture (olive and forage) and rainfed agriculture. Forest are dominated at the western part of the study area near Jerash and KTD, while olive trees and mixed agriculture dominated at the eastern part of the study area near As-Samra WWTP. Rainfed wheat is cultivated in high rainfall areas, while Barley in low rainfall area. Fodder crops (Corn, Alfalfa, Sugar beat and Sudan grass) are cultivated along the strip of Om Sallieh, Garisa, and Sukhna. The expansion of irrigation has been enhanced by overexploration of groundwater and the use of treated wastewater. Non –agricultural activities include urban, villages, As-Samra and Jerash WWTPs (Duqqah, 2000).

Figure 1: General location of the Study Area.

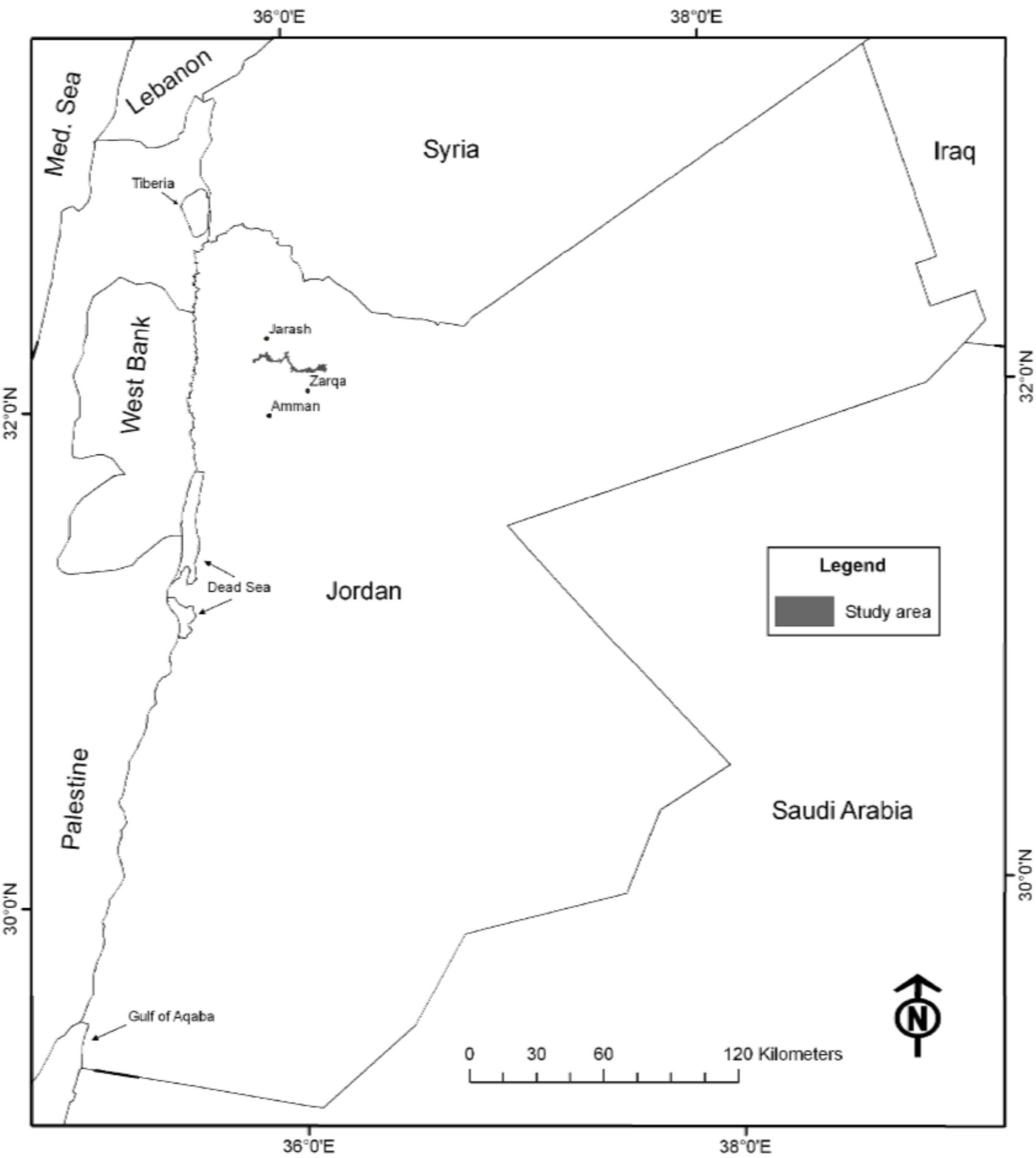
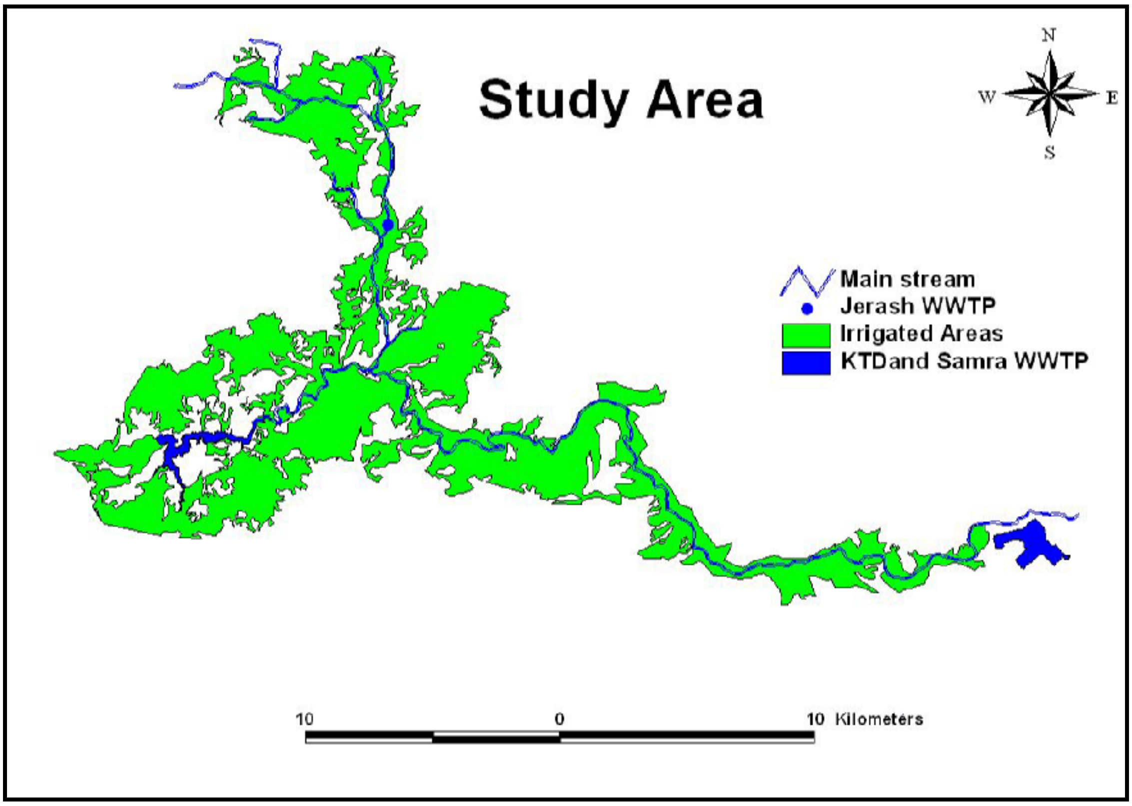


Figure 2: Location of the study area.



3.1.2 Climate

Generally, the study area represents a transitional area between the semi arid Mediterranean highlands in the west to arid climate of Irrano-terranean zone in the east. Annual rain varies from more than 350 mm in Jerash to less than 150 mm in Zarqa. Maximum mean daily temperature occurs in July or August and varies from 23 to 27 °C. Minimum mean temperature in January varies from 2 to 3°C (OPTIMA,2004). The amount of actual evapotranspiration is very high and reaches to 90% of total amount of rainfall (Al-Abed et al., 2005).

3.1.3 Soil

According to the soil maps of MOA (1995), the dominant soil types in the study area are mainly xerochreptic xerochrepts, Typic xerochrepts and xerochreptic combrthid (According to the USDA-SSA (1990) soil classification system).The general description for each soil mapping unit of the NSMLUP is presented in (Table 1), and (Appendix 6). The average soil depth for most soil mapping units is ranging between 57 cm to 97 cm.

3.1.4 Water resources

The main water resource in the study area is Zarqa River which consists of Wadi Dhuleil and Siel Zarqa that joins at Sukhna to form Zarqa River. The second water resources are coming from treated wastewater from As-Samra and Jerash WWTPs. The contribution of As-Samra and Jerash is about 77MCM and 1.3 MCM, respectively.

3.1.5 Study area zones

The study area can be arbitrary divided into four zones (Duqqah, 2000) between As-Samra and KTD depending on water quality, vegetation pattern and soil. The first zone lies in the eastern part of the study area and includes As-Samra WWTP, Hashmiya village, Om-Sallaih and As-Sokhna to the point where Zarqa River mix with water coming from As-Samra WWTP. The climate is an Arid Mediterranean with cool, moist winter and hot dry summer. The long term average annual precipitation is 150 mm and the average temperature is 18°C (RSS, 1995). Soil is not shallow with fine, mixed thermic family of xerochreptic calcids. The upper 20cm of the soil is clay-loam while the sub-soil is clay. The zone is cultivated with olive trees, forest and forage irrigated by the effluent from As-Samra WWTP. The main forage crops grown in the study area are: barley (*Hordeum vulgare*); alfalfa (*Medicago sativa*); Egyptian clover (*Trifolium alexandrinum*); Sudan grass (*Sorghum bicolor*) and corn (*Zea maize*).

The second zone of the study area extends from As-samra WWTP to Tawahen Al-Odwan. The climate is an Arid Mediterranean with cool, moist winter and hot dry summer. The area is characterized by steep slopes and contains few areas of natural forest, especially in the western parts. Also, several farms of orchards, vegetables are irrigated by ground water. Soil is Haploxereptic Haplocalcides.

The third zone of the study area lies between Tawahen Odwan and the point of mixing with water coming from Jerash WWTP. The area has steep slopes with few areas of natural forest near KTD, Soil is Haploxereptic Haplocambids .In general scattered farms of orchards, nurseries and vegetables are irrigated by ground water and treated wastewater from Jerash WWTP on both sides of Zarqa River. Treated wastewater from jerash WWTP discharged into wadi Jerash flows into Zarqa River at Jerash Bridge. Upstream of Jerash Bridge, surface water containing TWW is used for restricted irrigation (forage and trees). In addition a series of wells has been drilled beside the river and is used to irrigate 120 hectares of vegetables. Down stream of the bridge, water is pumped from the river to irrigate vegetables eaten cooked. .

The fourth zone of the study area is the King Talal Dam which was constructed in 1978 to a height of 92 m and a capacity of 52 MCM. The dam was upgraded in 1986 to a capacity of 86 MCM. The stored water is a mixture of TWW coming from As-Samra and Jerash WWTP, water floods and natural springs. The main use of KTD water is for irrigation in Jordan Valley. The average annual inflow to KTD is about 113 MCM (MWI, 2001). The average residence time on inflows in reservoir is approximately 10 months. The water quality of KTD is greatly influenced by As-Samra wastewater, which has a contribution of about 50% of the reservoir capacity. The concentration of nutrients of As-

Samra treatment plant is diluted by the Zarqa River inflow to the reservoir. At the outset, the dam allowed the irrigation of about 6000 hectares, but later after the raising and after further depletion in the Yarmouk summer flow, the dam water was made to reach some 17000hectars (MWI, 2001).

The main wastewater treatment plants in the study area are:

- Jerash: The plant was established in 1984 and treatment type is extended aeration (EA), maturation ponds (MP) (tertiary treatment) for domestic wastewater. The effluent is discharged into wadi Jerash and flows into the Zarqa River at Jerash Bridge. The treated wastewater is proclaimed for restricted irrigation (fodder and trees). In addition, a series of wells has been drilled beside the river and used to irrigate 120 hectares of vegetables. Down stream of the bridge, water is pumped from the river to irrigate different vegetable crops.
- As–Samra: The plant was established in 1985, about 40 km northeast of Amman, as the main plant in the country. It occupies about 181 hectares and handle wastewater from cities of Amman, Zarqa, and Rusifa, using stabilization ponds (SP). The plant was originally designed to receive an average influent of 68 thousands m^3/day. However, it is receives an average of 169 thousands m^3/day (RSS, 2000) from both domestic and industrial sources. As a result, effluent quality discharged into Zarqa River and KTD threatens and pollutes ground water aquifers. An increased portion of treated wastewater, which is discharged from As- Samra treatment plant, is used for an on- site irrigation of fodder and variety of orchards. The planned

improvements of the plant expected to be completed by the end of the year 2007 and is to reduce water parameters to be within Jordanian standards. The expected effluent from As-Samra by the year 2020 is 137.9 MCM.

3.2 Research approach

The study attempts to use the FAO-1976 approach as a starting point to examine land suitability for irrigated alfalfa. The approach requires information on; soil, available water holding capacity, salinity, soil depth, rock outcrop/stone and infiltration rate (FAO, 1976; FAO, 1985; and Mazahreh, 1998). The suitability maps were digitized from the 1:50 000 soil maps of the NSMLUP. Suitability codes were appended as a new column to the map. The output map (Figure 3) shows that the area includes four suitability classes for the main soil mapping units (Table 1). This study aims to evaluate land suitability for alfalfa based on soil salinity, available water holding capacity and existing land use. The analysis was carried out for a narrower strip on both sides of Zarqa River where land slop is less than 6%; suitable for border irrigation which requires mild slope.

Due to the high requirements of the FAO framework and lack of detailed data of soil (only four soil mapping units of NSMLUP cover the study area) for the 26.4 km^2. This research proposes alternative approach based on interpolated soil properties and climatic data to evaluate suitability of the area for alfalfa. The approach incorporates selected soil properties and crop evapotranspiration to evaluate the suitability of the area for irrigating alfalfa. Results will be presented and discussed for both approaches to evaluate land suitability for alfalfa.

Figure 3: Suitability map for the study area and locations of soil samples collected from the field.

Note: codes of suitability are presented in (Table 1).

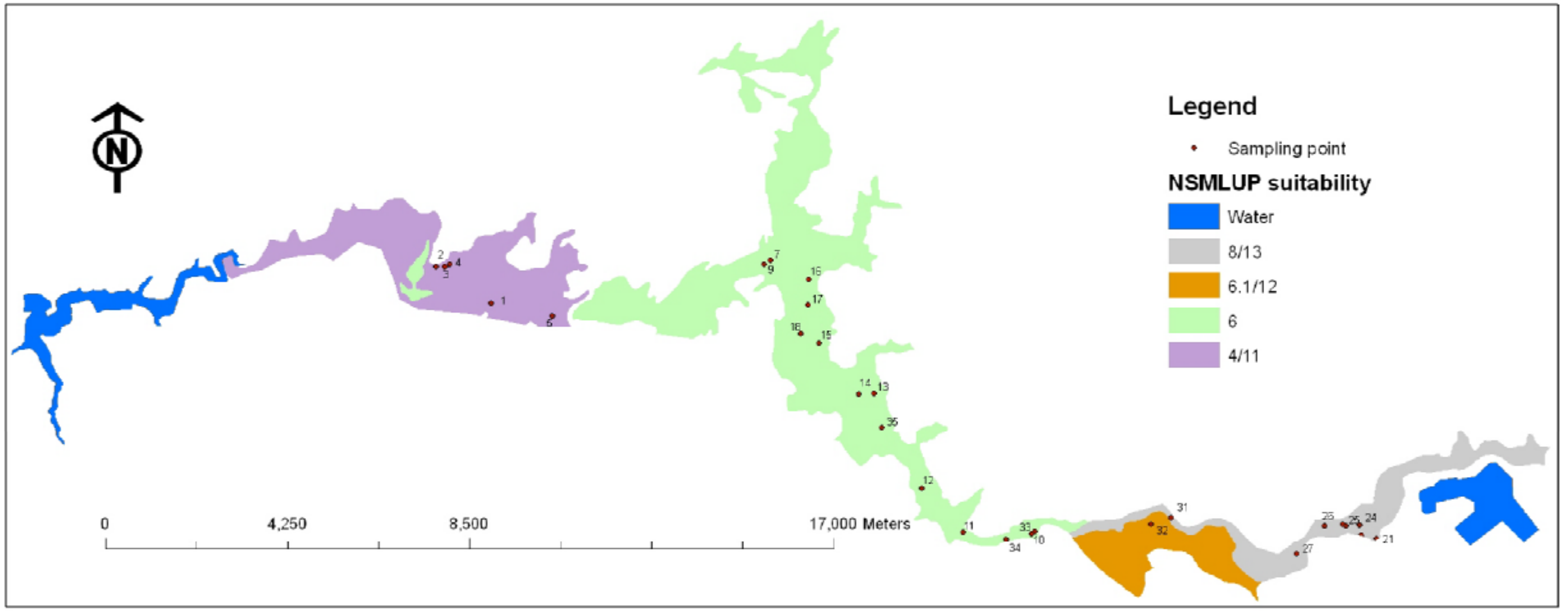


Table 1: The NSMLUP suitability codes for the study area

Suitability code	Description	Rainfed arable	Rainfed tree crops	Drip irrigated vegetables	Rangeland	Forestry
4	Marginal suitable for rainfed arable Marginal suitable for rainfed treecrops Mainly suitable for dry climate limitation	S3c	S3c	S1	S1	S2c
6	Good for drip irrigation Not suitable for rasinfed cultivation Marginal for forestry	N6c	N6c	S1	S2c	S3c
6.1	Good for drip irrigation Not suitable for rainfed cultivation Not suitable for forestry	N6cs	N6cs	S1	S3c	N6c
8	Not suitable for rainfed cultivation Moderately drip irrigated vegetables Marginal for rangeland	N6cs	N6cs	S2cs	S3cs	N6cs
11	Not suitable for rainfed cultivation Not suitable for irrigated vegetables Marginally suitable for rangeland Marginally suitable for forestry	N6cs tr	N6cs tr	N6cs tr	S3cs	S3s
12	Not suitable for rainfed cultivation Not suitable for irrigated vegetables Not suitable for forestry Marginal suitable for rangeland	N6cs tr	N6cs r	N6cs tr	S3cs	N6cs
13	Not suitable for rural land use	N6cs tr	N6cs	N6cs tr	N6cs	N6cs

The research approach (Figure 4) was based on integrating remote sensing data, GIS techniques, and ground survey and data obtained from random samples in order to identify the areas that might be recommended for cultivation of alfalfa.

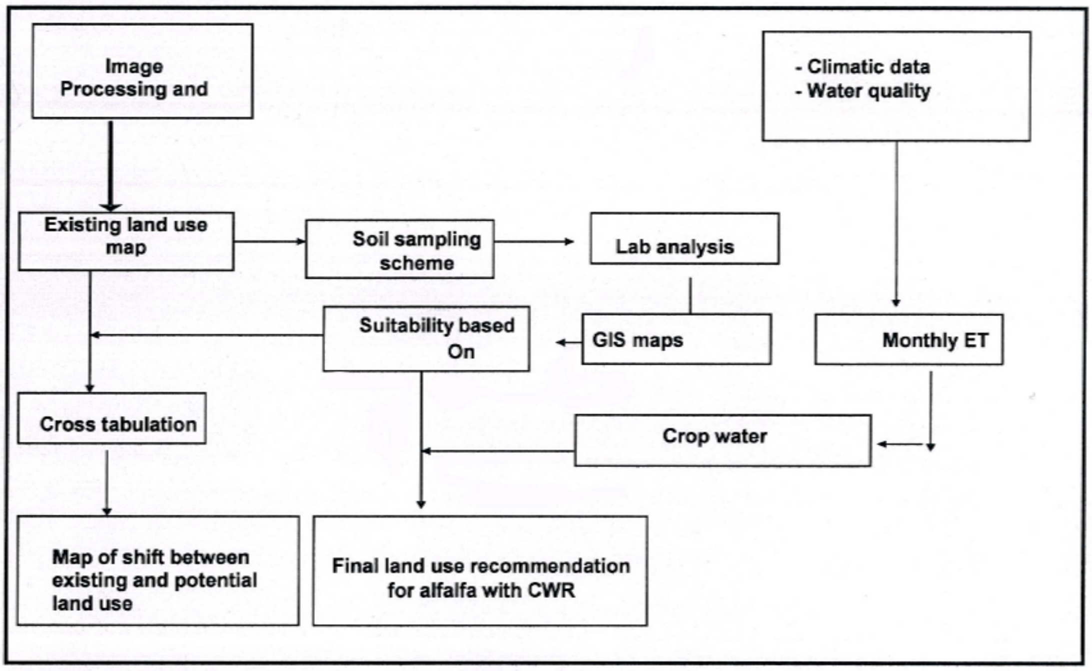


Figure 4: schematic diagram of the research approach

The study was carried at different stages as follows:

3.2.1 Land use mapping

This stage was included visual interpretation of high resolution images to derive land use/cover of the study area. The stage included the following steps:

3.2.2 Processing of images

Advanced Space born Thermal Emission and Reflection Radiometer (ASTER) imagery was used in the study. The imagery was acquired on May 2005 and included three spectral bands, of 15m spatial resolution. The level of ASTER processing included a preliminary geometric correction with standard cartographic projection. A fieldwork was carried out to collect ground control points (GCP's) using global positioning system (GPS) with a positional error of less than 5 meters. Nine GCP's were used in a second order polynomial transformation model to correct the imagery with a root mean squared error RMS of less than one pixel. Image re-sampling was then applied to transform digital numbers (DN) to corrected locations. The imagery was registrated into the Universal Transverse Mercator (UTM) projection system (Datum: WGS84, zone37). The study area was covered by two images in UTM zones 36 and 37. Therefore, both images were joined together using mosaic function in image processing software (ERDAS, 1999).

3.2.3 Visual interpretation of images

An on –screen digitizing was carried out to delineate land use/cover within the study area with a classification scheme of six classes (Table 2). Interpretation of existing landuse was based on tone, shape, texture, location and size. Results from this stage were verified by several field visits, and the resulted landuse map was analyzed to determine the percentage of each land use/cover. The output of this stage was a map with six classes. Definition of mixed agriculture is based on the minimum mapable unit on Landsat ETM^+ at the level of mapping which were nine pixels. The total area of the unit was 7.3 ha. Therefore, this class dose not mean a farm of olives and forage only.

Table 2: composition of Land Use/Cover of the Study Area.

Class NO.	**Class**	**Definition**
1	Forest	Areas of forests and woodland used mainly for recreation.
2	Olive trees	Olive trees irrigated with treated wastewater.
3	Mixed agriculture	Olive trees (with some fodder crops between trees) irrigated with treated wastewater and some wells.
4	Non cultivated	Open spaces with little or no vegetation.
5	Water bodies	King Talal Dam and AS-Samra wastewater treatment plant.
6	Rainfed arable and forage	Rainfed wheat in high rainfall areas barley in low rainfall area and fodder crops (Corn, Alfalfa, Sugar beat and Sudan grass)

3.3 Soil sampling

A systematic random sampling scheme was designed to obtain 1 observation/km² in each location of cultivated areas where reuse of treated wastewater was evident. Location of sampled points is shown in (Figure 3).

Soil was sampled for two depths 0-20cm and 20-40cm. Samples were taken from each field and from each depth. Then it was dried, sieved and prepared for analysis of pH (paste extract), electrical conductivity (EC) from paste extract using conductivity bridge and cell. Available phosphorous was determined by extraction with sodium bicarbonate, while exchangeable potassium was extracted with NH_4OAC. Total nitrogen was measured after digesting the soil sample in concentrated H_2SO_4, with salicylic acid by micro Kjeldahl method as described by Bremner (1982). The soil is digested in concentrated H_2SO_4 with a catalyst mixture to raise the boiling temperature and to promote the conversion from organic-N to NH_4^+-N. Ammonium in the digest is determined by steam distillation, using excess NaOH to raise pH. The distillate is collected in saturated H_3PO_3 and titrated with dilute H_2SO_4.

Soil texture was determined by Hydrometer method, as described by Day (1965) sample preparation included removal of carbonate and organic matter using of H_2O_2 and sodium acetate. Sodium hexametaphosphate and 10g of sodium carbonate in 1 L de-ionized water, adding of 60 ml of the dispersion agent to 40 g of soil, leaving the mixture overnight. Take hydrometer reading. Soil textural class is assigned using soil textural triangle. Location of each sampling site was recorded by GPS to derive GIS maps for the different properties.

Soil parameters such as bulk density (Bd), Prmanent Wilting Point (PWP), Field Capacity (FC), Available Water Holding Capacity (AWHC) were estimated from the hydraulic property model of USDA based on sand and clay percentages.

3.4 Preparing of GIS maps

Samples location coupled with their coordinate were entered in Arc GIS software (ERDAS, 1999) as points, while their chemical and physical properties were entered in spreadsheets. Tables, in spreadsheet format, were converted to point maps or joined to existing point maps using a common field between both. Maps were interpolated using the inverse distance weighted (IDW). Method to estimate the values at unknown points using the distance and values to nearby known points. A weight of each point is an inverse proportion to the distance using the following formula (Bostald, 2006):

$$z_j = \frac{\sum_i \frac{z_i}{d^n ij}}{\sum_i \frac{1}{d^n ij}} \qquad \ldots (1)$$

Where:

z_i : value of known point,

d_{ij} : distance to known point,

z_j: the unknown point,

n: a user selected exponent taken as 2.

3.5 Assessment of Water Quality

Annual reports for the period (1995-2004) were collected from the MWI. (Appendices 2 and 3). The data was extracted from the reports and arranged to assess the most important parameters of treated wastewater. These included Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), and Total Dissolved Solid (TDS). According to the official reports of MWI and RSS the method of measurement for BOD5 was Iodmetric titration while the method of measurement of COD was open reflux, TDS was measured by gravimetric (APHA, AWWA, WPCF, 1998). The data of water quality was arranged in spread sheets to calculate monthly averages of different parameters and to identify the most suitable fodder and leaching requirement for the crop.

3.6 Crop evapotranspiration (ET_c)

Available daily climatic data of air temperature (minimum, maximum and mean), solar radiation, rainfall, wind velocity and relative humidity for As-Samra and KTD station were collected from MWI. Climatic data for the period of 1996-2006 was used to calculate ET_c. Due to availability of data; reference evapotranspiration was calculated using two methods:

a) Penman-Monteith (for As-samra). For samples 10 to 35.
b) Blaney-Criddle equation (for KTD). For sample 1 to 9.

3.6.1 Reference evapotranspiration ET_o

The Penman-Monteith (PM) combination method was recommended as a new standard for reference evapotranspiration calculation. The published FAO paper number 56 describes the development of the Penman-Monteith method by defining the reference crop as a hypothetical crop with an assumed height of 0.12 m, with a surface resistance of 70 s m^{-1} and an albedo of 0.23 (Allen et al., 1998). The FAO-56 Penman-Monteith equation according to Allen et al. (1998) can be written as following:

$$ET_o = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)} \quad \ldots(2)$$

Where

ET_o: reference evapotranspiration [mm day^{-1}],

R_n: net radiation at the crop surface [MJ m^{-2} day^{-1}],

G: soil heat flux density [MJ m^{-2} day^{-1}], assumed to be zero,

T: mean daily air temperature at 2 m height [°C],

u_2: wind speed at 2 m height [m s^{-1}],

e_s: saturation vapor pressure [kPa],

e_a: actual vapor pressure [kPa],

(e_s - e_a): saturation vapor pressure deficit [kPa],

Δ: slope vapor pressure curve [kPa $°C^{-1}$],

γ: psychrometric constant [kPa $°C^{-1}$].

The meteorological data needed for FAO-56 PM ET_o calculation are air temperature, air relative humidity, wind velocity, atmospheric pressure and incident solar radiation. FAO-56 PM ET_o was used to compute daily ET_o for As-Samra station. Monthly ET_o was then computed using the daily ET_o data for each month. (Calculation procedure was shown in appendix 1)

3.6.2 Blaney-Criddle equation

A theoretical method of Blaney-Criddle to calculate the reference crop evapotranspiration ET_o is simple and based on temperature only. The FAO Blaney-Criddle (FAO-27 BC) formula can be written as following

$$ET_o = p(0.46T_{mean} + 8) \qquad \ldots(3)$$

Where

ET_o: Reference crop evapotranspiration (mm/day) as an average for a period of 1 month.

T_{mean}: mean daily temperature (°C).

p:mean daily percentage of annual daytime hours.

3.6.3 Leaching Requirement

It is the fraction of irrigation water that must be leached throughout the root zone to control salinity at any specified level. The following formula was recommended by FAO-56:

$$LR = \frac{EC_w}{5(EC_e) - EC_w} \qquad \ldots(4)$$

Where:

LR: is the minimum leaching requirement needed to control salts within the tolerance (EC_e) of the crop with ordinary surface methods of irrigation,

EC_w: salinity of applied water dS/m,

EC_e: average soil salinity tolerated by the crop as measured on a soil saturation extract.

EC_e was determined from paste extract using Conductivity Bridge and cell as described by Rhoades (1982). While EC_w was taken from annual reports of MOWI and RSS. The average values of monthly records were calculated for the period 1995-2006. Detailed data are shown in appendix 2 and 3. Water salinity (EC) is used as a measure of total dissolved solids (TDS), the values of EC and TDS were related to each other and were converted by the following equation described by (Pettygrove and Assano, 1985):

$$TDS(mg/L) \approx EC(dS/m) \times 640 \qquad \ldots(5)$$

The amount of LR was dependent upon the irrigation water quality and the salinity tolerance of the crop grown. Salts were assumed to be added to the soil with each irrigation event. These salts will reduce crop yield if they accumulated in the rooting depth to damaging concentrations. The crop would remove much of the applied water from the soil to meet its evapotranspiration demand (ET) but would leave most of the salt behind to concentrate in the decreased volume of the soil water. With each irrigation, more salt would be added and accumulated in the root zone. A portion of the added salt should be leached from the root zone before the concentration would affect crop yield (Table 3).

Table 3: Relative crop salinity tolerance rating according to Ayers and Wescot (1976).

Relative crop salinity tolerance rating	**Soil salinity at which yield loss begins (dS/m)**
Sensitive	< 1.3
Moderately sensitive	1.3 – 3
Moderately tolerant	3 - 6
Tolerant	6 - 10
Unsuitable for most crops (unless reduced yield is acceptable)	> 10

These guidelines (Table 3) were used to rank the sampling locations according to salinity levels (tables 7 and 8 in section 4.2.2)

3.7 Assessment of soil and water properties

The approach for assessing suitability of water and soil for the reuse of treated wastewater was not investigated in Jordan, this research proposed an approach which was based on the relative reduction of yield. It should be noticed that salinity was taken as a criteria after considering other parameters of soil and water, the evaluation was based on the Jordanian standards and FAO.1992. Those parameters would provide means to ensure sustainable irrigation practices and reduced levels of contamination. The most important evaluated parameters were:

- Biological oxygen demand(BOD_5)
- Chemical oxygen demand(COD)
- Total dissolved solids (TDS)
- Water pH

According to Ayers and Wescot (1976), the relative reduction in yield for some selected crops is variable according to the type of crop. Table 4 summarizes the EC range for three crops in relation to yield reduction.

Table 4: Average EC_w and reduction in yield (Ayers and Wescot ,1976).

Crop	**Relative yield decrease %**			
	0	**10**	**25**	**50**
	EC (dS/m)			
Barley	5.3	6.7	8.7	12
Wheat	4	4.9	6.4	8.7
Alfalfa	1.3	2.2	3.6	5.9
Suitability classes	Highly suitable	Moderately suitable	Marginally suitable	Not suitable

These values of reduction in yield are based on crop tolerance to average soil salinity of the root zone . Therefore, the average soil salinity was derived from surface and subsurface soil salinity maps (Figure7). Alfalfa was selected as the performed crop for irrigation under treated wastewater condition. Four classes of suitability were identified. (Table 4). Results of soil analysis were statistically valuated using t-test ($P<0.05$) to test differences among samples for surface and subsurface layers. (Appendix 4)

3.8 Crop water requirement (CWR)

Irrigation requirements (IR) during crop cycle could be determined by direct soil water measurement to compensate soil water losses due to crop ET_o. Crop coefficient (Kc) should be multiplied to the ET_o to estimate crop ET. Values for most crops are available at FAO-56 paper. Since Penman-Monteith method used alfalfa as a reference crop, Kc was already calculated at the final ET_o. On the other hand, ET_o Blaney-Criddle results were multiplied by Kc value of 1.2 to calculate crop ET_o. The net irrigation requirement IR was calculated as following:

$$IR = \frac{LR + ETc}{IE} \qquad ....(6)$$

Where:

IR: irrigation requirement,

LR: leaching requirement,

ETc: Crop evapotranspiration,

IE: Irrigation efficiency, for surface irrigation (40-60%),

Irrigation efficiency was taken as 60%. Finally crop water requirement (CWR) was calculated using the following formula:

$$CWR = IR - Pe \qquad ...(7)$$

Where:

IR: irrigation requirement

Pe: effective rainfall (mm/month).

Effective rainfall was computed on monthly basis using the approach of FAO 56, as shown in (Appendix 5). The resulted CWR tables were then interpolated using IDW to obtain CWR map for all the study area. Also, CWR data was used to obtain the quantity of water that can be consumed on both sides of Zarqa River.

3.9 GIS analysis

A GIS analysis was used to evaluate suitability map of the existing (current) land use and the suitability map for alfalfa. The soil EC map, which was interpolated using IDW, was cross – tabulated with existing land use map (excluding water and forest). Area percentages for each tabulated class were then calculated. Cross tabulation is the process by which two maps are overlaid to identify the agreement based on pixel by pixel location. The output from this procedure is the cross-tabulation matrix which shows agreement as a diagonal element of the table.

4. RESULTS AND DISCUSSION

4.1 Existing and potential land use

Results of land use mapping showed that mixed agriculture was dominating the study area. Analysis of land use map of the study area (Figure 5) showed that mixed agriculture constituted 53% of the existing land use (Table 5), while forest occupied small proportion of the area. Irrigated areas dominated both sides of Zarqa River (Figure 5).

Table 5: Distribution of land use/cover of the study area.

Class number	Class	Percent of area
1	Forest	4.1
2	Olive trees	9.6
3	Mixed agriculture	52.9
4	Non - cultivated	14.4
5	Water bodies	8.6
6	Rainfed arable and forage	10.4
Total		100

Rainfed arable and forage crops dominated the first zone of the study area along the strip Om-Salleih, Gharesah and As-Sukhna village. On the other hand, mixed agriculture is practiced in the area along As-Samra WWTP and the nearby villages such as Hashmiyah village and part of Al-Sukhna. These results were evaluated by several field visits. Some lands in the upstream were left without cultivation as pumping of ater was required and its cost could not be afford by farmers.

Suitability map (Figure 3) of NSMLUP showed that 54% of the study area was classified as highly suitable for drip irrigation. Also, 25% of the study area was either marginally suitable or not suitable for rainfed cultivation with climate being the main limitation for this land utilization types (LUT). About 9.4% of the study area was classified as not suitable for irrigating vegetable crops.

Visual inspection of the suitability map of NSMLUP showed that the areas of As-Samra, Al-Hashmyah village and parts of Om-Salleh village were moderately suitable for drip irrigation of vegetables, marginally suitable for rangeland and not suitable for rainfed arable and rainfed tree crops and forestry. The main limitations in this area are the slope and climate. The existing land use (Figure 5), on the other hand, showed that 35% of this area was cultivated by irrigated olive trees, 65% was dominated by forest, irrigated forge, and illegal plantation of vegetables. The results of the soil EC for our samples showed high levels of salinity in this area, therefore, most of the area at current time is not suitable for the drip irrigation proposed by the NSMLUP map.

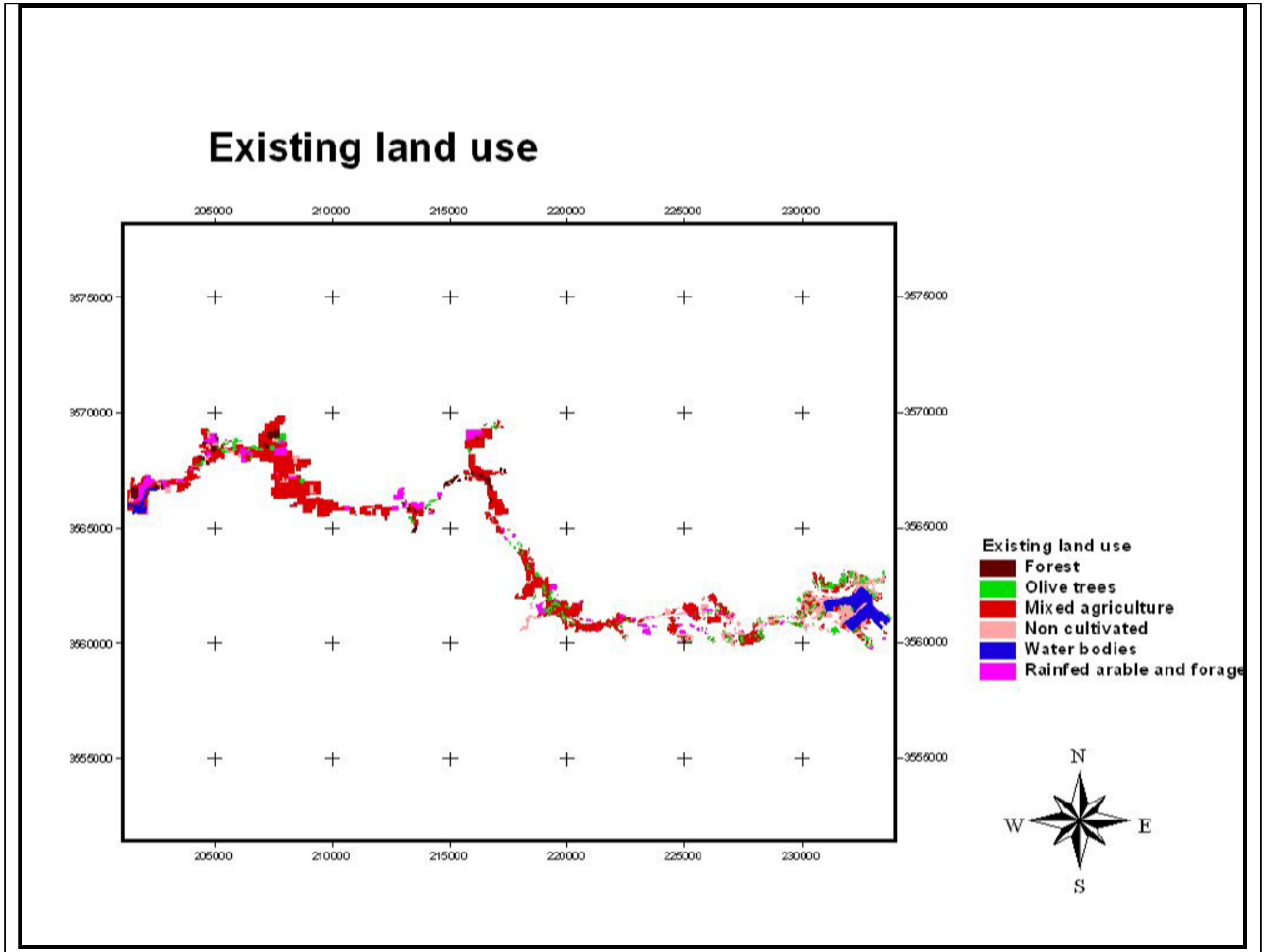
The second suitability class at the strip of Om sallieh- Garisah -and Sukhna villages was highly suitable for drip irrigation, marginally suitable for rangeland, and not suitable for rainfed arable, rainfed tree crop and forestry. The main limitations in this area were the slope and climate. The existing landuse in this area was rainfed arable and forage crops. Due to effluent quality, the area was not suitable for drip irrigation as EC_w values were high. It is worth to mention that in some locations within the area especially at Om sallieh and Garisah villages the use of treated wastewater was used to irrigate forage crops especially, alfalfa using surface irrigation.

The middle of the study area before Tawahen –Al Odwan was highly suitable for drip irrigation of vegetables, moderately suitable for rangeland and marginally suitable for forestry and not suitable for rainfed tree crops. Currently, the area has natural forests and several farms of orchards and vegetable irrigated by groundwater. The existing land use is in agreement with land suitability of the NSMLUP. In this area, EC values for most soil samples were low except for soil sample 19, 34 and 33. The main limitation in the area is the climate.

According to the NSMLUP map (Figure 3), the third part of the study area located from Tawahen –Al Odwan to KTD is highly suitable for drip irrigation and rangeland, moderately suitable for forestry and marginally suitable for rainfed arable and rainfed tree crops. Currently, existing landuse is in agreement with the NSMLUP suitability map. In addition, the soil salinity levels are relatively low and suitable for the existing land use types.

The semi-detailed map of the NSMLUP was useful in characterizing the study area for particular landuse. However, the continuous irrigation with TWW was expected to increase soil salinity and change the land suitability for irrigation with TWW. Therefore, our research approach complements the NSMLUP by adding more details to the suitability map and finding some areas inside each soil mapping unit for irrigating alfalfa. These results from the research approach are presented in the following sections.

Figure 5: Existing land use along the study area



4.2 Soil chemical characterization

4.2.1 Soil pH

Results showed no significant differences in soil pH among the different locations (Table 6). However significant difference was found between surface and subsaurface layers. Most of pH values ranged between 8-8.5 in the surface layer and between 7.5-8 in the subsurface layer. At both layers, pH values increased obviously at the western part of the study area near KTD, and decreased towards As-Samra. Its worth to mention that there were few locations near As-Samra with high pH values, which were in agreement with data of MOA (1995).

The soil pH of the two depths is considered to be within the acceptable range for alfalfa cultivation. Results indicated that soil pH was affected by the use of treated wastewater which increased soil pH. The slight increase of soil pH values in the study area were noticed when compared with the analyzed profiles and pits of NSMLUP for some locations (see Appendix 6). This slight increase could be attributed to the continuous irrigation with treated wastewater which would increase soil pH. The treated wastewater would have high contents of basic cations such as Na, Ca and Mg. These cations are the main causes of the increased soil pH Maps of soil pH for surface and subsurface are shown in Figure 6.

Figure 6: Maps of soil pH for surface (Top) and subsurface (Bottom) layers of soil.

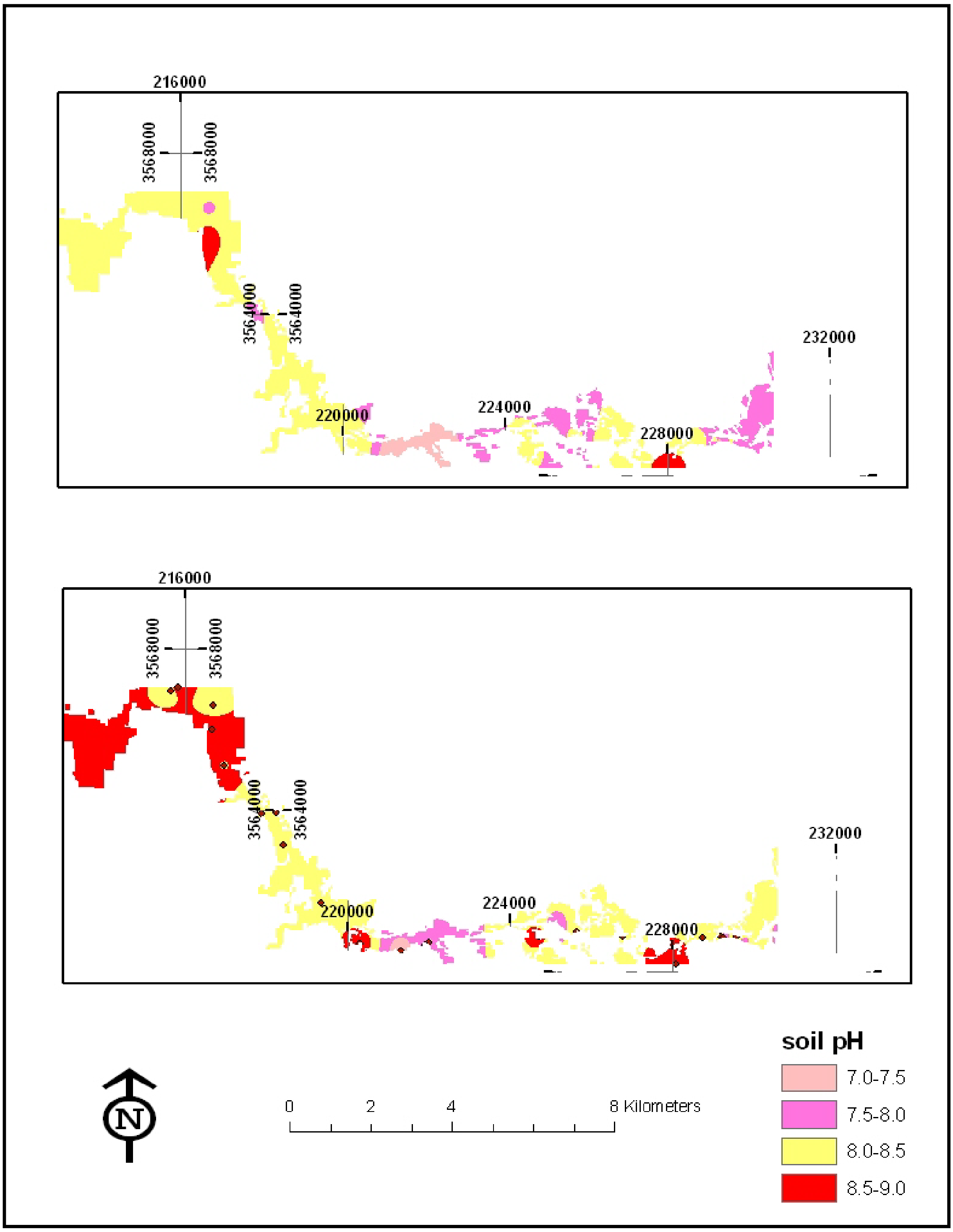


Table 6: Soil pH for surface and sub surface soil layer

Sample No.	E (m)	N (m)	Surface pH	Sub -surface pH
1	209288	3566030	8.1	8.0
2	208001	3566879	8.4	8.3
3	208318	3566947	8.0	7.8
4	208198	3566887	8.1	7.9
5	210707	3565741	8.2	7.9
6	221920	3562001	8.2	7.9
7	214522	3566262	8.3	8.2
8	215811	3567450	8.1	8.1
9	215651	3566939	8.0	8.0
10	221986	3560695	7.3	7.4
11	220304	3560680	8.3	8.0
12	219346	3561692	8.1	7.9
13	218230	3563935	8.1	8.0
14	217873	3563901	7.8	7.6
15	216827	3565256	8.1	7.4
16	216695	3566594	7.9	7.9
17	216693	3566016	8.4	7.8
18	216547	3565424	8.7	8.0
19	230604	3560604	7.3	7.3
20	230441	3560559	8.2	8.0
21	229958	3560516	7.9	7.4
22	229598	3560606	7.2	7.1
23	229179	3560858	8.2	8.0
24	229563	3560846	8.0	7.4
25	229237	3560831	7.3	7.3
26	228751	3560819	8.1	7.8
27	228096	3560178	8.7	8.5
28	227659	3569843	7.5	7.4
29	226765	3560861	8.0	7.2
30	225627	3560987	8.0	7.6
31	225148	3561006	7.4	7.0
32	224701	3560862	8.3	7.9
33	221910	3560641	7.6	8.1
34	221313	3560505	7.2	7.9
35	218416	3563128	8.0	7.1

4.2.2 Soil Electrical Conductivity (EC)

Soil EC was significantly different between the surface and subsurface soil layers (Table 7 and 8). In general, EC tended to increase towards the eastern parts near As-samra and decreases towards KTD. The maximum increase was recorded along the area near As-Samra WWTP, Al- Hashymia and As- Sukhna to the point where Zarqa River mixes with water coming from As-Samra WWTP due to the high rates of evapotranspiration, excessive use of TWW which contains high amounts of salts. After Jerash Bridge, soil EC declined due to the mixing of treated wastewater with flood water from wadies and springs.

Increased soil EC values in the study area were observed for the same locations of the analyzed pits and profiles of the NSMLUP MOA. (1995). This increase was attributed to the salt content of treated wastewater which could cause building up of soil salinity.

Generally, surface ECe was higher than the subsurface ECe. The distribution of ECe for both layers is shown in Figure 7. Differences among soil samples were evident for surface (Table 7) andsubsurface (Table 8) layers. Generally, no consistent trend between the surface and sub surface samples was observed. For example, sample 25 had ECe value of 48.4 while a subsurface EC_e was only 1.3. This could be attributed due to the sampling time which was in late spring to early summer. This inconsistent trend was also observed for other samples.

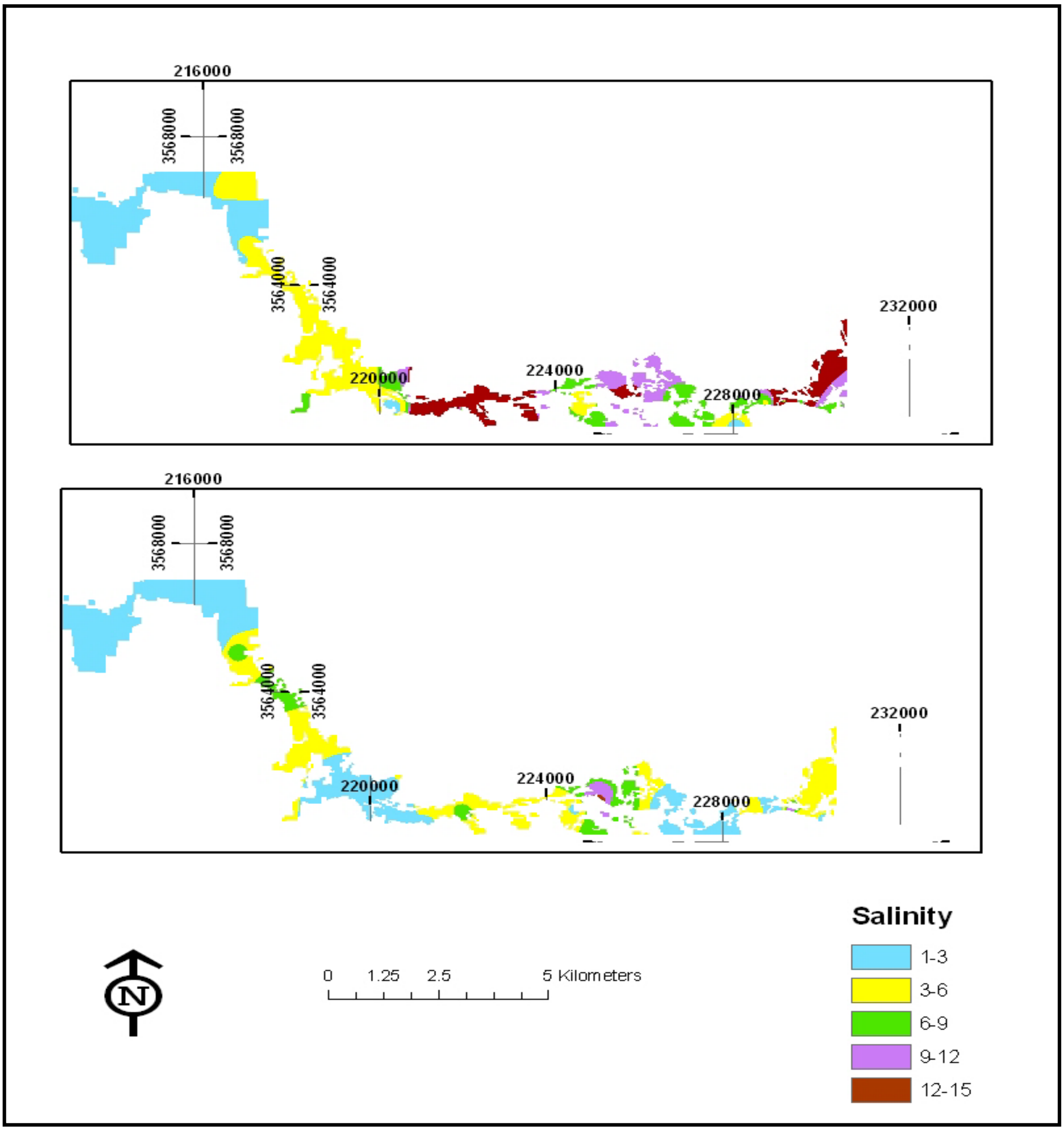
Table 7: Soil salinity for the different samples of soil surface and their relative tolerance rating.

Sample NO.	E(m)	N(m)	ECe(dS/m)	Relative crop salinity tolerance rating
1	209286	3566028	1.6	Moderately sensitive
2	208002	3566876	1.0	Sensitive
3	208321	3566944	2.0	Moderately sensitive
4	208202	3566883	2.4	Moderately sensitive
5	210710	3565734	2.7	Moderately sensitive
6	215714	3567028	1.3	Moderately sensitive
7	215813	3567028	2.1	Moderately sensitive
8	215813	3567028	1.2	Moderately sensitive
9	215656	3566934	3.1	Moderately tolerant
10	221986	3560695	32.5	Unsuitable for most crops
11	220304	3560680	1.3	Sensitive
12	219346	3561692	4.7	Moderately tolerant
13	218230	3563935	4.2	Moderately tolerant
14	217873	3563901	5.7	Moderately tolerant
15	216950	3565101	4.4	Moderately tolerant
16	216695	3566592	7.8	Tolerant
17	216675	3565988	1.1	Sensitive
18	216518	3565321	1.0	Sensitive
19	230604	3560604	18.2	Unsuitable for most crops
20	230441	3560559	3.9	Moderately sensitive
21	229958	3560516	6.5	Tolerant
22	229598	3560606	32.9	Unsuitable for most crops
23	229179	3560858	6.4	Tolerant
24	229563	3560846	10.1	Unsuitable for most crops
25	229237	3560831	48.4	Unsuitable for most crops
26	228751	3560819	7.5	Tolerant
27	228096	3560178	1.7	Tolerant
28	227796	3560861	7.4	Tolerant
29	226765	3560861	11.7	Unsuitable for most crops
30	225627	3560987	16.3	Unsuitable for most crops
31	225148	3561006	16.1	Unsuitable for most crops
32	224701	3560862	3.8	Tolerant
33	221910	3560641	8.2	Tolerant
34	221313	3560505	49.3	Unsuitable for most crops
35	218416	3563128	7.8	Tolerant
Average ECe			9.6	

Table 8: Soil salinity for the different samples of soil subsurface and their relative tolerance rating.

Sample NO.	**E(m)**	**N(m)**	**ECe(ds/m)**	**Relative crop salinity tolerance rating**
1	209286.1	3566028	6.6	Tolerant
2	208002.2	3566876	8.0	Tolerant
3	208320.6	3566944	2.2	Moderately sensitive
4	208202	3566883	1.7	Moderately sensitive
5	210710	3565734	2.4	Moderately sensitive
6	215713.5	3567028	1.1	Sensitive
7	215813.5	3567028	1.1	Sensitive
8	215813.5	3567028	1.5	Moderately sensitive
9	215656	3566934	1.4	Moderately sensitive
10	221986	3560695	8.3	Tolerant
11	220304	3560680	1.1	Sensitive
12	219346	3561692	2.7	Moderately sensitive
13	218230	3563935	8.0	Tolerant
14	217873	3563901	7.6	Tolerant
15	216949.7	3565101	7.4	Tolerant
16	216694.5	3566592	2.1	Moderately sensitive
17	216674.8	3565988	1.5	Moderately sensitive
18	216518.3	3565321	1.1	Sensitive
19	230604	3560604	7.8	Tolerant
20	230441	3560559	1.3	Moderately sensitive
21	229958	3560516	3.9	Moderately tolerant
22	229598	3560606	1.4	Moderately sensitive
23	229179	3560858	1.1	Sensitive
24	229563	3560846	11.1	Unsuitable for most crops
25	229237	3560831	1.3	Moderately sensitive
26	228751	3560819	4.9	Moderately tolerant
27	228096	3560178	1.2	Sensitive
28	227796	3560861	22.1	Unsuitable for most crops
29	226765	3560861	1.1	Sensitive
30	225627	3560987	7.6	Tolerant
31	225148	3561006	13.7	Unsuitable for most crops
32	224701	3560862	2.8	Moderately sensitive
33	221910	3560641	3.5	Moderately tolerant
34	221313	3560505	3.4	Moderately tolerant
35	218416	3563128	4.0	Moderately tolerant
Average ECe			4.5	

Figure 7: Maps of soil EC for surface (Top) and subsurface (Bottom) layers of soil.



4.2.2 Total Nitrogen (TN)

Total nitrogen was significantly higher in the surface layer compared with the sub-surface layer (Appendix 4). Generally, high levels of nitrogen were observed all over the study area. The area from As-Samra to Jerash Bridge had higher levels of nitrogen in the soil surface (Figure 8) were total nitrogen ranged between 0.7 to 0.8 percent. These levels of N could be attributed to the high contents of N in treated wastewater applied. Surface total nitrogen was higher than sub- surface layer in all location (Table 13). This indicated that nitrogen accumulated in the surface layer.

Maximum value (0.9-1.0%) of total nitrogen was observed near As-Samra WWTP which was higher than those expected in most agricultural areas (0.4-0.5%). This could be attributed to the insufficient treatment in As-Samra WWTP since the plant was not designed to remove nitrogen. The concentration of nutrients of As-Samra WWTP was diluted by the Zarqa River water inflow before reaching KTD. Also, self-flushing of water contributed to lower levels of N near KTD.

Water analysis taken from reports of (MWI), showed higher levels of nitrogen which exceeded the Jordanian standards of TWW; which stated that the maximum level of N should not exceed 50mg/l. Monthly averages of nitrogen for As-Samra and Jerash WWTPs (shown in Table 9 and 10, respectively) were relatively high and indicated the insufficient of treatment of water.

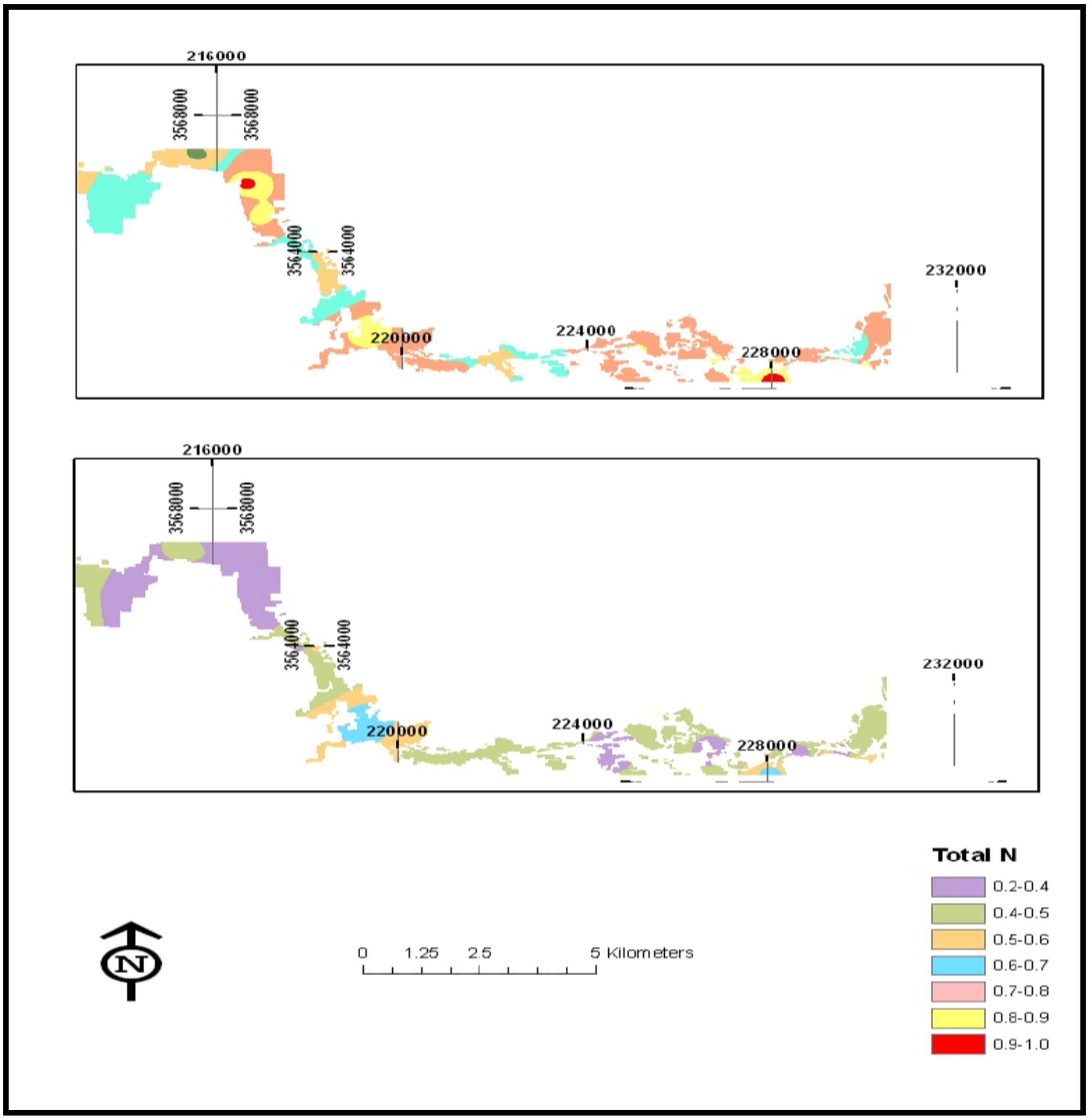
Table 9: Average monthly levels of N and P expressed as (mg/l) at As-Samra WWTP (MWI, 2001; 2002; 2003)

Year	Month	NH_4^+	NO_3^-	PO_4^{-3}
2000	JAN	88	0.1	13.6
	FEB	78	<0.25	17.9
	MAR	100	N.A	N.A
	APR	101	<0.25	N.A
	MAY	90	N.A	N.A
	JUN	71	75	12.6
	JUL	70.8	88.4	N.A
	AUG	82	<0.11	15
	SEP	89	N.A	N.A
	OCT	98	83	17
	NOV	97	N.A	N.A
	DEC	98	<0.25	21
Average		89	62	16
2002	JAN	96	0.1	N.A
	FEB	87	<0.5	N.A
	MAR	108	<0.27	N.A
	APR	102	<0.5	19
	MAY	103	<0.27	N.A
	JUN	90	0.14	N.A
	JUL	85	N.A	N.A
	AUG	82	<0.08	N.A
	SEP	85	N.A	N.A
	OCT	86	<0.27	N.A
	NOV	93	N.A	N.A
	DEC	99	N.A	19
Average		93	0	19
2003	JAN	99	N.A	19
	FEB	N.A	N.A	N.A
	MAR	N.A	N.A	N.A
	APR	N.A	N.A	N.A
	MAY	87	<0.5	N.A
	JUN	82	<0.5	15.5
	JUL	79	0.4	N.A
	AUG	79	<0.5	20.1
	SEP	81	<0.5	N.A
	OCT	N.A	N.A	N.A
	NOV	N.A	N.A	N.A
	DEC	N.A	N.A	N.A
Average		85	0	18

Table 10: Average monthly levels of N and p at Jerash WWTP (MWI, 2005; 2006)

Year	**Month**	**NH_4^+**	**NO_3^-**	**PO_4^{-3}**
2005	JAN	107	N.A	N.A
	FEB	60	1.1	N.A
	MAR	75	N.A	N.A
	APR	40	0.026	N.A
	MAY	45	1.25	N.A
	JUN	35	1	N.A
	JUL	62	3	N.A
	AUG	N.A	N.A	N.A
	SEP	86	1.5	N.A
	OCT	68	1.8	N.A
	NOV	N.A	N.A	N.A
	DEC	N.A	N.A	N.A
Average		64	1	N.A
2006	JAN	5.58	N.A	N.A
	FEB	N.A	N.A	N.A
	MAR	30	4.5	N.A
	APR	32	4.6	N.A
	MAY	38	3	N.A
	JUN	30	4	N.A
	JUL	2	4.8	N.A
	AUG	35	6	N.A
	SEP	N.A	N.A	N.A
	OCT	N.A	6.2	N.A
	NOV	N.A	N.A	N.A
	DEC	N.A	N.A	N.A
Average		27.83	5	N.A

Figure 8: Maps of soil total nitrogen for surface (Top) and subsurface (Bottom) layers of soil.



4.2.3 Soil Phosphorous (P)

The distribution of soil P for both layers is shown in (Figure 9). Differences among soil samples were evident for surface and subsurface layers (Table 11) but with no significant differences between the two soils layers (Appendix 4). Generally, no consistent trend between the surface and sub surface samples was observed. In some locations sub surface phosphorous was higher than the surface phosphorous for samples 33, 27, 21,20,16,13,12,10,5,6 and 2. For the rest of samples soil P for surface was higher than subsurface. These results could be attributed to the high content of $CaCO_3$ of calcareous soils which causes a fixation of P and decreases its mobility causing it to accumulate at the surface soil layer. Leaching of P by rainfall in the area, especially at As-Samra, is low because of low rainfall and the insufficient of treatment of water which causes P- enrichment at the area and decreases its levels towards KTD.

4.2.4 Soluble Potassium (K)

There were significant differences in K levels in the soil surface and subsurface layers (Appendix 4). Generally, an increase of P and K in the top soil (0-20 cm) could be attributed to the accumulation of these macro nutrient in the soil irrigated with treated wastewater which had a high contents of these nutrient in treated wastewater applied. The distribution of soil K for both layers is shown in Figure 10. Results showed high levels of K in the eastern part of the study area near As-Samra WWTP, where K levels ranged between 10 to 13 ppm and decreased gradually to KTD. Since alfalfa needs high amount of potassium, the area near As-Samra WWTP could satisfy the needs of alfalfa especially the area on the strip of Om-Sallieh- Gharesah-and Sukhna. In this area the density of plant was good and could indicate their suitability for water for this forage crop.

Table 11: Results of Chemical Analysis For Surface and Subsurface layer

	Total N (%)		Total P (ppm)		Soluble K (ppm)	
Sample NO.	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
1	0.5	0.4	48.5	50.7	2.3	3.1
2	0.7	0.6	49.8	56.5	1.0	1.2
3	0.5	1.1	45.1	41.3	0.6	2.4
4	0.5	0.5	46.8	60.9	1.8	4.5
5	0.5	0.5	65.3	106.2	3.4	8.0
6	0.8	0.6	62.5	105.9	3.0	4.9
7	0.7	0.4	83.5	83.5	5.1	4.9
8	0.4	0.3	62.0	70.3	1.6	4.8
9	0.5	0.5	152.9	91.8	3.3	6.0
10	0.7	0.5	136.8	186.8	8.8	14.2
11	0.8	0.5	167.2	110.9	1.7	3.9
12	0.9	0.7	65.6	98.2	2.1	3.9
13	0.6	0.5	86.6	100.9	2.4	5.3
14	0.7	0.4	94.9	93.5	3.4	5.1
15	0.9	0.4	100.4	77.5	3.1	5.0
16	0.8	0.3	95.7	117.0	3.3	6.2
17	1.0	0.3	59.8	69.7	1.3	2.6
18	0.8	0.4	115.6	104.3	1.2	2.6
19	0.8	0.3	108.7	70.0	5.8	6.9
20	0.8	0.7	216.4	231.6	2.4	4.3
21	1.1	0.7	99.8	203.7	12.0	13.1
22	0.4	0.3	93.8	54.0	9.4	7.8
23	0.7	0.4	168.9	102.6	4.4	8.7
24	0.6	0.3	71.7	95.1	3.4	8.9
25	0.9	0.6	121.4	107.8	8.5	15.0
26	0.8	0.3	210.9	149.3	4.9	6.7
27	1.0	0.7	105.9	160.0	3.3	4.5
28	1.1	0.7	95.7	95.4	9.6	10.4
29	0.9	0.4	171.9	112.5	11.5	19.1
30	0.8	0.5	48.5	56.2	3.7	4.4
31	0.9	0.4	69.2	76.1	5.8	10.7
32	0.8	0.4	165.0	152.3	4.3	11.0
33	0.5	0.4	118.6	149.8	3.5	6.0
34	0.8	0.5	59.0	56.7	10.7	9.0
35	0.6	0.4	104.3	81.9	3.8	6.5

Figure 9: Maps of soil phosphorous for surface (Top) and subsurface (Bottom) layers of soil.

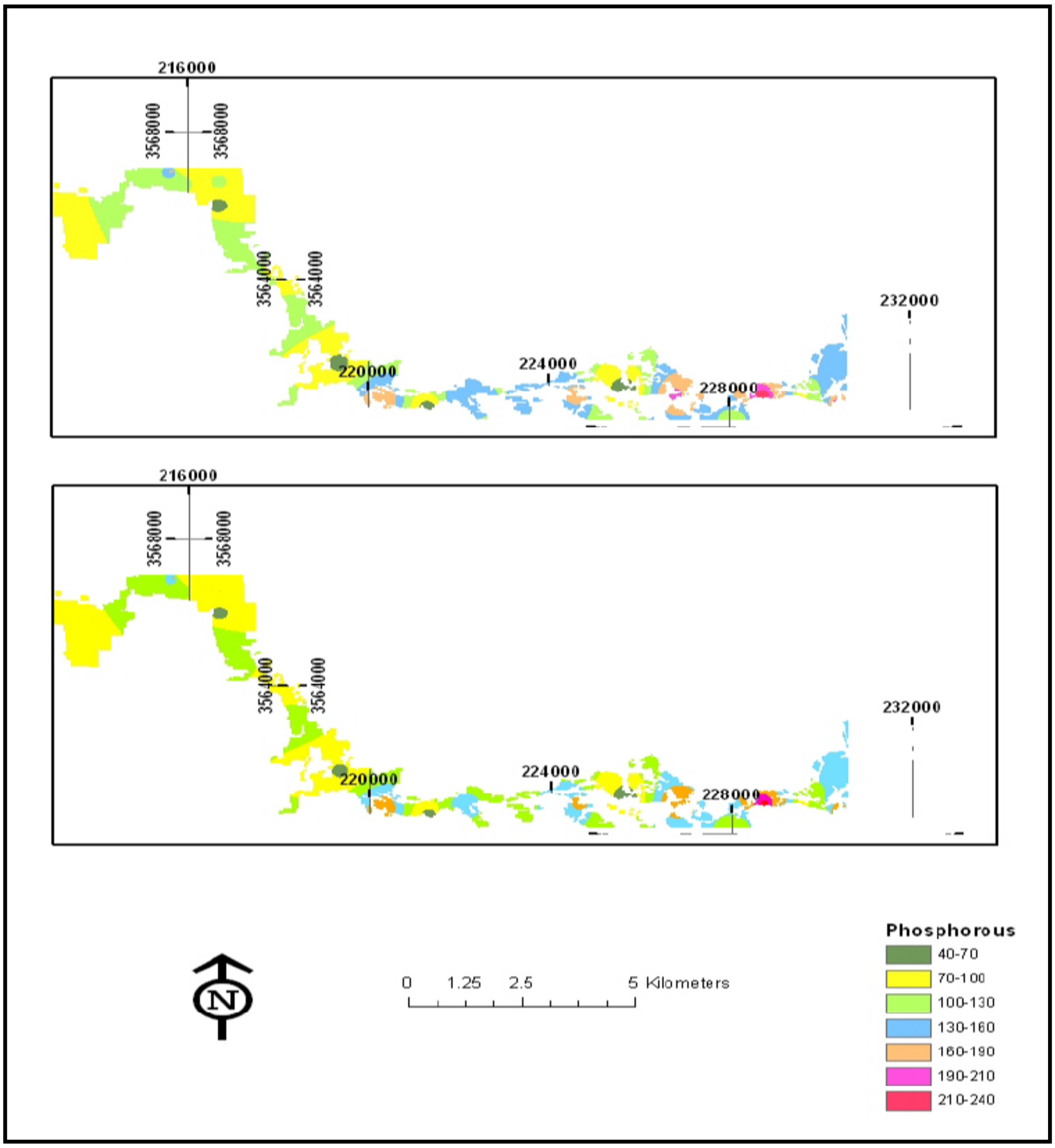
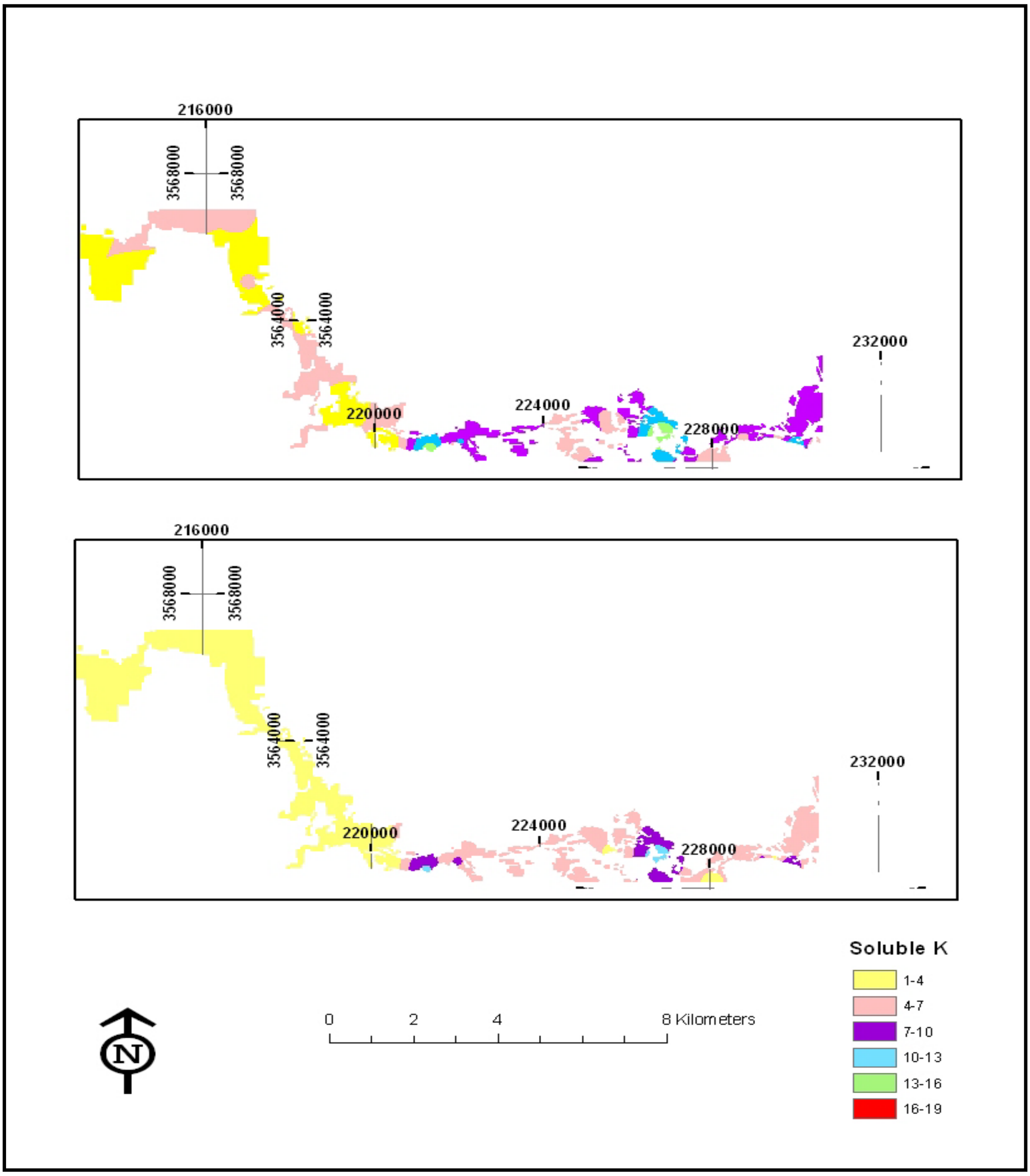


Figure 10: Maps of soil soluble potassium for surface (Top) and subsurface (Bottom) layers of soil.



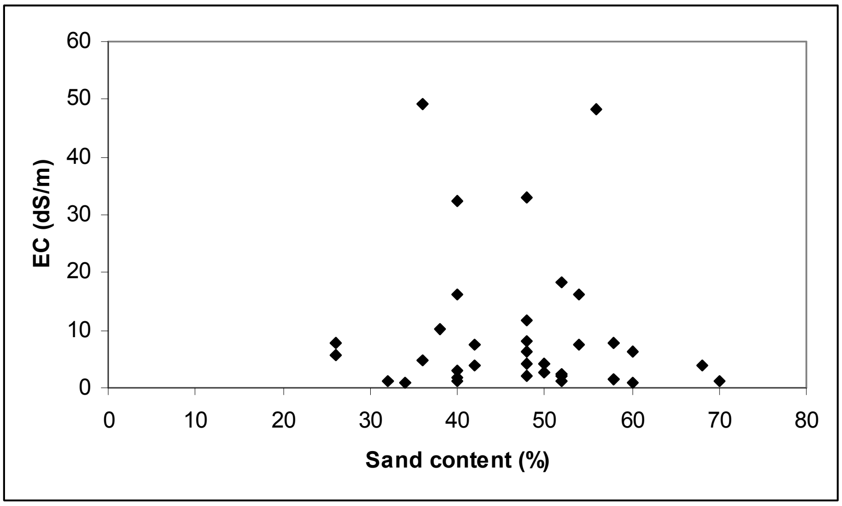
4.3 Soil physical properties

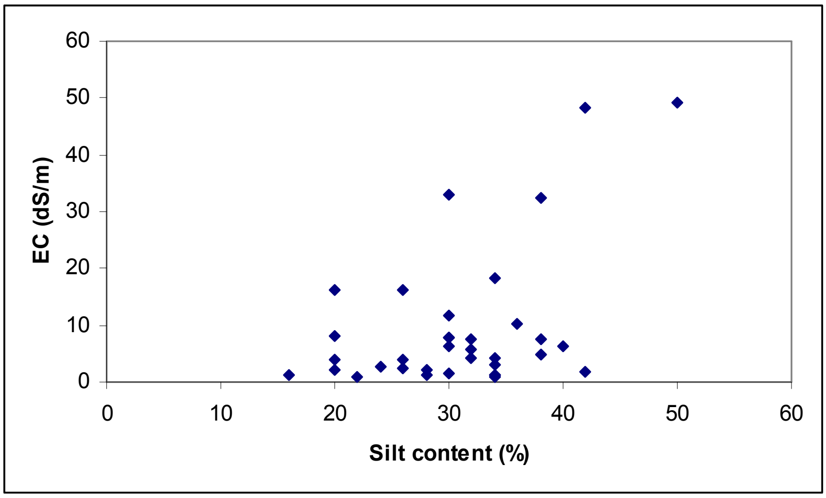
4.3.1 Particle size distribution

Soil particle distribution for the surface and subsurface layer is presented in table (12) and table (13) respectively. Correlating tables 12 and 13 with table 7 and 8 showed no obvious trends between particle size distribution and soil salinity for surface (Figure 11) and subsurface layer (Figure 12). This might indicate that the management practices were different at the different locations, particularly those with high salinity levels. Results showed variations among samples and between the two layers regarding particle size distribution. For both layers, no significant correlations ($P<0.05$) were observed between any of the soil separates and soil salinity.

Results of particle size distribution showed that most of the soils were sandy clay loam to loam for surface layer. The subsurface soil contained more clay than the surface layer.Soil sand contents were found to be relatively higher in the surface than in the subsurface except for soil samples 13, 24, 27, 30, 33, 34 and 35. Soil clay content was found to be higher in the subsurface than in the surface except for soil samples 9, 13, 26, 29, 30, 31, 32, 33 and 35.

Figure 11: Relationships between soil contents of sand (Top), silt (Middle) and clay (Bottom) and soil salinity for surface soil layers.





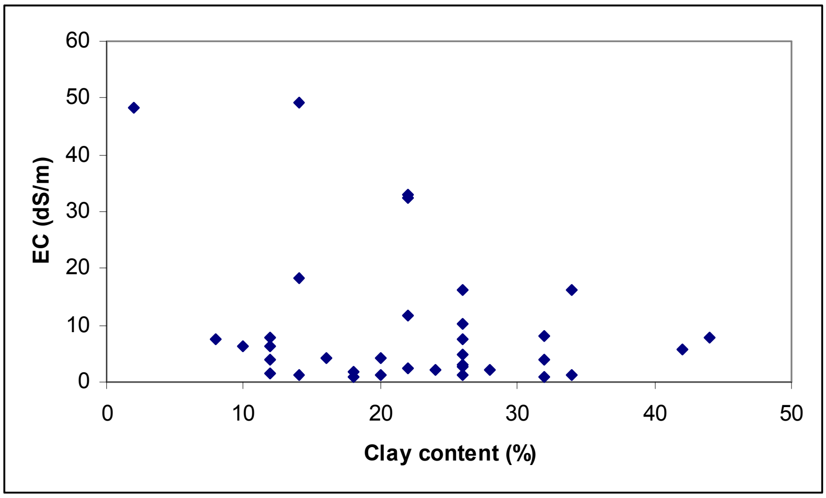


Figure 12: Relationships between soil contents of sand (Top), silt (Middle) and clay (Bottom) and soil salinity for subsurface soil layers.

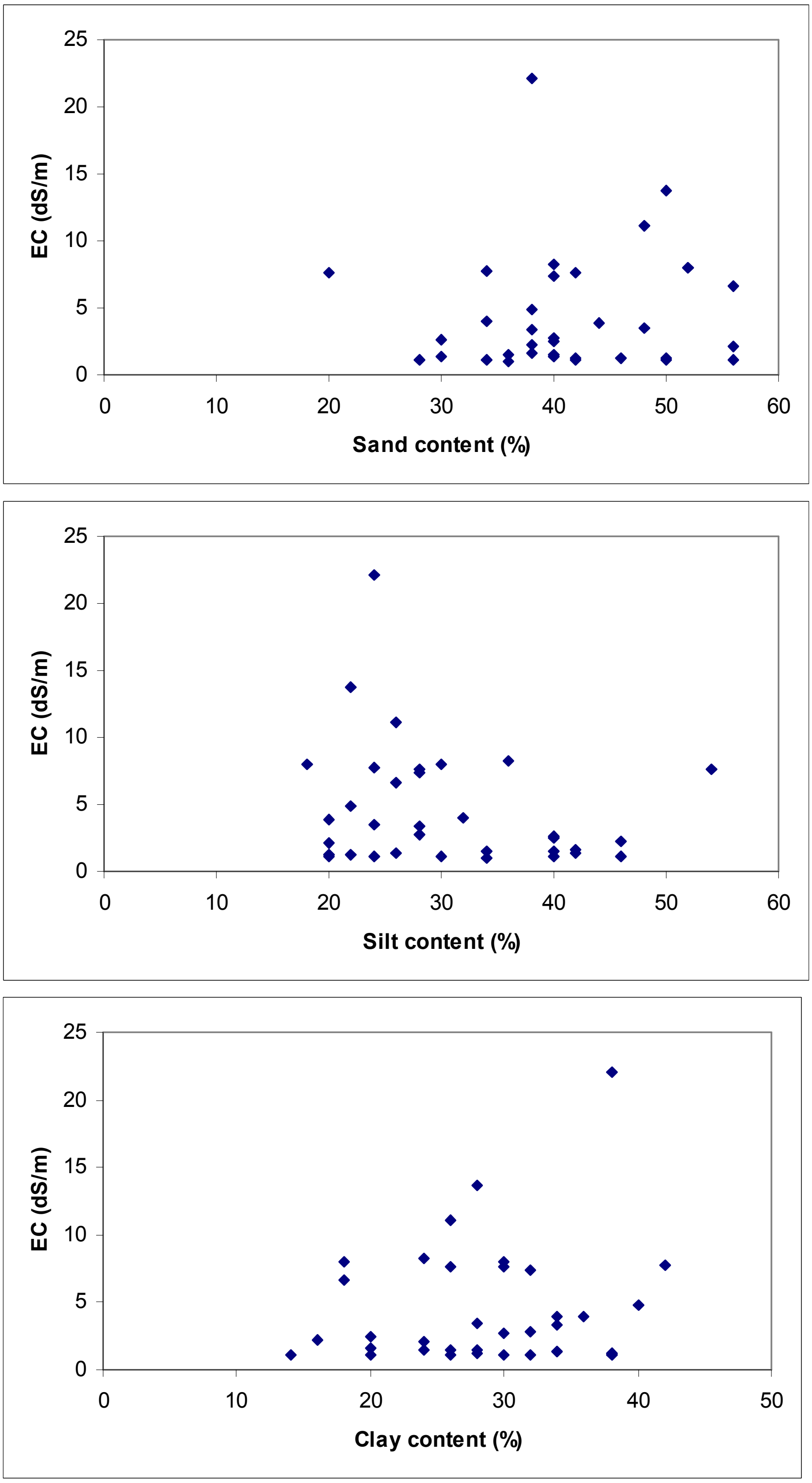


Table 12: Results of particle size distribution (%) in the surface soil layer

Sample NO.	Sand	Clay	Silt	Soil Texture
1	58	12	30	Sandy loam
2	60	18	22	Sandy loam
3	52	28	20	Sandy clay loam
4	52	22	26	Sandy clay loam
5	50	26	24	Sandy clay loam
6	70	14	16	Sandy loam
7	48	24	28	Sandy clay loam
8	52	20	28	Sandy clay loam
9	40	26	34	Loam
10	40	22	38	Loam
11	40	26	34	Loam
12	36	26	38	Loam
13	48	20	32	Loam
14	26	42	32	Clay
15	50	16	34	Loam
16	58	12	30	Sandy loam
17	32	34	34	Clay loam
18	34	32	34	Clay loam
19	52	14	34	Loam
20	68	12	20	Sandy loam
21	48	12	40	Loam
22	48	22	30	Loam
23	60	10	30	Sandy loam
24	38	26	36	Loam
25	56	2	42	Sandy loam
26	42	26	32	Loam
27	40	18	42	Loam
28	54	8	38	Loam
29	48	22	30	Loam
30	40	34	26	Clay loam
31	54	26	20	Sandy clay loam
32	42	32	26	Clay loam
33	48	32	20	Sandy clay loam
34	36	14	50	Silt loam
35	26	44	30	Clay

Table 13: Results of particle size distribution (%) in the subsurface soil layer

Sample NO.	Sand	Silt	Clay	soil texture
1	56	18	26	Sandy clay loam
2	52	18	30	Sandy clay loam
3	38	16	46	Clay
4	38	20	42	Clay
5	40	20	40	Clay
6	56	14	30	Sandy clay loam
7	34	20	46	Clay
8	40	26	34	Clay loam
9	30	28	42	Clay
10	40	24	36	Clay loam
11	36	30	34	Clay loam
12	30	30	40	Clay
13	52	30	18	Loam
14	20	26	54	Clay
15	40	32	28	Clay loam
16	56	24	20	Sandy clay loam
17	36	24	40	Clay
18	28	32	40	Clay
19	34	42	24	Loam
20	46	34	20	Loam
21	44	36	20	Loam
22	40	34	26	Loam
23	50	26	24	Sandy clay loam
24	48	26	26	Sandy clay loam
25	50	28	22	Sandy clay loam
26	38	40	22	Loam
27	42	38	20	Loam
28	38	38	24	Loam
29	42	38	20	Loam
30	42	30	28	Clay loam
31	50	28	22	Sandy clay loam
32	40	32	28	Clay loam
33	48	28	24	Sandy clay loam
34	38	34	28	Clay loam
35	34	34	32	Clay loam

4.3.2 Predicted soil physical properties

The soil physical properties that were predicted from USDA hydraulic property model are shown in tables 14 and 15 for surface and subsurface soil layers, respectively. Results of t-test (Appendix 4) showed that there were no significant differences between these properties for the surface and subsurface soil layers. There were no obvious trends found for the differences in the predicted soil bulk density for both surface and subsurface soil layers. Generally speaking, the PWP at the soil surface layers were found to be higher that that of subsurface soil layers, especially for the area near As-Samra WWTP soil samples. This could be attributed to the finer particles size distribution in this area.

4.3.3 Available water holding capacity

Available water holding capacity can be used to calculate possible irrigation interval assuming that the management allowable depletion (MAD) is about 60% for most sandy loamy soils. For most samples AWHC was 120-130 mm. These values agreed with the results of Abu Sarhan (2008) who found that the AWHC for most soil mapping units in the area was about 125 mm. For a soil depth of 40 cm the readily available water (RAW) is about 29 mm. Under maximum consumption use (ET), which was about 11 mm/day; the shortest irrigation interval was about 3 days. This interval could be accepted by many local farmers and could enhance the cultivation of alfalfa as irrigation interval is not short and dose not require high energy requirement for water pumping for Zarqa River to the farms.

Table 14: Predicted soil physical properties of surface samples.

Sample NO	Sand	Clay	Bulk Density g/cm^3	PWP m^3/cm^3	F.C m^3/cm3	AWHC m3/cm^3
1	58	12	1.52	0.10	0.21	0.12
2	60	18	1.46	0.12	0.23	0.10
3	52	28	1.38	0.16	0.27	0.11
4	52	22	1.42	0.14	0.25	0.11
5	50	26	1.39	0.15	0.27	0.11
6	70	14	1.52	0.11	0.20	0.09
7	48	24	1.40	0.14	0.26	0.12
8	52	20	1.43	0.13	0.24	0.12
9	40	26	1.37	0.15	0.28	0.13
10	40	22	1.39	0.13	0.27	0.13
11	40	26	1.37	0.15	0.28	0.13
12	36	26	1.36	0.15	0.29	0.14
13	48	20	1.42	0.13	0.25	0.12
14	26	42	1.27	0.23	0.38	0.14
15	50	16	1.46	0.11	0.24	0.12
16	58	12	1.52	0.10	0.21	0.12
17	32	34	1.31	0.19	0.33	0.14
18	34	32	1.33	0.18	0.32	0.14
19	52	14	1.48	0.10	0.23	0.12
20	68	12	1.54	0.10	0.20	0.10
21	48	12	1.50	0.10	0.23	0.13
22	48	22	1.41	0.14	0.26	0.12
23	60	11	1.55	0.09	0.21	0.12
24	38	26	1.36	0.15	0.28	0.13
25	56	2	1.47	0.07	0.21	0.14
26	42	26	1.37	0.15	0.28	0.13
27	40	18	1.42	0.12	0.26	0.14
28	54	8	1.57	0.08	0.22	0.13
29	48	22	1.41	0.14	0.26	0.12
30	40	34	1.33	0.19	0.31	0.12
31	54	26	1.40	0.15	0.26	0.11
32	42	32	1.34	0.18	0.30	0.12
33	48	32	1.35	0.18	0.29	0.11
34	36	14	1.45	0.10	0.26	0.15
35	26	44	1.26	0.25	0.39	0.14

PWP: Permanent welting point

FC: Field capacity

AWHC: Available water holding capacity

Table 15: Predicted soil physical properties of subsurface samples

Sample NO	Sand	Clay	Bulk Density g/cm^3	PWP m^3/cm^3	F.C m^3/cm^3	AWHC m^3/cm^3
1	58	12	1.52	0.10	0.21	0.12
2	60	18	1.46	0.12	0.23	0.10
3	52	28	1.38	0.16	0.27	0.11
4	52	22	1.42	0.14	0.25	0.11
5	50	26	1.39	0.15	0.27	0.11
6	70	14	1.52	0.11	0.20	0.09
7	48	24	1.40	0.14	0.26	0.12
8	52	20	1.43	0.13	0.24	0.12
9	40	26	1.37	0.15	0.28	0.13
10	40	22	1.39	0.13	0.27	0.13
11	40	26	1.37	0.15	0.28	0.13
12	36	26	1.36	0.15	0.29	0.14
13	48	20	1.42	0.13	0.25	0.12
14	26	42	1.27	0.23	0.38	0.14
15	50	16	1.46	0.11	0.24	0.12
16	58	12	1.52	0.10	0.21	0.12
17	32	34	1.31	0.19	0.33	0.14
18	34	32	1.33	0.18	0.32	0.14
19	52	14	1.48	0.10	0.23	0.12
20	68	12	1.54	0.10	0.20	0.10
21	48	12	1.50	0.10	0.23	0.13
22	48	22	1.41	0.14	0.26	0.12
23	60	11	1.55	0.09	0.21	0.12
24	38	26	1.36	0.15	0.28	0.13
25	56	2	1.47	0.07	0.21	0.14
26	42	26	1.37	0.15	0.28	0.13
27	40	18	1.42	0.12	0.26	0.14
28	54	8	1.57	0.08	0.22	0.13
29	48	22	1.41	0.14	0.26	0.12
30	40	34	1.33	0.19	0.31	0.12
31	54	26	1.40	0.15	0.26	0.11
32	42	32	1.34	0.18	0.30	0.12
33	48	32	1.35	0.18	0.29	0.11
34	36	14	1.45	0.10	0.26	0.15
35	26	44	1.26	0.25	0.39	0.14

4.4 Wastewater characterization

Data on treated wastewater quality is discussed for some properties including BOD_5, COD, TDS and pH. Data for other parameters such as SAR, Na, Ca, Mg and NO_3 is not discussed as the data was not available for many years. Also, all data for Jerash WWTP was missing for these parameters.

It should be noticed that the above parameters are important for managing soils since they have significant impact on soil physical properties. BOD_5 and COD are important for the crop and soil as they indicate the levels of organic matter in the irrigation water and crop contamination by pathogens.

4.4.1 BOD_5

Biological oxygen demand typically ranges from 10-20mg/l for most treated wastewater. However, values below 100mg/l pose no restriction for irrigation use (Pescod ,1992) According to Jordanian standard (JS893/2006), the acceptable limit of BOD_5 for forage crops, industrial crops and forest irrigation should be within 300mg/l. Data from MWI and RSS showed that, long term monthly average BOD_5 for As-samra (WWTP) in the period (1995-2004) was within the acceptable limit for forage crops. As for Jerash WWTP the long term monthly averages for the effluent BOD_5 were also acceptable for forage cultivation (Appendices 2 and 3).

4.4.2 COD

Chemical oxygen demand typically ranges from 25-50mg/l for most treated wastewater. However values below 150mg/l pose no restriction for irrigation use (Pescod, 1992) According to Jordanian standard (JS893/2006) the acceptable limit of

COD for cultivating forage crops, industrial crops and forest should be within 500mg/l. The long term monthly average of COD for As-Samra and Jerash WWTP's were within the acceptable limit for forage cultivation. However, variation among months could be noticed (Appendix 2 and 3).

4.4.3 pH

Soil pH typically ranges from 6.5-8.5 for most treated wastewater for irrigation. According to Jordanian standard (JS893/2006) the acceptable limit of pH to be reused for most agricultural practices is 6-9; this value is also recommended for all irrigation purposes. Long term average of pH for As-samra and Jerash WWTP's were within the acceptable limit for forage cultivation .It's important to mention that long term use of water outside this pH ranges could alter naturally pH level in the surface layer of soils to they applied and could possibly lead to micro nutrient imbalances and fertility problems.

4.4.4 Total Dissolved Solids

According to (JS293/2006) the acceptable limit of TDS to be reused for forage crops should be within 1500 mg/l. In the other hand, guidelines for irrigation indicate that only values below 450 mg/l pose no restriction to use, while 450-2000 mg/l is slight to moderate restriction, and values above 2000 mg/l pose a sever restriction on use (Pescod ,1992). Long term monthly average of TDS for As-Samra and Jerash WWTP's were within the acceptable limit for forage cultivation. Although water quality parameters were within the limits for irrigating forage, however, the salinity levels of water was relatively high and resulted in high leaching requirements which could result in high return flow from irrigated lands on both sides of the Zarqa River.

4.5 Land suitability based on interpolated soil properties

Initial results of suitability map for irrigating alfalfa showed eleven classes distributed in the study area. Most of the area was suitable for the proposed land use expect the area with high soil salinity. These areas were mainly located near As-Samra (Figure 7) where high salinity of water and high evaporation rates were existing. Crop water requirements were relatively high for most of the area. (As discussed in section 4.6). The result of cross tabulation analysis for land use and suitability map is shown in Table 16.

Table 16: Area percentages resulted from cross tabulation

Land use map	EC Classes				
Class	Highly suitable	Moderately suitable	Marginally suitable	Not suitable	Total
Olive trees	0.00	0.00	0.00	1.00	1.00
Mixed agriculture	0.23	0.08	0.31	0.38	1.00
Non cultivated	0.00	0.00	0.00	1.00	1.00
Rainfed arable and forage	0.00	0.33	0.33	0.33	1.00

Results show that only 23% of mixed agricultural area (olive trees and forage crops) were highly suitable class for forage. Generally, rainfed arable and forage compromises 33% of there area in moderately suitable class and 33% lies in marginally suitable. So, the rest of the area (33%) must be replaced with other suitable crops according to the EC values and the crop tolerant levels.

Farms of olive trees were mainly located in areas that do not suite for alfalfa cultivation, so these farms must not change toward forage cultivation. None cultivated area where pumping of water must be practiced was also not suitable for forage cultivation. Also, the most suitable area for forage is the down stream area around Jerash and few locations around As-Samra. The dominant cropping pattern is against soil potential and so this research recommends a shift program toward fodder cultivation and this can be done according to the resulted maps from the study.

4.6 Crop water requirement

Table 17 shows the average seasonal crop water requirement for each sampling site. Results showed that high rates of crop water requirements in the area near As-Samra where the annual CWR ranged between 3,800 to 4,200 mm/year and decreased towards KTD (Appendix 7). The average CWR was 3675 mm, while the total CWR at the study area was around 91 MCM calculated by multiplying average CWR with the total area. Such results could be attributed to high rates of evapotranspiration, and the low efficiency of surface irrigation. The interpolated map of CWR for the study area is shown in Figure 13.

Generally, the figures of CWR were relatively high as both soil and water were relatively saline. Therefore, it is important to reduce these figures by increasing irrigation efficiency at farm levels and by the use of fresh water to leach salts at the end of the season. For many farms, this is possible as ground water is available, particularly near Jerash. Considering the high CWR and the suitability map of the NSMLUP, most of the suitable areas for irrigation would require high CWR. This would increase soil salinity in the absence of drainage systems. Therefore, a monitoring scheme should be implemented to prevent salinity buildup in this area.

Figure 13: Map of crop water requirement of the study area

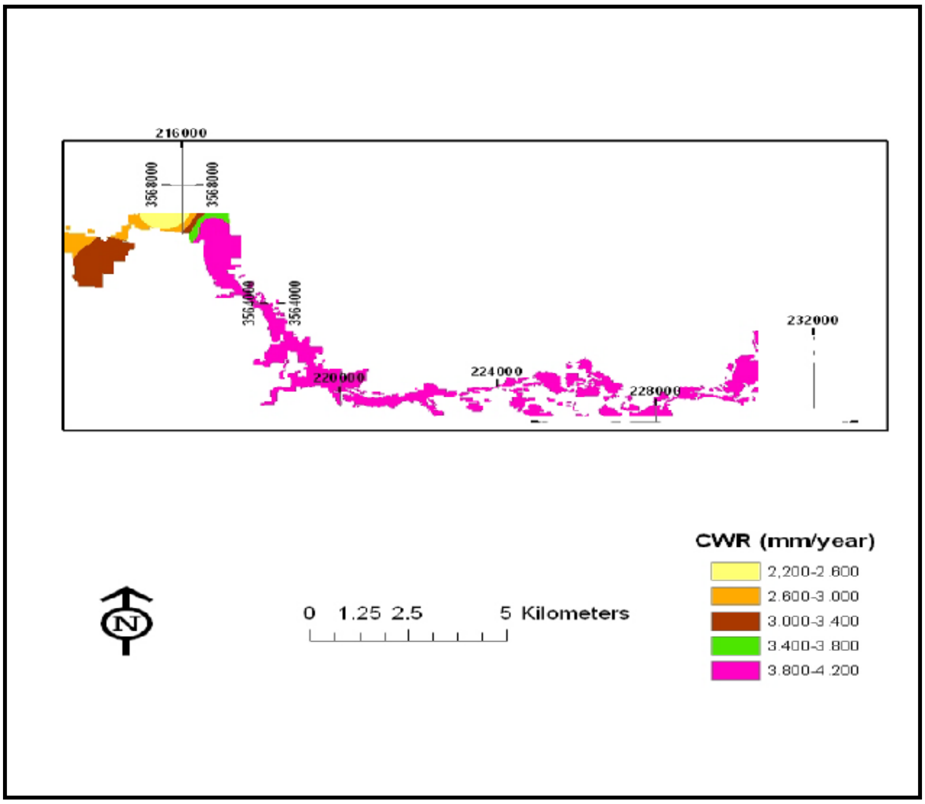


Table 17: Seosonal crop water requirment (mm) for sampling locations

Sample NO.	Seasonal CWR (mm)
1	2,234
2	2,225
3	2,241
4	2,242
5	2,216
6	2,289
7	2,262
8	2,286
9	2,245
10	4,153
11	4,249
12	4,182
13	4,168
14	4,179
15	4,160
16	4,167
17	4,220
18	4,247
19	4,170
20	4,170
21	4,179
22	4,150
23	4,186
24	4,159
25	4,155
26	4,024
27	4,213
28	4,151
29	4,151
30	4,151
31	4,157
32	4,172
33	4,172
34	4,141
35	4,160
Average	**3675**

5. CONCLUSIONS

- Results of the study showed that about 30 % of the area was suitable for alfalfa with estimated crop water requirements of less than 3000 mm/year. Other areas are either requiring high crop water requirements or not suitable for cultivation with alfalfa.
- Most of the study area had high salinity levels which could reflect improper management practices and/or the insufficient treatment of water.
- Most suitable area for alfalfa is the down stream area around Jerash and few locations near As-Samra.
- Water quality of the treated wastewater was within Jordanian standards limits
- High crop water requirements were observed in the area. This could lead to salinity buildup in the absence of good management and drainage.
- High levels of N, P and K in both soil and water were observed in the study area. This could enhance the cultivation of alfalfa as these macronutrients are not required as fertilizers.

6. RECOMMENDATIONS

- It is recommended to prioritize the down stream areas near Jerash and some locations around As-Samra for alfalfa cultivation according to the output maps of the study.
- It is recommended to enhance the cultivation of forage crops like alfalfa, as N, P and K enrichment was observed in the study area.
- It is recommended to adopt the proposed approach to estimate crop water requirement based on the interpolated soil properties and climatic data on the form of GIS maps.
- Crop water requirements, and possibly rotations, should be considered in using treated wastewater in irrigating crops

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APPENDICES

APPENDIX 1

EVAPOTRANSPIRATION CALCULATION

Appendix 1.1. Parameters of evapotranspirartion.

Atmospheric pressure (P)

$$P = 101.3\left(\frac{293 - 0.0065z}{293}\right)^{5.26} \qquad \ldots(1)$$

where
P: atmospheric pressure [kPa],
z: elevation above sea level [m].

- **Latent heat of vaporization (λ)**

The latent heat of vaporization was assumed to be 2.45 MJ kg^{-1}. This is the latent heat for an air temperature of about 20°C.

- **Psychrometric constant (γ)**

$$\gamma = \frac{c_p P}{\varepsilon\lambda} = 0.665 \times 10^{-3} P \qquad \ldots(2)$$

where
λ: psychrometric constant [kPa $°C^{-1}$],
P: atmospheric pressure [kPa],
γ: latent heat of vaporization, 2.45 [MJ kg^{-1}],
cp: specific heat at constant pressure, 1.013 10^{-3} [MJ kg^{-1} $°C^{-1}$],
ε: ratio molecular weight of water vapor/dry air = 0.622.

- **Mean air temperature (T_{mean})**

$$T_{mean} = \frac{T_{\max} - T_{\min}}{2} \qquad \ldots(3)$$

where
T_{max}: maximum air temperature,
T_{min}: minimum air temperature.

- **Mean saturation vapor pressure (e_s)**

$$e^o(T) = 0.6108 \exp\left[\frac{17.27T}{T + 237.3}\right] \quad \ldots(4)$$

where
e°(T): saturation vapor pressure at the air temperature T [kPa],
T: air temperature [°C].

$$e_s = \frac{e^o(T_{max}) + e^o(T_{min})}{2} \quad \ldots(5)$$

- **Slope of saturation vapor pressure curve (Δ)**

$$\Delta = \frac{4098\left[0.6108 \exp\left(\frac{17.27T}{T + 237.3}\right)\right]}{(T + 237.3)^2} \quad \ldots(6)$$

where
Δ: slope of saturation vapor pressure curve at air temperature T (kPa $°C^{-1}$),
T: air temperature [°C].

- **For RH_{max} and RH_{min}:**

$$e_a = \frac{e^o(T_{min})\frac{RH_{max}}{100} + e^o(T_{max})\frac{RH_{min}}{100}}{2} \quad \ldots(7)$$

where
e_a: actual vapor pressure (kPa),
$e°(T_{min})$: saturation vapor pressure at daily minimum temperature (kPa),
$e°(T_{max})$: saturation vapor pressure at daily maximum temperature (kPa),
RH_{max}: maximum relative humidity (%),
RH_{min}: minimum relative humidity (%).

- **Vapor pressure deficit (e_s - e_a)**

The difference between Equation 5 and 7.

- **Extraterrestrial radiation (R_a)**

$$R_a = \frac{24(60)}{\pi} G_{sc} d_r [\omega_s \sin(\varphi)] \sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_s) \qquad \ldots(8)$$

where
R_a: extraterrestrial radiation [MJ m^{-2} day^{-1}],
G_{sc}: solar constant = 0.0820 MJ m^{-2} min^{-1},
dr: inverse relative distance Earth-Sun,
ω**s:** sunset hour angle [rad],
φ**:** latitude [rad],
δ**:** solar decimation [rad].

$$[Raidians] = \frac{\pi}{180}[decimal \deg rees] \qquad \ldots(9)$$

The inverse relative distance Earth-Sun, d_r, and the solar declination, δ, is given by:

$$d_r = 1 + 0.033\cos\left(\frac{2\pi}{365}J\right) \qquad \ldots(10)$$

$$\delta = 0.409\sin\left(\frac{2\pi}{365}J - 1.39\right) \qquad \ldots(11)$$

where J is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December), i.e. DOY. Values for J for all days of the year and an equation for estimating J are given in Annex A. The sunset hour angle, ω**s**, is given by:

$$\omega_s = \arccos[-\tan(\varphi)\tan(\delta)] \qquad ...(12)$$

- **Clear-sky solar radiation (R_{so})**

$$R_{so} = (0.75 + 2\times10^{-5} z)R_a \qquad ...(13)$$

where z: station elevation above sea level which equals 980 m.

- **Net solar or net shortwave radiation (R_{ns})**

$$R_{ns} = (1-\alpha)R_s \qquad ...(14)$$

where
R_{ns}: net solar or shortwave radiation [MJ m^{-2} day^{-1}],
α: albedo or canopy reflection coefficient, which is 0.23 for the hypothetical grass reference crop [dimensionless],
R_s: the incoming solar radiation [MJ m^{-2} day^{-1}].

- **Net longwave radiation (R_{nl})**

$$R_{nl} = \sigma\left[\frac{T_{\max K}{}^4 + T_{\min K}{}^4}{2}\right]\left(0.34 - 0.14\sqrt{e_a}\right)\left(1.35\frac{R_s}{R_{so}} - 0.35\right) \qquad ...(15)$$

where
R_{nl}: net outgoing longwave radiation [MJ m^{-2} day^{-1}],
σ: Stefan-Boltzmann constant [4.903 10^{-9} MJ K^{-4} m^{-2} day^{-1}],
$T_{max, K}$: maximum absolute temperature during the 24-hour period [K = °C + 273.16],
$T_{min, K}$: minimum absolute temperature during the 24-hour period [K = °C + 273.16],
e_a: actual vapor pressure [kPa],
R_s/R_{so}: relative shortwave radiation (limited to ≤ 1.0),
R_s: measured or calculated solar radiation [MJ m^{-2} day^{-1}],
R_{so}: calculated clear-sky radiation [MJ m^{-2} day^{-1}].

- **Net radiation (Rn)**

$$R_n = R_{ns} - R_{nl} \qquad .....16$$

Appendix 1.2: Results of daily evapotranspiration.

Date Month Day	MAX Tair (C)	MIN Tair (C)	MAX RH (%)	MIN RH (%)	AVG WindSpd (m/s)	AVG Rn MJ	AVG Press (Kpa)	Tmean	Kpa e(Tmax)	Kpa e(Tmin)	Kpa es	Kpa ea	Kpa es-ea	ETo mm/day Alfa-alfa
01-JAN	19.36	4.09	97.00	42.94	2.27	3.59	94.90	11.73	2.25	0.82	1.53	0.88	0.65	3.16
02- JAN	18.18	3.60	100.00	54.69	1.36	3.95	94.88	10.89	2.09	0.79	1.44	0.97	0.47	2.02
0-3 JAN	18.82	3.64	91.00	77.27	2.27	4.18	94.89	11.23	2.17	0.79	1.48	1.20	0.28	1.84
04- JAN	17.68	3.36	86.00	78.30	1.91	3.65	94.88	10.52	2.02	0.78	1.40	1.13	0.27	1.61
05- JAN	18.36	2.64	76.00	61.75	2.41	3.69	94.87	10.50	2.11	0.74	1.43	0.93	0.49	2.68
06- JAN	17.18	3.00	97.00	54.94	2.55	3.53	94.87	10.09	1.96	0.76	1.36	0.91	0.45	2.56
07- JAN	17.00	2.45	98.00	41.53	2.86	3.25	94.86	9.73	1.94	0.73	1.33	0.76	0.57	3.26
08- JAN	13.27	1.00	98.00	43.69	1.45	3.63	94.80	7.14	1.52	0.66	1.09	0.65	0.44	1.98
09- JAN	17.55	1.91	97.00	36.55	1.14	3.79	94.86	9.73	2.01	0.70	1.35	0.71	0.65	2.26
10- JAN	15.27	2.82	91.00	44.90	2.36	4.01	94.84	9.05	1.74	0.75	1.24	0.73	0.51	2.84
11- JAN	16.82	2.64	96.00	47.57	2.18	3.61	94.86	9.73	1.92	0.74	1.33	0.81	0.52	2.66
12- JAN	17.91	2.00	100.00	33.18	1.68	3.83	94.86	9.95	2.05	0.71	1.38	0.69	0.69	2.91
13- JAN	16.18	0.73	97.00	33.46	2.82	3.92	94.83	8.45	1.84	0.64	1.24	0.62	0.62	3.64
14- JAN	18.45	3.00	97.00	49.62	1.91	4.03	94.88	10.73	2.12	0.76	1.44	0.89	0.55	2.63
15- JAN	18.00	3.18	97.00	73.98	4.73	4.24	94.88	10.59	2.06	0.77	1.42	1.14	0.28	2.37
16- JAN	16.09	2.55	99.00	53.95	1.05	4.10	94.85	9.32	1.83	0.73	1.28	0.86	0.42	1.74
17- JAN	15.41	2.00	100.00	50.96	0.55	3.70	94.83	8.70	1.75	0.71	1.23	0.80	0.43	1.31
18- JAN	13.18	1.36	100.00	76.30	1.45	3.64	94.80	7.27	1.52	0.67	1.09	0.92	0.18	1.18
19- JAN	14.41	1.64	97.00	60.65	2.18	3.50	94.82	8.02	1.64	0.69	1.16	0.83	0.33	1.94
20- JAN	13.27	2.73	92.00	81.00	1.82	4.23	94.82	8.00	1.52	0.74	1.13	0.96	0.17	1.34
21 - JAN	14.45	3.00	99.00	66.32	2.55	4.55	94.84	8.73	1.65	0.76	1.20	0.92	0.28	1.99
22-- JAN	14.09	2.64	98.00	84.78	2.00	4.36	94.83	8.36	1.61	0.74	1.17	1.04	0.13	1.22

Appendix 1.2 continued

23- JAN	13.55	2.09	83.00	73.50	2.55	4.76	94.81	7.82	1.55	0.71	1.13	0.87	0.27	1.95
24- JAN	13.59	2.45	62.00	60.66	2.55	4.14	94.82	8.02	1.56	0.73	1.14	0.70	0.44	2.69
25- JAN	14.82	1.82	93.00	50.51	2.36	4.54	94.83	8.32	1.69	0.70	1.19	0.75	0.44	2.64
26- JAN	14.18	2.36	96.00	49.29	1.73	4.37	94.83	8.27	1.62	0.72	1.17	0.75	0.42	2.21
27- JAN	14.64	3.64	99.00	55.59	2.86	4.32	94.84	9.14	1.67	0.79	1.23	0.86	0.37	2.48
28- JAN	14.86	2.36	99.00	47.18	2.27	4.87	94.83	8.61	1.69	0.72	1.21	0.76	0.45	2.67
29- JAN	13.91	2.09	95.00	46.20	2.32	4.36	94.82	8.00	1.59	0.71	1.15	0.70	0.45	2.61
30- JAN	12.85	2.29	91.00	40.75	2.09	4.90	94.81	7.57	1.48	0.72	1.10	0.63	0.47	2.7
31- JAN	19.09	3.27	95.00	47.39	3.91	5.09	94.89	11.18	2.21	0.77	1.49	0.89	0.60	4.15
01-FEB	17.73	1.64	95.00	30.94	1.73	5.26	94.86	9.68	2.03	0.69	1.36	0.64	0.72	3.33
02- FEB	17.00	2.36	100.00	48.69	1.73	5.34	94.86	9.68	1.94	0.72	1.33	0.83	0.50	2.61
03- FEB	16.00	2.73	100.00	36.77	2.41	5.08	94.85	9.36	1.82	0.74	1.28	0.71	0.57	3.29
04- FEB	15.09	3.09	97.00	71.64	2.73	4.75	94.84	9.09	1.72	0.76	1.24	0.98	0.25	1.94
05- FEB	14.05	1.73	96.00	72.48	2.55	4.31	94.82	7.89	1.60	0.69	1.15	0.91	0.23	1.74
06- FEB	14.14	1.36	99.00	59.30	2.27	5.70	94.81	7.75	1.61	0.67	1.14	0.81	0.33	2.31
07- FEB	15.45	2.82	99.00	56.58	3.18	5.86	94.84	9.14	1.76	0.75	1.25	0.87	0.38	2.87
08- FEB	15.91	2.55	99.00	78.54	2.00	5.96	94.85	9.23	1.81	0.73	1.27	1.07	0.20	1.75
09- FEB	16.36	3.45	86.00	78.00	2.64	5.51	94.86	9.91	1.86	0.78	1.32	1.06	0.26	2.06
10- FEB	17.64	4.00	73.00	71.62	2.36	6.41	94.88	10.82	2.02	0.81	1.42	1.02	0.40	2.71
11- FEB	16.09	1.91	87.00	68.58	5.18	5.72	94.84	9.00	1.83	0.70	1.26	0.93	0.33	3.01
12- FEB	15.55	4.27	86.00	71.92	27.27	7.23	94.86	9.91	1.77	0.83	1.30	0.99	0.31	4.03
13- FEB	17.09	1.91	95.00	64.07	2.23	7.43	94.85	9.50	1.95	0.70	1.32	0.96	0.37	2.72
14- FEB	15.95	4.36	99.00	76.75	3.91	5.51	94.87	10.16	1.81	0.83	1.32	1.11	0.21	2.03
15- FEB	14.45	1.91	94.00	64.79	2.36	6.90	94.82	8.18	1.65	0.70	1.17	0.86	0.31	2.44
16- FEB	17.09	2.64	97.00	61.20	1.64	6.43	94.86	9.86	1.95	0.74	1.34	0.95	0.39	2.4

Appendix 1.2 continued

17- FEB	15.98	2.83	94.00	41.57	5.00	6.53	94.85	9.40	1.82	0.75	1.28	0.73	0.55
18- FEB	18.36	2.36	90.00	39.47	1.82	6.80	94.87	10.36	2.11	0.72	1.42	0.74	0.68
19- FEB	17.27	2.82	97.00	41.86	2.68	7.05	94.86	10.05	1.97	0.75	1.36	0.78	0.58
20- FEB	17.18	2.55	100.00	74.01	4.45	7.58	94.86	9.86	1.96	0.73	1.35	1.09	0.25
21- FEB	16.00	2.27	97.00	51.46	2.91	6.81	94.84	9.14	1.82	0.72	1.27	0.82	0.45
22- FEB	16.18	2.73	85.00	69.30	2.68	7.05	94.85	9.45	1.84	0.74	1.29	0.95	0.34
23- FEB	18.45	2.55	80.00	59.96	2.77	7.27	94.87	10.50	2.12	0.73	1.43	0.93	0.50
24- FEB	19.45	2.91	96.00	72.22	3.45	8.23	94.89	11.18	2.26	0.75	1.51	1.18	0.33
25- FEB	17.27	2.36	72.00	60.00	4.09	7.66	94.86	9.82	1.97	0.72	1.35	0.85	0.50
26- FEB	17.06	2.54	97.00	60.41	3.08	7.99	94.86	9.80	1.95	0.73	1.34	0.94	0.40
27- FEB	19.09	3.73	92.00	60.37	2.73	8.04	94.89	11.41	2.21	0.80	1.50	1.03	0.47
28- FEB	18.59	2.73	60.00	59.07	1.68	7.96	94.88	10.66	2.14	0.74	1.44	0.86	0.59
29- FEB	18.00	3.20	50.00	37.35	1.20	6.53	94.88	10.60	2.06	0.77	1.42	0.58	0.84
01-MAR	21.59	4.41	44.00	26.57	3.09	6.99	94.93	13.00	2.58	0.84	1.71	0.53	1.18
02- MAR	21.27	4.91	56.00	48.76	3.36	6.98	94.93	13.09	2.53	0.87	1.70	0.86	0.84
03- MAR	21.18	5.27	70.00	54.23	2.98	8.08	94.93	13.23	2.51	0.89	1.70	0.99	0.71
04- MAR	21.59	4.55	55.00	35.62	3.64	8.64	94.93	13.07	2.58	0.85	1.71	0.69	1.02
05- MAR	22.55	4.36	56.00	39.15	2.55	7.69	94.94	13.45	2.73	0.83	1.78	0.77	1.02
06- MAR	22.82	5.09	90.00	66.48	5.36	9.66	94.95	13.95	2.78	0.88	1.83	1.32	0.51
07- MAR	22.82	5.09	80.00	39.38	5.36	7.51	94.95	13.95	2.78	0.88	1.83	0.90	0.93
08- MAR	19.23	4.45	92.00	75.31	2.45	10.17	94.90	11.84	2.23	0.84	1.53	1.23	0.31
09- MAR	20.00	4.09	70.00	66.00	3.00	9.96	94.91	12.05	2.34	0.82	1.58	1.06	0.52
10- MAR	20.59	4.27	88.00	50.58	3.55	10.17	94.92	12.43	2.43	0.83	1.63	0.98	0.65
11- MAR	22.41	4.91	67.00	60.00	2.27	9.65	94.94	13.66	2.71	0.87	1.79	1.10	0.69
12- MAR	19.09	5.55	85.00	61.37	2.36	10.11	94.91	12.32	2.21	0.91	1.56	1.06	0.49
13- MAR	20.91	4.27	96.00	45.88	2.18	9.46	94.92	12.59	2.47	0.83	1.65	0.97	0.69
14- MAR	21.27	4.27	96.00	33.86	2.18	8.58	94.92	12.77	2.53	0.83	1.68	0.83	0.85
15- MAR	22.36	4.27	80.00	52.55	2.50	7.62	94.94	13.32	2.70	0.83	1.77	1.04	0.72
16- MAR	21.68	4.82	60.00	40.35	3.45	8.75	94.93	13.25	2.59	0.86	1.73	0.78	0.95
17- MAR	20.27	4.95	60.00	33.18	3.36	8.10	94.92	12.61	2.38	0.87	1.62	0.66	0.97
18- MAR	21.64	6.09	83.00	63.55	3.09	8.76	94.95	13.86	2.59	0.94	1.76	1.21	0.55

Appendix 1.2 continued

19-MAR	20.82	5.82	87.00	50.59	2.64	10.73	94.94	13.32	2.46	0.92	1.69	1.02
20- MAR	21.50	4.64	92.00	50.47	3.00	11.55	94.93	13.07	2.56	0.85	1.71	1.04
21- MAR	21.36	12.55	80.00	44.00	2.82	10.54	95.01	16.95	2.54	1.45	2.00	1.14
22- MAR	21.64	4.91	60.00	44.12	3.55	9.21	94.94	13.27	2.59	0.87	1.73	0.83
23- MAR	18.58	4.92	50.00	30.00	5.08	8.79	94.90	11.75	2.14	0.87	1.50	0.54
24- MAR	19.09	4.86	40.00	30.00	4.09	7.79	94.91	11.98	2.21	0.86	1.54	0.50
25- MAR	21.64	4.73	65.00	61.69	4.20	9.19	94.93	13.18	2.59	0.86	1.72	1.08
26- MAR	22.73	5.09	68.00	46.17	2.18	10.35	94.95	13.91	2.76	0.88	1.82	0.94
27- MAR	22.64	7.00	65.00	28.42	2.36	8.91	94.97	14.82	2.75	1.00	1.88	0.72
28- MAR	23.41	6.18	26.00	25.00	3.27	10.27	94.97	14.80	2.88	0.95	1.91	0.48
29- MAR	24.41	6.09	32.00	30.00	3.09	9.16	94.98	15.25	3.06	0.94	2.00	0.61
30- MAR	25.09	6.36	49.00	30.12	2.82	10.99	94.99	15.73	3.18	0.96	2.07	0.71
31- MAR	24.73	5.73	87.00	33.00	2.18	12.21	94.98	15.23	3.12	0.92	2.02	0.91
01-APR	24.73	5.73	96.00	39.89	2.18	9.43	94.98	15.23	3.12	0.92	2.02	1.06
02- APR	24.55	6.82	75.00	35.37	2.82	11.05	94.99	15.68	3.08	0.99	2.04	0.92
03- APR	24.09	6.45	84.00	39.57	2.15	10.40	94.98	15.27	3.00	0.96	1.98	1.00
04- APR	23.82	6.64	86.00	29.70	2.18	13.01	94.98	15.23	2.95	0.98	1.96	0.86
05- APR	25.73	6.45	46.00	42.74	31.91	13.10	95.00	16.09	3.31	0.96	2.14	0.93
06- APR	26.73	7.27	40.00	37.57	3.09	12.92	95.01	17.00	3.51	1.02	2.26	0.86
07- APR	25.55	6.55	90.00	34.22	3.36	12.06	94.99	16.05	3.27	0.97	2.12	1.00
08- APR	25.86	5.95	80.00	46.40	4.55	13.27	94.99	15.91	3.33	0.93	2.13	1.15
09- APR	25.23	6.64	62.00	37.84	2.86	11.54	94.99	15.93	3.21	0.98	2.09	0.91
10- APR	25.00	6.55	40.00	25.51	2.73	12.12	94.99	15.77	3.17	0.97	2.07	0.60
11- APR	23.18	6.64	34.00	23.59	2.68	11.56	94.97	14.91	2.84	0.98	1.91	0.50
12- APR	28.05	6.36	28.00	25.00	2.73	10.81	95.02	17.20	3.79	0.96	2.37	0.61
13- APR	28.55	7.73	27.00	25.00	2.82	10.81	95.04	18.14	3.90	1.05	2.48	0.63
14- APR	24.91	7.45	29.00	25.00	2.73	12.33	95.00	16.18	3.15	1.03	2.09	0.54
15- APR	24.09	7.27	44.00	30.00	3.00	11.88	94.99	15.68	3.00	1.02	2.01	0.67
16- APR	28.86	9.41	86.00	25.88	3.36	12.32	95.06	19.14	3.97	1.18	2.58	1.02
17- APR	30.75	7.80	87.00	19.23	4.50	11.95	95.06	19.28	4.43	1.06	2.74	0.89
18- APR	31.64	8.45	81.00	37.68	3.18	13.69	95.08	20.05	4.66	1.11	2.88	1.33

Appendix 1.2 continued

19- APR	17.27	2.82	97.00	41.86	2.68	7.05	94.86	10.05	1.97	0.75	1.36	0.78	0.58	3.79
20- APR	17.18	2.55	100.00	74.01	4.45	7.58	94.86	9.86	1.96	0.73	1.35	1.09	0.25	2.61
21- APR	30.45	8.41	75.00	39.30	4.00	12.09	95.07	19.43	4.35	1.10	2.73	1.27	1.46	9.05
22- APR	27.27	7.27	85.00	35.37	4.45	14.14	95.02	17.27	3.62	1.02	2.32	1.07	1.25	9
23- APR	27.73	6.55	82.00	43.74	2.36	14.40	95.02	17.14	3.72	0.97	2.35	1.21	1.13	6.82
24- APR	28.86	7.09	87.00	29.39	2.73	11.65	95.04	17.98	3.97	1.01	2.49	1.02	1.47	7.77
25- APR	27.95	6.91	92.00	47.81	2.27	13.88	95.02	17.43	3.77	1.00	2.38	1.36	1.02	6.25
26- APR	28.09	7.27	41.00	30.00	3.73	12.85	95.03	17.68	3.80	1.02	2.41	0.78	1.63	9.93
27- APR	29.27	7.18	29.00	25.00	2.91	12.26	95.04	18.23	4.07	1.01	2.54	0.66	1.89	9.69
28- APR	28.45	7.91	35.00	23.26	3.27	13.20	95.04	18.18	3.88	1.07	2.47	0.64	1.84	10.23
29- APR	27.73	7.32	35.00	30.31	3.80	13.43	95.03	17.52	3.72	1.02	2.37	0.74	1.63	10.14
30- APR	26.95	7.73	88.00	28.54	3.36	12.61	95.02	17.34	3.56	1.05	2.30	0.97	1.33	8.2
01-MAY	32.73	8.55	94.00	32.93	2.45	12.36	95.09	20.64	4.95	1.11	3.03	1.34	1.69	8.05
02-MAY	33.27	8.64	84.00	32.74	2.18	12.06	95.10	20.95	5.11	1.12	3.11	1.31	1.81	7.86
03 MAY	33.36	8.45	75.00	35.00	2.00	11.36	95.10	20.91	5.13	1.11	3.12	1.31	1.81	7.4
04 MAY	33.82	8.27	95.00	33.18	2.27	14.92	95.10	21.05	5.27	1.09	3.18	1.39	1.79	8.6
05 MAY	32.64	8.18	71.00	29.72	3.36	14.82	95.09	20.41	4.93	1.09	3.01	1.12	1.89	10.57
06-MAY	33.91	8.64	68.00	22.22	2.73	12.58	95.10	21.27	5.29	1.12	3.21	0.97	2.24	10.2
07 MAY	34.95	10.36	31.00	25.23	2.70	14.06	95.13	22.66	5.61	1.26	3.43	0.90	2.53	11.17
08 MAY	32.91	10.36	38.00	30.72	3.00	13.74	95.11	21.64	5.00	1.26	3.13	1.01	2.12	10.48
09-MAY	32.64	9.05	37.00	34.65	2.64	13.19	95.09	20.84	4.93	1.15	3.04	1.07	1.97	9.37
10-MAY	32.82	9.00	25.00	16.00	2.50	13.72	95.10	20.91	4.98	1.15	3.06	0.54	2.52	10.97
11-MAY	35.45	10.91	71.00	38.02	3.45	15.54	95.14	23.18	5.77	1.30	3.54	1.56	1.98	10.76
12-MAY	34.32	11.64	96.00	35.20	3.27	15.55	95.14	22.98	5.41	1.37	3.39	1.61	1.78	9.85
13-MAY	34.05	12.09	96.00	35.92	5.00	15.53	95.14	23.07	5.33	1.41	3.37	1.64	1.74	11.44
14-MAY	32.00	10.91	42.00	41.55	2.64	13.95	95.11	21.45	4.75	1.30	3.03	1.26	1.77	8.8
15-MAY	32.68	11.36	80.00	35.86	1.91	15.38	95.12	22.02	4.94	1.34	3.14	1.42	1.72	7.91
16-MAY	31.09	9.36	82.00	42.27	3.00	16.71	95.08	20.23	4.52	1.18	2.85	1.44	1.41	8.72
17-MAY	32.36	10.82	87.00	37.56	3.82	15.51	95.11	21.59	4.85	1.30	3.08	1.48	1.60	9.9
18-MAY	34.00	13.82	50.00	39.14	2.30	16.50	95.16	23.91	5.32	1.58	3.45	1.44	2.01	9.36
19-MAY	34.27	13.55	41.00	25.01	2.40	15.18	95.16	23.91	5.40	1.55	3.48	0.99	2.48	10.48

Appendix 1.2 continued

20- MAY	32.18	10.55	65.00	45.21	3.36	16.33	95.11	21.36	4.80	1.27	3.04	1.50	1.54	9.4
21- MAY	34.10	12.10	80.00	46.03	4.10	17.29	95.14	23.10	5.35	1.41	3.38	1.80	1.58	10.3
22- MAY	32.82	11.95	86.00	38.44	2.91	15.97	95.13	22.39	4.98	1.40	3.19	1.56	1.63	9.06
23- MAY	34.09	10.40	81.00	37.87	2.64	16.71	95.12	22.25	5.35	1.26	3.30	1.52	1.78	9.39
24- MAY	34.00	11.30	64.00	43.17	2.91	16.90	95.13	22.65	5.32	1.34	3.33	1.58	1.75	9.65
25- MAY	36.73	12.30	45.00	38.79	3.18	16.41	95.17	24.51	6.18	1.43	3.81	1.52	2.29	11.45
26- MAY	35.27	12.10	64.00	47.94	3.18	15.34	95.15	23.69	5.71	1.41	3.56	1.82	1.74	9.47
27- MAY	32.27	16.30	38.00	35.00	3.00	15.44	95.17	24.29	4.83	1.85	3.34	1.20	2.14	10.52
28- MAY	33.64	14.00	72.00	31.40	2.36	16.13	95.16	23.82	5.21	1.60	3.41	1.39	2.01	9.37
29- MAY	34.36	13.90	76.00	60.35	3.91	17.91	95.16	24.13	5.43	1.59	3.51	2.24	1.27	8.9
30- MAY	34.45	11.00	44.00	40.00	3.09	15.94	95.13	22.73	5.46	1.31	3.38	1.38	2.00	10.52
31- MAY	35.36	15.10	36.00	49.24	3.09	16.17	95.18	25.23	5.74	1.72	3.73	1.72	2.01	10.24
01-JUN	34.18	13.09	72.00	39.38	3.82	16.72	95.15	23.64	5.37	1.51	3.44	1.60	1.84	10.87
02- JUN	33.68	13.36	80.00	40.80	3.83	17.11	95.15	23.52	5.23	1.53	3.38	1.68	1.70	10.43
03- JUN	34.00	14.09	97.00	44.24	5.50	17.29	95.16	24.05	5.32	1.61	3.46	1.96	1.51	10.91
04- JUN	33.82	12.91	80.00	37.01	3.52	17.17	95.15	23.36	5.27	1.49	3.38	1.57	1.81	10.55
05- JUN	34.23	14.09	68.00	33.37	3.98	16.96	95.16	24.16	5.39	1.61	3.50	1.45	2.05	11.88
06- JUN	35.14	13.91	42.00	25.43	2.00	15.93	95.17	24.52	5.67	1.59	3.63	1.05	2.57	9.98
07- JUN	36.77	13.36	50.00	38.58	2.97	16.87	95.18	25.07	6.20	1.53	3.87	1.58	2.29	11.15
08- JUN	35.05	14.82	40.00	36.00	2.80	16.53	95.18	24.93	5.64	1.69	3.66	1.35	2.31	10.88
09- JUN	34.77	14.45	73.00	42.79	2.88	17.61	95.17	24.61	5.55	1.65	3.60	1.79	1.81	9.77
10- JUN	35.05	14.27	94.00	41.80	3.92	17.56	95.17	24.66	5.64	1.63	3.63	1.94	1.69	10.44
11- JUN	34.95	14.18	92.00	37.51	2.62	16.95	95.17	24.57	5.61	1.62	3.61	1.80	1.82	9.31
12- JUN	36.32	14.82	60.00	38.94	3.00	16.97	95.19	25.57	6.05	1.69	3.87	1.68	2.18	10.81
13- JUN	33.68	17.27	47.00	43.00	3.00	16.97	95.19	25.48	5.23	1.97	3.60	1.59	2.01	10.3
14- JUN	35.91	15.36	45.00	33.41	2.92	16.26	95.19	25.64	5.91	1.75	3.83	1.38	2.45	11.31
15- JUN	36.14	14.91	58.00	39.09	2.64	17.19	95.19	25.52	5.99	1.70	3.84	1.66	2.18	10.32
16- JUN	35.82	14.73	61.00	31.12	2.06	15.91	95.18	25.27	5.88	1.68	3.78	1.43	2.35	9.5
17- JUN	36.68	14.45	49.00	37.33	3.00	16.89	95.19	25.57	6.17	1.65	3.91	1.55	2.35	11.32

Appendix 1.2 continued

22- JUN	35.14	15.27	85.00	35.01	3.51	17.79	95.18	25.20	5.67	1.74	3.70	1.73	1.97	11.03
23- JUN	35.27	14.55	77.00	29.98	3.35	14.18	95.18	24.91	5.71	1.66	3.68	1.49	2.19	10.8
24- JUN	35.77	15.73	90.00	30.05	2.87	13.63	95.19	25.75	5.87	1.79	3.83	1.69	2.14	9.67
25- JUN	35.23	15.27	89.00	35.46	3.00	17.70	95.18	25.25	5.69	1.74	3.71	1.78	1.93	10.26
26- JUN	36.00	15.18	88.00	33.54	3.45	16.74	95.19	25.59	5.94	1.73	3.83	1.76	2.08	11.04
27- JUN	36.32	15.18	83.00	31.82	2.44	17.04	95.19	25.75	6.05	1.73	3.89	1.68	2.21	10.02
28- JUN	35.36	15.55	50.00	25.72	2.68	16.15	95.19	25.45	5.74	1.77	3.75	1.18	2.57	11.25
29- JUN	35.91	14.64	34.00	30.00	2.36	16.29	95.18	25.27	5.91	1.67	3.79	1.17	2.62	10.83
30- JUN	36.77	15.55	40.00	35.00	2.42	16.60	95.20	26.16	6.20	1.77	3.98	1.44	2.54	10.69
01-JUL	37.64	16.77	89.36	40.22	2.45	17.35	95.22	27.20	6.50	1.91	4.20	2.16	2.04	9.55
02- JUL	38.14	16.82	86.54	29.71	2.82	16.97	95.23	27.48	6.67	1.92	4.29	1.82	2.47	11.1
03- JUL	38.86	16.09	96.42	24.45	2.64	16.86	95.23	27.48	6.94	1.83	4.38	1.73	2.65	11.24
04- JUL	38.27	17.27	89.26	40.59	2.27	17.88	95.23	27.77	6.72	1.97	4.35	2.24	2.10	9.53
05- JUL	37.55	16.27	85.71	38.88	3.09	12.12	95.22	26.91	6.46	1.85	4.16	2.05	2.11	9.34
06- JUL	38.23	17.27	98.23	38.48	3.00	17.95	95.23	27.75	6.71	1.97	4.34	2.26	2.08	10.47
07- JUL	37.36	16.00	77.31	43.14	3.45	11.97	95.21	26.68	6.40	1.82	4.11	2.08	2.03	9.57
08- JUL	36.45	17.18	67.92	37.51	2.23	11.35	95.22	26.82	6.09	1.96	4.03	1.81	2.22	8.11
09- JUL	37.41	17.82	63.39	29.52	2.55	16.26	95.23	27.61	6.42	2.04	4.23	1.59	2.63	10.85
10- JUL	38.36	16.45	77.77	31.04	2.00	15.86	95.23	27.41	6.76	1.87	4.31	1.78	2.54	9.52
11- JUL	37.55	16.91	100.00	25.41	2.73	16.34	95.22	27.23	6.46	1.93	4.20	1.78	2.41	10.66
12- JUL	38.09	16.36	80.42	30.77	2.70	16.25	95.22	27.23	6.66	1.86	4.26	1.77	2.49	10.79
13- JUL	38.64	17.55	86.87	32.72	3.00	16.74	95.24	28.09	6.86	2.01	4.43	1.99	2.44	11.14
14- JUL	38.00	16.36	79.59	38.85	3.09	17.44	95.22	27.18	6.62	1.86	4.24	2.03	2.22	10.93
15- JUL	35.82	15.91	68.35	33.36	2.82	16.55	95.20	25.86	5.88	1.81	3.84	1.60	2.25	10.59
16- JUL	37.59	15.36	76.47	36.26	2.18	16.82	95.21	26.48	6.48	1.75	4.11	1.84	2.27	9.62
17- JUL	37.77	17.55	72.12	30.45	2.20	16.53	95.23	27.66	6.54	2.01	4.27	1.72	2.56	10.08
18- JUL	38.36	16.00	68.16	29.26	2.45	16.40	95.22	27.18	6.76	1.82	4.29	1.61	2.68	10.89
19- JUL	38.00	17.32	89.08	26.56	2.64	16.12	95.23	27.66	6.62	1.98	4.30	1.76	2.54	10.72
20- JUL	38.14	17.36	89.20	26.16	2.00	16.65	95.23	27.75	6.67	1.98	4.33	1.76	2.57	9.76
21- JUL	38.45	17.59	96.42	28.48	2.14	16.93	95.24	28.02	6.79	2.01	4.40	1.94	2.46	9.83
22- JUL	37.09	16.45	65.61	31.43	3.00	16.19	95.21	26.77	6.31	1.87	4.09	1.61	2.48	11.35

Appendix 1.2 continued

23- JUL	38.14	17.09	63.15	36.47	3.18	16.45	95.23	27.61	6.67	1.95	4.31	1.83	2.48	11.55
24- JUL	36.82	17.36	78.31	38.94	4.09	17.18	95.22	27.09	6.21	1.98	4.10	1.99	2.11	11.81
25- JUL	37.45	16.36	66.42	27.85	2.18	15.91	95.22	26.91	6.43	1.86	4.15	1.51	2.63	10.16
26- JUL	37.82	16.55	81.11	32.46	2.50	16.37	95.22	27.18	6.56	1.88	4.22	1.83	2.39	10.25
27- JUL	36.27	17.09	63.20	29.32	2.09	15.81	95.21	26.68	6.03	1.95	3.99	1.50	2.49	9.66
28- JUL	37.82	16.36	87.87	25.84	2.55	16.18	95.22	27.09	6.56	1.86	4.21	1.67	2.55	10.68
29- JUL	39.55	17.14	72.52	28.44	2.55	16.05	95.25	28.34	7.20	1.95	4.58	1.73	2.84	11.19
30- JUL	36.32	15.91	95.48	25.10	1.73	15.91	95.20	26.11	6.05	1.81	3.93	1.62	2.30	8.68
31- JUL	39.90	18.40	78.86	28.63	2.50	16.01	95.26	29.15	7.34	2.12	4.73	1.88	2.84	10.95
01-AUG	38.23	17.45	89.36	40.22	2.50	16.74	95.24	27.84	6.71	1.99	4.35	2.24	2.11	9.56
02- AUG	38.27	17.00	86.54	29.71	2.70	16.11	95.23	27.64	6.72	1.94	4.33	1.84	2.49	10.71
03- AUG	37.45	16.91	96.42	24.45	3.73	13.31	95.22	27.18	6.43	1.93	4.18	1.71	2.46	11.66
04- AUG	36.86	16.91	89.26	40.59	8.45	16.61	95.22	26.89	6.23	1.93	4.08	2.12	1.95	14.72
05- AUG	37.68	16.73	85.71	38.88	2.55	15.66	95.22	27.20	6.51	1.90	4.21	2.08	2.13	9.46
06- AUG	37.64	17.55	98.23	38.48	1.68	16.45	95.23	27.59	6.50	2.01	4.25	2.23	2.02	8.11
07- AUG	32.64	21.27	77.31	43.14	3.64	16.10	95.22	26.95	4.93	2.53	3.73	2.04	1.69	9.58
08- AUG	36.36	17.59	67.92	37.51	3.55	15.73	95.22	26.98	6.06	2.01	4.04	1.82	2.22	11.17
09- AUG	37.55	17.23	63.39	29.52	2.91	14.76	95.23	27.39	6.46	1.97	4.21	1.58	2.64	11.17
10- AUG	38.36	17.82	77.77	31.04	2.50	14.98	95.24	28.09	6.76	2.04	4.40	1.84	2.56	10.16
11- AUG	38.00	16.36	100.00	25.41	2.82	15.25	95.22	27.18	6.62	1.86	4.24	1.77	2.47	10.71
12- AUG	38.36	16.55	80.42	30.77	3.00	15.09	95.23	27.45	6.76	1.88	4.32	1.80	2.52	11.07
13- AUG	36.41	17.18	86.87	32.72	2.55	15.43	95.22	26.80	6.08	1.96	4.02	1.85	2.17	9.57
14- AUG	39.91	17.09	79.59	38.85	3.18	15.79	95.25	28.50	7.34	1.95	4.64	2.20	2.44	11.12
15- AUG	38.59	17.73	68.35	33.36	2.55	15.17	95.24	28.16	6.84	2.03	4.43	1.83	2.60	10.4
16- AUG	38.32	18.27	76.47	36.26	2.91	15.44	95.24	28.30	6.74	2.10	4.42	2.02	2.40	10.51
17- AUG	38.14	17.41	72.12	30.45	2.10	14.73	95.23	27.77	6.67	1.99	4.33	1.73	2.60	9.49
18- AUG	38.41	17.36	68.16	29.26	3.36	13.06	95.24	27.89	6.77	1.98	4.38	1.67	2.71	11.67
19- AUG	38.55	17.64	89.08	26.56	2.36	14.39	95.24	28.09	6.82	2.02	4.42	1.80	2.62	9.9
20- AUG	37.45	16.36	89.20	26.16	2.50	13.99	95.22	26.91	6.43	1.86	4.15	1.67	2.47	9.88
21- AUG	38.27	17.09	96.42	28.48	2.64	15.11	95.23	27.68	6.72	1.95	4.34	1.90	2.44	10.2
22- AUG	37.00	16.73	65.61	31.43	2.45	14.61	95.22	26.86	6.27	1.90	4.09	1.61	2.48	9.98

Appendix 1.2 continued

23- AUG	37.68	16.55	63.15	36.47	3.09	14.56	95.22	27.11	6.51	1.88	4.20	1.78	2.42	10.83
24- AUG	38.00	16.91	78.31	38.94	2.82	14.84	95.23	27.45	6.62	1.93	4.28	2.04	2.23	9.9
25- AUG	38.45	16.82	66.42	27.85	2.55	14.16	95.23	27.64	6.79	1.92	4.35	1.58	2.77	10.64
26- AUG	37.08	16.42	81.11	32.46	2.25	14.71	95.21	26.75	6.30	1.87	4.09	1.78	2.30	9.24
27- AUG	36.45	15.91	63.20	29.32	2.73	14.09	95.20	26.18	6.09	1.81	3.95	1.46	2.49	10.46
28- AUG	36.27	16.09	87.87	25.84	3.18	14.00	95.20	26.18	6.03	1.83	3.93	1.58	2.35	10.79
29- AUG	36.64	16.18	72.52	28.44	1.80	13.89	95.21	26.41	6.15	1.84	4.00	1.54	2.45	8.54
30- AUG	37.55	15.82	95.48	25.10	2.27	14.18	95.21	26.68	6.46	1.80	4.13	1.67	2.46	9.52
31- AUG	38.64	15.73	78.86	28.63	1.91	13.97	95.22	27.18	6.86	1.79	4.32	1.69	2.64	9.06
01-SEP	37.55	15.27	76.81	37.46	2.55	12.93	95.21	26.41	6.46	1.74	4.10	1.88	2.22	9.11
02- SEP	37.09	15.36	83.64	31.38	2.32	13.75	95.20	26.23	6.31	1.75	4.03	1.72	2.31	9.18
03- SEP	36.00	13.64	88.91	31.60	1.86	13.61	95.18	24.82	5.94	1.56	3.75	1.63	2.12	8.07
04- SEP	34.64	15.09	86.96	25.47	2.45	12.78	95.18	24.86	5.51	1.72	3.61	1.45	2.17	8.99
05- SEP	35.27	15.09	98.15	33.00	2.36	13.65	95.18	25.18	5.71	1.72	3.71	1.78	1.93	8.4
06- SEP	36.45	15.18	92.78	35.06	2.27	13.58	95.20	25.82	6.09	1.73	3.91	1.87	2.04	8.46
07- SEP	36.45	15.36	71.17	42.96	3.00	13.51	95.20	25.91	6.09	1.75	3.92	1.93	1.99	9.34
08- SEP	35.32	14.91	41.23	35.47	2.73	11.16	95.18	25.11	5.72	1.70	3.71	1.36	2.34	9.53
09- SEP	36.91	14.91	65.10	39.88	2.00	13.74	95.20	25.91	6.24	1.70	3.97	1.80	2.17	8.35
10- SEP	37.14	15.55	82.41	32.79	2.45	11.72	95.21	26.34	6.32	1.77	4.04	1.76	2.28	8.81
11- SEP	35.82	15.05	85.87	33.49	2.82	12.62	95.19	25.43	5.88	1.71	3.80	1.72	2.08	9.2
12- SEP	35.14	50.82	95.19	30.60	2.82	19.80	95.52	42.98	5.67	12.85	9.26	6.98	2.27	9.8
13- SEP	36.18	14.73	53.50	28.69	2.00	11.56	95.19	25.45	6.00	1.68	3.84	1.31	2.53	8.63
14- SEP	35.36	14.45	71.94	25.45	2.18	11.55	95.18	24.91	5.74	1.65	3.69	1.32	2.37	8.7
15- SEP	36.45	15.45	82.58	22.04	2.23	11.68	95.20	25.95	6.09	1.76	3.92	1.40	2.53	9.05
16- SEP	36.95	14.09	71.17	23.54	2.91	11.32	95.19	25.52	6.26	1.61	3.93	1.31	2.62	10.65
17- SEP	35.45	14.45	92.27	25.07	3.00	11.91	95.18	24.95	5.77	1.65	3.71	1.48	2.22	9.83
18- SEP	35.91	15.00	78.54	25.47	2.82	11.41	95.19	25.45	5.91	1.71	3.81	1.42	2.39	9.81
19- SEP	34.82	14.05	80.24	34.12	2.91	10.53	95.17	24.43	5.57	1.60	3.58	1.59	1.99	8.72
20- SEP	36.18	14.36	90.90	36.02	2.55	11.90	95.18	25.27	6.00	1.64	3.82	1.82	1.99	8.4
21- SEP	36.09	14.55	66.81	29.02	2.27	10.83	95.19	25.32	5.97	1.66	3.81	1.42	2.39	8.7
22- SEP	35.45	15.00	55.95	24.21	2.00	10.29	95.18	25.23	5.77	1.71	3.74	1.17	2.56	8.4

Appendix 1.2 continued

23- SEP	35.14	14.36	71.16	34.96	2.00	11.21	95.17	24.75	5.67	1.64	3.65	1.57	2.08	7.61
24- SEP	35.64	39.55	88.90	34.90	2.45	15.30	95.42	37.59	5.82	7.20	6.51	4.22	2.30	8.51
25- SEP	35.18	13.82	84.27	33.51	1.68	11.00	95.17	24.50	5.68	1.58	3.63	1.62	2.01	6.87
26- SEP	34.82	12.95	95.53	38.84	1.64	11.09	95.16	23.89	5.57	1.49	3.53	1.79	1.74	6.32
27- SEP	34.45	14.09	63.36	36.52	1.82	9.61	95.16	24.27	5.46	1.61	3.53	1.51	2.03	6.81
28- SEP	34.64	12.55	48.66	28.43	2.27	9.43	95.15	23.59	5.51	1.45	3.48	1.14	2.35	8.5
29- SEP	36.05	12.45	38.40	32.79	2.36	9.51	95.16	24.25	5.96	1.45	3.70	1.25	2.45	8.87
30- SEP	37.36	13.64	49.17	34.96	2.27	10.07	95.19	25.50	6.40	1.56	3.98	1.50	2.48	8.68
01-OCT	35.91	13.18	44.13	31.18	2.09	8.95	95.17	24.55	5.91	1.52	3.71	1.26	2.46	8.13
02- SEP	34.73	13.27	43.26	37.94	1.68	9.74	95.16	24.00	5.54	1.52	3.53	1.38	2.15	6.88
03- SEP	34.82	13.18	72.55	39.59	1.77	10.46	95.16	24.00	5.57	1.52	3.54	1.65	1.89	6.69
04- SEP	34.00	12.73	96.02	39.43	2.00	10.27	95.15	23.36	5.32	1.47	3.40	1.76	1.64	6.49
05- SEP	34.27	12.91	74.02	36.73	2.41	9.53	95.15	23.59	5.40	1.49	3.44	1.54	1.90	7.57
06- SEP	34.18	11.82	79.84	38.02	1.18	9.88	95.14	23.00	5.37	1.39	3.38	1.57	1.80	5.41
07- SEP	33.82	12.82	83.17	34.13	2.36	9.50	95.15	23.32	5.27	1.48	3.37	1.51	1.86	7.41
08- SEP	33.27	12.91	82.89	29.70	1.86	9.05	95.14	23.09	5.11	1.49	3.30	1.38	1.92	6.65
09- SEP	32.55	12.55	86.30	26.94	2.09	7.90	95.13	22.55	4.90	1.45	3.18	1.29	1.89	6.76
10- SEP	32.00	11.88	80.41	29.99	1.88	8.51	95.12	21.94	4.75	1.39	3.07	1.27	1.80	6.38
11- SEP	33.86	11.27	65.17	32.49	1.77	8.33	95.13	22.57	5.28	1.34	3.31	1.29	2.01	6.57
12- SEP	32.50	12.00	76.21	26.92	1.55	8.07	95.12	22.25	4.89	1.40	3.15	1.19	1.95	5.96
13- SEP	31.36	12.00	79.45	35.32	2.86	7.74	95.11	21.68	4.59	1.40	2.99	1.37	1.63	7.23
14- SEP	31.64	11.64	83.60	31.72	1.95	8.24	95.11	21.64	4.66	1.37	3.01	1.31	1.70	6.24
15- SEP	32.36	11.50	69.22	29.96	3.09	7.55	95.12	21.93	4.85	1.36	3.11	1.20	1.91	8.45
16- SEP	31.10	10.40	73.24	30.22	3.00	7.23	95.09	20.75	4.52	1.26	2.89	1.14	1.75	7.86
17- SEP	31.25	11.10	56.06	37.82	1.65	5.84	95.10	21.18	4.56	1.32	2.94	1.23	1.71	5.2
18- SEP	32.60	10.70	48.30	46.82	1.80	7.28	95.11	21.65	4.92	1.29	3.10	1.46	1.64	5.61
19- SEP	33.05	11.20	46.71	44.53	1.39	7.20	95.12	22.13	5.04	1.33	3.19	1.43	1.75	5.07
20- SEP	32.20	10.30	56.24	37.38	1.60	7.21	95.10	21.25	4.81	1.25	3.03	1.25	1.78	5.59
21- SEP	33.10	10.60	79.58	29.46	1.72	7.23	95.12	21.85	5.06	1.28	3.17	1.25	1.91	6.06
22- SEP	32.80	10.95	83.46	30.02	1.94	7.14	95.12	21.88	4.97	1.31	3.14	1.29	1.85	6.29
23- SEP	31.00	10.40	73.70	38.22	1.80	7.52	95.09	20.70	4.49	1.26	2.88	1.32	1.55	5.55

Appendix 1.2 continued

24- SEP	31.80	9.80	66.91	39.50	2.05	7.28	95.09	20.80	4.70	1.21	2.96	1.33	1.62	6.05
25- SEP	31.55	9.70	57.44	30.71	1.65	6.33	95.09	20.63	4.64	1.20	2.92	1.06	1.86	5.72
26- SEP	30.15	9.90	43.32	29.25	2.25	4.45	95.08	20.03	4.28	1.22	2.75	0.89	1.86	6.51
27- SEP	29.00	9.20	39.92	39.82	1.35	5.38	95.06	19.10	4.01	1.16	2.58	1.03	1.55	4.41
28- SEP	28.20	9.10	54.70	52.18	2.00	6.53	95.05	18.65	3.82	1.16	2.49	1.31	1.18	4.78
29- SEP	28.70	9.60	80.52	53.35	2.65	5.76	95.06	19.15	3.94	1.20	2.57	1.53	1.03	4.81
30- SEP	27.30	8.90	86.45	52.27	2.50	6.19	95.04	18.10	3.63	1.14	2.38	1.44	0.94	4.53
31- SEP	27.30	8.30	73.76	48.91	1.39	6.66	95.03	17.80	3.63	1.09	2.36	1.29	1.07	3.85
01-OCT	28.36	7.41	60.94	37.16	2.20	6.05	95.03	17.89	3.86	1.03	2.45	1.03	1.41	5.71
02- OCT	27.73	7.86	73.28	44.44	2.82	6.34	95.03	17.80	3.72	1.06	2.39	1.22	1.18	5.73
03- OCT	28.33	7.21	83.75	46.25	3.00	6.49	95.03	17.77	3.85	1.02	2.44	1.32	1.12	5.72
04- OCT	29.20	7.85	77.35	40.86	1.40	6.13	95.05	18.53	4.05	1.06	2.56	1.24	1.32	4.23
05- OCT	27.82	8.36	64.22	39.49	1.73	5.40	95.04	18.09	3.74	1.10	2.42	1.09	1.33	4.61
06- OCT	25.36	8.45	77.07	39.52	2.00	5.42	95.01	16.91	3.24	1.11	2.17	1.07	1.11	4.46
07- OCT	28.09	7.73	68.81	39.01	1.73	5.16	95.03	17.91	3.80	1.05	2.43	1.10	1.32	4.56
08- OCT	27.18	8.36	79.71	28.62	1.64	5.20	95.03	17.77	3.60	1.10	2.35	0.95	1.40	4.63
09- OCT	26.55	7.73	85.23	41.07	2.41	5.48	95.02	17.14	3.47	1.05	2.26	1.16	1.10	4.91
10- OCT	26.73	7.64	66.34	49.83	2.09	5.71	95.02	17.18	3.51	1.05	2.28	1.22	1.06	4.46
11- OCT	24.45	8.18	68.41	40.50	2.09	5.22	95.00	16.32	3.07	1.09	2.08	0.99	1.08	4.51
12- OCT	25.45	6.91	63.56	32.91	2.09	4.69	95.00	16.18	3.25	1.00	2.13	0.85	1.27	5.01
13- OCT	23.82	6.18	89.48	33.09	2.00	5.02	94.97	15.00	2.95	0.95	1.95	0.91	1.04	4.31
14- OCT	25.00	7.18	76.63	33.37	1.95	4.76	95.00	16.09	3.17	1.01	2.09	0.92	1.17	4.54
15- OCT	25.09	7.64	67.27	43.17	2.59	4.88	95.00	16.36	3.18	1.05	2.12	1.04	1.08	4.96
16- OCT	24.36	7.09	82.15	40.92	2.27	4.50	94.99	15.73	3.05	1.01	2.03	1.04	0.99	4.3
17- OCT	23.91	6.18	89.87	35.05	2.73	4.01	94.97	15.05	2.97	0.95	1.96	0.95	1.01	4.81
18- OCT	23.00	6.27	100.00	51.76	2.82	3.91	94.96	14.64	2.81	0.95	1.88	1.20	0.68	3.54
19- OCT	23.64	5.77	100.00	37.69	2.18	3.87	94.97	14.70	2.92	0.92	1.92	1.01	0.91	3.88
20- OCT	22.91	5.73	90.01	30.71	2.73	3.69	94.96	14.32	2.79	0.92	1.86	0.84	1.01	4.83
21- OCT	23.64	5.00	78.59	25.24	1.45	3.85	94.96	14.32	2.92	0.87	1.90	0.71	1.18	3.79
22- OCT	25.09	5.64	97.81	24.20	1.36	3.72	94.98	15.36	3.18	0.91	2.05	0.83	1.22	3.62

Appendix 1.2 continued

23- OCT	25.18	5.55	94.20	21.15	1.36	3.68	94.98	15.36	3.20	0.91	2.05	0.77	1.29	3.77
24- OCT	24.00	4.91	91.21	22.43	3.59	3.71	94.96	14.45	2.98	0.87	1.93	0.73	1.20	6.53
25- OCT	21.45	6.64	94.37	23.07	1.95	3.69	94.95	14.05	2.56	0.98	1.77	0.76	1.01	3.98
26- OCT	22.91	5.45	94.97	38.24	2.59	3.96	94.95	14.18	2.79	0.90	1.85	0.96	0.89	4.24
27- OCT	21.36	5.55	94.41	41.14	2.09	3.92	94.94	13.45	2.54	0.91	1.72	0.95	0.77	3.42
28- OCT	22.27	5.55	100.00	51.24	2.23	4.40	94.95	13.91	2.69	0.91	1.80	1.14	0.66	3.18
29- OCT	19.45	4.45	100.00	49.13	1.64	4.17	94.91	11.95	2.26	0.84	1.55	0.98	0.57	2.52
30- OCT	21.64	3.77	95.22	50.80	1.41	4.35	94.92	12.70	2.59	0.80	1.69	1.04	0.66	2.57
01- NOV	19.45	2.82	85.65	35.59	1.86	3.55	94.89	11.14	2.26	0.75	1.50	0.72	0.78	3.3
02- NOV	22.40	5.03	97.00	43.27	1.96	4.04	94.94	13.72	2.71	0.87	1.79	1.01	0.78	3.33
03- NOV	20.73	2.09	84.65	41.04	1.32	3.43	94.89	11.41	2.45	0.71	1.58	0.80	0.78	2.65
04- NOV	18.82	4.00	84.12	45.06	5.59	3.44	94.89	11.41	2.17	0.81	1.49	0.83	0.66	5.02
05- NOV	19.36	3.86	72.00	46.16	2.68	3.29	94.90	11.61	2.25	0.81	1.53	0.81	0.72	3.69
06- NOV	18.82	4.00	79.93	48.80	1.64	3.42	94.89	11.41	2.17	0.81	1.49	0.86	0.64	2.58
07- NOV	19.41	4.45	83.25	59.98	1.68	3.56	94.91	11.93	2.25	0.84	1.55	1.03	0.52	2.27
08- NOV	19.73	3.64	100.00	54.83	1.18	3.58	94.90	11.68	2.30	0.79	1.55	1.03	0.52	1.92
09- NOV	19.00	4.18	97.32	38.69	2.00	3.12	94.90	11.59	2.20	0.82	1.51	0.83	0.68	2.98
10- NOV	19.64	3.18	100.00	32.17	1.82	3.14	94.89	11.41	2.29	0.77	1.53	0.75	0.78	3.14
11- NOV	18.27	3.09	100.00	43.91	1.41	3.31	94.88	10.68	2.10	0.76	1.43	0.84	0.59	2.25
12- NOV	18.27	2.82	97.09	36.02	1.91	2.98	94.88	10.55	2.10	0.75	1.42	0.74	0.68	2.93
13- NOV	18.64	3.64	91.43	33.15	1.64	3.07	94.89	11.14	2.15	0.79	1.47	0.72	0.75	2.88
14- NOV	16.45	3.73	100.00	28.89	1.91	3.25	94.87	10.09	1.87	0.80	1.33	0.67	0.67	2.94
15- NOV	16.09	3.27	100.00	23.14	1.77	3.03	94.86	9.68	1.83	0.77	1.30	0.60	0.70	2.92
16- NOV	16.85	2.50	85.72	37.84	1.80	3.07	94.86	9.68	1.92	0.73	1.33	0.68	0.65	2.77
17- NOV	17.82	2.27	81.35	35.28	1.95	3.04	94.86	10.05	2.04	0.72	1.38	0.65	0.73	3.17
18- NOV	16.36	2.00	87.68	28.27	2.95	2.81	94.85	9.18	1.86	0.71	1.28	0.57	0.71	3.96
19- NOV	17.00	1.91	82.71	42.90	2.05	3.10	94.85	9.45	1.94	0.70	1.32	0.71	0.61	2.86
20- NOV	17.73	2.45	82.06	45.16	2.64	3.33	94.87	10.09	2.03	0.73	1.38	0.76	0.62	3.33
21- NOV	16.36	1.45	88.43	58.60	1.05	3.55	94.84	8.91	1.86	0.68	1.27	0.85	0.42	1.64
22- NOV	16.91	1.73	97.06	44.31	1.91	3.58	94.85	9.32	1.93	0.69	1.31	0.76	0.55	2.6

Appendix 1.2 continued

23- NOV	16.73	2.50	83.66	33.78	2.09	3.23	94.85	9.61	1.90	0.73	1.32	0.63	0.69	3.21
24- NOV	16.91	2.55	87.80	57.51	2.55	3.68	94.86	9.73	1.93	0.73	1.33	0.88	0.45	2.61
25- NOV	17.36	2.73	97.46	51.53	1.55	3.57	94.86	10.05	1.98	0.74	1.36	0.87	0.49	2.14
26- NOV	15.00	2.40	100.00	43.64	1.85	3.46	94.83	8.70	1.71	0.73	1.22	0.74	0.48	2.32
27- NOV	13.32	1.18	100.00	44.29	1.50	3.40	94.80	7.25	1.53	0.67	1.10	0.67	0.43	1.94
28- NOV	15.55	1.64	93.70	49.42	1.45	3.65	94.83	8.59	1.77	0.69	1.23	0.76	0.47	2.05
29- NOV	18.18	2.45	73.90	40.39	1.91	3.30	94.87	10.32	2.09	0.73	1.41	0.69	0.72	3.12
30- NOV	17.91	3.18	53.07	44.29	2.09	3.24	94.88	10.55	2.05	0.77	1.41	0.66	0.75	3.39
31- NOV	19.09	2.00	50.87	34.50	2.05	3.06	94.88	10.55	2.21	0.71	1.46	0.56	0.90	3.85
01-DEC	19.36	4.09	97.00	42.94	2.27	3.59	94.90	11.73	2.25	0.82	1.53	0.88	0.65	3.16
02- DEC	18.18	3.60	100.00	54.69	1.36	3.95	94.88	10.89	2.09	0.79	1.44	0.97	0.47	2.02
0-3 DEC	18.82	3.64	91.00	77.27	2.27	4.18	94.89	11.23	2.17	0.79	1.48	1.20	0.28	1.84
04- DEC	17.68	3.36	86.00	78.30	1.91	3.65	94.88	10.52	2.02	0.78	1.40	1.13	0.27	1.61
05- DEC	18.36	2.64	76.00	61.75	2.41	3.69	94.87	10.50	2.11	0.74	1.43	0.93	0.49	2.68
06- DEC	17.18	3.00	97.00	54.94	2.55	3.53	94.87	10.09	1.96	0.76	1.36	0.91	0.45	2.56
07- DEC	17.00	2.45	98.00	41.53	2.86	3.25	94.86	9.73	1.94	0.73	1.33	0.76	0.57	3.26
08- DEC	13.27	1.00	98.00	43.69	1.45	3.63	94.80	7.14	1.52	0.66	1.09	0.65	0.44	1.98
09- DEC	17.55	1.91	97.00	36.55	1.14	3.79	94.86	9.73	2.01	0.70	1.35	0.71	0.65	2.26
10- DEC	15.27	2.82	91.00	44.90	2.36	4.01	94.84	9.05	1.74	0.75	1.24	0.73	0.51	2.84
11- DEC	16.82	2.64	96.00	47.57	2.18	3.61	94.86	9.73	1.92	0.74	1.33	0.81	0.52	2.66
12- DEC	17.91	2.00	100.00	33.18	1.68	3.83	94.86	9.95	2.05	0.71	1.38	0.69	0.69	2.91
13- DEC	16.18	0.73	97.00	33.46	2.82	3.92	94.83	8.45	1.84	0.64	1.24	0.62	0.62	3.64
14- DEC	18.45	3.00	97.00	49.62	1.91	4.03	94.88	10.73	2.12	0.76	1.44	0.89	0.55	2.63
15- DEC	18.00	3.18	97.00	73.98	4.73	4.24	94.88	10.59	2.06	0.77	1.42	1.14	0.28	2.37
16- DEC	16.09	2.55	99.00	53.95	1.05	4.10	94.85	9.32	1.83	0.73	1.28	0.86	0.42	1.74
17- DEC	15.41	2.00	100.00	50.96	0.55	3.70	94.83	8.70	1.75	0.71	1.23	0.80	0.43	1.31
18- DEC	13.18	1.36	100.00	76.30	1.45	3.64	94.80	7.27	1.52	0.67	1.09	0.92	0.18	1.18
19- DEC	14.41	1.64	97.00	60.65	2.18	3.50	94.82	8.02	1.64	0.69	1.16	0.83	0.33	1.94
20- DEC	13.27	2.73	92.00	81.00	1.82	4.23	94.82	8.00	1.52	0.74	1.13	0.96	0.17	1.34
21 - DEC	14.45	3.00	99.00	66.32	2.55	4.55	94.84	8.73	1.65	0.76	1.20	0.92	0.28	1.99
22-- DEC	14.09	2.64	98.00	84.78	2.00	4.36	94.83	8.36	1.61	0.74	1.17	1.04	0.13	1.22

Appendix 1.2 continued

23- DEC	13.55	2.09	83.00	73.50	2.55	4.76	94.81	7.82	1.55	0.71	1.13	0.87	0.27	1.95
24- DEC	13.59	2.45	62.00	60.66	2.55	4.14	94.82	8.02	1.56	0.73	1.14	0.70	0.44	2.69
25- DEC	14.82	1.82	93.00	50.51	2.36	4.54	94.83	8.32	1.69	0.70	1.19	0.75	0.44	2.64
26- DEC	14.18	2.36	96.00	49.29	1.73	4.37	94.83	8.27	1.62	0.72	1.17	0.75	0.42	2.21
27- DEC	14.64	3.64	99.00	55.59	2.86	4.32	94.84	9.14	1.67	0.79	1.23	0.86	0.37	2.48
28- DEC	14.86	2.36	99.00	47.18	2.27	4.87	94.83	8.61	1.69	0.72	1.21	0.76	0.45	2.67
29- DEC	13.91	2.09	95.00	46.20	2.32	4.36	94.82	8.00	1.59	0.71	1.15	0.70	0.45	2.61
30- DEC	12.85	2.29	91.00	40.75	2.09	4.90	94.81	7.57	1.48	0.72	1.10	0.63	0.47	2.7
31- DEC	19.09	3.27	95.00	47.39	3.91	5.09	94.89	11.18	2.21	0.77	1.49	0.89	0.60	4.15

APPENDIX 2

Wastewater quality for As-Samra

Summary of annual reports

Appendix2.1: Long term averages of BOD_5 in As-Samra WWTP

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	176	193	204	180	120	125	110	93	124	118	56	229
1996	234	272	304	340	150	190	100	129	170	324	406	234
1997	353	355	310	297	212	168	113	98	99	87	106	154
1998	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1999	145	161	145	149	95	92	96	102	92	106	111	118
2000	142	140	162	122	149	123	126	117	139	149	127	174
2001	353	355	310	297	212	160	113	98	99	87	106	154
2002	172	191	213	93	122	100	110	113	100	112	114	183
2003	219	215	156	118	85	91	88	100	81	102	100	126
2004	166	175	231	183	120	99	98	101	99	103	120	157
Average	**133.0**	**137.4**	**135.2**	**106.9**	**87.0**	**73.9**	**70.1**	**70.1**	**67.8**	**73.2**	**75.3**	**101.3**

Appendix2.2: Long term averages of TDS in As-Samra WWTP

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	974	1146	1225	1262	1438	1314	1260	1240	1252	1202	1186	1128
1996	1040	1018	1045	1090	1230	1254	1212	1280	1260	1222	1300	1334
1997	13335	1300	1190	1180	1205	1190	1312	1320	1286	1274	1126	1266
1998	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1999	1216	1112	1180	1188	1242	1314	1334	1334	1350	1256	1292	1276
2000	1126	1108	1180	1182	1216	1270	1262	1378	1246	1240	1198	1238
2001	1335	1500	1180	1205	1190	1320	1274	1286	1274	1222	1266	1286
2002	1064	967	1188	1100	1210	1248	1294	1332	1298	1222	1250	1150
2003	1150	N.A	N.A	N.A	1188	1230	1242	1174	1188	N.A	N.A	N.A
Average	**736.4**	**1,164.4**	**1,169.7**	**1,172.4**	**755.8**	**797.8**	**800.8**	**813.0**	**794.5**	**1,234.0**	**1,231.1**	**1,239.7**

Appendix2.3: Long term averages of COD in As-Samra WWTP

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	371	401	414	353	405	314	340	306	273	293	360	439
1996	436	469	460	523	483	382	344	456	385	426	656	743
1997	645	656	639	634	534	514	38	277	350	383	262	252
1998	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1999	557	508	590	544	502	540	480	432	403	376	476	519
2000	512	489	516	488	491	376	382	446	560	570	564	567
2001	436	469	460	523	483	382	338	277	317	383	262	252
2002	485	505	577	494	438	518	482	501	465	542	520	546
2003	637	560	455	473	528	497	489	495	301	463	527	493
2004	642	708	554	622	531	854	459	302	432	475	605	690
Average	**363.2**	**359.9**	**350.2**	**349.3**	**330.3**	**351.9**	**292.2**	**272.6**	**275.3**	**312.1**	**328.2**	**340.8**

APPENDIX 3

Wastewater quality for Jerash

Summary of annual reports

Appendix 3.1: Long term averages of BOD_5 in Jerash WWT

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	30	45	29	45	26	25	21	77	73	31	28	31
1996	24	29	37	44	24	15	17	16	28	18	23	17
1997	17	25	30	35	43	28	24	22	19	18	24	28
1998	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1999	33	31	30	30	35	30	33	36	34	28	32	40
2000	35	40	40	40	44	44	44	54	44	45	44	45
2001	44	47	46	46	50	44	40	50	56	42	30	42
2002	46	NA	25	NA	9	44	26	20	42	34	44	13
2003	7	27	12	21	NA	NA	29	47	41	33.5	38	29.5
2004	57	72	48.2	50	48.5	29	58	NA	91	53	54	67
Average	**37.0**	**49.5**	**33.5**	**35.5**	**48.5**	**29.0**	**38.3**	**38.8**	**51.3**	**39.3**	**40.3**	**39.4**

N.A: Not Analyzed.

Appendix 3.2: Long term averages of TDS in Jerash WWTP

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	811.0	760.0	645.0	970.0	1,359.0	940.0	874.0	1,452.0	1,014.0	1,142.0	1,245.0	1,270.0
1996	105.2	951.0	1,104.0	982.0	1,064.0	1,270.0	476.0	957.0	1,036.0	1,182.0	1,152.0	1,078.0
1997	1,078	896.0	848.0	1,100.0	985.0	1,033.0	1,034.0	1,078.0	1,037.0	1,073.0	1,065.0	993.0
1998	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1999	1,027	969.0	1,021.0	1,121.0	1,166.0	1,088.0	1,103.0	1,088.0	1,593.0	1,083.0	1,168.0	1,155.0
2000	400.0	850.0	650.0	620.0	330.0	600.0	620.0	700.0	964.0	720.0	700.0	710.0
2001	1,200	1,284.0	1,270.0	1,150.0	1,200.0	1,200.0	1,100.0	150.0	1,185.0	111.0	1,552.0	1,465.0
2002	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
2003	163	N.A	510.0	N.A	730.0	N.A	971.0	1,327.0	1,424.7	1,144.5	1,887.0	679.0
Average	**683.5**	**951.7**	**864.0**	**990.5**	**976.3**	**1,021.8**	**882.6**	**964.6**	**1,179.1**	**922.2**	**1,252.7**	**1,050.0**

Appendix 3.3 :Long term averages of COD in Jerash WWTP

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	93.0	138.0	106.0	84.0	158.0	142.0	198.0	248.0	178.0	113.0	79.0	111.0
1996	93.0	99.0	158.0	101.0	124.0	80.0	74.0	82.0	92.0	83.0	153.0	61.0
1997	61.0	144.0	101.0	101.0	110.0	82.0	101.0	98.0	118.0	118.0	118.0	113.0
1998	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1999	120.0	123.0	118.0	148.0	133.0	118.0	116.0	115.0	142.0	107.0	115.0	115.0
2000	100.0	114.0	110.0	100.0	110.0	109.0	110.0	115.0	102.0	110.0	115.0	120.0
2001	115.0	120.0	125.0	120.0	145.0	110.0	150.0	140.0	150.0	146.0	160.0	170.0
2002	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
2003	150.0	181.0	76.0	81.0	147.0		185.0	183.0	209.0	205.0	265.0	211.0
2004	150.0	297.0	177.0	265.0	339.0	148.0	164.0	139.0	370.0	89.5	219.0	166.5
AVR	110.3	152.0	121.4	125.0	158.3	112.7	137.3	140.0	170.1	121.4	153.0	133.4

APPENDIX 4

Results of statistical analysis

Appendix 4.1 :Pair T-test of some chemical properties of soil between surface and sub -surface layer.

Pair layers		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	pH_Surface	7.971	35	0.3967	0.0671
	pH Sub -surface	7.746	35	0.3713	0.0628
Pair 2	EC surface	9.613	35	12.5126	2.115
	EC Sub- surface	4.502	35	4.514	0.763
Pair 3	Total N Surface (%)	0.741	35	0.177	0.0299
	Total N Sub- surface (%)	0.487	35	0.1581	0.0267
Pair 4	Total P Surface (ppm)	101.957	35	46.721	7.8973
	Total P Sub- surface (ppm)	102.312	35	44.442	7.5121
Pair 5	Soluble K Surface (ppm)	4.467	35	3.146	0.5318
	Soluble k sub -surface (ppm)	6.903	35	3.9637	0.67

Appendix 4.2: T-test of some chemical properties of soil between surface and sub -surface layer.

		Paired Differences							
					95% Confidence Interval of the Difference				
Pair NO.		Mean	Std. Deviation	Std. Error Mean	Lower		t	df	Sig. (2-tailed)
Pair 1	pH - pH	0.227	0.323	0.0546	0.1148	0.3367	4.134	34	0
Pair 2	EC - EC	5.1112	13.0037	2.198	0.6442	9.5781	2.325	34	0.026
Pair 3	Total N - Total N	0.2535	0.215	0.0363	0.1797	0.3274	6.977	34	0
Pair 4	Total P- Total P	-0.3551	37.1722	6.2832	-13.1242	12.414	-0.057	34	0.955
Pair 5	Soluble K - Soluble K	-2.4355	2.1625	0.3655	-3.1784	-1.6927	-6.663	34	0

APPENDIX 5

Calculation of effective rainfall

Appendix 5.1: Effeective rainfall in relation to rainfall amount (mm/month)

P(mm/month)	P_e(mm/month)	P(mm/month)	P_e(mm/month)
0	0	130	79
10	0	140	87
20	2	150	95
30	8	160	103
40	14	170	111
50	20	180	119
60	26	190	127
70	32	200	135
80	39	210	143
90	47	220	151
100	55	230	159
110	63	240	167
120	71	250	175

Source: FAO Paper no.27

APPENDIX 6

Analyzed pits and profiles of NSMLUP (MOA. 1995)

Appendix 6.1:Analyzed pits located at the study area done by NSMLUP.1994

Pit #	Location	sand %	silt %	clay %	PH	Ece (mS/cm	N %	Total P (ppm)	Available P (ppm)	K
PH 100	Sukhna	48.9	27.7	23.3	8.3	0.5	N.A	N.A	N.A	N.A
PT 001	Mubus	10	43.4	48.1	7.8	3	0.1	850	1.4	0.4
PT 002	Sarrot	10.3	43.3	48.1	8.3	0.8	0.04	530	1.2	0.1
PC 007	Baqaa	7.9	48.5	43.6	7.8	0.4	0.2	590	N	0.1
PH 340	Wadi khalah	11.3	45.4	43.3	7.5	1	N.A	N.A	N.A	N.A
PT 004	Alouk	17.9	41.8	40.3	7.7	0	0.2	1110	0.8	0.3

N.A: Not analyzed

Appendix 6.2:Description of sil map unit in the study area (MOA.1995)

Map unit	Area Km²	Altitude(m) and slope	Mean annual rainfall (mm)	Geomorphology/parent material	Vegetation and landuse	Moisture regime	Stone/rock outcrop	USDA subgroup and particle size class
2	67.9	370-600 300-750 5-40%	400-500	Mid and low slopes on limestone deep to moderately deep cllovium	Intensive rainfed trecrops and arable +afforestation	Xeric(wet)	6% A-hor stones 6%surface stones <5% rock outcrop	Calcixerollic xerochrepts (F) 30?% Calcixerollic xerochrepts (F) 20?% Typic xerochrepts (nd) 20% Lithic haploxeroll 20% (97 cm average depth)
7	235	400-1150 0-20%	400-600	High rolling plateau and terrrace remnxnt; moderately deep colluvial cover	Intensive rainfed arabel and tree crops minor irrigation	Xeric (wet)	4% A-hor stones 4% surface stones <5% rock outcrop	Typic xerochrepts (F) 25% Typic xerochrepts (F) 25% Vertic xerochrepts (F) 15% Lithic xerochrepts (nd) 10% (75 cm average depth)
17	231	400-1000 26-60% 9-90%	400-550	Very steep mass movement slopes in major deep dissected valleys	Brush range, much with good cover forest and reafforestation some irrigation	Xeric (wet)	15% A-hor stones 10% surface stones 10% rock outcrop	Typic xerochrepts (F) 30% Lithic haploxerolls (F) 15% Lithic xerochrepts (F) 15% Lithic xerothents (mh) 10% 61 cm average depth
23	369	600-1100 250-600 9-16% 0-40%	500-600 and wind hazards	High, convex ridge tops and upper slopes shallow collovium	Brush ranges, forest some tree crops	Xeric (wet)	6% A-hor stones 5% surface stones and boulders ; 5% rock outcrops	Lithic xerochrepts (F) 30% Typic xerochrepts (F) 20% Lithic xerocthents (nd) 20% Lithic haploxerolls (nd) 10% 49 cm averg depth
34	78.5	400-770	250-350	Mid and lower slopes on limestones	Rainfed arable and tree crops	Xeric	5% A-hor stones	Calcixerollic xerochrepts (F) 30?%

		5-16%		moderately deep collovium	brush ranges		5%surface stones	Typic xerochrepts (F)	20%
39	181.2	450-950	200-300	High, convex ridge tops	Brush rangeland, afforestation	Xeric (Drier areas)	4% A-hor stones	Lithic xerocthents (mh)	30%
		5-25%		dissected limestone platau			5%surface stones	Lithic xerochrepts (F)	20%
		0-40%					5% rock outcrop	Typic xerochrepts (F)	15%
								Typic xerochrepts (F)	10%
								57cm averg depth	
62	111.8	520-700	140-190	Rolling to hilly	Poor brush rangeland	Transitional	8% A-hor stones	Xerochreptic camorthids (Qmhv)	35%
		0-25%		finely disscted limestone plateau.			40%sites v.stony	Lithic xeric Torriorthents (Qmhv)	15%
							25% rock outcrop	Lithic xeric Torriorthents (mh)	15%
								Lithic xeric Torriorthents camorthids (Qmhv)	15%
								47cm averg depth	

APPENDIX 7

Crop water requirement calculation

Appendix 7: Results of crop water requirment for different sampling sites.

Sample NO.	Month	EC_e(dS/m)	EC_w (dS/m)	LR	ET_C (mm/day)	Irrigation efficiency (%)	IR (mm/day)	Total rainfall (mm/month)	Effective rainfall (mm/month)	Effective rainfall (mm/day)	CWR (mm/day)
1	JAN	4.125	1.00	0.05	3.01	0.60	5.07	28.25	7.25	0.23	4.84
	FEB	4.125	0.96	0.05	3.14	0.60	5.27	29.90	8.00	0.29	4.99
	MAR	4.125	1.01	0.05	3.35	0.60	5.64	29.88	8.00	0.26	5.38
	APR	4.125	0.86	0.04	3.75	0.60	6.30	15.00	1.00	0.03	6.26
	MAY	4.125	0.95	0.05	4.14	0.60	6.95	5.80	-	-	6.95
	JUN	4.125	1.03	0.05	4.36	0.60	7.31	-	-	-	7.31
	JUL	4.125	0.80	0.04	4.30	0.60	7.20	-	-	-	7.20
	AUG	4.125	1.11	0.06	4.21	0.60	7.08	-	-	-	7.08
	SEP	4.125	1.15	0.06	3.96	0.60	6.66	-	-	-	6.66
	OCT	4.125	1.07	0.05	3.66	0.60	6.15	12.00	0.50	0.02	6.14
	NOV	4.125	0.94	0.05	3.34	0.60	5.62	19.30	2.00	0.06	5.55
	DEC	4.125	1.04	0.05	3.15	0.60	5.30	40.70	14.00	0.45	4.85
2	JAN	4.51	1.00	0.05	3.01	0.60	5.06	28.25	7.25	0.23	4.83
	FEB	4.51	0.96	0.04	3.14	0.60	5.27	29.90	8.00	0.29	4.98
	MAR	4.51	1.01	0.05	3.35	0.60	5.63	29.88	8.00	0.26	5.37
	APR	4.51	0.86	0.04	3.75	0.60	6.29	15.00	1.00	0.03	6.26
	MAY	4.51	0.95	0.04	4.14	0.60	6.94	5.80	-	-	6.94
	JUN	4.51	1.03	0.05	4.36	0.60	7.31	-	-	-	7.31
	JUL	4.51	0.80	0.04	4.30	0.60	7.20	-	-	-	7.20
	AUG	4.51	1.11	0.05	4.21	0.60	7.07	-	-	-	7.07
	SEP	4.51	1.15	0.05	3.96	0.60	6.65	-	-	-	6.65
	OCT	4.51	1.07	0.05	3.66	0.60	6.15	12.00	0.50	0.02	6.13
	NOV	4.51	0.94	0.04	3.34	0.60	5.61	19.30	2.00	0.06	5.55
	DEC	4.51	1.04	0.05	3.15	0.60	5.30	40.70	14.00	0.45	4.85
	JAN	2.1005	1.00	0.11	3.01	0.60	5.12	28.25	7.25	0.23	4.89

Continued

3											
	FEB	2.1005	0.96	0.10	3.14	0.60	5.33	29.90	8.00	0.29	5.04
	MAR	2.1005	1.01	0.11	3.35	0.60	5.69	29.88	8.00	0.26	5.43
	APR	2.1005	0.86	0.09	3.75	0.60	6.34	15.00	1.00	0.03	6.31
	MAY	2.1005	0.95	0.10	4.14	0.60	7.00	5.80	-	-	7.00
	JUN	2.1005	1.03	0.11	4.36	0.60	7.37	-	-	-	7.37
	JUL	2.1005	0.80	0.08	4.30	0.60	7.24	-	-	-	7.24
	AUG	2.1005	1.11	0.12	4.21	0.60	7.14	-	-	-	7.14
	SEP	2.1005	1.15	0.12	3.96	0.60	6.72	-	-	-	6.72
	OCT	2.1005	1.07	0.11	3.66	0.60	6.21	12.00	0.50	0.02	6.20
	NOV	2.1005	0.94	0.10	3.34	0.60	5.67	19.30	2.00	0.06	5.60
	DEC	2.1005	1.04	0.11	3.15	0.60	5.36	40.70	14.00	0.45	4.91
4	JAN	2.03	1.00	0.11	3.01	0.60	5.13	28.25	7.25	0.23	4.89
	FEB	2.03	0.96	0.10	3.14	0.60	5.33	29.90	8.00	0.29	5.04
	MAR	2.03	1.01	0.11	3.35	0.60	5.70	29.88	8.00	0.26	5.44
	APR	2.03	0.86	0.09	3.75	0.60	6.34	15.00	1.00	0.03	6.31
	MAY	2.03	0.95	0.10	4.14	0.60	7.00	5.80	-	-	7.00
	JUN	2.03	1.03	0.11	4.36	0.60	7.37	-	-	-	7.37
	JUL	2.03	0.80	0.09	4.30	0.60	7.25	-	-	-	7.25
	AUG	2.03	1.11	0.12	4.21	0.60	7.14	-	-	-	7.14
	SEP	2.03	1.15	0.13	3.96	0.60	6.73	-	-	-	6.73
	OCT	2.03	1.07	0.12	3.66	0.60	6.22	12.00	0.50	0.02	6.20
	NOV	2.03	0.94	0.10	3.34	0.60	5.67	19.30	2.00	0.06	5.61
	DEC	2.03	1.04	0.11	3.15	0.60	5.37	40.70	14.00	0.45	4.91

Continued

5	JAN	2.585	1.00	0.08	3.01	0.60	5.02	28.25	7.25	0.23	4.78
	FEB	2.585	0.96	0.08	3.14	0.60	5.23	29.90	8.00	0.29	4.94
	MAR	2.585	1.01	0.08	3.35	0.60	5.59	29.88	8.00	0.26	5.33
	APR	2.585	0.86	0.07	3.75	0.60	6.25	15.00	1.00	0.03	6.22
	MAY	2.585	0.95	0.08	4.14	0.60	6.90	5.80	-	-	6.90
	JUN	2.585	1.03	0.09	4.36	0.60	7.26	-	-	-	7.26
	JUL	2.585	0.80	0.07	4.30	0.60	7.16	-	-	-	7.16
	AUG	2.585	1.11	0.09	4.21	0.60	7.02	-	-	-	7.02
	SEP	2.585	1.15	0.10	3.96	0.60	6.60	-	-	-	6.60
	OCT	2.585	1.07	0.09	3.66	0.60	6.10	12.00	0.50	0.02	6.08
	NOV	2.585	0.94	0.08	3.34	0.60	5.57	19.30	2.00	0.06	5.50
	DEC	2.585	1.04	0.09	3.15	0.60	5.25	40.70	14.00	0.45	4.80
6	JAN	1.1975	1.00	0.20	3.01	0.60	5.22	28.25	7.25	0.23	4.99
	FEB	1.1975	0.96	0.19	3.14	0.60	5.41	29.90	8.00	0.29	5.13
	MAR	1.1975	1.01	0.20	3.35	0.60	5.79	29.88	8.00	0.26	5.53
	APR	1.1975	0.86	0.17	3.75	0.60	6.42	15.00	1.00	0.03	6.39
	MAY	1.1975	0.95	0.19	4.14	0.60	7.09	5.80	-	-	7.09
	JUN	1.1975	1.03	0.21	4.36	0.60	7.47	-	-	-	7.47
	JUL	1.1975	0.80	0.16	4.30	0.60	7.31	-	-	-	7.31
	AUG	1.1975	1.11	0.23	4.21	0.60	7.25	-	-	-	7.25
	SEP	1.1975	1.15	0.24	3.96	0.60	6.84	-	-	-	6.84
	OCT	1.1975	1.07	0.22	3.66	0.60	6.32	12.00	0.50	0.02	6.30
	NOV	1.1975	0.94	0.19	3.34	0.60	5.75	19.30	2.00	0.06	5.69

	DEC	1.1975	1.04	0.21	3.15	0.60	5.46	40.70	14.00	0.45	5.01

Continued

7	JAN	1.5795	1.00	0.15	3.01	0.60	5.16	28.25	7.25	0.23	4.93
	FEB	1.5795	0.96	0.14	3.14	0.60	5.36	29.90	8.00	0.29	5.08
	MAR	1.5795	1.01	0.15	3.35	0.60	5.73	29.88	8.00	0.26	5.47
	APR	1.5795	0.86	0.12	3.75	0.60	6.37	15.00	1.00	0.03	6.34
	MAY	1.5795	0.95	0.14	4.14	0.60	7.04	5.80	-	-	7.04
	JUN	1.5795	1.03	0.15	4.36	0.60	7.41	-	-	-	7.41
	JUL	1.5795	0.80	0.11	4.30	0.60	7.27	-	-	-	7.27
	AUG	1.5795	1.11	0.16	4.21	0.60	7.19	-	-	-	7.19
	SEP	1.5795	1.15	0.17	3.96	0.60	6.77	-	-	-	6.77
	OCT	1.5795	1.07	0.16	3.66	0.60	6.26	12.00	0.50	0.02	6.24
	NOV	1.5795	0.94	0.14	3.34	0.60	5.70	19.30	2.00	0.06	5.64
	DEC	1.5795	1.04	0.15	3.15	0.60	5.40	40.70	14.00	0.45	4.95
											74.32
8	JAN	1.33	1.00	0.18	3.01	0.60	5.20	28.25	7.25	0.23	4.96
	FEB	1.33	0.96	0.17	3.14	0.60	5.39	29.90	8.00	0.29	5.11
	MAR	1.33	1.01	0.18	3.35	0.60	5.76	29.88	8.00	0.26	5.51
	APR	1.33	0.86	0.15	3.75	0.60	6.40	15.00	1.00	0.03	6.37
	MAY	1.33	0.95	0.17	4.14	0.60	7.07	5.80	-	-	7.07
	JUN	1.33	1.03	0.18	4.36	0.60	7.44	-	-	-	7.44
	JUL	1.33	0.80	0.14	4.30	0.60	7.30	-	-	-	7.30
	AUG	1.33	1.11	0.20	4.21	0.60	7.22	-	-	-	7.22
	SEP	1.33	1.15	0.21	3.96	0.60	6.81	-	-	-	6.81
	OCT	1.33	1.07	0.19	3.66	0.60	6.29	12.00	0.50	0.02	6.27
	NOV	1.33	0.94	0.17	3.34	0.60	5.73	19.30	2.00	0.06	5.67
	DEC	1.33	1.04	0.19	3.15	0.60	5.44	40.70	14.00	0.45	4.99

Continued

9	JAN	2.265	1.00	0.10	3.01	0.60	5.12	28.25	7.25	0.23	4.88
	FEB	2.265	0.96	0.09	3.14	0.60	5.32	29.90	8.00	0.29	5.03
	MAR	2.265	1.01	0.10	3.35	0.60	5.68	29.88	8.00	0.26	5.43
	APR	2.265	0.86	0.08	3.75	0.60	6.33	15.00	1.00	0.03	6.30
	MAY	2.265	0.95	0.09	4.14	0.60	6.99	5.80	-	-	6.99
	JUN	2.265	1.03	0.10	4.36	0.60	7.36	-	-	-	7.36
	JUL	2.265	0.80	0.08	4.30	0.60	7.24	-	-	-	7.24
	AUG	2.265	1.11	0.11	4.21	0.60	7.13	-	-	-	7.13
	SEP	2.265	1.15	0.11	3.96	0.60	6.71	-	-	-	6.71
	OCT	2.265	1.07	0.10	3.66	0.60	6.20	12.00	0.50	0.02	6.19
	NOV	2.265	0.94	0.09	3.34	0.60	5.66	19.30	2.00	0.06	5.59
	DEC	2.265	1.04	0.10	3.15	0.60	5.35	40.70	14.00	0.45	4.90
10	JAN	20.39	0.98	0.01	2.36	0.60	3.95	27.70	6.50	0.21	3.74
	FEB	20.39	0.94	0.01	2.96	0.60	4.94	22.90	3.50	0.13	4.82
	MAR	20.39	0.86	0.01	5.54	0.60	9.23	27.00	6.50	0.21	9.02
	APR	20.39	0.99	0.01	8.37	0.60	13.96	9.00	-	-	13.96
	MAY	20.39	1.24	0.01	9.68	0.60	16.15	-	-	-	16.15
	JUN	20.39	1.25	0.01	10.59	0.60	17.66	-	-	-	17.66
	JUL	20.39	1.28	0.01	10.34	0.60	17.25	-	-	-	17.25
	AUG	20.39	1.28	0.01	10.31	0.60	17.20	-	-	-	17.20
	SEP	20.39	1.26	0.01	8.67	0.60	14.46	-	-	-	14.46
	OCT	20.39	1.06	0.01	6.15	0.60	10.26	10.70	0.50	0.02	10.24
	NOV	20.39	1.05	0.01	4.31	0.60	7.19	11.00	0.50	0.02	7.18
	DEC	20.39	1.03	0.01	2.89	0.60	4.83	30.00	8.00	0.26	4.57

Continued

11	JAN	1.176	0.98	0.20	2.36	0.60	4.14	27.70	6.50	0.21	3.93
	FEB	1.176	0.94	0.19	2.96	0.60	5.12	22.90	3.50	0.13	5.00
	MAR	1.176	0.86	0.17	5.54	0.60	9.40	27.00	6.50	0.21	9.19
	APR	1.176	0.99	0.20	8.37	0.60	14.15	9.00	-	-	14.15
	MAY	1.176	1.24	0.27	9.68	0.60	16.40	-	-	-	16.40
	JUN	1.176	1.25	0.27	10.59	0.60	17.92	-	-	-	17.92
	JUL	1.176	1.28	0.28	10.34	0.60	17.51	-	-	-	17.51
	AUG	1.176	1.28	0.28	10.31	0.60	17.46	-	-	-	17.46
	SEP	1.176	1.26	0.27	8.67	0.60	14.72	-	-	-	14.72
	OCT	1.176	1.06	0.22	6.15	0.60	10.47	10.70	0.50	0.02	10.45
	NOV	1.176	1.05	0.22	4.31	0.60	7.40	11.00	0.50	0.02	7.38
	DEC	1.176	1.03	0.21	2.89	0.60	5.03	30.00	8.00	0.26	4.77
12	JAN	3.68	0.98	0.06	2.36	0.60	3.99	27.70	6.50	0.21	3.78
	FEB	3.68	0.94	0.05	2.96	0.60	4.99	22.90	3.50	0.13	4.86
	MAR	3.68	0.86	0.05	5.54	0.60	9.27	27.00	6.50	0.21	9.06
	APR	3.68	0.99	0.06	8.37	0.60	14.01	9.00	-	-	14.01
	MAY	3.68	1.24	0.07	9.68	0.60	16.21	-	-	-	16.21
	JUN	3.68	1.25	0.07	10.59	0.60	17.72	-	-	-	17.72
	JUL	3.68	1.28	0.07	10.34	0.60	17.31	-	-	-	17.31
	AUG	3.68	1.28	0.08	10.31	0.60	17.26	-	-	-	17.26
	SEP	3.68	1.26	0.07	8.67	0.60	14.52	-	-	-	14.52
	OCT	3.68	1.06	0.06	6.15	0.60	10.31	10.70	0.50	0.02	10.29
	NOV	3.68	1.05	0.06	4.31	0.60	7.24	11.00	0.50	0.02	7.23
	DEC	3.68	1.03	0.06	2.89	0.60	4.88	30.00	8.00	0.26	4.62

Continued

13	JAN	6.11	0.98	0.03	2.36	0.60	3.97	27.70	6.50	0.21	3.76
	FEB	6.11	0.94	0.03	2.96	0.60	4.97	22.90	3.50	0.13	4.84
	MAR	6.11	0.86	0.03	5.54	0.60	9.25	27.00	6.50	0.21	9.04
	APR	6.11	0.99	0.03	8.37	0.60	13.98	9.00	-	-	13.98
	MAY	6.11	1.24	0.04	9.68	0.60	16.18	-	-	-	16.18
	JUN	6.11	1.25	0.04	10.59	0.60	17.69	-	-	-	17.69
	JUL	6.11	1.28	0.04	10.34	0.60	17.28	-	-	-	17.28
	AUG	6.11	1.28	0.04	10.31	0.60	17.23	-	-	-	17.23
	SEP	6.11	1.26	0.04	8.67	0.60	14.49	-	-	-	14.49
	OCT	6.11	1.06	0.04	6.15	0.60	10.29	10.70	0.50	0.02	10.27
	NOV	6.11	1.05	0.04	4.31	0.60	7.22	11.00	0.50	0.02	7.20
	DEC	6.11	1.03	0.03	2.89	0.60	4.85	30.00	8.00	0.26	4.59
14	JAN	6.65	0.98	0.03	2.36	0.60	3.97	27.70	6.50	0.21	3.76
	FEB	6.65	0.94	0.03	2.96	0.60	4.96	22.90	3.50	0.13	4.84
	MAR	6.65	0.86	0.03	5.54	0.60	9.25	27.00	6.50	0.21	9.04
	APR	6.65	0.99	0.03	8.37	0.60	13.98	9.00	-	-	13.98
	MAY	6.65	1.24	0.04	9.68	0.60	16.17	-	-	-	16.17
	JUN	6.65	1.25	0.04	10.59	0.60	17.69	-	-	-	17.69
	JUL	6.65	1.28	0.04	10.34	0.60	17.27	-	-	-	17.27
	AUG	6.65	1.28	0.04	10.31	0.60	17.22	-	-	-	17.22
	SEP	6.65	1.26	0.04	8.67	0.60	14.49	-	-	-	14.49
	OCT	6.65	1.06	0.03	6.15	0.60	10.28	10.70	0.50	0.02	10.27
	NOV	6.65	1.05	0.03	4.31	0.60	7.22	11.00	0.50	0.02	7.20
	DEC	6.65	1.03	0.03	2.89	0.60	4.85	30.00	8.00	0.26	4.59

Continued

15	JAN	5.875	0.98	0.03	2.36	0.60	3.97	27.70	6.50	0.21	3.76
	FEB	5.875	0.94	0.03	2.96	0.60	4.97	22.90	3.50	0.13	4.84
	MAR	5.875	0.86	0.03	5.54	0.60	9.26	27.00	6.50	0.21	9.05
	APR	5.875	0.99	0.04	8.37	0.60	13.99	9.00	-	-	13.99
	MAY	5.875	1.24	0.04	9.68	0.60	16.18	-	-	-	16.18
	JUN	5.875	1.25	0.04	10.59	0.60	17.69	-	-	-	17.69
	JUL	5.875	1.28	0.05	10.34	0.60	17.28	-	-	-	17.28
	AUG	5.875	1.28	0.05	10.31	0.60	17.23	-	-	-	17.23
	SEP	5.875	1.26	0.04	8.67	0.60	14.49	-	-	-	14.49
	OCT	5.875	1.06	0.04	6.15	0.60	10.29	10.70	0.50	0.02	10.27
	NOV	5.875	1.05	0.04	4.31	0.60	7.22	11.00	0.50	0.02	7.20
	DEC	5.875	1.03	0.04	2.89	0.60	4.85	30.00	8.00	0.26	4.59
16	JAN	4.95	0.98	0.04	2.36	0.60	3.98	27.70	6.50	0.21	3.77
	FEB	4.95	0.94	0.04	2.96	0.60	4.97	22.90	3.50	0.13	4.85
	MAR	4.95	0.86	0.04	5.54	0.60	9.26	27.00	6.50	0.21	9.05
	APR	4.95	0.99	0.04	8.37	0.60	13.99	9.00	-	-	13.99
	MAY	4.95	1.24	0.05	9.68	0.60	16.19	-	-	-	16.19
	JUN	4.95	1.25	0.05	10.59	0.60	17.70	-	-	-	17.70
	JUL	4.95	1.28	0.05	10.34	0.60	17.29	-	-	-	17.29
	AUG	4.95	1.28	0.05	10.31	0.60	17.24	-	-	-	17.24
	SEP	4.95	1.26	0.05	8.67	0.60	14.50	-	-	-	14.50
	OCT	4.95	1.06	0.04	6.15	0.60	10.29	10.70	0.50	0.02	10.28
	NOV	4.95	1.05	0.04	4.31	0.60	7.23	11.00	0.50	0.02	7.21
	DEC	4.95	1.03	0.04	2.89	0.60	4.86	30.00	8.00	0.26	4.60

Continued

17	JAN	1.3095	0.98	0.18	2.36	0.60	4.11	27.70	6.50	0.21	3.90
	FEB	1.3095	0.94	0.17	2.96	0.60	5.10	22.90	3.50	0.13	4.98
	MAR	1.3095	0.86	0.15	5.54	0.60	9.38	27.00	6.50	0.21	9.17
	APR	1.3095	0.99	0.18	8.37	0.60	14.13	9.00	-	-	14.13
	MAY	1.3095	1.24	0.23	9.68	0.60	16.37	-	-	-	16.37
	JUN	1.3095	1.25	0.24	10.59	0.60	17.89	-	-	-	17.89
	JUL	1.3095	1.28	0.24	10.34	0.60	17.48	-	-	-	17.48
	AUG	1.3095	1.28	0.24	10.31	0.60	17.43	-	-	-	17.43
	SEP	1.3095	1.26	0.24	8.67	0.60	14.69	-	-	-	14.69
	OCT	1.3095	1.06	0.19	6.15	0.60	10.44	10.70	0.50	0.02	10.43
	NOV	1.3095	1.05	0.19	4.31	0.60	7.37	11.00	0.50	0.02	7.36
	DEC	1.3095	1.03	0.19	2.89	0.60	5.00	30.00	8.00	0.26	4.75
18	JAN	1.041	0.98	0.23	2.36	0.60	4.17	27.70	6.50	0.21	3.96
	FEB	1.041	0.94	0.22	2.96	0.60	5.15	22.90	3.50	0.13	5.03
	MAR	1.041	0.86	0.20	5.54	0.60	9.42	27.00	6.50	0.21	9.21
	APR	1.041	0.99	0.24	8.37	0.60	14.19	9.00	-	-	14.19
	MAY	1.041	1.24	0.31	9.68	0.60	16.45	-	-	-	16.45
	JUN	1.041	1.25	0.32	10.59	0.60	17.97	-	-	-	17.97
	JUL	1.041	1.28	0.32	10.34	0.60	17.56	-	-	-	17.56
	AUG	1.041	1.28	0.33	10.31	0.60	17.51	-	-	-	17.51
	SEP	1.041	1.26	0.32	8.67	0.60	14.77	-	-	-	14.77
	OCT	1.041	1.06	0.26	6.15	0.60	10.51	10.70	0.50	0.02	10.49
	NOV	1.041	1.05	0.25	4.31	0.60	7.44	11.00	0.50	0.02	7.42
	DEC	1.041	1.03	0.25	2.89	0.60	5.06	30.00	8.00	0.26	4.81

Continued

19	JAN	12.985	0.98	0.02	2.36	0.60	3.95	27.70	6.50	0.21	3.74
	FEB	12.985	0.94	0.01	2.96	0.60	4.95	22.90	3.50	0.13	4.82
	MAR	12.985	0.86	0.01	5.54	0.60	9.24	27.00	6.50	0.21	9.03
	APR	12.985	0.99	0.02	8.37	0.60	13.97	9.00	-	-	13.97
	MAY	12.985	1.24	0.02	9.68	0.60	16.15	-	-	-	16.15
	JUN	12.985	1.25	0.02	10.59	0.60	17.67	-	-	-	17.67
	JUL	12.985	1.28	0.02	10.34	0.60	17.25	-	-	-	17.25
	AUG	12.985	1.28	0.02	10.31	0.60	17.20	-	-	-	17.20
	SEP	12.985	1.26	0.02	8.67	0.60	14.47	-	-	-	14.47
	OCT	12.985	1.06	0.02	6.15	0.60	10.27	10.70	0.50	0.02	10.25
	NOV	12.985	1.05	0.02	4.31	0.60	7.20	11.00	0.50	0.02	7.18
	DEC	12.985	1.03	0.02	2.89	0.60	4.83	30.00	8.00	0.26	4.57
20	JAN	2.59	0.98	0.08	2.36	0.60	4.02	27.70	6.50	0.21	3.81
	FEB	2.59	0.94	0.08	2.96	0.60	5.01	22.90	3.50	0.13	4.89
	MAR	2.59	0.86	0.07	5.54	0.60	9.30	27.00	6.50	0.21	9.09
	APR	2.59	0.99	0.08	8.37	0.60	14.03	9.00	-	-	14.03
	MAY	2.59	1.24	0.11	9.68	0.60	16.24	-	-	-	16.24
	JUN	2.59	1.25	0.11	10.59	0.60	17.76	-	-	-	17.76
	JUL	2.59	1.28	0.11	10.34	0.60	17.34	-	-	-	17.34
	AUG	2.59	1.28	0.11	10.31	0.60	17.29	-	-	-	17.29
	SEP	2.59	1.26	0.11	8.67	0.60	14.56	-	-	-	14.56
	OCT	2.59	1.06	0.09	6.15	0.60	10.34	10.70	0.50	0.02	10.32
	NOV	2.59	1.05	0.09	4.31	0.60	7.27	11.00	0.50	0.02	7.26
	DEC	2.59	1.03	0.09	2.89	0.60	4.90	30.00	8.00	0.26	4.64

Continued

21	JAN	5.165	0.98	0.04	2.36	0.60	3.98	27.70	6.50	0.21	3.77
	FEB	5.165	0.94	0.04	2.96	0.60	4.97	22.90	3.50	0.13	4.85
	MAR	5.165	0.86	0.03	5.54	0.60	9.26	27.00	6.50	0.21	9.05
	APR	5.165	0.99	0.04	8.37	0.60	13.99	9.00	-	-	13.99
	MAY	5.165	1.24	0.05	9.68	0.60	16.18	-	-	-	16.18
	JUN	5.165	1.25	0.05	10.59	0.60	17.70	-	-	-	17.70
	JUL	5.165	1.28	0.05	10.34	0.60	17.29	-	-	-	17.29
	AUG	5.165	1.28	0.05	10.31	0.60	17.24	-	-	-	17.24
	SEP	5.165	1.26	0.05	8.67	0.60	14.50	-	-	-	14.50
	OCT	5.165	1.06	0.04	6.15	0.60	10.29	10.70	0.50	0.02	10.28
	NOV	5.165	1.05	0.04	4.31	0.60	7.23	11.00	0.50	0.02	7.21
	DEC	5.165	1.03	0.04	2.89	0.60	4.86	30.00	8.00	0.26	4.60
22	JAN	17.105	0.98	0.01	2.36	0.60	3.95	27.70	6.50	0.21	3.74
	FEB	17.105	0.94	0.01	2.96	0.60	4.94	22.90	3.50	0.13	4.82
	MAR	17.105	0.86	0.01	5.54	0.60	9.24	27.00	6.50	0.21	9.03
	APR	17.105	0.99	0.01	8.37	0.60	13.96	9.00	-	-	13.96
	MAY	17.105	1.24	0.01	9.68	0.60	16.15	-	-	-	16.15
	JUN	17.105	1.25	0.01	10.59	0.60	17.66	-	-	-	17.66
	JUL	17.105	1.28	0.02	10.34	0.60	17.25	-	-	-	17.25
	AUG	17.105	1.28	0.02	10.31	0.60	17.20	-	-	-	17.20
	SEP	17.105	1.26	0.01	8.67	0.60	14.46	-	-	-	14.46
	OCT	17.105	1.06	0.01	6.15	0.60	10.26	10.70	0.50	0.02	10.25
	NOV	17.105	1.05	0.01	4.31	0.60	7.20	11.00	0.50	0.02	7.18
	DEC	17.105	1.03	0.01	2.89	0.60	4.83	30.00	8.00	0.26	4.57

Continued

23	JAN	3.745	0.98	0.06	2.36	0.60	3.99	27.70	6.50	0.21	3.78
	FEB	3.745	0.94	0.05	2.96	0.60	4.99	22.90	3.50	0.13	4.86
	MAR	3.745	0.86	0.05	5.54	0.60	9.27	27.00	6.50	0.21	9.06
	APR	3.745	0.99	0.06	8.37	0.60	14.01	9.00	-	-	14.01
	MAY	3.745	1.24	0.07	9.68	0.60	16.20	-	-	-	16.20
	JUN	3.745	1.25	0.07	10.59	0.60	17.72	-	-	-	17.72
	JUL	3.745	1.28	0.07	10.34	0.60	17.31	-	-	-	17.31
	AUG	3.745	1.28	0.07	10.31	0.60	17.26	-	-	-	17.26
	SEP	3.745	1.26	0.07	8.67	0.60	14.52	-	-	-	14.52
	OCT	3.745	1.06	0.06	6.15	0.60	10.31	10.70	0.50	0.02	10.29
	NOV	3.745	1.05	0.06	4.31	0.60	7.24	11.00	0.50	0.02	7.23
	DEC	3.745	1.03	0.06	2.89	0.60	4.87	30.00	8.00	0.26	4.62
24	JAN	10.615	0.98	0.02	2.36	0.60	3.96	27.70	6.50	0.21	3.75
	FEB	10.615	0.94	0.02	2.96	0.60	4.95	22.90	3.50	0.13	4.83
	MAR	10.615	0.86	0.02	5.54	0.60	9.24	27.00	6.50	0.21	9.03
	APR	10.615	0.99	0.02	8.37	0.60	13.97	9.00	-	-	13.97
	MAY	10.615	1.24	0.02	9.68	0.60	16.16	-	-	-	16.16
	JUN	10.615	1.25	0.02	10.59	0.60	17.67	-	-	-	17.67
	JUL	10.615	1.28	0.02	10.34	0.60	17.26	-	-	-	17.26
	AUG	10.615	1.28	0.02	10.31	0.60	17.21	-	-	-	17.21
	SEP	10.615	1.26	0.02	8.67	0.60	14.47	-	-	-	14.47
	OCT	10.615	1.06	0.02	6.15	0.60	10.27	10.70	0.50	0.02	10.25
	NOV	10.615	1.05	0.02	4.31	0.60	7.20	11.00	0.50	0.02	7.19
	DEC	10.615	1.03	0.02	2.89	0.60	4.84	30.00	8.00	0.26	4.58

Continued

25	JAN	24.83	0.98	0.01	2.36	0.60	3.94	27.70	6.50	0.21	3.73
	FEB	24.83	0.94	0.01	2.96	0.60	4.94	22.90	3.50	0.13	4.82
	MAR	24.83	0.86	0.01	5.54	0.60	9.23	27.00	6.50	0.21	9.02
	APR	24.83	0.99	0.01	8.37	0.60	13.96	9.00	-	-	13.96
	MAY	24.83	1.24	0.01	9.68	0.60	16.14	-	-	-	16.14
	JUN	24.83	1.25	0.01	10.59	0.60	17.66	-	-	-	17.66
	JUL	24.83	1.28	0.01	10.34	0.60	17.24	-	-	-	17.24
	AUG	24.83	1.28	0.01	10.31	0.60	17.19	-	-	-	17.19
	SEP	24.83	1.26	0.01	8.67	0.60	14.46	-	-	-	14.46
	OCT	24.83	1.06	0.01	6.15	0.60	10.26	10.70	0.50	0.02	10.24
	NOV	24.83	1.05	0.01	4.31	0.60	7.19	11.00	0.50	0.02	7.18
	DEC	24.83	1.03	0.01	2.89	0.60	4.83	30.00	8.00	0.26	4.57
26	JAN	6.175	0.98	0.03	2.36	0.60	3.97	27.70	6.50	0.21	3.76
	FEB	6.175	0.94	0.03	2.96	0.60	4.96	22.90	3.50	0.13	4.84
	MAR	6.175	0.86	0.03	5.54	0.60	9.25	27.00	6.50	0.21	9.04
	APR	6.175	0.99	0.03	8.37	0.60	13.98	9.00	-	-	13.98
	MAY	6.175	1.24	0.04	9.68	0.60	16.18	-	-	-	16.18
	JUN	6.175	1.25	0.04	10.59	0.60	17.69	-	-	-	17.69
	JUL	6.175	1.28	0.04	10.34	0.60	17.28	-	-	-	17.28
	AUG	6.175	1.28	0.04	10.31	0.60	17.23	-	-	-	17.23
	SEP	6.175	1.26	0.04	8.67	0.60	14.49	-	-	-	14.49
	OCT	6.175	1.06	0.04	6.15	0.60	10.29	10.70	0.50	0.02	10.27
	NOV	6.175	1.05	0.04	4.31	0.60	7.22	11.00	0.50	0.02	7.20
	DEC	6.175	1.03	0.03	2.89	0.60	4.85	30.00	8.00	0.26	4.59

Continued

27	JAN	1.468	0.98	0.15	2.36	0.60	4.09	27.70	6.50	0.21	3.88
	FEB	1.468	0.94	0.15	2.96	0.60	5.08	22.90	3.50	0.13	4.96
	MAR	1.468	0.86	0.13	5.54	0.60	9.36	27.00	6.50	0.21	9.15
	APR	1.468	0.99	0.16	8.37	0.60	14.11	9.00	-	-	14.11
	MAY	1.468	1.24	0.20	9.68	0.60	16.34	-	-	-	16.34
	JUN	1.468	1.25	0.20	10.59	0.60	17.85	-	-	-	17.85
	JUL	1.468	1.28	0.21	10.34	0.60	17.44	-	-	-	17.44
	AUG	1.468	1.28	0.21	10.31	0.60	17.40	-	-	-	17.40
	SEP	1.468	1.26	0.21	8.67	0.60	14.66	-	-	-	14.66
	OCT	1.468	1.06	0.17	6.15	0.60	10.42	10.70	0.50	0.02	10.40
	NOV	1.468	1.05	0.17	4.31	0.60	7.35	11.00	0.50	0.02	7.33
	DEC	1.468	1.03	0.16	2.89	0.60	4.98	30.00	8.00	0.26	4.72
28	JAN	14.77	0.98	0.01	2.36	0.60	3.95	27.70	6.50	0.21	3.74
	FEB	14.77	0.94	0.01	2.96	0.60	4.95	22.90	3.50	0.13	4.82
	MAR	14.77	0.86	0.01	5.54	0.60	9.24	27.00	6.50	0.21	9.03
	APR	14.77	0.99	0.01	8.37	0.60	13.96	9.00	-	-	13.96
	MAY	14.77	1.24	0.02	9.68	0.60	16.15	-	-	-	16.15
	JUN	14.77	1.25	0.02	10.59	0.60	17.67	-	-	-	17.67
	JUL	14.77	1.28	0.02	10.34	0.60	17.25	-	-	-	17.25
	AUG	14.77	1.28	0.02	10.31	0.60	17.20	-	-	-	17.20
	SEP	14.77	1.26	0.02	8.67	0.60	14.47	-	-	-	14.47
	OCT	14.77	1.06	0.01	6.15	0.60	10.26	10.70	0.50	0.02	10.25
	NOV	14.77	1.05	0.01	4.31	0.60	7.20	11.00	0.50	0.02	7.18
	DEC	14.77	1.03	0.01	2.89	0.60	4.83	30.00	8.00	0.26	4.57

Continued

29	JAN	6.395	0.98	0.03	2.36	0.60	3.97	27.70	6.50	0.21	3.76
	FEB	6.395	0.94	0.03	2.96	0.60	4.96	22.90	3.50	0.13	4.84
	MAR	6.395	0.86	0.03	5.54	0.60	9.25	27.00	6.50	0.21	9.04
	APR	6.395	0.99	0.03	8.37	0.60	13.98	9.00	-	-	13.98
	MAY	6.395	1.24	0.04	9.68	0.60	16.17	-	-	-	16.17
	JUN	6.395	1.25	0.04	10.59	0.60	17.69	-	-	-	17.69
	JUL	6.395	1.28	0.04	10.34	0.60	17.27	-	-	-	17.27
	AUG	6.395	1.28	0.04	10.31	0.60	17.23	-	-	-	17.23
	SEP	6.395	1.26	0.04	8.67	0.60	14.49	-	-	-	14.49
	OCT	6.395	1.06	0.03	6.15	0.60	10.28	10.70	0.50	0.02	10.27
	NOV	6.395	1.05	0.03	4.31	0.60	7.22	11.00	0.50	0.02	7.20
	DEC	6.395	1.03	0.03	2.89	0.60	4.85	30.00	8.00	0.26	4.59
30	JAN	11.975	0.98	0.02	2.36	0.60	3.95	27.70	6.50	0.21	3.74
	FEB	11.975	0.94	0.02	2.96	0.60	4.95	22.90	3.50	0.13	4.82
	MAR	11.975	0.86	0.01	5.54	0.60	9.24	27.00	6.50	0.21	9.03
	APR	11.975	0.99	0.02	8.37	0.60	13.97	9.00	-	-	13.97
	MAY	11.975	1.24	0.02	9.68	0.60	16.15	-	-	-	16.15
	JUN	11.975	1.25	0.02	10.59	0.60	17.67	-	-	-	17.67
	JUL	11.975	1.28	0.02	10.34	0.60	17.26	-	-	-	17.26
	AUG	11.975	1.28	0.02	10.31	0.60	17.21	-	-	-	17.21
	SEP	11.975	1.26	0.02	8.67	0.60	14.47	-	-	-	14.47
	OCT	11.975	1.06	0.02	6.15	0.60	10.27	10.70	0.50	0.02	10.25
	NOV	11.975	1.05	0.02	4.31	0.60	7.20	11.00	0.50	0.02	7.19
	DEC	11.975	1.03	0.02	2.89	0.60	4.83	30.00	8.00	0.26	4.58

Continued

31	JAN	14.925	0.98	0.01	2.36	0.60	3.95	27.70	6.50	0.21	3.74
	FEB	14.925	0.94	0.01	2.96	0.60	4.95	22.90	3.50	0.13	4.82
	MAR	14.925	0.86	0.01	5.54	0.60	9.24	27.00	6.50	0.21	9.03
	APR	14.925	0.99	0.01	8.37	0.60	13.96	9.00	-	-	13.96
	MAY	14.925	1.24	0.02	9.68	0.60	16.15	-	-	-	16.15
	JUN	14.925	1.25	0.02	10.59	0.60	17.67	-	-	-	17.67
	JUL	14.925	1.28	0.02	10.34	0.60	17.25	-	-	-	17.25
	AUG	14.925	1.28	0.02	10.31	0.60	17.20	-	-	-	17.20
	SEP	14.925	1.26	0.02	8.67	0.60	14.47	-	-	-	14.47
	OCT	14.925	1.06	0.01	6.15	0.60	10.26	10.70	0.50	0.02	10.25
	NOV	14.925	1.05	0.01	4.31	0.60	7.20	11.00	0.50	0.02	7.18
	DEC	14.925	1.03	0.01	2.89	0.60	4.83	30.00	8.00	0.26	4.57
32	JAN	3.3045	0.98	0.06	2.36	0.60	4.00	27.70	6.50	0.21	3.79
	FEB	3.3045	0.94	0.06	2.96	0.60	4.99	22.90	3.50	0.13	4.87
	MAR	3.3045	0.86	0.05	5.54	0.60	9.28	27.00	6.50	0.21	9.07
	APR	3.3045	0.99	0.06	8.37	0.60	14.01	9.00	-	-	14.01
	MAY	3.3045	1.24	0.08	9.68	0.60	16.21	-	-	-	16.21
	JUN	3.3045	1.25	0.08	10.59	0.60	17.73	-	-	-	17.73
	JUL	3.3045	1.28	0.08	10.34	0.60	17.32	-	-	-	17.32
	AUG	3.3045	1.28	0.08	10.31	0.60	17.27	-	-	-	17.27
	SEP	3.3045	1.26	0.08	8.67	0.60	14.53	-	-	-	14.53
	OCT	3.3045	1.06	0.07	6.15	0.60	10.32	10.70	0.50	0.02	10.30
	NOV	3.3045	1.05	0.07	4.31	0.60	7.25	11.00	0.50	0.02	7.24
	DEC	3.3045	1.03	0.07	2.89	0.60	4.88	30.00	8.00	0.26	4.63

Continued

33	JAN	5.83	0.98	0.03	2.36	0.60	3.97	27.70	6.50	0.21	3.97
	FEB	5.83	0.94	0.03	2.96	0.60	4.97	22.90	3.50	0.13	4.73
	MAR	5.83	0.86	0.03	5.54	0.60	9.26	27.00	6.50	0.21	8.97
	APR	5.83	0.99	0.04	8.37	0.60	13.99	9.00	-	-	13.73
	MAY	5.83	1.24	0.04	9.68	0.60	16.18	-	-	-	16.14
	JUN	5.83	1.25	0.04	10.59	0.60	17.69	-	-	-	17.69
	JUL	5.83	1.28	0.05	10.34	0.60	17.28	-	-	-	17.28
	AUG	5.83	1.28	0.05	10.31	0.60	17.23	-	-	-	17.23
	SEP	5.83	1.26	0.05	8.67	0.60	14.50	-	-	-	14.50
	OCT	5.83	1.06	0.04	6.15	0.60	10.29	10.70	0.50	0.02	10.29
	NOV	5.83	1.05	0.04	4.31	0.60	7.22	11.00	0.50	0.02	7.20
	DEC	5.83	1.03	0.04	2.89	0.60	4.85	30.00	8.00	0.26	4.79
34	JAN	26.335	0.98	0.01	2.36	0.60	3.94	27.70	6.50	0.21	3.73
	FEB	26.335	0.94	0.01	2.96	0.60	4.94	22.90	3.50	0.13	4.82
	MAR	26.335	0.86	0.01	5.54	0.60	9.23	27.00	6.50	0.21	9.02
	APR	26.335	0.99	0.01	8.37	0.60	13.96	9.00	-	-	13.96
	MAY	26.335	1.24	0.01	9.68	0.60	16.14	-	-	-	16.14
	JUN	26.335	1.25	0.01	10.59	0.60	17.66	-	-	-	17.66
	JUL	26.335	1.28	0.01	10.34	0.60	17.24	-	-	-	17.24
	AUG	26.335	1.28	0.01	10.31	0.60	17.19	-	-	-	17.19
	SEP	26.335	1.26	0.01	8.67	0.60	14.46	-	-	-	14.46
	OCT	26.335	1.06	0.01	6.15	0.60	10.26	10.70	0.50	0.02	10.24
	NOV	26.335	1.05	0.01	4.31	0.60	7.19	11.00	0.50	0.02	7.18
	DEC	26.335	1.03	0.01	2.89	0.60	4.82	30.00	8.00	0.26	4.57

Continued

35	JAN	5.895	0.98	0.03	2.36	0.60	3.97	27.70	6.50	0.21	3.76
	FEB	5.895	0.94	0.03	2.96	0.60	4.97	22.90	3.50	0.13	4.84
	MAR	5.895	0.86	0.03	5.54	0.60	9.25	27.00	6.50	0.21	9.05
	APR	5.895	0.99	0.03	8.37	0.60	13.98	9.00	-	-	13.98
	MAY	5.895	1.24	0.04	9.68	0.60	16.18	-	-	-	16.18
	JUN	5.895	1.25	0.04	10.59	0.60	17.69	-	-	-	17.69
	JUL	5.895	1.28	0.05	10.34	0.60	17.28	-	-	-	17.28
	AUG	5.895	1.28	0.05	10.31	0.60	17.23	-	-	-	17.23
	SEP	5.895	1.26	0.04	8.67	0.60	14.49	-	-	-	14.49
	OCT	5.895	1.06	0.04	6.15	0.60	10.29	10.70	0.50	0.02	10.27
	NOV	5.895	1.05	0.04	4.31	0.60	7.22	11.00	0.50	0.02	7.20
	DEC	5.895	1.03	0.04	2.89	0.60	4.85	30.00	8.00	0.26	4.59

تخطيط استعمالات الأراضي حول محطات تنقية مختارة باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية

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ملخص

تم القيام بهذه الدراسة لتقييم ملائمة الأرض لزراعة البرسيم الحجازي حول محطتي معالجة المياه العادمه في خربة السمرا وجرش. وقد تم إجراء الدراسة باستخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية لتحديد المناطق الملائمة لزراعة هذا المحصول اعتمادا على خصائص المياه المعالجة والتربة.

تم عمل خرائط استعمالات الأراضي في المنطقة باستخدام التفسير البصري لاثنتين من صور الأقمار الصناعية واستخدمت الخرائط الناتجة لتحديد مواقع عينات التربة التي تم أخذها بشكل عشوائي من الحقول الزراعية في المنطقة عل عمقين مختلفين بعد انتهاء موسم الزراعية. دلت النتائج على أن تربة منطقة الدراسة تحتوي كميات كبيرة من النيتروجين والفسفور والبوتاس وخاصة حول محطة الخربة السمرا. وهذه العناصر تعتبر كافية لتوفير الاحتياجات الأساسية للبرسيم الحجازي, وعليه يمكن التقليل من استخدام الأسمدة في هذه المناطق. من ناحية أخرى تم تقييم نوعية المياه العادمة المستخدمة وصلاحيتها لزراعة الأعلاف من خلال تحاليل الأكسجين المستهلك حيويا و الأكسجين المستهلك كيميائيا والأملاح الذائبة والأس الهيدروجيني، في حين تم تصنيف ملائمة التربة بناءا على معدل الملوحة ومقارنتها بمقدار النقص في الإنتاجية.

أظهرت نتائج تحاليل خرائط استعمالات الأراضي بأن 23% من الأراضي مختلطة الزراعة (أعلاف وزيتون) هي ضمن المناطق الأكثر ملائمة للبرسيم الحجازي ، في حين أن 33% من

الأراضي البعلية والأعلاف تقع ضمن المناطق الغير ملائمة لزراعة هذا المحصول بينما تعتبر باقي الأراضي غير ملائمة لزراعة هذا المحصول. وعليه توصي الدراسة بتغيير النمط الزراعي في المنطقة وزراعتها بالمحاصيل العلفية الملائمة . كما توصي الدراسة بعدم زراعة البرسيم الحجازي في المناطق المنحدرة والتي تحتاج ضخ مياه لزراعتها, علما بأن هذه المناطق غير ملائمة أصلا لزراعة مثل هذا المحصول, نتيجة ملوحة التربة وانحدار الأرض.

دلت النتائج أيضا أن النمط الزراعي في الأراضي الواقعة حول محطة جرش و بعض المناطق حول الخربة السمرا بأن النمط الزراعي السائد غير مناسب لزراعة المحاصيل الموجودة حاليا في المنطقة وعليه يعتبر القيام بتحوير في استعمالات الأراضي ضرورة ملحة في المنطقة.كذلك توصي الدراسة باستخدام النهج الذي تم اتباعه في هذا البحث لتخطيط استعمال الأراضي وحساب الاحتياجات المائية للمحاصيل وخصوصا المحاصيل العلفية في منطقة الدراسة.